ECOSYSTEMS, SOCIOCULTURAL SYSTEMS, AND ECOLOGICAL ECONOMICS FOR UNDERSTANDING DEVELOPMENT: THE CASE OF ECOTOURISM ON THE ISLAND OF BONAIRE, N.A.

By

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This dissertation is dedicated to my parents, Marling and Marion Abel, and my brother Bill and sisters, Maryanne and Sally. They have surrounded me with encouragement and love these years.

ACKNOWLEDGMENTS

This Ph.D. process for me has had many twists and turns. Maybe surprisingly, the final product has become close to what I envisioned while in the field. On my return from the field, however, I discovered that I needed some more technical skills, and I still had several fundamental theoretical differences with Dr. Odum about modeling "people and culture." I therefore threw myself into improving my systems ecology skills. Specifically, I learned simulation modeling, which I have used sparingly in the dissertation, but which is an essential prerequisite for good systems diagramming and, generally, for systems thinking. That is to say, systems principles make much more sense after experiencing the modeling process. In order to address the "people and culture" problem, I chose to apply systems modeling and simulation to one of the most fundamental general models in anthropology, cultural evolution. This was the source of my theoretical discussion that appears at the end of the dissertation. That exercise, I feel, improved all the work that has come after. This last year has been nothing but Bonaire, applying analysis to data, writing text, and assembling the pieces into a whole. The book is an ending of sorts. Time for a new beginning.

I have many people to thank. I want to gratefully thank my chair, Dr. William Keegan, for his enthusiastic support and encouragement these years. I am also very grateful to the rest of my committee, Dr. H.T. Odum, Dr. Mark Brown, and Dr. James Stansbury. I want to thank Dr. Marvin Harris, who was a committee member until only recently when his ill health slowed him up. His writings were inspirational in my undergraduate years, and his academic interrogations were always interesting. I also want to add special thanks to H.T. Odum, whose work and energy have been no less inspiring, and whose committed mentoring of students is just another of his great skills.

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ECOSYSTEMS, SOCIOCULTURAL SYSTEMS, AND ECOLOGICAL ECONOMICS
FOR UNDERSTANDING DEVELOPMENT:
THE CASE OF ECOTOURISM ON THE ISLAND OF BONAIRE, N.A.

By

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Major Department: Anthropology

The occurrence of economic development associated with ecotourism on the island of Bonaire in the Netherlands Antilles is described in this dissertation and evaluated with a form of ecological economics known as e*m*ergy accounting. Emergy is an alternative currency that places all products of world ecosystems on one scale, based on the human-ecological work that contributed to the production of that product. Emergy is thus a *donor* system of value because it measures contributions to production rather than willingness to pay.

Multiple scales were analyzed simultaneously and were compared to describe the event of ecotourism development on Bonaire and produce arguments in explanation after the fact. The recent economic growth on Bonaire was seeded by infrastructural investments from the Netherlands and the Netherlands Antilles that began in the 1950s. Development on Bonaire (and Curacao) is subsidized by the high-emergy inputs of crude oil from Venezuela, refined on Curacao. The results of these macro events on Bonaire have been a significant transformation of the island's social-economic hierarchy,

which was lead by export industry growth in the 1970s, and followed by tourism in the 1980-90s. Tourism development has "filled in" the economic hierarchy on Bonaire, fueling the emergence of many small and medium size businesses.

In addition to these findings, this dissertation will measure and explain: (1) the "underdevelopment" of Peripheries worldwide, including Bonaire in particular, (2) sustainability, with a measure called "percent renewable", (3) structural complexification of an economy as it has undergone 50 years of development activity, (4) why households in a development context would abandon fishing and farming for participation in the market, (5) why wages are low, or sometimes high, in a development context, (6) a recommended development size with an index called "development intensity."

CHAPTER 1
INTRODUCTION

Figure 1: Kite Flying Contest
Available energies attract use by people and nature. Strong and incessant trade winds have long been harnessed by Bonairians for sailing, fishing, windmill pumps, natural air conditioning, and kite flying, each refined to skillful end.

How can you do holistic science halfway? We say a whole is more than the sum of its parts. With the intensifying global nature of human affairs this has never been more true. The so-called developing countries cannot be fully understood without placing them in the context of developed countries, international markets, historical circumstance, and world energy supplies. At a smaller scale, development choices *within* developing countries cannot be evaluated thoroughly without situating them in ecosystems and national economies that channel material resources, exports, and waste by-products. Finally, people, work, and households, cannot be sufficiently understood without adequately locating them within this national or regional ecological-economic context.

It was therefore the intention of this research from its inception to pick a manageable topic and research site and to evaluate it within whole systems at multiple scales. Bonaire is a small island, and ecotourism development is a single event (with instances worldwide) that has transformed the lives of Bonairians for the last 15 years. While some social researchers make efforts to describe the "setting" of their fieldwork, it can be argued that without explicit methods that give the researcher analytic tools to address multiple scales and academic disciplines, their efforts are incomplete.

Few scientific methods attempt to traverse spatial and temporal scales, and especially disciplinary boundaries (see CHAPTER 15 for further discussion). Our scientific tradition often tends in the opposite direction, toward reductionist, experimental and narrowly disciplinary work. As the ecologist C.S. Holling (Holling 1995:12) contends, the single-scaled, disciplinary approach is valuable for some problems or questions that are addressed by science and the public, i.e., molecular biology or genetic engineering. However, we have many more questions for which this approach is simply inadequate, i.e., questions about weather, ecosystems, and much of human social behavior. By contrast, a few approaches to science are interdisciplinary, integrative, historical, analytical, comparative, and experimental (at appropriate scales). Examples are ecology, evolutionary biology, global climate science, and systems science. The last century has seen the social sciences pushed and pulled between these poles, and even beyond into literature and the humanities.

This dissertation research uses methods from this second stream of science to address the multiple-scaled contexts and consequences of ecotourism development on Bonaire. Methods for the research come from systems ecology and e*m*ergy analysis, as they have been devised by H.T. Odum, his colleagues, and students, over the last 40 years (Odum 1971, Odum and Odum 1976, Odum 1983, Odum 1996a, Hall 1995, Odum and Odum 2000). Odum has studied systems of countless variety, and has worked to produce theory and methods to explain them. His intention has been to identify general principles for natural systems at all scales (Odum 2000). His methods are quantitative, with precision that is appropriate to capture determinant processes at each scale. His focus is energy and the transformations of energy in ecosystems and other self-organizing systems, which applies to all scales in nature.

This dissertation research is therefore broad in scope and simultaneously directed to multiple scales of analysis. In order to deal with large scales, appropriate units and details of analysis are chosen.

The results of this research are not typical to the reductionist stream of science. Systems science does not expect disproof by experiment, and ultimate agreement by the scientific community. Natural, complex systems must be evaluated not by experiment, but by case studies of undirected transformations of whole systems, as with the emergence of ecotourism on Bonaire. Peer assessment and judgement, not unanimous agreement, are the final measure of this type of research (see CHAPTER 15 for further discussion).

The dissertation is divided into three sections. They are "An Ecological Ethnography," "Emergy Analyses," and "Issues and Discussion." The first two sections are the heart of the empirical research and evaluation. The section of Emergy Analyses is further divided into three scales: Households, the island-international scale, and the web of corporate production between these two poles. The last section, Issues and Discussion, elaborates on and discusses the issues of emergy analysis, evolution, complex systems, self-organization, hierarchy and scale, which are all raised by the dissertation fieldwork and analysis that precedes them. This section is referenced countless times by the prior two sections, and thus also serves as a *defacto* appendix to them.

Understanding Development

The impacts of economic "development" are many and manifold. Development transforms people and nature simultaneously at multiple spatial and temporal scales. It invariably captures the natural production and mineral resources of less-developed countries and funnels them into the global economy. What do they get in return? How does development ripple through an economy (and ecology), transforming the economic strategies of people and their relationships with nature? Ecological economics is a quantitative alternative to economic analysis that can address these questions. It aims to locate economic behavior within its ecological context, incorporating environmental limits and multi-scaled impacts. E*m*ergy analysis is a form of ecological economics, or environmental accounting, that provides means to evaluate national economies and natural systems with quantitative measures (Odum 1996a). Emergy is a *donor* system of value because it represents what is put into a thing rather than what can be received for a thing (Brown and Ulgiati 1999). Emergy is a single currency that can represent flows or storages of energy, materials, goods or services. Emergy is first and foremost a systems concept, which was constructed from the systems principles of self-organization, hierarchy, scale, pulsing, and others. In his recent book, *Environmental Accounting*, Odum expressed his hopes for emergy analysis:

> Whereas environmental issues are now characterized by adversarial decision making, rancor, and confusion, these conflicts may not be necessary in the future. A science-based evaluation system is now available to represent both the environmental values and the economic values with a common measure. Emergy, spelled with an "m," measures both the work of nature and that of humans in generating products and service. By selecting choices that maximize emergy production and use, policies and judgements can favor those environmental alternatives that maximize real wealth, the whole economy, and the public benefit. (Odum 1996a:1).

Anthropologists can infuse ecological-economic analyses with the rich data of human-ecological fieldwork, and in return gain tools that link communities with the global economy.

Understanding the environmental and cultural impacts of economic development choices is a global imperative as world resources are being depleted and international capital overtakes the last natural frontiers. Theoretical frameworks from systems science are necessary to evaluate the nested, multiple-scaled effects of human actions in nature. Even ecotourism development generates effects that ripple through natural and cultural environments. What is the extent and nature of the impacts of ecotourism development on Bonaire? How can the interrelated effects of development on ecology and culture be evaluated? Can general principles about ecotourism development be stated? Through research that explicitly addresses the interconnected human and natural impacts of development, this research can give policy-makers useful results for decision making.

Evolution

One underlying goal of this research is to demonstrate the usefulness of evolutionary theory to cultural anthropologists in their fieldwork. In recent years, a strong critique of evolutionary theory was led by research into the thermodynamics of self-organization and complex systems, with important implications for anthropologists interested in the evolution of cultural forms. Evolution is now argued by many researchers to be a multiple-scaled and hierarchical process, that includes the special case of biological evolution, but that also includes physical and chemical selection at smaller scales, and ecosystem and biosphere self-organization at larger scales. People are parts within open systems of nature that are constantly in flux, and that self-organize within the real limits of their material environments. Anthropologists should understand the implications of this new science for studies of culture change, of economic development, and at larger time-scales, of the evolution of cultural forms.

Purposes of the Study

The issues raised in this introduction are here distilled into a nested list of research purposes.

1) *Improved Infrastructure Evaluation with Systems Ecology*. Cultural Materialists, and other ecological anthropologists, lack methods for dealing with the infrastructure in its entirety. Many environmental features can be limiting factors on sociocultural systems. Ingestible calories or protein are single measures of limits to individuals. But countless other environmental features limit one another and humans. And the process of limiting is highly dynamic, not static. Methods are needed that can explicitly model the complex and dynamic human-environment conjunction. This study demonstrates the use of systems modeling to represent these complex processes.
2) *Evolution for All Anthropologists*. Some say that evolutionary theory is being transformed by new theories from the study of complex systems, chaos, etc. Complex systems are understood to be thermodynamic and self-organizing phenomena. Ecosystems are complex systems that self-organize within the thermodynamics of the biosphere. Sociocultural systems are intimately joined with ecosystem self-organization. This study demonstrates the usefulness of complex systems theory, evolutionary theory, and cultural evolutionary theory for cultural anthropologists interested in culture change.
3) *Ecological Evaluation of Development*. So-called “economic development” has impacts on a region that ripple through ecological and cultural systems. Economists and others focus on the monetary impacts, balance of trade, etc. Better measures of the impacts of development focus on the inflows of new materials, fuels, and other goods that transform the infrastructure of a region. Material goods can be judged on an “ecological economic” basis, which embodies their productive value—not monetary value. Imports and exports of material goods are important indicators of development impacts. This study will measure and judge the effects of imports and exports on the material basis of livelihoods on the island of Bonaire. It will use the brand of ecological economics known as e*m*ergy accounting.
4) *Sociocultural Transformation with Ecotourism Development*. Ecotourism is one currently popular development strategy. Some see tourists and dollars coming in, tourists going out, with minor impacts on local culture and ecology. But a much broader lens must be focused on an entire region within which an ecotourism destination resides. Methods that explicitly identify and measure the material transformations associated with development should be applied. Furthermore, methods should be used that register and measure the cultural self-organization that occurs with material transformations. This study measures these processes that accompany ecotourism to the island of Bonaire.

Methods Research

This research is "methods research," demonstrating that it is possible to do anthropological fieldwork at the multiple scales of individual, societal, and ecological.

- How do you do fieldwork? Anthropologists (and other scientists) have lacked scientific methods that deal with complex systems, aggregate variables, human/environment systemic interactions, and evolutionary change.
- (Scientific) Anthropologists (and other scientists) have been directed (and restricted) by the methods associated with reductionist science, and by the expectations of mechanistic explanations and control (also of reductionist science), to focus on simple problems with single or very few independent variables, essentially to abandon the study of the organization of emergent variables (such as social organization, or class, or world systems), which for many years sustained anthropology and set it apart from other sciences.
- Anthropologists are being driven by political-economic imperatives to focus research on simple, amenable (and within the relatively short-term) "problems" within other-cultural contexts. Research is therefore rarely contributing to a body of theory that is more than very narrowly focused and single-scaled.
- Can you do fieldwork at the individual level AND at the aggregate societal/economic/ecological organizational level? How do you do fieldwork at the aggregate level? Do you have to build up from the simple to the aggregate? Or can you use variables that exist only at the aggregate scale? This research will address this issue of performing anthropological fieldwork at multiple scales.

Hypothesis

With these intentions in mind, a simple and general hypothesis can be stated:

> Increases in imported goods and services associated with tourism development on Bonaire can explain changes in individual economic strategies and societal economic organization.

The hypothesis does not predict how economic strategies and organization will change with development. Instead an historical explanatory scenario is produced that, it will be argued, can better explain observed changes that occurred on Bonaire than can competing scenarios. This explanatory scenario is retrospective or retrodictive in nature. It is driven by theories of dynamics and evolution in complex systems. It incorporates structural, functional, and processual explanation from cultural evolutionary theory. In restated form:

- The hypothesis does not predict the details of change.
- It states that an explanatory scenario can be produced that can better explain the changes than a competing scenario.
- Research creates a retrospective or historical (retrodictive) understanding of the process of change.
- Explanation is grounded in systems and evolutionary theory of structure, function and process.

Methods

How do you identify and measure material/ecological/infrastructural variables? This is the most important and under-explored question within materialist/ecological anthropology. This question often is answered in reductionist models with food calories consumed, which omits all other material or energy limits within ecosystems. This research uses the ecological economics of emergy accounting to redress this problem with measurements of material variables at multiple spatial and temporal scales.

How do you determine which infrastructural variables are important? The answer is to use theoretical models of ecological structure and function. Ecological theory focuses your attention to the inflows of materials, energy, and economic goods. How do you measure these flows? Again, this research will use emergy accounting.

What sociocultural processes will therefore be evaluated? They are the following: (1) Subsistence economic behaviors, (2) Social-economic hierarchy, (3) Social-economic structure and function, and (4) International lending and trade.

This research addresses these questions and issues through the analysis of a case study of undirected culture change. The event of ecotourism on Bonaire is a fascinating example of economic development and the transformations that it can bring.

Results and Conclusions

The ecological-historical and systems-descriptive explanatory account of the processes of change associated with ecotourism development on Bonaire is the principle result of this research. A number of intermediate results and conclusions are also reached. Among its conclusions, the dissertation will measure and explain:

(1) the "underdevelopment" of Peripheries worldwide, including Bonaire in particular
(2) sustainability, with a measure called "percent renewable"
(3) structural complexification of an economy as it has undergone 50 years of development activity
(4) why households in a development context would abandon fishing and farming for participation in the market
(5) why wages are low, or sometimes high, in a development context
(6) a recommended development size, with an index called "development intensity"

SECTION I: AN ECOLOGICAL ETHNOGRAPHY

This first section is descriptive. It is intended to present a picture of Bonaire and its inhabitants to unfamiliar readers. As a picture, it has a point of focus. The section begins with a brief chapter to characterize the island via some physical parameters. This is followed by a chapter that locates Bonaire in the flow of history. A brief descriptive and comparative ecology follows that. Next comes an ethnographic account of farming, based on participant-observation and informal interviews. Last is a survey of household economic strategies. The focus or thread that joins each of these chapters is an accounting of ecological, material, and economic processes. These processes have shaped, and been shaped by, a human presence on Bonaire.

CHAPTER 2
BONAIRE IN THE CARIBBEAN

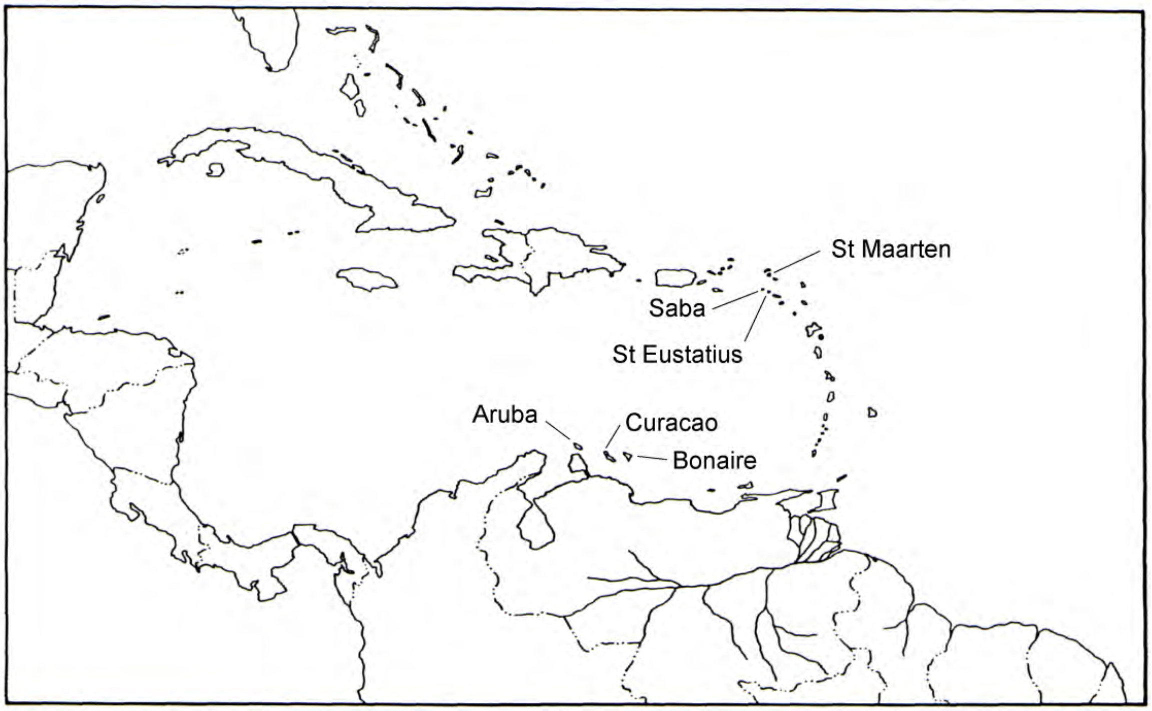

Figure 2: The Netherlands Antilles and Aruba in the Caribbean

As this century began, six Caribbean islands (the Netherlands Antilles), Suriname, and the Dutch East Indies (Indonesia) were possessions of the Netherlands. The East Indies declared independence in 1945. In the early 1950s, the Netherlands Antilles improved its position within the Kingdom of the Netherlands when it was granted domestic political autonomy via a new constitution. Suriname became an independent nation in 1975. In 1986, Aruba gained a separate status (*status aparte*), removing itself from the Netherlands Antilles (and Curacao's shadow) as an equal partner in the Kingdom of the Netherlands. In recent years, the Netherlands Antilles (five islands) and

Aruba (Figure 2) voted against referendums for independence from the Kingdom of the Netherlands.

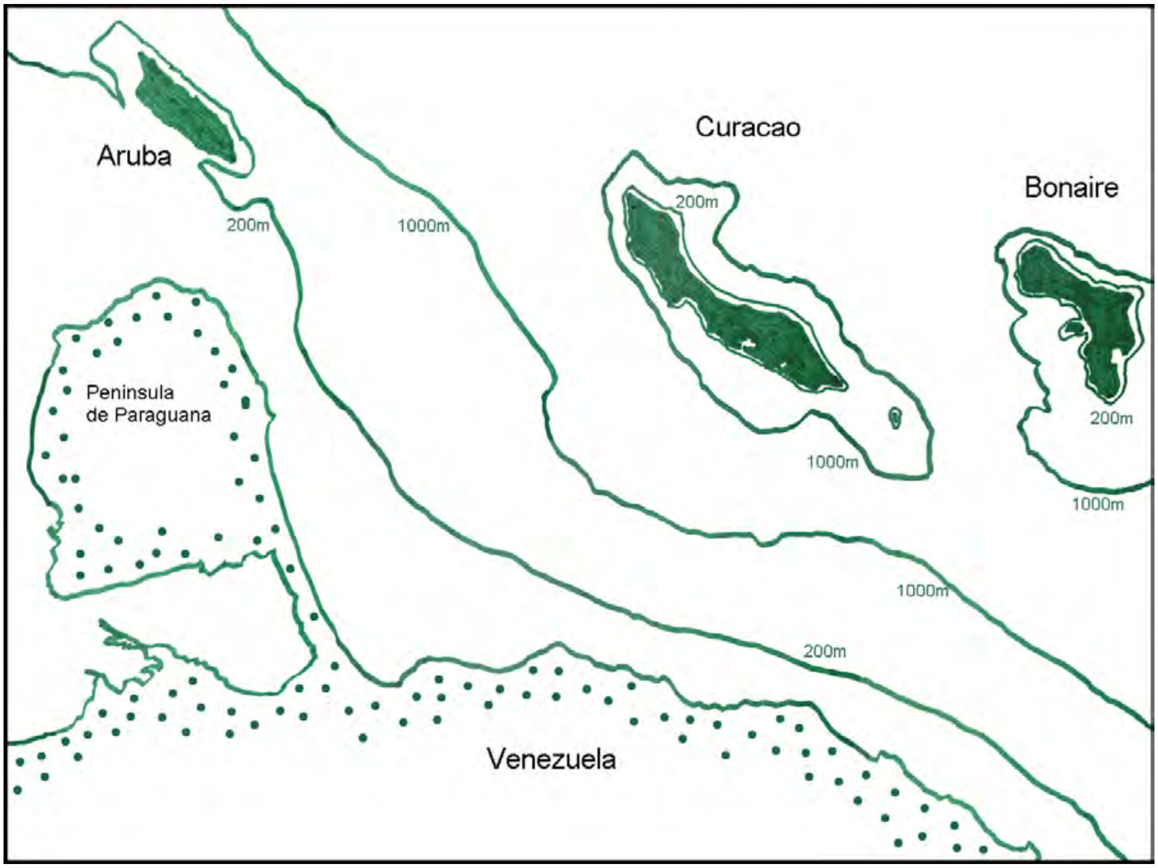

Figure 3: The Leeward Islands of the Netherlands Antilles and Aruba
Aruba, Bonaire and Curacao are also known as the ABC Islands. This map shows marine topography. Note the steep underwater descent of Curacao and Bonaire, and the relatively deep trench between the islands and the mainland. The result is narrow reefs and nearby deepwater marine ecosystems. Based on (US_Defense_Mapping_Agency 1993)

Of the Caribbean islands, the southern three form one cohesive historical and linguistic group, sometimes called the Leeward Islands (Figure 3). The northern group is known as the Windward Islands (although actually in the Leeward group of the Lesser Antilles). The first language of residents of the Leeward group is a creole called Papiamentu. In Papiamentu the islands are known as *Boneiru*, *Korsow*, and *Aruba*. The origins of Papiamentu are debated, but the creole indicates influence of Portuguese, Caquetio (Amerindian), Spanish, Dutch, and a mixture of African languages (Ratzlaff 1992). Additional vocabulary has been borrowed from English and French. The surprising and strong Portuguese influence comes from the ex-Brazilian Portuguese Jews who migrated to Curacao in the early 17th Century as slave traders. In the Windward group, Dutch is the first language, and English is widely spoken.

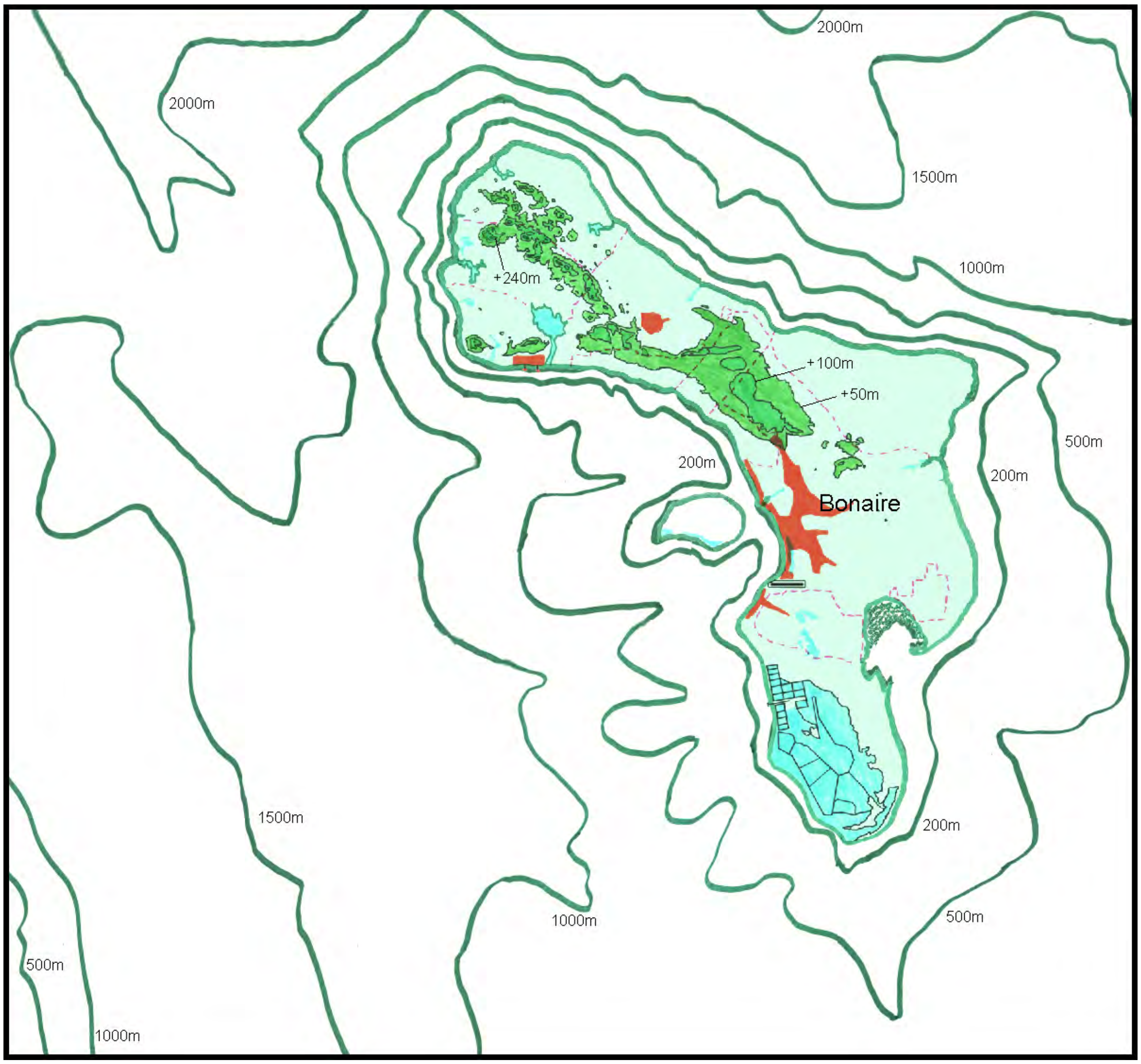

Figure 4: Bonaire Topography
Note the proximity of the 200-meter line to the coast. This indicates a steep dropoff, which means several things to the island. Large ships can dock very close to shore, which is a benefit for the oil transshipment terminal, the salt works, and for cruise ship tourism. Perhaps of greatest value to the island today, the steep drop means that coral

reefs form very close to shore. Bonaire has some of the best scuba diving, and especially shore diving, in the world. Based on (US_Defense_Mapping_Agency 1996).

The Marine Setting

Bonaire is located 87 km from the coast of Venezuela, and 40 km to the east of Curacao (Figure 3). Its greatest length is 35 km and its greatest width is 11 km. The island is 287 sq km, and is located at approximately 12 degrees north latitude.

Figure 5: Seru Grandi Limestone Terrace
An ancient marine limestone terrace, Seru Grandi was once an underwater reef. Much of Bonaire is uplifted limestone.

Between Bonaire and Venezuela the separating sea reaches a depth of 1700 m (Voous 1983:20). The immediate sea surrounding the island is characterized by a shallow terrace stretching 20 to 250 m from the coast, leading to a steep drop-off of the sea floor. Compare the 200-meter line of Bonaire (and Curacao) with that of the

Venezuelan mainland and notice that Bonaire slopes away far more quickly (Figure 3 and Figure 4). Note also that Aruba has a different underwater topography, located on the continental shelf of the mainland.

Strong and persistent easterly trade winds build high waves on the eastern coast and calm seas on the west. The mean tidal range is only about 30 cm.

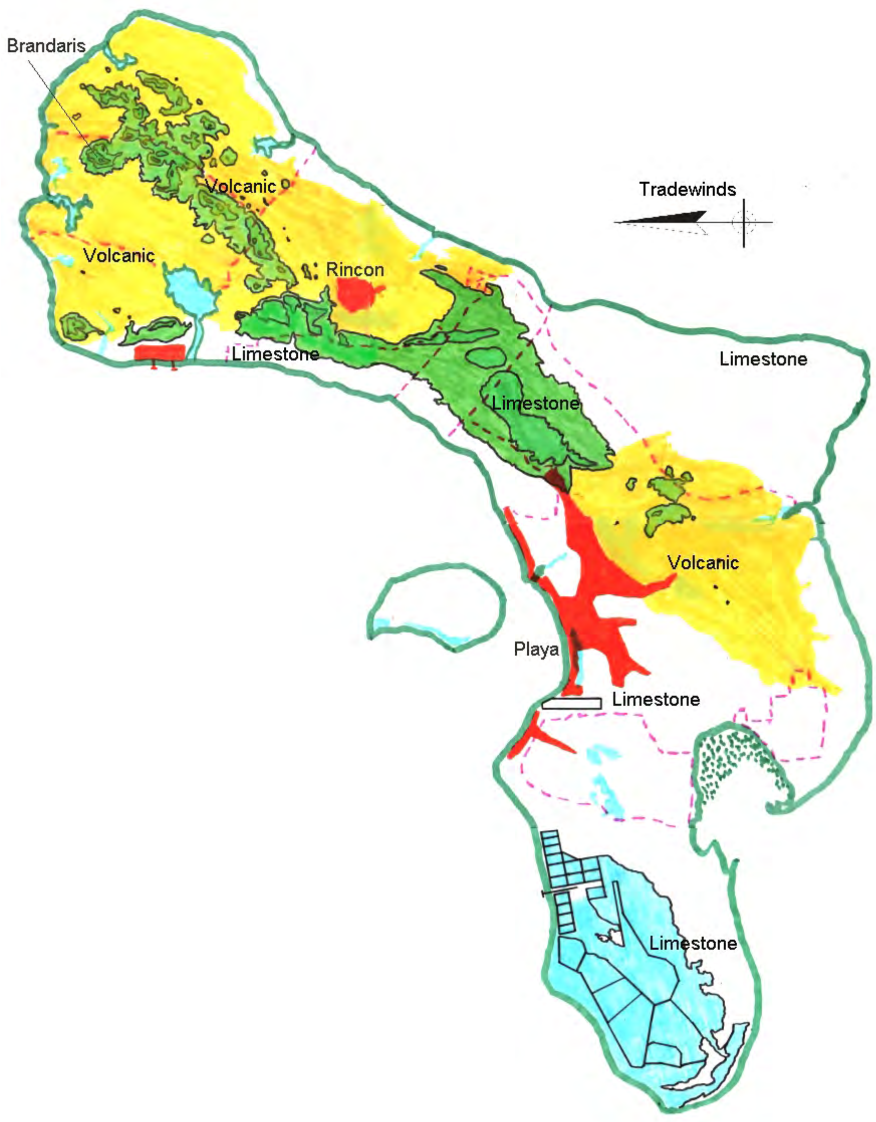

Figure 6: Topography and Soils
Two large areas of volcanic soils surround the original volcanic peaks (Brandaris is the high point of the island at 240 m). A high limestone ridge lies between them. Lower limestone terraces account for the remainder of the island.

Terrestrial Bonaire

Submarine volcanoes erupted on the ocean floor over 50 million years ago. Perhaps 3 to 5 million years ago the inactive volcanoes were uplifted above sea level. Reefs formed and erosion reduced the volcanoes. As uplift continued, reefs were raised from the sea producing the distinctive limestone terracing of Bonaire (Figure 5). The most ancient limestone terrace is the high ridge (130 m Seru Domi formation) located between Playa and Rincon (Figure 6).

Figure 7: Brandaris - the Highpoint of the Island (240 m).

Urban Bonaire

Major urban areas are in red in Figure 8. The principle urban distinction is between Rincon in the north and Playa in the south. "Playa" often refers to the entire southern urban area, and not simply the beach as the name implies. Scattered households also exist behind the limestone ridge in the middle of the island (*Tra'i Montaña*), along Lac Bay, and in the *kunukus*.

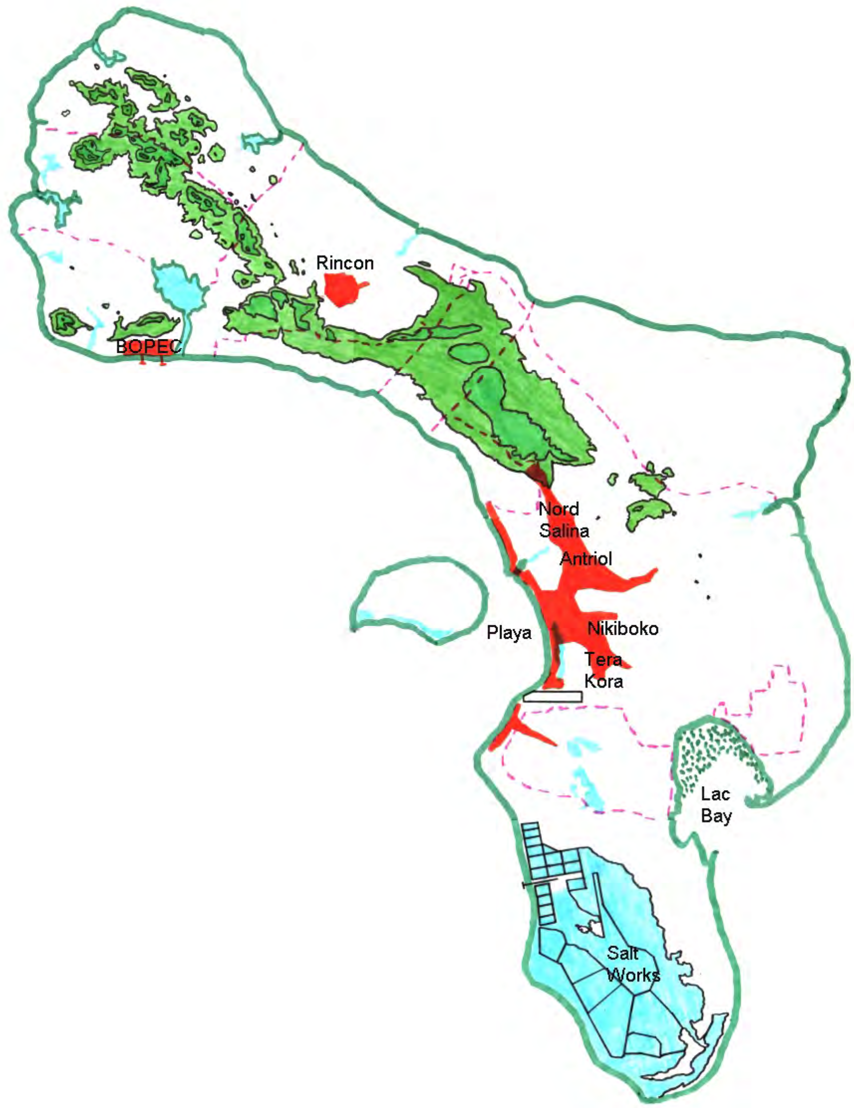

Figure 8: Major Urban Areas
The major urban areas are Rincon in the north and "Playa" in the south (shown in red). Bonaire is home to approximately 14,000 persons, with nearly 3,000 living in Rincon. The international airport is located just south of Playa.

CHAPTER 3
ECONOMIC HISTORY AND DEMOGRAPHY

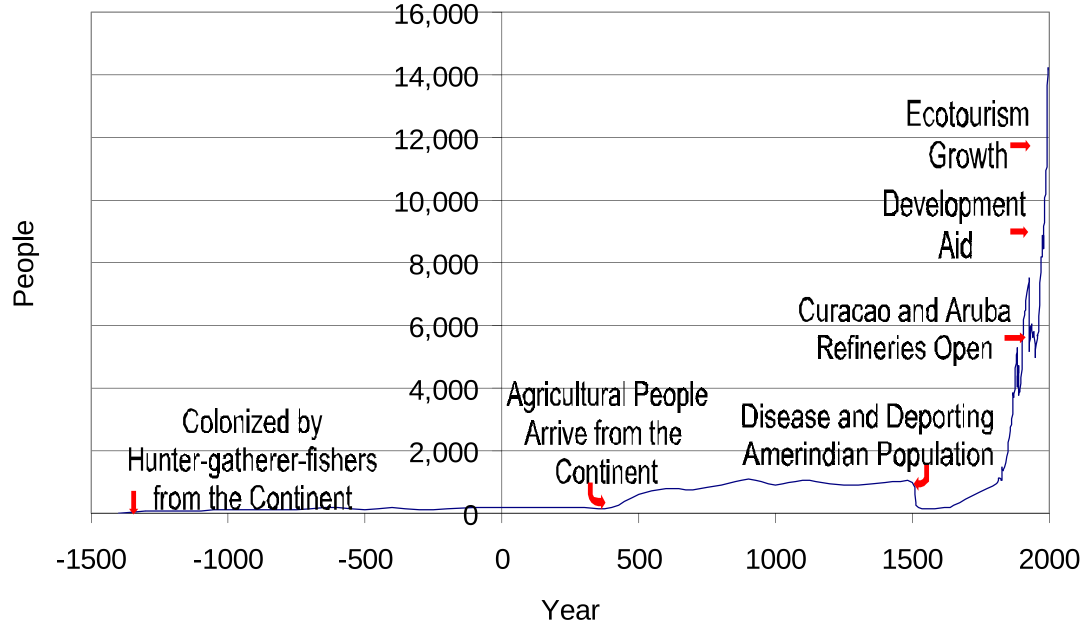

Figure 9: Population of Bonaire
The first inhabitants of the island were foragers who arrived about 3400 years ago. Ceramic using agriculturalists migrated to Bonaire around 500 AD (Haviser 1991:188-9). A hypothetical curve is drawn for both populations (notice the population is not shown to be in "equilibrium" but exhibits some fluctuations or pulsing). In the last 150 years the population of Bonaire has risen dramatically due to articulation with world fossil fuel economies (See Figure 10 and Figure 13 for details of this rise, see APPENDIX CC, Table 46).

The focus of this chapter is the economic history and demography of Bonaire and surroundings. It is decidedly not a detailed history, but in brief form traces transformations in production and population that channel other events of history. The interwoven dynamics of demography and economy, the push and pull of population with production, is a nexus of cause and effect that has properties at scales larger than individual persons in space and time. Although details from small scales may go unseen, greater knowledge of the processes of history can be teased into view.

The Amerindian Population

The first Spanish contact with the Amerindian inhabitants of Bonaire was in 1499. At contact, the agriculture and pottery-using population of Bonaire was Caquetio, related to the Caquetio on the Venezuelan coast. The Amerindian population of Bonaire was small relative to the current island population (see Figure 9 and Figure 10). According to (Haviser 1991:190):

> On Bonaire, the Ceramic Age peoples probably never exceeded a population of about 800-1200 people, who lived in Sedentary Communities with pole-construction huts, located in the vicinity of their various manioc, maize, and possibly agave, agricultural fields.

The historian Hartog reports that the entire population of Bonaire was captured and exported to Española to work in copper mines (Hartog 1978:11). However, this feat seems beyond the capabilities of the Spanish, Goslinga disagrees with it (Goslinga 1979:14), and Haviser does not repeat the claim. Rather it is more likely that the Caquetio population was crippled by Spanish disease in the great epidemic that so reduced the whole of the Americas, and that much, but not all, of the remaining population was captured and deported. Haviser indicates that Caquetio populations remaining on Bonaire maintained a great deal of autonomy throughout the Spanish reign, and distinct Amerindian ethnic communities persisted on Bonaire until the 19th Century.

> With the eventual 15th and 16th century contacts of Spanish slave hunters and explorers, the Amerindians of Bonaire became more cautious of Europeans and retreated to more isolated settlements at Fontein and Rincon. However, the general lifeways of these Bonairean Amerindians who survived slave captures and disease, were relatively undisturbed by the 16th century Spanish political domination. It was the Amerindians responsibility to provide livestock and agricultural produce for the Spanish, but otherwise they were allowed to maintain their own lifeways (Haviser 1991:190).

The Spanish Reign

Perhaps the single most transformational act of the Spanish was to bring livestock from the Old World to Bonaire. Horses, cattle, donkeys, goats, sheep, etc. were brought to Bonaire in 1527 (Hartog 1978:11). The impact of these large herbivores must have been no less than revolutionary for the Bonaire ecology. Goats and sheep were especially successful in the semi-arid climate, and by 1679 there were 8,500 sheep and goats on Bonaire (Hartog 1978:34). The presence of these small and mobile grazers and browsers meant selection for thorn forest vegetation (acacia, mesquite, many cactus species, etc.) that could defend itself from foraging animals, and that today dominates the landscape.

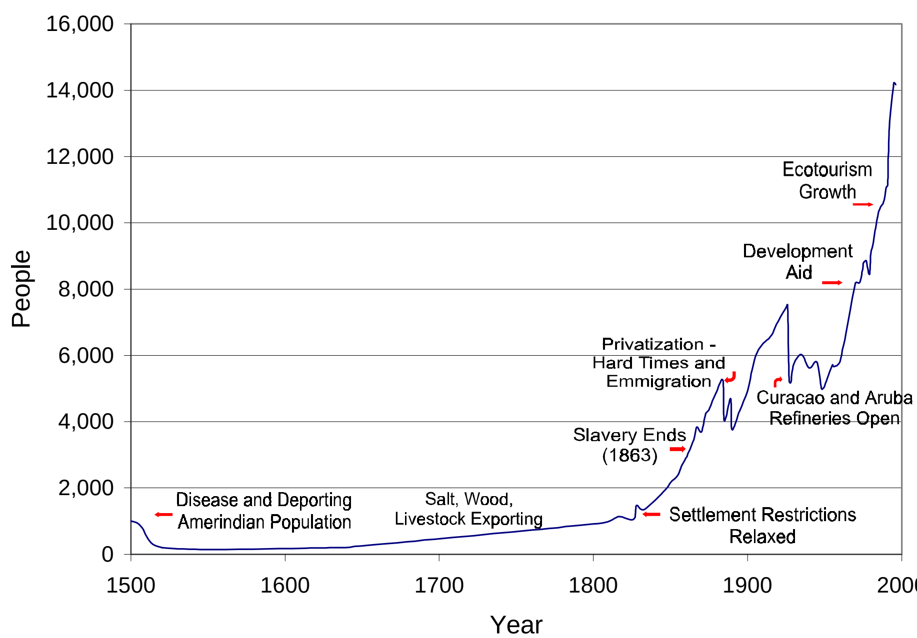

Figure 10: Bonaire Population since Contact
Bonaire's population reflects the supporting role it has played to Curacao, and later also Aruba. Recent years of Dutch development aid, and ecotourism have brought a

population explosion to Bonaire, not on the scale of Curacao and Aruba (Figure 11), but remarkable in absolute terms. This is especially true considering the slim natural resource base of the island, a condition also of Aruba and Curacao. See APPENDIX CC, Table 46 for citations.

Tree cutting was another activity of the Spanish that had long-lasting effects. At the time of contact, Bonaire was called "Isla de Palo Brasil" or "Dyewood Island" by Juan de la Cosa, presumably because of its great abundance of dyewood (Hartog 1978:4). Dyewood (*Haematoxylon brasiletto*, *Brasia* in Papiamentu) was a highly desirable forest timber of the day because it could be rasped or ground to obtain cardinal red dyes. It was valuable in both the Spanish, and later the Dutch, textile industries, and trade in dyewood continued until the beginning of this century.

The Dutch in the Caribbean

Comprehending the Dutch relationship with contemporary Bonaire requires some mastering of the history of the their union. In a critique of evolutionary theory from some years ago, Gould (1979) demonstrated that constraints on the evolution of new forms are often as interesting as the new forms themselves. Present form is always a transformation from a past form, with future options channeled, though not determined, by the past. Although contemporary Bonaire is shaped by many ecological, political, and economic limits that will be discussed in other chapters, its present form is also a product of its history.

The Leeward Islands of the Netherlands Antilles--Aruba, Bonaire, and Curacao--are islands of similar physical size, however the current population of Bonaire is about 14,000, compared to 152,000 on Curacao and 88,000 on Aruba (Figure 11). What historical events channeled these developments and set the stage for Bonaire today?

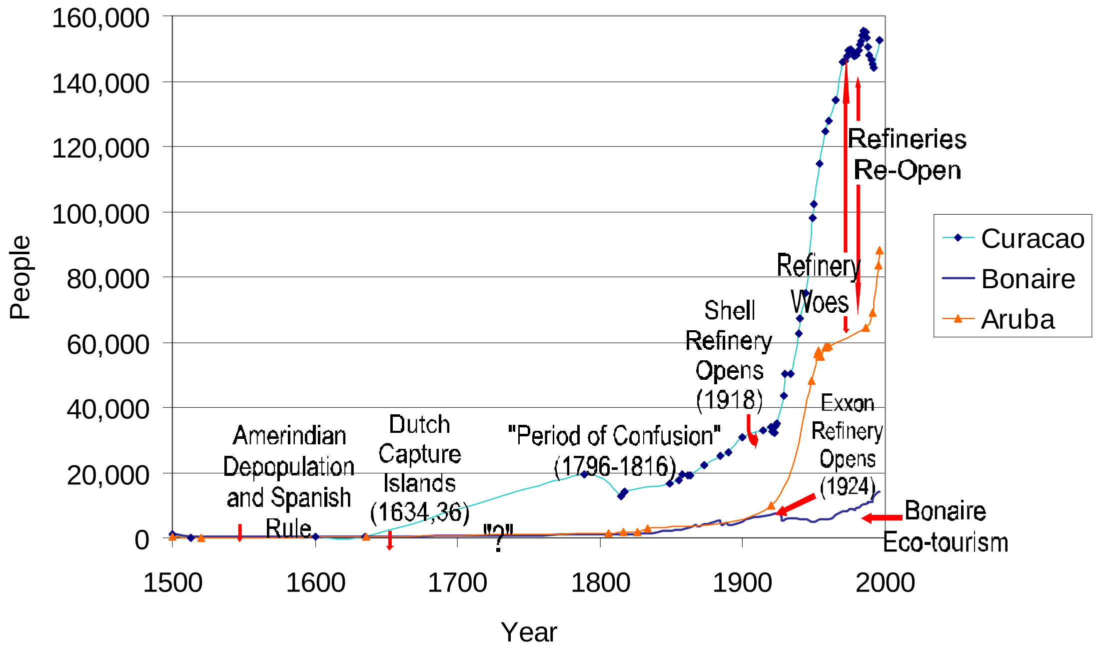

Figure 11: Population of the Leeward Islands of the Netherlands Antilles and Aruba Note the early distinction of Curacao from Bonaire and Aruba, and the much later separation of the refinery islands of Curacao and Aruba from Bonaire. The exact path of population growth on Curacao between 1634 and 1775 is not known, but beginning and end points are. Curacao, with its remarkable natural harbor, was the center of Dutch slave trade in the 17th and 18th Centuries. Dutch wars with France and England brought periods of English occupation and general confusion to Curacao, however Dutch control was re-established after 1816. The next major event was the arrival of refineries, which sent populations skyrocketing. Refinery hard-times came in the mid-1980s, but they have recovered in recent years. Economic diversification, led by offshore banking and tourism, is adding further expansion. See APPENDIX CC, Table 46 for citations.

In 1623 the first Dutch ships came to the islands (Hartog 1978:17). The Dutch had been at war with the Spanish since 1568, and the "Eighty Years' War" would last until the Dutch prevailed in 1648 (Figure 16). An important economic resource, and therefore strategic resource, of the day was salt, which the Dutch used extensively for curing herring and other food preservation (Goslinga 1979:20-25). Cut off by the Spanish from the salt pans of the Cape Verde Islands, the Dutch were forced to seek it elsewhere. Sights were set on the Caribbean.

The famous Dutch East India Company (the VOC) was formed in 1602, which united competing trading companies in pursuit of trade to the "Indies", actually Asia and the islands of Indonesia. Modeled after the VOC, an Atlantic charter was granted in 1621 to the Dutch West India Company (the WIC), whose mission in fact went beyond trade:

> Like its sister company in the East, the WIC was a joint-stock corporation organized by private merchants and individual shareholders. Unlike the other company, however, the WIC was an explicit instrument of war and privateering against Spain (Goslinga 1979:21).

The WIC would harass the Spanish fleet, especially the great flota, which had brought tremendous wealth to Spain for many years. Incidentally, islands were scouted for salt and other strategic value. The salt pans of Curacao and its excellent natural harbor were identified, and in 1634 the Dutch invaded the island and took it from a small outpost of Spanish.

Curacao's strategic position for shipping might be obvious, but is more so from the sailor's perspective of the day:

> …her position relative to the trade wind system allowed for sailing to and from a wide arc of the Antilles, from Cuba to Guadeloupe, without having once to beat to windward. This could prove an enormously time-consuming operation against the boisterous Caribbean trades and heavy currents and was so recognized by the earliest European navigators in that sea (Jackson 1965:4).

The island harbor, with narrow entrance and large deep bay (today called Schottegat and the home of the giant PDVSA (ex-Shell) oil refinery), was quickly fortified. In 1636, Aruba and Bonaire were also occupied to secure the Dutch position on Curacao. This supporting role played by Aruba and Bonaire to Curacao marked a division of labor that persisted until this century. Besides eliminating easy staging points for attack on Curacao, Aruba and Bonaire became resource islands, occupied to supply Curacao with goods, and to produce export commodities for the homeland. From Bonaire the Dutch exported meat for the inhabitants of Curacao. Aruba was used for horse raising. From Bonaire also was taken salt from natural salt ponds for curing herring in the Baltic and for making butter and cheese, dyewood for textile dyes, lignum vitae (*Guajacum officinale*), a hard wood used in ship's pulley-blocks, *watapana* pods for tanning hides, and sorghum grown also for Curacao (Hartog 1978:15-38).

As the Dutch became important slave traders in the 17th and 18th Centuries, Curacao became the center of the slave market. In the 50 years between 1675 and 1725 it can be estimated that 100,000 slaves passed through the Curacao harbor (Goslinga 1985:188). A small number of slaves were used on Bonaire for salt production, but extensive slave labor was never employed as it was on the sugar islands of the Caribbean.

Throughout the 18th and 19th Centuries, Bonaire continued its meat and resource production role, a supporting role to Curacao and the Netherlands (Figure 10). The entire island was "managed" as a salt plantation, first by the Dutch West Indies Company and later by the Dutch government. It was even leased by a New Yorker for a short time, when it could not turn a profit for its Dutch managers (Hartog 1978:36-37). Small-scale farms, owned or held by ex-slaves, filled in the cracks where they occurred. Goats, sorghum, and fish provided subsistence, and goats and sheep were allowed to forage on government lands. In 1863, slavery was abolished on the Dutch islands and approximately 650-750 mostly salt-producing slaves on Bonaire were freed (Klomp 1986:18).

By 1868 the Netherlands government recognized the difficulty in making money on Bonaire without slave labor, and they attempted to sell off the island. Bonaire was gradually divided into private "plantations" with private ownership (Figure 12). Ex-slaves suffered now low wages, monopolies by plantation owners, and reduced access to grazing land, and many emigrated (Figure 13). Migration and remittances became a common pattern for Bonairians, as they came to experience the Caribbean migration/remittances phenomenon that persists to this day.

Figure 12: Plantations
Following the abolition of slavery in 1863, the island was put up for sale in 1868. After some hand changes, these "plantations" remain. Washington, Slagbaai, and Brazil were bought back by the government, and today form the Washington-Slagbaai National Park.

The "plantations" of Bonaire, atypical in the Caribbean, teetered between economic survival and failure. Salt continued to be the main export commodity, with *watapana* pods for tanning a distant second (Goslinga 1990:353-55). Salt production was and is a precarious industry. With all Caribbean export commodities, it was vulnerable to international competition and demand fluctuations. Add to that the vagaries of Bonaire's weather, which in some years can have five times the rainfall, spelling defeat for a year's salt crop (Hartog 1978:50-51).

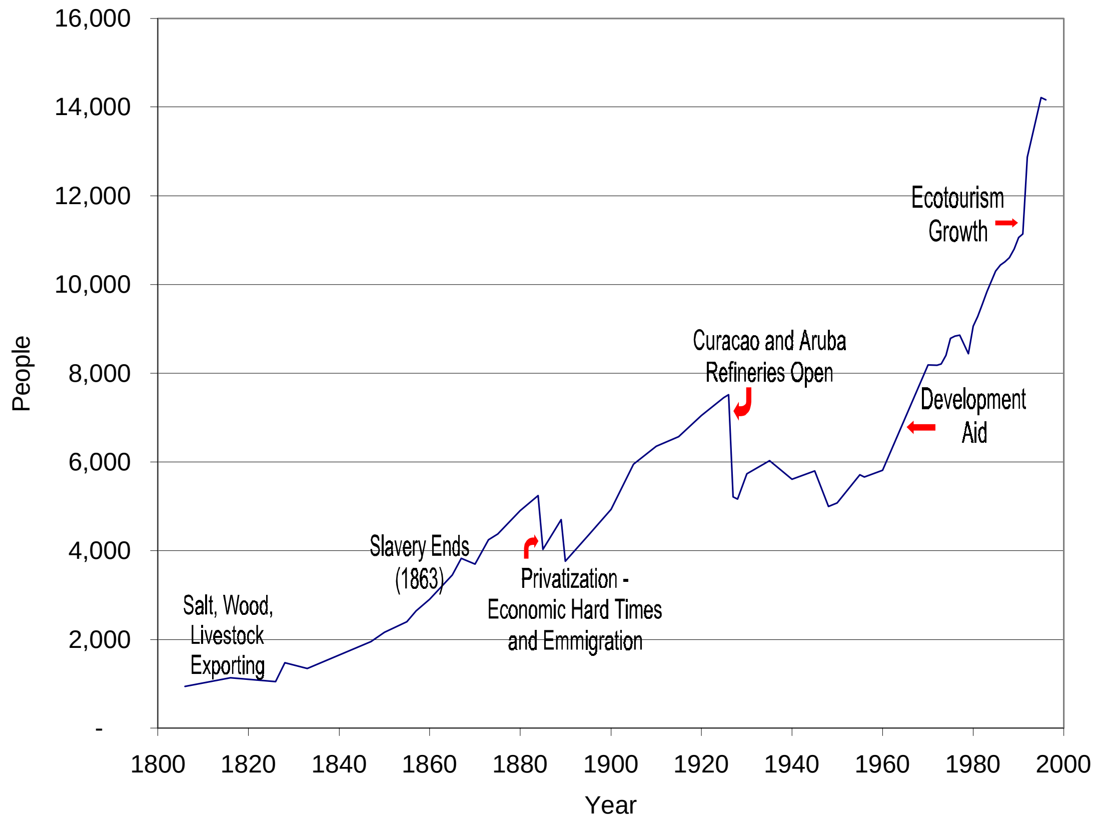

Figure 13: Bonaire's Population in the Last 200 Years
Two significant emigrations occurred due to external events, one a Dutch policy decision, and the other a development decision of oil companies to place refineries on Curacao and Aruba. Dutch development aid, ecotourism, and a new retirement law have fueled population growth since mid-century. See APPENDIX CC, Table 46 for citations.

At the turn of this century the population of Bonaire was approximately 5000 and growing as the effects of world industrialization trickled into the islands (Figure 13). In

1915, the Dutch-British Shell with the General Asphalt Company of the United States signed an agreement to drill for oil in the Maracaibo region of Venezuela (Goslinga 1979:141-43). Due to concerns for political stability and shallow harbors in Venezuela, a refinery was built on Curacao to refine and ship the Venezuelan oil (Figure 11). In 1924, Lago Oil, a subsidiary of Esso, later Exxon, began another refinery on Aruba. Aruba, with even fewer citizens than Bonaire in that day, was completely transformed. For Bonairians the refineries offered a new source of cash remittances, and emigration nearly emptied the island of its workforce. By 1926 the population of Bonaire had risen to 7,521 (Hartog 1978:71), but in 1928 the figure had slid dramatically to 5,166 as Bonairians moved to their neighbor's refineries (Figure 13). In 1948 there were only 4,995 Bonairians on Bonaire, and in 1960 there were still only 5,812 inhabitants on the island (Hartog 1978:88).

The 1960s brought significant "development" funds from Holland to Bonaire. Infrastructure was improved for island travel, shipping and air travel (Hartog 1978:90) (see CHAPTER 13, The State Equation and Financial Aid). In the 1950s, salt production had declined to zero. In 1967, after careful study, the Dutch multinational chemical company Akzo took over and reconstructed the salt ponds on Bonaire (Hartog 1978:108). In 1972, Northville Industries, an American petroleum storage company, began construction of an oil transshipment terminal on Bonaire (Hartog 1978:93). Two giant microwave radio broadcasting stations were built on Bonaire in the 1960s, Trans World Radio, an American company beaming religious fare to Latin America, and a relay station for Radio Nederland. A rice milling facility was constructed on Bonaire in the 1980s to gain tariff free access to the European Union for South American rice. Following the construction phase of these export industries, they have not directly provided significant employment to the island population.

The European Context

Why were the Leeward Islands settled by the Dutch? Why did the particular patterns of resource extraction, commerce, and slave trade appear? Why was slavery practiced on these islands in such small numbers? Why do the Dutch in our century provide "development aid"? Why did the Netherlands Antilles not achieve independence in the 1970s with much of the Caribbean? To understand this history of Bonaire it is necessary to understand the position and goals of its metropolitan colonizing power--the Netherlands, especially the coastal province of Holland, which includes the 17th Century world trade powerhouse of Amsterdam. Those of us who think we know the history of Western Imperialism will be quite surprised by the view from the Low Country.

"Too much water"--TeBrake, in his ecological archaeology, called it the "greatest of all obstacles to human presence in the western Netherlands" (TeBrake 1985:148). The unlikely hydrology of peat bogs, salt marshes, and storm surges kept the Roman Empire south of the Rhine, and nearly so the Carolingian Empire of Charlemagne which followed them. The coastal dune populations of the western Netherlands were buffered from the social and political forces overtaking western Europe by a nearly impassable terrain--the "Low-Country", the Neder-lands--of bogs and marsh. While remaining European woodlands were being felled and put to the plow in the first millenium AD, the western Netherlands underwent a very different transformation.

Neolithic farmers had first brought cattle and mixed fishing and foraging strategies to the coastal sandy ridges of the Netherlands in the third millenium BC (TeBrake 1985:81-86) (Figure 14). From the Bronze Age (1900-750 BC) onward, trade from western Europe to the British Isles and Scandinavia was sailed across the low country, especially along the Rhine and through the Baltic and North Sea, and trading settlements grew on the dune ridges at the mouths of great rivers. Coastal populations, known as Frisians, could trade cattle hides for bronze, and chiefdoms could exact payment for safe passage (TeBrake 1985:88). The Frisians were equally at home on land and water, described by an anonymous 10th Century biographer as "people who lived in water like fish and rarely traveled outside their home territory unless they could do so by ship (TeBrake 1985:144)."

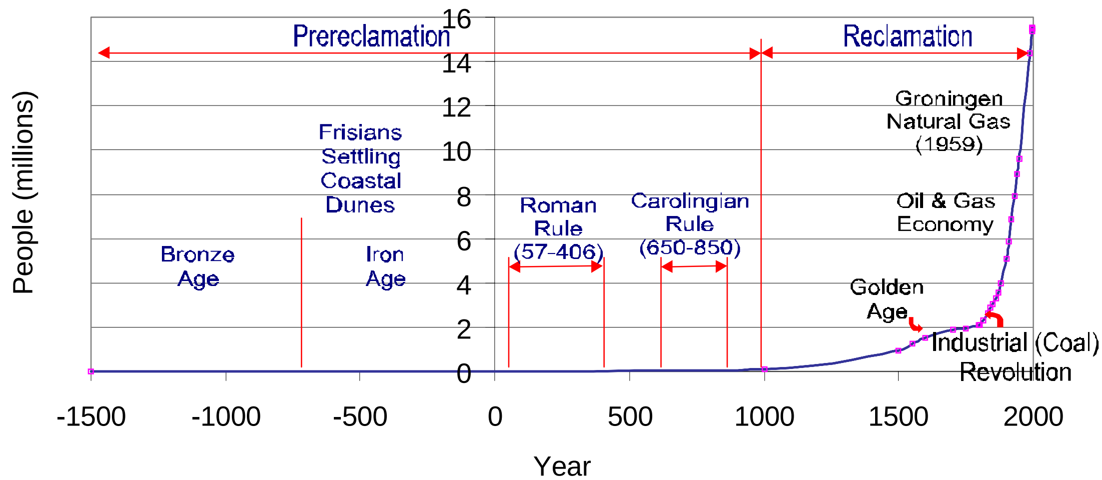

Figure 14: Population of the Netherlands
The "prereclemation" population of the Netherlands is not zero (see the log scale curve in Figure 15). As explained in the text, the Roman and Carolingian periods had little effect on coastal Netherlands' populations. In the "prereclamation" era, the Frisians expanding into the coastal dune areas were effectively buffered from other western Europeans by the "Low Country" of peat bog and salt marsh. The rapid population increase of the "reclamation" era is evident in this graph. See APPENDIX CC, Table 47 for citations.

From the Bronze Age onward, the food production of coastal populations came to settle on livestock, crop raising, and fishing. Peat was burned for fuel. Livestock were cattle, plus sheep, goats, pigs, dogs, and chickens. Cattle supplied meat, milk and traction, and later cheese and butter. Crops were einkorn, emmer wheat, bread wheat, hulled barley, flax, and field weeds. Food production overwhelmingly emphasized…

…raising livestock that were grazed on the ample grasslands available everywhere in the coastal districts, cultivation of the sandy and sandy-clay ridges that were the focus of settlements, and fishing in the plentiful waters of estuaries, salt marshes, rivers, and peat bogs (TeBrake 1985:172).

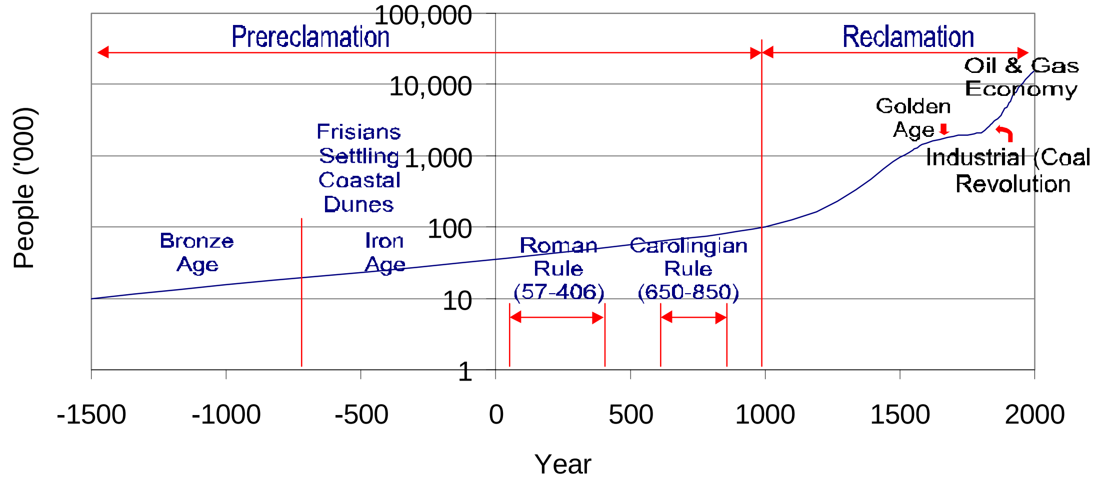

Figure 15: Netherlands Population in Log Scale
In log scale format, it is now possible to see that the early Netherlands populations were not unsubstantial, although relative to the 15 million inhabitants of today they were not visible in Figure 14. Even in log scale, the appearance of population growth since "reclamation" is striking. (Population figures prior to 1000 AD are difficult to find and have been estimated.) See APPENDIX CC, Table 47 for citations.

In sum, prior to 1000 A.D., the Frisians had become agro-pastoralist-fishers, and "the merchants par excellence of northwestern Europe" (TeBrake 1985:177). The high natural productivity of coastal estuaries, mighty rivers, deltas, bogs and marshes, reminds us of the natural environmental bonanza afforded to the American Indians of the Northwest Coast. Amerindians like the Kwakiutl formed big man collectivities supported principally by the foraging of marine and estuary resources (Johnson and Earle

1987:160-186)[1]. The high natural productivity of western Netherlands was coupled with the domesticated livestock and agricultural crops available to western Europeans. This potent mix sent population densities to 20 per square kilometer in the northwest, only exceeded by the Paris basin and parts of Flanders in the day (TeBrake 1985:171).

Johnson and Earle (Johnson and Earle 1987:248-274) contend that 10th and 11th Century France is better recognized as the home of family-level groups, local groups, and simple and complex chiefdoms, rather than "kingdoms" (archaic states) as they are usually labeled in the historic literature. The name "kingdom" denotes a level of political, military, and production specialization that was not evident. The same can be said for the coastal Netherlands. Terms translated as "count", or "duke", or "noble" only cloud the picture (Rietbergen and Seegers 1992), conjuring images of political centralization that would remain unimagined for several centuries along the coastal dunes. Small communities operated autonomously, and formed shifting alliances with leadership contended between competing clans. Merchant trade was "decentralized" among "innumerable little villages", and only a few port towns appeared, such as Dorestad on the Rhine (TeBrake 1985:131). Absent were large polities with standing armies, public works, great economic inequalities, and weak peasantries. These would await the "reclamation" period.

Intensification of Production

Reclamation for Farming

The era before 1000 A.D. in the western Netherlands is known as "prereclamation" (Figure 14 and Figure 15). What followed was a dramatic

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[1] The fact that these two similar settings are located in the northwest corner of great continents at identical latitudes is not coincidence. Year-round rainfall and high-energy storms impart great driving energies in both environments. Evidence the evolution of windmills in the Netherlands. While the Netherlands lacks the coastal cliffs to catch

transformation of land and water, unequaled perhaps in the world. The reclamation and settlement of the peat bogs of the western Netherlands was accomplished with ditches, dikes, dams, bridges, canals, sluices, polders, pumps and windmills. Not at once, and not by grand design, but piecemeal the peat bogs were drained for crops and pasture. Ditching at first did the trick, as peat will stop forming and dry out when water tables are lowered. Later, as subsidence, oxidation, and mining had consumed peat surfaces and lowered them to below sea level, much more ingenious methods were innovated to hold back the water. Today practically all of western Netherlands is below sea level.

Central authority was not a prerequisite for ditching a peat bog, but community cooperation was. As populations and food production expanded in the peat bog areas, the organizational impacts of reclamation became felt:

> From the very beginning of the reclamation and colonization process there was a need to coordinate diking and drainage operations in an effort to combat the natural tendency of individuals simply to send unwanted water downstream without worrying about how it might affect someone else (TeBrake 1985:228).

Emerging communities were forced to organize and coordinate their reclamation activities and emergent elites often took key roles. In later years, the economic and political elites of the Dutch state could turn these duties into coercive powers to exact taxes, labor, or military service. Reclamation was the lever to create a "hydraulic empire", but of an inverted sort in which water was a commodity to be removed not partitioned.

Merchant Shipping

Balancing the agricultural intensification in the peat countryside was an expansion of merchant towns. When it is an option, water transport is an energetically superior means of moving bulk goods, especially when medieval roads are the

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equal rains, its wide rivers and deltas return the rainfall and sediments of the continent to the low country.

alternative. As the reclaimed peat-bog wilderness filled with farmers, river market towns appeared, such as Dordrecht, Leiden, Haarlem, Amsterdam, Rotterdam, Leeuwarden, and Groningen. Growing urban markets would have been supplied by the newfound countryside and by trade from western Europe and Baltic Sea ports.

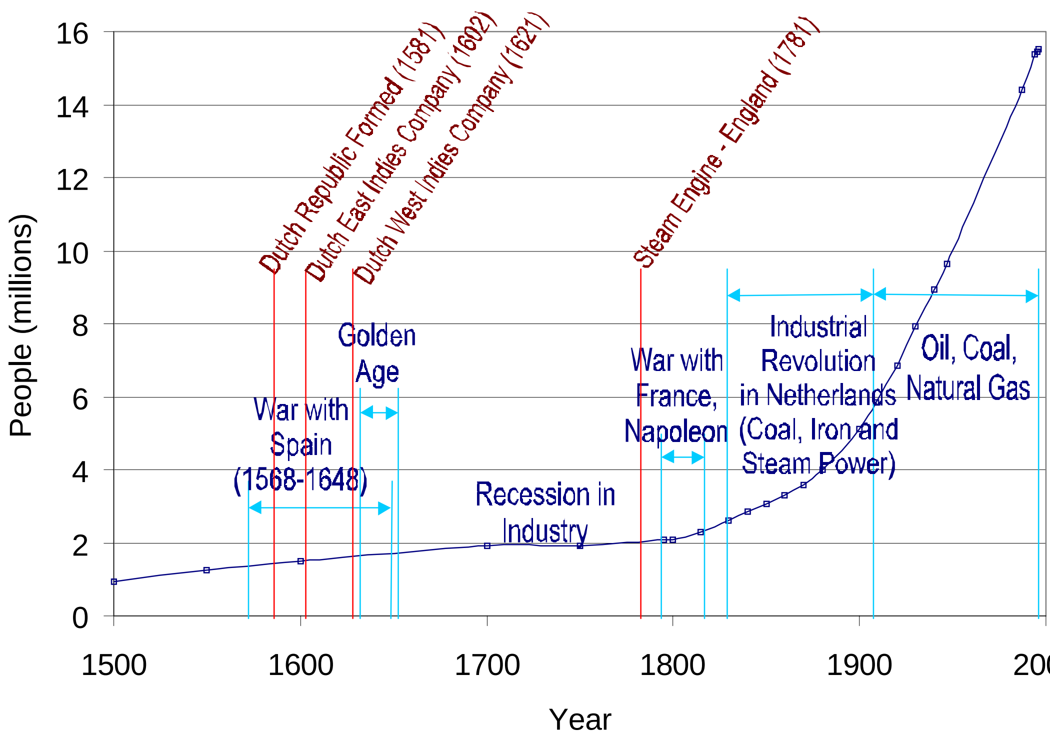

Figure 16: Netherlands Population Since 1500
In the last 500 years the population of the Netherlands had two major growth eras, one prior to the "Golden Age", and one which coincided with the Industrial Revolution of coal, iron, and steam power, and now oil and natural gas. See APPENDIX CC, Table 47 for citations.

Salted Herring

Another production strategy to blossom in the late Middle Ages was herring fishing. Herring had long been fished in the coastal waters, but now gutted, salted, and cured, it could be shipped in barrels (called barrel herring) to emerging markets (Rietbergen and Seegers 1992:57), (Van der Wee 1993:129). Salt was thereafter a critical commodity for Dutch merchants. In the 16th Century, specialized fleets of fishing boats, called *haringbuis*, were factory ships for herring fishing that possessed speed, durability, and increased cargo. These ships were "factory" ships because herring could be gutted and salted on board. Salted herring has been called the "Dutch gold mine" for its market success. The technology of salted fish and *haringbuis* permitted the Dutch to dominate the North Sea herring fishery, and later the Iceland cod fishery, and Spitzbergen whale fishery.

Textiles

The production of wool and linen from sheep and flax had great antiquity in the Netherlands as household goods. A thriving textile export industry emerged in the Netherlands with the shipping industry to make it work. Wool was soon also imported from England. The Dutch traded textiles, a secondary commodity, throughout Europe for primary goods, the typical pattern of an industrial world system (Wallerstein 1974:96). By 1560, other imported "raw materials and unfinished products" were Baltic grain, Spanish wool, French dyes, Portuguese sugar, French salt, Portuguese spices and Italian silk (Van der Wee 1993:106). These commodities fed people and fueled the textile industry.

Shipbuilding

Shipbuilding became a keystone industry, labeled an "industry" in the modern sense because it was conducted in standardized, repetitive methods. One 17th Century warship could require 2000 oak trees, most brought from the Baltic. Holland's advantage in shipbuilding became autocatalytic, as Dutch shipbuilding used the shipping of lumber to perpetuate itself. In 1630-50, when the Dutch Republic dominated European world trade, they possessed a merchant fleet of 2500 ships, plus 2000 or more *haringbuis* (Rietbergen and Seegers 1992:93). The Dutch became masters of Baltic trade and thus Eastern Europe's wheat exports. Amsterdam in the 16th Century emerged as "the granary of Western and, from the end of the century, also of Southern Europe" (Van der Wee 1993:32).

Other valuable export commodities were beer, cheese, and butter. Low country hops fed breweries. Cheese and butter were produced from dairy cattle and preserved with salt, the value of which to the Dutch was thus further punctuated.

Banking and Finance

One final pillar in the hegemony of the Golden Age (1630-50) Dutch Republic, and a force to this day, was the success of Dutch financial technologies. The private bankers of Amsterdam and the Amsterdam Stock Exchange led innovations in finance, credit, stock, and currency, which captured and unleashed new resources into the production stream. Bankers around the world would copy Dutch financial innovations. In the 17th Century, the Dutch guilder was the dominant currency of the world (Van der Wee 1993:33).

Competition would topple Holland from its short-lived world economic hegemony (see World System Simulation Results). Both military and economic warfare was waged by the French and British against the Dutch, and against each other. Their neighbors did not destroy the Dutch, rather they simply surpassed them. The second half of the 17th and the 18th Centuries brought economic recession in the once powerful textile and shipbuilding industries. Capital was becoming international, and much of it moved to Britain, as did many of the merchants who owned it. Population growth in the Netherlands stagnated with economic stagnation (and some contraction) in these years (Figure 16). During the years of stagnation (contraction) the gap between the rich and poor widened and the elite class became impenetrable (Rietbergen and Seegers 1992:107).

The Industrial Era - Coal, Oil and Natural Gas

The invention of the steam engine in Britain in 1781 began a revolution in the production of mechanical work. Coal, iron, and steam technologies fueled the economies of Europe and the world. New unimaginable energies were unleashed into industry, transport (trains and ships), and warfare, in an "industrial" revolution. In the next 100 years the population of the Netherlands would triple (Figure 14, Figure 15, Figure 16). "Carboniferous Capitalism" seized the world.

Of particular importance for the Netherlands was the second carbon fuel revolution. Oil would follow coal as the fire of industry in this century (see McGrane 1994:180-207) for a fascinating account of the historical dynamics of coal and oil use). Oil, natural gas, and the petrochemical industry that they spawned, are the yet underpinnings of the current world. In 1906 the Shell Transport and Trading Company of Britain merged with Dutch interests in the Far East to form the Royal Dutch/Shell Group, owned 60% by Royal Dutch with majority shareholders in the Netherlands. Today this oil company is the largest in the world, and one of the world's largest multinationals. Begun in the Dutch East Indies, Shell moved early into Venezuela and Mexico. Royal Dutch/Shell has remained the most international of the major oil companies, with operations in more than 130 countries worldwide[2] (Jones 1988:171) (Shell 1998:20).

One last stroke of energy fortune for the Netherlands has been the discovery in 1959 of large natural gas reserves beneath Dutch soil. The Netherlands today is the largest producer of natural gas in Western Europe. In 1996, the Netherlands consumed

[2] Giant transnationals like the Royal Dutch/Shell Group operate much like independent nations, as Jones reported back in 1988 (Jones 1988:171): "Shell…has its own global private telecommunications system, an extremely efficient economic intelligence network and a world wide network of representatives and government relations advisers. In this it is probably comparable or superior to the diplomatic services of all but the top few international powers."

approximately half of the natural gas that it produced, the highest level of domestic penetration in the world. The Dutch meet 98% of household energy needs with natural gas, 70% in the commercial sector, 65% in industry, and 55% in power production (International_Energy_Agency 1998:216).

The value of fossil fuels to the Netherlands cannot be overstated. Emergy analysis has shown that fossil fuels have high net emergy yields (6/1), i.e., they contribute far more work to an economy than is paid for on the market (Odum 1996a:136-163). Early in this century, when fuel reserves were plentiful and near the surface, that yield was even higher (60/1). The Netherlands economy has benefited mightily from their fortunate affiliations with fossil fuel. Today they have the highest emergy self-sufficiency index in the world (Odum 1996a:217), one of the highest emergy per person ratios (Odum 1996a:206), and surely one of the highest empower densities, given the small size of the country. This emergy bounty supports a tremendous population density of 457 people per square km. For comparison, this exceeds the density of New Jersey (402 people per square km), and over a land area twice the size of that US state (see CHAPTER 8 for further discussion).

The contemporary economy of the Netherlands is buoyed by industries other than fossil fuels, which have had remarkable success considering the size of the country (15 million persons), but are perhaps less surprising in the context of history. A number of Dutch-born companies can be found today in the top fifth of the Global Fortune 500. ABN AMRO Holding is a banking giant, while the Ing Group is an insurance multinational, both the descendants and beneficiaries perhaps of Dutch financial advantage achieved in centuries past. Unilever and Ahold are huge multinational food-processing corporations, which sit squarely in the tradition of 17th Century food export expertise. The Akzo Group is a multinational chemical giant that began with the salt industry. Millions of cattle, pigs and poultry provide meat and dairy products for domestic and export markets. A once light-bulb manufacturing company has become multinational electronics giant Philips Electronics. Rotterdam is the world's largest port for petroleum processing and transshipment, which serves Royal Dutch Shell, the chief successor to Dutch merchant shipping.

The Netherlands and Netherlands Antilles in Brief

To summarize, in comparison to the rest of western Europe, the Low Country of peat-bogs and marshes in the Early Middle Ages was scarcely populated. Political control was distributed throughout scattered populations of agro-pastoral-fisher-traders who lived in a highly productive but difficult natural environment of estuaries, deltas, pasturage, and coastal fisheries, along river trade routes that tapped the entire continent. These populations were nearly inaccessible by land and thus escaped foreign domination for millennia.

From at least 1000 AD, the Frisian populations in the west and northwest began a slow and piecemeal process of intensifying agricultural production by draining peat bogs for farming. This process literally "fueled" a population explosion, by providing peat for cooking and heating fuel, and tapping ancient storages of nutrients for agricultural production. As populations swelled, intensification occurred in shipping and fishing technologies as well. An inverted "hydraulic empire" appeared in which emergent elites could force further intensifications by controlling the politics of water management, in this case the displacement of water and not its distribution.

Canals came to link growing urban areas, and merchants of waterborne trade rose to great importance in the emerging economic strategies of the coast. Financial institutions appeared and innovated in support of mercantile activities. The Baltic trade in wheat and lumber fed populations and supplied shipping industries. Economic production on the coast geared itself toward producing nonperishables for exchange, and wool and linen textiles grew into industries, as did preserved foods, such as cheese, butter, and herring (all reliant on salt), and beer. Needless to say, salt refining became another linchpin industry.

By the 16th Century the stage was set for the Netherlands to become a world leader in trade. Possessing shipping virtuosity, and thus military might, the Dutch besieged the Spanish and Portuguese, and eventually toppled their monopolies over Atlantic trade. By closing the port at Antwerp, the Dutch nearly monopolized textile production, and instigated mass migration to Amsterdam of additional merchant and financial expertise. The Golden Age (1630-1650) of Dutch economic history followed.

The Dutch, however, would soon be supplanted by the British who were having a like revolution in production. International investment had become more mobile, and the British inherited much of Dutch banking and industry. While the Dutch would continue to be world players in shipping, shipbuilding, finance, textiles, and other industries, they would now begin a long slide from the top. The stagnation in 18th Century demography reflects an economic stagnation that would not relent until the steam-powered industrial revolution shook the world (Figure 16).

In essence, the Dutch had spent their ancient storages of untapped resources. They had consumed their peat landscape and now were putting greater energies into defending that position against the sea. They must have certainly pulsed the Atlantic fisheries near their coasts, and were probably facing diminished returns on fishing investments. Their local lumber was all but gone, and only imports could quench their thirst for wood. Intensive agriculture had sapped the countryside of easy nutrients.

Coal power, "Carboniferous Capitalism", brought the Netherlands out of its slump in the early 19th Century, as it did much of the world. The British led intensification of coal, iron, and steam engines channeled new energies to virtually every facet of economic life and food production. Dutch population--and as well western European--

took off. The Dutch colonies of Suriname in the west, and Indonesia in the east, supplied the Republic with raw goods. The Netherlands Antilles meanwhile, were still the backlands, with only Willemstad paying its way.

The place of the Netherlands Antilles, and as well the Netherlands economy, would change with the next carbon revolution--oil. Royal Dutch/Shell, formed in 1906, is today one of the largest corporations in the world. The Shell refinery on Curacao could not have rocked the island more if it had been a direct hit from a hurricane. The Lago (Exxon) refinery on Aruba likewise, or more so. High emergy oil poured into the Dutch economy and leaked into the islands as industry and population exploded. In this second half-century, Groningen natural gas has been the succeeding engine of Dutch growth, and therefore the basis of Dutch development aid to the islands, which has been significant.

Bonaire received perhaps the overflow of this "prosperity", as labor moved to refineries and remittances returned in countercurrent. In addition, a rather odd assortment of export industries came to dot the landscape, as concerted efforts were made by the Netherlands, by the Central Government of the Netherlands Antilles (anchored in Curacao), and by some Bonairians to establish a paying niche for Bonaire in the world market economy. Giant microwave antenna farms, a rice processing mill (on a rice- and water-less island), a salt works covering 1/10 of the island surface (fortunately the least-desirable of all terrains), and a great oil transshipment terminal, all appeared on Bonaire. These industries abut small urban centers, rural *kunukus*, fertile fisheries, and strikingly beautiful living coral reefs.

Bonaire within Multiple Scales

The place of Bonaire in the world political economy is not uncomplicated. It is at once a small island with an Island government; one of five islands in the Netherlands

Antilles, governed by a Central government; a part of an autonomous state (the Netherlands Antilles) within the Kingdom of the Netherlands and subject to its laws and privileges; and a participant in the global economy and therefore variously bound by the IMF, World Bank, and other supra-national institutions, treaties, and corporations.

As the home of 14,000 persons, Bonaire is a place to live, work, and raise children. Throughout its post-contact history, the island residents have interacted with this layered context at various times in manifold ways. When ignored, Bonairians have nearly sustained themselves, albeit as fishers and goat farmers. However, in the last half-century, the layered context has increasingly impinged.

The placement of refineries on Curacao and Aruba emphatically inserted these two islands into the Dutch and global economies. Bonaire's politicians were mandated to seek similar development opportunities for their island constituency, and to demand aid for infrastructure from the Central and Dutch governments (Klomp 1986). Aid for schools, transportation, water, electricity, housing, etc. was forthcoming (see The State Equation and Financial Aid). Economic prosperity, it was hoped, would come to everyday Bonairians as it had come to some fortunate Antilleans on other islands.

At the national scale, many Caribbean islands have innovated new development options in recent decades, including tourism, transshipment, and offshore banking. Some might be suited to Bonaire if the island could be outfit with the proper infrastructure and policy. Bonaire had been a longtime (minor) liability to the Netherlands and Central government, and if development could succeed, Bonaire might be cajoled to pay for its own public sector, at the least.

In the largest context (of the IMF, World Bank, and transnational corporations), public sector debt is a mechanism that binds an economy to the global market (the Netherlands Antilles has over $2 billion in 1998 public debt). When governments accept international loans they must generate foreign currency to repay them. Export goods, often primary commodities like timber or metal ores, bring foreign currency to an economy. In the Caribbean, the most viable export industry is often tourism, which generates foreign currency by "exporting" a tourism product to be consumed by foreigners, albeit on domestic soil. Irrespective of internal economic well being, national governments are pressured to generate foreign exchange to service international loans. International capital gives the global context immense leverage to influence national policies, *vis*. Structural Adjustment Programs.

The 1980s and 1990s

Refineries

The 1980s and 1990s brought substantial transformations to the Netherlands Antilles context. Economic good fortune temporarily turned its back on the Netherlands Antilles when the corporate owners of the two refineries did the same (Figure 11). Exxon's subsidiary, Lago Oil and Transport, closed its refinery on Aruba in 1985. Closure of the Shell refinery on Curacao was narrowly averted by international intervention (negotiations between the Netherlands, Venezuela, the Netherlands Antilles and Shell Curacao). The Curacao refinery was instead sold to the Netherlands Antilles government for the symbolic price of one guilder, but with $47 million going for existing stocks and machinery (EUROPA 1989:1887). As part of the deal, the state oil company of Venezuela, PDVSA, agreed to lease the refinery (at reduced production levels), and keep 1900 employees (with a 40% wage cut).

In fact, the Antillean refinery business had suffered since the OPEC oil crisis of 1973. In 1982 the refinery labor force was 4,000 jobs, compared to 21,000 in the 1950s (EUROPA 1989:1887). Dutch and Antillean governments took steps to diversify the economies of the Antilles. One approach was to build infrastructure for shipping, air travel, water and electric as they did on Bonaire and St. Maarten. St. Maarten emerged from economic obscurity in the 1970s, and with Aruba established successful mass tourism products. Since 1980, tourism has been the leading employer outside of the public sector for the Netherlands Antilles and Aruba (EUROPA 1989:1887).

Tax Haven

Besides tourism and refining, offshore banking has been a large revenue generator for the islands. Since 1963, tax treaties have made Curacao a tax haven for wealthy persons avoiding tax obligations in the US, Europe, and elsewhere. In 1986, tax revenues from offshore companies amounted to 53% of the revenues of the Curacao Island government and 15% of the foreign exchange receipts of the entire Netherlands Antilles (ECLAC 1987:8). In 1994, there were 33,048 companies registered in Curacao, of which 21,149 were "offshore" companies (EUROPA 1998:2477).

Tax law income generating strategies have also come to Bonaire. The Retiree Incentive Law (or *Pensionado* Law) was designed to "encourage wealthy individuals (primarily Dutch and other heavily taxed Europeans) to retire in the Netherlands Antilles (Island Government 1990:II-12)." The law allows "wealthy Dutch nationals to pay only 5% tax, providing that they purchase or build a house in the Netherlands Antilles costing over 240,000 guilders, employ at least one servant and are over 30 years of age (EIU 1997:34)." The Netherlands Antilles Central government earns 100 million guilders per year in taxing Dutch citizens. The Bonaire economy is directly stimulated by the influx of Dutch, who bring construction jobs in the short-term, but who's spending in the long-term may fuel inflation.

Structural Adjustment Programs

Total public debt for the Netherlands Antilles and Aruba was over $2 billion in 1994 (EIU 1997:69). Bonaire's contribution to that sum is small, and much of the development aid to Bonaire has been in grants. In 1988, the Netherlands required the Antilles to cut its public expenditure by 40% as a condition of receiving more aid (EIU

1989:55). One thousand civil servants were dismissed in 1987, and 1,400 more in 1988. The ruling party in the Central government was toppled in the next election, but the cuts stood. Numerous government industries were (semi-) privatized on all the islands, including sewage, water and electric. Perhaps the most devastating change for average citizens has been the tightening and re-writing of tax laws for personal income and property.

After carrying budget deficits again for several years, the Central government, in consultation with the IMF, undertook a structural adjustment program in 1996. It is intended to eliminate fiscal deficits in four years. Adjustment measures included "a rationalization of the civil service, a wage "freeze" during 1996-97, reform of civil-service pensions, the introduction of a health insurance scheme, and the introduction of new taxes (this last was reportedly a precondition for assistance from the Netherlands in restoring international reserves) (EUROPA 1998:2478)." Voters again held the ruling political party responsible. Still, as the situation stands, the incoming government is "likely to have little opportunity to relax austerity measures if the support of its international creditors [is] to be retained (EUROPA 1998:2478)."

Persevering in a Many-Scaled World Context

Countless writers have recognized the dangers to smaller countries in the global market context. Lack of control is the greatest threat, as events and decisions made elsewhere can have dramatic effects at home. Stated succinctly (and with remarkable honesty) in an investment guide (Coopers & Lybrand 1995:33):

> Bonaire has an open economy largely dependent on external factors outside of the island's immediate control, such as tourism and related activities, oil transshipment, salt manufacturing and shipment and external transfers of development aid and investment capital.

Recent events have shaken the current development strategies for the Netherlands Antilles, and punctuate its precarious position in the many-scaled world context. Offshore banking tax laws have repeatedly been amended or repealed, as efforts have been made to curtail suspected drug-money laundering on Curacao. The Retiree Incentive Law was amended in 1997 to raise the tax rate to 15%, to increase the house value to 750,000 guilders, and to increase the age limit to 55. The Dutch government claimed that it lost 600 million guilders per year as the law previously stood. But the loss of 100 million guilders to the Central government of the Netherlands Antilles is one-third of the total tax revenue (EIU 1995:34).

A bitter appraisal was made of the oil industry situation in 1986, at the time of Aruba's refinery closure and the sale of Shell Curacao:

> …the Caribbean oil industry always was, and still is, dependent, well-nigh absolutely, on decisions taken by external interests with no inherent or permanent commitment to the level of oil industry activities needed to ensure that they contribute to the well-being and development of the Caribbean nations (Odell 1986:44).

Since that time, in another big turnaround, the Aruba refinery was sold to Coastal Oil of Houston, Texas, and reopened in 1991. The refinery was refurbished in 1989-91, helping to fuel another construction boom on Aruba (note Aruba's latest population jump in Figure 11).

Recently the European Union decided to restrict the import of rice and sugar from Overseas Countries and Territories, which has crippled the rice mill on Bonaire (Central-Bank 1997).

The tourism industry in small countries is sometimes directly foreign owned, and even when not, is highly dependent on foreign tourism operators, airlines, and the state of the world economy.

Perhaps the greatest challenge to self-determination is the global economy itself. Foreign borrowing requires foreign exchange in repayment. Foreign exchange generation requires export earnings from world trade. Countries like the Netherlands

Antilles are forced by their international creditors to facilitate economic development in order to produce export goods. This rationale of capitalism requires growth.

Ecotourism at Appropriate Intensities

Tourism might be the most sensible "export" industry to emerge on Bonaire since the salt works (see also Tourism). Caribbean islands in the world marketplace are synonymous with vacation travel, and Bonaire's ecotourism product distinguishes itself in the market for its pristine coral reefs and easy shore-dive coastlines. In its Structure Plan (Island Government 1990), the *National Tourism Policy* (TCB 1995 and APPENDIX Z) and the so-called "Pourier Report" (Pourier 1992 and APPENDIX Y), Bonaire has made exceptional efforts to define policy that will maintain its tourism product and include its citizens in the economic benefits.

Bonaire's ecotourism policies are intended to protect the island from hotel over-building and reef destruction. Policies protect local labor, with various provisions for educating and training the tourism workforce and restricting foreign labor immigration. Policies guarantee public access to the coastal zones. Policies aim to limit foreign capital investment when locally-available capital resources can be found. Policies intend to expand the linkages between tourism and other sectors of the local economy, particularly agriculture, livestock, fishery, handicraft and services. Policies exist to limit casino gambling and restrict foreign fast-food chains from entering the market. In general, policies strive to support tourism development that will raise the wealth of Bonaire and its inhabitants.

The three greatest challenges to ecotourism could be the related issues of economic (over-) growth, resident workforce participation (at all levels of the industry), and population density. Government policy-makers are aware that the very tourism product that the island is selling can be ruined by an over-zealous development strategy.

As stated in the National Tourism Policy, "Development which does not take careful account of environmental and human resource concerns could deplete or eliminate the very assets which makes Bonaire attractive to visitors and local residents alike." Especially in tourism that is "eco-", depleting the natural ecology from above or below the sea will degrade the tourism product itself.

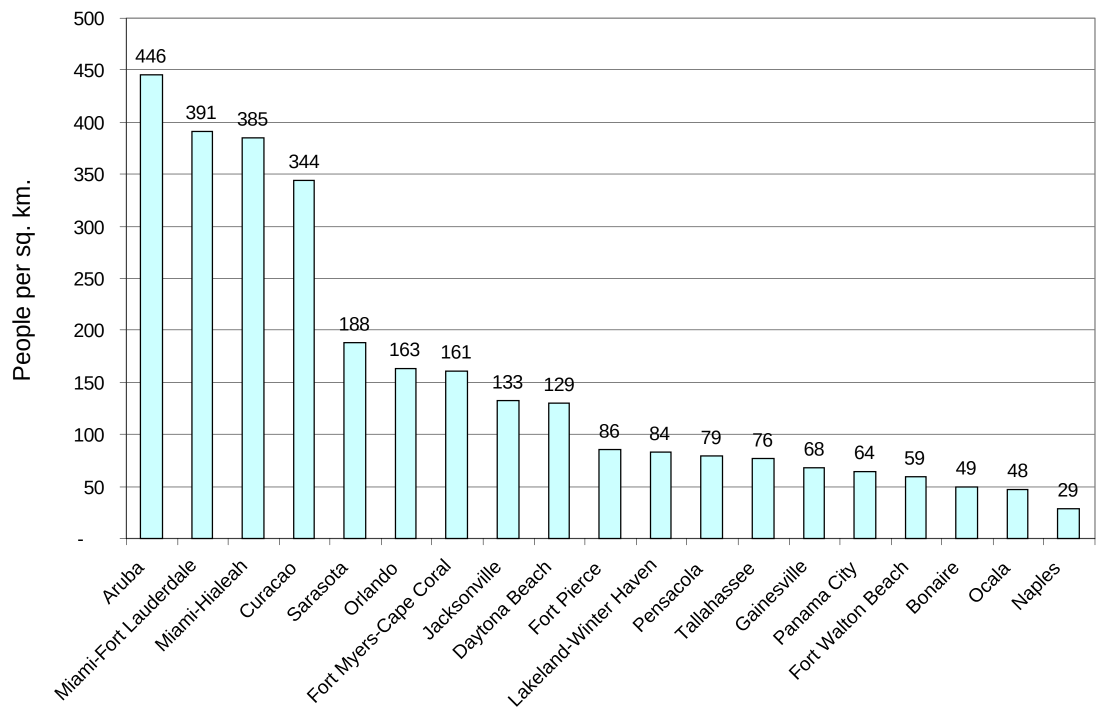

Figure 17: Population Densities, Metropolitan Areas Comparison.
This graph compares the population densities of Aruba, Curacao and Bonaire with select Florida metro areas, as defined in the US Census for 1990. By this metric, the densities of Aruba and Curacao are very high, comparable to the Miami metro areas. Bonaire's density is comparable to the Ocala metro area. This comparison seems to appropriately suggest the relative intensities of development of the islands. (Comparing population densities is always problematic. If the island densities were compared to city densities, they would be under-valued because they have both rural and urban areas. If the islands were compared to county densities, the island might be either over-valued or under-valued, depending on the size of the urban area in the county and the political-economic intentions in creating county boundaries. This comparison with Florida metropolitan areas is a better solution, because the metropolitan standard is used.)

Maintaining natural assets is ultimately a human density and development intensity issue. Facilitating the training of local populations to assume leading positions in the tourism industry is a related concern. Figure 17 compares population densities for the Leeward Islands with the densities of metropolitan areas in Florida. While there are difficulties with any comparison, the graph suggests that development on Aruba and Curacao is dense. High-density development draws greater resources from the natural environment, increasing the *intensity* of development.

Development intensities calculated with emergy measurements indeed show Curacao to have a far greater intensity of development (see CHAPTER 8). The development intensity of Bonaire, however, is also seen to be fairly high. This may not be an issue in itself, as will be discussed in CHAPTER 8. Development intensity is a relative measure. Ecotourism that is not disruptive to local ecosystems and sociocultural systems is development that matches the existing system in intensity. In the Amazon, for example, the existing intensity may indeed be very low, and ecotourism intensity should be low if not to disrupt existing systems, while at other sites, like Bonaire, the pre-ecotourism development intensity may be higher to begin with. The Tourism section in CHAPTER 12 discusses this issue in full.

CHAPTER 4
HUMAN-ECOSYSTEMS ON BONAIRE

Bonaire's Natural Systems

Stoffers differentiates a number of terrestrial plant communities on Bonaire (Stinapa 1982). The terrestrial vegetation has been more generally described by Westermann and Zonneveld (Westermann and Zonneveld 1956:58):

Figure 18: Thorn Forest Vegetation

> Bonaire's primary vegetation is largely a factor of the tropical semi-arid climate with its prolonged dry season, and consists mainly of tropical dry scrub and woodlands of slightly varying types. The xerophytic character is pronounced and there is a distinct predominance of low and thorny trees and shrubs--some of which are semi-deciduous--belonging to the *Leguminosae, Euphorbiaceae, Rubiaceae, Cactaceae*, and other families of less importance. Almost everywhere the soil is greatly exposed

> through lack of a coherent plant cover. It is only during the infrequent wet seasons that a close herbaceous cover develops in places. The limestone plateaus, with their typical "Karst" features, are practically devoid of normal soil, but may nevertheless carry a fairly dense vegetation of low trees and shrubs. The influence of the strong trade-winds is apparent: the windward slopes of the higher mountains show a much poorer vegetation cover than the leeward slopes.

An aggregated description of the ecosystems of Bonaire might be three: (1) the thorn forest (Figure 18, Figure 21, Figure 22), which covers the semi-arid terrestrial environment (called *mondi* in Papiamentu), (2) the salinja and salt lake regions (Figure 37, Figure 38), and (3) the coastal ecosystems, including the coral reefs, the small coves (Figure 19), and the large estuary in the southeast (Lac Bay, Figure 24). The thorn forest may be split into the limestone and volcanic soil areas (see Figure 6, in CHAPTER 2), although much vegetation is not strictly limited to one soil type or another.


Figure 19: Coastal Ecosystems

Terrestrial life on Bonaire must contend with the low rainfall of its semi-arid environment (Figure 20). Rainfall averages 530 mm/yr, but yearly totals vary widely, some years with 250 mm and others with 950 mm (Westermann and Zonneveld

1956:54). There is also great variation between a short rain season and longer drought period.

Figure 20: Short-Lived Rainfall Collected in *Dam*s

> The total annual rainfall is not the only important figure since there is a critical point in monthly rainfall below which evaporation exceeds precipitation, and plant growth begins to experience drought.
>
> In the tropics, this point is represented by 100mm of rainfall per month. In general, in Bonaire there are only one or two months per year in which rainfall exceeds 100 mm. Consequently the vegetation--as far as it is dependent on the precipitation--suffers from drought for the greatest part of the year (Stoffers in Stinapa 1982:34).

Figure 49, CHAPTER 5 depicts the use of water on Bonaire. See APPENDIX E for the water budget emergy analysis.

Natural Production in Arid and Semi-arid Regions of the World

Bonaire's ecosystems can usefully be compared to other desert arid or semi-arid regions of the world. Arid environments often show low productivity, with pulses of production following rains.

> [In arid environments] productivity and biomass are low…below most other ecosystems. However, at certain times and places, deserts show high levels of productivity and biomass that are well within the range of temperate and tropical grasslands, shrublands and woodlands. (Noy-Meir 1985:93)

Primary production can be irregular during the year, and vary significantly between years.

> In deserts…productivity is highly variable and highly correlated with rainfall. Plant productivity in most desert regions is extremely variable between years and between places, ranging from zero to several hundreds of grams per square meter. The main reason is the variability in time and space in rainfall, or more precisely in the effective water input to the root zone (Noy-Meir 1985:93-4).

Figure 21: *Kadushi* Candle Cactus

This pattern of great variability is similar to the rainfall pattern on Bonaire described above. In some deserts, annuals and short-lived or drought-deciduous perennials are a response to limited rainfall. On Bonaire, however, there is additionally a predominance of long-lived trees (*watapana*, acacia, mesquite, kibrahacha (Poui tree, *Tabebuia billberghii*), the once exported wayaka (lignum-vitae, *Guaiacum officinale*), and the large candle cacti, kadushi (*Cereus repandus,* Figure 21)) and yatu (*Lemaireocereus griseus*, Figure 26).

> …in some hot deserts there are…long-lived non-deciduous shrubs, trees or succulents. Where these forms are dominant, the biomass turnover of the desert community may even be slower than that of an adjacent semi-arid grassland (Noy-Meir 1985:95-6).

Detritus and Wind

Arid environments have several unique and interesting features, one of which is the fate of live plant matter. Fewer herbivores may be present than might be expected to consume live plant primary production.

> In deserts…utilization efficiency of plant production by herbivores is low. Theoretically, it may be expected that herbivores are able to utilize only a small proportion of plant production in deserts, because most herbivore populations cannot respond fast enough to the large and rapid variations in available plant biomass water…On the other hand, a large proportion of seed production in deserts and semi-arid regions (up to 90-95%) may be taken by granivores (ants, rodents and birds). (Noy-Meir 1985:96)

Bonaire has a large population of domestic goats, which is kept alive in droughts by their owners, and which is therefore available when plant production pulses. Even so, much live plant matter becomes litterfall on Bonaire and in other arid environments. Wind erosion and detritivores play an important role in removing plant detritus in arid environments.

> In deserts…most plant material is removed by physical erosion and/or by detritivores. Since only a small proportion (2-10%) of leaf and stem biomass in deserts is consumed by herbivores while green, most of it remains as litter or standing dead biomass. In temperate forests and grasslands this materials is then mostly decomposed by bacteria and fungi. In deserts microbial activity is limited to the short periods of the year when the soil surface is moist. There is probably little or no microbial decomposition in the long dry periods which usually follow the accumulation of dead plant material at the end of the growing season. Most of the material, nevertheless, disappears from the surface during the dry season or the following wet season; only dead wood and some rather tough stems may remain on the desert surfaces for years. The finer material is removed by a combination of two processes: consumption by soil invertebrate detritivores (termites, ants, mites, isopods) which are quite abundant in deserts; and physical fragmentation, erosion and

> transport by wind and water [high winds on Bonaire therefore must play an important role]. The transported organic material accumulates around obstacles (e.g. shrubs) and in gullies and depressions, where it is then attacked by detritivores (Noy-Meir 1985:97).

Fertile Islands and *Tera Pretu* on Bonaire

Another defining feature of arid environments is the existence of "fertile islands" of productivity (Figure 22). This characteristic is recognized by Bonairians who call the valuable soil under trees and shrubs *tera pretu* (black soil).

Figure 22: Fertile Soil (*tera pretu)* under Vegetation.

> Nutrients are concentrated around shrubs and in the top soil layer. Most indicators of soil fertility (organic matter, total and available nitrogen, phosphorus and cations, numbers and activity of microbial and arthropod decomposers) are generally low in desert soils, but in the soil under and around shrubs, and particularly in the top layer there, these measurements are all several times higher than elsewhere. There are several reasons for this: the direct input of shrub litter, additional deposition of litter transported by wind or water, microclimatic and soil surface conditions under the shrub which are more favorable for biological activity, and enrichment by animals which prefer the shrub micro-environment (e.g. ants). West and Skujins (1978) described the desert landscape as consisting of "fertile islands" with high biological

> activity covering a small fraction of the area, surrounded by a generally infertile surface. (Noy-Meir 1985:98).

Nitrogen is a sometimes-limiting nutrient in arid systems, and "fertile islands" may assist in holding on to it.

Figure 23: Plowed Fields
Characteristically leaning *watapana* trees grow in plowed fields.

> The distribution of nitrogen in arid soils is closely tied to organic matter; hence , it is greatest in areas of aboveground and below ground carbon accumulation.
>
> In North American deserts, it has been well established that annual plants are concentrated under shrub canopies. Litter accumulates under shrub canopies, producing a soil with higher organic matter, higher nutrient levels, and enhanced water infiltration. These factors combine to support luxuriant growth of annual plants under the canopy. The low nutrient levels in the intershrub spaces, lower infiltration, and harsher thermal environment combine to produce sparse annual plants in these areas. Shrubs with litter layers are the "islands of fertility" in a shrub-dominated desert…
>
> Nitrogen may enter a system through atmospheric dust (translocation) or by N fixed by the energy of electrical storms in the atmospheric N2…

> Symbiotic nitrogen fixation by Rhizobium or free-living rhizosphere organisms needs to be measured in desert ecosystems. Noy-Meir (1974) and Hadley and Szarek (1981) point out that this process occurs in leguminous and other desert plants and could be substantial... (Whitford 1986:111-2).

On Bonaire there are many leguminous plants, including acacia, mesquite, *watapana*, and tamarind. These trees are often permitted to grow within *kunukus* (Figure 23). In fact, many sorghum fields are dotted with *watapana*, despite the difficulty of plowing around them, etc. These trees provide nutrients to the soil as well as shade, seeds and leaves for goats.

Plants on Bonaire

Plants on Bonaire must meet the difficult problems of low rainfall, irregular rainfall, and rainfall concentrated in a 3 month rainy season.

The pattern of plant diversity on Bonaire may be a response to this stressful water regime, among other factors:

> [On Bonaire] the flora comprises about 340 species, a relatively large number if one takes into account the small surface of the island and the low rainfall. It is rather peculiar that in Bonaire many of the plant families (ca 40%) are represented by a single species only, whilst there are only a few families with 15 or more species. Among the latter are found the legume family, composite family, spurge family, sedge family, and the grasses (Stoffers in Stinapa 1982:34).

The relatively high diversity on Bonaire might be explicable by considering the close proximity of the three ecosystems described above, thorn forest (Figure 18), salinja (Figure 38), salt lakes (Figure 37), and coastal (Figure 19, Figure 24). Rather than being peculiar, the pattern of few species within a functional group is not uncommon in other high stress environments, because diversity *within* an ecosystem might require sufficient or stable energy flows (Odum 1983:344-45).

Figure 24: Coastal Systems Include Mangroves at Lac Bay

Adaptations of plants in arid environments listed by Whittaker (1970) include the following. Each of these features can be found among Bonaire's vegetation:

(a) deep or wide-ranging root systems;
(b) water-storage tissues;
(c) protective covering by wax, hairs and other coatings;
(d) reducing leaf surface by shedding leaves;
(e) use of green stems for photosynthesis;
(f) stomatal functions including 'reversed' actions with carbon dioxide being taken in at night and fixed as malate which is then available as carbon dioxide source during the day (CAM);
(g) tolerance of tissue to reduced water-content even to nearly air-dry conditions in some club mosses and ferns;
(h) high osmotic concentrations allowing water uptake from relatively dry soils;
(i) growth during seasons when water is available

Figure 25: Sorghum in a *Kunuku*.
Sorghum is green in the short growing season.

It is often repeated in the literature that there are four ecological methods by which plants and animals meet drought conditions (McGinnies 1984:313). This functional model has been usefully applied to Bonaire (Westermann and Zonneveld 1956:59-60):

Drought-escaping

> Plants: Annuals and ephemerals which grow during moist seasons and live through dry seasons in the seed stage. Seeds of these plants germinate with the first substantial rains and the plants complete their entire life cycle in the brief one to three months before the desert becomes too dry again for growth. Woody species that leaf when it is rainy and drop their leaves during dry periods have similar drought avoiding systems. (Simpson and Solbrig 1977:15)
>
> Animals: Animals that enter arid lands only when moisture is available--largely insects and other invertebrates [migratory birds on Bonaire]
>
> Bonaire (Westermann and Zonneveld 1956:59):
>
> > Many annuals
> > Sorghum - *Sorghum vulgare* (*Maishi chikitu*)(see Figure 25, Figure 35)
> > *Ipomoea*

Ruellia tuberosa

Drought-evading (avoiding)

Plants: Plants making economical use of limited soil moisture supply through wide spacing, reduced leaf and stem surface.

Animals: Burrowing animals, with night activity, that do not need to provide water for temperature control.

Bonaire (Westermann and Zonneveld 1956:60):

> …xerophytic shrubs and trees with large root systems and special adjustments for reducing evaporation, i.e., relatively small size, flat, umbelliform crowns, small, often leathery leaves, and thorny stems and branches. Several have some value as fodder for goats and sheep.
> *Acacia*
> *Watapana*
> Brazilwood
> Pokhout
> *Weli-sali (Croton)*

Drought-resistant

Plants: Succulents that store water and are able to continue growth when soil moisture is not available. Not characteristic of extreme deserts.

Figure 26: *Yatu* Candle Cactus and *Aloe vera*

Animals: Animals that resist drought through physiological processes by which they are able to concentrate their urine, lose little water in the feces, stop perspiration, endure dehydration and still remain active--the camels is a fine example [goats on Bonaire].

Bonaire:

Cactuses--*Yatu (*Figure 26*), kadushi (*Figure 21*), tuna*, others
Agaves
Aloe vera

Drought-enduring

Plants: Drought-dormant plants that estivate when drought occurs and continue growth when moisture is available. This includes many prominent desert seed plants and also algae, lichens, mosses, and ferns.

Animals: Animals that estivate and any invertebrates that recover after desiccation. Also vertebrates such as ground squirrels and gophers that estivate during hot dry periods. (McGinnies 1984:313)

Bonaire:
Several grasses
(Sorghum can also estivate for short periods)

A fifth category (phreatophytes) is suggested by (Simpson and Solbrig 1977:16-7), and Bonaire possesses, in great abundance, a very important member of this functional group--mesquite.

Phreatophytes

Woody perennials that grow in and exploit water rich microhabitats. These species…have exceedingly long tap roots as well as more shallow lateral root systems that allow them to top underground water below the surface of the soil when the superficial supply is depleted…Usually, phreatophytes are restricted in true deserts to wash edges where they can reach underground water sources, or to low areas of high water holding capacity. In less arid regions where rainfall is relatively high or local factors such as elevation or exposure increase the amount of superficial available moisture, individuals of Prosopis do not necessarily behave like phreatophytes. Despite their specialized root systems, phreatophytes are still exposed to high solar insolation and hot dry air. They consequently have specializations in morphology, physiology, and phenology that tend to reduce high transpiration rates.

Prosopis juliflora - Kuida - (a salt tolerant species of mesquite)

Animals on Bonaire

Adaptations of animals to arid environments listed by Whittaker (1970) include the following:

(a) increasing water intake by eating plant tissue with high water content or by drinking dew;
(b) direct water uptake from the air (arthropods);
(c) use of metabolic water from respiration of food;
(d) reduction of water loss by excretion and egestion of concentrated urine and nearly dry feces;
(e) impermeable body coverings to reduce water loss;
(f) reducing water loss by inactivity, shade and underground shelters (McGinnies 1984:311-3)

Figure 27: Iguana (*Iguana iguana*)

Invertebrates

As stated above, in arid environments where microbial activity and herbivory is low, much of plant production is consumed as litter or standing dead biomass by soil invertebrate detritivores. An important taxa in some arid ecosystems including Bonaire is termites. Not only do they decompose detritus, but they also perform vital functions in the mechanical production and conditioning of topsoil.

> Subterranean termites are diverse and abundant in the warm arid and semiarid regions of the world. Wood and Sands (1978) point out that in many semiarid ecosystems the biomass energy flow through termites is greater than or equal to that of mammals, including grazing herbivores…
>
> In the absence of termites, physical weathering and activity of fungi and bacteria accounted for only 4% mass loss from dung pats during the growing season…If termites were eliminated from such an ecosystem, dung would require from twenty-five to thirty years to be reincorporated into the soil. The accumulation of organic matter into dung and the physical presence of increasing quantities of this material would markedly reduce the productivity of semiarid rangelands for grazing livestock…
>
> Based on data from the Sahel in Africa and some data from Australia, Wood and Sands (1978) provide evidence that termites are "keystone" taxa in other arid and semiarid ecosystems. Termites are not only abundant but change the physical and chemical characteristics of the soil process, consume a major fraction of the primary productivity, and return nutrients to the ecosystem via salivary secretions, feces, corpses, and predators…
>
> The importance of termites in semiarid and arid ecosystems is not limited to organic matter processing and nutrient cycling. Nest construction, galleries, and tunnels all affect soil structure and soil chemistry…The large quantities of material turned over by this kind of activity can be very significant. (Whitford 1986:107-9)

Another critical invertebrate taxa on Bonaire is landsnails. The leeward group of the Netherlands Antilles (Bonaire, Curacao, and Aruba) boasts 30-40 different species of snails.

> Most landsnails prefer a limestone habitat, not only because this offers them an inexhaustible supply of limestone, needed for the development of their shells, but also because this habitat often presents better conditions for obtaining food, retains water and offers better protection against the radiation of the sun, compared to non-calcareous, crumbling substrates. (Hummelinck in Stinapa 1982:48).

Vertebrates

Vertebrates in arid ecosystems play many important and overlapping roles.

> …almost all organic materials except wood, detritus, and microorganisms are consumed by desert vertebrates. Most kinds of foods are eaten by more than one functional group: green vegetation by large reptiles, small mammals, and large mammals; seeds by small birds and small mammals; insects by small reptiles, small birds, small terrestrial mammals, and bats; vertebrates by large reptiles, large birds, and large mammals; and nectar by small birds and bats. This apparent overlap in

> diet means that different taxonomic and functional groups of vertebrates compete potentially for limited food resources in unproductive desert environments. (Brown 1986:59)

Figure 28: Colorful Lizard (*Cnemidophorus murinus ruthveni*)

Reptiles have special advantages in hot and arid environments. They are efficient users of limited available energies. Bonaire has 7 species of lizards (Figure 28, Figure 29), two of which are unique to Bonaire (Stinapa 1982:47). Bonaire's lizard population is tremendous, and includes the common iguana, *Iguana iguana (*Figure 27*)*, which in past times was known to reach 2 meters.

> Reptiles, especially lizards and snakes, are diverse and abundant in deserts. Much of their success can be attributed to a suite of traits that enable them to play ecological roles very different from those of birds and mammals. Unlike endotherms, which use internal heat production to maintain high, relatively constant body temperatures, reptiles are ectothermic; their body temperature varies with the thermal characteristics of their environment…Associated with these differences in thermoregulatory and activity patterns, reptiles have much lower energy requirements than those of birds and mammals. Even at comparable body temperatures (30-40 C) standard resting metabolic rates of ectothermic reptiles and amphibians are only 10 to 20% those of endothermic vertebrates of comparable size. Since desert reptiles spend substantial parts of their daily and annual cycles inactive and at much lower body temperatures, their long-term rates of energy intake are even

> lower, perhaps only 1 to 5% those of birds and mammals of comparable size…A habitat or food resource that could sustain only a small population of birds or mammals can support a much larger population of lizards, snakes, or tortoises. Thus, reptiles are ecologically more efficient than endotherms in the sense that a much larger proportion of the food they consume is incorporated into biomass and made available to their predators at higher trophic levels. Available data suggest that ectotherms are at least an order of magnitude more efficient as producers of biomass than are birds and mammals of comparable size. Furthermore, the reptiles can go dormant and survive for many months without eating food. (Brown 1986:53)

Figure 29: Countless Lizards on Bonaire

Birds are also very common on Bonaire and in other arid environments. Birds have very different energy problems than reptiles. They meet their food requirements with mobility, among other characteristics.

> First, they are endothermic. They maintain high, relatively constant body temperatures. This is associated with high rates of metabolism, and with high levels of foraging and activity…The vast majority of desert birds mush have high, relatively constant rates of food intake throughout the year.
>
> A second general attribute of birds is their ability to fly. The mobility conferred by flight enables birds to avoid many of the problems of continually meeting high energy requirements in an environment of low

> and fluctuating food resources. The temporal and spatial scale of movement varies among species, but almost all desert birds use their mobility to track food supplies. Many species are migratory; they are not permanent residents of arid habitats, but move into them only during seasons when sufficient food resources are available [Bonaire is visited by over 100 migratory bird species]. (Brown 1986:55)

Brown has identified three functional groups of birds in arid environments (Brown 1986:55-56):

> 1) Small insectivores. This taxonomically diverse assemblage contains many species with body weights in the range of 4 to 80 g. In includes diurnal woodpeckers, flycatchers, wrens, phainopeplas, verdins, and shrikes; the repuscular goatsuckers; and the small nocturnal owls. Although all of these feed primarily on insects, they exhibit a wide variety of foraging behaviors, including aerial hawking, sallying, foliage gleaning, and ground and trunk foraging. Rather than executing a special category for the few species of nectar-feeding hummingbirds, they are included here because they also feed, to a large extent, on insects.
>
> 2) Small granivores. Those birds which feed primarily on seeds are diurnal, weigh from 10 to 200 g, and belong to three groups: the finches, doves, and quail. The finches take seeds primarily in the winter, when migrant sparrows join the residents sparrows, house finches, and towhees. The sparrows often form mixed-species flocks and forage over large areas. Doves and quail tend to be present throughout the year, although they may move around within the deserts.
>
> 3) Large carnivores. This group contains the large nocturnal owls and the diurnal hawks [on Bonaire], eagles, ravens, and roadrunners. These are relatively large birds, weighing from 100 g to 5 kg. They take a variety of prey, including lizards, snakes, other birds, and small mammals.

Bonaire has many members of these functional groups. The most common bird fauna on Bonaire are:

> … the Bananquit *Coereba flaveola* is by far the commonest. Yellow Warblers *Dendroica petechia*, Tropical Mockingbirds *Mimus gilvus*, Smooth flycatchers *Sublegatus modestus*, Brown-crested Flycatchers *Myiarchus tyrrannulus*, Common Ground Doves *Columbigallina passerina* and Eared Doves *Zenaida auriculata*, are also conspicuous by their numbers, as are Parakeets *Aratinga pertinax* and two species of hummingbird, particularly the Ruby-topaz *Chrysolampis mosquitus*. (Voous 1983:20).

In number, there are many bird species on Bonaire. A large number of those species are migratory, taking advantage of the pulses of production that occur with irregular rains in arid ecosystems:

> The number of bird species recorded in Bonaire is 181; among these are 51 breeding species, 91 migrants from North America, 21 visitors from continental South America; besides 24 species of seabirds. Three subspecies of birds are restricted to Bonaire, viz. The Parakeet [*Prikichi* in Papiamentu] *Aratinga pertinax xanthogenius*, the Pearly-eyed Thrasher [*Chuchubi spanyo*] *Margarops fuscatus bonairensis*, and the Bananaquit [*Chibichibi*] *Coereba flaveola bonairensis*. (Voous 1983:22)

Mammals in arid environments are perhaps faced with the greatest difficulties. They must endure heat and drought, while maintaining a constant body temperature and moisture intake.

Figure 30: Donkeys Graze Freely over Much of Bonaire

> All mammals are basically endothermic, and most species, like birds, require sustained high levels of food intake to support their high metabolic rates. Many species of rodents or bats either hibernate or estivate. During seasons when food is unavailable they become inactive, allow their body temperatures to drop to near ambient levels, and drastically reduce their energy requirements.

1) Small granivores. It is composed exclusively of small (7-120 g), nocturnal rodents of the families *Heteromyidae* and *Cricetidae*. These burrowing rodents exist largely or exclusively on the seeds of desert plants.

2) Small to medium-sized folivores. This group includes several kinds of rodents and lagamorphs. These grazers and browsers span a fairly wide range of body sizes (100 g to 1 kg), are both diurnal and nocturnal, and include hibernators and fossorial species.

3) Small to medium-sized omnivores. Most representatives of this group are small (15-100g) rodents…Most of these are primarily insectivorous…

4) Large carnivores…foxes and coyotes…[Dogs on Bonaire]

5) Large folivores. This group includes the native grazers and browsers…To these must be added domestic sheep, goats (Figure 31, Figure 32), cattle, burros (Figure 30), and horses.

6) Bats. Most of the bats are exclusively insectivorous, although nectar- and pollen-eating forms occur in some habitats [on Bonaire]. (Voous 1983:57-8)

Vertebrates play important feedback roles in arid ecosystems:

> Vertebrates are among the largest and most active of desert organisms. They can play potentially important roles by transporting objects and by changing the physical nature of materials…Certain birds and bats are the primary, often obligate pollinators of many desert plants, including some of the dominant shrubs and succulents… Other vertebrates, especially the highly mobile birds and large mammals, are important dispersers of seeds.
>
> During the processing of food, all vertebrates transform and transport materials. When they deposit feces and urine, they leave physically altered organic and inorganic substances in new locations, sometimes far from where they are produced and ingested.
>
> Vertebrates also process and modify soil. Many of the small mammals are burrowers, and their extensive digging activities mix the soil and alter its physical properties…These rodents also transport large quantities of organic material to their dens, which then become highly concentrated sources of decomposing detritus. (Brown 1986:60-1)

On Bonaire, goats disperse prickly-pear cactus (*Opuntia wentiana*, called *tuna* in Papiamentu), a critical early succession species that quickly cover bare ground when abandoned. Goats also provide for the transport of nutrients from the *mondi* into sorghum *kunukus*, which may be vital in maintaining soil fertility in fields that receive no fertilizers.

Goats

Goats are numerous on Bonaire (Figure 31, Figure 32). They have been on Bonaire since the earliest days of colonial control, and have clearly played an important role in shaping the ecology of the island. The resulting thorn forest terrestrial ecosystem is well armed to limit the damage of foraging goats. Goats contribute to the movement of nutrients and seeds, and provide mechanical services to their arid ecosystems. They are flexible browsers that can survive the most uncertain environments with a little help from humans.

Figure 31: Goats Are Flexible Browsers

> The wide distribution of goats, from the temperate zone to the semi-arid and super-humid tropical environments, is possibly due to their ability to feed on a wide variety of foodstuffs--mainly tree and shrub leaves and grasses. They are able to utilize feeds normally not eaten by cattle or sheep.
>
> …[Goats] relish variety in their feed and do not thrive well when kept on a single type of feed for any length of time. They prefer to select from many varieties of feeds, such as a combination of grasses and shrub plants or tree leaves. Goats tend to nibble at the shoots and leaves of growing plants and reject the stems. Even the same plant may be consumed at one time and rejected at other times…The most important factor affecting choice of feed is the availability of a variety of feeds. (Devendra and McLeroy 1982:55)

Figure 32: Goats on the Move

Despite the valuable ecosystems roles played by goats, their presence and numbers on Bonaire, and their free ranging browsing of the *mondi* make them controversial island inhabitants (Figure 32). Here is a typical negative depiction of the effects of goat foraging:

> Tens of thousands of goats and sheep are running half wild over the islands. In consequence, much of the exposed soil has been removed by wind and water. In some areas this has led to secondary deserts, e.g. in

> the north-western part of Curacao and along the north-east coast of Aruba. It is very unlikely that vegetation will re-establish itself, for much of the land is spoilt, and the voracity of the half-wild goats prevents rejuvenation in those parts where a plant cover is still present. (Stoffers 1956:57)

While goats indeed consume the plant cover of Bonaire, the island ecosystems have been adjusting to the presence of goats for 400 years and have self-organized for their presence. Stoffer's apparent dislike for goats ("half wild" is used twice in this passage), perhaps biases his opinion against their presence on Bonaire. Such feelings are not uncommon from the perspective of European or American cattle, sheep and pig farmers whose animals are tightly controlled in pens and corrals. The perspective of many Bonairians is contrary.

Fodder Food for Goats

Fodder trees and shrubs are common food for goats, which are browsers of vegetation and not grazers like sheep or cattle (Figure 33). The value of fodder trees and shrubs in raising livestock was often ignored in the west, but is now recognized around the world.

> [In range and farming systems in dry tropical Africa…] Fodder trees and shrubs constitute a vital component in livestock productivity in the arid and semi-arid zones …They supply goats and camels with the bulk of their nutritive requirements and complement the diet of cattle and sheep with protein, vitamins, and minerals in which bush straw is deficient during the dry season. (Dicko and Sikena 1992:27)

Leguminous plants have particularly high nutrient value as fodder for goats. Bonaire has an important suite of leguminous trees, including *watapana*, acacia, mesquite and tamarind.

> Ligneous plants, which may be trees, small trees, shrubs or undershrubs, are an important component of the fodder resources for livestock and wildlife. The fodder value of their leaves and fruits is often superior to herbaceous plants, particularly in the case of legumes. In arid and semi-arid zones, they provide the largest part of the protein supply during the driest months…(Baumer 1992:1, in Speedy and Pugliese 1992)

In India, tree and shrub fodder are major components of the diet of ruminants. This inexpensive food production source has been vital to small farmers.

> The semi-arid climate in many parts of India and the pressure on land use have made tree and shrub fodders a more important component of feeds for ruminants compared to grasses or grass-legume pastures. Dry deciduous vegetation is mostly found in semi-arid regions…Many of the fodder trees are not cultivated and the landless population which owns small herds of sheep and goats depends on shrubs and tree feed resources growing near the villages, roadsides and community lands…In Pakistan, which has a semi-arid climate, trees play a dominant role in livestock feeding and in providing fuel. (Baumer 1992:14)

Figure 33: Mesquite Can Provide Fodder for Goats

Bonairians have historically been low-income farmers and fishers. Goat farming provides an inexpensive means of subsistence. The extensive use of common property *mondi* lands have made this possible.

Farming on Bonaire

Westermann and Zonneveld (Westermann and Zonneveld 1956:46) described the state of animal domestics on Bonaire in the 1950s:

> There are no permanent grass pastures owing to the dry climate and lack of irrigation water. Nevertheless a large portion of Bonaire is used for pasturing of goats and sheep: in recent years their numbers were estimated at 20,000-30,000 and 3,000-6,500 respectively. In addition, according to counts or estimates, there were in 1955 1,000 donkeys, 3 horses, 300 cattle and 500 pigs. The great majority of the goats, sheep and donkeys live in a semi-wild state, grazing and browsing on the perennial shrub and tree vegetation and--in favorable rain seasons--on annual herbs and grasses…
>
> Agricultural plots are protected against the roaming goats, sheep and donkeys by fences or cactus hedges, especially the fields used for the growing of sorghum or other food crops. Aloes fields need no protection, since this crop is inedible.
>
> Bonaire's present brush range lands comprise practically all the area outside the agricultural plot region (called *mondi*).

Figure 34: A *Kunuku* (Farm)
In the right foreground is an actively farmed *kunuku* in Rincon. Note the *watapana* growing throughout the fenced field for goat fodder, shade and soil nutrients. Sorghum is also planted for fodder, eaten clean at the time of this photo.

The situation of domesticates on Bonaire has changed little (Figure 34). Goats and sheep are still raised in similar large numbers. Currently goats can still forage the *mondi* (essentially common property which supplies the majority of the fodder for goat production), although some rumblings can be heard for penning all domesticates. This would have a dramatic and devastating effect on low-cost subsistence farming still practiced by many Bonairians. See the farming emergy analysis for specific details.

Figure 35: Pulling Sorghum for Goat Fodder

Agriculture in the same period was focused on sorghum, aloe, and some vegetables (Westermann and Zonneveld 1956:45-6):

> Sorghum (*Sorghum vulgare*) is the main cereal and fodder crop of Bonaire. It is well adapted to dry climatic conditions, provided that there is adequate precipitation during a period of at least 2-3 months annually. In years of prolonged drought--which are more frequent than those with a good seasonal rainfall--this crop fails. Volcanic and non-saline alluvial soils offer the most favorable conditions for growing sorghum (300

> hectares in 1949). Soils derived from limestone are rarely used; in 1949 only some 35 hectares were planted with this crop…
>
> Aloes (*Aloe vera*), a drought-resistant and little demanding crop, is still widely grown, notwithstanding the unsteady market for the product. In 1949 aloes occupied 550 hectares of limestone land and 850 hectares of old-volcanic and non-saline alluvial soils…
>
> [In 1949] many of the agricultural plots, although properly demarcated by fences or hedges, were not cultivated and were covered to a greater or lesser extent with wild vegetation such as *Croton flavens*, *Opuntia*, columnar cactuses, *Acacia*, and other shrubs and small trees. Apparently many of the lands had been abandoned for a number of years.

Aloe has ceased to be exported from Bonaire. Past aloe fields can still be seen in the agriculture zones, although much overgrown by *Opuntia, Croton* and others. Sorghum continues to be important to the farming systems on Bonaire (Figure 35). It is today rarely used as a cereal crop, but its value as fodder remains. Volcanic soils are the soil of choice for agriculture, as they have been since the earliest days of colonialism.

As for "abandoned" lands, it seems likely that at least some of those lands are farms with forage (*mondi*) grown within the fences. This pattern is common today, and will be discussed further.

Export forestry products were principally charcoal and *watapana* pods (called either *watapana* or *divi-divi* in papiamentu), which were loaded with natural tannins and used in the tanning of leather (Westermann and Zonneveld 1956:47):

> The livestock range lands are also used for the cutting of firewood, the burning of charcoal and the harvesting of divi-divi pods. The exploitation of commercial woods (brazilwood and pokhout) has long since ceased.
>
> Charcoal burning--for which are used wabi (*Acacia tortuosa), indju (Prosopis juliflora)* [mesquite, called *kuida* today on Bonaire, Figure 36] and other trees--is carried out chiefly on the large plantations some of which have been opened up by bulldozer tracks for that purpose. It is not always easy to assess the hazards of charcoal burning for the maintenance of vegetation and soil, but it is the impression of the authors that in many places the quantity of wood cut and burnt exceeds the annual natural increase. Such excessive exploitation has caused and is still causing gradual deterioration of the land…

> Exports of charcoal decreased from approximately 614,000 kg in 1946 to 111,000 kg in 1955. It is uncertain whether this decrease will continue and whether export will eventually cease.
>
> The production and export of *divi-divi (watapana)* pods are also declining steadily. In 1953 and 1955 there was no export at all. The market for these pods, from which tannin is extracted for tanning high-quality leather, is shrinking and, for the rest, is unreliable. Apart from a diminishing demand, the production is affected by a definite diminution of the number of *divi-divi* trees (*Caesalpinia coriaria*). Old trees are gradually dying off and rejuvenation of the stock is hampered in some parts even precluded by the depredations of goats and sheep or by soil washing.

Figure 36: Charcoal Is Still Produced in Smaller Quantities

Today the exporting of both of these products has ceased. Charcoal (called *carbón* in Papiamentu) is still produced for local consumption. *Watapana*, while no longer used for exporting pods, remain one of the most vital and productive natural plants on the island, evident by their liberal "cultivation" within sorghum / goat enclosures (*kunukus*).

Salinjas **and Salt Lakes**

Figure 37: Salt Lakes Support Rare Flamingo Breeding Populations

> [*Salinjas* are] barren alluvial areas, usually the embouchures of dry watercourses in the sea or in land-locked bays. During the rainy season they are occasionally flooded. The soil is sandy and often of a high salinity. The sandy and salty flats of South Bonaire bear the same name. The term salinja is also used for salt lakes and land-locked bays which have a salinity higher than that of sea water (Westermann and Zonneveld 1956:16).

Figure 38: *Salinjas* Are Usually Dry

CHAPTER 5
KUNUKU: FARMING ON BONAIRE

In times past, small farms called *kunuku'*s were the center of economic subsistence strategies for most Bonairians. Today they remain an important component of multiple economic strategies for some. For others they might provide weekend retreats. Some are unused and fallow, which offers natural foraging for goats that browse the *mondi*. A few have been acquired by foreigners, but the majority remain in the hands of Antilleans. More than any feature of life on Bonaire, *kunuku*s represent a link to the past. Most can tell stories of themselves or parents who lived and worked in the *kunukus* on weekdays, returning to their permanent houses in the small urban areas on weekends to attend mass, buy goods, and socialize.

Figure 39: *Mondi* and *Kunuku*'s North of Playa (foreground)

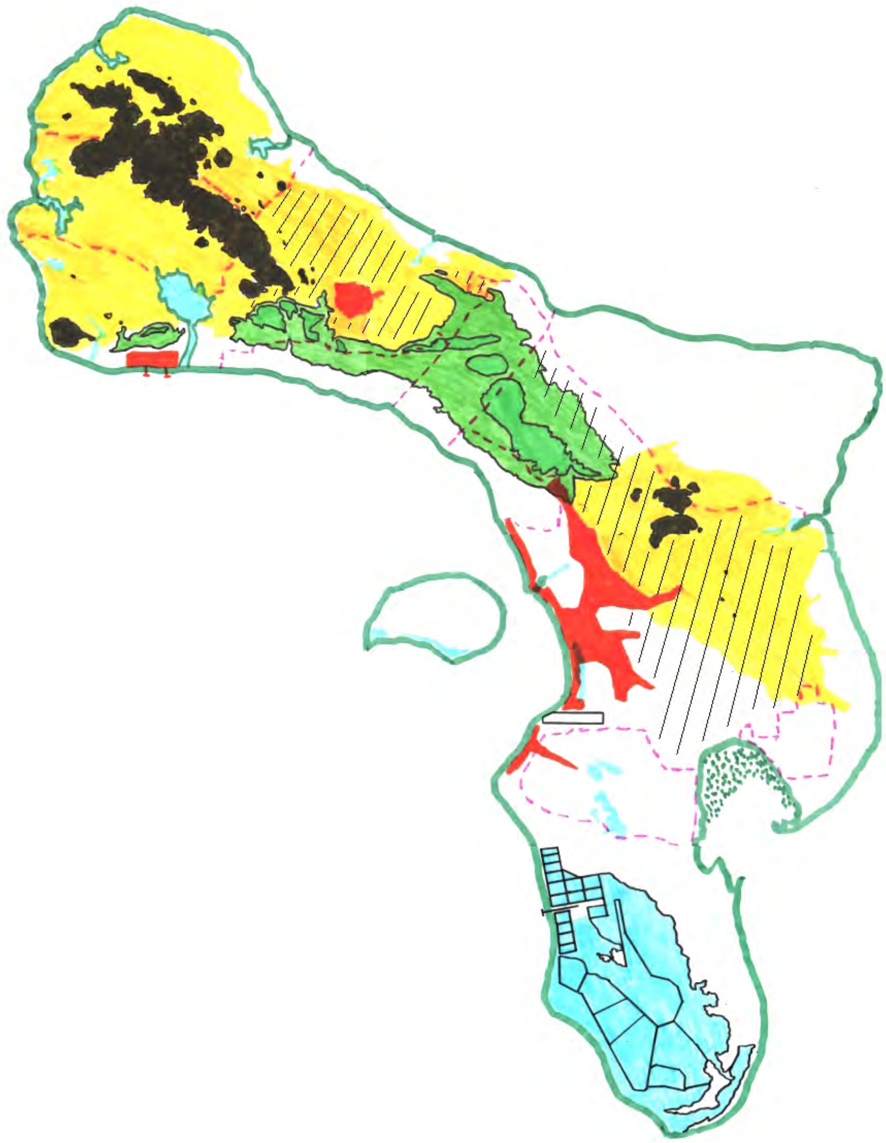

Figure 40: *Kunuku* Lands
Hatched areas are traditional farmlands on Bonaire, areas where sorghum is grown. Note that they occur primarily in volcanic sediment soils. Goats forage throughout the island on both limestone and volcanic soil vegetation. Dotted areas are private or government "plantations." Washington-Slagbaai National Park is in the north.

This quotation from my survey describes that life, and many Bonairians tell a similar story. I was asking a woman about her house:

> [When you were young, were there many houses here (in this part of town)?] No. See, I wasn't raised here. I mean, I wasn't raised…we came here on weekends only…or on Easter or New Years, we spent Easter or New Years at home. But for the most part we stayed in the

kunuku. [Oh, you lived in the *kunuku*?] Yea, all the time. [All weeks…all the time? So came to the house…] Yea, weekends only…In the past the way all people lived on Bonaire. The house was for times you go…like when you go down for the weekend, you go to the church on Sunday, so Sunday afternoon you went back up to the *kunuku*. You go to school ordinarily from the *kunuku* on foot, and then went back again. So on fiesta days you again went down to the house. Everybody lived like that on Bonaire. [And people could get everything to live from the *kunuku*? Food, water…?] Yea. Now they have water pipes from WEB, but in the past they didn't have it. In the past you had to go by the well. You need to go to the wells and fetch water. I myself lived like that. We had to go fetch water from the well and come back. For washing clothes, for cooking, for bathing. All these things were from the wells. [And in the past it was easy to live from the *kunuku*s, or wasn't easy…People could get everything for making a living…?] Yea, you lived. You lived good yea. [And come to Playa for…] Yea. When you need things, you went down to Playa to go buy your things, come back to the *kunuku*. [Ok…Do you know--this house--people built it a long time ago? Your family?] That I can't say, because I don't know. [Ok, and the *kunuku* house, your family build that house?] That one my uncles built it, because he…the wood he had. More wood than block.

[Tempu señora ta' mas chikitu, mas .. ah .. tin hopi kas aki?] Nò. Pasó ami no a lanta 'kinan. Kemen, mi n' ta' lantá ... nos a bin 'kinan wikènt so ... òf temporand'i Pasku ku Aña Noba, nos ta bin pasa Pasku ku Aña Nobo na kas. Pero mayoría parti nos ta' pas'é na kunuku. [Ah! Señora a biba na kunuku?] Si. tur e tempu. [Tur siman .. tur tempu? Anto bin kas ah ..?] Si. Wikènt so, anto ku .... [Anto antes hende por biba ah ...?] Antes asina tur hende ta' biba riba Bonèiru. Antes tur hende ta' tin kunuku ku kas. Kas ta' pa ora bo bai .. mané ba baha wikènt, bo bai misa djadumingu, anto djadumingu atardi bo ta bole subi bèk bai kunuku. Bo ta bai skòl gewon via kunuku na pia, bole bin bèk. Anto dia 'i fiesta tambe bo ta bah' bin kas. Mané Pasku ku Aña Nobonan ei, bo ta baha bin kas bèk. Tur hende ta' biba asina na Bonèiru. [Aha. I hende por haña tur kos pa biba den kunuku? Kuminda, awa ah ..?] Si. Awor aki nan tin pip'i awa di WEB, pero antes sí no ta' tin e. Antes bo ta' tin ku bai pos. Bo tin ku bai pos bai kue awa. Mi mes ta' biba 'sina. Nos ta' bai kue awa na pos bin bèk. Pa laba paña, pa kushiná, pa baña. Tur eseinan via pos. [I taba' tin uhm ... fásil pa biba den kunuku òf no ta fásil, pero ah ... Hende por haña tur .. tur pa ah tene na bida. Ta ...?] Si, bo ta' biba. Bo ta biba bon si. [Uhun. I bin Playa pa ...] Si. Ora bo meste 'i kos, bo ta bah' bin Playa bin kumpra bo kosnan, bolbe bai kunuku. [Aha. O.K. Bon. Ahm ... I ah señora sa, e kas aki, hende a traha hopi aña pasá. Hende di famia ah .. nan a traha su mes?] Esei si mi n' por bisa, pasó mi no sa. [O.K. I e kas di kunuku, hende di famia a traha e kas ei?] Eseinan, mi tionan mes a trah'é, pasó e ta .. di palu e ta. Mas di palu k'e ta di blòki.

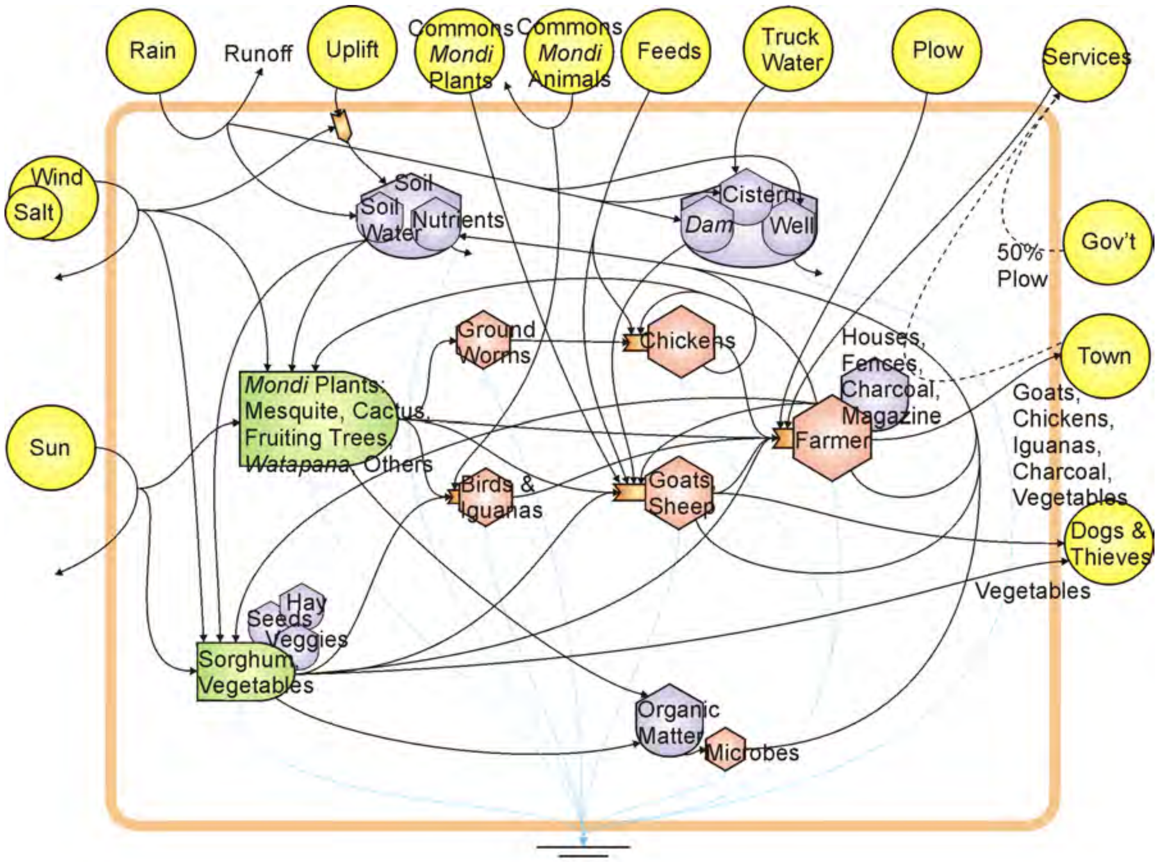

Figure 41: *Kunuku* System
Farmers may raise goats, sheep, chickens, or other animals on *kunukus*. They may grow sorghum, vegetables, and fruit trees. Some *kunukus* have *kunuku* houses, storage magazines, cisterns, wells, and windmills. Farm animals eat from the *mondi*, or are provided feed and water by the farmer. Farmers might sell any of their crops or animals. This diagram is therefore intended to represent a *range* of farming designs within the diversified *farmer niche*, which on contemporary Bonaire is only one component within multiple economic strategies used by households.

Kunukus are fenced areas. The fences keep goats and sheep in (and hopefully dogs and thieves out). In *kunukus* today, a house may or may not be present (Figure 43). Most *kunuku*s are in the large *huurgrond* areas to the east of Playa, and surrounding Rincon. By law, *kunuku* houses on *huurgrond* must be wood structures. Some *kunuku*s have a storage house (magazine), a cistern, a well and a windmill pump. People who live more permanently in *kunuku*s today may have solar electricity generation.

Farmers often have a car or access to a car for bringing feed bags and water tubs to the *kunuku*s in dry times (in the past this was done with donkeys, Figure 47). *Kunukus* are approximately 3-12 hectares, a few are bigger, and one is 200 hectares. *Kunukus* may be split into a sorghum part and *mondi* part. During planting season the goats are corralled in the *mondi* part, where they are kept from the sorghum. After the harvest, the goats will forage in both parts (Figure 51). The sections may or may not be rotated. Both planted part and *mondi* part will contain *watapana* trees. These leguminous trees build soil and provide food for goats in dry times (leaves and berries).

Figure 42: Many *Kunukus* Are Fenced With Cactus (*Yatu*)

Goats are often allowed to forage the commons *mondi*, open areas of natural vegetation. The commons *mondi* includes large public areas that were once the colonial plantations at Karpata, Columbia, Brazil, and Onima. It includes also the unused *kunuku*s, those said to be open. The commons *mondi* also includes the spaces in-between (town, roadside, etc., Figure 48), which may be browsed by wondering goats.

Surprisingly the sorghum fields are planted continuously for many years without fallow. Farmers on Bonaire do not use fertilizers. There are a number of natural nutrient sources. Leguminous trees (*watapana*, mesquite, acacia) build microenvironments of good soil called *tera pretu* (black soil). Nutrient weathering and the uplifting of volcanic and coral rock is accelerated by wind and heat. Goats foraging outside the *kunuku* or on purchased seeds thus capture external nutrients, and disperse them back into the *kunuku*s where they are corralled. When the *dam*s are "cleaned" the extracted organic matter (*e gordura di ter, fo'i dam* - the earth's fat, from the *dam*s) is placed on the fields to be plowed in by the tractors.

Figure 43: *Kunuku* House with Cistern

Kunukus contain earthen *dams* (reservoirs) which catch and hold rainwater for 2 months to year-round (Figure 46). Bonarians are master *dam* builders, knowing the drainage paths of fields, channeling and conserving water on very flat landscapes.

Water must be brought into the *kunukus* during dry times (Figure 45). Truck water is delivered by the government water truck - brackish water (50-50). Tubs of water can be fetched with a car by the farmer, usually from brackish wells. WEB water might be used in the (rare) cases where a house and *kunuku* are on the WEB network. This is very expensive and might be used in emergency for the animals and a few vegetables or fruit trees.

Figure 44: Feeding Goats and Chickens
Giving goats a little rice and water ensures that they will return from the *mondi* each evening. Dry sorghum in the background and a large *watapana* tree in the field.

These days, *kunukus* are rarely a full time concern. Many are now used with low labor input, visited by farmers in the mornings, evenings, and weekends. In the past, farmer families had (at least) two houses, one in the *kunuku*s and one in town. During the week they lived in the *kunuku*, and on weekends they lived in town and went to Sunday mass.

Farmers have had a plowing service available since 1957. Before that, plowing was done in large work parties using hoes, called *chapi*. Plowing was worked as labor exchange between farmers, planted in one day, with rum and food provided by the owner.

Farm Timelines and Rainwater

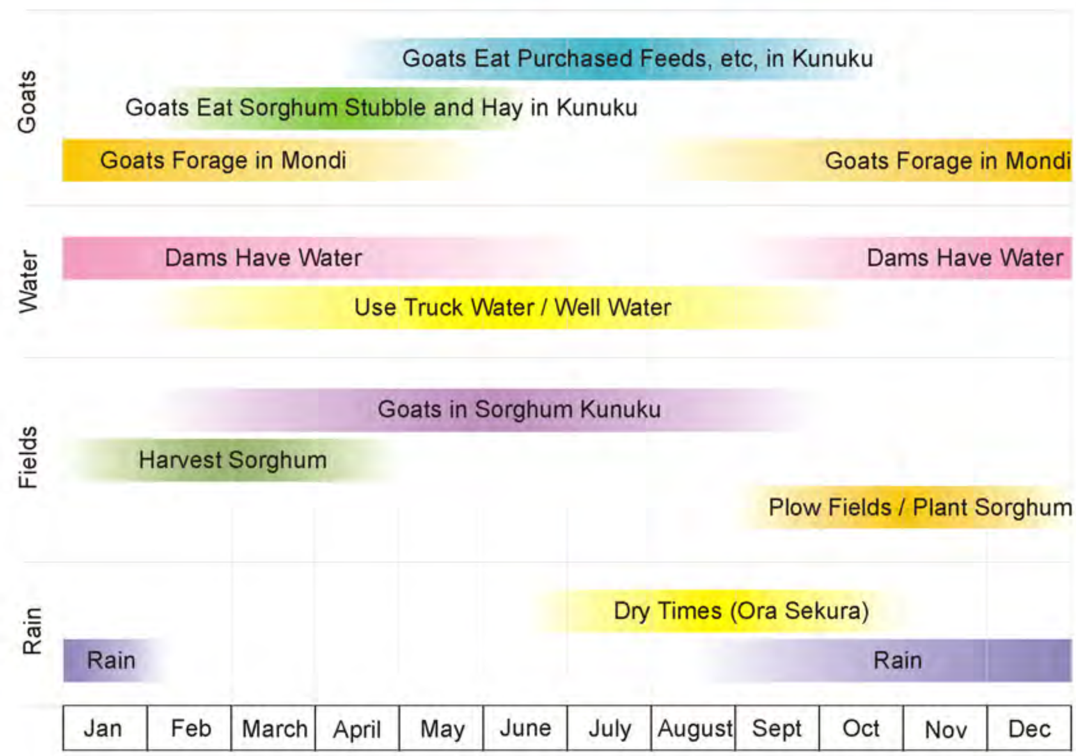

Figure 45: *Kunuku* Timelines

Rain Timeline

Scarce rains come to Bonaire primarily between October and January. As a flat island, Bonaire does not create its own rain shadow, but must rely on chance passing showers. Some say it does not rain but spits, although occasional winter downpours can create torrents of runoff. Rainfall is extremely variable from year to year, averaging 500 mm/year, but ranging from 200-900 mm/year.

Personal accounts of rains in years past are spirited, and often tinged with frustration. All farmers can remember years when some rain fell year-round (and thus the goats could forage year-round).

Most farmers claim that in the past rains came in July and planting began at that time. Almost unanimously farmers attested that it used to rain more. For good farming, a little rain every day in the rain season is better than a few big rains.

Figure 46: A Large *Dam* Holds Rainwater for Weeks or Months

Fields Timeline

Since the late 1950s, sorghum fields have been plowed with the government owned and operated plows. This service is purchased by a farmer, and takes about 1-2 hours per field. Farmers hope to get their fields plowed before the rains start, but plows are limited in number, and waiting usually occurs. Because the onset of rainfall is erratic from year to year, the synchronizing of plowing with first rainfall is largely chance. Farmers plant after plowing.

Water Timeline

Rainfall is caught on farms with reservoirs called *dam*s. Goats and sheep require a minimal but reliable source of drinking water. Vegetables must also have water, and can be grown around *dam*s with flood recession techniques (successively planting as the water recedes). On years with low rain, *dam*s may be dry by January. On high rain years, water will last all year in some large *dam*s. The water company has trucks that deliver water to the *kunuku*s. It is brackish water that comes from large wells. Truck water is unreliable, and can be days late, which can kill vegetables if they depend on it. Farmers today often use private vehicles to fetch water from the wells.

Figure 47: Water Brought to the *Kunuku* with a Truck

Goats Timeline

After fields are harvested, goats are allowed to forage on the stubble. They are said to eat it clean (*kome limpi limpi*). On exceptional rain years, goats can forage in the *mondi* nearly year-round (timeline would be solid).


Figure 48: Goat Browsing Is Tolerated by Bonairians

Water Budget

Rough estimates were made to produce a water budget for Bonaire. When rain falls on Bonaire the majority is evapo-transpired through plants, or evaporated directly. Of the remaining water, much enters the groundwater supply, or runs off into salt lakes, salinjas, or the sea. A small portion is captured by *dams* or cisterns. Figure 49 shows these relationships in a systems diagram.

> Owing to the semi-arid climate there are very few surface waters in Bonaire. The valleys in the non-calcareous regions only carry water after

heavy rains. Much of this water flows direct into salt-water bays or into the sea, carrying with it loads of silt. Another part of the water soaks into the soil; in various places this process is promoted by artificial *dams* built across the valleys. The water temporarily caught behind the *dams* and in tankis is used for watering animals and, in some cases, for growing subsistence crops along the receding water front. Permanent springs in the non-calcareous formation are very rare (Bronswinkel, on the northern slope of the Brandaris mountain) but in many places the ground-water can be pumped up with windmills…

In the limestone areas practically all rain water disappears into cracks and holes in the porous rock and adds to the ground-water reservoir. In the elevated limestone terraces this ground-water slowly drains along the abrasion plain separating the older impervious volcanic rocks and the overlying Caenozoic limestone; it may feed springs where this abrasion plain is exposed along escarpments (Fontein). (Westermann and Zonneveld 1956:55)

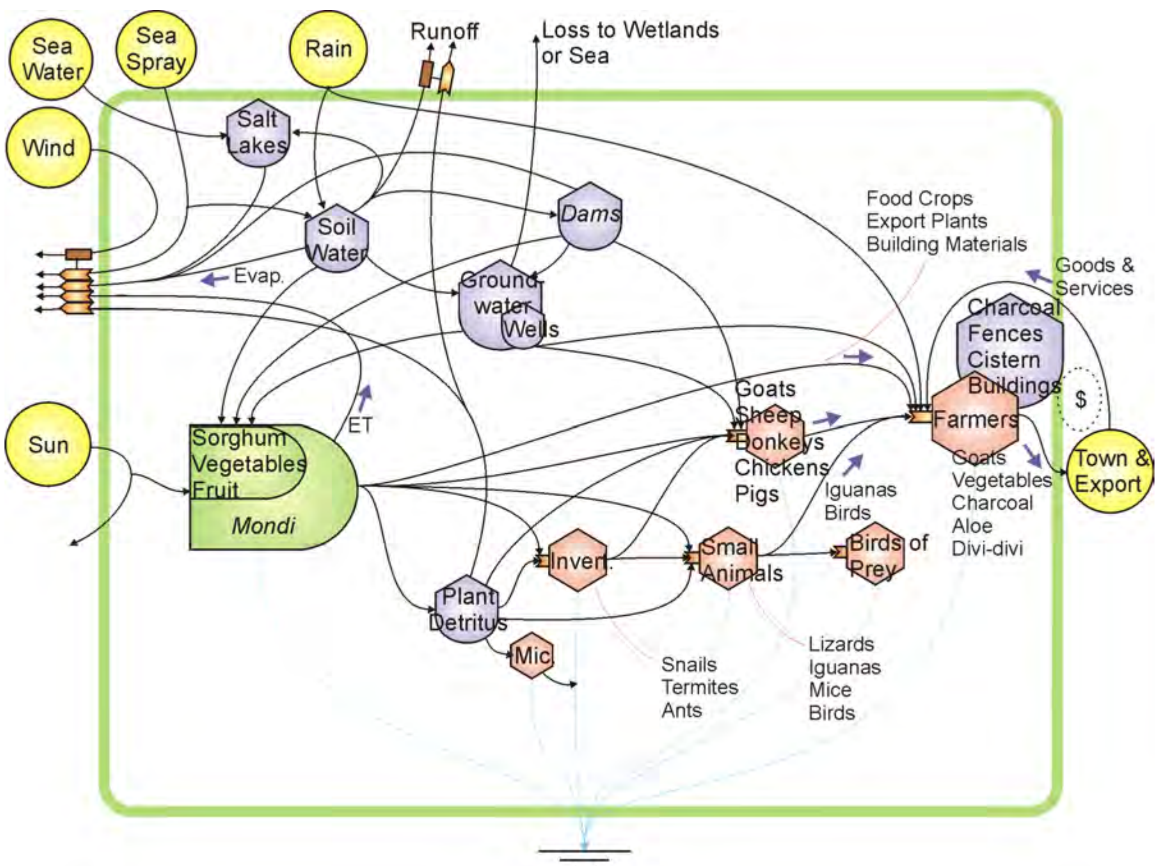

Figure 49: Water Budget, the *Mondi*, and *Kunuku*'s
The systems diagram depicts the natural partitioning of rainwater on Bonaire, and its use by plants, animals and people. See APPENDIX E for emergy analysis.

Goats on Farms

Hartog reports that in 1527 the Spanish brought the first livestock to Bonaire, including the first goats (Hartog 1978:39). Bonaire has not been the same since. Island vegetation has self-organized with the goats to produce the thorn forest communities now prevalent. In 1679 there were 8,500 sheep and goats on Bonaire (Hartog 1978:34). Meat was slaughtered and salted (called *yorki*) on Bonaire and shipped to Curacao to feed its growing population. The years 1930-1955 averaged approximately 28,000 goats and 6,100 sheep on the island (Westermann and Zonneveld 1956:41)

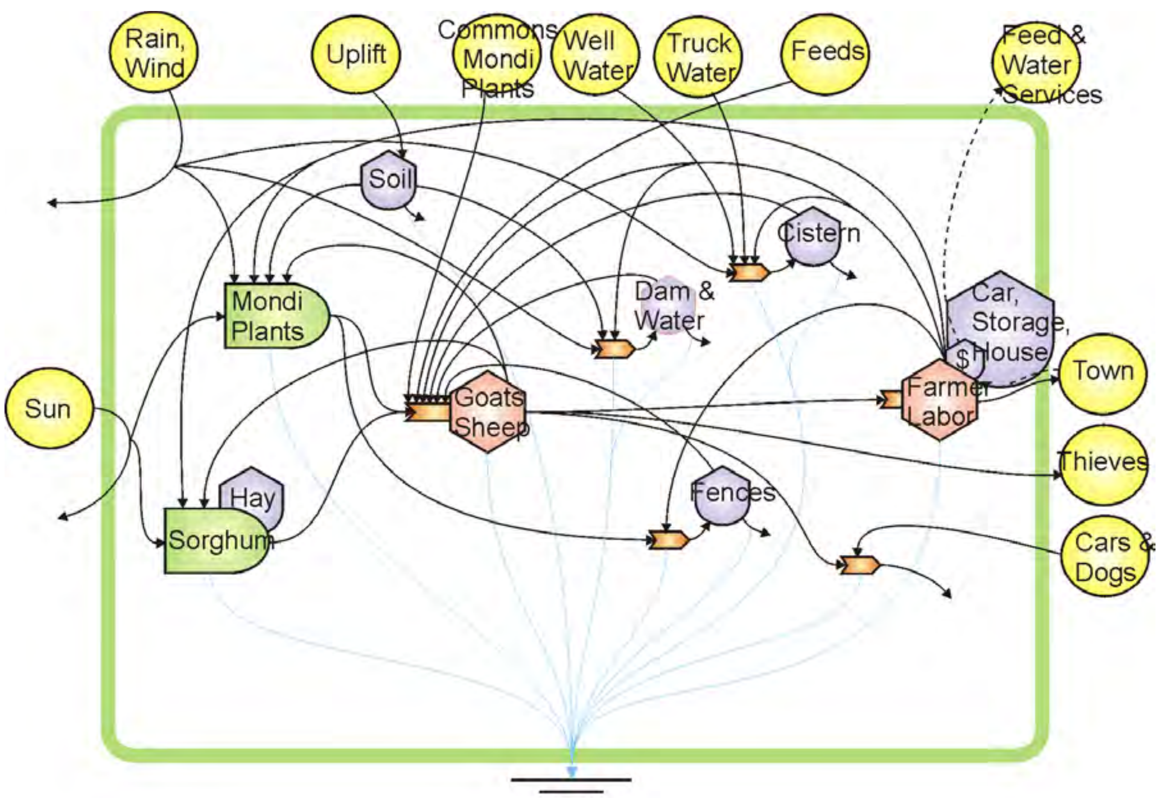

Figure 50: System for Raising Goats
This diagram focuses on the water and food sources needed to raise goats. Another critical component is fences, which are made from wood, cactus, and wire, and must be maintained.

*Kunuku*s are fenced areas. Fences are commonly made from mesquite, wire, and cactus (Figure 42). Fences keep goats and sheep in a farm, and out of other farms. Fences within a *kunuku* keep goats out of the sorghum *kunuku* during growing season.

Figure 51: Goats Eating in a Sorghum Field

Water and food are limiting factors for goats. Farmers catch rainwater in *dam*s and in cisterns. *Dam*s catch runoff rain. They are positioned along natural drainages (*rooi*'s). Cisterns catch rain from the roofs of buildings (*kunuku* house, storage house, Figure 43)

Cisterns can be refilled with Truck Water from the water company. The water is brackish (*awa dushi ku awa salu*). Farmers may fetch water in tubs using cars, usually from public wells (in the past this was done with donkeys, Figure 47). Both tubs and cisterns are covered (and locked) to prevent evaporation and theft. Goats are slaughtered when rains fail.

Figure 52: Sorghum Hay for Goats

Goats eat from several food sources (Figure 50). Goats forage in *mondi* plants when they are green. *Mondi* plants are inside *kunuku*s and outside, some *kunuku*s have an extensive *mondi* thorn forest that is indistinguishable from commons *mondi*. In the systems diagram (Figure 41), commons *mondi* plants are shown entering the *kunuku* system. In actuality, the goats leave the *kunuku*s, consume them, and then return.

Goats are fed sorghum hay (*pal'I maishi*) when it is harvested. Some sorghum crops are grown only for hay production (Figure 52). Goats are fed with purchased feeds, cactus, *watapana*, and other emergency foods for the remaining dry time. Cactus are cut by farmer, and its spines are cut off to get at the heart. Cactus grow back easily.

Figure 53: Farmer and His Sheep
This farmer also owns many goats. His goats forage in the commons *mondi* and within his *kunuku* when he has a crop (Figure 51). His sheep are corralled year-round and fed and watered from feed and sorghum hay.

Dogs and cars are a source of goat mortality. Semi-domestic dogs travel in packs at night, sometimes entering the *kunuku* areas and chasing and killing goats and sheep. I was told that one man quit farming when 100 goats were killed in one night by dogs. More commonly, 5-20 goats are killed by dog packs. Speeding cars and trucks on improved roads are an increasing cause of goat mortality as goats forage along roads.

Thieves are a distressing source of lost goats and sheep. Since few people today live in their *kunuku*s there is more opportunity for stealing goats. Goats are said to be stolen for cash, the goats are slaughtered and their meat is sold.

Short-haired sheep are also raised by farmers in lesser numbers (Figure 53). Sheep do not forage in the *mondi* - they are grazers, not browsers like goats. Sheep require more feed, 2-3 times as much as goats, but in return they have more meat per animal. Sheep will graze sorghum stubble (like goats) and will eat the grasses that may also grow in the *kunuku*. Sheep and goats have two throws a year, one if there is no rain.

Below is a list of some *mondi* plants that provide fodder for goats (generally called *foyo* - vegetation)

Liki loki (Phyllanthus botryanthus) - a shrub, deciduous with small fruit in clusters
Weli sali (Croton flavens) - a sage, deciduous
Watapana (Caesalpinia coriaria)
Yatu (Lemaireocereus griseus) - a large candle cactus, Kadushi is better for goats
Kadushi (Cereus repanolus) - a large candle cactus
Oliba (Capparis odoratissima) - Jamaica Caper
Sia Blanku (Bursera bonairensis)
Shimaruku (Malpighia punicifolia) - West-Indian Cherry
Kalbas (Crescentia cujete) - Calabash tree - leaves and fruit eaten by goats
Kohara (Cordia alba) - English clammy Cherry
Wayaká (Guaiacum officinale) - Lignum-vitae
Kinipa (Melicocca bijuga)
Tur Palu di Fruta (all fruiting trees)
Hoba (or *Hobada*) *(Acacia tortuosa)* - Acacia
Kuida (Prosopis juliflora) - Mesquite

Sorghum

Sorghum is an excellent drought crop. It can weather short droughts, and continue to grow when rains resume. If a drought is prolonged, sorghum crops may fail before they produce seeds, forcing farmers to purchase seeds for the following year. If crops fail, the sorghum hay production will also be small, forcing farmers to buy more feeds for their goats.

Today many farmers grow sorghum to produce fodder for goats. They can get a crop of hay in 4-6 weeks, cut it, and get another crop before the rains end. Getting seeds takes 3 months, plus one more month for seeds to dry. Drying seed clusters are bound with rags to protect them against bird pests (called *mara tapushi,* Figure 55). Common Bonaire varieties of sorghum are: Rikla, Gloria (*maishi blanku*) (white sorghum), *Danki di Shon* (gray sorghum), and *Maishi korá* (red sorghum). Many varieties are being tested at the agricultural extension office on Bonaire.

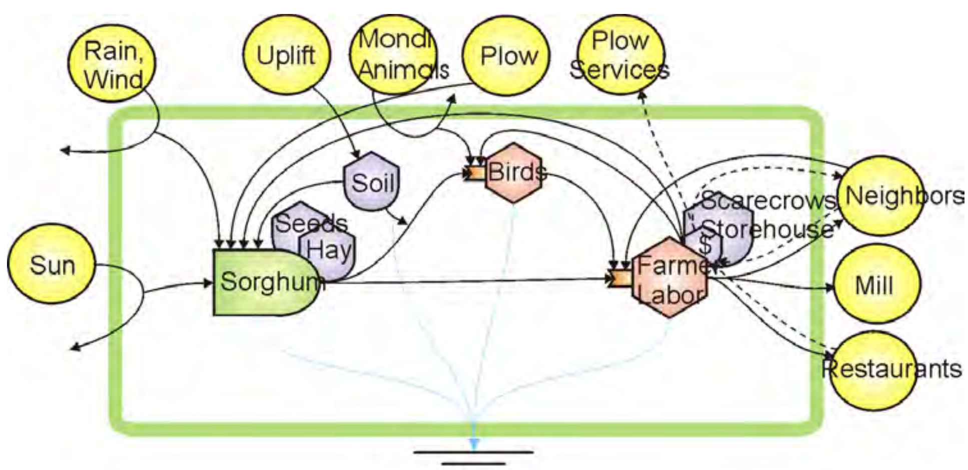

Figure 54: Growing Sorghum

A few farmers today, and all farmers in the past made sorghum flower (*hariña*). Popular foods from sorghum are: sorghum porridge (*papa*), sorghum cake (*repa*), and sorghum cornbread (*funchi*).

Birds are serious pests for sorghum. The early mass on Bonaire is called the Bird's Mass (*Misa di para*). In the past during the growing season mass was very early so that people could be in their fields at sunrise to scare away the birds (Hartog

1978:57). Farmers also use scarecrows (*spantapara*) to frighten birds. Farmers tie bandanas around individual seed clusters (*mara tapushi*), to protect them from birds (Figure 55). Farmers can stay in the *kunuku*s in the mornings and evenings to frighten the birds. In the past, when families stayed in the *kunuku*s all day, children would clap, yell, and otherwise scare the birds.

Figure 55: Sorghum (*maishi chikitu*)

List of common bird pests (with Papiamentu name):

Flys (*Moskita*) - the first pest, eating very young seeds
Black-Faced Grassquit (*Mofi*) - Eats the milky seeds

Parakeet (*Prikichi*) - eats the young seeds
Eared-Dove (*Patrushi*)
Pigeon (*Paloma*)
White-tipped Dove (*Yiwiri*)
Parrot (*Lora*)
Bare-Eyed Pigeon (*Alablaka*)
Common Ground Dove (*Totoliki*) - Eat seeds knocked to the ground by other birds)
Tropical Mockingbird (*Chuchubi*)
Bananaquit (*Chibichibi*)

Vegetables and Fruit

Vegetables are often grown on top of *dams*, or in the *dams* with a flood recession method. Iguanas are a big problem for growing vegetables because they eat the young vegetables and flowers. Farmers use scarecrows to protect them. When farmers are in the *kunuku*s they can watch for iguanas. I was told that in the past there were fewer iguanas in the *kunuku*s because all the *kunuku*s were being actively farmed. Today there are many "unused" *kunuku*s (*habri* - open), which provide living space for the big lizards.

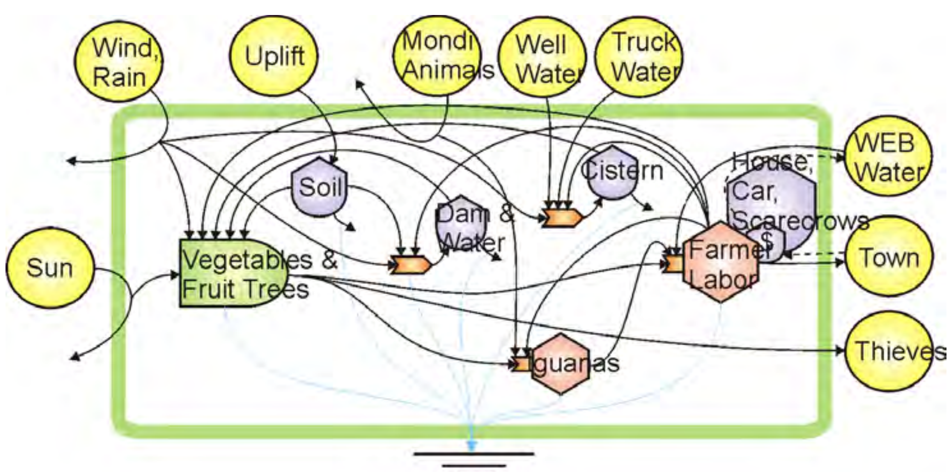

Figure 56: Growing Fruit and Vegetables

Today fewer vegetables are grown in the *kunuku*s. This is due to the combination of less intensive farming, and the growing risk of thieving.

Common vegetables list (with Papiamentu name):
Watermelon (*Patia*) - planted on *dam*s
Melon, Cantaloupe (*Milon*) - planted on *dam*s
Beans (*Bonchi*) - planted with sorghum
Cucumber (*Konkomber*) - small, round, prickly, stewed with goat
Pumpkin (*Pampuna*)
Okra (*Yambu*)
Sweet Potato (*Batata Dushi*)
Sweet Pepper (*Promenton*)
Banana (*Bakoba*) - small variety
(*Yinyin*)

Common Fruit Trees list:
Soursop (*Sorsaka*)
Medlar Fruit (*Mespol*)
Orange (*Apelsina*)
Papaya
Pomegranate (*Garnatapel*)
Lemon Tree (*Lamunchi*)
(*Kinipa*)
Guava (*Guyaba*)
Tamarind (*Tamarin*)

Timber Export and Charcoal on Farms

Bonaire was called "Isla de Palo Brasil" or "Dyewood Island" by Jaun de la Cosa after its first contact by the Spanish in 1499 (Hartog 1978:4). Dyewood was a desirable commodity, which can be rasped or ground to obtain cardinal red dyes. Dyewood (*Haematoxylon brasiletto, Brasia* in Papiamentu) must have been widely abundant at contact, but is today much reduced in coverage. It was valuable in both the Spanish and Dutch textile industries, and trade continued until the beginning of this century.

Lignum-vitae (*Guaiacum officinale, Wayaká* in Papiamentu) was another important export wood in early colonial days (Hartog 1978:16). This wood was renown for its hardness and natural lubricating qualities, and was used to produce pulley-blocks for ships. Heavy export of these two woods, combined with the foraging activities of goats and other livestock, reduced the forest cover on Bonaire.

Figure 57: Charcoal Pit

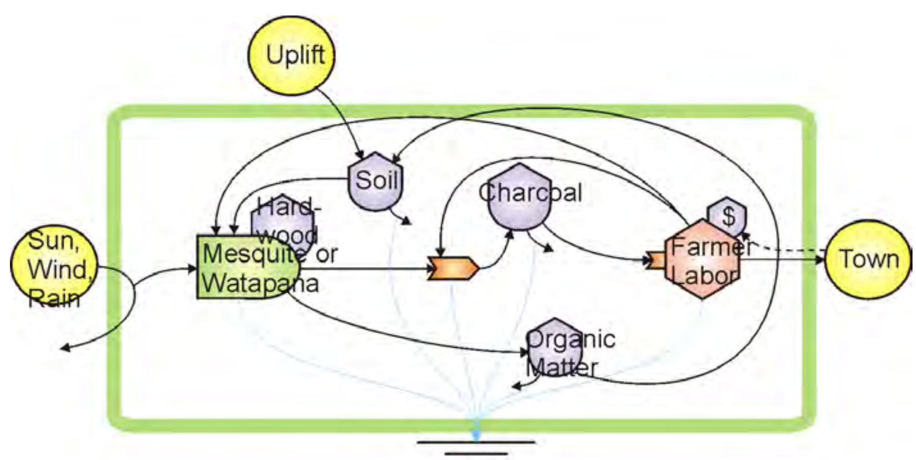

Figure 58: Making Charcoal

The seedpods of *watapana* (*Caesalpinia coriaria*) were another valuable export commodity from Bonaire. *Watapana* seedpods are loaded with tannin and were used in

Dutch tanneries before they started to use chromic acid as a tanning agent (Reijns 1984). *Watapana* pods were exported until 1954.

From early times to present, the hardwoods mesquite and *watapana* have been excellent sources for charcoal (Figure 36). Both trees live to be 50-100+ years old. If they are pruned, they can grow taller, with bigger and straighter branches, which are good for fence posts and for charcoal

Charcoal making is accomplished as follows. (1) Dig a long hole or pit 1-2 feed deep (Figure 57). (2) Fill it with mesquite (or *watapana* (dead from pest/disease)). (3) Cover it with leaves. (4) Cover the wood and leaves with sand. (5) Leave a small air hole at one end and a large air hole at the other end. (6) Burn it for several days (8-9), let it cool for a day.

Chickens

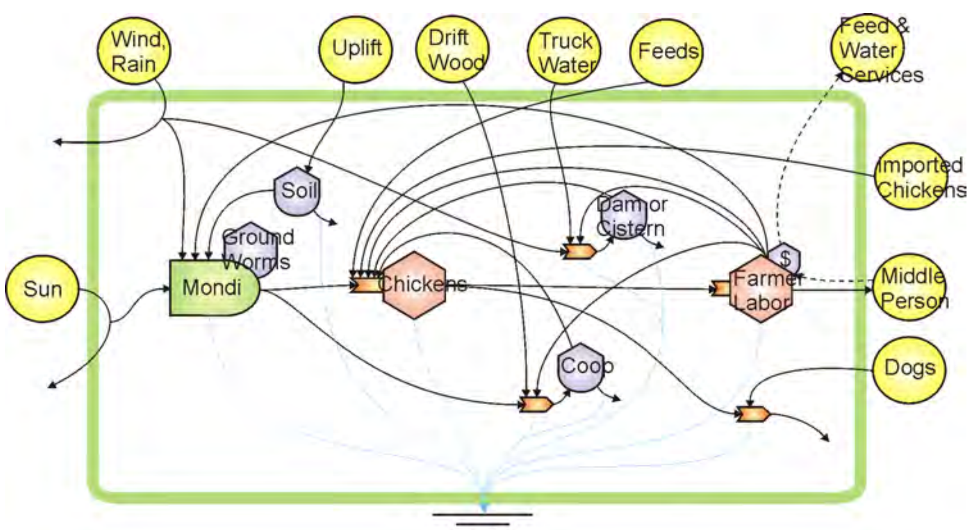

Figure 59: Raising Chickens

Native chickens are grown on many farms (*galiňa kriyoyo*). Chickens are allowed to forage in the *mondi* (inside and outside of *kunuku*s). Chickens are given some feed and some water by the farmers, but otherwise their needs are low. They may or may not be kept in chicken coops. As in most parts of the world, free ranging chickens are sources of both eggs and meat.

Some more intensive farms are growing imported chickens, both layers or broilers. These animals are kept in chicken coops and fed with purchased feeds. They do not forage in the *mondi*, and therefore have much higher inputs of energy and time from farmers.

Iguanas

In the past, iguanas were an important meat supplement to the Bonaire diet. They reportedly could reach almost 2 meters, but were generally less. Capturing and eating iguanas also protected vegetables. They are commonly eaten in soup or stew.

Figure 60: Iguanas Are Often Kept Alive Until Eaten

Figure 61: Iguanas Caught for Food

Today iguanas remain popular food items. Young men and boys often catch them for both fun and food. For many households, iguana remains a necessary food item. Like fishing, its great value lies in the fact that it is free to those who forage it. Iguana hunting has a long history, which many Bonairians take pride in. It is often said that eating iguana will improve one's sex life. Today, however, with foreign influence and greater purchasing power, some view iguana as undesirable.

In my survey I asked people about hunting and eating iguana. Usually after overcoming some embarrassment, people admitted enthusiastically that they eat or catch iguana. Here are some texts:

A man from Playa (36 years old):

> [Iguanas, do you catch iguanas?] Yea. I like it. Yea. [Yea. And at this time?] Sometimes, Saturday like that, or, not Saturday. Because now I don't have time Saturday, but Sunday, we go get iguana. Me and my brother. [Yea? And you eat iguana?] No. I don't eat them. [No. Sell them only?] Neither. For fun. You understand? [Yea. 'For the fun of it'.] 'Yes' But my brother eats them, and I get them for my father. My father really likes to eat them. My father and my mother. [They make soup?] Soup, yea, or stew. But I myself don't like it. [And when you go get iguana, you get a lot or…?] Sometimes we get 5, or sometimes 10. [Yea? And around here, or…?] We go more often, do you know Montaña? [Yea.] Patras di Montaña.
>
> *[Yuwana. Señor ta bai kue yuwana?] Si. Mi gusta. Si. [I e tempu aki?] Tin ora, djasabra asina 'ki, òf, no djasabra. Pasó awo'ki n' tin tempu djasabra, pero djadumingu, nos sa bai kue yuwana. Ami ku mi ruman. [Si? Anto bo ta kome yuwana?] Nò. Mi n' ta kome nan. [Nò? Bende so.] Tampoko. Pa divertishon. Bo komprondé? [Si. 'For the fun of it'.] 'Yes'. Pero mi ruman sí kom'é, anto mi trese pa mi tata. Mi tata sí gusta kome. Mi tata ku mi mama. [Nan ta traha sòpi.] Sòpi. Si. Òf stoba. Pero ami mes n' gusta nò. [I tempu bo ta bai kue yuwana, ta kue hopi òf ah ...?] Tin ora nos ta kue sinku, òf tin ora dies. [Si? Aki rònt aki, òf ah ..?] Nos sa bai mas tantu , mener sa Montaña? [Si.] Patras di Montaña.*

A woman from Playa (58 years old):

> [Does your husband catch iguana, or do you eat them, or buy them?] No, we get iguana yeah sometimes. My son goes to Washington, gets a couple iguana. We eat iguana also, a few we get, sometimes. Because my son, when he wants to go to look for goats, it's possible that when he runs the goats, they get one or two iguana, they give us one. [Yea, good, they taste good.] Yea. [And more or less how often in a month? Once, or less, or how often?] Sometimes we don't see any iguanas. Two, three months. It's not every day we eat, not all the time we have iguana. No. Now and then.
>
> *[Señora su kasá ta bai kue yuwana òf señora ta kome yuwana òf kumpra yuwana?] Nò, nos sa haña yuwana si tin ora. Mi yu bai Washington hasi un par 'i un par 'i yuwana ... Nos ta kome yuwana tambe, basta nos haña, tin ora. Pasó mi yu a ... ora k'e bai Washington bai buska kabritu, por ta e, e ta koredó 'e kabritunan, nan a kue un, dos yuwana, nan a dun'é unu .....[Si. Si. Bon. Si, e ta dushi.] Si. [Aha. I ah ... mas o menos kuantu bes pa luna? Un bes, òf menos, òf ... kuantu?] Si. Tin ora nos*

n' sa mira yuwana mes. Dos, tres lunanan ei. N' ta tur dia nos ta kome ... n' ta tur ora nos tin yuwana. Nò. De bes en kuando.

Figure 62: Man with Iguanas Tied to His Bike

Some view iguana hunting as hard work and time consuming. A man from Rincon (31 years old):

> [Do you hunt iguanas sometimes?] Iguanas, no. [No?] I don't like it much. I can go…I'll eat it yea, but buy it. From other people, but I don't go get them. Because of the time, you know, to go in the *mondi*. It 's a lot of work. Getting iguana is a lot of work. You go out early walking in the *mondi*. It's possible you come back with none, because there's times there aren't any. It's not easy. You have to go far. *Mondi*. Into Washington over there. The big *mondi*. *Kunukus*. I don't go. [Do you buy iguana in Rincon sometimes.] Yea, from local people. [Once, twice a month, or more?] Less, less. Sometimes once a month. No more. Maybe. Not all the time.

> *[Señor ta bai kue yuwana tin bia?] Yuwana sí, nò. [Nò?] Mi n' ta .... Mi n' gusta mashá. Mi po' bai .... Mi sa .. mi sa kome si, pero kome kumprá. Serka otro hende, pero ami no ta bai ki yamé. Pasé e tempu, no, pa bo bai mondi, bai ..... E ta .... e ta muchu ...muchu trabou. Kwement'i yuwana, ta hopi trabou. Pa bo sali tur ....trempan bai kana den mondi. Solo .... Por ta keda sin kue tambe pasobra tin ora no tin. No ta fasil. [Si?] Bo tin ku bai leu. Mondi. Den Washington por ayá ????? Mondi grandi. Kunukunan. Mi no ta bai. Esei sí nò. [Aha, si. Aha. Señor ta kumpra yuwana den Rincon tin bia?] Si. Hende lokal. Si. [Si. Hende lokal. I ah, un, dos bes pa luna, òf mas ...?] Menos. Menos. Por ta un bes pa luna. No mas. Por ta. No tur bia.*

Finally, this 43 year old woman from Rincon makes it clear that iguanas are still a part of feeding her family. She also expresses the problem of price inflation for food items like iguana (and fish):

> [Iguana, sometimes you buy iguana also?] Never. I don't buy iguana, because I get them. [Get them?] The husbands get iguana. The husband and kids go get them. [They get a lot?] Of course! There's a lot of kids! (laughs) I don't want to buy iguana, because iguana are also expensive. Because, if here at home I get iguana, I sell it cheap. But if other people get it, they sell it expensive…I can't buy it from them, because they sell it expensive. [Yes? And sometimes you sell it?] Yea. Sometimes I also sell iguana, but I don't sell it expensive. Good God! I sell it cheap. I don't sell it expensive, because I know what is what. How people must live. They sell iguana expensive now. Because the neighbors…sometimes I buy from the neighbors behind here, I buy one iguana for 8 florin…a big one it was. [I bought an iguana over there for 10 florin] One iguana! (laughs) [That's a lot?] Expensive! One iguana 10 florin!! One iguana he bought. (more laughs) [Because I didn't know…Yea, they see me, an American, that's easy.] A lot of money. [And you sell them for how much?] Me…sometimes I sell them for 5 florin, 6 florin, 7 florin. Sometimes 2 iguana for 10 florin. I don't sell it more expensive. I don't like it. There's people that don't compare with people. They sell stuff expensive, they don't have it. Sometimes they sell. That's not good! You must have understanding for people. [And when you get iguana, more or less, how many times a month do you eat it?] Per month? Sometimes I get it twice, or once a week…In one month I have it three or four times.
>
> *[Yuwana, tin bia señora 'a kumpra yuwana tambe?] Nunka. Mi n' kumpra yuwana, haña mi ta haña. [E 'a hañ'é ....?] E kasánan bai kue. E kasá k'e yunan bai kue.   [Ah si? Nan ta kue yuwana hopi, òf ....?] Kon por laga awó! Anto hopi yu! Hahahahaha. [Si?]   Ami n' tin mesté kumpra yuwana, pasó yuwana tambe 'a karu. [Ah si, tambe? Pa kumpra?] Pasó, si aki na kas, mi kue yuwana, mi ta bend'é barata. Ma si otro   hende kue, nan 'a bend'é karu. .... Mi n' po' kumpr'é seka nan, pasó   nan 'a bend'é karu. [Ah. Si, si. Tin bia señora ta bende .... ah ... yuwana, òf ....?] Si. Tin bia mi tambe 'a bende yuwana, ma mi sí n' ta bend'é karu.   Djó (Dios)*

> *libra! Mi 'a bend'é barata. Mi n' ta bend'é karu, pasó mi sa kiko ta kiko. Kon hende meste biba. Nan 'a bende yuwana karu awó'ki si. [Yuwana ta .....] Pasó e bisiña mes .... Tin bia mi kumpra serk'e bisiña dilanti'ki, seka esun ei, mi a kumpru un yuwana pa ocho florin! Anto e yuwana .... dje grandi'ki e yuwana ta'ta. [Ah, sii???!] Unda mi a bai? [Si ah .... m'a kumpra un yuwana den e kas di .... ayanan ..... i ah, pa dies florin.] Ún yuwana!! [Si. Un yuwana.] Haha. [Si. Ta karu no?] Karu!!!! Un yuwana dies florin!!!! Un yuwana, e a kumpra. [Si. Pasobra mi no sa .... mi no ...]. Ahannnnn! [Si. Nan ta mirá mi ... ah, Mericano, fasil. Mas fasil.] Ahannnnn. Mas sèn tin. [Mas sèn, no?] Hahahahah. [I, señora ta bende pa .... kuantu?] Ami .... tin ora mi 'a bende di sinku florin, ahm ... seis florin, shete florin. [Pa mas grandi. Esun mas grandi.] Si. Tin ora dos yuwana me' pa dies heldu. Mi n' ta bende ma' karu. Mi n' gusta no. .... Tin hende n' ta kosa .... nan n' tene komparashon ku hende. Nan 'a bende ko' karu, nan n' tin kunés. Basta nan bende. Asin'ei n' ta bon si! Bo meste' komprondé pa hende. [Aha. .... Ah si. Anto señora tin yuwana, ah, mas o menos, kuantu bes pa luna ..... ah, pa kome?] Pa luna? [Si.] Tin ora mi tin dos .... tin .... Mané un siman mi tin .... Den un luna mi tin tres òf kuater biaha pa kome yuwana.*

Iguanas continue to be an important meat source for many Bonairians. Both fish and iguana on Bonaire make excellent famine foods because they are foraged by the consumer themselves. Iguana may also be sold to neighbors. Officially, iguanas are protected, which restricts them against sale in restaurants. However, these restrictions are weakly enforced, and households are beginning to compete with some commercial interests for the animals, with the likely result that prices are inflated.

Fishing

While fishing is not a *kunuku* activity per se, it is part of the traditional economic strategies practiced on Bonaire. The status of fishing on Bonaire in the 1980s was described by (Leendertse and Verbeek 1986:169):

> At the moment there are 52 full-time fishermen and about 200 part-time fishermen on Bonaire. The full-time fishermen are totally dependent on fisheries for their income and in general they use the boats which are longer than 24 feet and are driven by inboard engines. Part-timers sail the small open boats, mostly driven by outboard engines, and they do this in addition to a regular job, so as a secondary occupation, or in addition to a social security allowance.

This account gives a picture of the relatively small scale fishing industry on Bonaire. It omits, however, the additional common practice of fishing "from the rocks", which is enjoyed by many Bonairians from time to time. One man told me that when he worked evening shifts at Radio Nederland near the coast north of Playa he would take his fishing line. After work he would fish, clean and cook the catch in the early morning hours on the rock cliffs. He said that no one should ever starve on Bonaire, because if you are hungry you can always catch something.

Figure 63: Fishing, Pleasure, and Live-in Boats
Moored on the calm west coast at Playa.

Many Bonairians occasionally fish by boat or from the rocks. From my survey I can estimate that about one-third of the adults from Playa fish on occasion, and about two-thirds of the Rincon residents (Question 6.1). One woman (29 years old) from Playa described how she and her husband get fish:

> [Does your husband fish?] As a hobby. [Now and then?] Now and then. Not every day. Ordinarily once a month. [He goes to Lac…?] No…Everywhere a little. [He has a boat?] No. [He goes to the rocks?] Normally on the rocks, sits fishing. [You don't sell the fish?] No. [Do you buy fish also?] Yes. [On Bonaire, where do people buy it?] Where

> people sell it, I mean, at houses of people that sell it, over there I buy it. [Not at a supermarket?] No, no. [For fresh fish people go…] Fresh, to people's houses. [How often do you eat fish?] Once a week.
>
> *[Señora su kasá ta bai piska?] Komo hòbi. [Ah, si?] Si. [De bes en kuando, òf ah ..?] De bes en kuando. No tur dia. Gewon un bia pa luna nan ei. [E ta bai na Lac òf ..?] Nò uh ... Tur kaminda un tiki. [Tur kaminda?] Ahah. [E tin boto òf ah ..?] Nò. [I ah ... Anto e ta bai na baranka òf ah ..?] Gewon na baranka, sinta piska. [Si, anto señora no ta bende e piská? Señora ta kome piská so?] Si. [I ah .. señora ta kumpra piská tambe ....?] Kumpra? Si. [.. na Bonèiru? Na unda hende ta ....] Kaminda hende ta bende, kemen, na kas di hendenan ta bende, einan mi ta bai kumpra. [Aha, O.K. No ta na supermarket?] Nò, nò, nò. [Aha. Pa piská fresku hende ta bai ...] .. fresku, ta na kas di hende. [Si .. Kuantu biaha pa luna señora ta kome piská?] Kuantu bia pa luna? Un bia pa siman nan ei.*

If you do not fish yourself, you can buy it from neighbors or from the few larger fish outlets on the island. Wahoo, dolphin, and swordfish are caught with drag lines from fishing boats, usually three lines per boat (Leendertse and Verbeek 1986:60). Red snapper and grouper are caught with deep lines, on the sloping narrow banks beyond the reefs. Many other fish are also caught including barracuda, bonito, shark, mackerel, and tuna.

Not one person in my survey stated that they do not eat fish (only about 55% claimed to eat iguana). Fish are caught year round, and knowledge about fish catches is spread informally. One Rincon man (33 years old) explained his approach to catching and buying fish:

> [Do you fish?] Now and then, yea. [Now and then?] Yea. [How many times a month will you…?] No, no, it's not like that. It is….I can't say, because it depends. You wake up one day, you say: yea, I'm going to the sea, going fishing, it's like that. But not every week, or every….no. [I follow you. Do you eat fish?] Do I eat fish? [(Dumb question) Fish, yea] You have some now? [Do I have….?] Fish for me? (laughs) [(laughs) No] Of course I eat fish!
>
> [Do people buy fresh fish, or…?] Here on Bonaire? [Yea] Look, fish, here we don't store fish alot. Fish you're not going to store much. I mean, if you're a fisher, you go to the sea and go fishing, you come back with fish today, maybe today or tomorrow you don't have any…..you caught a lot of fish, you don't have anything left, because people buy them immediately. Because it's eaten a lot/often, you know. I mean, you

> don't store fish, in a month's time there will still be fish. No! I mean, every time they go to the sea, they catch some fish, come back with it and sell it.
>
> [Do you fish?] Yea. But look, most of the time here in Rincon, primarily we ourselves go. Because you know where there's people that sell fish, you know. So when they have fish, you hear from someone, or you see people go by with fish, you say: yep, I need fish. So then you go, buy some for yourself.
>
> [So do you buy fish a lot of times in a month, or eh some…?] Is it possible to eat a lot of fish in a month? Not a lot I mean… it's not …the fish. We eat fish yea, but not for you to say that we get up and eat fish every week, a lot of fish, no.
>
> *[Señor sa bai piska?] De bes en kuando. Si. [De bes en kuando?] Ay si. [Ah, si. Kuantu bes pa luna señor ta ....?] Nò, nò. Esei no tin, no tin .... nò. E ta .... Mi n' po bisa, pasó ta dependé .... Bo ta lant'un dia, bo ta bisa: si, mi ta bai laman bai piska, k'e ko'nan ei. Pero no ku ta tur siman, òf ta tur .... nò. [Aha, si. M'a komprondé. Señor ta kome piská?] Ku mi ta kome piská? [Piská. Si.] Ahhh. Bo tin e ora ei? [Mi tin ...?] Piská pa mi? Hahaha. [Hahaha. Nò.] Hahaha. Kon po laga mi ta kome piská!*
>
> *[Hende ta kumpra piská fresku, òf ah .....] Akinan na Boneiru? [Si aki.] Si. Nò .... Wak, piská, aki nos n' ta warda piská hopi. Piská no ta wòrdu wardá hopi. 'Es decir' ku, (kemen ku,) si bo t'un piskadó, bo bai lamán bai piska, bo ta yega k'e piskánan awe, por ta awe mes òf pa mayanan ei bo n' tin .... b'a kue hopi piská, bo n' tin nada mas, pasó hendenan ta kumpra nan mes ora. Pasó, e ta wòrdu hopi komé, no. Kemen di, no ta warda piská, aki un luna ainda tin piská. Nò! Kemen di, ta kada bia nan bai lamán bai kue bin ku ne, nan ta bend'é.*
>
> *[Señor mes ta bai buska piská?] Piská .... Si. Nò, wak. Mayoria biaha .... aki na Rincon, prinsipalemente, ta nos mes ta bai. Pasó bo sa na unda tin hende ku ta bende piská, no. Anto ora nan tin piská, di mes bo ta tende di otro, òf bo ta mira hende pasa ku piská, bo ta bisa: Hepa, mesté tin piská. Anto e or'ei bo ta bai bai kumpra bo kos.*
>
> *[Ah, si. I ah, señor .... señor ta kumpra piská hopi den luna hopi tempu, òf ah, de bes ....?] Po' kome hopi piská den un luna? Nò masha .... kemen di, no ku ta .... e piská. Nos ta kome piská si, pero no pa bo bisa ku nos ta lanta kome piská tur siman, hopi piská, nò.*

From these two accounts it can be seen that purchasing fish on Bonaire has not been fully captured by the formal economy. Fish (or iguana) purchases from neighbors occur regularly. Fishing for yourself supplements household economic strategies without the use of cash.

This situation appears to be changing, however, as competition for fish catches within the growing island population, and between the inhabitants and the hotels/restaurants reduces supply and generates price inflation. Officially fish prices are controlled by the government, and have not been changed in 20 years. However, according to many people including this woman from Rincon, within the informal economy fish prices are indeed rising significantly:

> [How do you buy fish? From neighbors…?] Neighbors, yea…people sell expensive fish. That I don't like. Fish are a lot of money here. A lot of money. In Playa you can buy it cheaper…but in Rincon you buy it expensive. 9.50 NAf per kilo ($2.41/lb). [Fresh fish?] Look. The fresh fish are 9.50. The salted fish also sometimes is 9.50. There's times it's 10.50. Because now, a woman near here raises (the price) of all fish. Because dolphin was 6.50, now its 7.50. Wahoo was 8.50, now it's 9.50. [Five years ago it was much cheaper?] Five years ago? Last year it was much cheaper! [One year ago!] And this year it already went up! [Yea? In one year it went up!] I think it's a lot more expensive! [And five years ago it was a lot cheaper?] A lot cheaper. There was fish for 3 florin per kilo. Fish, 3 florin. Now no. It's gone up fast! Fast! Really fast it went up. [In 5 years, or 10 years?] More like 3 years. Not 5 years.
>
> *[Kon señora kumpra piská? Fo'i bisiña ah ....?] Bisiña sí .... Hendenan 'a bende piská karu si. Esei sí mi n' gusta. Piská 'a hopi sèn 'kinannan. Hopi sèn. Na Playa b'a kumpr'é barata, ma na Rincon si, b'a kumpr'é karu. Nuebe sinkuenta pa kilu! [E piská fresku?] Wak. E fresku 'a nuebe sinkuenta. E .... e salu, tambe tin ora e nuebe sinkuenta. Tin ora te dies sinkuenta. Pasó awo'ki ah, un señora aya banda a subi tu' piská. Pasó dradu tabata .... seis sinkuenta, awó'ki ela bira shete sinkuenta. Mulatu tabata ocho sinkuenta, ela bira nuebe sinkuenta. [Aha? I ... kuantu aña pasá e ... ela ta' mas barata?] Kuantu añ' pasá? Ta aña pasá e ta' dje barata ei! [Ahn, un aña pasá!] Anto e aña 'ki ya ela subi kaba! [Si? .... Ahh. Den un aña ela subi!] Mi 'a hañ'é masha karu mes! [Ah, si! I ah .... sinku aña pasá e tabata masha barata?] Hopi barata mes. [Si?] Ta' tin piská tres florin pa kilo. Piská, tres florin. Awó'ki sí, nò! Ta subi hopi duru! Lihé! Mashá lihé nan a subi nan. [Ah, si. Den sinku aña, òf dies aña so.] Si. Po' bisa den tres añ'. Ni sinku añ'.*

Both fishers and a fish outlet worker told me that selling fish to hotels is desirable. This is because they will buy the entire fish. Fishers at times will bypass the outlets and sell whole fish directly to hotels. Purchasing whole large fish saves the seller time and money. I interviewed three hotel chefs and each expressed the need for fresh fish in their restaurants. At times getting fish is difficult, they explained, because it is sold to first-comers. The situation is ripe for bidding wars between hotels for fish, which would hike prices further throughout the island. It might be that this already occurs unofficially.

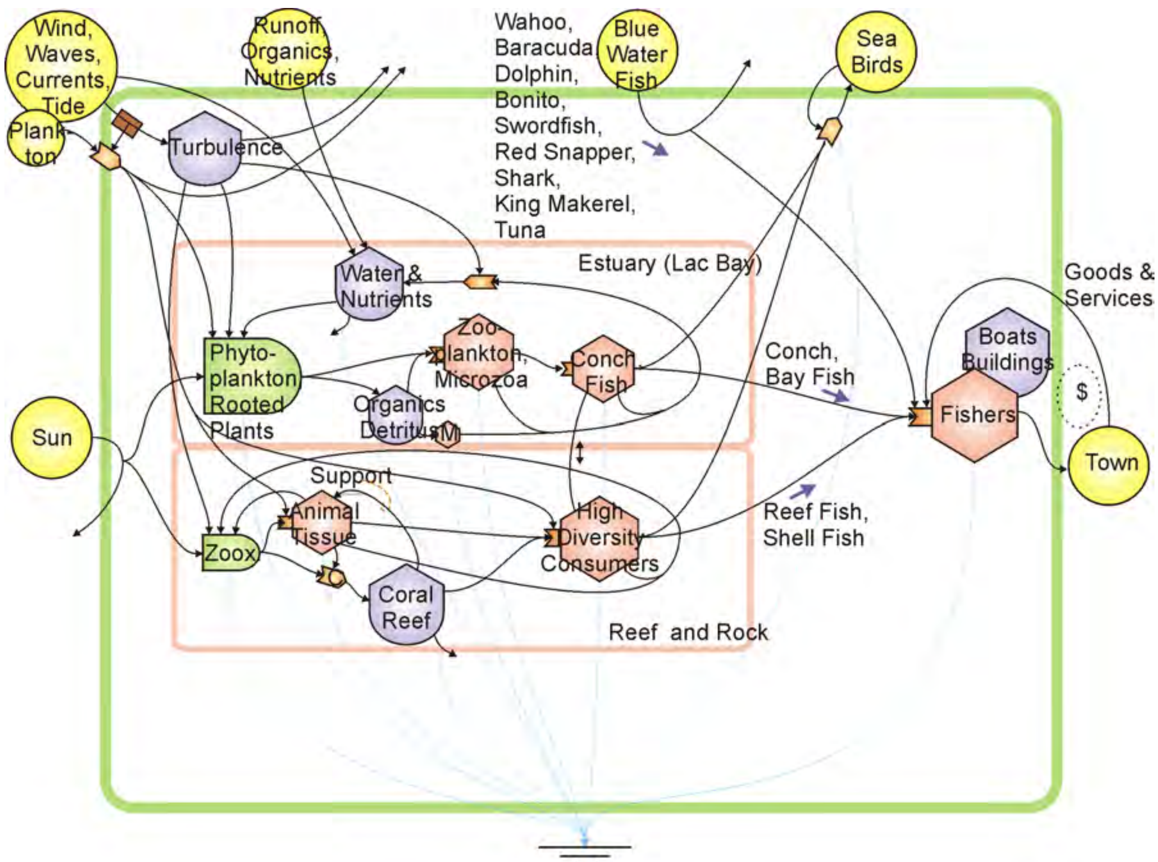

Figure 64: Major Coastal Systems are the Fringing Reefs and Lac Bay Estuary
The fringing reefs of Bonaire have long nurtured life in the sea and above it. Birds are avian foragers of the sea, humans terrestrial. Fishing has provided the island with a vital source of sustenance, complementary to farming. See emergy analysis in APPENDIX D2.

According to one fish outlet, additional competition in the modest Bonaire fishing industry comes from international trawlers. Using large nets they can quickly reduce fish stocks. By international law these are territorial waters of the Netherlands Antilles, but without a credible policing presence, these laws are regularly violated by ships from as far away as Japan.

Fish represent the contribution of a great deal of environmental work to an economy. Many environmental inputs to Bonaire enter through the coastal systems. These include the wind, waves, currents, and tide, in addition to deep-water nutrients and migrating fish. These inputs are depicted in Figure 64, and analyzed in APPENDIX D2.

CHAPTER 6
ECONOMIC STRATEGIES--INTERVIEWS

People and households on Bonaire use interesting and complex economic strategies to make a living. The preceding chapter offered a descriptive account of farming and fishing practices assembled from14 months of participant-observation fieldwork on the island. In that time, two samples of semistructured interviews were also conducted to collect statistical data on households and labor. The results from both sources are used in the emergy analyses in following chapters.

Environmental inputs to economic strategies are often overlooked in labor interviews, which tend to emphasize the formal wage labor component. The aims of the interviews were (1) to gain a more accurate picture of personal and household economics that included environmental inputs, (2) to gather data for my systems models of Bonaire households, which also include environmental inputs to the households, and (3) to allow respondents to share their feelings about tourism, work, and change on Bonaire.

With my first short trip to Bonaire in 1992, it appeared to me that some Bonairians were practicing combined farming and wage labor economic strategies. Given the less intense development history of Bonaire (see CHAPTER 3), I imagined that this mixed pattern had great longevity on the island. I also imagined that one impact of ecotourism development on Bonaire might be to transform these strategies for many Bonairians.

After being on Bonaire for about six months, I was aware that some Bonairians do indeed practice complex mixed economic strategies. These strategies may include some combination of formal wage labor, formal "jobs", informal "jobs", extensive (not intensive) farming, *mondi* foraging (for iguanas, shellfish, birds), and fishing (from rocks or boat). I wished to discover how common these mixed strategies were. I decided that interviewing persons about their economic strategies could give a clearer picture.

Methods

The interviews were conducted in Papiamentu, the first language of Bonairians. Some Bonairians speak English as a third language (after Papiamentu, Dutch, and maybe Spanish), but not all, and proficiency is uneven as would be expected in any multilingual context. Anthropologists know well the tremendous value of conducting fieldwork in the language of the community under study. This fact of fieldwork was stated with remarkable clarity by one interviewee in response to Question #14, "Do you have any questions or comments about this interview?":

> Ok. I think it is good. Um…it is appreciated that there's a person from America that is interested in the countries, Aruba, Bonaire and Curacao. Ok, let me put it like this, in the countries that speak Papiamentu, if you try to do your survey in Papiamentu you will get more direct answers, and therefore more understanding of the person. Because, if you needed to ask me in English, or in American, at that moment I will believe I need to slowly plan for my answers. So then, the answers you get maybe…not maybe, for sure…let me say it like that…you're not going to get the answers you need to get. Because I'm not speaking in my mother tongue. In my language itself. I am talking in your tongue. At that time you ask questions with a little more weight, with a little more quality, but me my answers are a little less quality, because it's not my language that I speak in. American is not my language. For that reason I would need to plan how to express myself when speaking with you, and the quality of my answers is lower then. Here it is just the opposite. I speak in my own language. What I mean to say, I can say the way I want. I can express everything that I want and everything that I feel. Where if I'm going to answer you in American or in English, the quality is going to be much less. I'll be looking for words. Surely I'll have times when I don't have the word. Then I give you half the answer or I don't give you the answer 'at all'. Or I tell you a thing that completely isn't the answer. [So you feel that this is better?] No. This is…this absolutely is better. We don't need to stop and think, wondering further if it is better yes or no. This is better, because the person answers in their own language. [Ok, good.]
>
> *Bon. Mi ta hañ'éle bon. Ahm ... ya ta di apresiá ku tin un hende di Merka ta interesá den e paisnan. Aruba, Bonèiru ku Kòrsòu. Bon, lagá mi ponele asina'ki, den e paisnan di abla Papiamentu, anto ku bo ta trata tambe di*

> *tene bo enkuesta na Papiamentu pa bo tin kontestanan mas direkto, anto mas yegá na e persona. Pa motibo, si bo mester a puntrámi na Inglés, òf na Merikano, n'e momento ei ami lo ta hañámi tin ku bai sinta pensa pa mi kontestábo. Anto e or'ei, e kontestanan bo haña kisas .. no kisas, sigur - lagámi bisá asina'ki - lo no ta e kontestanan ku bo mester haña. Pa motibu ku mi no ta papiando den lenga materna. Den mi lenga mes mes. Mi ta papiando den bo lenga. E or'ei abo ta puntra preguntanan k'un un tiki mas peso, ku un tiki mas kalidat, pero ami su kontestanan ta di un kalidat menos, pa motibu ku no t'ami lenga mi ta papiando aden. E Merikano no t'ami lenga. Esei ta nifiká ku mi tin ku bai pensa pa mi ekspresá mi mes pa papia ku bo, anto e kalidat di mi kontestanan ta baha e or'ei. Awor aki ta nèt kontrali. Mi ta papiando den mi mes lenguage. Kier men di, mi por ekspresá mi mes kon ku mi kier. Mi por trese padilanti tur loke mi ta pensa i tur loke mi ta sinti. Kaminda ku si lo mi ta' tin ku kontestábo nan na Merikano òf na Inglés, anto e or'ei e kalidat lo tabata mas abou. Lo mi tin ku buska palabra. Siertamente mi tin ora mi no ta ni haña palabra. Pues e or'ei mi ta dunábo mitar kontesta òf mi no ta dunábo kontesta 'at all'. Òf mi ta bisábo un kos ku 'at all'mente no t'e kontesta. [Anto señor ta kere ku esaki ta mihor?] Nò. Esaki ta .... esaki simplemente ta mihó. Nos n' tin mester di ni bai para pensa, filosofiá asina leu di si e ta mihó si òf nò. Esaki tá mihó, pasó e persona ta kontestá den su mes lenga. [Aha, aha. Bon, O.K.]*

Two separate rounds of interviews were conducted, one in Rincon and one in Playa. It was felt that there might be significant differences in some answers between the two regions. There are a number of characteristics that distinguish Rincon from Playa. In very simple terms, Rincon is more rural and Playa is more urban. I chose to conduct the interviews myself, and therefore to use small samples.

Using everything I knew about life on Bonaire to that point, an interview guide was constructed. The guide was pre-tested on volunteers from the Tourism Corporation Bonaire (TCB) and on other acquaintances. I tried to incorporate all suggestions, and many questions were re-written or thrown out.

Perhaps the greatest good fortune with the interviews was a meeting I had with the Central Bureau of Statistics (CBS) office on Curacao. They agreed to give me a small subset of the survey data from the 1992 census. Naturally they kept all sensitive materials to themselves. What they gave me was the name of all Bonairians in the census, plus their address, geographic district, birth dates, places of birth, and sex.

Figure 65: Conducting Interviews
Armed with notebook and tape recorder, I traveled to interviews by bike. Most Bonairians found this pretty strange. First, bikes are for kids. Second, the thorns of acacia and mesquite are everywhere and strong enough to puncture car tires. Riding a bike is a battle against flat tires that you cannot win. My thoughts about travel in the "field" of Bonaire were several. I did not want to bear the expense of a car, however the scale of Bonaire is a bit too large to travel by foot. More important, I was hoping to be as visible as possible to Bonairians. Furthermore, I hoped that by moving slowly wherever I went that there was more chance to see or meet people. Finally, I hoped to be as different as possible from the other foreigners on the island. With tourism, there are many people on Bonaire that look or dress like me. On my bike I was noticable. In fact, this strategy was only marginally successful. Many Bonairians today travel mostly by car and are not that easy to run into. These challenges are no doubt faced by other anthropologists today that work in similar urbanizing settings.

Needless to say, few fieldworkers have such good population data for drawing samples. Using the "district" data, I created a Rincon population and a Playa population. I further restricted both populations to persons over 25 years of age (therefore, with at least a short work history) and under 60 years of age (persons still working). I also limited the interviews to persons born on Bonaire, Aruba or Curacao. While responses by foreign-born persons would have been interesting for other reasons, the interviews sought to discover economic strategies that had evolved in the Antilles. From these two populations I used a random number generator to create two samples of 20 persons each. This random sampling has made it possible to use statistical inferential procedures to make statements about the larger populations.

Conducting the Interviews

The first round of interviews was conducted while I lived in Rincon. Locating sample members was difficult. With names, addresses, and some maps in hand, I often met empty houses or absent family members. I was gradually discovering that many people worked wage jobs in Playa and would return at 5:00-6:00. I would also discover that people did not like to be bothered after dark. This meant that I had a narrow window of opportunity to meet with those persons who worked regular hours. Other persons who did not work regular hours were easier to locate and interview. I had little luck on weekends, as people were often out, or were less in the mood to be interviewed on their days off.

Remarkably I was able to interview every member of my Rincon list except one. That person had moved to Playa. The interviews were semistructured, and followed my written interview guide. I intended for the interviewee to feel free to elaborate on any answer. I hoped to gain not only empirical (and sometimes numeric) data, but also to collect texts in Papiamentu. The interviews were a challenge because of my limited language skill, but I managed.[1]

Semistructured interviews provide the advantage of pre-arranging a conversation. The interview guide focused the respondent's comments to topics that I

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[1] After one two-month leisure course in Papiamentu, I had begun fieldwork. I essentially learned Papiamentu in the field. Using methods from anthropological linguistics, I produced a Papiamentu phonology, and began work on a Papiamentu morphology and syntax. While on Bonaire I also took one short course in Papiamentu when I lived in

expected, which made my comprehension better. Furthermore, many questions regarded topics that I had been researching for eight months, namely goat farms and island companies, for which I had pretty good understanding and vocabulary.

Another invaluable interview strategy was tape recording. I asked each respondent if they would mind if I recorded the conversation. I explained that my language skills were still limited. Not one subject refused the request. While I was aware that recording might inhibit some interviewees in their responses, I felt that the tradeoff of collecting verbatim texts was worth it. Following the interviews I would return to my home and listen to the interview, transcribing portions, and extracting numerical data. In fact, after my pre-test interviews, I realized that the responses were far more conversational and fluid and relaxed if I did not write responses to questions during the interview. I extracted those responses after the interview at my home while listening to the tapes.

This worked well, and it improved my Papiamentu enormously. However, I discovered that verbatim transcription was very time consuming. I decided to abbreviate the responses in my notes as best I could, to assure that no interview would be lost if the tape became damaged. I then sought the assistance of a professional transcriber on Curacao. I would not have hired a person to transcribe the interviews from Bonaire, because I did not want to risk the chance that confidential responses could become known to Bonairians. The transcriber on Curacao agreed to maintain all confidentiality, was not given the names of any interviewees, and would not have been able to recognize voices or personal histories.

The result is that I now have beautifully transcribed Papiamentu texts of each of the interviews. These interviews I have translated into English, and now have extracted

---

Playa. After eight months I felt that I could attempt to conduct my interviews in Papiamentu.

responses. Some day I hope to use the texts to improve my write-up of Papiamentu morphology and syntax. At present, I am limiting their use to producing interview responses, improving my general understanding of life on Bonaire, and providing occasional verbatim texts for illustrative purposes (as above).

One negative result of this approach was that in the flow of conversation I occasionally did not ask some questions. These answers are "missing" in the data. Very rarely did I skip an important topic completely, but there are numerous occasions where I missed some of the details.

The second round of interviews was conducted when I moved back to Playa on about month 10. For these interviews I had more difficulty getting respondents. Often several trips were made to each location. One person refused, I believe because I contacted them after dark (after several attempts to come earlier). It was strange enough to have an American show up on your door speaking "uneven" Papiamentu and asking to interview you, but to appear after dark was, I believe, too much. A few other sample persons put me off on repeated occasions for one reason or another. One actually slipped out the back door as I spoke to his sister at the front. When it became clear that they did not wish to be interviewed I stopped calling on them. I believe Bonairians are generally too polite to decline an interview. The persons who did not wish to be interviewed chose avoidance over confrontation. These sample persons are scored as missing from the sample. This result is not at all surprising, considering the very common low response rates to many surveys in the US. Perhaps the surprising result is the high response rate of the Rincon sample.

I considered the sampling strategy of moving on to the person next door, but I thought this to be inappropriate for Bonaire where there is often no clear "next door" (as houses in some barios are scattered about). Furthermore, after coming to a house several times for perhaps a week, talking to neighbors or family members about a particular person in my sample, I thought it would seem suspicious that I could so easily change my request for an interview to someone else nearby. The Playa group therefore has only 13 respondents. I am aware that this reduces the value of the results. All conclusions from the interviews should be considered in light of this difficulty. The small sample size of both groups is, of course, another important consideration in judging the results of the interviews. The fact that I had good samples should also be considered.

Some interview results are compared to the Breadbasket Survey (CBS 1994a), the 1992 Census (CBS 1993b), the Statistical Yearbook (CBS 1994c), or some other data source. These comparisons provide some verification of the results.

The most common discriptive statistic that I produced in the results below is the sample mean. I wished to compare means between the Playa and Rincon interviews for many different measurements. Since my samples are smaller than 30, I used the t statistic (t-Test for two-samples assuming equal variances) to determine if the sample means were significantly different. If $P < 0.05$ then the sample means are significantly different.

Introduction

For the interviews I had a prepared introduction that I read/recited when I made contact with an interview subject. The intention was to explain myself and my motivation, and to explain that they had the right to refuse the interview, or to refuse to answer any questions in the interview. I also asked the person if I could record the conversation. The introduction is reproduced here.

> Introduction
>
> I am Tom Abel and I am a student of the University of Florida in America. I study anthropology. I am on Bonaire to do a study of the influence of tourism development on work in general, and on the way of life of Bonairians, with the intention of writing a book about it. For this reason, I'd like to ask you some questions about your work today and in the past. You are free to answer or not answer my questions. The answers will

stay confidential, nobody else from Bonaire will get to know them. My intention is to get a better understanding of how people work on Bonaire. Are you interested in helping me with these questions? Can you help me? I'd like to record the conversation, because I don't speak Papiamentu that well. Do you have anything against me recording the conversation? Is that ok? Does that worry you? [If they ask, "How did you pick me?"] We put the names of everyone from Rincon/Playa over 25 years old in a hat, and we pulled out 20 names.

Introdukshon

Ami ta Tom Abel i mi ta un studiante di Universidat di Florida na Merka. Mi ta studia antropologia. Mi ta na Boneiru pa mi hasi un estudio riba e influensha di desaroyo turístiko riba trabou en general i forma di biba di e pueblo Boneriano, ku e idea pa yega na un buki tokante esaki. Pa e motibu aki mi kier a hasi señora algun pregunta tokante señora su trabou di awor i den pasado. Señora ta liber pa kontestá òf keda sin kontestá mi pregunta. E kontestanan ta keda konfidensial, niun otro hende di Boneiru lo haña sa di nan. Mi intenshon ta pa haña mihó bista di kon hende ta traha na Boneiru. Señora ta interesá pa yuda mi ku e enkuesta aki? Señora por yuda mi? Lo mi kier a graba e kòmbersashon, pa motibu ku mi no ta papia papiamentu asina bon. Señora tin algu kontra ku mi ta graba e kòmbersashon? Esei ta bon? Señora ta wòri?

Nos ta pone tur nòmber di hende di Rincon riba binti sinku aña den un rei i nos ta skohe binti nòmber

Interview Guide - Questions, Issues, and Results

The semistructured interviews followed the interview guide in conversational form. I altered the order of questions when appropriate. If an interviewee introduced a topic, I often followed their lead into that set of questions. This approach led to some missed questions, however I feel that the advantages of maintaining the conversational format outweighed some occasional missed data.

Current Employment

Question #	**1**
Question	I'd like to start by asking some questions about the work that you do now. Do you work? What kind of work do you have? Describe it? Housewife? Or work only "jobs"? → Go to Question 3. Looking for work?
Papiamentu	*Mi kier a kuminsá hasi algun pregunta tokante di e trabou ku señora ta hasiendo awor aki. Señora tin trabou?* *Ki sorto di trabou Señora tin? Señora por konta mi algu di Señora su*

	trabou?
	Señora ta prefará pa keda kas (ku e muchanan) i no bai traha? Dikon? Señora ta buskando trabou?
Issues	This question is open-ended and the interviewee was given free reign to respond with a description of their occupation, to explain it, and to give details. This permitted the interviewee to dive into the meat of the interview, and in a format that is conversational. This built trust, and allowed the interviewee to feel in control of the interview. It also allowed us both to warm up, and gave the interviewee time to judge my language fluency. Follow-up questions were asked, and often all of Question 1 was collected seamlessly.
Results	The Rincon interviews uncovered some work patterns: Men in construction/painting/masonry/carpentry = 4 Of these, 2 work for construction companies, and 2 work construction "jobs" Women selling lottery = 2 Women housewives = 2 The Playa interviews: Men in construction/painting/masonry/carpentry = 1 This 1 works construction "jobs" Two other men worked in more specialized construction work (one in metalworking, one in architecture) Women selling lottery = 1 Women housewives = 2

Question #	**1.1**
Question	What year did you start?
Papiamentu	*Ki aña Señora a kominsá traha?*
Issues	Interested in the duration of work and jobs
Results	Average length of employment is about 6 years, but there was much variation, with responses ranging between 1 and 27 years. Playa (11) = 5.6 years (SD = 7.6) Rincon (16) = 7.3 years (SD = 8.4) P = 0.304 (Difference between Playa and Rincon is NOT significant)

Question #	**1.2**
Question	Where do you work?
Papiamentu	*Na kua lugar (na unda) Señora ta traha?*
Issues	Wanted to know if people were travelling to Playa, etc.
Results	The great majority of persons with formal employment are working in Playa. Playa (10) = 90% Rincon (16) = 75% P = 0.182 (Difference between Playa and Rincon is NOT significant)

Question #	**1.3**
Question	How do you get to work?
Papiamentu	*Kon Señora ta bai trabou?*
Issues	Some businesses supply transportation where minibus drivers come to

	your house.
Results	The majority of persons get to work by car or bus, although a significant percentage of people travel by foot. Car / bus to get to work? Playa (11) = 82% Rincon (17) = 71% P = 0.26 (Difference NOT significant) Bus / carpool to get to work? Playa (9) = 22% Rincon (12) = 50% P = 0.106 (Difference NOT significant)

Question #	**1.4**
Question	Do you own a car? Is there a car in the household?
Papiamentu	*Señora tin outo?*
Issues	This question collects both transportation information, and an important household asset for the household emergy analysis.
Results	Many persons on Bonaire nowadays own cars. There might be significantly more car owners in Playa than in Rincon (P = 0.07, very close to 0.05 threshold). Playa (12) = 75% Rincon (17) = 47% P = 0.07 (Nearly significantly different, 0.05) The Census (CBS 1993b:28) says 62% of households had cars in 1992. This is close to the result from interviews. The Statistical Yearbook (CBS 1994c) says 25% of people on Bonaire own cars. With 2-3 wageworkers per household that would equal +50% of households with cars. That result is also close.

Question #	**1.5**
Question	How many days a week do you work? (All day?)
Papiamentu	*Kuantu dia den siman Señora ta traha? (Henter dia?)*
Issues	Looking for unusual work hours.
Results	The average workweek is about 40 hours. However, there were a number of persons in both interview groups working 50 hours or more. Bonaire has its share of workaholics. Some of the workers with long hours were in larger companies that forced employees to work overtime. Balancing these numbers, some employees worked odd hours and shorter workweeks. Lottery workers commonly fell into this group. Playa (10) = 41.3 hours Rincon (14) = 40.6 hours P = 0.203 (Difference NOT significant)

Question #	**1.6**
Question	Do you work on contract? Salaried?
Papiamentu	*Señora ta traha riba kontrakt?*
Issues	There are three work categories that I identified for Bonairians (permanent salaried, contract, "jobs"). If a person works only jobs then the interview jumped to Question 3. People that work jobs are hired for a particular work task, and are paid for the task when completed, irrespective of the time it took to complete the task. Jobs are sometimes

worked black or informal, meaning that income is not reported and taxes are not taken. Bonairians who work contract work or job work have a "workbook" within which their employers are expected to record any salaries paid. Employers are supposed to hold back taxes from wages paid, and pay those taxes to the government. Some employees allege that the companies keep those taxes for themselves.
Contract vs permanent salaried employee. Bonairians use the Dutch phrase *vaste dienst* to refer to salaried employment. Much work on Bonaire is via contract. The big companies can save money by hiring contractors. Government employees who are salaried cannot be fired, so it is difficult to become salaried (*vaste dienst*) for the government. It is maybe easier to become salaried for private companies.

Results Perhaps half or more of Bonairians who have formal employment are salaried. Often a six-month or one-year probation precedes this status. These policies are similar to the policies of many companies in the US.
Playa (11) = 45% salaried
Rincon (14) = 71% salaried
P = 0.101 (Difference NOT significant)

Question # **1.7**
Question Do you pay for your pension
Papiamentu *Señora tin penshon (ta paga pa penshon)?*
Issues Private companies pay AOV and AWW from their paychecks (in addition to Wage Tax). AOV is the government pension for people over 60. About 450 fl/person, 700 fl/couple. AWW is paid to a spouse or children when a husband/wife dies.
These two pay into the SVB, Social Insurance Bank, along with two types of health insurance:
ZiekteVerzekering (Sickness Insurance) pays them their salary (or part) when they are sick and cannot work (is this AO?).
ZiekteKosten (Sickness Costs) pays for some costs of medical care.
PP Card. This is a medical insurance card for people not working and therefore without SVB, or for families of an employed person. You buy it from the island government for 6 fl for 3 months, elderly pay 6 fl for one year.
Results I was not aware of this system when I started the interviews. The question was answered at times, but other times it was not understood. This question was thrown out.

Question # **1.8**
Question How did you get this work?
Papiamentu *Kon Señora a yega na e trabou aki?*
Issues I was looking for personal networks, etc. Also, I wanted to understand hiring practices.
Results It turned out that many people are asked to work by friends or acquaintances, rather than solicit employment in more formal ways.
Playa (8) = 63% acquaintance asked them to work
Rincon (13) = 54% acquaintance asked them to work
P = 0.357 (Difference NOT significant)

Question # **1.9**

Question	Would you want your kids to do this work? / Do you like the work?
Papiamentu	*Señora lo ke su yu hasi mesun trabou ku señora ta hasiendo awor? / Señora ta gusta e trabou?*
Issues	Job satisfaction. The first question was really too long and very inappropriate in some cases. However, I did not really want to ask the second simpler alternative, because it was often answered with an unconvincing "Yes" (Who would answer "No" to something they choose to do for 40 hours a week?)
Results	There must be a better way to ask this. The question was thrown out.

Question #	**1.10**
Question	Do you work with people in your family? Who?
Papiamentu	*Na Señora su trabou, tin mas hende di Señora su famia ta traha? Ken?*
Issues	Looking for the role of kin in getting jobs, with Question 1.8. People understood this question to include distant kin, and often responded with answers like, niece or cousin.
Results	Working with kin is not uncommon, and has some significance in hiring practices, but it appears that non-kinship considerations are more important. These percentages are suspect because the response rate is low. Playa (9) = 33% work with kin Rincon (11) = 45% work with kin P = 0.302 (Difference NOT significant)

Question #	**1.11**
Question	I have a scale here. More or less, in which scale is your salary (see scale)?
Papiamentu	*Mi tin un skal aki. Mas of menos den ki skal Señora su salario ta kai (pa luna/pa kinsena)?* *1) menos ku 500 fl pa luna* *8) 2700-3000 fl pa luna* *2) 500-800 fl pa luna* *9) 3000-3300 fl pa luna* *3) 800-1100 fl pa luna* *10) 3300-3700 fl pa luna* *4) 1100-1400 fl pa luna* *11) 3700-4000 fl pa luna* *5) 1400-1700 fl pa luna* *12) mas ku 4000 fl pa luna* *6) 1700-2000 fl pa luna* *7) 2000-2400 fl pa luna*
Issues	I did not want to ask salaries directly. I felt that using a scale would be far less threatening to people. People easily responded to this question in this format.
Results	This question is of great interest, and was analyzed in several ways. 1) The most simple is to calculate an average wage. This was done using the midpoint of the salary ranges. Playa (10) = 1,790 fl per month (SD = 975) Rincon (16) = 1,756 fl per month (SD = 1,163) P = 0.469 (Difference NOT significant) This is approximately 21,300 fl per year. The Statistical Yearbook (CBS 1994c) says that the average wage on Bonaire is 18,100 fl per year. These two numbers are close. The Breadbasket survey says that the average expenses for a household is 31,644 fl per year. This appears at first to be a significant discrepancy, however when one considers that on

average there are 2-3 persons working per household (Question 9.6.2), this result may also be acceptable.

2) A systems principle is that hierarchies emerge when energies are available. Another version of this principle is Hollings' "lumpiness" in ecosystems. Common inferential statistics like "means" smooth out lumpiness. However, in this case I expect to find lumpiness. I expect that wages will distribute themselves unequally. In fact, the large standard deviations in the mean above suggest this. In order to get at this principle (very roughly) I have split the wages into two means. This is done by dividing the sample at the median value.
   Lower paid half
      Playa (5) = 1,020 fl per month
      Rincon (8) = 1,043 fl per month
      Approximately 12,300 fl per year
   Upper paid half
      Playa (5) = 2,560 fl per month
      Rincon (8) = 2,469 per month
      Approximately 30,000 fl per year

3) Using this principle of two means, one other measurement was attempted, total household income. This measurement was attempted by examining each household in the sample, counting the number of other adults working in the households, and estimating their incomes from their employment types. These numbers are very crude but they can be used as a starting point for doing systems analyses of households.
   Lower household half
      Playa (6) = 21,100 fl per year
      Rincon (9) = 19,187 fl per year
      Approximately 20,000 fl per year
   Upper household half
      Playa (6) = 50,700 fl per year
      Rincon (10) = 55,320 fl per year
      Approximately 53,000 fl per year

Past Employment

Question #	**2**
Question	I would like to continue by talking about work that you did in the past. Can you tell me about the work you did in the past? What type of work did you do? And before that?
Papiamentu	*Mi ke sigui papia awor tokante trabounan ku señora a hasi den pasado. Señora por konta mi algu di Señora su trabou den pasado? Ki sorto di trabou Señora tabatin?* *Anto promé ku esei?*
Issues	Work history. In contrast to asking people for their life history, which is threatening and difficult for the researcher to justify, work histories yield very similar results and are far less threatening. People understand the desire for researchers to collect labor data and improve the labor market. It is far more difficult to explain the need to collect life histories,

	which seem to be very personal. Many people do not want to see themselves as living museums. But much of a person's life history is tied with their work history on Bonaire (and in other market economies). People were generally proud of how they have made a living.
Results	This question is again open-ended, and it often resulted in long and complex recounting of life/work histories. Spouses were sometimes asked to verify dates or events. The responses were fascinating, and often matched perfectly the development histories of the Leeward Islands. Specifically, a number of respondent's parents had moved to Aruba or Curacao when the refineries were booming in the 1930-50s. They and/or their children had now moved back to Bonaire. In other cases, some had spent more recent years in Holland looking for work or attending school. Others had spent those years shuffling back and forth between Bonaire, Aruba, and Curacao looking for work. Now residents of Bonaire, the respondents have apparently all chosen Bonaire over Holland, Aruba, and Curacao. Details of the responses will not be published. Obviously on an island as small as Bonaire, persons might be identifiable by their work histories.

Question #	**2.1**
Question	What year did you start working?
Papiamentu	*Ki aña Señora a kominsá traha?*
Issues	I wished to get a work history, including start and stop dates. This question was asked for each different work experience. Rather than ask people how long they work somewhere, asking for dates is often easier because people relate them with other dates in their lives (birth of a child, etc.). The researcher can do the math.
Results	

Question #	**2.2**
Question	What year did you stop working?
Papiamentu	*Te ki aña Señora a traha?*
Issues	See Question 2.1

Question #	**2.3**
Question	Where did you work?
Papiamentu	*Na kua lugar (na unda) Señora ta (tabata) traha?*
Issues	See Question 1

Question #	**2.4**
Question	How did you get to work? Owned a car?
Papiamentu	*Kon Señora tabata bai trabou? Señora tabatin outo?*
Issues	See Question 1

Question #	**2.5**
Question	How many days in the week did you work? All day?
Papiamentu	*Kuantu dia den siman Señora tabata traha? (Henter dia?)*
Issues	See Question 1

Question #	**2.6**

Question	Did you work on contract? Steady job?
Papiamentu	*Señora tabata traha riba kontrakt? E tabata un trabou fast?*
Issues	See Question 1

Question #	**2.7**
Question	How did you get that work?
Papiamentu	*Kon Señora a yega na e trabou aki?*
Issues	See Question 1

Question #	**2.8**
Question	Did you work with people in your family?
Papiamentu	*Señora tabata traha ku hende di su famia? Ken?*
Issues	See Question 1

Question #	**2.9**
Question	More or less, in which scale did your salary fall?
Papiamentu	*Mas of menos den ki skal Señora su salario ta kai (pa luna/pa kinsena)?*
Issues	See Question 1. This question was seldom asked. With sometimes numerous past employments, I deemed that this data would be very unreliable. Furthermore, I did not wish to emphasize this sometimes-delicate topic, which is important, but which is just one piece of the complex patchwork of formal, informal, farming, foraging, and fishing activities.

Question #	**2.10**
Question	Why did you quit that work?
Papiamentu	*Dikon señora a kita for di trabou?*
Issues	Reasons for ending an employment were interesting, if not generally surprising. The reasons offered are grouped into categories below. The fifth category below is an indication of Bonaire's relative attractiveness in recent years. The number of responses is high because some respondents had several occupations in the past.

Results

Playa	Rincon	
2	4	Better job - more satisfaction
4	7	Better job - more money, security, etc.
2		Stay home with the kids
1	3	Laid off / Work ended (contracts, etc.)
2	3	Curacao, Aruba, etc. was bad (Bonaire good)
1	1	Health reasons

Working "Jobs", Being a Housewife

Question #	**3**
Question	[Respondents who only work "jobs" come here directly from Question 1.] Next to the work that you do now, do you do other work? Do you work "jobs"? Housewife: Next to being a housewife, do you do other work? Do you do something to keep yourself busy?
Papiamentu	*Banda di e trabou ku señora ta hasi awor aki, señora tin mas of otro trabou ta hasi? Señora ta kue djop?*

Housewife. *Aparti di ta ama di kas, señora tin mas of otro trabou ta hasi?*
Señora ta hasi algu pa tene man?
Señora ta hasi kos pa lora man?
Examples:

Masonry, tiling, plumbing, painting, clean yard (men)
mesla, pega mosaiku abou i na muraya, drecha pipa, ferf, limpia kura
Baking cakes, sewing clothes, housework, work in a snack, sell lotto, sales, cut hair (woman more commonly)
traha bolo/pastechi, kosé paña/kortina, hasi trabou di kas, traha den snak, bende briechi, korta kabei

Probes for others:

Work for people when sick?
Señora sa haña trabou pa motibu ku hende ta malu (traha stanbai)?
Do you work all year, or special times?
Señora ta kue un djop henter aña of sierto temporada so? (pa Karnaval? pa Regatta? pa Aña Nobo? pa Dia di Rincon?, pa otro?)

Issues

People that work "jobs" are hired for a particular work task, and are paid for the task when completed, irrespective of the time it took to complete the task. Jobs are sometimes worked black or informal, meaning that income is not reported and taxes are not taken. Bonairians who work contract work or "job" work have a "workbook" within which their employers are expected to record any salaries paid. Employers are supposed to hold back taxes from wages paid, and pay those taxes to the government.

While I personally know some women whose only cash income came from working jobs (housewives who bake cakes on request, etc.), no women in this category showed up on my sample (perhaps because this group is small). On the other hand, a well-recognized economic strategy for men is to work construction/painting/masonry/carpentry "jobs" as their only form of cash income.

Results

There are men in both Playa and Rincon who work construction/painting/masonry/carpentry "jobs" as their form of employment. The interviews said that this number is about 10%.

Playa (13) = 8%
Rincon (18) = 11%
P = 0.38 (Difference NOT significant)

There is a significant difference between Playa and Rincon in persons who have ever worked "jobs." Several Rincon men stated that they had worked occasional construction "jobs" in the past. In Rincon there were women in the sample who worked occasional extra "jobs" as substitutes, housekeeping, and teaching. The Playa sample did not show any women working jobs, however, it is well known that some women from Playa do indeed work jobs. Another interesting form of "job" work is as occasional paid musicians (men).

Playa (13) = 15%
Rincon (18) = 61%
P = 0.004 (Difference IS significant)

Question #	**3.1**
Question	Where do you work these jobs?
Papiamentu	*Señora ta hasi e trabou aki den Rincon of na unda?*
Issues	I thought I might discover a trend in location. However, this question was not well received, and the common response was "wherever" the jobs are. In fact, few of the "jobs" follow-up questions were well received. The results are mostly uninteresting.
Results	"Wherever the jobs are"

Question #	**3.2**
Question	How many days per week?
Papiamentu	*Kuantu dia den siman Señora ta traha? (Henter dia?)*
Issues	Again this question was not well received. The common answer was "now and then", or "whenever there is work."
Results	"Now and then", "Whenever there is work."

Question #	**3.3**
Question	How many hours a week?
Papiamentu	*Kuantu ora pa siman?*
Issues	Poor response.
Results	Thrown out.

Question #	**3.4**
Question	At what time?
Papiamentu	*Ki ora señora ta hasi e trabou aki?*
Issues	Poor response.
Results	Thrown out.

Question #	**3.5**
Question	How long does a job last (in general)?
Papiamentu	*Kuantu tempu e lo dura (generalmente)?*
Issues	This question is important for the persons who work construction "jobs" as their main form of cash income.
Results	Responses ranged from 1 day-several days for one respondent, to 1-2 months for two others.

Question #	**3.6**
Question	How long have you done this type of work?
Papiamentu	*Pa kuantu tempu Señora tin ta hasi e trabou aki kaba?*
Issues	This issue is also important for the professional "jobs" workers. It suggests the durability of this economic strategy.
Results	Two respondents have been working this way for over 10 years. The other respondent has been working construction "jobs" for the past 2 years.

Question #	**3.7**
Question	Why do you do this work?
Papiamentu	*Dikon Señora ta hasi e trabou aki?*
Issues	This question was particularly interesting for the part-time or occasional "jobs" workers.

Results	Several said that they were "asked" to work, either to fill-in for someone else, or to help complete some construction project that needed their expertise (i.e., electrical or metal-working). One respondent said he did it to work with his son and give him some experience in construction.

Question #	**3.8**
Question	Do you do this work for the same people generally?
Papiamentu	*Señora ta hasi e trabou aki pa e mesun hendenan generalmente?*
Issues	Response poor.
Results	Thrown out.

Question #	**3.9**
Question	How do you get these jobs?
Papiamentu	*Kon Señora a yega na e trabou aki?*
Issues	With Question 3.7, this question asks how a person gets a "job."
Results	Again for the occasional "job" workers, the overwhelming response was that they were "asked" to work. For the professional "job" workers, one respondent explained that he was constantly looking and listening for new "jobs" at the same time that he was working another "job." That respondent explained that he aimed to keep working constantly, sometimes seven days a week.

Working "Jobs" (Man, 33 yrs old)

[What kind of work do you do?] Ok, actually I'm a worker in all kinds of work… in construction. I work as a bricklayer, I work as a peon (gofer, day-laborer), as a carpenter, in everything. And I'm not a worker for any company, any person. I mean, I work for myself. Which means, if people need work done, they come to me, ask me, yea, this or that thing, and then I go, I go do the work. [You work for a small company?] No, myself only. [So how do you get the work? People come…] Yea, yea. People come and ask me to do such things. … [And do you ever build the whole house?] No. Completely? No. Till now no. Till now I've never built a whole house by myself. But…let's say, small things. I mean like painting, or making a little balcony, or something for style. You know, things…but completing a house from the bottom up, no. [So, people say you work a "job"…?] Yes, work jobs, yes. [Do you work every week? Or when you can?] Let's say, if you have something to do. Now, that work is hard…in one month, two months, those two months I build it. But when I'm done with it, I have to wait for someone else to come and ask me again to do it. [Is it easy or hard to get jobs?] On the one hand it's easy, you know, in one way it's easy, because… you need to watch how it goes, let's say, pick out jobs, you know. Let's say, for example, I'm a worker for you now, but it's not that I'm not watching, looking for who might have another. So, when I finish yours, I can go to another. I don't stay long with nothing.

[Ki sorto di trabou señor tin?] Bon, aktualmente mi ta trahando tur, kemen, tur sort'i trabou. Pero no .... Den 'bouw'. Di 'bouw', no? Kemen di .... [Trah' kas.] Si. I, mi mes ta trah' komo mètsla, mi mes ta traha komo .... pión, komo karpinté, komo tur kos. Anto, no ku mi ta trahando

tampoko pa ningún .... kompania, ni nada. Kemen, mi ta trahando riba mi mes. Kemen di, si un hende mesté un trabou pa hasi, e ta bin seka mi, e ta puntrámi, ya, tal I tal kos, anto e or'ei mi ta bai, mi ta bai traha e kos ????? … [Aha. I tin biaha e señor ta traha un kas tur, ah ....?] Nò. Kompleto? Nò. Te ainda nò. Te ainda mi no a trah' un kas kompleto mi so. Pero .... laga bisa, kosnan chikitu, no. Kemen di, mané fèrfmentu, òf traha un pida balkon, òf algu por estilo. Kemen di, kosnan .... pero kompletamente un kas fo'i otro. [Anto, señor ta .... hende ta bisa señor, ta kue un djòp, òf ....?] Si. Kue un djòp. Si. [Kue un djòp. Ahn, si. Anto señor no ta trah' tur siman? Señor ta trah' ora señor por.] Nò. Ami, mayoria bes, laga bisa ku mi tin ?????? Laga bisa, mi bo tin un, ah ... un trabou pa hasi. Awó k'e trabou ei ta dura .... un luna, òf dos luna mes, e dos lunanan ei mi ta trah'é. Anto ora mi kaba k'esei, mi meste warda un otro un bin, pa mi bolbe bai hasi'é. [Ah, si. E ta fasil, o no ta fasil pa señor ta haña e trabou?] Bonnnn ..... Un banda e ta fasil si, pasó un band'e ta fasil, bo sa ..... bo meste wak kon, kon bo ta, laga bisa, hinka e trabounan den otro, no. 'Es decir' (same as: kemen) laga bisa por ehèmpel, mi ta trahando pa bo awor aki, pero nó, ku mi no ta mirando, buskando, òf wak ken no por tin otro. Kemen, pa ora mi kaba seka bo, mi por bolbe bai ayanan. Kemen, pa mi no keda hopi por nada.

Exchanging Labor

Question #	**4**
Question	Do you "help" other people with work, on weekends, or in the evenings?
Papiamentu	*Señora ta yuda otro hende ku trabou (algu di hasi), durante weekend, of anochi?*
Issues	This question was unevenly understood. Some people responded immediately, with answers like "Of course, I swap work with friends all the time." Others clearly did not follow the idea. Others still understood, but pointed out that any help they offered acquaintances was paid for.
Results	Thrown out, question not always understood.

Question #	**4.1**
Question	When do you help them?
Papiamentu	*Ki ora señora ta yuda nan?*
Issues	Not always understood.
Results	Thrown out.

Question #	**4.2**
Question	What kind of help?
Papiamentu	*Ki sorta di yudansa?*
Issues	Not always understood.
Results	Thrown out.

Question #	**4.3**
Question	How many hours a week?
Papiamentu	*Kuantu ora pa siman?*
Issues	Not always understood.
Results	Thrown out.

Question #	**4.4**
Question	Who do you help?
Papiamentu	*Ken señora ta yuda?*
Issues	Not always understood.
Results	Thrown out.

Question #	**4.5**
Question	Why do you help them?
Papiamentu	*Dikon señora ta yuda nan?*
Issues	Not always understood.
Results	Thrown out.

Question #	**5**
Question	Five years ago, did you get jobs also?
Papiamentu	*Sinku aña pasá señora tabata kue djop tambe?*
Issues	This question was usually asked with Question 3, and the results are presented there
Results	See Question 3.

Getting Food - Farming, Fishing and Foraging

Question #	**6**
Question	Now I want to ask about food.
Papiamentu	*Awor lo mi ke papia tokante kuminda*
Issues	At this point the interview shifts rather dramatically to its second focus, household resource flows. I ask about food, utilities, fishing, foraging, and *kunuku*s. These are means that I knew were used by some households to supplement wage income within complex economic strategies.

Question #	**6.1**
Question	Do you go fishing on the rocks or by boat? (Does your husband?) Do you buy fish?
Papiamentu	*Señor ta bai piska na baranka of ku boto? (Señora su kasá?) Señora ta kumpra piská?*
Issues	Many people fish from the coast (from the rocks) on Bonaire. It is a cheap and easy way to get food. This became a complex question with several parts that could have been split up. If they do not fish, I still wanted to know if they ate fresh fish and where they bought it.
Results	Do you or does your spouse go fishing? Many people fish some on Bonaire. For some Bonairians it is a regular part of their economic strategy, fishing every week. For others it is less common, "now and then." It appears that significantly more people from Rincon fish than do people from Playa. This is a reasonable result, since Rincon is generally considered to be more "rural." Playa (12) = 33% go fishing Rincon (19) = 68% go fishing P = 0.02 (Difference IS significant) Do you fish by boat? A boat is an important asset for a household

economic strategy. For those that responded that they fish by boat, I did not unfortunately always ask who owned the boat. Of those who provided this information, one owned the boat and another's brother owned the boat. The most that can be said is that about 15% fish by boat, and less than that number own boats themselves.

Playa (13) = 15%
Rincon (19) = 15%
P = 0.488 (Difference NOT significant)

There were no full-time fishers in the sample. Yet, not one person in the interviews said that they do not eat fish, either buying it or catching it themselves.

Question #	**6.1.1**
Question	How often in a month do you eat fish?
Papiamentu	*Kuantu biaha pa luna Señor ta kome piská?*
Issues	Bonairians eat a lot of fish. Some persons said that they will eat it every day if there is fish. I scored these people as 15 days a month. Other persons gave me numbers like twice a week, which I converted to 8 days a month. Several persons responded with "It depends, when there is fish." Those persons I treated as "no response."
Results	Days that fish are eaten per month: Playa (10) = 8.3 times a month Rincon (12) = 9.6 times a month P = 0.319 (Difference NOT significant) This suggests that Bonairians eat fish about every 3rd day, on average. This is a big part of the average diet. The Breadbasket survey says that Bonaire households spend 175 fl per year on fish. This number is low if all fish is purchased. However, if much of the fish is caught by households themselves, then the results may not disagree.

Question #	**6.1.2**
Question	How many fish do you catch?
Papiamentu	*Kuantu piská Señor ta kue?*
Issues	This question was often answered with "it depends."
Results	Thrown out.

Question #	**6.1.3**
Question	Do you sell the fish?
Papiamentu	*Señor ta bende piská?*
Issues	Of the people who fish, I wanted to know if they also sell their fish. This is a source of informal income to a household. Recall that none of the respondents were professional fishers. The response rate to this question was unfortunately very low (forgot or skipped it).
Results	Playa (5) = 20% sell fish sometimes Rincon (5) = 40% sell fish sometimes P = 0.272 (Difference NOT significant) This result does not seem unreasonable. It was said that if you fish a lot, or catch a lot of fish, then of course you would sell some. This would probably not be a regular source of income (although one Rincon fisher said he sells fish to buy other food).

Question # **6.2**
Question Do you hunt iguana? Eat iguana?
Papiamentu *Señor ta bai kue yuana? Kome yuana?*
Issues I also asked if someone in their family hunts iguana. This question yielded several results.
Results Is there a hunter in the household?

Playa (13) = 15% of households
Rincon (19) = 26% of households
P = 0.239 (Difference NOT significant)

This suggests that perhaps 20% of households have someone who occasionally hunts iguana--a husband, father, or son.

Is there a hunter in the larger family? This included someone the person could name as kin who hunts iguana on occasion.

Playa (13) = 30% of larger families
Rincon (19) = 26% of larger families
P = 0.267 (Difference NOT significant)

Do you eat iguana on occasion?

Playa (13) = 54% eat iguana on occasion
Rincon (19) = 58% eat iguana on occasion
P = 0.41 (Difference NOT significant)

This result actually surprised me. This indicates that a significant percentage of the population does not eat iguana. I assumed that most Bonairians would sometimes eat this food that has long been a part of the Bonaire diet.

Question # **6.2.1**
Question How often in a month do you eat iguana?
Papiamentu *Kuantu biaha pa luna Señor ta kome yuana?*
Issues I guessed that iguana might be an important part of the Bonaire diet. If the respondent answered "once in a while" (*di bes en kuando*), a common response for Bonairians to many questions, I scored the response as once every 3 months.
Results

Playa (11) = 0.6 times per month
Rincon (12) = 0.9 times per month
P = 0.207 (Difference NOT significant)

These low numbers surprised me. It appears that iguana are only eaten very rarely. Perhaps they serve as a "famine food", eaten when nothing else is available. They are also a "festival food", eaten on occasions of "country cooking" (*kuminda krioyo*).

Question # **6.2.2**
Question How many do you catch?
Papiamentu *Kuantu yuwana Señor ta kue?*
Issues Response poor.
Results Thrown out.

Question # **6.2.3**
Question Do you sell them?
Papiamentu *Señora ta bende yuana?*
Issues Response poor.
Results Thrown out.

Question #	**6.3**
Question	Do you have a *kunuku*?
Papiamentu	*Señora tin kunuku?*
Issues	In the past, Bonairians lived in their *kunuku*s, raising goats, sheep, chickens, donkeys, sometimes pigs or cows, foraging iguanas, and growing sorghum, vegetables and fruit. Today a subset of this farming system is used by some Bonairians, usually in combination with wage labor.
Results	I split this into two measures, ownership by household and ownership by the broader family (as recognized by Bonairians). I wished to discover not only if persons owned a *kunuku*, but also if they had access to the products of a *kunuku* from within their larger family. Own a *kunuku* by a household: Playa (13) = 8% Rincon (19) = 47% P = 0.008 (Difference IS significant) It appears that less that half the households of Bonaire still own *kunuku*s, and that percentage is significantly less for persons from Playa. Access to a *kunuku* from within the larger household: Playa (13) = 62% Rincon (19) = 84% P = 0.07 (Difference NOT significant, but close) While Playa households own less *kunuku*s, it appears that a majority of households still have access to *kunuku*s through kin. Rincon residents may have greater access through kin.

Question #	**6.3.1**
Question	How long have you had a *kunuku*?
Papiamentu	*Kuantu tempu Señora tin e kunuku?*
Issues	I also split this into two measures. I want to know if the *kunuku*s are in the family or recently acquired. I also want to know if they had a *kunuku* but sold it, and when.
Results	If have (access to) a *kunuku*, is it a long-time family *kunuku*, or newly acquired? Playa (7) = 86% long-time family *kunuku* Rincon (13) = 92% long-time family *kunuku* P = 0.33 (Difference NOT significant) Most *kunuku*s that are owned are long-time family *kunuku*s. Was there a *kunuku* that is now sold by parents? Playa (9) = 22% had *kunuku*s now sold Rincon (15) = 13% had *kunuku*s now sold P = 0.295 (Difference NOT significant) A number of persons have recently sold family *kunuku*s.

Question #	**6.3.2**
Question	Who's *kunuku* was it in the past? (parents?, brother/sisters?)
Papiamentu	*Di ken e kunuku aki tabata? (mayornan?, ruman?)*
Issues	This answer is combined with the previous question
Results	See Question 6.3.1

Question #	**6.3.3**
Question	How big is the *kunuku*?
Papiamentu	*Kon grandi e kunuku ta?*
Issues	This question was very poorly responded to. Many of the *kunuku*s were in the larger family, and the respondents did not have this information.
Results	Thrown out.

Question #	**6.3.4**
Question	Does the *kunuku* have goats? (sheep?, pigs?) Do you eat goat?
Papiamentu	*Señora tin kabritu, karne, porko? Kome kabritu?*
Issues	This response has two parts. I asked if the *kunuku* had goats. This question was sometimes answered that the *kunuku* is open (*habri*), meaning that there is no fence and goats can therefore not be kept. In the second part I asked if the respondent eats goat? I was particularly interested in goat, more than sheep or pig, because of goat's greater contribution to the diet. Sheep/goat questions were inconsistently asked and responded to.
Results	For those households with access to *kunuku*s, do the *kunuku*s have goats (and a fence)? Playa (9) = 67% have access to goats Rincon (16) = 56% have access to goats P = 0.313 (Difference NOT significant) Probably just more than half the *kunuku*s have goats. There is no significant difference between Playa and Rincon. This means conversely that just less than half the *kunuku*s do not have goats. This indicates that many of the *kunuku*s on Bonaire are not being used *as they were in the past* to raise goats. This would not surprise most Bonairians, who know that many of their family *kunuku*s are now open. This also accords with my observations of the *kunuku*s. However, it does not mean that less goats are being raised on Bonaire than were in the past. Open *kunuku*s mean more *mondi* for foraging goats. This point will be discussed further elsewhere. For the second part of this question, do you eat goat meat? Playa (11) = 82% Rincon (14) = 100% P = 0.05 (Difference IS significant) It can be said that most Bonairians eat goat meat at times, with perhaps a slightly larger percentage of people from Rincon eating goat meat. This is not at all surprising, considering how common goat stew (*kabritu stobá*) is at large family or public functions.

Question #	**6.3.4.1**
Question	How often in a month do you eat goats?
Papiamentu	*Kuantu biaha pa luna Señora ta kome kabritu?*
Issues	I wished to discover how much of the Bonaire diet is goat.
Results	Response was small and answers were often very vague. An effort was made to put numbers to general statements, in order to get an idea. These numbers are very rough. Some respondents said they do not cook it much at home. Others said it is eaten at special events. Playa (9) = 2.9 times per month

Rincon (8) = 3.6 times per month
P = 0.341 (Difference NOT significant)

These results suggest that Bonairians eat goat a little less than once a week. This is about 3 times less than fish reported in Question 6.1.1. The Breadbasket survey said that households spend 110 fl/yr on goat meat. This equates to about 10-20 kg/yr/household. This seems low, and suggests that goat is consumed outside of the cash economy, like fish.

Question # **6.4.3.2**
Question How many goats do you (or your family) have?
Papiamentu *Kuantu kabritu Señora tin?*
Issues This question was poorly collected.
Results Thrown out.

Question # **6.4.3.3**
Question Do you give the goats water?
Papiamentu *Señora ta duna nan awa?*
Issues This question was poorly collected.
Results Thrown out.

Question # **6.4.3.4**
Question Do you give them food?
Papiamentu *Señora ta duna nan kuminda?*
Issues This question was poorly collected.
Results Thrown out.

Question # **6.3.5**
Question Do you have other animals also? What types? Chicken?
Papiamentu *Señora tin otro bestia tambe? Ki sorto otro bestia mas Señora ta kria?*
Issues I focused on chickens, asking people directly if they raise chickens or if they have family access to domestic chickens (*galiña krioyo*). Chickens can also be raised without a *kunuku*, so these results are for all respondents, not just people with access to *kunuku*s.
Results The percentage for Rincon seems too large and may be do to the low response rate from the Rincon sample.

Playa (12) = 17%
Rincon (11) = 45%
P = 0.07 (Difference NOT significant, but close)

The results suggest that a relatively small percentage of households have access to domestic chickens.

Question # **6.3.5.1**
Question How often in a month do you eat chickens?
Papiamentu *Kuantu biaha pa luna Señora ta kome galiña?*
Issues Poor response.
Results Thrown out.

Question # **6.3.6**
Question Do you plant sorghum? What kinds of sorghum?
Papiamentu *Señora ta planta maishi tambe? Ki sorto maishi señora a planta, maishi*

chikitu?..

Issues Today sorghum is almost exclusively planted for fodder for goats or sheep. Therefore, these results reflect the percentage of goat/sheep farmers who plant sorghum. The response rate is low.

Results
Playa (4) = 75% plant sorghum
Rincon (7) = 71% plant sorghum
P = 0.455 (Difference NOT significant)

I expected this result to be 100%. The common approach to raising goats that I had observed in the *kunuku*s and in interviews with farmers is to feed the goats or sheep with sorghum in the dryer season after the harvest. This result suggests that some goat raising has extremely low inputs (water only, or perhaps some purchased sorghum or concentrate). The response rate is low, and perhaps the best that can be said is that NOT ALL goat/sheep farmers plant sorghum.

Question # **6.3.7**

Question Do you plant vegetables or fruit also? What kinds?

Papiamentu *Señora ta planta berdura i fruta tambe? Ki sorto?*

Issues Vegetables or fruit can be grown in *kunuku*s or at home. If they are grown at home they can be watered with WEB water, but at great expense. In the past vegetables were produced in great amounts from the *kunuku*s. Pumpkin, watermelon, cantaloupe, okra, beans, were routinely grown by families living in the *kunuku*s. Since people stopped living in the *kunuku*s, the occurrence of vegetable growing has dropped dramatically. People commonly complain that melons are stolen from the *kunuku*s if grown. Another reason not to grow them is that they require greater care in watering.

Results Vegetables planted?
Playa (13) = 8% plant vegetables
Rincon (15) = 7% plant vegetables
P = 0.460 (Difference NOT significant)

As expected, few people report growing vegetables today.

Fruit trees planted?
Playa (13) = 38% have fruit trees
Rincon (15) = 27% have fruit trees
P = 0.261 (Difference NOT significant)

This number is higher than vegetables, as could have been expected. Fruit trees are less vulnerable to theft and require less care.

Question # **6.4**

Question Do you sell your goats? (For how much?)

Papiamentu *Señora ta bende un kabritu? Kuantu Señora ta bende un kabritu, un yuana, berdura?*

Issues This question was poorly responded to.

Results There were some responses in the affirmative. The most that can be said is that some people sell their goats.

Question # **7**

Question In the past did you do these things? Fish? Get Iguanas? Raise goats?…

Papiamentu *Señor tabata bai piska ántes? kue yuana ántes?…*

Issues I asked specifically if their parents used *kunuku*s.
Results
Playa (12) = 67%
Rincon (12) = 83%
P = 0.184 (Difference NOT significant)

This result suggests that the majority of parents had *kunuku*s and used them (often living on them). These numbers are much higher than the number of households that have *kunuku*s today (Question 6.3).

Using *Kunuku*s Today (Woman, 40)

My family has a *kunuku*. [Siblings, or…?] My father has a *kunuku*. My mother-in-law also has a *kunuku*. [Do they plant now?] No. Nowadays they don't plant, because it doesn't rain. But in the times when it rains well, yeah they plant. [Do they have goats also?] Yea, they have goats also, yea. [And sheep?] Yeah sheep also. [Pigs?] No. [Chickens?] Chickens also [Do they sell the meat?] No, no. For they're private use. [And do they give you meat sometimes?] Yea. When they kill them they give me some. [Is it often?] No. It's not a lot of the time. Mostly at fiesta times only. I mean Easter…certain times only. Not all the time. There needs to be a special time to slaughter them. They don't slaughter goats in that way, it's crazy. [At the times you go to the *kunuku*, or they have fiestas everywhere, I mean, other places, or…?] No (lost her) [Or at home also?] No. At home at Easter…we eat together. The family gets together…at that time… not on account of the fiesta no(?). [So they don't have a lot of animals, a lot of goats?] They don't have a lot. All are gone. There's not a lot more. [So more or less…?] Dogs eat them. People also steal them. [Yea, that's a problem. A lot of people told me…] Dogs eat them. Yea. People break in (enter) and take them. [Yea, a lot of people told me there is a problem with dogs and with stealing.] Yeah [The *kunuku* is near Playa or…?] No. The *kunuku* is much further. … [Do they grow fruit or vegetables?] No, that they…my mother-in-law doesn't do. [Do you plant fruit or veggies?] No, me neither, that I don't do.

Mi famianan si tin kunuku. [Ruman òf ah ..?] Mi tata mes tin kunuku. Mi suegra tambe tin kunuku. [Aha. Nan ta planta awor aki?] Nò. E temporadanan aki si nan no a planta, pasó dor ku awa n' ta kai. Pero asina ku temporada di awa kai bon, si nan sa planta. [Si? I ah nan por ... nan tin kabritu tambe, òf ..?] Si. Nan tin kabritu tambe. Si. [I karné, òf kabritu so?] Karné tambe. Si. [Porko?] Porko si nò. [Ah galiña?] Galiña tambe. [Aha. I ah nan ta bende e karni, òf ..?] Nò, nò. Pa nan propio uso. [I nan ta duna e señora karni tin biaha?] Si. Ora ku nan mata nan dunámi. [Aha. E ta hopi ah .. hopi bia òf ..?] Nò. E n' ta hopi bia si. 'Vooral' ora 'i fiestanan ei so. Kemen Pasku ... Sierto temporada so. No ta tur ora. Meste tin un kos spesial pa nan mata. Nan n' ta mata kabritu asina, pa loko. [Aha. E tempu e señora ta bai kunuku, òf nan tin fiesta tur kaminda òf otro kaminda òf ..?] Nò. [Òf na kas tambe?] Nò. Na kas tin or'i Pasku .. nos ta kome huntu. Famia huntu ... E temporada ei bo ... No kuent'i fiesta si nò. [Anto nan no tin hopi ah bestia, hopi ah kabritu ..?] Nan n' tin hopi. Tur a kaba. N' tin hopi mas. [Aha. Anto mas o menos

?????] Kachó kome nan. Hende tambe hòrta nan. [Si. Ta problema. Tur hende .. tur kome.] Kachó ta kome. Si. Hende ta drenta kue nan. [Aha. Ahm .. Si, hopi hende a bisámi e ta .. e ta problema ku kachó, ku ah hòrta.] Si. Hòrtamentu. [E kunuku ta banda di Playa òf ...?] Nò. E kunuku ta masha leu mes. … [Ah. Aha. I ahm nan tin .. nan te krese bèrdura òf fruta?] Nò. Esei si nan .. mi suegra n' ta hasi. [Señora ta kria ... señora ta planta bèrdura òf fruta aki na kas?]   Nò, tampoko. Esei mi no ta hasi.

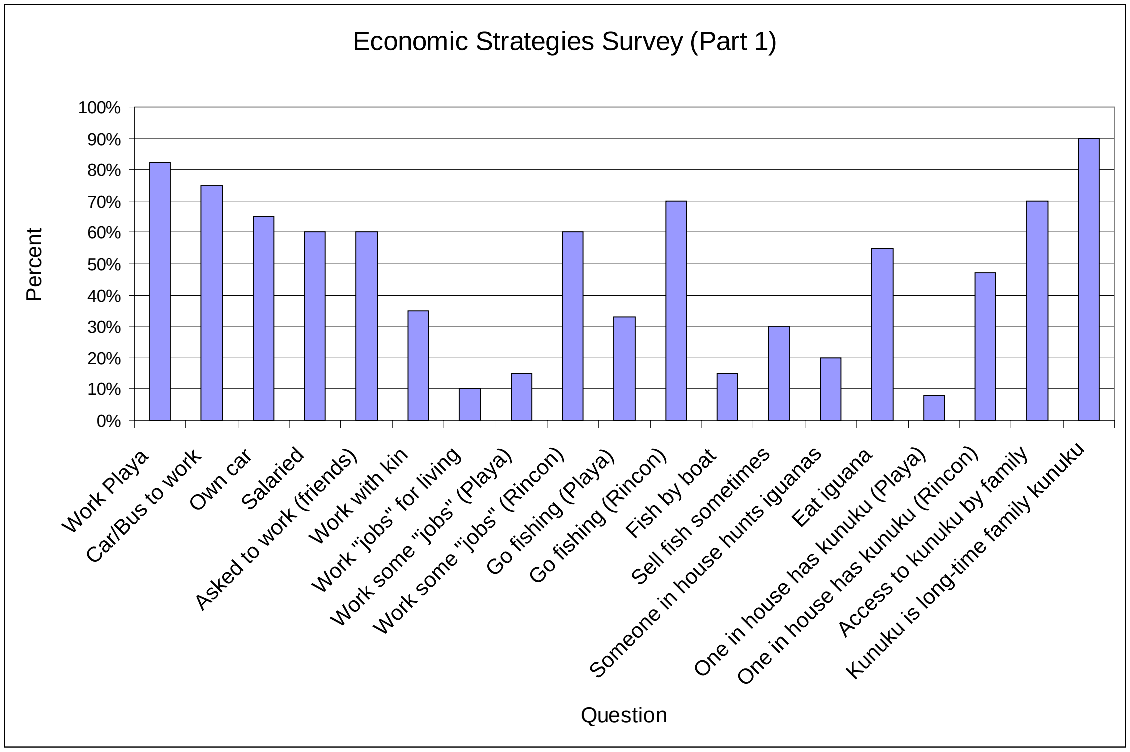

Figure 66: Selected Responses to First Half

Buying Food, Utilities

Question #	**8.1**
Question	About food that you have to buy, more or less how much do you spend on food per month?
Papiamentu	*Tokante kuminda Señora mestir kumpra, mas of menos kuantu sen Señora ta kompra na kuminda tur luna?*
Issues	These numbers are very rough, but people did not have too much trouble making an estimate of this number. Often men had to ask their wives. These amounts are for the household.
Results	Playa (11) = 402 fl per month (SD = 168) Rincon (13) = 447 fl per month (SD = 224) P = 0.294 (Difference NOT significant) This result suggests perhaps 425 fl/month, which equals 5100 fl/yr. The Breadbasket survey says 6510 fl/yr. These values are fairly close.

Question #	**8.2**
Question	More or less, how much do you spend on electric per month?
Papiamentu	*Mas of menos kuantu Señora ta paga koriente pa luna?*
Issues	Some people knew this amount separate from water. If they did not, I split the combined amount in half. Kilowatts of electricity were calculated from the costs, based on 2.7 kWh / florin.
Results	Playa (12) = 90 florin / month Rincon (19) = 94 florin / month P = 0.379 (Difference NOT significant) This result is about 1,080 fl/yr on average. The Breadbasket survey says about 1,354 fl/yr on electricity. These number are fairly close. 1,080 fl/y is about 3000 kWh/yr of electricity.

Question #	**8.3**
Question	How many months does a bottle of gas last? Big or little bottle?
Papiamentu	*Un bot'I gas ta bon pa kuantu luna? Bot'I grandi of chikitu? E ta dura kuantu luna mas o menos?*
Issues	This question was well understood in this form. People think in terms of bottles of gas, rather than a monthly cost, since they do not pay for it by the month usually. The big bottles are about 350 lbs of propane (or 1325 liters). The cost of a big bottle is 59 fl / bottle
Results	Playa (13) = 2.3 large bottles per year Rincon (19) = 4.3 large bottles per year P = 0.0000046 (Difference IS significant) For Playa this converts to about 3050 liters/yr and 135 fl/yr for gas. For Rincon the amount is about 5700 liters/yr or 250 fl/yr. The Breadbasket survey said about 60 fl/yr. This is a significant discrepancy that I cannot explain at this time. The evidence that Rincon uses more gas per household than Playa is interesting. As we will see in Question 9.6, the Rincon households are slightly, but significantly larger than Playa households. Another hypothesis might be that Playa residents eat outside of the house more.

Question #	**8.4**
Question	More or less, how much do you spend on water per month?
Papiamentu	*Mas of menos kuantu Señora ta paga awa pa luna?*
Issues	Water was sometimes included with electricity in responses. As stated in Question 8.2, this amount was split in half to produce separate values. Desalinated (WEB) water is expensive on Bonaire, and households conserve water, compared to US standards. Per the published water costs tables, 81 florin buys 13 cubic meters.
Results	Playa (11) = 75 fl/month Rincon (19) = 78 fl/month P = 0.418 (Difference NOT significant) These values suggest about 156 cubic meters per year or 972 fl/yr. The Breadbasket survey says 862 fl/yr. These values are close.

Houses - Building, Owning, Renting, Taxes

Question # **9**
Question Now I would like to talk about your house. Do you own your house?
Papiamentu *Awor lo mi ke papia tokante señora su kas. Señora ta doño di e kas aki? Señora ta hur?*
Issues Many people on Bonaire own their houses. There are many reasons for this, and these are discussed under Land and Taxes. Some houses have remained in families for generations. These are called "houses from the past" (*kas di ántes*).
Results
Playa (13) = 46%
Rincon (19) = 68%
P = 0.110 (Difference NOT significant)

This suggests that perhaps half or more of the households on Bonaire own their houses. The Statistical Yearbook (CBS 1993a:30) says that 60.7% of the houses are self-owned, which is very close. These numbers are high by US standards where new houses and mortgages, or renting are the rule. However, on Bonaire, this number has probably been dropping steadily in the last few decades as the island population is growing with both Antilleans and foreigners.

Question # **9.1**
Question Did you build it? When?
Papiamentu *Ta Señora nan mes a traha e kas aki? (Señora su famia of otro hende?) Ki aña?*
Issues This question was split into three measures. Many houses on Bonaire since the 1950s have been built with assistance of the now semi-state foundation called the FKB (*Fundashon Kas Boneiru*).
Results Did you build the house?
Playa (11) = 45%
Rincon (19) = 58%
P = 0.263 (Difference NOT significant)

This suggests that perhaps half of the households today built their houses (within about the last 30 years). This is a large number, and may be due to the growth of Bonaire, but also the movement of Bonairians off the *kunuku*s and into towns.

Is the house FKB?
Playa (13) = 31%
Rincon (19) = 32%
P = 0.481 (Difference NOT significant)

This suggests that about 30% of Bonairians own houses built by, or with the assistance of the FKB. This is also a large number, but it does coencide with the fact that the FKB built its 1000th house while I was on Bonaire.

What year did you build it?
Playa (5) = 8 years ago
Rincon (9) = 18 years ago
P = 0.036 (Difference IS significant)

The response to this question is low. The data suggests that Playa has more houses built in recent years, as might be expected since this is the region undergoing the greatest economic growth.

Question #	**9.1.1**
Question	Who helped? Your family?
Papiamentu	*Ken a yuda bo? Señora famia a yuda Señora?*
Issues	I wondered if many Bonairians built their own houses. A common response was that the owner worked on their house along with paid workers. The results are whether the construction was all paid, or whether the owner or owner's family worked significantly on the house.
Results	Playa (6) = 83% worked on building their house Rincon (8) = 63% worked on building their house P = 0.216 (Difference NOT significant) As I expected, of houses built by current owners in the sample, in a majority of cases the owners and family or friends worked on building their own houses. Only one owner said that he built his house by himself (taking 4 years). The rest said that they did pay some contractors, usually electricians or other specialists.

Question #	**9.1.2**
Question	How long did it take to build the house?
Papiamentu	*Kuantu tempu a dura pa traha e kas?*
Issues	This question was unevenly responded to. Some respondents said 30 years, or 50 years, or 18 years. They were obviously referring to the time it took to get the house in its current form. The response I was after was the time it took from beginning construction until moving in.
Results	There were a few good responses to this question that are meaningful. The shortest response was 9-10 months. Another was 2 years. There were 2 respondents who said it took 4 years, working after work or in spare time. These few results illustrate what I expected, that those who built their houses themselves usually took much longer compared to construction that is done entirely by hired builders.

Question #	**9.2**
Question	Is the land private property?
Papiamentu	*E tera aki ta propiedat?*
Issues	I wanted to know how many households are living on private property. The alternative is that a house may be built on long-lease land (*erfpacht*) (see **The State Equation, Land and Taxes**).
Results	Playa (12) = 17% Rincon (16) = 6% P = 0.198 (Difference NOT significant) This indicates that houses built on private land are a small percentage of household properties. The Statistical Yearbook ((CBS 1994c:30) says that 17.4% of self-owned houses are on private property. This is close.

Question #	**9.3**
Question	How much do you pay in rent?
Papiamentu	*Kuantu Señora ta paga hur?*
Issues	If a house is rented, then I asked for the monthly rent. If a house is owned and the land is *erfpacht*, then I asked for the yearly *erfpacht* amount (*erfpacht* owners also pay a yearly land tax (*grondbelasting*)). If the land was private, then I asked for the yearly land tax

(*grondbelasting*). This question is therefore divided into three parts.

Results Monthly rent for rented houses?

Playa (3) = 185 fl/month
Rincon (5) = 161 fl/month
P = 0.404 (Difference NOT significant)

This works out to about 2,100 fl/yr. The Breadbasket survey says 1,865 fl/yr, which is close. The Census (CBS 1993b:361) says that 32% of the population pays less than 149 fl/yr in rent, and 63.5% pays less than 299 fl/yr. These numbers are also close. The number of respondents here is very small.

Erfpacht per month?

Playa (2) = 194 fl/yr
Rincon (6) = 99 fl/yr
P = 0.05 (Difference IS significant)

The number of respondents is again very small. According to the Breadbasket survey, erfpacht is 38 fl/yr. These numbers are not very close. With the recent effort by the government to increase taxes by re-assessing properties, I would expect the erfpacht values to be high.

Yearly land tax for private property (*grondbelasting*)?

Playa (2) = 496 fl/yr
Rincon (3) = 162 fl/yr
P = 0.119 (Difference NOT significant)

Again the number of respondents is very small. With the property tax re-assessment, these values are expected to be much higher than they were in past years.

Question # **9.4**
Question Is this a good price?
Papiamentu *Señora ta haña e kas (tera) ta bal e hur?*
Issues This question was poorly administered.
Results Thrown out.

Question # **9.5**
Question How long have you lived in this house?
Papiamentu *Kuantu aña señora ta biba den e kas aki?*
Issues With the other housing measures, I wanted to know how often people moved, built new houses, rented new houses, etc.
Results

Playa (12) = 6 years
Rincon (14) = 21 years
P = 0.0002 (Difference IS significant)

It appears that Playa residents are significantly more likely have lived in the same house for long. This probably reflects the greater mobility of Playa residents and the population growth in that region of Bonaire.

Question # **9.6**
Question How many people in total live in the house?
Papiamentu *Kuantu hende na tur ta biba den e kas?*
Issues This number is important because it defines household size. It indicates the number of persons that are being produced by an average household economy.
Results

Playa (12) = 3.3 persons per household

Rincon (19) = 4.6 persons per household
P = 0.034 (Difference IS significant)

This result provides two average household sizes. It also indicates that more persons live in a Rincon household than in a Playa household on average. These numbers will be useful in the household systems analysis. The Census (CBS 1993b:19) says that the average household size for Bonaire in 1992 was 3.4 persons (there were 2,988 households on Bonaire in 1992). This is close, especially considering that the majority of Bonaire's population is in Playa.

Question # **9.6.1**

Question Who do you live with?

Papiamentu *(Kasá, Kompaña (Kompañero/a di bida), Yu, Ruman, Mayornan, Prima/Primo, Otro) Señora su mama, of Señora su tata, of Señora su ruman, of otro? Tur ta famia?*

Issues I wanted to get some demographics for the household. This question was divided into two measures.

Results Parents are in the household?

Playa (13) = 8% of households have parents
Rincon (19) = 26% of households have parents
P = 0.098 (Difference NOT significant)

A relatively small percentage of respondent's households do have parents in them. This indicates that some (but not many) households contain large extended families, which was reportedly a more common pattern in the past when extended families lived together in *kunuku*s.

Siblings are in the household?

Playa (13) = 8% of households have siblings
Rincon (9) = 16% of households have siglings
P = 0.256 (Difference NOT significant)

Again a relatively small percentage of respondent's households do have siblings (brothers or sisters). This pattern is another example of an extended family pattern, perhaps in decline.

Question # **9.6.2**

Question How many other people in the house work?

Papiamentu *Kuantu otro hende den e kas aki ta traha?*

Issues This is another important measure, which indicates the current amount of labor that is being produced by a household.

Results

Playa (12) = 1.7 working persons per household
Rincon (16) = 2.8 working persons per household
P = 0.020 (Difference IS significant)

This result suggests that all houses have more than one laborer, and that Rincon households have more than two, which is significantly larger than the Playa number. This agrees with the larger size of Rincon households. It also suggests that Bonaire household strategies use 2 or 3 wage laborers to maintain the household.

Question # **9.7**

Question Are you married? (includes common law marriage)

Papiamentu *Señora ta kasá?*

Issues I wanted to know how many of the workers were married. On Bonaire, the term *kasá* refers simultaneously to legal marriage and common law marriage.

Results

Playa (11) = 73% are married
Rincon (19) = 63% are married
P = 0.303 (Difference NOT significant)

This result indicates that a majority of work age persons are married. There is however a significant percentage of the working population that is not married.

Houses and *Kunuku*s - Living in *Kunuku*s in the Past (Woman, 40)

The house here is pretty old. It has a lot of years. It's not a house from nowadays. A house from the old days. The house here is a house of grandparents (ancestors). I mean grandmothers, grandmother's grandparents. I don't know. So they passed it on to my mother, because my mother is younger. Like that. [So maybe 50 years ago or…?] Pretty long time ago, because I don't know any of my grandmothers themselves that had it. More than 30 years ago. [In the past there weren't a lot of houses near here?] No, no. [When you were young, were there many houses here?] No. Because I wasn't raised here. I mean, I wasn't raised…we came here on weekends only…or on Easter or New Years, we spent Easter or New Years at home. But for the most part we stayed in the *kunuku*. [Oh, you lived in the *kunuku*?] Yea, all the time. [All weeks…all the time? So came to the house…] Yea, weekends only…In the past the way all people lived on Bonaire. The house was for times you go…like when you go down for the weekend, you go to the church on Sunday, so Sunday afternoon you went back up to the *kunuku*. You go to school ordinarily from the *kunuku* on foot, and then went back again. So on fiesta days you again went down to the house. Everybody lived like that on Bonaire. [And people could get everything to live from the *kunuku*? Food, water…?] Yea. Now they have water pipes from WEB, but in the past they didn't have it. In the past you had to go by the well. You need to go to the wells and fetch water. I myself lived like that. We had to go fetch water from the well and come back. For washing clothes, for cooking, for bathing. All these things were from the wells. [And in the past it was easy to live from the *kunuku*s, or wasn't easy…People could get everything for making a living…?] Yea, you lived. You lived good yea. [And come to Playa for…] Yea. When you need things, you went down to Playa to go buy your things, come back to the *kunuku*. [Ok…Do you know--this house--people built it a long time ago? Your family?] That I can't say, because I don't know. [Ok, and the *kunuku* house, your family build that house?] That one my uncles built it, because he…the wood he had. More wood than block.

E kas aki ta masha tempu. E tin hopi ahm aña. E kas n' ta djawoki di awor aki E kas uhm ... Temp'i antes. E kas aka 'a kas di grandinan. Kemen mi wela .. mi wela, wela grandinan. Mi n' konosé. Anto nan a pas'é pa mi mama, pasó mi mama ta' mas chiki. Asina. [Aha. Ah! Anto, kisas, sinkuenta aña pasá òf ah ...?] Basta tempu pasá, pasó mi n' konosé niun di mi welanan mes ku ta' tin e. Mas ku trinta añ' pasá.

[Antes no tin hopi kas aki banda?] Nò, nò. Hahan. [I e tempu señora ta' mas chikitu, mas .. ah .. tin hopi kas aki?] Nò. Pasó ami no a lanta 'kinan. Kemen, mi n' ta' lantá ... nos a bin 'kinan wikènt so ... òf temporand'i Pasku ku Aña Noba, nos ta bin pasa Pasku ku Aña Nobo na kas. Pero mayoría parti nos ta' pas'é na kunuku. [Ah! Señora a biba na kunuku?] Si. tur e tempu. [Tur siman .. tur tempu? Anto bin kas ah ..?] Si. Wikènt so, anto ku .... [Anto antes hende por biba ah ...?] Antes asina tur hende ta' biba riba Bonèiru. Antes tur hende ta' tin kunuku ku kas. Kas ta' pa ora bo bai .. mané ba baha wikènt, bo bai misa djadumingu, anto djadumingu atardi bo ta bole subi bèk bai kunuku. Bo ta bai skòl gewon via kunuku na pia, bole bin bèk. Anto dia 'i fiesta tambe bo ta bah' bin kas. Mané Pasku ku Aña Nobonan ei, bo ta baha bin kas bèk. Tur hende ta' biba asina na Bonèiru. [Aha. I hende por haña tur kos pa biba den kunuku? Kuminda, awa ah ..?] Si. Awor aki nan tin pip'i awa di WEB, pero antes sí no ta' tin e. Antes bo ta' tin ku bai pos. Bo tin ku bai pos bai kue awa. Mi mes ta' biba 'sina. Nos ta' bai kue awa na pos bin bèk. Pa laba paña, pa kushiná, pa baña. Tur eseinan via pos. [I taba' tin uhm ... fásil pa biba den kunuku òf no ta fásil, pero ah ... Hende por haña tur .. tur pa ah tene na bida. Ta ...?] Si, bo ta' biba. Bo ta biba bon si. [Uhun. I bin Playa pa ...] Si. Ora bo meste 'i kos, bo ta bah' bin Playa bin kumpra bo kosnan, bolbe bai kunuku. [Aha. O.K. Bon. Ahm ... I ah señora sa, e kas aki, hende a traha hopi aña pasá. Hende di famia ah .. nan a traha su mes?] Esei si mi n' por bisa, pasó mi no sa. [O.K. I e kas di kunuku, hende di famia a traha e kas ei?] Eseinan, mi tionan mes a trah'é, pasó e ta .. di palu e ta. Mas di palu k'e ta di blòki.

Cost of Living

Question #	**10**
Question	Do you believe that things are becoming expensive on Bonaire? What types of things?
Papiamentu	*Señora ta haña ku kosnan ta birando karu na Boneiru? Ki tipo di kosnan ta subi of baha?*
Issues	I wanted to know if people percieved rising prices on Bonaire. I hoped they would discuss the cost of living.
Results	100% of persons in both Playa and Rincon stated (usually emphatically) that prices are going up on Bonaire. This question was often met with laughter, followed by a list of items that were going up. Groceries, household goods, clothes were commonly mentioned. Taxes were another common category mentioned.

Question #	**10.1**
Question	Are salaries going up also?
Papiamentu	*I salario ta subi tambe?*
Issues	Do people percieve that salaries are keeping up with the cost of living? This also therefore provides one measure of whether people think that their standard of living is improving or becoming worse.
Results	Only one person in the interviews said that salaries were keeping up with inflation. Everyone else either said that they are going up (usually very slightly, not near the inflation rate), or they said that they are not

going up at all.

Playa (10) = 70% say salaries rising, but not keeping up with inflation

Rincon (10) = 50% say salaries rising, but not keeping up with inflation

P = 0.194 (Difference NOT significant)

These results show that similar numbers of people believe that salaries are rising slightly or not rising at all. In both cases, they are not felt to be keeping up with inflation. This would suggest that they are perceiving that their standard of living is declining, however this does not agree with responses collected from other questions, such as Questions 11, 12, and 13, which in general indicate an optimistic attitude toward the future.

Salaries Not Keeping Up (Woman, 35)

One thing I'd say, the wages are low here on Bonaire. They need to raise the pay a lot, because sometimes you work hard to earn a ridiculous amount. Because things are expensive now. That they need to fix. Yea, because they raised the price of things, but wages haven't gone high. Or when wages go up, the prices of things then go up much more. Well, that they have to fix here on Bonaire. Or, lower the price of things. Groceries, everything. Without that, some days there's no…you can't eat anything. You can't eat, you can't get dressed… Because now you need to pay for everything. The kids want to go to school, you have to pay, you have to buy uniforms. Everything you want to do…everything is money. And day by day things are becoming more expensive.

Un ko' mi tin 'i bisa, e salaris sí 'a poko na Boneiru aki. Nan meste subi e sèn mas tantu, pasó tin ora b'a traha duru pa gana ko'i kèns. Anto k'e ko karunan dj'awó'ki, esei nan meste drecha. Si, pasó nan 'a hisa prèis di ko anto salaris nan ei n' ta bai haltu. Òf ora salaris bai haltu mes, prèis di e kosnan 'a subi mas tantu e or'ei. Awèl, t'esei nan tin ku drecha na Boneiru 'ki. Òf, baha prèis di kosnan. Komestibel, ku tu ko (tur kos). Sino aki poko dia no tin .... bo n' po kome ma (bo n' por kome mas). Bo n' po kome, bo n' po bisti, ... Pasó awo'ki ta tu kos bo tin 'i paga. E yu tin 'i bai skol, bo tin 'i paga, bo tin ku kumpra ünifòrm. Tu ko bo tin ku hasi ..... tu ko ta sèn. Anto dia pa dia e konan 'a bira mas karu.

Changes in Your Life

Question #	**11**
Question	Do you feel that your life has changed compared to 10 years ago?
Papiamentu	*Señora ta haña ku Señora su bida kambia kompará ku dies aña pasá?*
Issues	This question was not that well understood. I was expecting that persons might have focused on the dramatic increase in tourism development in the last 10 years. Instead, for those who did respond, most focused on more personal life-stages, such as "went to work" or "got married."
Results	For those who did respond well, in general the only persons who said

their lives had not change much were the older respondents. This seems reasonable and might have been expected.

Question # **11.1**
Question In what way did it change?
Papiamentu *Den kua manera el a kambia?*
Issues Question unevenly understood.
Results Thrown out.

Question # **11.2**
Question Why did it change?
Papiamentu *Dikon el a kambia?*
Issues Again, question unevenly understood.
Results Thrown out.

Tourism Development

Question # **12**
Question Do you think that tourism development has affected your life?
Papiamentu *Señora ta haña ku e desaroyo turistiko ta afekta señora su bida?*
Issues This asks the question more directly. Similar to question 11, this asks people if tourism growth has affected them. Still, at times this question was not well understood. I believe now that this is because people see tourism development as gradual change (more hotels gradually going in, etc.), and perhaps do not see connections between that growth and their lives. Another problem is perhaps the wording of the question, some respondents answered as if the word "affected" (*afekta*) implies a negative connotation. This was not intentional in writing the question, and was not discovered in my pre-testing. Perhaps, similar to the word "affected" in English, some persons will hear that word as negative, and others will not.
Results This question was sometimes taken very directly, and responded to with answers like "I don't work with tourists." Others responded with longer comments about crime. Some repeated a common slogan on the island, "The more tourists the better" (*Mas turista, mas mihó*). Still others responded much more philosophically.

Development, Crime, and Foreigners (Man, 42)

> Ok. Affect your life directly. No. But…Bonaire is not staying the Bonaire of the past. The tranquility that you had in the past, you don't have any more. Many foreigners. The tranquility of the past--because there's a lot of things that are happening--in the past on Bonaire you didn't here those things. In the past you didn't--I'm one of those people--in the past when you went out of your house, you normally left your house wide open. Now here you can't do that any more. [Yea? Robbery, or…?] Oohh! Not yet, my house, so far it hasn't happened. But, yea, you can't take the risk. Because they are coming slowly. There will be a day when it comes to you also. Uhuh. [I'm also a foreigner. But I don't live here.] No, no.

That's different…we are talking about those that come to settle here. People who come to work, live here. […come to work…live. Their families come also.] While a lot of things don't happen because of foreigners, … the things started happening when they started coming a lot. Because Bonaire was a place the people knew each other. Everybody knew everybody else. But now, you see that there are a lot of strange faces, and you don't know who they are.

Bon. Afektá bo bida direktamente. Nò. Pero .. Bonèiru no ta keda e Bonèiru di antes. E trankilidat ku bo taba' tin antes, bo no tin e mas. Hope stranhero. E trankilidat di antes - pasó tin hopi kosnan ta pasando - antes riba Bonèiru bo n' ta' tende e kosnan ei. Antes bo tabata - ami mes t'un hende - antes bo tabata sali fo'i bo kas, bo ta' bai laga bo kas habrí gewon. Awor aki bo n' por hasi'é mas.[Uhun? Hòrtamentu i ...?] Oohh! Ounke ku ainda, akinan, te ainda no a pasa. Pero, ya, bo n' por tuma e risiko. Pasobra nan ta biniendo poko poko. Ta yeg'un dia ku nan ta yega kaminda ku bo ta tambe. Uhun. [Mi tambe ta un estrañero. Pero mi no ta biba 'ki.] Nò, nò. Esei ta otro ... esei, nos ta papiando ku nan a bin 'vestig' nan mes aki ribanan. Hendenan ku ta bin traha, biba aki riba. [.. bin traha ... biba. Nan famia ta bin tambe.] Ounke hopi biaha kosnan no ta pasa dor di e estranheronan, pero, ya ... e kosnan a kumisá pasa temporada ku nan a kumisá bini na hopi. Pasó Bonèiru tabata un lugá ku tur hende tabata konosé otro. Tur tur hende konosé otro. Pero awor aki bo ta hañábo ku hopi kara straño, ku bo no sa ta ken nan ta.

Work, in General

Question #	**13**
Question	Do you have any other comments about work in general?
Papiamentu	*Señora tin otro komentario of algu di agregá tokante trabou en general?*
Issues	I wanted people to have an opportunity to offer any comments about work on Bonaire. This question is asked in an open-ended fashion, and it elicited many long and interesting responses.
Results	Somewhat surprising to me, many persons took this opportunity to criticize other Bonairians who are complaining about work opportunities on Bonaire. Many said it is easy to get work on Bonaire if you really want it. Often they pointed out that foreigners would work certain jobs, so other Bonairians could too. On the other hand, many criticized the influx of foreigners who were said to be taking jobs from Bonairians and keep the wages low. Others still, commented that not enough Bonairians were getting the good jobs. They often blamed a different group of foreigners, especially the Dutch or Americans, who were getting many of the valuable management jobs. They criticized the government for not providing training for better jobs, and they criticized the companies for circumventing existing laws to hire foreign managers.

Bonairians Can Do Anything in Tourism (Woman, 42)

[Do you have any other comments about work in general?] I think if kids, when they finish, they need to look into how to get started in hotels…[The kids? For work?] Yea. Because there's hardly any Antillians in hotels. They look for all foreign people to bring to Bonaire. Bonaire itself has kids that can do it. [Yes.] They need to have the taste for it, you know, the "will"…so you can (??) this place, you know. Don't let people from outside come…We ourselves can do it. [Yea. There's a school here?] Yea. A 'hotelvakschool'(?) [It's the BGTC, or another, or…?] It is the 'scholengemeenschap'. At the SGB. But the kids don't need to learn papers. They need to go follow a 'stage' (work experience program, intern program). The internship is very important. One month in restaurants, one month in bars, one month in kitchens. That way is much easier, you know? Don't take a kid that comes to do the 'stage', take them and say, go clean the table, and the chair. Let them do it…(end of tape) [Yea. There's a 'stage' at school now for kids?] No. Not yet. Now we have 'stage' yea, but from Holland. They come to do internships from Holland here to Bonaire. [A lot of Dutch kids, they come to do internships with you at the hotel?] Yes. [And that's good, or you want more kids from Bonaire…?] Yeah more kids. School…more kids come, come to grow up…come to get ahead. Don't let only us come. Because we have a lot of kids that have the capacity for tourism. I know the fear they have to face the people, you know what I mean? Talking with people. They can do it. They can do it. It's really beautiful, a hotel job. Really beautiful work to attend to the tourists. You get your annoying people, people argue sometimes…there's happy people, there's people that don't like something… I explain to them, talk with them, don't treat them with an angry face. Sometimes there's people at work, they have problems, you know. At home. They come to work with the problem. So the tourists say, what? Problems need to stay at home, so work is calm. Although you don't want to laugh, but don't let the tourists see you with problems. That happens alot here (on Bonaire). Bonairians, alot. People go (to work) with problems from home, like arguing. Not good. [Leave it at home] Yes. Leave it at home. Come to the hotel in a good mood. (Someone comes to door) [So you told me that kids should go work in the hotels?] Yea. There's a lot of kids that can go work. [And you work with people from Venezuela, Santo Domingo, …] All. All. Everywhere. Venezuela, Columbia, Holland…everywhere. [Is it good, do you think it is good for foreigners to come work, or…?] No. I prefer the Bonairians (yu di tera). Because they need to do it. They can do it. Kids of this land can do it. But yea, if they don't want to! [Are there more kids now that work in hotels, compared to 10 years ago?] No. There's not a lot. There's not really a lot. [And in all the jobs…in the hotel, Bonairians, they work what types of jobs? All the…?] Yea, all. Ok, in the kitchen, bar…In the kitchen the majority of them are Venezuelan, or Colombian, or Santo Domingans. Yea. In the bar it is possible there's Bonairans. From Bonaire. In the rooms there's, the majority are Colombian or Santo Domingan. Yea. [And the onwers, or the bosses, are they Bonairians?] No, Dutch. There's Dutch bosses…there's…the majority there's Bonairian bosses, very few. [But the Bonairians, they can do it?] Yes, they can. They can do it. Yes. They can do it. [Yea] They need to do it yea.

[Uhun. Bon. Señora tin otro komentario òf algu di agregá tokante trabou en general na Bonèiru?] Mi ta kere sí ku, muchanan ku, ora kaba nan mester buska moda di drenta hotèlnan, òf buska ... [E mucha? Pa trabou. Pa traha.] Si. Pasó no tin kasi Antiyano pa den hotèlnan. Nan ta buska tur hende afó trese Bonèiru. Bonèiru mes tin mucha ku por hasi'é. [Si.] Nan mester tin e smak, no, e wil pa bo por ???????, no. No laga e hendenan bin djafó bin .... Nos mes por hasi'é. [Uhun. Tin un skol aki?] Si. Un 'hotelvakschool'. [E ta e BGTC, òf tin otro, òf ...?] E ta na 'scholengemeenschap'. [Ah, na skol.] Na SGB. [Ah, SGB. Hende ta ... mucha ta siña? Si.] Pero e muchanan no mester siña di papel. Nan mester bai kore 'stage'. I e 'stage' 'a mas importante. Un luna den restorant, un luna den bar, un luna den kushina. Asina mas fásil, no. No kue un mucha ku bin 'stage', kue bis'é, bai limpia e mesa k'e stul. Lag'e hasi p'e (END OF TAPE). [Si. Tin e 'stage' na skol awor aki pa mucha?] Nò. [Nò?] Ainda nò. Awor aki nos tin 'stage' si, pero di Hulanda. Nan ta bin 'stage' di Hulanda aki na Bonèiru. [Hopi mucha di Hulanda, nan ta bin ... ku 'stage' traha ku señora na hotèl?] Si. [I ah e ta bon òf señora ta ... señora ke mas hende di Bonèiru?] Si. Mas hende. Mas mucha. Skol ... mas mucha bin, bin pa bin krese ... bin pa bai dilanti. No laga nos so bini. Pasó, nos tin hopi mucha ku tin kapasidat pa huza ku turismo. Pero ???? Mi nos sa ta miedo nan tin di enfrentá e persona, bo sa kon? Papia k'e persona. Nan por hasi'é. Por hasi'é. Ta masha bunita un trabou di hotèl. Un hotèl bo ... Masha bunita trabou pa bo atendé ku turista. Bo ta hañábo ku hende 'vervelend', bo sa, hendenan rabiá tin ora ... tin hende kontentu, tin hende ku n' ta gusta esaki ... Mi ta splika nan .... papia ku nan ... no trata nan ku kara rabiá. Tin be tin hende di trabou, nan tin problema, no? Na kas. Na ta bin trabou k'e problema. Anto e turista 'a bisa ????? Problema mester keda kas, anto trabou bin kontentu. Ounke ku bo n' ke hari, pero no laga e turista mira ku bo tin problema. E kos ei 'a pasa hopi 'ki riba. Hend'i Bonèiru, hopi. [Si? Hopi 'ki riba?] Kemen, aki, no. Aki riba Bonèiru, no. Hende ta bai ku nan problemanan kas, mané rabiá. Nò. [Lag'é na kas.] Si. Lag'é na kas. Bin hotèl kontentu. (Someone knocks at the door and she attends). [Si. Señora a bisámi .... Señora ta kere e muchanan mester bai traha na hotèl?] Si. Tin hopi mucha ku por bai traha. [Uhun. I ah ... Si, señora ta traha ku e hende di Venezuela, di Santo Domingo, di ...?] Tur. Tur. [Tur kaminda?] Tur kaminda. Venezuela, Colombia, Hulanda .. tur kaminda. [I ah e ta bon, señora ta kere e ta bon pa e strañero ta bin traha, òf señora ...?] Nò. Mi ta preferá e yu di tera. [Si? Preferá yu ti tera.] Si. Pasó tin ku por hasi'é. Nan por hasi'é. Yu di tera mes por hasi'é. Pero ya, si nan n' ke! [Aha. Tin mas yu .. mas mucha awor .. na ta trah' den hotèl, kompará ku dies aña pasá? Antes?] Nò. No tin hopi. [Nò, no tin hopi.] No tin hopi hopi hopi. [I den tur e trabou ... Ah den hotèl, hende di Bonèiru, nan ta traha ki sorto di trabou? Tur e ...?] Si, tur. Bon, den kushina, bar ... Den kushina mayoria di nan ta di Venezuela, òf Colombia òf di Santo Domingo. Si. Den bar por ta tin Bonèriano mes. Di Bonèiru mes. Na kamber tin .. mayoria di nan ta Colombia ku Santo Domingo. Si. [Ah, si. I ah e doño, òf e hefe ... ta di Bonèiru?] Nò, makamba. Tin

makamba hefe ... tin ... mayoria tin Bonèiriano hefe. Masha poko. [Pero hende di Bonèiru, nan por?] Si, nan por. Por hasi'é. Si. Por hasi'é. [Uhun. Si, no?] Nan mester hasi'é si.

Wrap-Up

Question #	**14**
Question	Do you have questions or comments about this interview?
Papiamentu	*Señora tin pregunta of algu di agregá tokante e enkuesta aki?*
Issues	I wanted to give people a chance again (now that the interview was over) to ask any new questions about the interview. I did not want to leave a household with misunderstandings about my role or the fate of their responses. Also, I was seeking some general appraisals of the experience, similar to the quotation that began this chapter.
Results	Responses were most commonly a polite "no, nothing to add." I did get, however, a few requests that I return to Bonaire with my results, and that something would be written in Papiamentu. I assured them that this was always my intention.

Question #	**15**
Question	Assets:
Results	This is not a question. On leaving a household, I attempted a quick summary of visible assets, which would be used in the systems analysis of households. An example of such a list might be, "Medium house, no car, *kunuku*, boat."

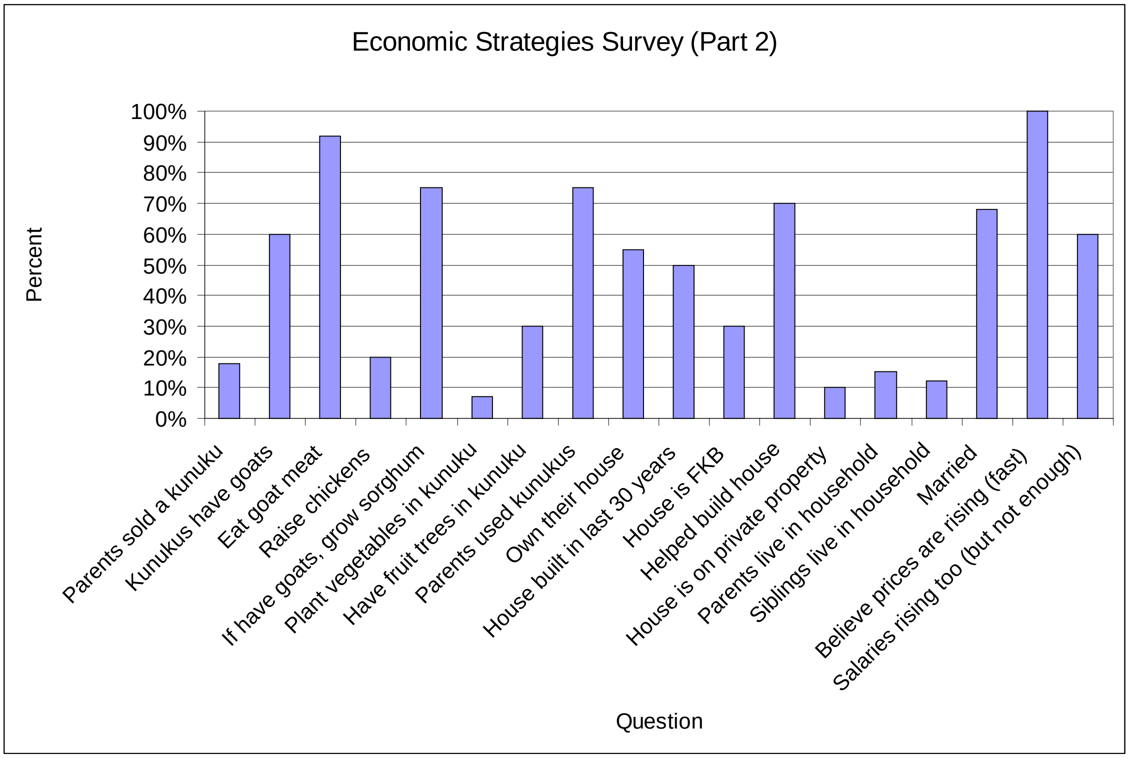

Figure 67: Selected Responses to Second Half

SECTION II: EMERGY ANALYSES

The next eight chapters are centered on emergy analyses of Bonaire. Emergy analysis is a form of ecological economics, or environmental accounting, that provides means to evaluate national economies and natural systems with quantitative measures. The first chapter will use information from the preceding chapters to conduct an emergy analysis of households on Bonaire. It will therefore conclude the descriptive account of households and labor within the Bonaire ecological-economy.

The next chapter jumps to the larger scaled context of Bonaire, the Netherlands Antilles and the Netherlands, to conduct "national emergy analyses." Systems research often begins at this scale, and indeed my fieldwork preparation began with a cursory national analysis of Bonaire. However, I felt it was important to present the preceding chapters first, in order to keep this research familiar to anthropologists, and to thoroughly introduce the fieldwork site, for which traditional ethnography is an outstanding tool.

From the island and global contexts of the next chapter will follow analyses of the web of production subsystems *within* the Bonaire economy. This middle scale will describe the emergent organization of social-economic production on Bonaire. The subsystem work will make use of the analysis of households from the Households chapter. Households are the source of labor for the island web of production subsystems.

CHAPTER 7
HOUSEHOLDS AS SYSTEMS

Households can be modeled as a production subsystem. Home, house, hearth is a nexus of kin on a site that offers support and security for the reproduction and nurturing of family. From a systems perspective, households produce people, which in a market economy is also wage labor. Labor is a *source* for the other human-economic subsystems, as will be discussed in subsequent chapters.

Figure 68: Typical House
This house in Rincon possesses some typical features of older house styles on Bonaire. It has a large cistern for rainwater catchment, and a fireplace for cooking. There is a fenced area behind the house that prevents browsing goats from getting at vegetables or other plants. The high roof alleviates heat buildup, and would have been made of tin in the past. Windows and doors are normally left wide open, allowing the house to make use of the ample and constant tradewinds. These houses are cool and comfortable.

A house is a critical asset in the formation of a household production subsystem. A contemporary house on Bonaire is a current version of ancient technologies for producing human shelter. A house is a technology for shelter, for family organization and cooperation, for child rearing, for protection, and for the storage of other vital personal assets (private property). Today households are locations for receiving electricity and water, and for waste removal. Furthermore, they are protected locations for the storage of useful personal assets, such as appliances, TVs, family deeds and titles, etc.

Figure 69: Other Typical Houses
High tin roofs and open windows provide cool living space. Few Bonaire houses have or need air conditioning because of this simple design. Crowded urban spaces on Curacao or Aruba, however, must have air conditioning. One often unforeseen cost of intensive development is that emergy from economies must be spent to supplement services that had been provided free from natural systems at earlier times and lower population densities. Another cost associated with development is an increase in crime, especially theft. Many Bonairians told me that in the past people left their houses wide open day and night. Notice that some of the houses above are shuttered closed while residents are presumably elsewhere.

An additional critical asset for households is food. Households are the sites for raising and nurturing young and old alike, and a house is a place to store preserved and fresh foods. Households are one of a few production subsystems on Bonaire that have an important natural/ecosystem source (see CHAPTER 5). Many households own *kunuku*s, which produce goats, iguanas, or vegetables for family members. Furthermore, many households use coastal ecosystems as a natural source of fresh fish. These assets are produced by nature, and are procured by a household at very low monetary expense relative to their contribution to the household.

Private housing reproduces the type of wage labor that is desirable for service workers. While private subsidized housing may be a symbol of economic independence for a young family, it is typically on a small, undesirable piece of land without access to a *kunuku* (Figure 119). Compared to past times when extended kin groups commonly had several houses with practically no tax or rent liability, subsidized housing comes with significant monthly payments. The result is an emerging wage labor workforce with few options other than market employment. Many family houses have been lost to foreigners, *pensionados*, and Antillean immigrants, and government housing can replace those houses when owners are willing to bear the cost (which judging by the demand for subsidized housing, many Bonairians are willing).

Household-Labor Production System

There are countless configurations for representing humans in systems diagrams (see discussion in CHAPTER 21). In some systems diagrams, people have been represented as top consumers, which highlights their role within food webs in ecosystems. In others, humans have been lumped into "Institutions", which has other theoretical underpinnings more closely linked to an equilibrium brand of sociological functionalism. Sometimes drawings show "economic sectors" with flows leading to a storage of "humans" or "culture." Every approach embodies a different understanding of people and culture, and different models for understanding their behavior.

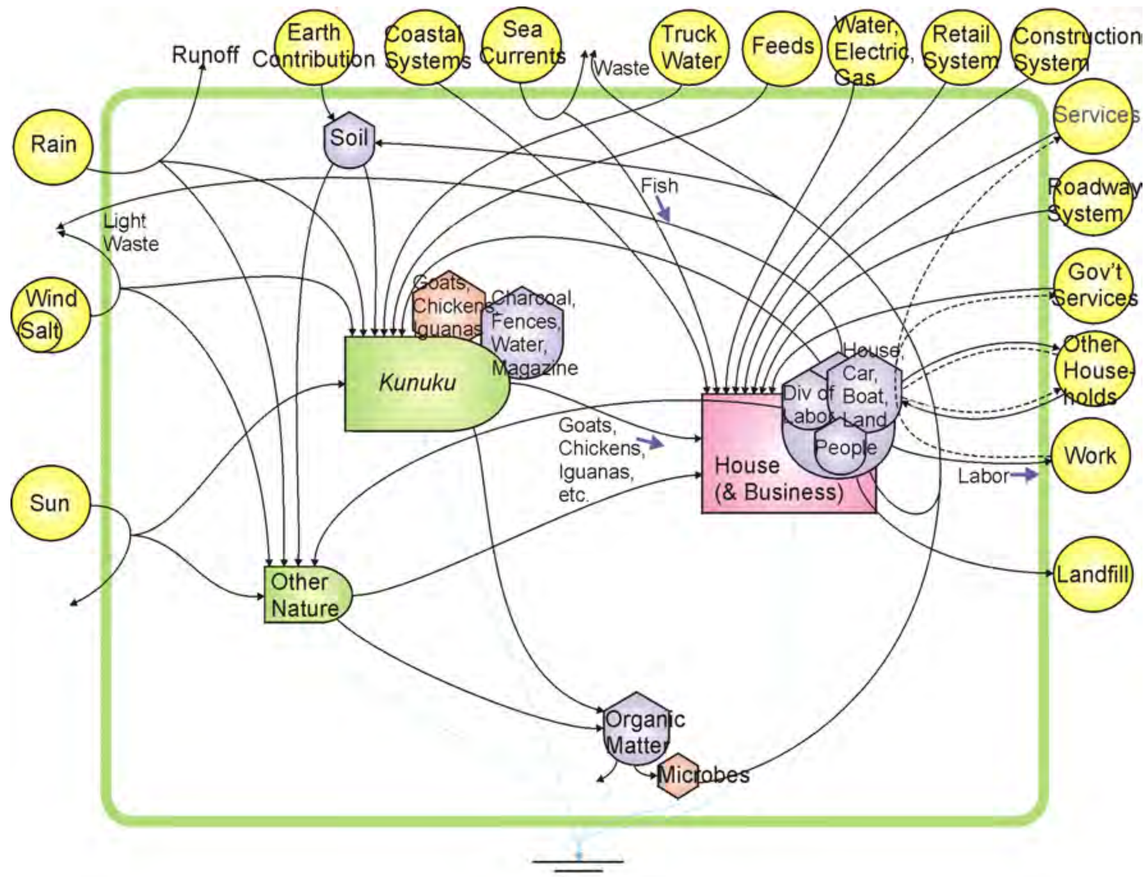

Figure 70: Household System
The green boundary defines the Household System, which can include *kunukus* or other natural production.

The modeler's choice of a design for systems diagrams with humans is not simple or trivial. The design chosen embodies the theoretical model that the system modeler has selected, consciously or not. The design in Figure 70 is for Wage Laborers within the context of a market economy within a State/World System (see discussion, CHAPTER 16). This design will be very distinct, for example, from a model of Family Groups within a Hunting/Gathering society (see Case Study: !Kung San Family Level

Foragers, CHAPTER 16), or from a Household within a Village within a Local Group within a Chiefdom (see Chiefdoms case, CHAPTER 16).

In State societies with economic markets the "ownership" of assets is a critical component of social structure. Ownership of land, stores of money, ownership of physical assets like buildings or automobiles, these are determinant components of a Wage Laborer's economic strategies, and their presence and role in that strategy should be explicit in the model.

For these reasons, the model structure chosen here for Bonaire (Figure 70) has several features:

1. Households, and not individuals, are chosen as the smallest unit of the wage-laborer production strategy. Humans modify their economic strategies through the use of technologies, and a western-style house found on Bonaire is a very important technology. For Bonairians, households are usually composed of family and kin, and the members commonly cooperate with one another in their production strategies and in the raising of children. On Bonaire, a house is a significant asset that is often owned (60% of houses owned, (CBS 1993b)), and was probably inherited from a family member. Houses are valuable for the obvious reasons of providing shelter and living/working space, providing storage for appliances for cooking and cleaning, and running water and electricity.
2. Another important component of some household production systems, as defined here, is *kunuku* farmland, which may or may not be adjacent to the house. A farm is a valuable asset for households, providing some meat in goats or chickens, and occasionally vegetables. According to the rough estimates from the Economic Strategies Survey in the previous chapter, 8% of Playa households and 47% of Rincon households have a family member who owns a *kunuku*. Households with near-kin *kunuku* owners are 62% (Playa) and 84% (Rincon). Of those *kunuku*s, 60% have goats and 25% have chickens. Therefore, the output from the *kunuku* symbol is another important input to many households on Bonaire.
3. In this diagram, the primary output of a Household is Wage Labor. In systems ecology terms, the storage of Wage Laborers flows out of the diagram and into the Corporate Production of an employer. In return for labor the Household receives money, which will be held in storage within the Household, and will travel out of the diagram for the purchase of goods and services from one of the three sources.
4. The three sources of goods and services for the Household are, first, the employer, as when an employee purchases the goods or services from the company that they work for. Second, and most commonly for Households on Bonaire, the Household may purchase goods or services from other Island production systems (see the Web of Corporate Production, CHAPTER 10). Finally, the Household may purchase goods or services directly from foreign sources.

5. Approximately 260 households on Bonaire own businesses. These households do not produce labor as an output, but instead keep and use their labor within the household. These household businesses produce goods or services used by other households or production subsystems. The ownership of businesses by households is discussed further in CHAPTER 10.
6. Another important storage in this Household Production system is the storage of Division of Labor. This storage represents the fact that there is great diversity in production systems at the Household level on Bonaire. The types of labor that are generated within Households on Bonaire are highly specialized, to fit the specialized work environment on Bonaire. While the Web of Corporate Production diagram (Figure 104) shows numerous functionally distinct production subsystems, the specialization among Households would be even larger. A realistic drawing of the web of specialization that exists today among Bonaire's wage laborers is depicted in the alternate "web" drawing (Figure 108). Compare this with the relatively smaller specialization that occurred among the Non-Elites of the first State societies (see Inka Non-Elites, CHAPTER 16).
7. This configuration of Households that includes Farms (*kunukus*) provides an indication of Household access to the (ecological) "means of production." Wage Laborers characteristically are cut off from traditional means of production since they have no access to food production themselves, and the only subsistence strategy available to them is to sell their labor. This process commonly occurs in development frontiers, and the process is accelerating on Bonaire, however as was discussed in the previous chapter, Bonairians have long maintained access to alternative food production strategies.

Emergy Analysis of Households

The emergy analysis of households is an attempt to use emergy to evaluate the contribution of labor to the Bonaire ecological-economic system (APPENDIX F). To that end, it first attempts to identify *all* inputs to the households of Bonaire, including the many free or low-paid environmental contributions to households. Economic analyses typically omit environmental inputs to any production system. Furthermore, they do not attempt to calculate the *value* of that labor, but argue instead that the market should assign value (wages). Emergy analysis provides a unique opportunity to propose a wage level commensurate with the inputs to labor production in households.

Figure 71: Newer Middle Class Housing
This newer house in Playa is not built in the traditional island style (but notice the also newer house to the left, and see Figure 115). Fences still must keep goats away from plants, and ventilation is provided by wind.

Natural systems (including social-economic systems) are supported by numerous *sources* of energy and materials. Sources are distinguished as Renewable (sun, wind, rain), Slow-Renewable (topsoil, groundwater), Non-Renewable (metal ores, fossil fuels), and Purchased (imported manufactured goods). Natural systems are open systems that require constant inflows of energy and materials for their maintenance. Despite the apparent permanence of forests or cities, without regular inputs (sun and rain for forests, oil and raw materials for cities) they would crumble into dust. This is per the Second Law of Thermodynamics, also called Time's Arrow, which states that concentrations (storages) of available energy are continuously degraded (depreciated) (see An "Arrow in Time": Direction and Teleology Reexamined, CHAPTER 15). Energy sources (renewable and otherwise) supply the energy that is self-organized by natural systems to maintain themselves against depreciation (alternatively said, to maximize energy dissipation (Prigogine and Stengers 1984), or to maximize useful work--maximize empower (Odum 1996a) (see The Fourth Law?: Maximum Empower, CHAPTER 15)).

Renewables. Renewable sources of energy enter natural systems in many forms (Table 1). Sun, rain, wind, waves, tide, currents, and uplift provide renewable driving energies to ecosystems. Households with *kunukus* receive the benefits of four times more renewable emergy (1,172 E16 sej/yr compared to 302 E16 sej/yr) than households without *kunuku*s.

Figure 72: Sorghum Production Depends on Rainfall
Rainfall emergy structures Bonaire ecosystems. Sorghum (*maishi chikitu*) is one renewable product of rain and soil. Goats are another, dependent on rainfall drinking water, and rainfall for producing sorghum hay.

Figure 73: Corralled Goats Fed with Sorghum Hay

Table 1: Renewable Resources for Households
Total renewable resources are calculated by adding rain, tide, currents and earth contributions. This omits sunlight, wind, and waves from the total. This is because sunlight, wind, waves and rain are ultimately all the result of solar radiation. Counting each of them would be double counting. The highest number is picked to represent the input of all four, which is Rain (679 E16 sej/yr) (The full analysis is in APPENDIX F).

	Item	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej/yr)*	*Emdollar Value (1993 US$)*
HOUSE & *MONDI* & *KUNUKUS*						
1	Sunlight	1.05E+18	J	1	105	763,820
2	Rain, Chemical Potential Energy	4.40E+14	J	15,444	679	4,954,769
3	Rain, Geopotential Energy	2.03E+12	J	8,888	2	13,162
4	Wind, Kinetic Energy	8.20E+15	J	584	479	3,496,897
5	Wave Energy	1.83E+14	J	25,889	474	3,457,720
6	Tidal Energy	3.44E+13	J	49,000	169	1,229,776
7	Currents Energy	1.08E+13	J	1.0E+05	108	785,807
8	Earth Contribution	2.18E+09	g	1.0E+09	218	1,589,782
	Total of Renewable Sources (*Mondi* & *Kunukus*)				**1,172**	**8,560,134**
HOUSE & OTHER						
1b	Sunlight	2.70E+17	J	1	27	197,115

	Item	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej/yr)*	*Emdollar Value (1993 US$)*
2b	Rain, Chemical Potential Energy	1.13E+14	J	15,444	176	1,278,650
3b	Rain, Geopotential Energy	5.24E+11	J	8,888	0.5	3,397
4b	Wind, Kinetic Energy	2.12E+15	J	584	124	902,425
5b	Wave Energy	4.72E+13	J	25,889	122	892,315
6b	Tidal Energy	8.87E+12	J	49,000	43	317,361
7b	Currents Energy	2.78E+12	J	1.0E+05	28	202,789
8b	Earth Contribution	5.62E+08	g	1.0E+09	56	410,266
	Total of Renewable Sources (House & Other)				**302**	**2,209,067**
Total of Renewable Sources (Rain + Tide + Currents + Earth)					**1,475**	**10,769,201**

In the past on Bonaire, when renewable resources were the main driving emergies for the economy, it is not surprising that most residents were fishers or farmers. Today, however, imported emergies are 20 times larger than renewable sources, and households have been drawn away from dependence on farming or fishing.

Figure 74: Waves, Wind, Tide, and Currents Emergy Converge on the East Coast Productive coastal ecosystems produce fish and shellfish that fed households in the past and continue to contribute to renewable food production.

Slow-Renewables. Slow-Renewable sources are sources of energy that are renewable, but at the temporal scale of human lifespans those sources can be depleted (Table 2). Topsoil can regenerate itself if it is stripped, but only after many years of fallow. Groundwater will recharge in underground aquifers, but only after many years. Coral reefs recover slowly when damaged by ship anchors or divers. It was estimated that these sources (storages) are consumed by households, but their contribution is relatively small.

Table 2: Slow Renewable Island Sources
The full Households analysis is in APPENDIX F.

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej/yr)*	*Emdollar Value (1993 US$)*
HOUSE & *MONDI* & *KUNUKUS*						
15	Top Soil	2.06E+12	J	63,000	12	94,542
16	Groundwater and *Dam*s	1.28E+11	J	617,760	8	57,783
17	Coral Reef	3.99E+06	g	1.0E+09	0.4	2,913
	Total of Slow-Renewable Sources (*Mondi* & *Kunukus*)				**21**	**155,238**
HOUSE & OTHER						
15b	Top Soil	5.31E+11	J	63,000	3.3	24,398
16b	Groundwater and *Dam*s	3.31E+10	J	617,760	2	14,912
17b	Coral Reef	1.03E+06	g	1.0E+09	0.1	752
	Total of Slow-Renewable Sources (House & Other)				**5.5**	**40,061**
Total of Slow-Renewable Sources					**27**	**195,300**

Figure 75: Eroded Topsoil is a Cost of Development
Topsoil is a slow-renewable source that is consumed whenever thorn forest is cleared for construction of new housing. After heavy rains, uncovered soil erodes down this hillside. Topsoil is also lost when quarries are dug for construction materials (Figure 76). Agriculture can be another source of topsoil loss when soils are not managed. Emergy accounting would predict that people will accept this loss when compared to the large emergy gains of development. It would also predict that people will institute regulations to minimize this loss.

Non-Renewables. Sources that are formed by geologic processes are considered to be non-renewable (Table 3). On Bonaire there are no significant mineral sources (iron, bauxite, oil, etc.). Only the island rock itself is a non-renewable source to households, and other production subsystems on the island (see CHAPTER 11). The work of ancient marine volcanoes followed by millenia of living reefs was required to raise the island from the sea floor, and the island rock embodies that work. The island's (minimal) relief contributes greatly to productivity on the island (compare ecosystems in the hilly north with the flat south). The contribution of non-renewables to households on Bonaire is relatively small (there are more additional non-renewables not counted here that enter the household system from construction, roadways, the airport and others).

Figure 76: Volcanic Rock is Mined for Construction
Volcanic Rock and Limestone are used in all construction sites, including house construction. They are therefore a source of non-renewable emergy to households (see CHAPTER 11).

Table 3: Non-Renewable Island Sources
The full Households analysis is in APPENDIX F.

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej/yr)*	*Emdollar Value (1993 US$)*
HOUSE & *MONDI* & *KUNUKUS*						
18	Volcanic Rock	2.00E+06	g	4.50E+09	0.9	6,554
19	Limestone	2.00E+06	g	1.00E+09	0.2	1,456
	Total of Non-Renewable Sources (*Mondi* & *Kunukus*)				**1.1**	**8,011**
HOUSE & OTHER						
18b	Volcanic Rock	5.15E+05	g	4.50E+09	0.23	1,691
19b	Limestone	5.15E+05	g	1.00E+09	0.05	376
	Total of Non-Renewable Sources (House & Other)				**0.28**	**2,067**
Total of Non-Renewable Sources					**1.38**	**10,078**

Purchased Sources. Households today depend greatly on purchased resources (Table 4). This is known intuitively by Bonairians, but is quantified here with emergy. By these calculations, households receive 33,687 E16 sej/yr, or 96% of the household emergies from purchased goods and services. This is an average, and these percentages will vary from one household to another.

Figure 77: Propane Gas for Households
Propane is used for cooking on Bonaire. Propane, desalinated water, electricity, and gasoline are the purchased "fossil fuel" inputs to households on Bonaire.

In fact, this percentage is overestimated. Note that two important purchased inputs to households have large environmental components. Construction inputs use rock and sand from the island (see CHAPTER 11), and the fish catch is an environmental source that is technically "imported" from outside the Bonaire system as defined here (see Fishing, CHAPTER 5). Roads and the airport runway also include a significant environmental input. A more accurate representation of the ratio of economic to environmental inputs to households might be 80-90% economic (purchased).

Table 4: Imported Emergy and Island Technology Sources
The full Households analysis is in APPENDIX F.

Note	*Item*	*Raw Units*	*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej/yr)*	*Emdollar Value (1993 US$)*
20	Construction System			5,037	36,763,705
21	Roadway System			460	3,353,985
22	Cars and Trucks	4.41E+08 g	6.70E+09	295	2,155,248
23	Travel (Airport) System			4,372	31,914,556
24	Retail System (Food & Goods)			3,549	25,905,796
25	Fish Catch	4.24E+11 J	3.97E+07	1,684	12,294,776
26	Buildings	8.34E+08 g	9.26E+07	7	56,376
27	Gasoline	9.40E+13 J	6.30E+04	592	4,320,661
28	Potable Water	3.09E+12 J	1.38E+06	426	3,107,380
29	Electricity	4.50E+13 J	2.72E+05	1,227	8,952,754
30	Propane Gas	7.30E+11 J	4.80E+04	3.5	25,577
31	Retail Services	1.09E+07 $	2.36E+12	2,565	18,722,195
32	Financial Services (Loans)	1.55E+06 $	2.36E+12	366	2,671,513
33	Education Services	1.09E+06 $	4.72E+12	514	3,752,895
34	Health Care Services	8.16E+05 $	4.72E+12	385	2,814,672
35	Legal Services	1.36E+05 $	4.72E+12	64	469,112
36	Travel Services	1.09E+07 $	4.72E+12	5,141	37,528,954
37	Media Services	8.98E+05 $	4.72E+12	424	3,096,139
38	Telecommunication Services	1.12E+05 $	2.36E+12	26	193,324
39	Other Services (Expenses)	8.53E+06 $	2.36E+12	2,009	14,664,710
40	Govt Services (Taxes)	9.61E+06 $	4.72E+12	4,538	33,127,233
Total Imports and Outside Sources				**33,687**	**245,891,561**

Even with this correction, it is clear that contemporary Bonaire households depend on purchased (and largely imported) emergy sources. This fact is a product of island development of the past 50 years, and especially tourism development. Figure 78 summarizes the inputs to households on Bonaire. Notice that most important inputs are from other island subsystems. Each of these is evaluated in later chapters.

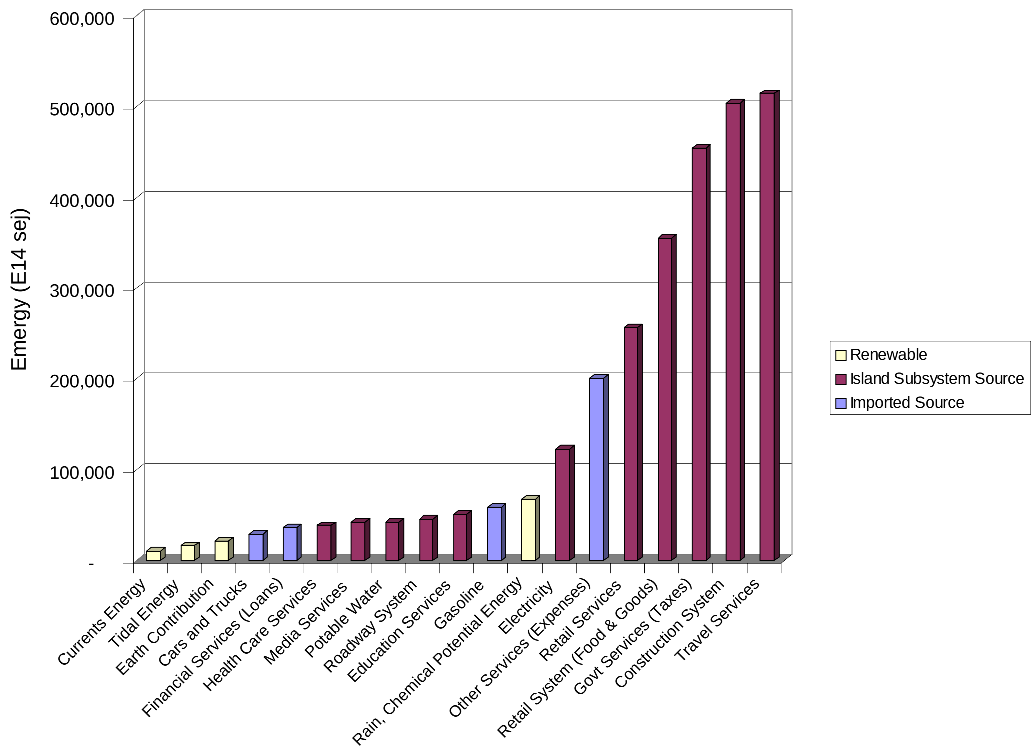

Figure 78: Household Emergy Inflows
These values are calculated in APPENDIX F.

Household emergy flows from the previous four tables and Figure 78 are summarized in Figure 79. Notice especially the relative magnitudes of inflows from the four types of sources. As stated above, purchased emergy sources dominate all others for the average Bonaire household. There is variation around this mean, with some households making more use of environmental resources. However, even so, this diagram suggests the dramatic increase of emergy inputs that come from participation in the market economy for Bonairians. In world regions with more productive natural environments and less fossil fuel it should be expected that this choice is far less clear. In such a setting, foragers and farmers might co-exist with wage laborers in more equal proportions than found on Bonaire.

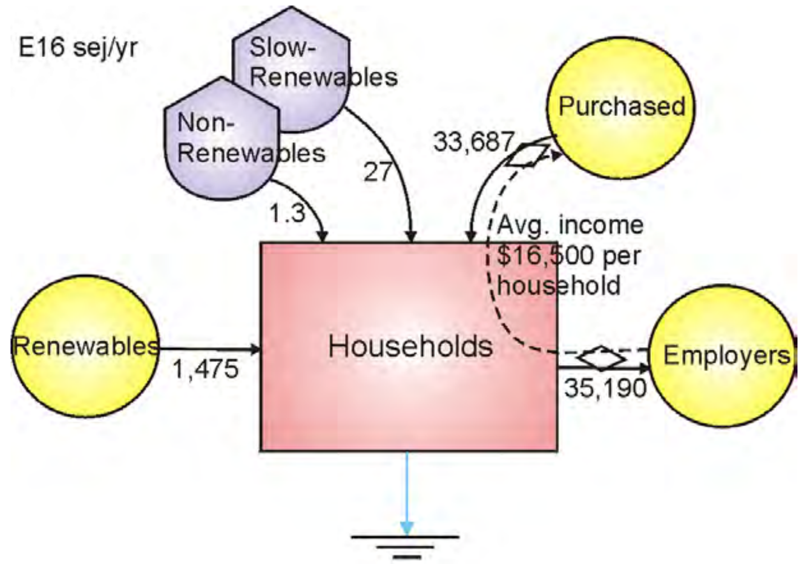

Figure 79: Household Emergy Flows Summary
These values are calculated in APPENDIX F.

Table 5 assigns Bonaire emdollar values to emergy flows. The emdollar is a proscriptive monetary currency that is calculated from emergy values. In other words, it is a non-market monetary value for goods, which is calculated from the emergy/money ratio (see discussion, CHAPTER 18) for a country or region. It is a recommended valuation of goods that is based on emergy principles. In this case, it is calculated that Bonaire households receive approximately em$960 Bonaire per year in free services from environmental sources (Renewable (em$945), Slow-Renewable (em$17), Non-Renewable (em$0.90)). This value may be doubled if including the environmental services that come with some purchased emergies. This comes to about 5% of the total emdollars entering a household (in more productive ecosystems elsewhere in the world with more fortunate endowments of mineral wealth, this environmental percentage could be much higher for households).

The remaining emergies entering a household are purchased, and in emdollar terms are valued at em$21,567. Considering that the average "household" income in 1995 was $16,500, and therefore maximum household expenditures are only $16,500, this suggests that households are gaining an emergy benefit from purchased goods and services (valued at em$21,567). This might be reasonable, considering the high emergy inputs to the island in fossil fuel, which subsidize all other goods in the economy.

Table 5: Emdollar Values for Emergy Flows
These values are calculated in APPENDIX F.

Emergy Inflows	E16 sej/yr	1995 Bonaire Emdollars per Household	1993 US Emdollars per Household
Renewable	1,475	945	3,255
Slow-Renewables	27	17	60
Non-Renewables	1.3	0.9	3
Purchased	33,687	21,567	74,000
	35,190	22,530	77,318

On the other hand, if wage labor is understood as the product of households, then the labor purchased by employers is also underpaid. Employers get em$22,530 worth of labor from the average household, while paying $16,500. The benefit to employers is in this case subsidized by both fossil fuel emergy, plus the natural environmental emergies, which are never compensated monetarily with market dollars. It requires an ecological-economic currency like emdollars to quantify and include the contribution from nature. Again, in world regions where ecosystem productivity is greater, one can expect an even larger subsidy to employers from environmental emergies.

The fourth column in Table 5 gives the US emdollar values for Bonaire households. These higher values indicate exchange inequalities that can arise in the global economy that uses monetary currencies for trade. Because of the different ratios of *emergy to money* in the U.S. and in Bonaire (and other "developing" economies), Bonaire households must overpay for imported goods and services from the U.S.

Furthermore, if wages are paid directly with dollars from the U.S. economy, Bonaire households receive much less emergy buying power for their services (as when foreign companies pay wages with foreign currency). This effect is felt not directly at the household level, but it effects the island economy as a whole. See CHAPTER 8 for a discussion of ecological economics at the island scale.

Incomes and Emergy

While the average household income on Bonaire is $16,500, there is a range of incomes for the island, which falls into a typical income distribution curve. In Figure 80, note that the majority of households (blue bars) are in the first three income groups (over 70%). After that, there is an exponential drop toward the higher income "fortunate" few (the curve goes further to the right, not shown).

The total emergy inputs to households were divided over these income categories. In a hypothetical argument, the majority of environmental emergy inputs (yellow bars) are shown here entering the lower income groups. This would be equivalent to lower-income households relying on farming and fishing to supplement wage income, which seems reasonable.

Households are next grouped into four labor-household categories per an argument constructed in CHAPTER 14. The first and second columns form Labor Household 1. The third column forms Labor Household 2. The fourth, fifth, and sixth columns are divided into Households 3 and 4. The remaining household groups are perhaps the owners (or managers) of island companies.

Table 6 uses these Household groups to aggregate the distribution in Figure 80. Notice that while not perfect, this distribution of households into groups produces five categories with very similar emergy percentages, and steeply decreasing population percentages. This indicates a typical energy transformation hierarchy, as found arguably in all natural, self-organizing systems, including ecosystem webs. This suggests directions for the further study of households that could focus upon interactions within these groups and between them.

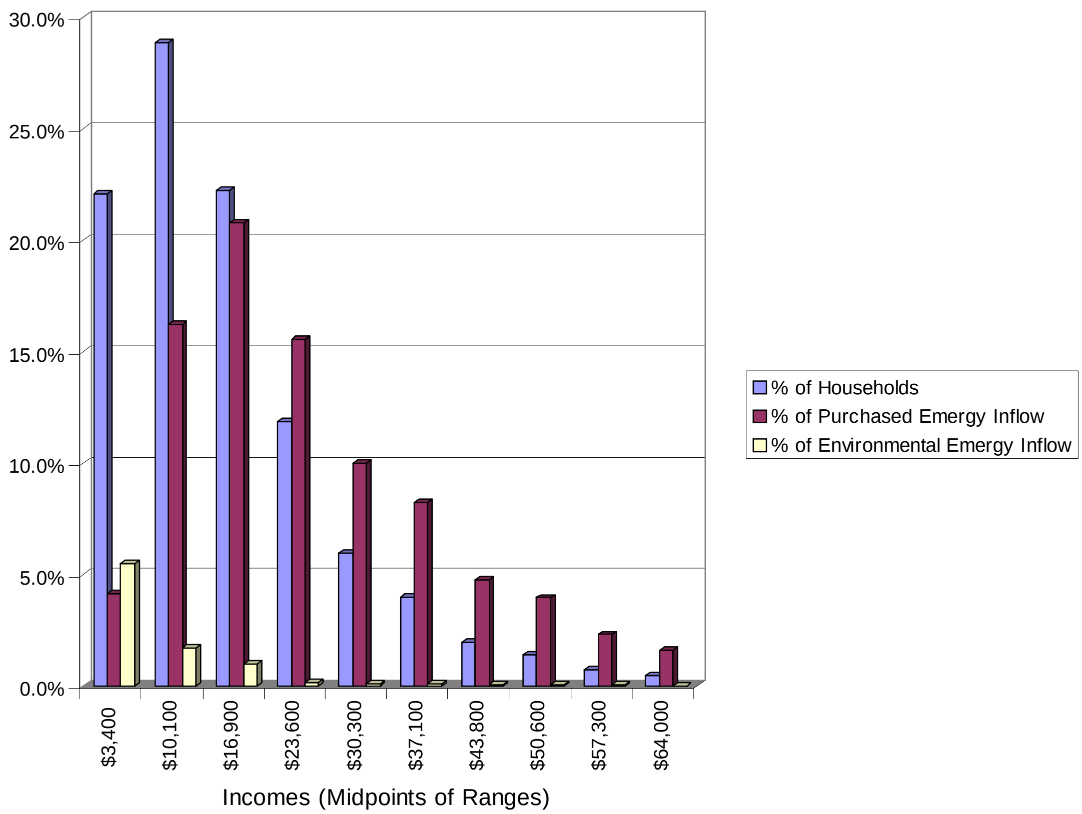

Figure 80: Household Income and Emergy Inflows
Data is from Table 43 in APPENDIX F.

Odum contends that income inequalities are due ultimately to emergy subsidies at the point that (environmental) externalities enter sociocultural systems, combined with the tendencies of hierarchies to converge larger quantities of emergy into fewer and fewer units (Odum 1983:494). In other words, because renewable and non-renewable environmental emergies are not accounted for in the market, the Houssehold1 group is not compensated for the "free" emergies that are actually embodied in their labor. As households are farther removed from free environmental emergy and dependent on once, or twice, or more, purchased goods and services (so-called "value added") those households *pay* more. In Figure 80 there are fewer and fewer households (including business-owning households) further to the right in the hierarchy.

Table 6: Constructed Household Hierarchy
Aggregated values from Figure 80, see text.

	Population	Emergy
Household 1	51%	27%
Household 2	22%	22%
Household 3	16%	22%
Household 4	6%	12%
Owners	5%	17%

In order to produce their goods and services for sale, business-owning households must converge labor and materials, which they pay for in the market. However, if these commodities and labor are closer to the environment, they are highly subsidized by free environmental emergy. The further up the hierarchy, the less input is subsidized by free emergy, and the more expensive those goods and labor service inputs become. Labor and business-owning households will take whatever salaries they can negotiate from the larger or smaller scales that purchase their commodities.

Note that the largest scale owner-households do not need to negotiate with a larger scale, and so their salaries are only controlled by negotiation with smaller scale subsystems that supply labor and commodities. Odum believes that excessive wealth concentration at the top of a sociocultural hierarchy is evidence of weedy early successional growth based on abundant energy (Odum and Odum 2000). The fossil fuel pulse of this century has provided plentiful energy for weedy growth. After an initial surge (over the last century), however, self-organized systems eliminate waste to maximize empower. In sociocultural terms, the concentration of wealth into elite salaries and luxury goods will be greatly reduced, commensurate with their positions in sociocultural hierarchies. That is one interpretation of this model of self-organization.

Note also the tremendous bonus gained by cores of world systems that capture the labor services of highly trained professionals that were raised and educated with cheap environmental emergy from their foreign peripheries. That labor was produced at a low cost to the core of the system, which allows the labor services to be purchased for less. This therefore puts downward pressure on salaries paid in the core market for those services.

Labor Output and Emergy per Dollar for Wages

Finally, Table 7 contains the output emergies of households, and an emergy per dollar value for household services. The output emergies will be used in calculating the labor inputs to all of the island subsystems that were analyzed in CHAPTER 7-CHAPTER 14. To be specific, the *emergy per laborer* value (5.7 E16 sej/yr) can be multiplied by the number of employees in a company to calculate the emergy input of labor[1]. Once converted to emergy, the labor input to any process can be compared to all other inputs by use of this single currency, emergy.

Table 7: Output and "Emergy per Dollar"
These values are calculated in APPENDIX F.

Note	*Item*	*Raw Units*		*Emergy per dollar (sej/$)*	*Solar Emergy (E16 sej/yr)*	*Emdollar Value (1993 US$)*
44	Labor Services, Average	5.44E+07	$	6.47E+12	35,190	256,866,140
45	Emergy per Person				2.5	18,066
46	Emergy per Household				11	77,680
47	Emergy per Laborer				5.7	41,685

1
While it was shown in the previous section that households differ in emergy inflows, and therefore in the emergy per laborer, I will assume that most businesses have a hierarchy of employees (workers, managers, upper mgmt, owners) that is similar to the hierarchy of total households. Therefore the average emergy per laborer value is adequate to estimate the labor emergy contribution for the total workforce.

The *emergy per dollar* value was calculated for labor wages for Bonaire as 6.47E12 sej/$. This was done by dividing the total wages paid on Bonaire, $54,400,000 per year, by the emergy flow to all households, 35,190 E16 sej/yr. This value is higher than the emergy/$ ratio for the island, which again suggests that labor contributes disproportionally to the island economy.

CHAPTER 8
BONAIRE WITHIN WORLD SYSTEMS

Bonaire finds itself, as do we all, in a world of transnational corporations astride a global economy. The Netherlands Antilles and Bonaire should be located and understood within the world systems of international markets, and political-military hegemony. Bonaire is touched in many ways by the US, Europe, and Latin America. The international media, maritime agreements, global financial markets, world energy supplies, and more, including its colonial history, all link Bonaire into a larger scale. Fieldworkers recognize the need to place ethnography within regional scales, but they often lack the methods and models to do so. Systems modeling and emergy analysis provide one means to this end.

Figure 81: Bonaire within World Systems
There are times that the world systems context becomes visible, even on Bonaire.

National Emergy Analyses

National emergy analyses provide means to measure ecological-economic production and consumption over large areas. Within the nested scales of the biosphere, they afford analysis at the scale of a nation. For anthropologists, they offer a larger context within which to interpret ethnographic fieldwork. Drawing national systems diagrams and quantifying flows of natural and economic goods and services serves the invaluable role of forcing the researcher to clearly and concisely define the material and economic context of fieldwork. While this might be done descriptively by some fieldworkers, a national emergy analysis forces precision and (hopefully) eliminates the omission of essential flows and storages that are easy to miss with less rigorous approaches.

A second invaluable service of national emergy analyses is to permit comparisons between nations. For instance, it is possible to measure and compare the percent of national emergy flows that come from environmental sources. For several nations, these percentages can be compared to judge the relative sustainability of a national system, and the intensity of its economic development. Another index, called the Investment Ratio, can judge the dependence of a national economy on external, foreign economies.

Finally, national analyses permit calculations of global ecological economics. As discussed previously, emergy is an alternative currency that measures the value of a good or service in terms of the emergy flows that resulted in the product. With this currency, international trade can be re-evaluated to judge existing equities or inequities. National emergy analyses produce emergy/money ratios that can be used to judge any international monetary exchange. While monetary exchanges, by definition, are equal in terms of money, emergy analysis suggests that they are often unequal, because natural resources are systematically undervalued in the market.

National emergy analyses were conducted for Bonaire and the Netherlands Antilles. In addition, for comparison purposes, very rough national analyses were performed for Bonaire in the 1950s and for the Amerindian population of Bonaire. A national emergy analysis for the Netherlands was conducted by (Braat 1987) for the 1980s and is also used for comparison.

Bonaire Emergy Analysis, ca. 1995

National emergy analyses begin by constructing a systems diagram of the nation. Emphasis is placed on defining the emergy flows that cross the national boundary, and the emergy storages that exist within the nation. Figure 82 depicts Bonaire in the mid-1990s.

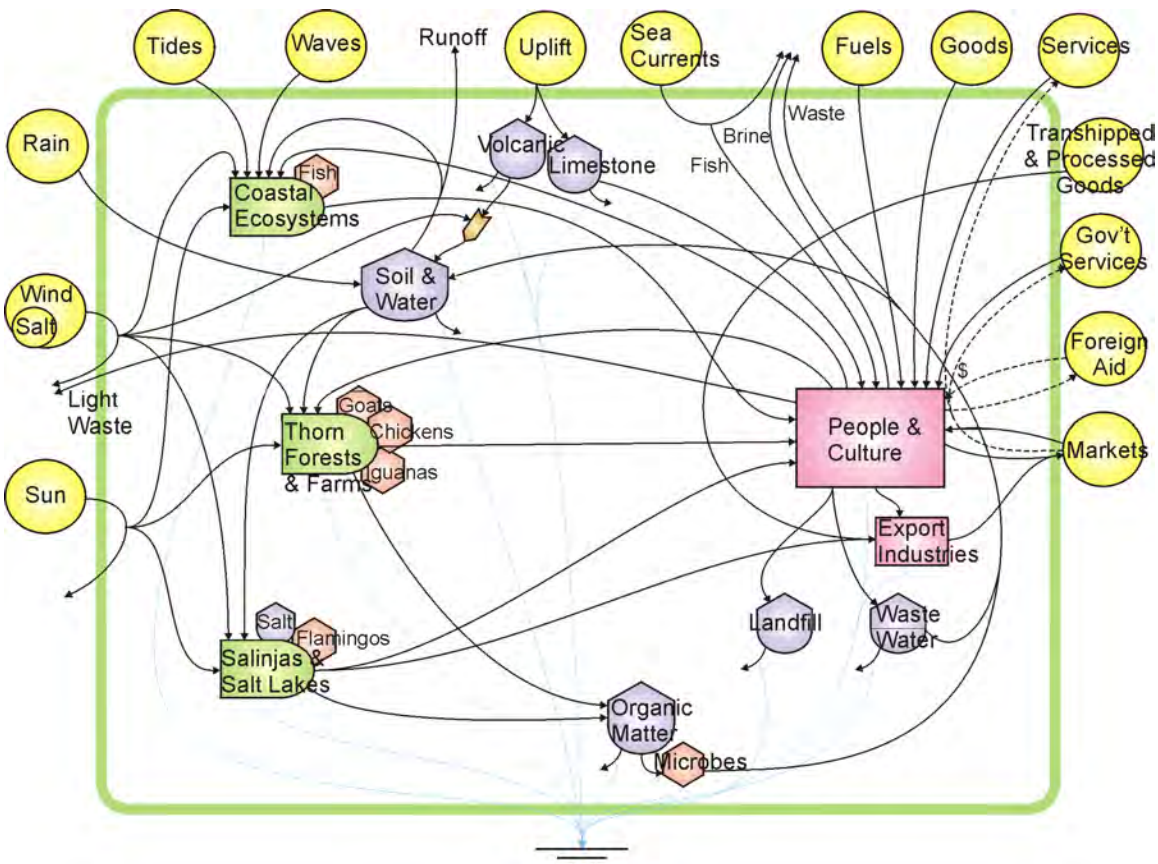

Figure 82: National Systems Diagram of Bonaire
In a national diagram, the aim is to identify important emergy sources (yellow circles) and storages (blue tanks), both renewable and non-renewable, and to briefly depict the island processes that use or produce them.

Renewables. Once the diagram is made, the researcher can begin to collect emergy data. Emergy values for each of the flows and storages are calculated and placed in tables. APPENDIX A contains the full emergy analysis of Bonaire. Table 8 contains the renewable sources that are driving the Bonaire economy. The fifth column contains the emergy value of the flow, which is calculated by multiplying energy (or mass) by a known conversion value[1], called "Emergy per Unit" in column four.

Table 8: Renewable Island Sources
Note that the total of renewable emergies is calculated by adding only Rain, Tide, Currents, and Earth emergy. Sun, Rain, Wind, and Wave emergies are ultimately the products of sunlight, and adding them would be double counting. The largest value (Rain) is therefore chosen to be added to Tide, Currents and Earth to produce a total. The full Bonaire emergy analysis is in APPENDIX A.

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*
1	Sunlight	2.62E+18	J	1	262	1,914
2	Rain, Chemical Potential Energy	1.10E+15	J	15,444	1,701	12,415
3	Rain, Geopotential Energy	5.08E+12	J	8,888	5	33
4	Wind, Kinetic Energy	2.06E+16	J	584	1,200	8,762
5	Wave Energy	4.58E+14	J	25,889	1,187	8,664
6	Tidal Energy	8.62E+13	J	49,000	422	3,082
7	Currents Energy	2.70E+13	J	1.0E+05	270	1,969
8	Earth Contribution	5.46E+09	g	1.0E+09	546	3,984
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				2,939	21,450

Slow-Renewables. Some natural emergy storages are renewable, but only at a time scale much greater than a human lifetime. The production of significant storages of topsoil or groundwater requires the ecosystem work of decades or centuries. These emergy storages are therefore called slow-renewables. Table 9 contains those storages for Bonaire. If slow-renewable storages are consumed at slow rates, the storage can be

[1] Emergy per Unit conversion values have been assembled over the last 25 years from analyses of many types of energy and matter within systems. Emergy per Energy

sustainable. I.e., many stable ecosystems loose topsoil to erosion as fast as new topsoil is formed. However, agriculture typically reduces or consumes the storage of topsoil. Pumping groundwater for drinking water or agriculture typically drains groundwater storages. When groundwater or topsoil storages are gone they will return, but it will take many years. It was estimated in the water budget analysis that the current groundwater storage of Bonaire took 755 years to form (APPENDIX E).

For emergy analyses, any consumption of a storage that is greater than sustainable recharge is calculated as an emergy flow into a system. These values for Bonaire are shown in Table 9.

Table 9: Slow-Renewable Island Sources
The full Bonaire emergy analysis is in APPENDIX A.

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*
16	Top Soil	1.80E+13	J	63,000	114	829
17	Groundwater and *Dam*s	3.21E+11	J	617,760	20	145
18	Coral Reef	2.50E+07	g	1.0E+09	3	182
		Total of Slow-Renewable Sources			136	993

Non-Renewables. Most storages that are produced by geologic processes are called non-renewable. The formation of volcanic rock, or limestone, for example, are products of geologic work at the time scale of millenia. Table 10 contains measures of the consumption of those storages for Bonaire.

Table 10: Non-Renewable Island Sources
The full Bonaire emergy analysis is in APPENDIX A.

Note	*Item*	*Raw Units*	*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*

values are also called Transformities. See Odum (1996:304-311) for many known emergy/unit values.

Note	Item	Raw Units		Emergy per Unit (sej/unit)	Solar Emergy (E16 sej)	Emdollar Value (1993 E3 US$)
19	Volcanic Rock	1.00E+09	g	4.50E+09	450	3,285
20	Limestone	4.00E+09	g	1.00E+09	400	2,920
	Total of Non-Renewable Sources				850	6,204

Imported Emergy. For contemporary nations participating in global trade, emergy that is purchased and imported can have significant driving effects in an economy. For the cases of Caribbean islands this is especially true. Bonaire must import oil and manufactured goods from around the world. These vital emergy inflows to Bonaire's economy are shown in Table 11.

Table 11: Imported Emergy
The full Bonaire emergy analysis is in APPENDIX A.

Note	Item	Raw Units		Emergy per Unit (sej/unit)	Solar Emergy (E16 sej)	Emdollar Value (1993 E3 US$)
21	Goods	3.49E+10	g	3.52E+09	12,288	89,691
22	Fuel	1.43E+15	J	6.60E+04	9,414	68,713
23	Foreign Aid				2,280	16,645
24	Services of NA Govt	1.68E+06	$	5.35E+12	896	6,542
25	Services in Fuel Imports	3.72E+06	$	5.35E+12	1,987	14,502
26	Services in Other Imports	1.13E+08	$	2.36E+12	26,635	194,415
	Total Imports and Outside Sources				51,219	373,862

Exported Emergy. Emergy exports are also calculated for national emergy analyses. Emergy exports are quantities of goods and services that are exported into the global economy. For Bonaire these include the services produced in the Bonaire economy. Services are normally reported in some monetary currency. Emergy values for services are calculated by multiplying the monetary value by the Emergy/money ratio for the nation exporting the services. In this case the emergy/money ratio for Bonaire is multiplied by the services exported. Bonaire exports services from the salt industry, from tourism, from oil transshipment, and from the two large antenna arrays on the island. Additional emergies not included in those services are the natural environmental emergies that support them. These are calculated separately in Table 12 and added together to produce a total.

Table 12: Emergy of Exports
The full Bonaire emergy analysis is in APPENDIX A.

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*
29	Salt Works (Environ.)				574	4,190
30	Tourism Product (Environ.)				856	6,251
31	Oil Transhippment (Environ.)				401	2,924
32	Antenna Arrays (Environ.)				675	4,925
33	Services in Exports	1.42E+08	$	4.72E+12	67,190	490,436
				Total Emergy Outflows	69,695	

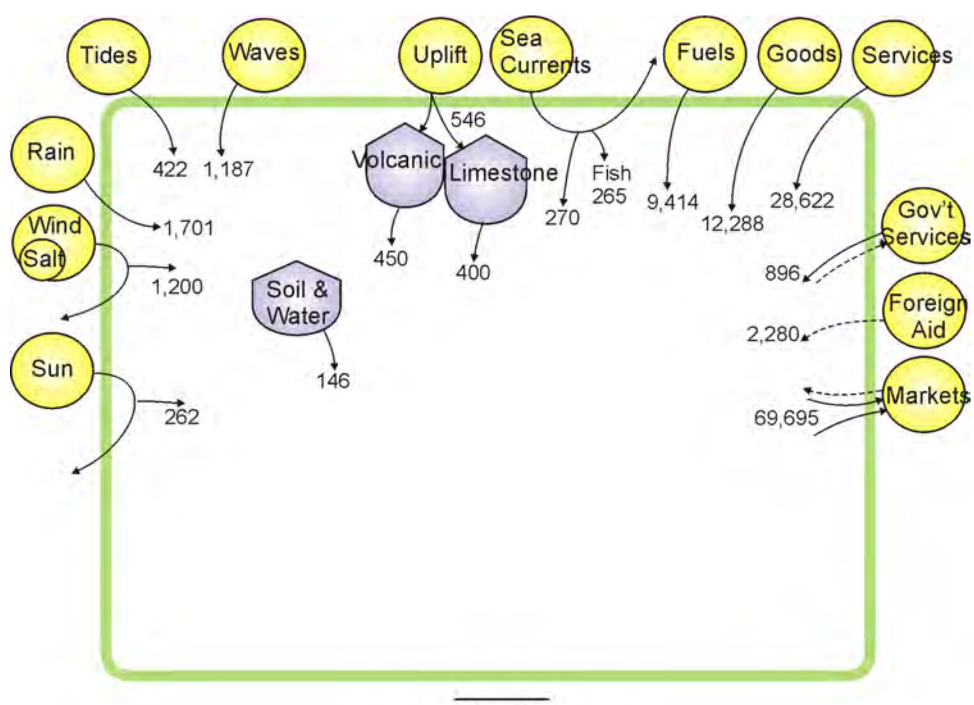

Figure 83: Emegy Sources and Storages of Bonaire
Source and storage flows are calculated in the preceding tables, and were derived in APPENDIX A. For example, the Goods emergy imported is Item 21 in Table 11, fifth column. Compare this with Figure 82.

Figure 83 is now modified from Figure 82 to depict only the major sources and storages of emergy that drive the Bonaire ecological-economy. Emergy values of flows are calculated in the tables above.

Summary Diagrams for Bonaire and the Netherlands Antilles

Summary diagrams and indices may now be produced from the tables above. The purpose of summary diagrams is to present a simple picture of emergy inflows and outflows to a nation. These distilled versions of the more complex diagrams make general patterns visible. Summary diagrams are also the sources of the ecological-economic indices for the nation. Indices provide numerical values that can be easily compared between nations.

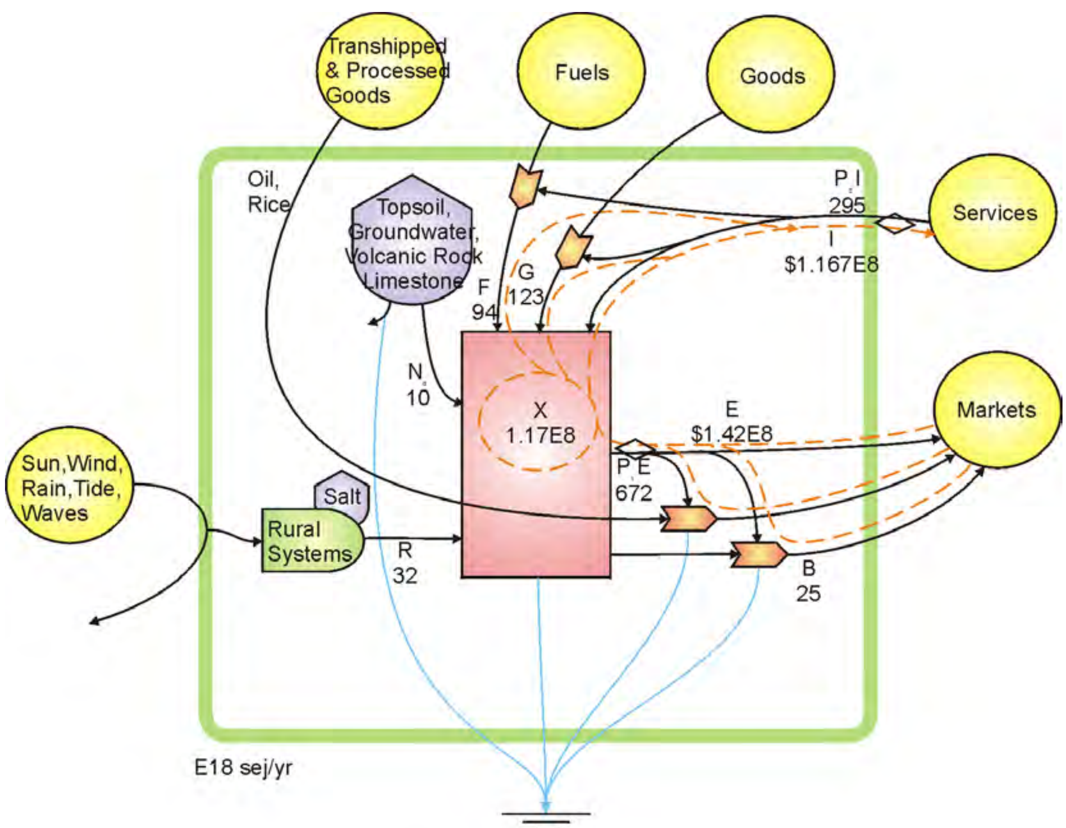

Figure 84: Overview Diagram of Bonaire, ca. 1995
Renewable resources (R), Non-Renewables and Slow-Renewables (N), Fuels (F), Goods (G), Import Dollars (I), Import Emergy in Services (P_2I), Export Dollars (E), Export Emergy in Services (P_1E), exported Goods Emergy (B), and Gross Domestic Product (X). Emergy flow values are in E18 sej/yr. Data values are from APPENDIX A, Table 2.

Figure 84 is the overview diagram for Bonaire, ca. 1995. Some of the emergy indices that follow are calculated from this diagram.

One final simple diagram is produced from this data. This is a summary diagram of inflows and outflows (Figure 85) and is called a three-arm diagram. For this diagram, the flows of Figure 84 are aggregated into Indigenous Sources, Imports and Exports. Note that the transshipped oil is not included in these flows. Only oil products used on the island are included in the Imports.

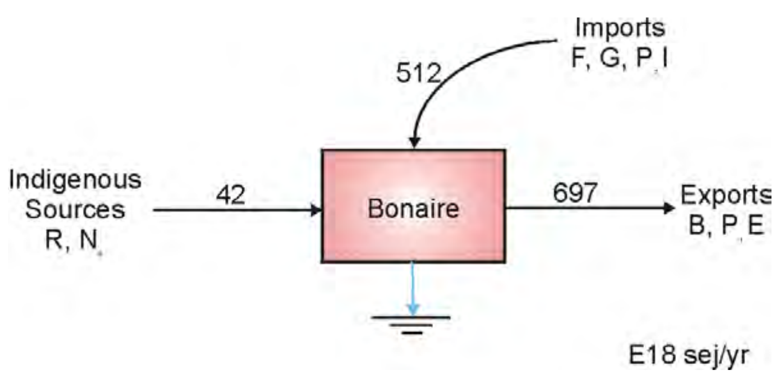

Figure 85: Bonaire Three-Arm Diagram
Data values are from APPENDIX A.

Another simple means to depict the relative flows of emergy imports and exports is to use a standard barchart. Annual emergy flows for Bonaire, which ultimately drive the island ecological-economy, are depicted in Figure 86. Note the relatively low usage of natural sources, both renewable and non-renewable. In part this is due to the few indigenous mineral sources and the relatively low productivity of natural systems on a dry island. In part this is also due to the relatively high intensity of development.

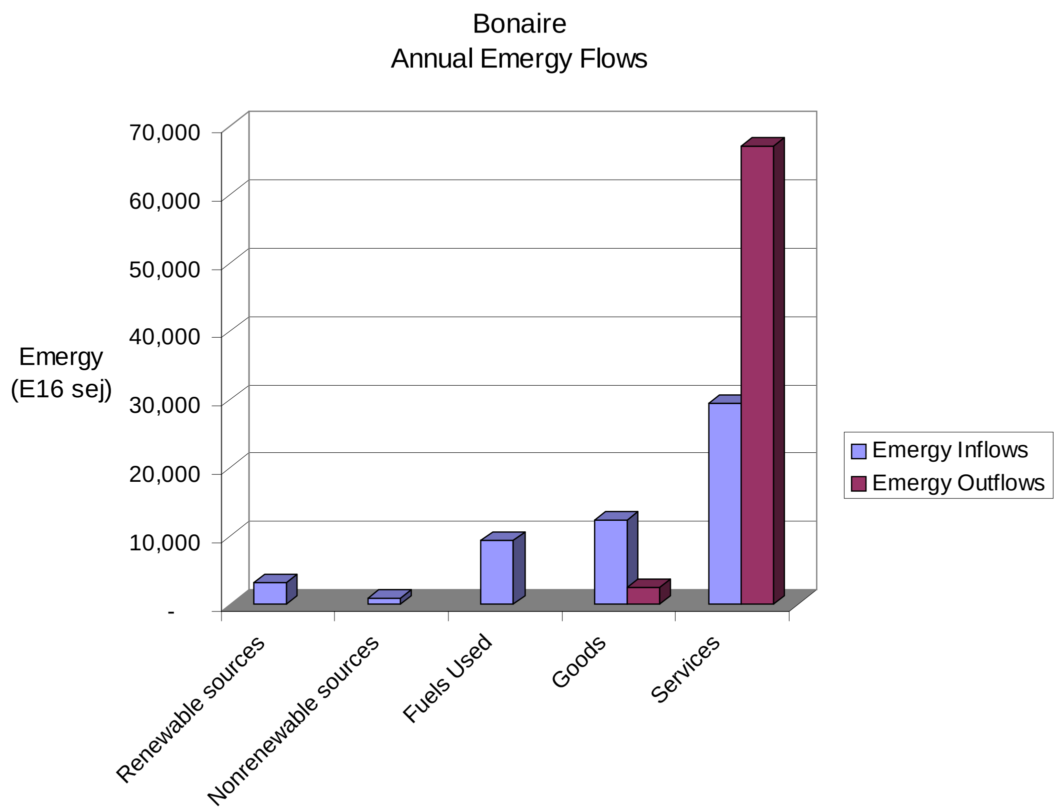

Figure 86: Bonaire Emergy Flows
Transshipped fuels are not included. Fuels are only those used in the economy.

Two other three-arm diagrams were produced. An emergy analysis was performed for Bonaire of the 1950s. See APPENDIX AA for details. The three-arm diagram is in Figure 87.

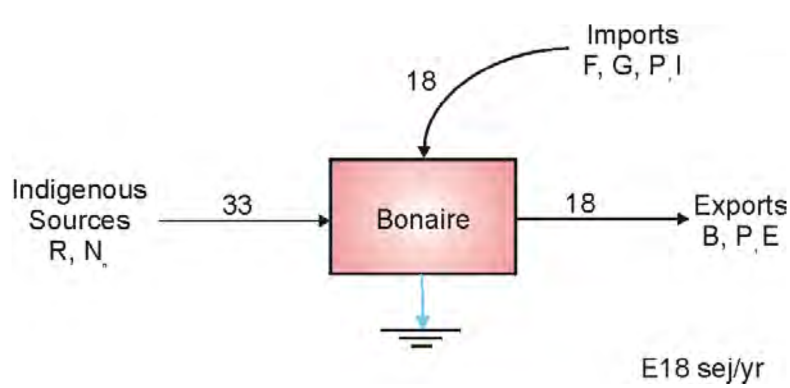

Figure 87: Three-Arm Diagram for Bonaire, ca. 1955
Data values are from APPENDIX AA.

Figure 88: Old-fashioned House (*Kas'i Antes*)
In the 1950s, economic strategies were centered on the *kunuku*'s or fishing. This old house was probably built by the owner from local materials (except the tin roof). Imports and exports for the island were low in those years.

Figure 89: Millstone
This old technology was used for grinding sorghum grain in the past. In those years, unlike today, most food was grown locally or hunted or fished.

An emergy analysis was also performed for the larger-scaled context of the Netherlands Antilles, which includes Bonaire. The emergy analysis is in APPENDIX B, and the Three-arm diagram is in Figure 90. Refined oil is not included in these flows. A large component in the Exports flow is services for Offshore Banking. Curacao has a large banking sector, as discussed in CHAPTER 3.

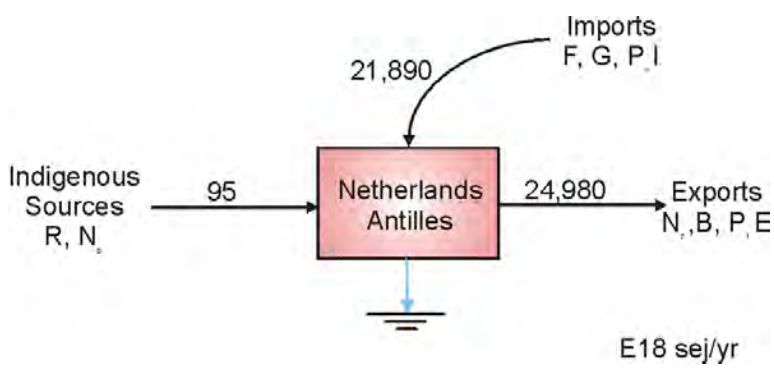

Figure 90: Three-Arm Diagram for the Netherlands Antilles, ca. 1995
Data values are from APPENDIX B.

Notice the significant difference in the magnitude of emergy inflows, first between Bonaire of old, and today, and then between current evaluations of Bonaire and the Netherlands Antilles. Bonaire's economy of today clearly attracts far more emergy than did the island economy of only 50 years ago. This is primarily due to the intensive use of fossil fuels and imported goods and services.

The Netherlands Antilles in turn has significantly larger emergy flows than does Bonaire by itself. This is due to the high emergy inflows from oil, which come to the giant refinery on Curacao. Only the oil emergy that is actually consumed on the island is calculated in the imports shown. Refined and shipped oil is not counted. Figure 91 presents those emergy flows in table format. This fuel emergy is the source of fuel that also drives the Bonaire economy.

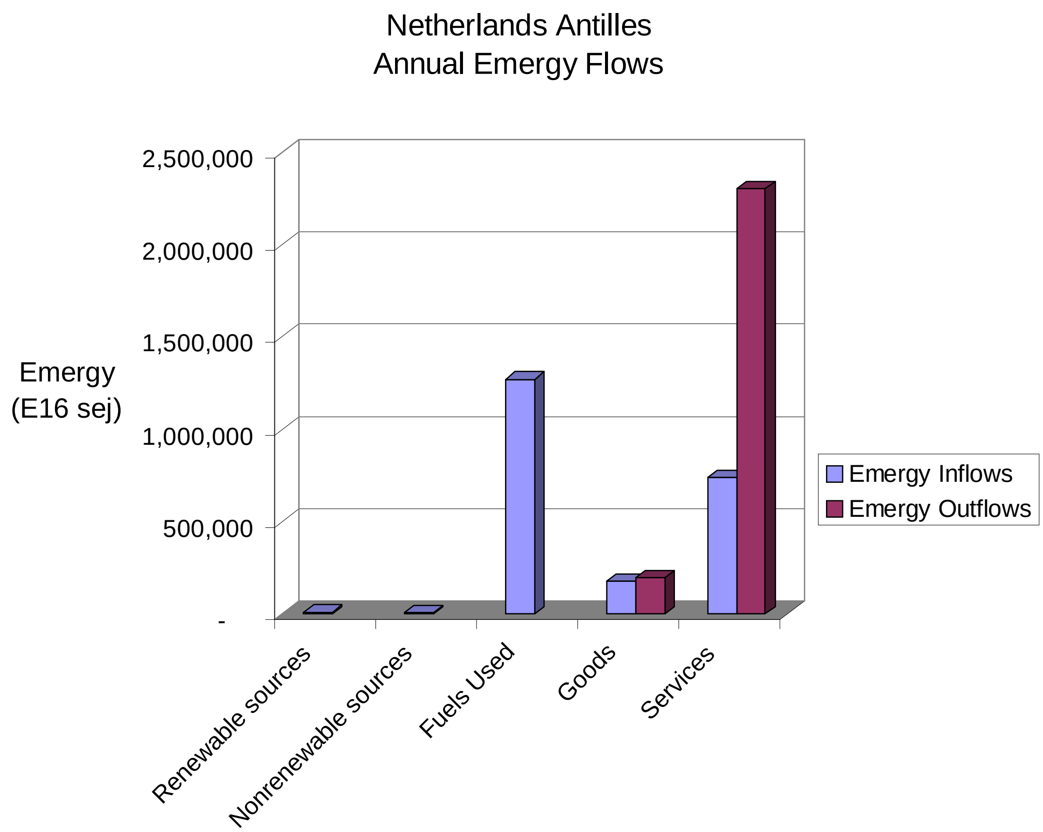

Figure 91: Netherlands Antilles Emergy Flows
While this diagram resembles the Bonaire barchart in form (with high fuel imports, high service exports, and few goods exported), the values on the vertical emergy axis are 50 times larger. Only fuels used in the economy are included. Refined and shipped fuels are not counted. Data values are from APPENDIX B.

Summary Indices for Bonaire and the Netherlands Antilles

Indices may now be calculated from the aggregated emergy flows depicted in the diagrams above. Emergy indices provide a simple means of comparisons between nations.

Several indicators of development intensity and exchange equity were produced from the preceding data and diagrams (Table 13). Each item will be discussed in the text that follows.

Table 13: Emergy Indices for Nations
Data values are from APPENDIX A, APPENDIX B, APPENDIX AA, and APPENDIX BB.
Additional sources are (Odum 1996a, Doherty, et al. 1994, Braat 1987)

	Amer-indian Bonaire	*Bonaire 1950s*	*Bonaire 1995*	*Nether-lands Antilles 1995*	*Nether -lands 1980*	*Puerto Rico*	*USA*
National Ecological economics							
1) Emergy Use / Person (E15 sej/person)	25	4	39	106	26.3	17	29
2) Empower Density (Emergy/m^2) (E10 sej/m^2)	7	12	127	1,906	1,000	736	70
3) Economic / Environmental Ratio (Average Investment Ratio)		0.56	12	169	3.3	46	7.1
4) Percent Environmental Emergy	100%	64%	8%	0.59%	23%	2.1%	12%
5) Percent Renewable Emergy (Environmental Loading)	98%	63%	6%	0.37%	6%	1.6%	10%
Global Ecological economics							
6) Emergy / Money Ratio (sej/$) (E12 sej/$)		8.7	4.7	5.4	2.2	1.65	1.39
7) Exports / Imports (Emergy Yield Ratio, Y/F)		1.00	1.36	1.14	0.83	0.74	0.57

National ecological economics

Emergy Use per Person. This value is the total emergy used by a nation, divided by the number of inhabitants (Table 13, Item 1). It therefore produces an index that is normalized to different population sizes. In general terms, a high emergy/person ratio suggests a high "standard of living." A high standard of living, in this sense, does not preclude less developed economies. Some natural environments are highly productive, with large natural emergy inflows, and at low population densities their emergy/person ratio will be high. For example, the emergy/person for Papua New Guinea is 38 E15 sej/yr, see Table 14. As another example, the estimated emergy/person was greater for Amerindian Bonaire than for Bonaire in the 1950s (see APPENDIX AA and APPENDIX BB). In both of these cases, due simply to environmental production at low population densities, the emergy/person exceeded the current world average of 4 E15 sej/yr. For anthropologists, this index can provide perhaps a reasonable measure of the "original affluent society(s)."

Figure 92: PDVSA Refinery on Curacao
The Curacao refinery, originally owned by Shell, was once the largest in the world. The refinery and related oil inputs to the economy have arguably shaped the island into its present urban form, home to 160,000 people.

Table 14: Emergy User per Person
Sources are (Odum 1996a:206, Doherty, et al. 1994)

Country	Emergy E15 sej/person/yr	Country	Emergy E15 sej/person/yr
India	1	Brazil	15
Bonaire 1950s	3.6	Soviet Union	16
World	4	Puerto Rico	17
Mexico	6	Liberia	26
China	7	New Zealand	26
Taiwan	8	**Netherlands** (1980)	26
Poland	10	West Germany	28
Ecuador	11	U.S.A.	29
Switzerland	12	Papua New Guinea	38
Japan	12	**Bonaire**	39
Dominica	13	Australia	59
Amerindian Bonaire	15	**Netherlands Antilles**	106

For refinery islands like Curacao, however, this index must be interpreted carefully and in conjunction with the others. As discussed in CHAPTER 3 (Figure 17), the population density of Curacao (and Aruba) is comparable to that of many dense metropolitan areas (such as the Miami-Fort Lauderdale metro area). By comparison, the population density of Bonaire is found to be similar to the lower density, Ocala metro area in Florida.

Dense metro areas in the U.S. are often surrounded by large areas of rural countryside that recharge underground aquifers, process liquid wastes, furnish raw materials, and offer remote space for landfills. In systems ecology terms, the inflows of imported emergy are "matched" by inflows of environmental emergy. Emergy imported to an economy will "pull" on natural emergies. Other researchers following Odum have renamed this phenomenon the "ecological footprint" of development. The Economic / Environmental Ratio is Odum's term for this process (Table 13, Item 3).

Figure 93: Urban Population of Curacao

Emergy per Person, and Empower Density are high for Curacao. This is due to the developed urban economy and high population density on a small island with modest natural production and few mineral resources.

Empower Density. Empower Density measures emergy use per unit area, which is another attempt to normalize total emergy use by some constant, unit area in this case (Table 13, Item 2). In other words, for example, the total emergy use of the U.S. is high, but on an area basis it is well below that of the Netherlands. In fact, for a small country, the Netherlands has one of the highest population densities and empower densities in the world (see CHAPTER 3). As can be seen in Table 13, the empower density of the Netherlands Antilles, dominated by Curacao, is even higher. A good comparison is with Puerto Rico, another Caribbean island with oil refineries. Like Curacao, Puerto Rico's empower density is very high. In these cases, this number represents a high intensity of development and an imperative for environmental management.

Economic/Environmental Ratio. This measure (also called the Average Investment Ratio) attempts to judge the availability of natural resources to "match" the imports of purchased goods and services (Table 13, Item 3). Notice, for example, that the Netherlands with its high empower density has a relatively lower Economic / Environmental Ratio. This is the result of large environmental contributions to total emergy flows, in the form of river, marine, and farm inputs, but especially oil and gas storages beneath its soil. In contrast, Curacao (the Netherlands Antilles) has a very high ratio, and Bonaire's ratio is also relatively high (though 15 times less than Curacao's). Puerto Rico is, once more, a good comparison, and it also is very high on this index. This is due, again, to the relatively low natural inputs into these island economies, and the high intensity of development, especially on Curacao.

Table 15 compares several other countries on this ratio. In general, high economic / environmental ratios suggest a highly developed economy, a potentially high level of environmental stress (low resilience), and a need for vigilant management of environmental systems. Such economies must feedback large emergy flows to environmental management, or risk contractions when inevitable natural perturbations occur (hurricanes, droughts, insect outbreaks, etc.). One of the largest feedbacks on these islands is the maintenance of a fresh water supply. This need has been met with saltwater desalination, a very expensive feedback of goods and services that make the islands livable at high population densities. Another feedback example is the Bonaire Marine Park. Tough regulations exist on scuba diving and ship moorings to protect reef structure. Commercial fishing is restricted on the reefs to retain fish populations. Wastewater sewage is a problem that is being addressed. A team of resident biologists monitors and manages the Park. The regulations cost money, services, and fish to the local economy.

Table 15: Economic / Environmental Ratio
Data values are in APPENDIX A, Table 4.

Country	Ratio
Papua New Guinea	0.21
Bonaire 1950s	0.56
Brazil	0.74
New Zealand	0.80
Australia	1.10
World	2.4
Taiwan	2.8
Netherlands 1980	3.3
U.S.A.	7.1
Bonaire	12
Puerto Rico	46
Netherlands Antilles	169

Percent Environmental Emergy. This measure is identical to the Economic / Environmental Ratio, given as a percentage (Table 13, Item 4). In other words, for example, 23% of the emergy flows in the Netherlands in 1980 were environmental flows.

Percent Renewable Emergy (Environmental Loading). This percentage is similar to the last, however, it includes only environmental emergy sources that are renewable (Table 13, Item 5). Notice that the Netherlands drops to 6% in this measure, because most of its "environmental" emergy is in the form of natural mineral storages of oil and natural gas, located within its borders. This measure, perhaps more precisely than the previous two, can indicate a developed, market economy, and an economy that requires greater feedback to maintain natural renewable systems.

Table 16: Percent Renewable Emergy (Environmental Loading)
This table shows the percent of emergy entering a region that is renewable. The remainder is supplied by non-renewable sources or is imported from external economies. Refinery islands such as Curacao (Netherlands Antilles), Puerto Rico and Taiwan are highly subsidized by non-renewable fossil fuel sources. World economies today are on average supported by 60% non-renewable emergy and 40% renewable. Notice that the estimate for Amerindian Bonaire is less than 100% renewable. This is intended to represent the theoretical argument that prehistoric agriculture was not indefinitely sustainable without further technological innovations because it depletes slow- or non-renewable storages like topsoil, forests, or desirable stone. Additional values are calculated from (Odum 1996a).

Country or State	Renew-able %	Country or State	Renew-able %
Netherlands Antilles	0.37%	Dominica	27%
West Germany	1.1%	Scotland	36%
Puerto Rico	1.6%	Japan	37.5%
Taiwan	4%	**World**	40%
Netherlands 1980	6%	Australia	48%
Bonaire	6%	Thailand	48%
Texas	6%	India	50%
Italy	9.5%	New Zealand	55%
USA	10%	Brazil	59%
Switzerland	12%	**Bonaire 1950s**	63%
Spain	12%	Ecuador	65%
Sweden	12.5%	Papua New Guinea	87%
China	13%	Liberia	92%
Mexico	23%	Alaska	92.5%
Soviet Union	24%	**Amerindian Bonaire**	98%

Global ecological economics

The final two indices in Table 13 indicate the positions of nations within the global economy.

Emergy / Money Ratio. This important ratio is calculated by dividing the total emergy used in an economy by the money expended for final purchases in an economy (the Gross Domestic Product, GDP) (Table 13, Item 6). For example, the emergy/$ ratio of the U.S. measures the amount of emergy used in the U.S. economy for each dollar spent.

Money is a technology. As discussed in the section, Hierarchy and Convergence in Markets, in CHAPTER 16, money is an ancient technological innovation that permits exchanges to be deferred in space and time. It is a placeholder for goods that, by the nature of agricultural cycles or geographical distance, cannot be exchanged at the same point in space or time.

Money is paid between people. People do work in planting, harvesting, manufacturing, and transporting a good. Money is paid to people for that work. However, in thermodynamic terms, ecosystems do a great deal of work in the natural production of a tree, coral reef, or field of corn. The intention of ecological-economic currencies such as emergy is to produce a measure of value that represents the contributions of work from both people and nature. Therefore, the emergy values of natural resources or agricultural products is usually higher than the market value (except during scarcities) because that value reflects ecosystem work, plus the human services that contribute to mining or harvesting and transportation.

Emergy/money ratios are higher when much of the emergy in an economy is environmental. The reason is that money in an economy only pays for human services. Money is not paid to a tree when it is cut, or a mine when it is dug. Money is only paid to the people for their services in cutting, digging, etc.. Money is paid for processing and delivering, but not for the work provided by an ecosystem to build topsoil, deliver rainwater, etc.

The emergy/money ratio indicates how much work has been done in an ecological-economy in relation to the money flows in the economy. In countries with high emergy/money ratios, much work was done by both people and nature to produce a product. Therefore, in such countries, when people pay money for a product they receive more emergy for that money. Within an economy, this is acceptable (though imperfect) because all persons are using the same currency. However, when countries with high emergy/money ratios sell goods to countries with lower emergy/money ratios, they receive a price that greatly undervalues the goods they have sold. In reverse, when they purchase goods from a country with a low emergy/money ratio, they receive a price that still undervalues the goods they receive (because only services are paid), but much less so. The result is systematic exchange inequity[2].

Exports / Imports Ratio. This measure (also called the Emergy Yield Ratio) indicates, in emergy terms, the relationship between the national exports of emergy and national imports (Table 13, Item 7). In other words, it measures the global equity of international exchange for a country. In principle, this ratio should be 1.0 for all nations, indicating that exchange is equitable in emergy terms. Table 13, however, indicates that this is not the case. In stepwise fashion, moving from Bonaire 1995, to the Netherlands Antilles, to the Netherlands, to the U.S., this index moves downward, beginning above 1.0 in the periphery and moving below 1.0 at the core. Systematically, core nations that import substantial environmental goods from their peripheries receive a windfall of emergy. This process is discussed further in the next section.

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[2] The process is actually more complicated than this, because international transactions of goods are usually preceded by the purchase of foreign currencies in money markets. However, this intermediate step has no effect on the process described.

Bonaire within the US-EC-Japan World System

This diagram and the next (Figure 94, Figure 95) depict Bonaire's world system context. The design of this diagram is taken from CHAPTER 16, Figure 202. As discussed on page 397ff, it may be that a massive free market world system is emerging that includes the US, the EC, and the Japan regional systems. Figure 94 depicts such a system, including Bonaire within its periphery.

Figure 94 shows world regions linked by trade. Each region has its own sources and storages of renewable, slow-renewable, and non-renewable resources. Each region has consumer symbols representing Elites and Non-Elites (except Bonaire, which has no world system elites). It is understood that additional, not shown, social hierarchy and division of labor exist within both Elite and Non-elite consumer groups. In the diagram, one core region is depicted, within which transnational entities concentrate vast resources, and feed them back for amplification effects.

While the exchange of goods and services travels in both directions between the periphery and the core, because of the high emergy value of primary commodities (higher emergy/money ratio), the core gains greater wealth at the expense of the peripheries. This is demonstrated by the values that were calculated for flows in the national emergy analyses in APPENDIX A, and which are shown in Figure 94. Note that Bonaire exports 7.0 E20 sej/yr, while it receives in imports only 5.1 E20 sej/yr. Note particularly that in emergy terms, the imports that enter the Unites States are ten times the value of exports that are traded in return, i.e., 81,060 E20 sej/yr are imported and 8,700 E20 sej/yr are exported in return (the US values are shown on the diagram as indicative of the Core, but are only part of the Core). This is overwhelmingly due to the high-emergy, primary commodities that are imported from the "developing" world. Finally, note that the Netherlands receives only slightly more in emergy imports than it receives in emergy exports, which places it within the Core, but at a lesser standing than the US.

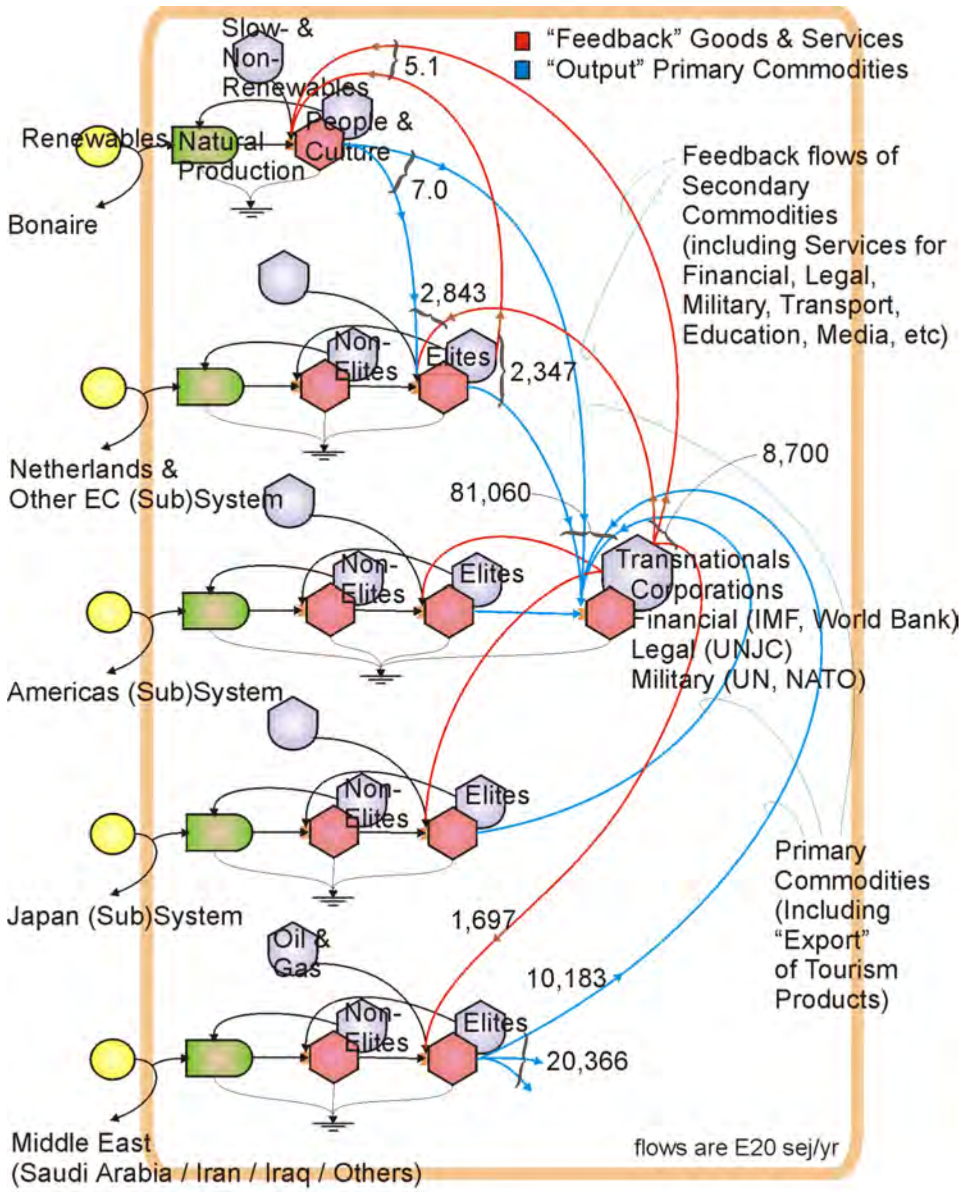

Figure 94: Bonaire within the US-EC-Japan World System
Note the asymmetry in emergy flows between imports and exports. As a Core nation, the US imports nearly ten times more emergy than it exports. As a Periphery, Bonaire exports significantly more emergy than it imports. This pattern defines the international relationships within a World System. Note that the Middle East numbers are a very rough estimate for illustrative purposes, based on total exports of 6.11 billion barrels/day (Youngquist 1997:169) and a 6/1 emergy yield for oil. Assume that the US-EC-Japan system gets half of Middle East production, and pays for it with 1/6 of the emergy. Other numbers are from APPENDIX A, APPENDIX B, and (Odum 1996a).

It can be suggested, as demonstrated in the world system simulation in CHAPTER 16 (Figure 201), that this social asymmetry emerged as small initial emergy advantages were amplified in a time when emergy storages in the world were sufficiently high to fuel growth. This amplifying, autocatalytic behavior is a fundamental process in the self-organization of complex sytems.

Bonaire within the US-EC-Japan World System (Ver 2)

The diagram of Bonaire's world systems context (Figure 95) is an alternative depiction, following model and discussion for Figure 196. This format shows one aggregated Non-elite consumer and one aggregated Elite consumer. In addition, a single aggregated Non-elite consumer has been added to represent Bonaire.

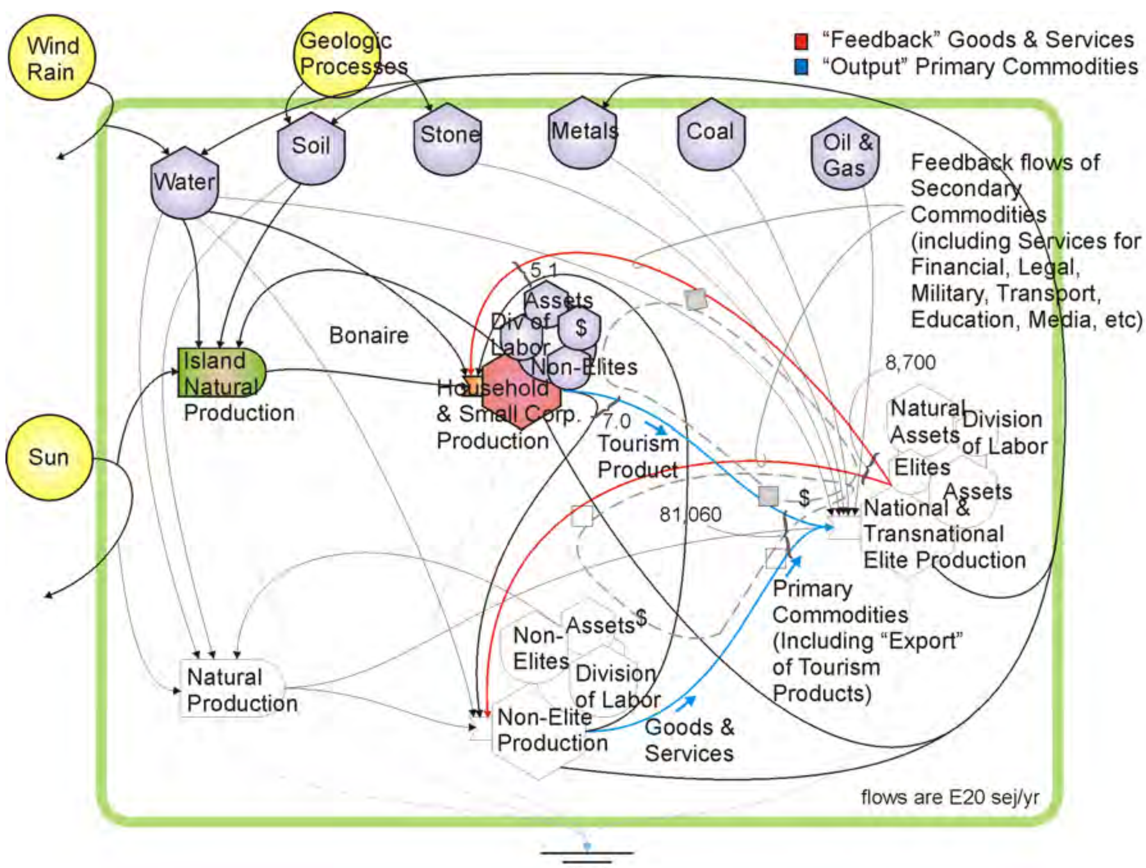

Figure 95: Bonaire within the US-EC-Japan World System (Ver 2)
Numbers are from APPENDIX A, APPENDIX B, and Odum (1996a).

The diagram emphasizes the role of Elites in the capture and control of large storages of very productive assets (oil, gas, coal, metals, stone). This concentration of assets is then used to feedback and amplify production within the system. Specific assets have very important feedback roles. These assets are listed to the right in the drawing, and are discussed in CHAPTER 16.

Bonaire and the Netherlands and the Netherlands Antilles

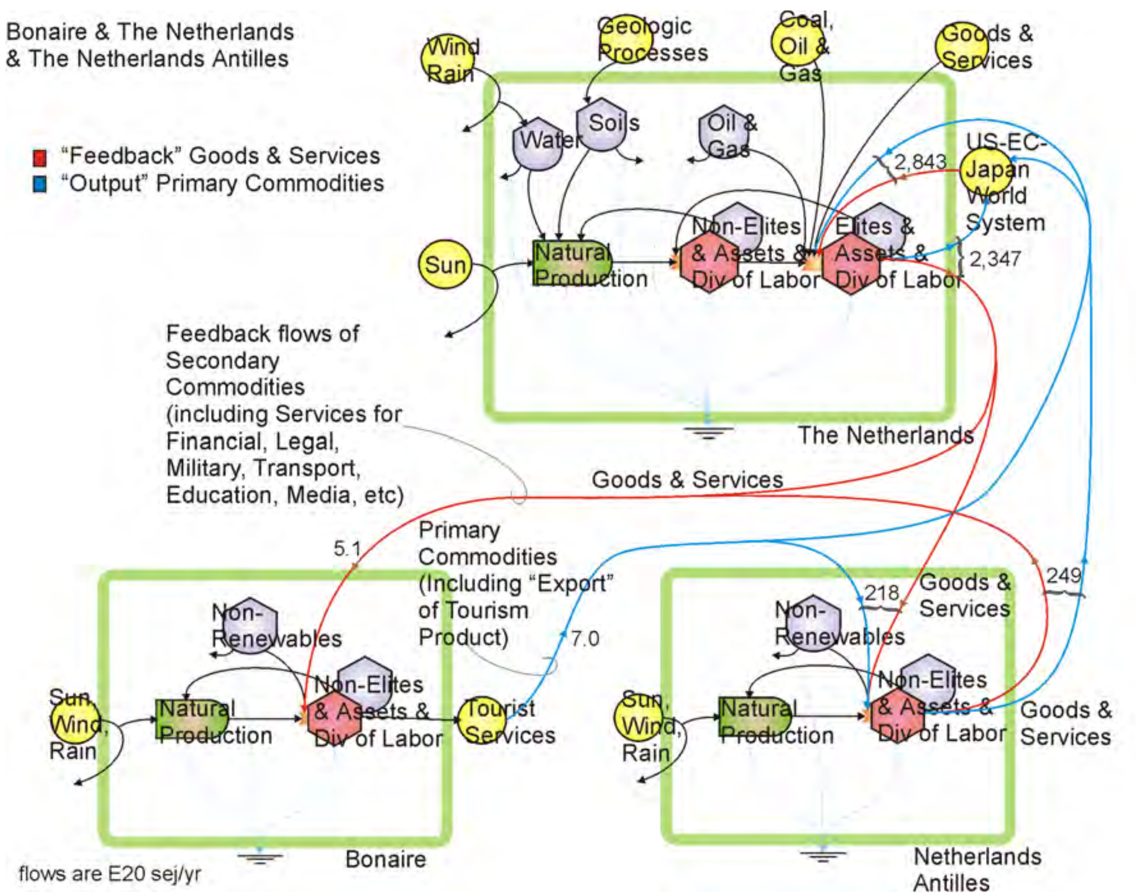

Figure 96: Bonaire in Dutch Context
The same general pattern of asymmetrical exchange is visible for Bonaire within its Netherlands Antilles and Netherlands context. Numbers are from APPENDIX A, APPENDIX B, and Odum (1996a).

This multiple box format (Figure 96) is a common way to represent the relationships between geographic regions. The individual diagrams are highly aggregated. As in the last section, the important feedback assets entering Bonaire from the larger system are accentuated. Bonaire's primary output is tourism, which is here and elsewhere treated as an export.

CHAPTER 9
NATURAL SYSTEMS E*M*ERGY

Over evolutionary time, life has transformed its material surroundings. We know that the contemporary atmosphere rich in oxygen, sea chemistry, and sedimentary land formations, all bear the imprint of life. In a sense, life has negotiated its place on earth, transforming by its presence, and channeled by earth limits.

Figure 97: Northeast Coast
Energy sources for ecosystems are sun, wind, rain, tide, and earth deep heat. The cycles of life, energy and materials in ecosystems are visible wherever we look. For example, this photo was taken from atop a once living coral reef. It has since been uplifted by geologic processes to form a limestone terrace. The rock terrace is now being weathered by sun, wind, and rain to release nutrients for soil formation. Soil nutrients will soon be reincorporated into new life, this time terrestrial plants.

Re-stated from a global perspective, life evolved as parts within ecosystem wholes. Ecosystems have self-organized over evolutionary time within the open energetic systems of the earth. Solar energy and earth deep heat are the energy sources that move mountains, drive ocean currents, create weather, and cycle materials (Figure 97). Ecosystems emerged within open earth systems, and are inextricably conjoined with them.

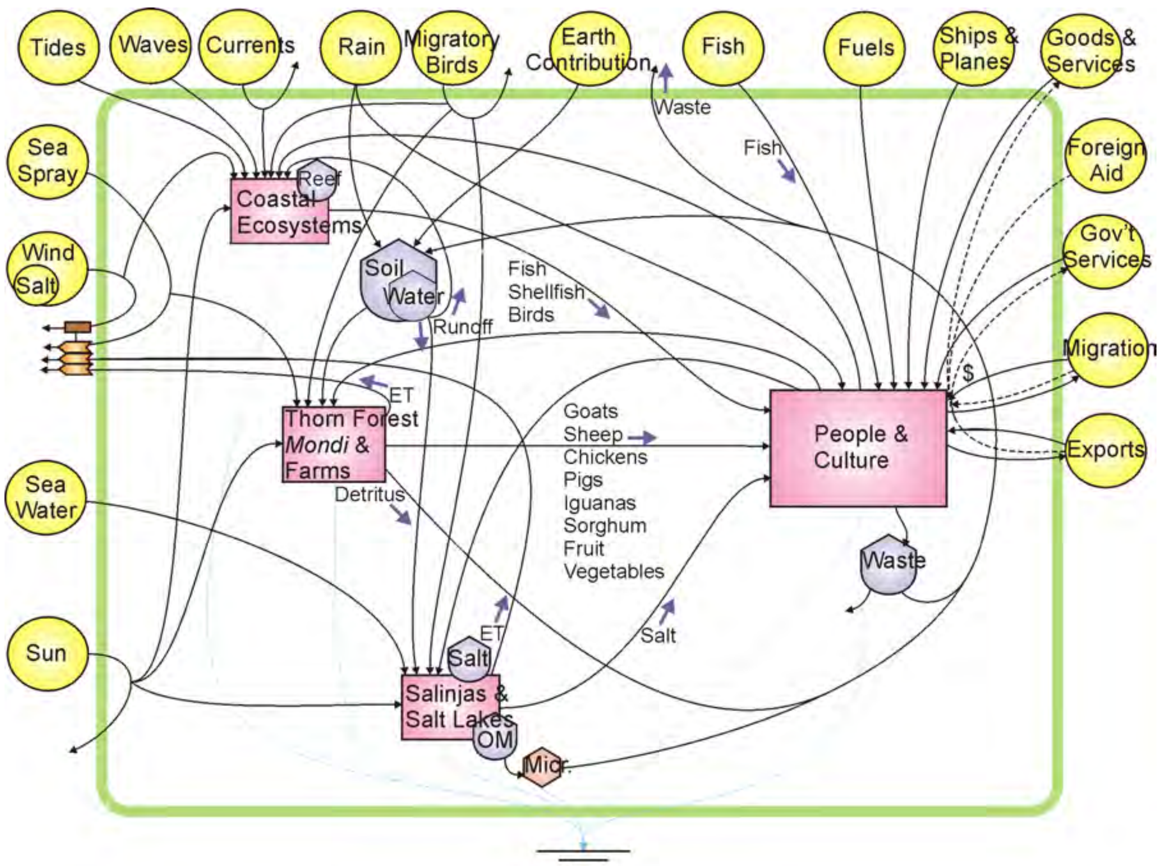

Figure 98: Bonaire Natural Systems
Bonaire's natural systems are aggregated into the three shown here and discussed in CHAPTER 4, Coastal Ecosystems, Thorn Forest, and Saliñas & Salt Lakes.

The contemporary human-ecosystems of Bonaire were described in CHAPTER 4, and are depicted in Figure 98. As all ecosystems, Bonaire's natural systems are driven ultimately by energy from sunlight, and earth-lunar gravity. Sunlight interacts with land and sea to form rain, wind, waves, and ocean currents. The moon creates tides, and earth deep heat fuels earth cycles that drive earth geology. These energy sources are depicted for Bonaire in Figure 98 as primary sources (yellow circles, furthest to the left).

For over three thousand years the ecosystems of Bonaire have been human-ecosystems (see CHAPTER 3 for a chronology of contact). In that time humans have deliberately modified and simultaneously self-organized with the natural systems of the island to great effect. Figure 98 and Figure 99 depict the plants and animals that are used by contemporary people. Additional and very important emergy sources flow into the modern economy to support Bonaire's fourteen thousand inhabitants. The feedback effects of the human inhabitants on the island ecosystems are depicted as flows moving from right-to-left, from people back to ecosystems.

The Bonaire system today uses both renewable, non-renewable, and purchased emergy sources. The sources on the right side of Figure 98 represent imported goods and services. Per CHAPTER 8, Figure 85, the purchased emergy to the modern Bonaire economy exceeds the renewable emergy inputs. Today 6% of emergy inputs to Bonaire are local renewable sources. In Amerindian days this would have been perhaps 98% (with 2% non-renewables like stone, or slow-renewables like topsoil). In the 1950's this percentage is estimated to have been 63%.

Thorn Forest Production and Island Natural Sources

The emergy analysis of APPENDIX A quantifies the natural emergy sources that drive the Bonaire Island system. The primary renewable emergy source for the island is rain (chemical potential energy). This might seem surprising considering the relatively low, half-meter rainfall that reaches the island each year. However, rainwater represents the convergence of energies from sea, land, and air over great distances. Rainfall events embody vast contributions of work from the biosphere. It should be no surprise therefore that systems make many uses of rainfall. Rain moves mountains, literally, by eroding them and exposing nutrients that plants use (Figure 97). Rain converges organic matter into highly productive riverine and estuary ecosystems. Most significantly perhaps, rainwater is evapotranspired by plants, which use the chemical potential energy of fresh water to carry nutrients to immobile roots.

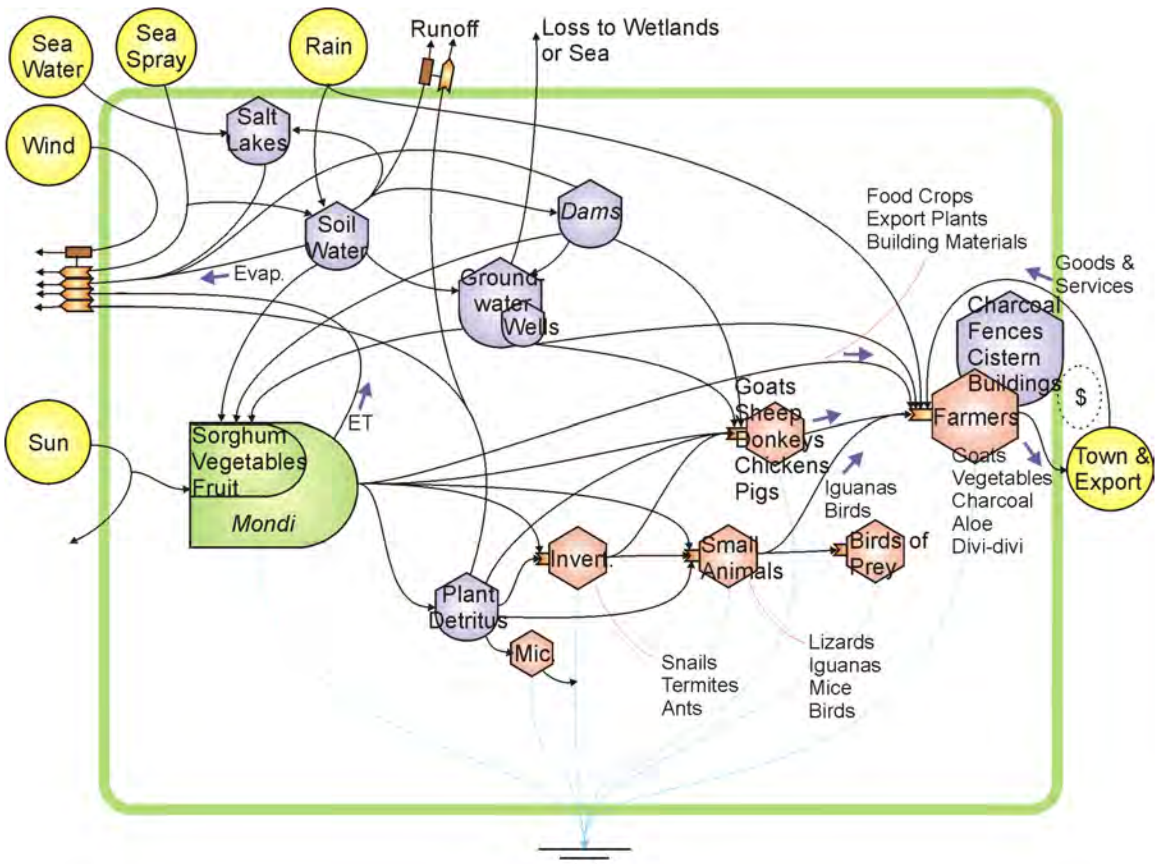

Figure 99: Thorn Forest (*Mondi*) Ecosystem

Wind and wave emergy are also very high sources for the Bonaire natural systems. This is not surprising considering a year-round easterly tradewind that *averages* 14 mph (van Duyl 1985:4), and builds consistent waves of over a meter on the east coast. For summing the total renewable emergy sources for Bonaire natural systems, we cannot add wind, waves, sun and rain together, because they are all products of the atmospheric systems that are driven by solar energy. Summing them would be counting them twice. The largest, the rain emergy, is therefore selected to be added to the remaining renewable sources of tide, ocean currents, and uplift, which are the products of larger-scaled earth systems.

The Thorn Forest ecosystem is depicted in Figure 99, and is described in detail in CHAPTER 4. Rainfall, sun and wind are obvious major sources of emergy for this ecosystem.

Coastal Systems

About half of all renewable emergy that reaches the island ecosystems arrives in the offshore Coastal systems (APPENDIX D2). This should not surprise anyone who knows the flourishing reefs that surround the island and attract scuba divers from around the world. Figure 100 identifies the renewable sources of sun, wind, waves, currents, tide, and uplift that converge on the coastal zone.

Wave energy is the largest single contribution to the Offshore Coastal system. Strong, consistent tradewinds build waves that break on the rock and shell coast or crash into rock cliffs (Figure 19, CHAPTER 4). Again, sun, wind, waves and rain are all produced by the same solar powered atmospheric systems. Adding them together would be double-counting, and therefore only the largest--waves (102,659 E14 sej/yr)--is counted in the coastal total. Ocean currents, tide, and earth uplift are products of larger hemispheric and global systems. They can thus be added to the waves-value to produce a total for the Offshore Coastal system.

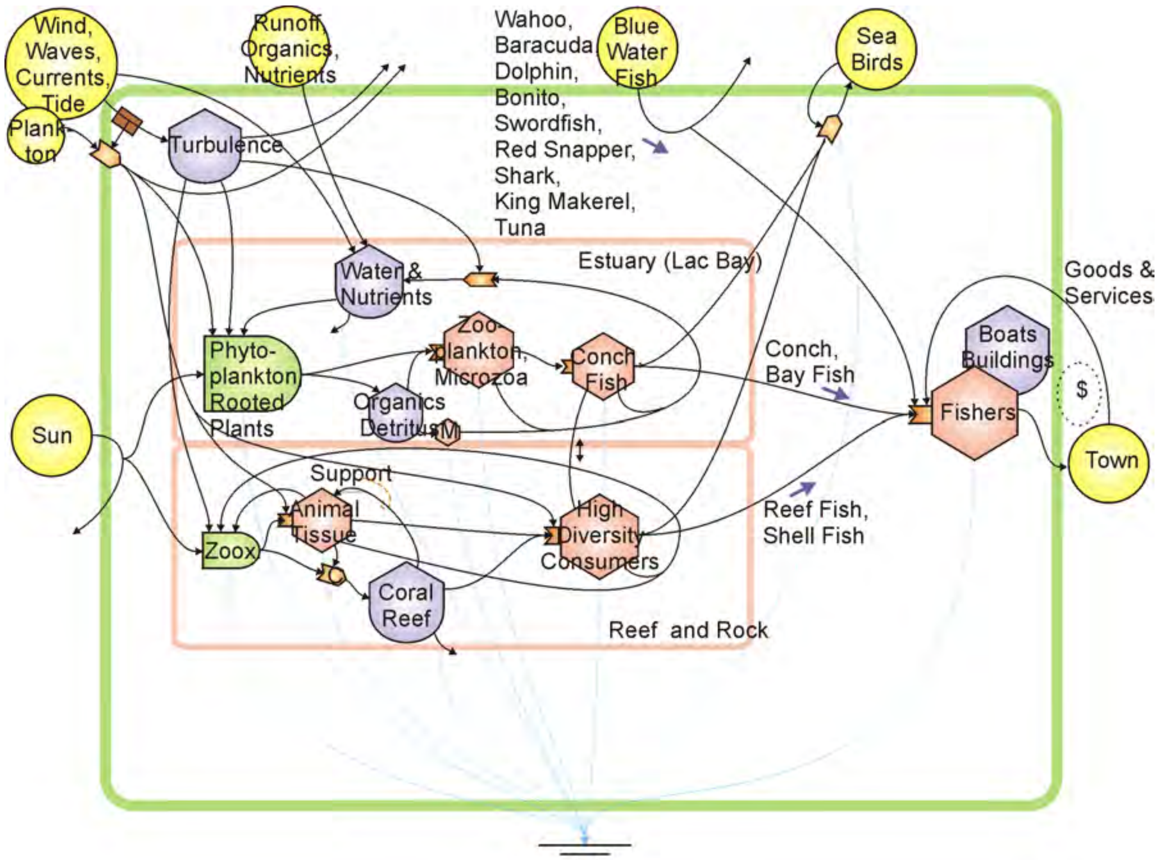

Figure 100: Coastal Sytems

The Inshore coastal system on Bonaire is the Lac Bay estuary. This large, shallow bay is carpeted with sea grasses and provides a nursery for many fish and shellfish species. In addition to the marine sources that enter the offshore system, Lac Bay receives significant organic run-in from seasonal river courses called *rooi*'s that turn brown with organics and silt after heavy rains. The last remaining mangroves on Bonaire fringe portions of the bay and nourish fish and birds alike (Figure 24, CHAPTER 4). In emdollar terms, this single bay contributes over 1 million emdollars per year of environmental work to the Bonaire economy.

Figure 101: East Coast Coral Reefs
The wind-sheltered East Coast is ideal for coral reef formation. The narrow shelf profile of Bonaire allows reefs to grow close to the rocky coast.

***Saliñas* and Salt Lakes**

Emergy analysis of this third major ecosystem was not performed (but see Salt Works analysis, APPENDIX Q) (see Figure 147, CHAPTER 12). However, from Figure 102 it can be seen that the probable driving emergies are Sun, Wind, Rain, Run-in (with suspended organic matter), and Groundwater Seepage. The large salt lakes of Bonaire are an unusual phenomenon that is created by high solar radiation, low rainfall, and permeable barriers to seawater. Medium salinity salt water is pushed through permeable rock and shell barriers into the salt lakes when water levels are dropped by evaporation. Evaporation exceeds rainfall on Bonaire 10-11 months of the year (Stinapa 1982:34). The salt lakes themselves have areas of lower and higher salinity, as depicted in Figure 102, each supporting different flora and fauna.

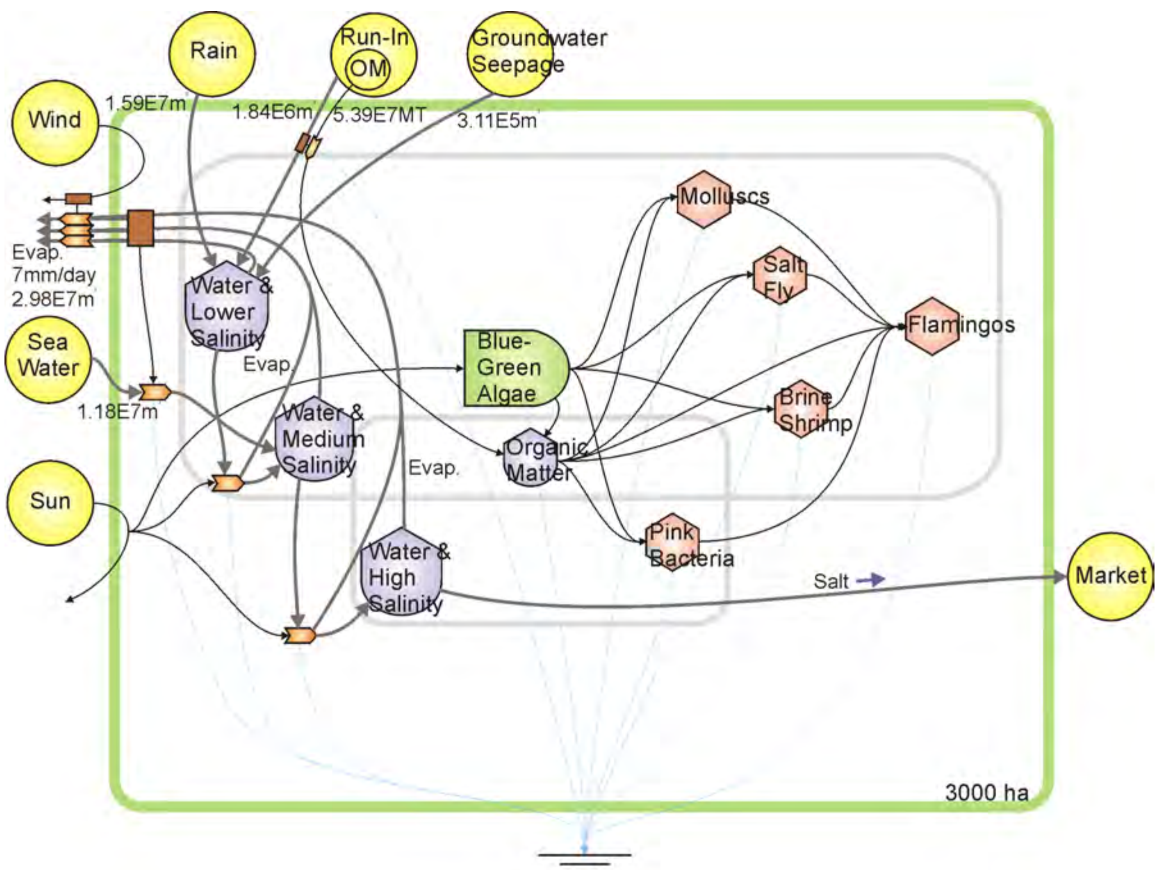

Figure 102: Saliñas and Salt Lakes
Sunlight evaporates lake water, which is carried away by wind. Rain exceeds evaporation only 2 months of the year on Bonaire. When water is evaporated, seawater is forced through permeable rock that divides sea from lake. With increased evaporation, the salinity of the salt water is increased. Pink bacteria can live in high salinity. Salt crystals form in natural and human-made shallows of the lakes. In the past, salt was collected from several salt lakes on Bonaire. Today only the salt from the Akzo Nobel salt works in the south is mined and sold.

Figure 103: A Large Salt Lake in the Northwest (*Gotomeer*)
Home to flamingos and brine shrimp, this large lake is cut off from the sea by a narrow barrier of rock and shell. High evaporation maintains the salinity of the water.

CHAPTER 10
WEB OF SOCIAL-ECONOMIC PRODUCTION SUBSYSTEMS

Human subsistence production on Bonaire is manifest in a web of market and non-market production subsystems. The features of this drawing depict the unique nature of the Bonaire web of social-economic production subsystems.

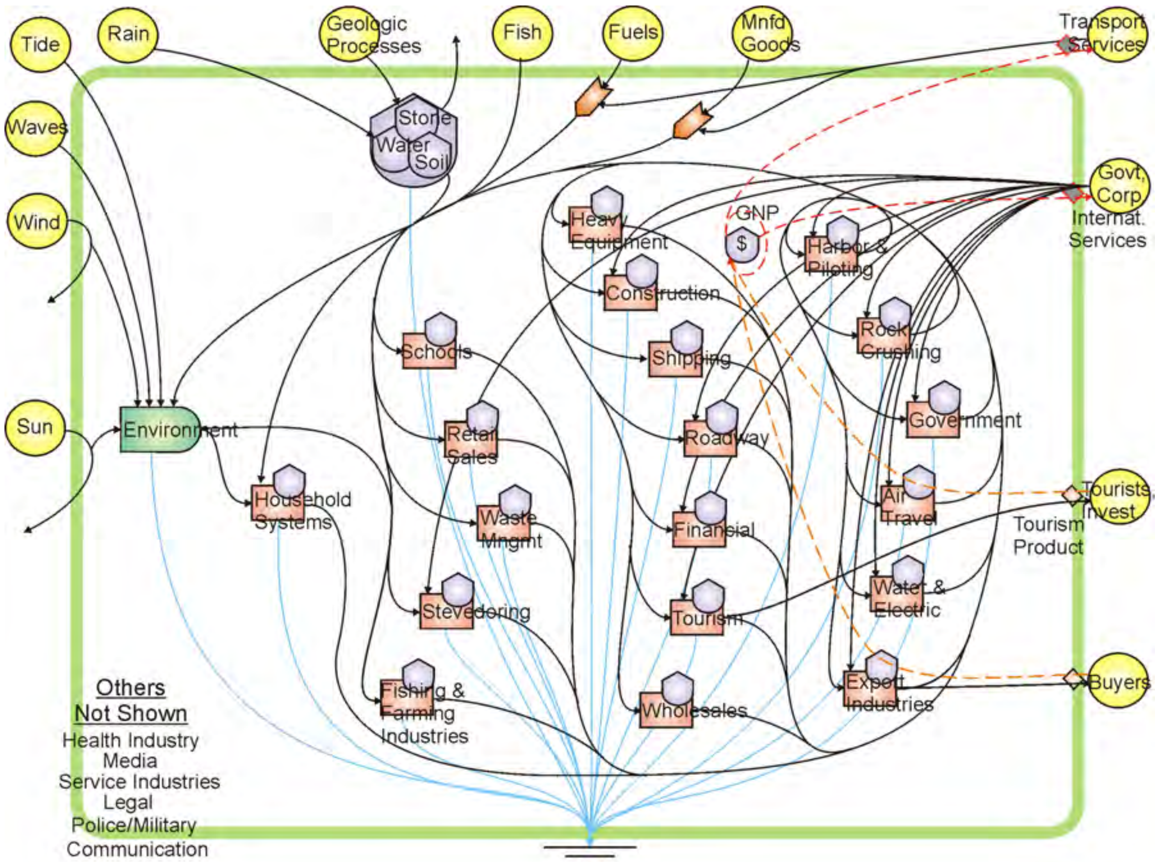

Figure 104: Web of Social-Economic Production
Compare this drawing with an alternative version in Figure 108.

Bonaire does not possess every conceivable economic production subsystem. As a small island with few mineral resources, Bonaire has very little primary economic production. There are no fuel or metal sources mined locally. There is also no heavy industry. These vital ingredients to Bonaire's system are imported, represented by the "Fuels" and "Mnfd Goods" shown coming from outside the boundaries of this diagram. This drawing provides a way to depict the production subsystems that do exist on Bonaire, and how they are related to one another.

In Figure 104, the subsystems are arranged in the web (or hierarchy) in accordance with the emergy analyses conducted on each (see following chapters and appendices). Figure 105 shows the per establishment emergy inflows to companies within each of the subsystems. For example, the total emergy inflows to the Retail Sales subsystem is calculated to be 503,429 E14 sej/yr, however with 151 companies (many small Snacks), the emergy per establishment is only 15,483 E14 sej, which places it low in comparison, and thus to the left in the web.

This analysis produces a web that is analogous to an ecosystem food web. Lower trophic levels of an ecosystem contain numerous individual organisms that attract a small percentage of available emergy inflows individually, but that process great quantities of available emergy, concentrating it, and making it available to higher trophic levels. In an economy, production subsystems on the left of the diagram capture dispersed resources and concentrate them. Production systems on the right have larger storages of assets with slower turnover times, and have bigger feedback effects when applied to other subsystems of Bonaire society.

Wage labor should be understood to feed into each of the subsystems (see the aggregated diagram, Figure 107), and could have been drawn with a paired "Wage Labor" symbol for each of the subsystems. Wage laborers are reproduced within a Household Production subsystem that is linked to market and non-market sources (see Households, CHAPTER 7).

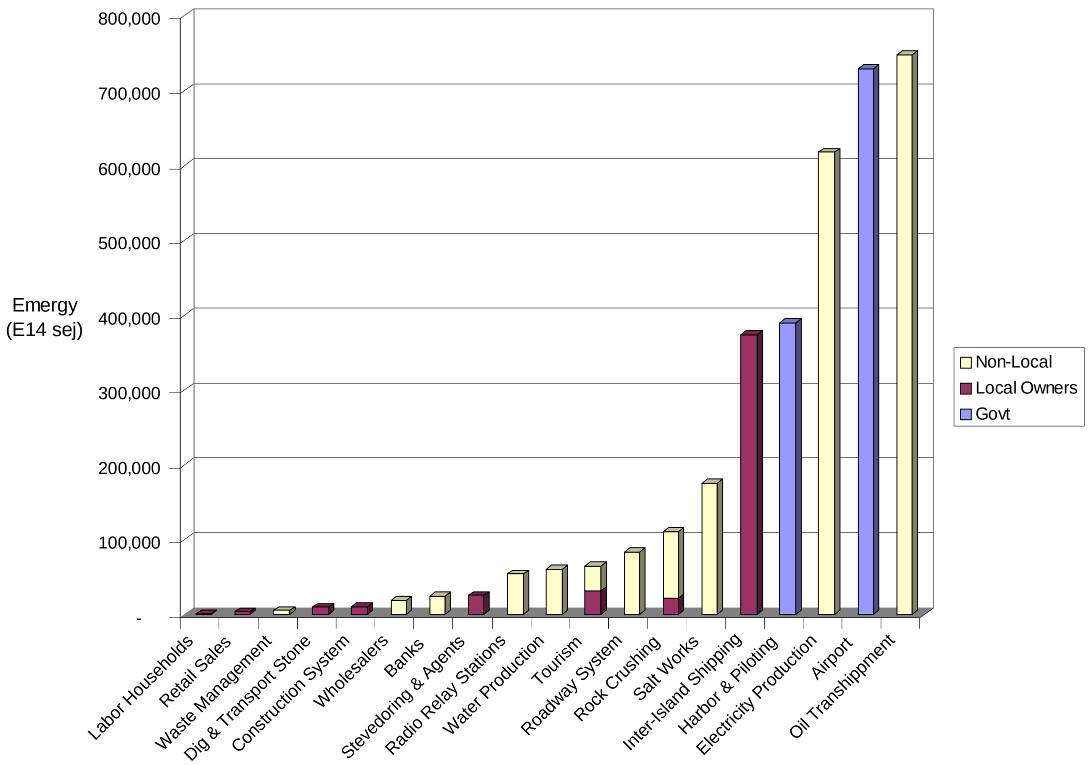

Figure 105: Emergy Inflows *per Establishment*
See individual emergy analyses in the appendices for data values.

The Figure 104 drawing shows each production subsystem connected to every other subsystem. This is a hypothesized relationship, and may not hold in fact. It is however important to expect a high degree of interconnectedness between subsystems as they self-organize.

Foreign Owners, Lenders, and Governments are important sources of resources in the creation and support of Bonaire production subsystems. They are represented by the symbol to the right (Govt., Corporate, International Services), with flows of goods and services leading to many subsystems (many high-transformity subsystems). This suggests Bonaire's high degree of dependency on the will of outsiders, and the feedback control that outsiders can levy on Bonaire. The dashed line leading out to these sources represents the flow of money that is returned for those goods and services in the form of taxes, loan payments and interest, and profits.

Bonaire's several export industries are shown with a flow leaving Bonaire and going to "Buyers." These export industries are unusual and weakly integrated into the rest of the Bonaire social-economic system. They include an oil transshipment terminal, a rice processing facility, a salt production facility, and two large relay-antenna farms. In return for these exported goods, some money enters the Bonaire system and is shown leaving the system for the purchase of Fuels and Goods and for payments of taxes and debt.

One final important source of cash to Bonaire is Tourism. It is depicted here as another "export" industry, with goods and services leaving Bonaire and going to "Tourists" and with tourist money entering the system and adding to the island money supply. This is a convention that was chosen here, but is not uncommon in discussions of the tourism industry. Most of the direct "product" of tourism is "consumed" by foreign tourists, just as export goods are consumed by foreign buyers. The difference is that the buyers travel to Bonaire to consume the goods.

The next four chapters will detail each of the production subsystems on Bonaire. The first will include the subsystems involved in the mining and use of stone on Bonaire, one of the few natural resources from the island that is an integral ingredient in the development process. The second chapter will describe the subsystems for shipping, importing, and exporting, which includes tourism and those other economic sectors that contribute to moving goods and services to and from the island. The following chapter will describe the role of government on Bonaire, which is intimately conjoined with economic development of the island. Finally, the fourth chapter will summarize the emergy analyses of the production subsystems on Bonaire.

Production Subsystems on Bonaire

The production subsystems identified for Bonaire are not a typical list of economic sectors. These categories are functional units/components of the island ecological-economic production system. The categories were not defined beforehand, but emerged from the systems analysis/diagramming, which incorporated economic thinking together with political, social and ecological principles (ecological principles cross additional disciplinary boundaries to synthesize physics, chemistry, biology, geology and other sciences). Unusual production subsystems like *Households* and *Schools* are the result, not traditional economic categories, but practical, functional groupings that emerged from this interdisciplinary analysis of a specific case study.

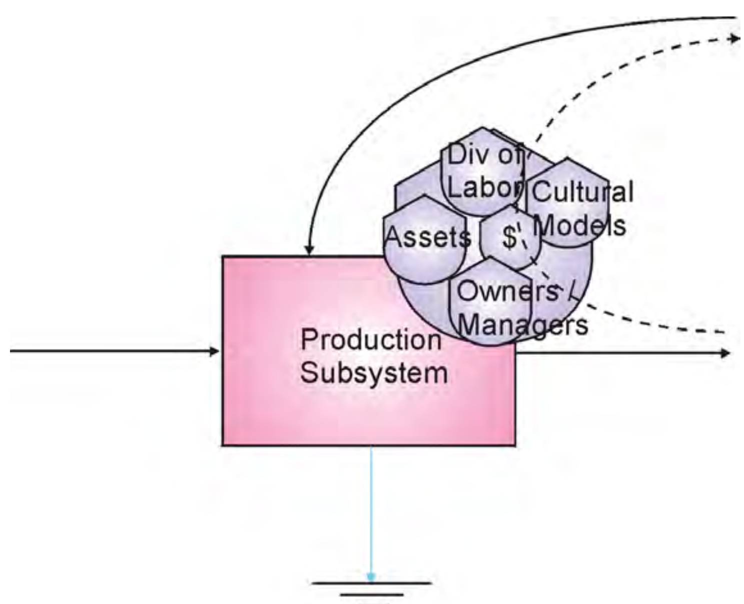

Figure 106: Production Subsystem

Production subsystems have inputs, interactions, storages and outputs of goods or services (Figure 106). The storages of a human-cultural system are typically Assets, Division of Labor (Diversity), People, and Cultural Models (CHAPTER 19). Assets are often the limiting component of a production subsystem. They are often manufactured in another subsystem and must be purchased by the subsystem, or supplied by some higher quality subsystem (such as government). Examples are the *Water Desalination* and *Electric Generation* subsystems on Bonaire, which have relied on government aid for purchasing high-technology desalination and electricity generation hardware. Lower technology assets in these subsystems are the delivery components--transformers, wires, water pipes, etc. The output from these subsystems is (delivered) electricity and (delivered) potable water.

The several "transport" subsystems (*Roadways, Shipping, Harbor & Piloting, Stevedoring*) are also defined with familiar and less familiar features. These are subsystems for the movement of people and bulk goods. Since early times, technologies have emerged that meet this need. In contemporary times, roads, wharves, and the vehicles that utilize them can be considered part of transport systems. Furthermore, the human services and hardware necessary for coordinating and scheduling those operations are also included (i.e., *Shipping Agents, Consolidators*).

On Bonaire financial aid has been paid for the construction of roads and wharves/piers. These objects are commonly labeled infrastructure, but this term obscures their place among other technologies. In prehistory, roads were a technological innovation for moving bulk goods or soldiers, just as were the wheeled carts that moved over them. Wharves or piers are similarly technological innovations for receiving or sending goods or people by sea. (See further discussion under Archaic States, CHAPTER 16) Financial aid for roads or wharves is funding for transport technologies.

Schools is another category with an unconventional meaning. School buildings can be understood as a technology. In the last few hundred years, the "school house" has evolved into a highly specialized, non-residential building. This building is a technological innovation for the intensive training of young people. Access to the building is tightly restricted to children and specially trained adults. As we all know from experience, the building walls provide isolated spaces for uninterrupted hours of training.

Schools are also a storage place for other technological innovations that enhance the training experience, such as science labs, books, maps, chalkboards, computers, etc. For these reasons, the label *Schools* was chosen for this production subsystem, emphasizing the school building as an extremely valuable technology for the training of our young. This meaning is not conveyed by the more common term education, which is a nebulous term referring simultaneously to psychological, physical, and social phenomena. The financial aid for schools is primarily funds for school buildings and equipment.

Air Travel is distinguished from transport as the production subsystem for moving people on and off the island of Bonaire. This highly specialized sector includes the assets for air travel. The principle asset is the airport itself. This technological innovation consists of huge, flat, slabs of concrete, lights, an airport terminal, and support equipment. Travel also includes the amazing high-technology aircraft that land and takeoff from the airport.

Tourism has been recognized as Bonaire's greatest potential "development" sector. The tourism industry depends on great stores of assets, many of which are located off of the island and are not controlled by Bonairians. Tourism operators, tourism advertising, air travel assets, booking and scheduling hardware, and others are necessary technologies for modern tourism industries. Even ecotourism depends critically on the international air travel industry, and upon multinational advertising corporations to create demand. Of course, Bonaire supports a tourism subsystem, the destination of an ecotourism vacation, and a small but vital portion of the tourism product. *Tourism* assets on Bonaire include hotels, a yacht harbor, restaurants, dive boats, tourism roads and beaches, nightclubs, and others.

Governments provide many services that can be considered independent of one another. In the systems design described here, *government* is not a single production subsystem, but is a loose affiliation of many. With IMF driven structural adjustment reforms, an increasing number of once government services are now being provided by the private sector, or are semi-private entities. Schools, Air Travel, Water & Electric, Police/Military, and others, are subsystems that could have been lumped under government, but this design would have been less useful. Some additional services, however, have been included here under the general category of *government*. These include raising taxes to fund the government, economic planning, land management, and some others (CHAPTER 13).

The *Construction* subsystem uses specialized storages of technology and labor in the construction of storages for the other subsystems. In other words, construction equipment and training are needed in the building of houses, roads, wharves, airports, etc. When funds are made available to build schools, those funds also maintain the storages of specialized construction equipment owned by construction companies. *Construction* is another of the few subsystems that is significantly subsidized by island natural resources. Limestone and volcanic sediments from the island are important sources for the subsystem. They have a high emergy content because they are produced by slow geologic and ecosystem processes.

Aggregated Social-Economic Production Subsystems

Figure 107 is a simplified or aggregated drawing that is based on the complex "web" drawing (Figure 104). Aggregated drawings are used to simplify analysis and focus on general patterns of resource flows within the drawing and with outside sources.

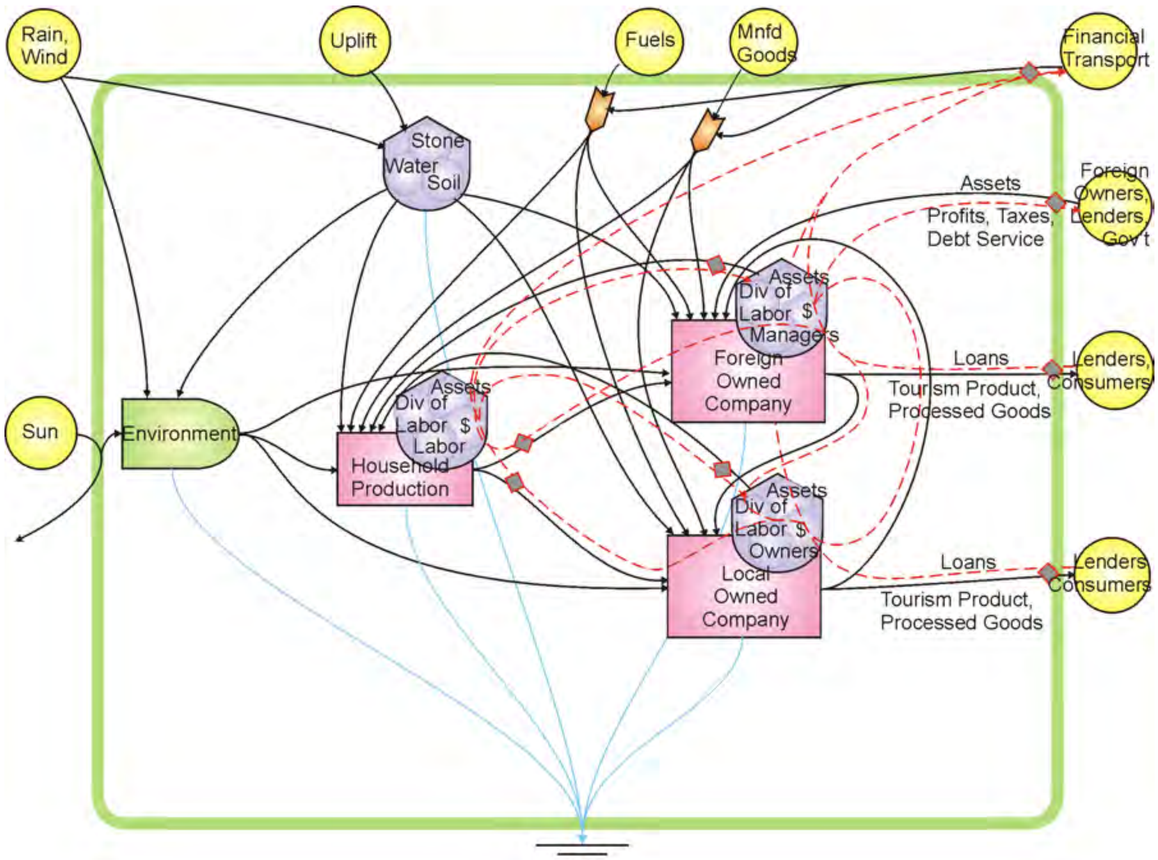

Figure 107: Aggregated Social-Economic System

The many economic sectors of production are here aggregated into the two Corporate Production symbols on this drawing. The distinction between the two Corporate Production symbols is "ownership" of the corporation. The upper symbol is Foreign-Owned Corporate Production, and it has an extra "input" of foreign goods and services coming from a source of "Foreign Owners, Lenders, and Gov't." A flow of money runs counter to the inflow of goods and services to pay for them.

Details of the three production symbols are visible. The Local-Owned Corporate Production symbol contains within itself a Household and Household assets. This is because the Owners of a company are also maintained in Households, build Household Assets, have a (smaller) Division of Labor, and reproduce themselves through their children.

The Foreign-Owned Corporate Production symbol may or may not include a storage of people. The owners do not live on Bonaire, and therefore no household gains directly from corporate assets. However, managers "control" corporate assets for the Foreign Owners and therefore wield much power in the company. Managers are rewarded by Foreign Owners with large salaries. In addition, they may be prone to manipulate the assets and money of the company to increase their personal storages of assets (i.e., when a manager awards a contract to a relative or friend and is later rewarded in some way).

The Local-Owned Corporate Production symbol is different in that it always has a storage of Owners. These persons own the corporate assets and will use them to amplify production to pull in more assets when possible. In this structure, the Household assets and Corporate assets are more overtly co-mingled, with one being used to amplify the other when possible (very "successful" Owners will buy larger houses, have larger savings, etc., which may in turn attract more assets to the business, as when perceived "wealthy" business owners are approached with other opportunities for expansion, diversification, etc.).

On Bonaire, the Foreign-Owned Corporate Production systems will probably have more corporate assets (i.e., large hotel assets "owned" by a foreign hotel chain) with less Household assets (i.e., a middle-class house "owned" by the hotel Manager). In contrast, a Local-Owned Corporate Production system may have more Household Assets, co-mingled with the Corporate assets (i.e., a local entrepreneur with a large estate).

The Foreign-Owned and Local-Owned systems shown here are not necessarily in competition with one another. While initially in the late 1980s, with rapid ecotourism development, many Foreign-Owned businesses appeared on Bonaire, with time a number of those interests have left Bonaire and a Foreign/Local division of labor has appeared. This is indicated in the Web of Social-Economic Production diagram (Figure 104) by the flows of Foreign goods and services that go to some but not all of the production symbols.

Alternative Web of Social-Economic Production Subsystems

Figure 108 is a second, alternative "web" diagram of production subsystems on Bonaire. Compared to Figure 104, the diagram emphasizes additional features of the web of subsystems, while de-emphasizing others. The same hierarchy of production subsystems is present (though less symmetrical and rigid in appearance), however the single "Households" symbol in the first diagram is greatly expanded here. This unusual feature of a systems diagram depicts the *hierarchy* of household niches that exists on Bonaire. In state societies, households produce labor that is economically specialized, which produces not one but many labor economic niches. These niches differ in their ownership and control of assets, and this feature places the households in the hierarchy (household niches with greater assets are located on the right). Recall that each of the locally-owned production subsystems also include the households of their owners. Those households are placed the furthest to the right on Bonaire because they control the greatest asset stores, and can feedback the greatest effects on the rest of the social-economy.

This diagram also depicts the divergence of goods into the Bonaire economy (see Hierarchy and Convergence in Markets, CHAPTER 16, for a more thorough discussion of trade convergence and divergence). A few production subsystems function to move goods to Retailers on the left, and eventually to Households. In the Bonaire social-economy, the goods and services are then re-converged to the right of the diagram. This convergence is typical in ecosystem webs, and is depicted in this type of left to right fashion in systems diagrams.

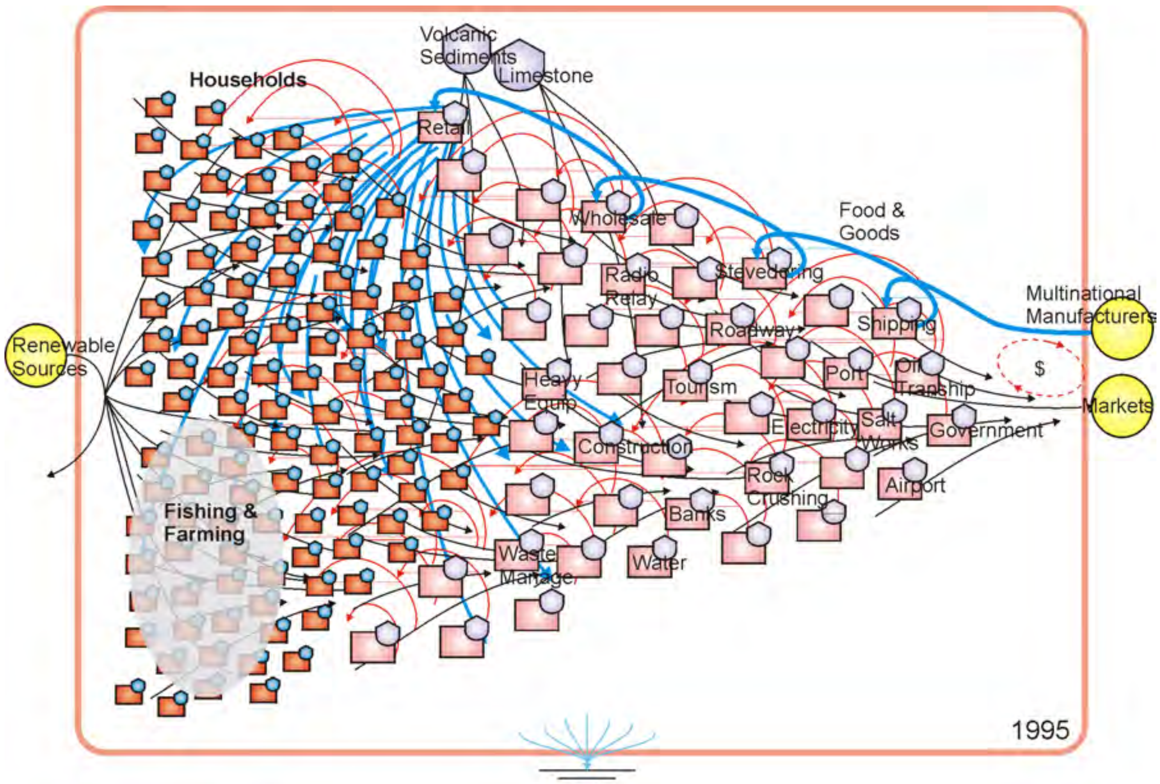

Figure 108: Web of Social-Economic Production (Ver 2)

Alternative Aggregated Diagram

Figure 109 is another aggregated view of the two web diagrams. Aggregated models simplify diagrams in order to accentuate the fundamental patterns and processes. This diagram depicts the hierarchy of households by showing two separate "Households" niches, and two "Company" niches, which also include Households. The Households are separated by function and by the size of storages of Assets. The Asset storages increase in size *per household* as the diagram moves from left to right, which is a basic principle of Hierarchy.

The Household figure on the left represents more individual households than the Household figures on the right. This is analogous to ecosystem web diagrams in which the Producer and Consumer symbols on the left represent many more individual plants and animals than do the symbols on the right of a diagram.

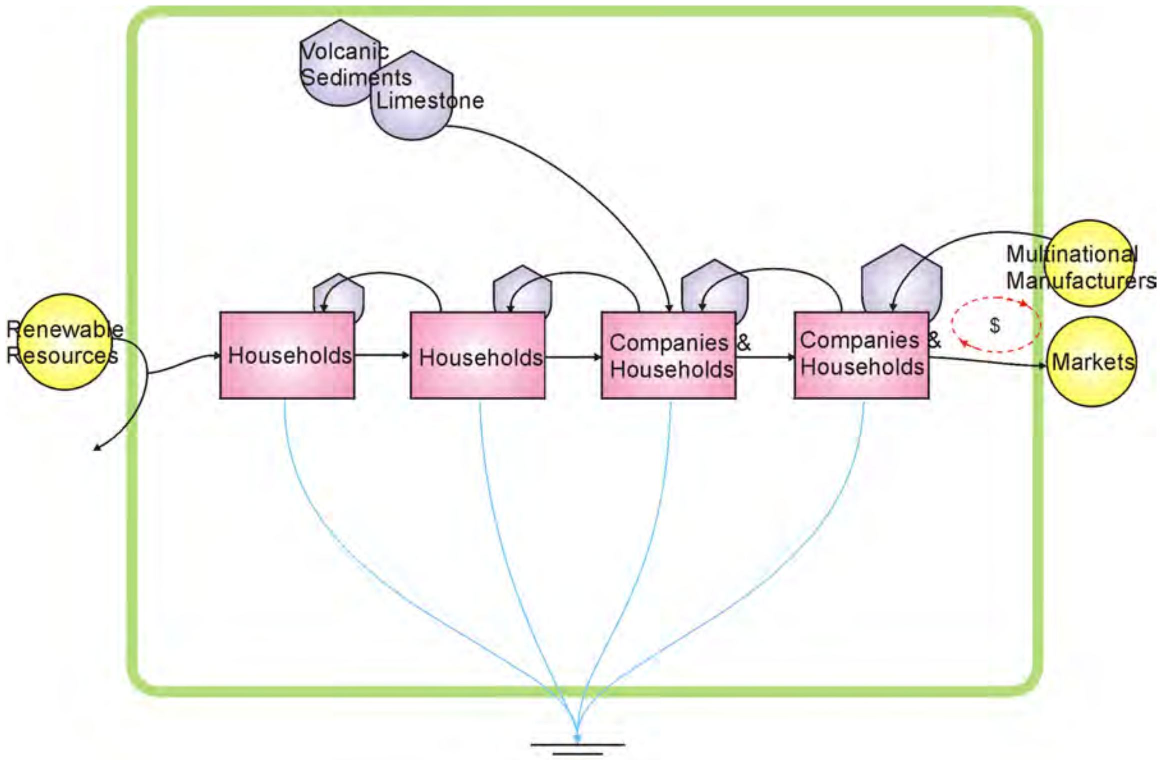

Figure 109: Aggregated Social-Economic System (Ver 2)

CHAPTER 11
STONE AND SAND FOR CONSTRUCTING MATERIAL ASSETS

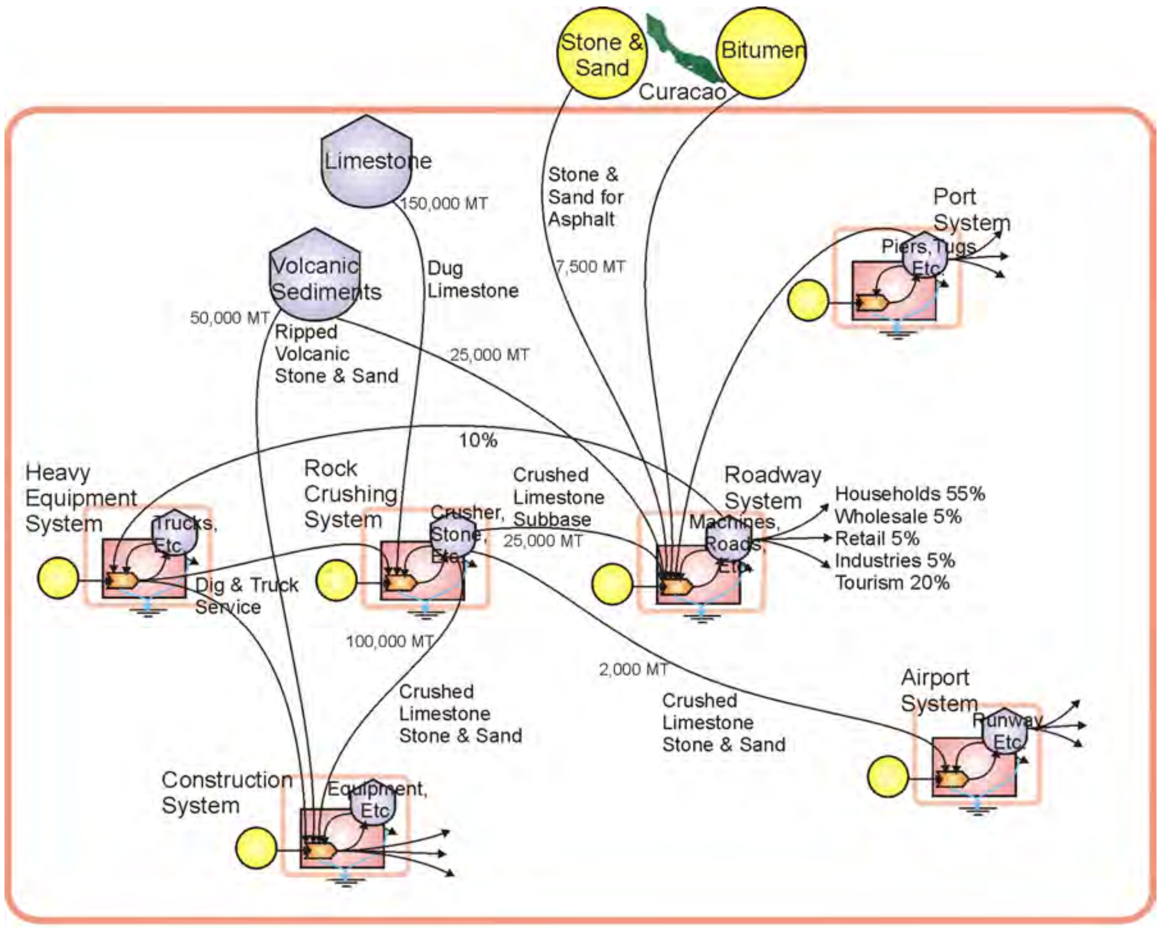

Figure 110: Stone and Sand on Bonaire
These production subsystems use or mine stone and sand from Bonaire. Estimates are shown of the quantities that are mined, and of their distribution. The properties of Bonaire's limestone make it insufficient for asphalt production, and some additional stone and sand is yearly imported from Curacao, along with the required bitumen. The port system makes this possible and is therefore included in the diagram. Other imported goods that feed each of these industries, such as gasoline, water, processed goods and services are not detailed, but are represented by the yellow source entering each of the subsystems. See individual emergy analyses for data values.

When thinking about economic development on Bonaire (and many other tourism sites), what comes to mind is hotels, beach-front properties, fragile reefs, and maybe expanding needs for water, electricity and waste management. Cost and benefits can be compared between clearing coastal property of vegetation and earning hotel foreign exchange, or between larger towns and waste management needs. However, in high-energy fossil fuel economies, the footprint of development is never confined to a spatially circumscribed development site. Development needs raw materials and processed goods. For typical development projects, natural resources are drawn from a wide domestic terrain of oil wells, bauxite mines, wood plantations, etc. None of these resources exist on Bonaire. Therefore the footprint of development on the island extends beyond its borders. Setting aside that issue, there are in addition a few natural storages that do exist on Bonaire, and that are susceptible to capture by development. These include groundwater, domestic goats, fish, thorn forests, and the limestone and volcanic island itself. The use of limestone and volcanic rock has expanded dramatically as development has funded growth. Stone and sand are largely Bonaire's environmental contribution to its own development and at least the toes in the ecological footprint of ecotourism.

Stone and sand feed any developed economy. Matched with fossil fuel energy to run tractors, make asphalt, mix concrete, and flatten roadbeds, stone and sand are essential ingredients to producing some of the basic assets of an economy. The mining and use of stone and sand have created local industries on Bonaire, and provided inputs to others like construction. It may be that the businesses on Bonaire most dramatically effected by economic development are those that process and use stone and sand.

Emergy analysis provides a means to evaluate the contributions of stone and sand to an economy, and to weigh those benefits against costs. Mining practices that strip large surface areas of topsoil reduce the natural production of thorn forests. In emergy terms, how do these compare? Mined stone and sand remain on the island, much of it used by locals, but some is "exported" in the tourism industry. How do the costs of exporting compare to the emergy benefits of tourism development?

Mining, transport, and construction are largely locally owned industries. As such, they are one of the major sectors of emerging economic hierarchy among locals on Bonaire. It other words, they are one of the few sectors in which some Bonairians have become relatively wealthy. Many Bonairians desire the success of the owners of companies in these industries.

Heavy Equipment Subsystem

Figure 111: Rock and Sand Truck

One of the most common sights today on Bonaire is a truck like this one (Figure 111) rattling along any road on the island. These trucks carry sand and rock from quarries to construction sites or to the rock crusher, they carry Curacao limestone from the port to the asphalt machine, and they move other bulk goods. Obvious inputs to this important industry are gasoline, parts, trucks, and the roads to drive them on. Figure 112 depicts the system. See APPENDIX G for the detailed emergy analysis.

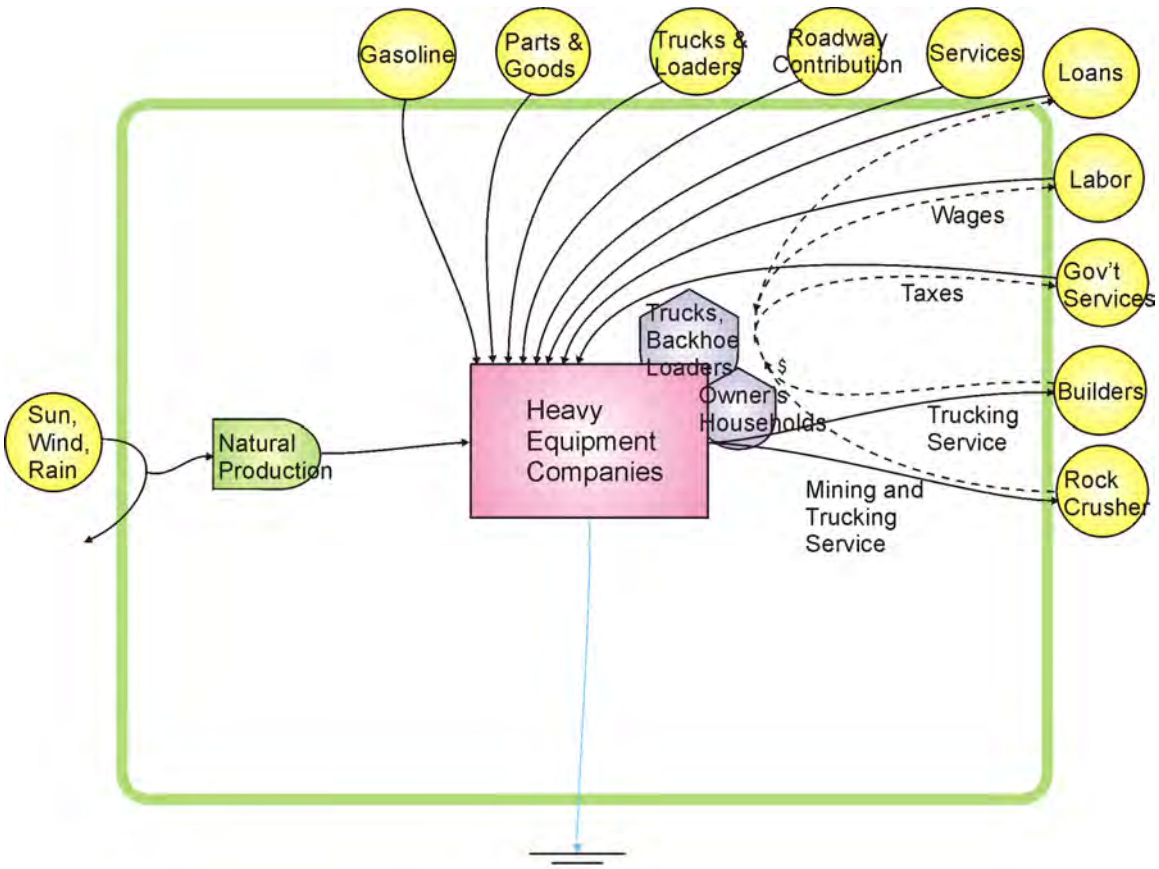

Figure 112: Heavy Equipment Subsystem

When compared to other industries (see CHAPTER 14), Heavy Equipment captures a relatively small amount of emergy. However, on a *per worker* basis, heavy equipment is in the middle of the range, which might suggest that it is a desirable job. Furthermore, on a *per establishment* basis as a *local* industry, it also ranks in the middle, which suggests that being an owner of heavy equipment is also desirable.

The investment ratio of the Heavy Equipment industry is high (417). This is not surprising considering the fact that it relies on imported gasoline, trucks, and parts. This indicates that Bonaire's Heavy Equipment industry is a component in a developed economy. The emergy yield ratio of Heavy Equipment is low, but relatively high (1.34) for an economic subsystem on Bonaire. It could not fuel an economy, but it can contribute to a next scale.

Machines like this backhoe loader (Figure 113) are used to mine both limestone and volcanic rock. Rock is mined from private properties with the consent of the owners (Figure 117, Figure 118). It is also mined from government quarries.

Figure 113: Backhoe Loader

The sand and stone industry (which includes heavy equipment, rock crushers, road builders, and construction) has its detractors. Some Bonairians I spoke with questioned the rights of private property owners to sell their stone and sand, to literally sell the island. Systems analysis suggests that stone that contributes to the local economy is not lost. Stone and sand that builds houses, for example, is a contribution to the island system (whether that system is sustainable in the long term is another question, discussed in CHAPTER 16 and CHAPTER 17). On the other hand, stone and rock sold to the tourism industry is a loss to the local economy. However, this must be balanced against the emergy in the tourism dollars that flow into the economy in return. This can only be calculated at the island scale. See the Bonaire system for details.

Vegetation scraped from quarry sites is a loss to the island. If it takes 50-100 years for a thorn forest ecosystem to self-organize in an abandoned quarry, then the loss to the island is that amount of natural production. In other words, without the vegetation in place to capture the sun, wind and rain energies, those energies are mostly lost to Bonaire. This loss can also be compared against the gain to the island, and this will be estimated in the Rock Crushing Subsystem section. One suggestion for environmental engineering on Bonaire is to dig quarries in the shape of holes, or *dams*. While less efficient for extracting rock, quarrying of this type would create valuable resources for goat production.

Another common complaint about this industry is less easy to measure. Trucks moving constantly along Bonaire's small rural and urban roads are dangerous and noisy. Goats are run down, which I saw myself, as trucks race to make their deliveries and return for more. Container trucks from the wholesale industry are another contributor to this problem.

In an interview question about tourism, one interviewee offered this about truck traffic:

> [Tourism effects your life, or…?] No. Because where I live is very quiet. Where I lived before was really tiresome. Noise from container trucks, from rice trucks, from cement trucks. Everything passed in front of there. [Next to street…?] We were on the road that goes by xxxx hotel. Container trucks passed going to Playa.

> [Tourismo ta afektá señora su bida òf ah ...?] Nò. Pasó kaminda mi ta biba 'a masha trankil. [Si. Boneiru ta keda trankil.] Kaminda ku mi tabata biba promé sí tabata fastioso. Ruido di konteiner di aros, sement. Tur kos ta pasa ei dilanti. [Band'i Kaya…?] Nos tabata e kaya dilanti xxxx. Kontainernan ta pasa pa bai Playa.

Problems like this are solved with reasonable success throughout the industrialized world. As Bonaire's economy self-organizes it will probably restrict truck traffic to certain roads, which will add to the costs of development, but which will improve the livability of urban and rural areas.

Construction Subsystem

The construction industry is not a new industry on Bonaire. Since at least 1967 the government of Bonaire has received financial aid from the Netherlands to build low-income housing. Construction workers were needed to build the piers at the port, the salt works, the radio stations, the oil transshipment terminal, all in the 1970s and earlier. However, with the growth of ecotourism in the later 1980s and early 1990s the construction industry has expanded. According to the Labor Office (Labor Office 1993), construction is now the largest profession on the island, with over 1000 persons, mostly men, working as carpenters, painters, bricklayers, peons, etc. When hotel construction was heating up in the 1980s, the demand for additional cheap labor pressed government to exceed the existing pro-Antillean labor policies, and foreign construction workers were accepted onto the island, mostly Venezuelans (APPENDIX H).

Figure 114: Typical Construction Site
Houses on Bonaire are built up on low foundations of brick, stone and cement floors. This elevates the living space above the occasional flash floods that move across the hard rock surface of much of Bonaire. While unclear, the foundation in this photo appears to contain limestone that was ripped and not crushed. The pile of dark stone to the left (behind the goat) is ripped volcanic sediment. The white piles in the back are finely crushed limestone from the rock crusher for cement. The bricks appear to be the locally produced variety, made from crushed limestone. Homesites like this dot the island. Some remain in this state for years, which lays claim to the lot for the erfpacht "owner" as they gather the time or funds to continue the project.

Figure 115: Professional Construction
This small house was built by professional builders (perhaps the FKB). Houses in the past were often built by family members, and at a slow pace. This house went up in less than 6 months. In the photo at top can be seen the same brick and sand, and additionally bags of cement and the concrete mixer. Houses like this indicate the emerging middle class on Bonaire, and the availability of mortgage loans.


Figure 116: Ship with Cement
Cement is imported to Bonaire. Imported cement is used with local rock to make bricks and concrete. Cement is an essential ingredient in the construction industry.

Working in construction can take several forms. A construction worker may be employed as a contractor for one of the few large companies; employed as a contractor for one of the 60 plus small construction companies; or self-employed, taking "jobs" when available. I asked one man who works construction "jobs", but had also worked for construction companies big and small, to comment on the large companies:

> [Which is better, working for a big company or for yourself, or both are good?] Look. Both are good. There are problems with both. When you work for a big construction company, it's not you that decides, let's say, price. I mean, for example, the boss decides. You, there's one salary you get. If you have to work hard, you work hard, but the salary stays that salary. Yea, let's say, for example, if it's 40 florin you get per day, if you pour concrete, I mean, from morning till afternoon, it's the same 40 florin. Or if you finished pouring concrete at noon, you don't get…you have to stay and keep working for the whole day. But when you work like this (for yourself), if you finish pouring concrete at noon, you go home. But the day, the pay is for the day, you're done. On the other hand, that side has the facilities and all, you know. I mean, for that part the big contractors are good. Because when you get sick the insurance works. When it rains, you don't work, they have to pay you still. But when you work like me, if it rains, I don't have any income, because nobody's gonna pay me because it rained.

[Kiko ta mas mihó, ah pa konstrukshon grandi, òf pa señor su mes, òf tur dos ta bon?] I Wak. Tur dos ta bon. Debí na dos sistema. Ora bo ta trah' pa konstrukshon grandi, no t'abo ta disidá, laga bisa, prèis. Kemen, por ehèmpel, ta e hefe ta disidí. Abo, ta un salario bo tin. Si bo meste traha duru , bo mesté traha duru, pero ta e salario ei ta keda e salario ei. Si, laga bisa, un por ehèmpel, si ta kuarenta florin bo ta haña pa dia, si bo basha un betòn, kemen di, fo'i mainta te atardi, ta e mesun kuarenta florin ei. Òf si bo kab'i basha betòn mes mèrdia, bo n' ta haña kuare ... bo ta haña, bo ta haña .. bo meste keda sigui traha pa bo kompletá bo dia. Pero ora bo ta trah' asina'ki si bo kaba 'i basha betòn merdia, bo ta bin bo kas. Pero e dia, e pago dje dia, ta kompleto. Kemen, ei bandanan ei tin e, e fasilidatnan ei tambe, no. Kemen di, ku .... pero pa e parti di, di kontratista grandi ta bon. Pasó ora bo bira malu, seguro ta traha. Ora awa sera a kai, ku no por traha, nan meste pagábo tòg. Pero ora bo ta traha mané ami, ku awa seru kai, mi n' tin niun entrada, pasobra niun hende n' ta bai pagámi pasó awa seru a kai.

Figure 117: Volcanic Sediments Quarry

Another self-employed construction worker had other interesting reasons for disliking the big contractors. He said that if you are hired as a bricklayer, you do bricklaying…for ten years, and nothing else. If they fire you some day, what can you do? He explained that he can build a house by himself, except for the final electrical and the sanitary, and I met others who said the same.

As in some other industries on Bonaire that are not foreign owned (some businesses in wholesale, retail, stevedoring, and others), a few of the large owners are foreign-born residents of the Antilles. This same construction worker explained that it is expensive to start a company, and few native Bonairians (*yu di tera*) can afford the initial costs. As for loans, he said that it is much easier for Americans, Dutch, even Chinese to get loans to start a business. This complaint against the banks I heard repeatedly, however, it should be recognized that the foreigners often come with collateral for loans. The banks are protecting their interests. It may be that sudden construction demands (such as the hotel boom, and others) create niches for large construction companies, which, in essence, the banks fill with foreigners (and some locals). This solution is expedient for the industry, and more secure for the banks, however the side effect is to create some resentment amongst the native-born.

Figure 118: Ripped Volcanic Sediments
Volcanic stone mined from a private *kunuku* in eastern Bonaire.

Another source of growing resentment in the (1995) construction industry was against foreign construction labor, which is often hired by native Antillean companies. Despite Bonaire's progressive worker-protection policies, which rigidly restrict the admission of foreign labor to cases of demand that cannot be met by locals, there is some potential for misuse by owners. One construction worker put it this way:

> [It is easy to get work on Bonaire or it is not easy? Do you know?] I mean, in general ('in het algemeen')? I mean in general? [Uhuh.] Not at this moment…compared to a year ago, two years ago, it was easier. Because, if you look around Bonaire they…construction, building houses, building hotels…I mean, a lot of people could get work. Now everything is starting to get finished, and…one thing that the Government of Bonaire has done wrong, a lot of foreigners came to work. There was a lot of work and not the workers. Foreigners. Um…Venezuelans, Domini…Yea, come to work. I don't know if you see them riding the bus. A lot of people came to work. Now work has stopped, but the people are still here. So the bosses send the locals home (*nos di tera*), stay with the foreigners. Because the foreigners are a lot cheaper. I mean, our foreigners, they don't have work, because…I mean, our locals don't have work, because the foreigners work. And they work much cheaper. I mean it is bad for our workers. [The foreigners go back, go…?] A lot of them stay here. [Ah. They live here.] Yea. There's those that stay living, they get jobs much cheaper than us. [At this time construction is stopping or…?] Yea. Almost stopped. I mean, there's not a lot of work…compared to two years ago. Two years ago, if you wanted work, go…get work at that moment.
>
> *[Ta fásil pa haña trabou na Boneiru òf no ta fásil? Señor sa?] Kemen, 'in het algemeen'? Kemen di en general? [Uhun.] N'e momentunan aki ... kompará ku añ' pasá, dos añ' pasá, tabata mas fásil. Pasobra, si bo mira rònt Boneiru nan .. konstukshon, traha kas, trah' hotèl…kemen di, hopi hende por haña trabou. Awor aki tur kos ta kumisá yega na su final, antobra ahm .. un kos ku Gobièrnu di Boneiru a hasi fout, hopi estranhero bin trah'. Tin hopi trabou, no tin trahadó. Estranhero. Ahm .. hende 'i Venezuela, Domini .. Si, bin traha. Mi n' sa mener sa mira nan kore den bùs. Hopi hende 'a bin traha. Awo'ki trabou stòp, pero e hendenan sí t'ei ainda. Anto e doño di trabou 'a keda manda nos di tera kas, keda ku e estranheronan. Pasó e estranheronan mas barata. Kemen di, nos estranhero, n' tin trabou, pasobra .. mi kemen, nos di tera no tin trabou, pasobra estranheronan a traha. Anto nan traha mas barata. Kemen, malu pa nos trahadónan. [E strañero ta bai bèk, bai ..?] Hopi di nan keda 'kinannan. [Aha. Nan ta biba aki.] Si. Tin 'i nan a keda biba, nan a kue djòp mas barata ku nos. [Awor aki e tempu den konstrukshon ta stòp òf ..?] Si. Kasi stòp. Kemen, no tin hopi trabou .. manera ku dos aña pasá. Dos aña pasá, ku bo ke traha, bai .. ey .. haña trabou mes ora.*

This statement reflects some potential problems for Bonaire, but it also indicates the pulsing nature of the construction industry. With dramatic fluctuations in labor needs, construction company owners must assure that they have a workforce, which might at times mean keeping foreign workers when there is less need. This is a complicated problem for Bonairians to solve, and there is no simple solution.

Figure 119: Public Housing
The Fundashon Kas Boneriano has been providing public housing assistance on Bonaire for over 20 years. They build housing for rent (above), arrange loans, provide builder assistance, and other services. Low cost housing is in demand, which regularly exceeds supply. The FKB has had over 1000 clients, on an island with just over 3000 houses. Large building contracts usually go to one of the 2 or 3 large construction companies on the island. Public housing is replacing the traditional practice of owner-built houses, constructed by family members without loans. As elsewhere in the developed world, public housing is a product people chose, despite the fact that regular mortgage or rent payments force persons into regular participation in the wage labor market.

The emergy analysis of the construction industry makes several points (APPENDIX H, and Figure 120). Construction is clearly one of the largest industries on

Bonaire. Construction attracts 800,351 sej/yr, which places it only behind Tourism and the Government for total inflow. In other words, construction pulls vast resources into the Bonaire economy, much, but not all, from foreign sources. Unlike some other industries, construction has a large environmental component. Houses, hotels, restaurants, businesses occupy land, which by their presence is lost to natural production. Furthermore, construction requires large inputs of rock and stone, as discussed above.

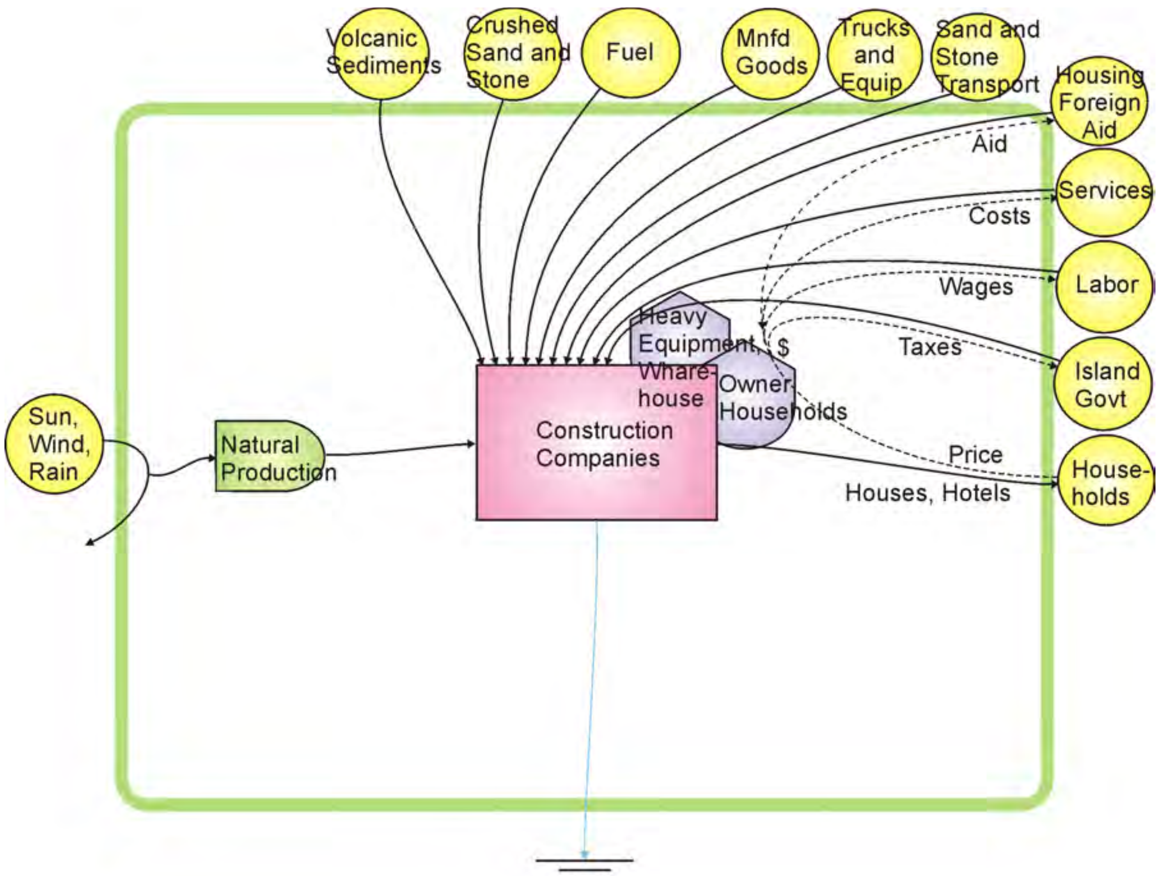

Figure 120: Construction Systems Diagram

For these reasons, construction's investment ratio is relatively low, and its emergy yield ratio is relatively high. Like all industries on Bonaire, the investment ratio is substantial (above 19), and therefore it would not exist without the world fossil fuel economy, however because it has a significant environmental component it perhaps stresses the natural systems less than some. With an emergy yield ratio of 1.27, construction by itself cannot fuel an economy, but it can contribute to a next scale.

Construction has a large workforce, the largest on the island. Therefore, emergy inflow per laborer is not high, placing construction in the lower third of industries. This might suggest that the rewards to each laborer are not high, which is indeed the case.

With many small and medium construction businesses, the per establishment emergy inflow is not high. Construction ranks again in the lower third. This places construction further back in the structural hierarchy, which seems reasonable. However, compared to other locally owned companies, construction emergy per establishment is in the middle. In other words, for local owners it is an attractive business choice. In fact, considering the significant size variations in construction companies, it is not surprising that the large companies are considered by many Bonairians to be some of the most successful local businesses on Bonaire.

Stone Crushing Subsystem

These next two sections, stone crushing and asphalt roadways, are related. Two private companies, they occupy one site near the airport. Stone crushing is owned 80% by a Curacao company, and 20% locally. Roadways production is wholly owned by the same Curacao company. That Curacao company is owned by the Dutch-based transnational construction group Royal Volker Wessels Stevin (KVWS). In the 1990s stone crushing was privatized, as were other government offices on Bonaire, with pressure from national and international lending sources (see Structural Adjustment Programs, CHAPTER 3). I recite this lineage only to indicate the transnational nature of some of the larger industries on Bonaire. Medium and high technology industries, with substantial fixed costs, are unlikely to self-organize in a place like Bonaire, but are more likely "inserted" into the economy from a scale larger than that economy (in this case the Dutch government, and now a transnational).

Figure 121: Large Limestone Quarry
This large quarry in the center of Bonaire fed much of the development of the 1980s. Note bicycle in center for scale. Limestone is delivered to the stone crusher where it produces small aggregate or sand for concrete.

The emergy analysis (Figure 122, and see APPENDIX I) indicates that rock crushing attracts a substantial amount of emergy, although it falls in the middle of the range of subsystems. The largest emergy sources are the limestone that is quarried, and the use of sand and stone transport (from a lower scale). On a *per worker*, and *per establishment* basis, however, rock crushing ranks very high. At only 20% locally owned, rock crushing also ranks very high for emergy attracted per *local* establishment. This is because there is only one rock crushing establishment and few employees, relatively speaking. This suggests that rock crushing is a desirable place to work, or to be an owner.

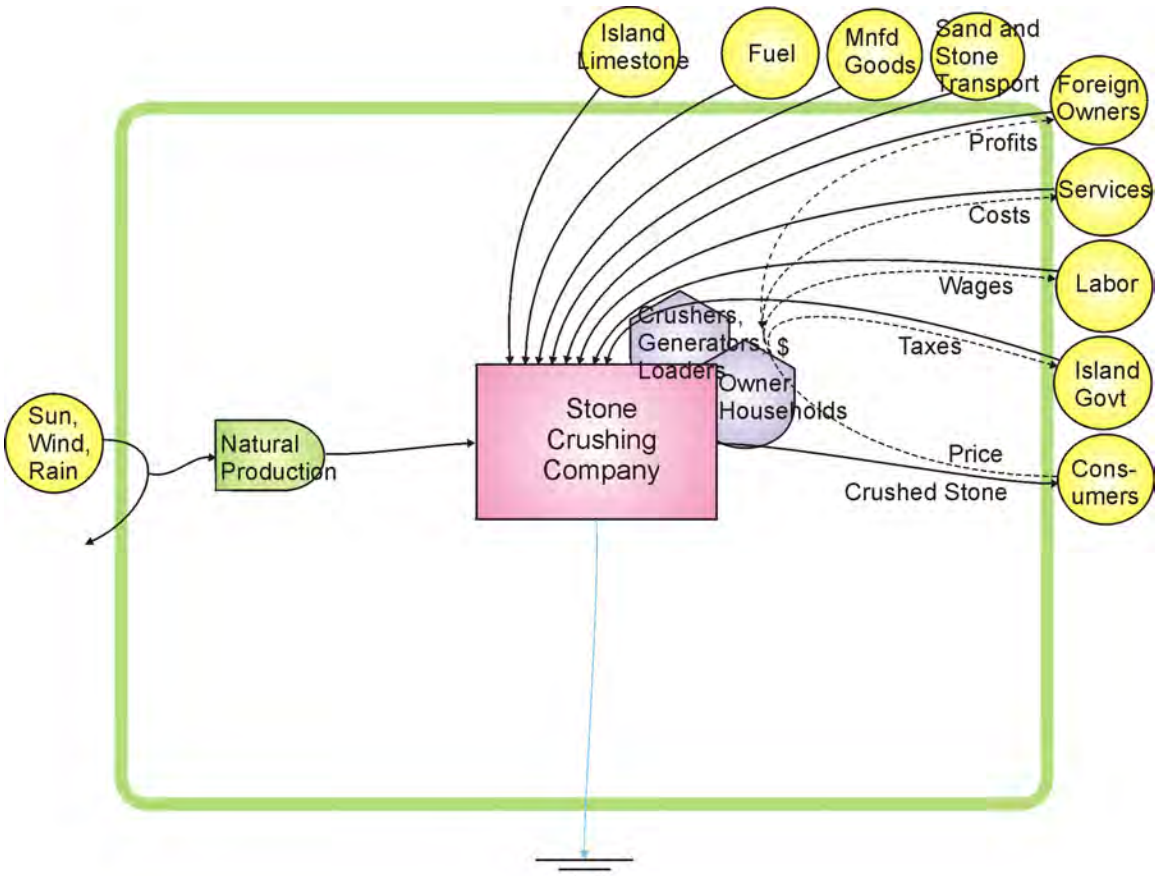

Figure 122: Stone Crushing Systems Diagram

With its large environmental inputs, rock crushing has a relatively high emergy yield ratio (1.5), and low investment ratio (2.7). In fact, the investment ratio is one of the lowest on the island. This is due to the high environmental inputs, matched to relatively small economic inputs. In other words, rock crushing is medium technology, with one plant that pulls from a large land area.

Figure 123: Smaller Limestone Quarry

An important question raised earlier is the tradeoff between mined rock and the loss of natural production from the thorn forest vegetation that was cleared for mining. It was estimated that 1,000 ha have been cleared for mining stone and sand on Bonaire (this is my high estimate). The average yearly emergy inputs to 1,000 ha on Bonaire is 7,712 sej/yr. That emergy produces the thorn forest ecosystems that cover much of the surface area. As any ecosystem, the thorn forests must require 50-100 years to self-organize. In other words, early plant colonizers must arrive on bare rock. That surface is transformed by plants and weathering, and topsoil slowly forms from mineral and bio-materials. Middle succession and later climax plant and animal species eventually arrive. These plants and animals have evolved on Bonaire to capture and make use of the available energies of sun, wind, rain, uplift, etc. Those driving energies are captured and drive the Bonaire ecosystems.

Figure 124: Stone Crushing Plant
Bonaire's incessant winds create problems for the stone crushing plant. In open systems, storages like this sand pile continuously degrade. Work is required to maintain a concentration of any substance. In natural systems, storages may be continuously replaced as they degrade, creating the illusion of permanence. Even as they reach maturity, organisms continuously replace themselves by taking in nutrients, air, sunlight, etc.

When mines are dug, the natural production of the thorn forest ecosystems is lost to that area for the length of time that it takes for the terrain to self-organize anew. If this takes 50 years to reach half production, and 100 years to completely recover, then the natural production of approximately 50 years is lost. If that amount is 7,712 sej/yr, then the total cost of the mine is (7,712 sej/yr)*(50 years), which equals 385,200 sej. If the total emergy gained to the Bonaire system per year from rock mining is 15,000 sej/yr from limestone mining, and 20,000 sej/yr from volcanic rock mining, then the contribution to the Bonaire human-ecosystem from mining is 5 times the cost (1,750,000 sej).

Figure 125: Limestone for Fill
In this development project limestone was used to elevate construction above a surface that seasonally floods. A common practice in industrial countries, the Dutch have a long history of creating land where none existed. Population growth creates demand for land. This land is near the center of Playa and may more easily be hooked into existing water and electric grids.

Roadway Subsystem

The Netherlands has been providing foreign aid for asphalt road construction on Bonaire since 1958. The stream of aid has been continuous, with new funding every few years to resurface or expand the paved roads network. While award amounts have increased 10 fold, the amounts converted to emergy have remained about the same (see APPENDIX J, Note 25 for details).

The emergy analysis for the Roadway Subsystem is in APPENDIX J. The main emergy input to roadway production is financial aid, followed by the services purchased from Curacao for mining and shipping the imported limestone (Figure 131). The truck transport of stone and sand is another big input.

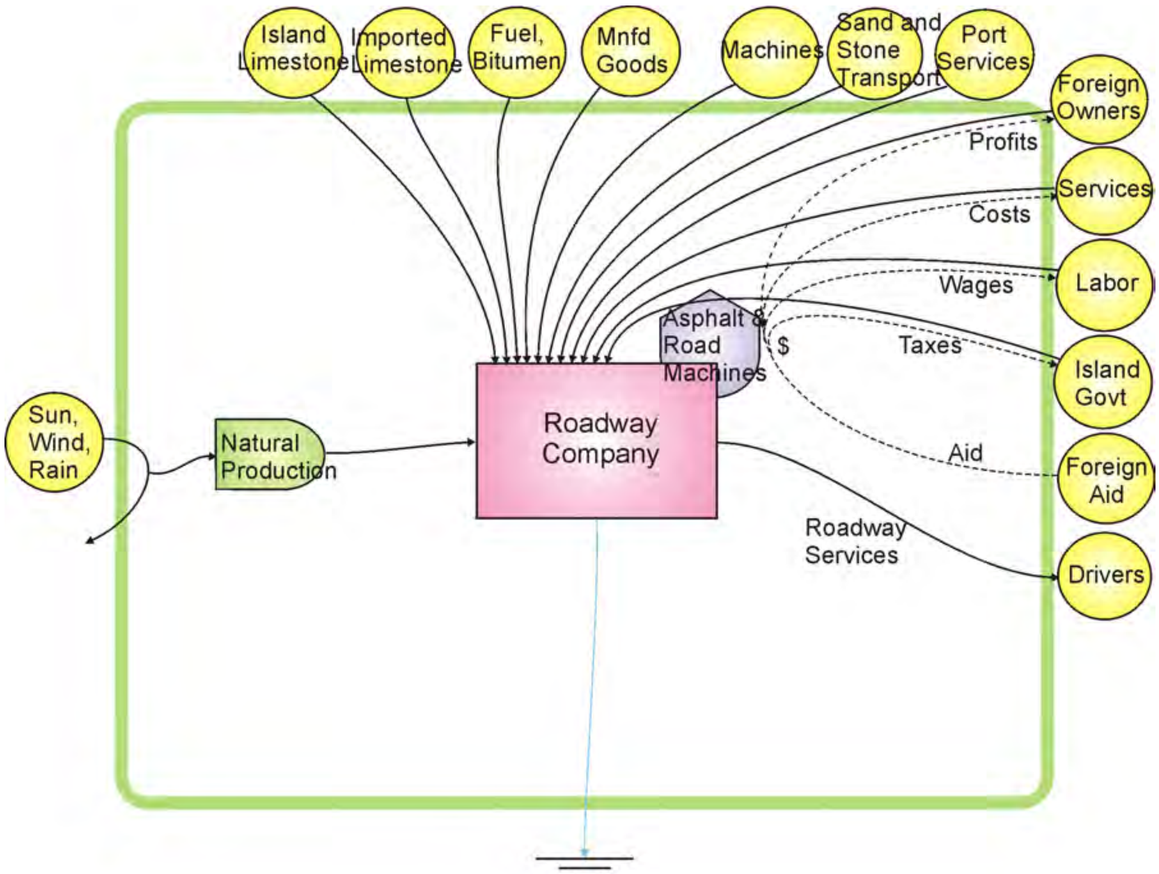

Figure 126: Roadways Systems Diagram

For total emergy inflows, the roadway subsystem is in the lower third of subsystems analyzed. On a *per laborer* and *per establishment* basis, however, the roadways subsystem falls in the upper third. This is not surprising considering the small number of workers, and single roadway company (there are actually two road laying companies, but only one asphalt making machine owned by the much larger of the two).

As for the stone crushing subsystem, the roadway subsystem has a relatively high emergy yield ratio (1.3), and low investment ratio (4). Again this is due to high environmental inputs, matched to relatively small economic inputs.

Figure 127: Road to Rincon
Abutting one limestone terrace, this major roadway to Rincon sits atop another. This road was first paved in 1958, and is heavily driven by commuters living in Rincon and working in Playa. There are several minibuses that make the 15-20 minute run several times a day.

Figure 128: Road in the Park
This narrow asphalt road winds through the Washington-Slaghbaai National Park, providing passage for tourists and residents alike. This is the minimum asphalt cover for paved roads on Bonaire. Newer more trafficked roads are more substantial.

Figure 129: New Road Subbase
This new road is built up half a meter above the flood prone part of Playa. In this case the subbase is volcanic sand. Though rains are infrequent on Bonaire, when they do come they often flood the less permeable limestone terrain, thinly covered with topsoil.

Figure 130: Asphalt Machine
This machine uses crushed limestone and bitumen, both imported from Curacao, for the production of road asphalt.

Figure 131: Stone and Sand for Asphalt
This barge brings limestone and sand from Curacao. This limestone is mined on Curacao and is said to be less soft and smooth than Bonaire limestone.

CHAPTER 12
INTERNATIONAL TRADE

Bonaire imports much of what it needs to support its fourteen thousand people. Export industries on the island are a small, eclectic group that includes ecotourism, the now leading source of foreign currency. This chapter will examine international trade and the production subsystems on Bonaire that make it possible. Trade systems have self-organized for centuries on Bonaire and in other Caribbean countries. Today they are being transformed again by the new global economy. As a periphery in a world system (see Modern States and World Systems, CHAPTER 16 for discussion), Bonaire should be expected to receive processed goods that diverge from the core of a world system, in exchange for raw materials that are converged to the core. This may indeed occur.

Figure 132: Importing on Bonaire

The Core-Periphery Model Within States and Between

The systems diagram in Figure 133 depicts the World Systems relationship between a Core and Periphery (see discussion, Modern States and World Systems, CHAPTER 16). Figure 134 shows the case of Bonaire and the Netherlands Antilles (as peripheries) within the US-EC-Japan world system. The core-periphery relationship has much in common with the relationship between Urban and Rural areas within a Nation.

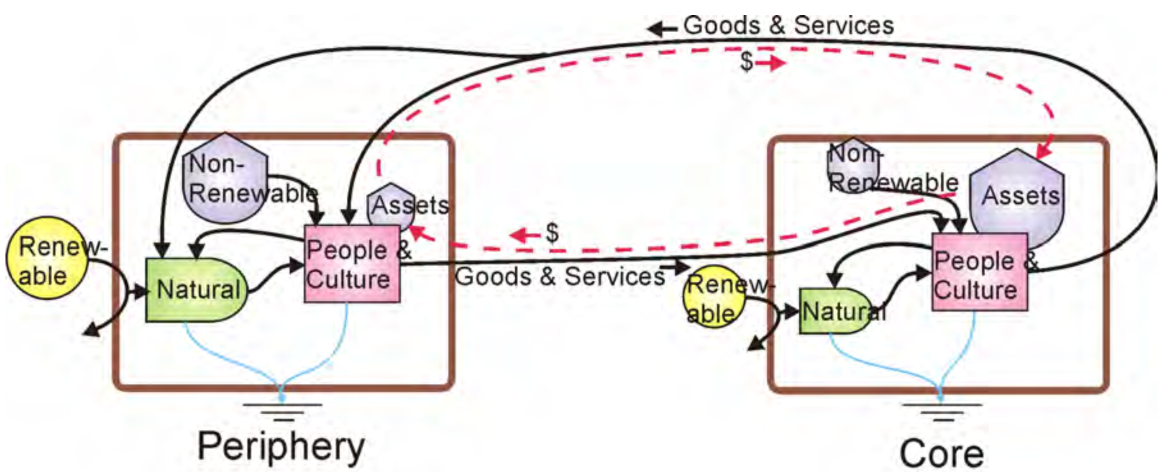

Figure 133: Core-Periphery Model

In the World Systems model, the Core states exchange Secondary commodities to the Periphery for which they receive Primary Commodities (see CHAPTER 8). E*m*ergy accounting offers an explanation of why this exchange is unequal and why peripheries therefore remain "underdeveloped" (Odum 1996a:208-219).

In *Environmental Accounting* (Odum 1996a:212), Odum gives two reasons for the unequal exchange between developed and undeveloped nations:

1. The emergy content of environmental products sold by undeveloped nations is higher than that in the money paid for them by developed nations.
2. The emergy/money ratio is much greater in the rural nation supplying the environmental product and raw materials than in the purchasing economy.

Therefore, when dollars leave an undeveloped country, much less work will be accomplished in that economy, compared to dollars lost from a developed economy.

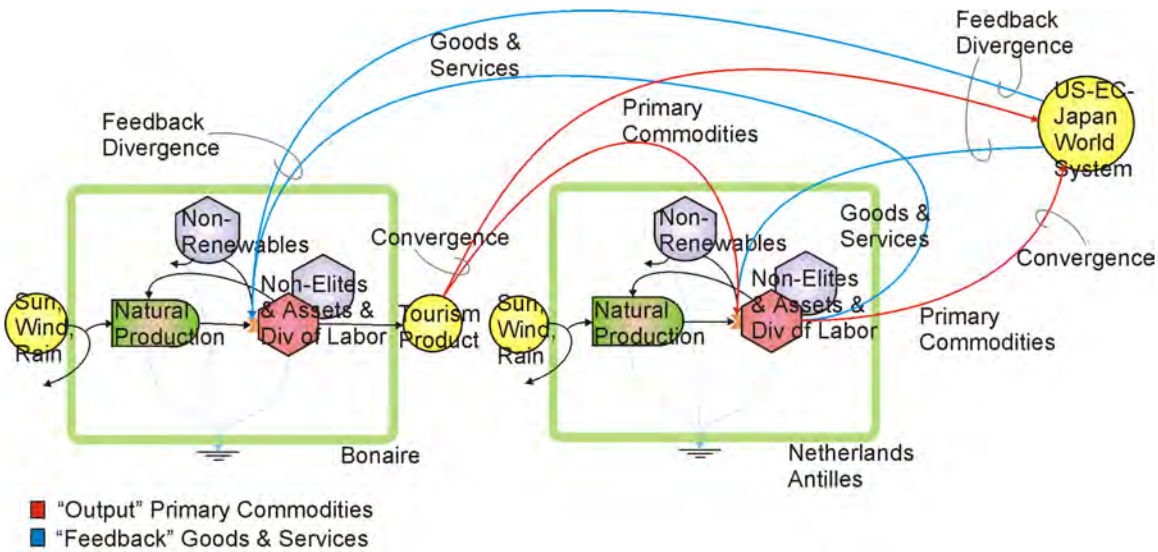

Figure 134: Hierarchy and Convergence in Trade with Bonaire
The core-periphery model places Bonaire and the Netherlands Antilles within the US-EC-Japan world system. Bonaire is perhaps also a periphery to Curacao's core. These relationships are formed by the convergence of primary commodities from periphery to core, and the divergence of secondary goods and services to the peripheries.

Resource Brokers

Brokers are persons who arrange deals between two parties. The term "resource broker" can be coined for a person who arranges a deal, so to speak, between a rural resource area and an urban or foreign core. The resource broker is the plantation owner, mine owner, or well owner who works in the rural area to extract primary goods to the core. This person removes the good from the local economy to the urban. The resource broker moves the good into a new larger scaled system.

The story of Third World "development" is the story of emerging resource brokers. Local resource brokers are individuals who recognize an opportunity for themselves by facilitating the export of some commodity. Actors at the larger scale encourage the emergence of resource brokers. They recognize the value in the service offered by a resource broker, and act to amplify that behavior by channeling goods and services to the broker from the larger scale. The net effect is that raw goods leave a peripheral area and move to a core.

Importing on Bonaire

Figure 135 illustrates the subsystems on Bonaire that function together to bring imported goods to Bonaire. These production subsystems compose the importing industry on Bonaire. Wholesalers and some Retailers contract for goods to be shipped to Bonaire. Agents make detailed arrangements. Inter-island and International shipping brings the goods. Agents pay the freight, customs, and harbor fees, and present the buyers with one bill. Stevedoring companies unload and occasionally unpack goods. Wholesalers sell to the many small retailers throughout the island. The Port system and Roadway system facilitate the movement of all bulk goods.

From a world systems perspective discussed above, vast quantities of raw goods are concentrated from peripheries to industrial cores. In steps they are refined and processed. In feedback, the processed goods (in far smaller quantities by mass) are then dispersed to the peripheries, where they amplify the capture and use of more energies and materials.

From this perspective, the importing system is that part of the dispersal process for feeding back secondary goods to the periphery. Goods are fed back and dispersed from cores to peripheries in steps. The subsystems in Figure 135 disperse secondary goods into the Bonaire economy with stepwise movements from few importers, to more handlers and wholesalers, to even more retailers, and finally to the many household consumers.

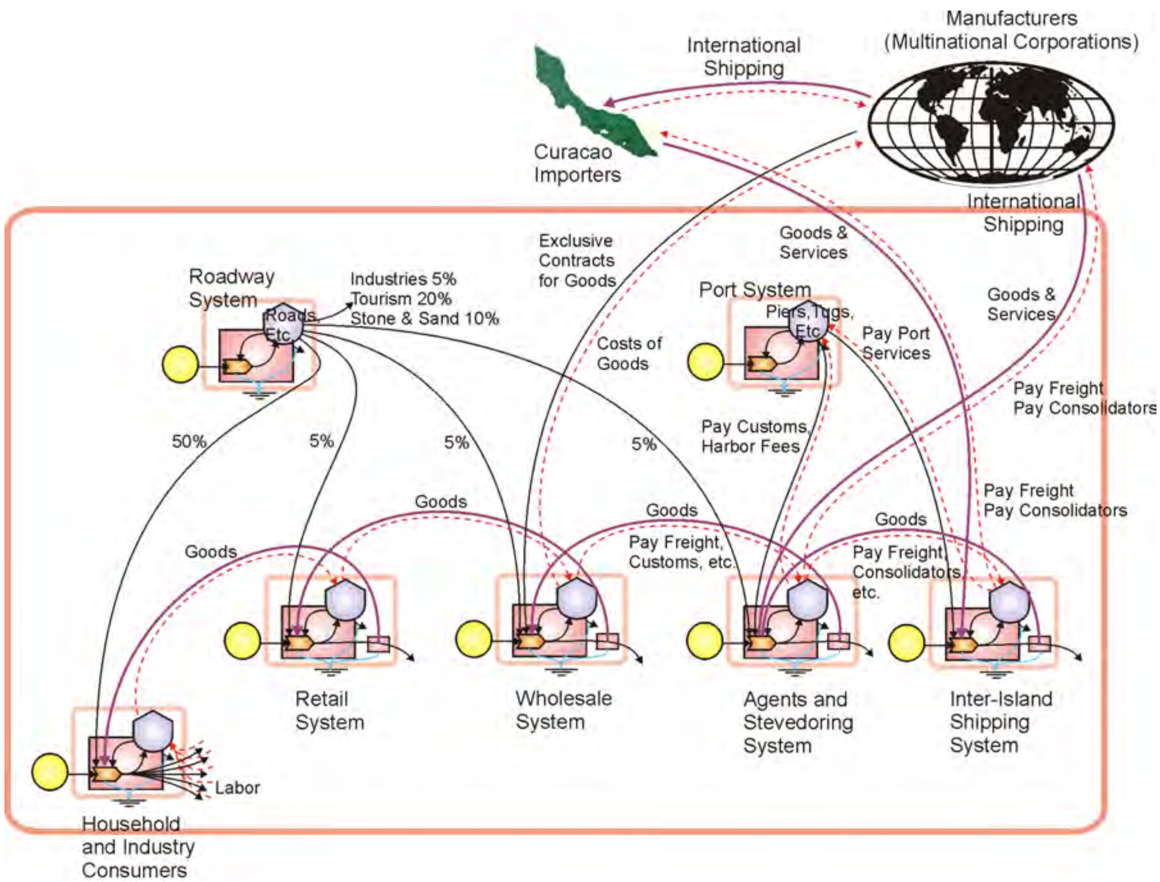

Figure 135: Importing Subsystems on Bonaire
Imported goods and services enter the Bonaire system at the points of inter-island shipping or stevedoring (for international shipping). These points are on the right of the diagram which indicates their position near the top of the Bonaire system emergy hierarchy. In contrast, ecosystem emergies normally enter a system at the base of the ecosystem hierarchy, as sunlight absorbed by plants. This pattern of emergy entering near the top of the hierarchy is perhaps a very general pattern that occurs throughout the global economy joined by trade. The difference between core and periphery nations might be that core nations receive primary commodities that are used in industries also near the top of their hierarchies to produce goods that are then fedback to the hierarchy bases. In periphery economies, the imported goods are often secondary commodities, which are immediately pushed to the base of the hierarchy without doing as much work in the economy. Notes: (1) There are flows from labor to each of the subsystems, not shown. In return, labor receives wage inflows (dotted money lines). (2) There are yellow source symbols entering each of the subsystems. These are intended to represent all sources not described in the text, i.e., renewable environmental sources like sun, wind, rain, and purchased sources like fuel, electricity, and water. See the individual emergy analyses for detailed accounting of emergy sources.

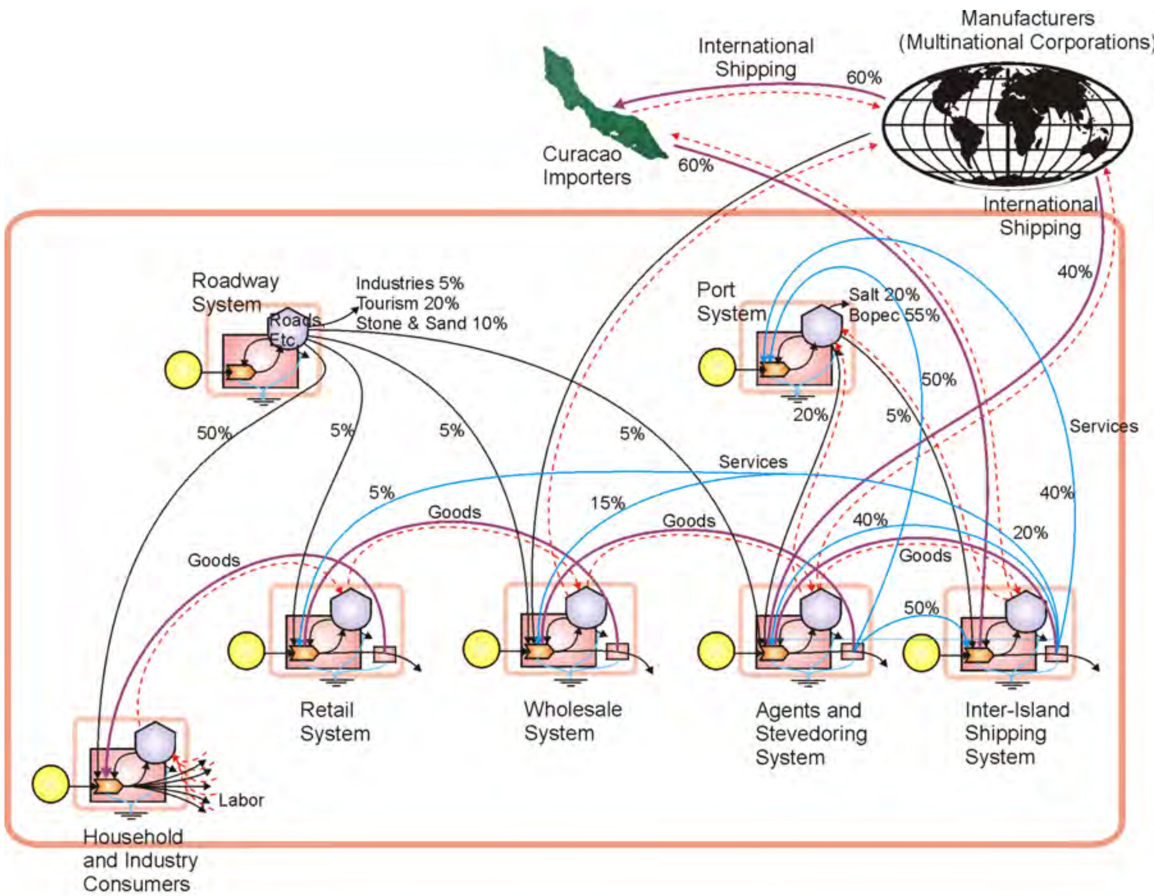

Figure 136: Importing Subsystems Including Feedback Services
This diagram starts with Figure 135 and adds estimations of the feedback service emergies from the shipping and handling industries. As discussed in the text, the shipping industry is interesting because it has high emergy inputs that enter the system near the top of the hierarchy. This emergy is fed-back to the wholesale, retail, and port industries that are served by shipping. In the diagram this controlling (services) feedback is represented by the blue lines, which are in addition to the goods feedback, shown by the thicker dark line. Estimates were made of the percentages of services feedback to each of the subsystems.

These subsystems in Figure 135 also use controlling services from one another. In the subsystem analyses that follow, an effort was made to estimate the contributions of each to the others, based on reasoned functional interrelationships (Figure 136). An unusual feature of the importing industry on Bonaire is the input of goods emergy (as discussed above), but also services emergy, directly to the *top* of the hierarchy, from which it flows to the bottom by feedbacks. In other words, services emergy enters the

Bonaire importing industry from the point of shipping and receiving (Stevedoring and Agents). That emergy is the large controlling emergy of foreign forwarding agents and international shipping. The timing of inter-island shipping is determined by the timing of international shipping. The cargo arriving at Bonaire is limited and timed by the activities of agents and consolidators thousands of miles away. These controlling emergies are real and inevitable and significantly structure the activities of receiving and distributing goods on Bonaire.

From the point of inter-island shipping, feedback services emergy is transferred to Agents, the Port, some Wholesalers and Retailers. In other words, the activities and timing of international shipping structures the activity of agents and the port, which then determine the timing and availability of goods distributed to wholesalers and retailers.

Inter-Island Shipping

Important emergy inflows to Inter-island shipping are (1) the ship itself, which is a high-technology machine (Figure 137), (2) diesel fuel for the ship, (3) Port services, (4) Stevedoring services, and (5) the foreign purchased services, i.e., those provided by the exporting country, by International shipping, and by the Curacao economy, which transfers the goods from large container ships sailing to Curacao and places them on the Inter-island ship (see emergy analysis, APPENDIX K). These external services make the Inter-island shipping industry possible. Without the consolidating and loading of goods at the foreign port, there are no goods for Bonaire. Without the ocean container ships there are no goods for Bonaire from Europe or the US. Without the transfer of goods on Curacao, it is argued, some goods will never get to Bonaire economically. All these pieces work together to disperse refined or processed goods to Bonaire.

Figure 137: Inter-Island Shipping
The Inter-island ship can carry eighteen 20' containers from Curacao to Bonaire.

The emergy value of these services can be estimated from their cost. Freight costs and consolidator's fees represent the services provided by the international and Curacao economies. The emergy/money ratio of Curacao is high (due to large cheap fossil fuel imports, see CHAPTER 8) and therefore the money paid to Curacao buys more emergy than money paid to Europe or the US. However, the services purchased from Curacao are a smaller percent of the total freight costs.

One interesting emergy input to shipping was not evaluated because it is estimated to be low. Shipping would not exist without the property of water to flow as currents, small and large. In other words, as a liquid, water can disperse the energy of a moving ship in small eddies that escape behind the vessel. The ship is supported by the water, and the energy of friction as the ship moves is easily dissipated. The same bulky vessel moved across rock and dirt, or even roadway, enjoys no such friction discount.

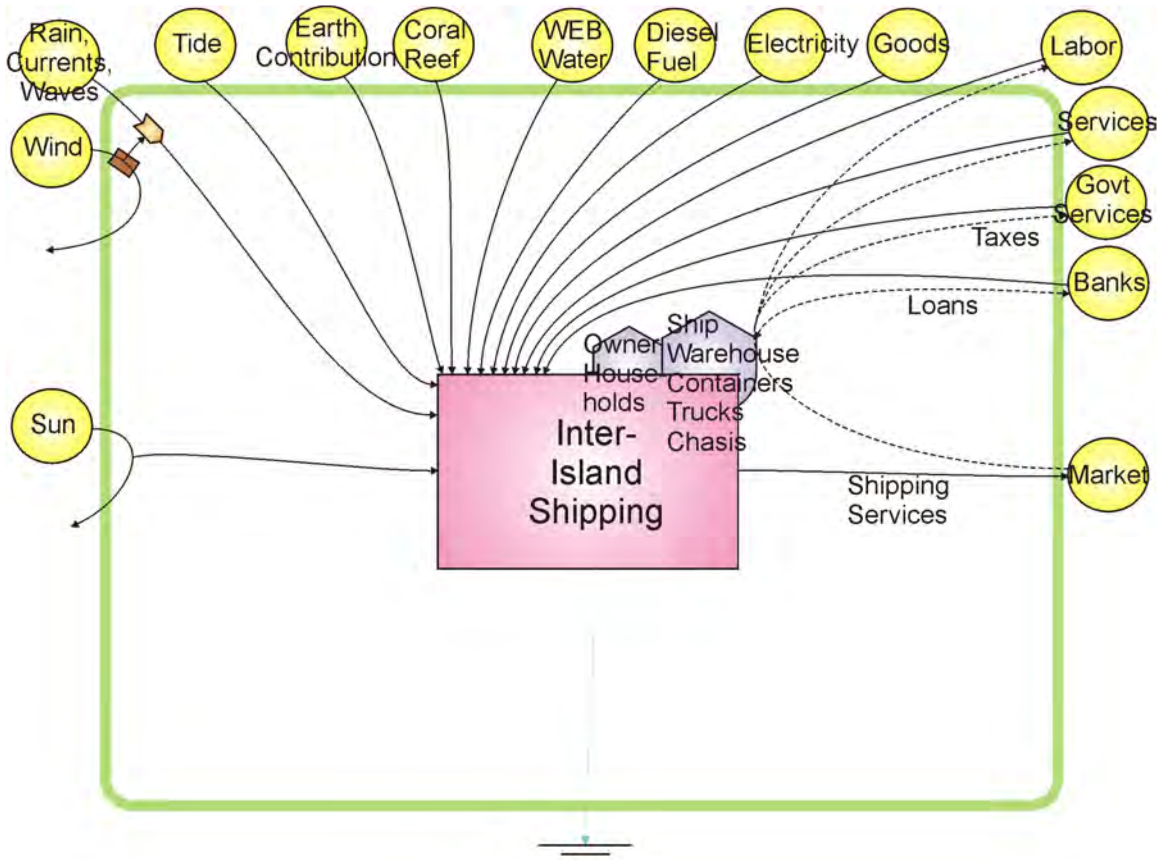

Figure 138: Inter-Island Container Shipping
Shipping relies on fuel, the ship, and services from the Port and Stevedoring companies.

It is estimated that the emergy contribution of seawater to shipping is thus proportional to the volume of water through which the ship passes, for the length of time that it takes for the eddies to dissipate. The energy is the energy of motion in water molecules, released by the geopotential energy of water in the Earth's gravity. This energy is not great, even for an international voyage, and the transformity is for water eddies which is also not large (compared to the transformity of large, slow trans-ocean currents). Therefore the vital emergy contribution of water to shipping is not significant for an industry powered by metal ships with fossil-fuel engines.

From one consideration, this argument is especially reasonable. Shipping was the first successful form of bulk goods transport (perhaps simultaneously with animal caravans). Shipping fueled the emergence of market towns in archaic times (see **Hierarchy and Convergence in Markets**, CHAPTER 16). Even foragers, with very low technological emergy inputs could build canoes to harness water geopotential energy for bulk transport. In other words, simple canoe technology is appropriately matched to the low emergy flow from still watercourses. It is not surprising that river canoes were the first technologies of bulk transport, because the emergies involved are lower. It would take higher-emergy technologies (roads and wheeled carts) to match the energy requirements of moving bulk goods over land. Trans-oceanic voyages, which contact larger scales of sea and atmospheric emergy, would likewise require the higher technologies of large ships, powered by sail or fuel.

As for storages, the largest concentration of assets for the inter-island shipping subsystem is the ship itself, not surprisingly. After that, the households of the owners are an important storage. Inter-island shipping is an industry that is owned by Bonairians, and therefore the owner's assets contribute to the success of the subsystem.

The Port (Harbor and Piloting)

The Port is an essential technology for moving bulk goods by ship. Cement piers (Figure 137, Figure 140, Figure 141, and Figure 142), tugboats (Figure 139), and piloting services compose the system. Important emergy inflows to the Port are (1) the tugboats and parts, (2) tugboat fuel, (3) the piers (and maintenance), (4) foreign aid for construction, and especially (5) the feedback flows of services from shipping and stevedoring (see emergy analysis, APPENDIX L). In other words, obviously shipping and unloading services give the port its reason to be.

Figure 139: Tugboat of the Bonaire Harbor and Piloting

The port's harbor and piloting services are employed to receive cruise ships and freight ships to Kralendijk's three cement piers, but also to the salt pier in the south and the oil transshipment pier in the north. In fact, the oil and salt piers receive the majority of shipping, and this is reflected in Figure 136. Large storages of assets that support the Port system are the two tugboats and the cement piers. As a government operation, harbor and piloting also have access to a share of the substantial assets of the Island government. On a *per establishment* basis the port ranks in the top third of emergy inflows and storages.

Figure 140: Cruise Ship at one of Cruise Piers

Stevedoring and Agents

Agents arrange for the shipping of goods to an island. They coordinate the receipt and packing of goods into containers on foreign ports. On arrival, the agents are responsible to assure that all freight and port services have been paid for, and to bill the buyer. Stevedoring is the unloading and unpacking of goods on Bonaire. While these two industries might have been analyzed separately, on Bonaire some companies provide both services and they are therefore modeled together.

Important emergy inflows to the Agents and Stevedoring subsystem are (1) the Port subsystem, (2) Inter-island Shipping, (3) International Shipping, and (4) the

Roadway subsystem for moving bulk goods over land (see emergy analysis, APPENDIX M).

Port services are piloting, tug boats, customs, and the physical infrastructure of the port. Port subsystem emergy supports the subsystems that use the port (oil transshipment, the salt works, and Inter-island and ocean freight shipping). The remainder is distributed to the Stevedoring and Agents operation (Figure 136).

Figure 141: Rice Boat at one of the Cruise Piers

Inter-island shipping services are fed back to the Stevedoring and Agents subsystem. It is estimated that some Wholesalers act as their own Agents, and that a few Retailers do also (See Figure 136, and Wholesalers and Retailers). The remaining Inter-island shipping services feedback to support the Port subsystem (more Shipping means a better Port, which facilitates more Shipping) and the Stevedoring/Agents subsystem. This is reasonable because the Stevedoring and Agents industries would not exist without Shipping.

International shipping services, by contrast, feed directly into the Stevedoring and Agents subsystem. It was estimated in the Inter-island shipping section that a percentage (20%) of the cost of goods is the freight and consolidator's fees (Figure 136). This amount is proportional to the services provided by International shipping, and when multiplied by the emergy/money ratio of the US or Europe, it gives an emergy value. Of the total imports to Bonaire (136 million NAf), it is estimated that 40% is imported directly by international shipping. Therefore the services cost of this shipping is (136 million NAf)*(40%)*(20%), which is about 8.7 million NAf. A portion of these services goes to Stevedoring and Agents.

Figure 142: Giant Automobile Ship at a Cruise Pier

Roadways are a necessity for moving bulk goods over land. The Stevedoring industry depends on the availability of paved roads for moving imports to Wholesalers and Retailers. It is estimated that 5% of Roadway services contribute to this industry (Figure 136). See the Roadway subsystem for a complete breakdown of service usage on Bonaire.

The largest storages of assets associated with Stevedoring are the household assets of owners. Stevedoring companies are locally owned, and the largest companies are successful island businesses. Other assets include the equipment for moving goods.

Wholesalers

Important emergy inflows to the Wholesalers subsystem are (1) services from Agents and Stevedoring, (2) Inter-island shipping (when acting as own Agents), (3) International shipping (when acting as own Agents), (4) Electricity for freezers and buildings, and (5) Labor (see emergy analysis, APPENDIX N).

On Bonaire, local Agents and Stevedoring services make it possible to move goods onto the island. Agents often arrange the shipping of goods from foreign ports. Agents pay the freight, customs, and harbor fees, and are reimbursed by the buyer.

At times Wholesalers act as their own Agents:

> "Wholesale food distribution in the Caribbean is mostly carried out by importer-distributors. There are usually only a few sizeable importer-distributors per island, and these companies usually act as manufacturers' agents." (USDA 1997:6) ["Manufacturers" are multinational corporations, such as Albert Heijn, Heiniken, or Del Monte.] "Under a typical agency agreement, the wholesaler is the exclusive distributor for a given product." (USDA 1997:7) "The largest wholesalers on [Caribbean] islands function as agents and offer the widest possible coverage, from the largest to the smallest retailers, to hotels, restaurants, and sometimes directly to individuals through warehouse sales. In many cases, the largest wholesalers on the islands are also the biggest retailers." (USDA 1997:15). [This is the case of Cultimara Supermarket retail on Bonaire, which is a sister company to Consales N.V.]

In these cases, therefore, Wholesalers receive service directly from the shipping subsystem. It was estimated that 15% of Shipping services pass directly to Wholesalers (116 million NAf)*(30%)*(20%)*(15%).

Electricity for running freezers is a critical service for Wholesale food importers, and for any industry that uses frozen foods (retailers, restaurants, hotels).

Retailers

Retailers on Caribbean islands have similar features in common:

> Below the level of supermarkets are the small shops. Known as 'colmados' in the Dominican Republic, 'counter shops' in the OECS, and 'Lo-Lo' in the French West Indies [and 'toko's or 'snacks' in the N.A.], these tiny outlets may be only a few hundred square feet in size and generally offer a very limited range of items. They are usually family-run and have a neighborhood customer base. Though they sometimes offer perks such as store credit to their loyal customers, the main draw of these stores is convenience. On certain islands, there is literally at least one of these stores on every street corner and in every village, making it easy for anyone to shop there. (USDA 1997:15)

Figure 143: Retail "Snack"

These small stores dot the island providing easy access to basic commodities and social gatherings.

Important emergy inflows to the Retail subsystem are (1) Wholesaler's services (2) Roadway services, (3) Shipping, (4) Stevedoring, (5) Electricity, and (6) a large Labor input (see emergy analysis, APPENDIX O).

The majority of Wholesaler's services goes to the 150 (more or less) Retailers on Bonaire. As stated above, some Wholesalers in the Caribbean sell directly to consumers. Some Retailers act as their own Agents and Wholesalers. In general, however, goods retailers, snacks, bakeries, restaurants, and food stores are the recipients of Wholesalers' services. It is therefore estimated that 90% of Wholesaler's services go to Retailers.

Figure 144: Another Snack (and Lottery Store)

The movement of goods to Retailers depends on private vehicles moving over Roadways. The contribution of Roadways to Retail is thus critical.

Shipping and Stevedoring services are estimated as they were for Wholesalers. A smaller percentage (5%) of Stevedoring services is estimated.

The Retail subsystem supports a large Labor force of almost 700 persons (APPENDIX O). Much of the emergy inputs to the subsystem are thus in the form of Labor.

Export Industries on Bonaire

As stated previously, the set of export industries on Bonaire is small and eclectic. An oil transshipment terminal, two large radio antenna arrays, a salt production facility, a rice mill (which became unprofitable after EU tariff laws were changed), and the new best hope, ecotourism. The international airport provides transport for tourism and will also be evaluated in this section.

Oil Transshipment

Figure 145: Oil Transshipment Terminal
A few of the 23 storage tanks within the terminal. Note the proximity of the ship that is loading (or unloading) crude oil to the tanks. Bonaire's uniquely steep underwater topography permits tankers to moor very close to shore.

The oil transshipment terminal came to Bonaire in the early 1970s under the name BOPEC, which remains the common name for the site. Owned today by Maraven, a division of PDVSA, it has a storage capacity of 10 million barrels. The unique underwater geography of Bonaire makes it possible to moor even supertankers close to shore (Figure 145).

Figure 146: Oil Terminal from the Air
The expanse of the "BOPEC" terminal is captured by this aerial shot of north Bonaire. It is not surprising that the value of emergy "storage" in the terminal infrastructure is the largest asset storage for any single company on the island.

Important emergy inflows to the terminal are (1) the 23 giant storage tanks (Figure 146), (2) Port services (tugs and piloting), (3) the piers, (4) gasohol for private electricity generators, (5) construction services, and (6) yearly purchased foreign services (see emergy analysis in APPENDIX P). Important storages for the transshipment terminal are (1) the tanks and piers, (2) the percentage of assets attributed to PDVSA, and (3) the storage of money estimated for the terminal. As with other subsystems, large storages (the tanks and piers) are calculated as both storage and flow. The tanks were built within a few years, but they depreciate slowly and that depreciation is considered the flow rate per year of the tanks into the subsystem.

With the vast infrastructure of the terminal and international support for the parent company, it should not be surprising that the terminal has the largest per establishment inflows and storages after the island government.

Salt Works

Figure 147: Mountains of Crystallized Salt
The salt works in south Bonaire covers one-tenth of the island by area. Solar salt works can exist only in areas with ample sunshine, and evaporation that exceeds rainfall for most of the year.

The Akzo Nobel salt company on Bonaire is the contemporary version of an export industry that has existed on the island since the earliest colonial times. Indeed, the natural salt ponds on Bonaire were one of the original magnets to colonization of the island. The current rendition of the salt industry covers the southern one-tenth of the island with salt evaporation ponds (see map, Figure 6). The historic salt ponds where greatly expanded in the 1960s to incorporate surrounding sparse *mondi* terrain. A flamingo sanctuary has been constructed in the center of the salt works in effort to preserve a rare breeding ground for the birds. The salt works, like the oil transshipment subsystem, has its own deep-water pier for easy loading (Figure 148).

Figure 148: Salt Works Pier
The feasibility of the Bonaire salt works is assisted by the steep marine topography that permits near-shore access to ocean-going vessels.

Important emergy inflows to the subsystem are (1) the loaders, trucks, wash plant, pier, and the goods and services to maintain them in the harsh salt environment (Figure 147), (2) the diesel and gasoline to run machines, (3) electricity purchased from the grid, (4) port services (piloting), and (5) the original construction services depreciated over time. Two important natural inputs were also estimated, (6) the shallow topsoil lost in the original construction, and (7) the limestone that was scraped and piled into the 100 kilometers of dykes that compose the evaporation ponds (see emergy analysis APPENDIX Q, and Figure 149).

Another vital emergy inflow to the system, indeed for all the export industries, is the flow of government services. As discussed in CHAPTER 13, private industry relies completely on the existence of governments for the maintenance of private property. Without government permission and assurances of secure private control of the vast tract of land, the Akzo Nobel multinational would not have invested in the project. The Labor inflows to the industry are also significant, but relatively small with 60 island employees. In fact, none of the export industries, with the exception of tourism, employs a large percentage of Bonaire labor, post construction.

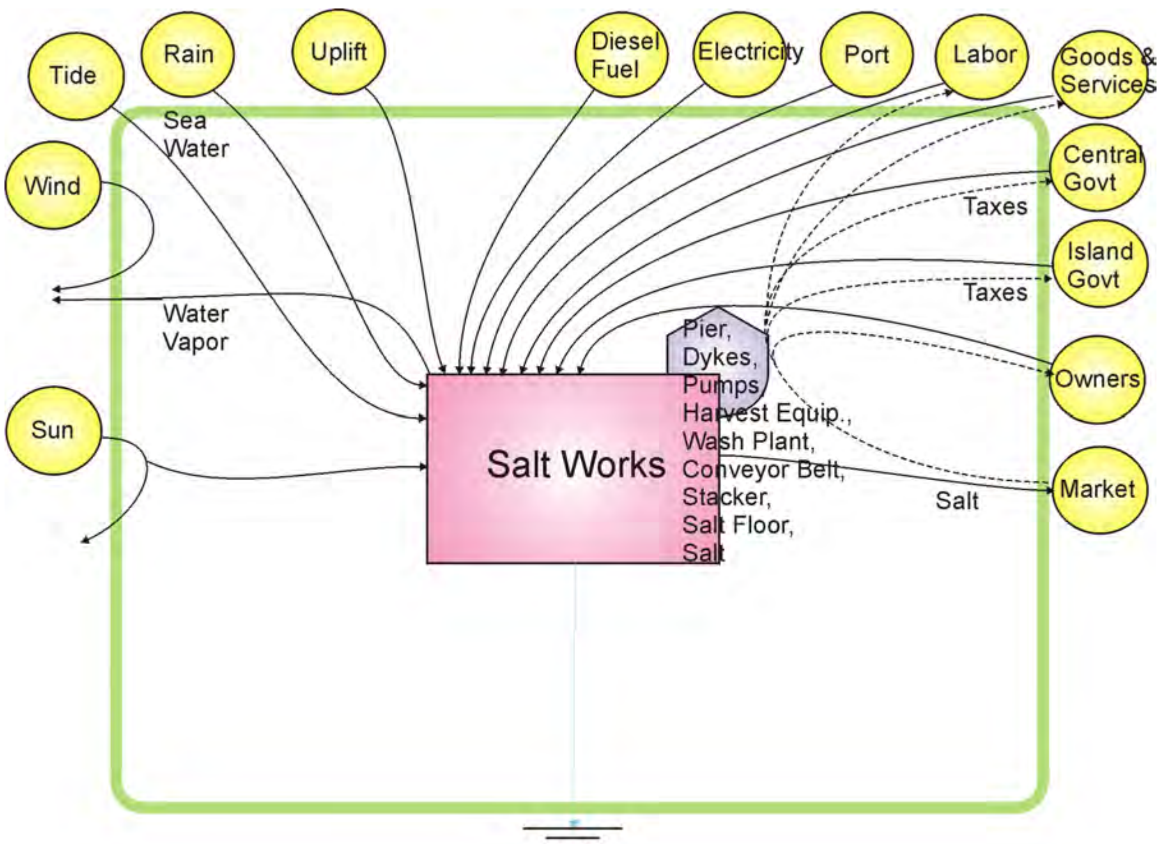

Figure 149: Salt Works Systems Diagram
Important natural inflows are obviously high solar radiation and low rainfall. Purchased inputs are fuels and equipment. The Port contributes ship piloting and tugboats. The Island and Central governments assure the critical rights to land and property, which make possible the involvement of a multinational corporation.

Important emergy storages for the salt works are (1) the limestone dykes, (2) the substantial hardware infrastructure of pier, wash plant, and harvesting equipment, (3) cash assets, and (4) the estimated parent company contribution of a multinational giant with 85,000 employees worldwide. Notice that as a foreign-owned company there are no "owner's household" assets combined in the calculations of inflows and storages.

On a *per establishment* basis, the salt works ranks near the top third of island production subsystems in emergy inflows and emergy storages (Figure 172). This places it to the right in the hierarchy of corporate production (Figure 104).

Radio Relay Stations

Figure 150: Short-wave Antenna Array of Radio Netherlands on Bonaire

There are two large antenna farms and transmitters on Bonaire that transmit short wave and medium wave signals to vast expanses of the world. Radio Nederlands Wereldomroep is a relay station for the Dutch International Radio Service. Radio

Nederlands has a short wave transmitter in Flevoland, the Netherlands, and two relay transmitters, one on Bonaire (1964) and one on Madagascar (1972). The main targets for Bonaire's site are the Americas, West Africa, Australia and New Zealand. Radio Nederlands receives around 7% of the total Dutch state funding for public broadcasting.

TransWorld Radio (TWR) is a non-profit, non-denominational missionary organization broadcasting from nine worldwide locations: Albania, Bonaire, Cyprus, Guam, Monaco, Russia, Sri Lanka, Swaziland, and Uruguay. TWR has some 40 transmitters from 13 primary sites, and an international staff of over 1,000 people.

The most important emergy inflow to the radio stations is gas oil to run the electricity generators, which produce the radio signals. Other inputs are parts, labor, and the original construction. Major storages in the subsystem are (1) the antennas and generators, (2) parent company assets, and (3) estimated cash reserves. Two other interesting storages for this subsystem are hardwood and groundwater. Both sites cover extensive areas of *mondi* with thorn forest cover and groundwater beneath, especially at the northern terminal (Figure 150). Use of this land is restricted, and therefore the storages are essentially captured by the arrays. On a *per establishment* basis the radio stations are located in the middle third of subsystems in emergy storage and flow.

Tourism

Ecotourism has been the engine of development for Bonaire since the mid-eighties. As should be clear by now, tourism on Bonaire has spurred expansions in support industries, especially construction and trade. At the same time, tourism on Bonaire has been facilitated by infrastructure (water, electricity, airport, roads, harbor) that was funded by the Dutch and Antillean governments (themselves fueled by the energy dividends of Dutch natural gas and island refineries, respectively).

Figure 151: Scuba Diving Ecotourism
This picture captures the attraction of ecotourism on Bonaire. The excellent and protected reefs of the Bonaire Marine Park lay immediately off shore in clear waters.

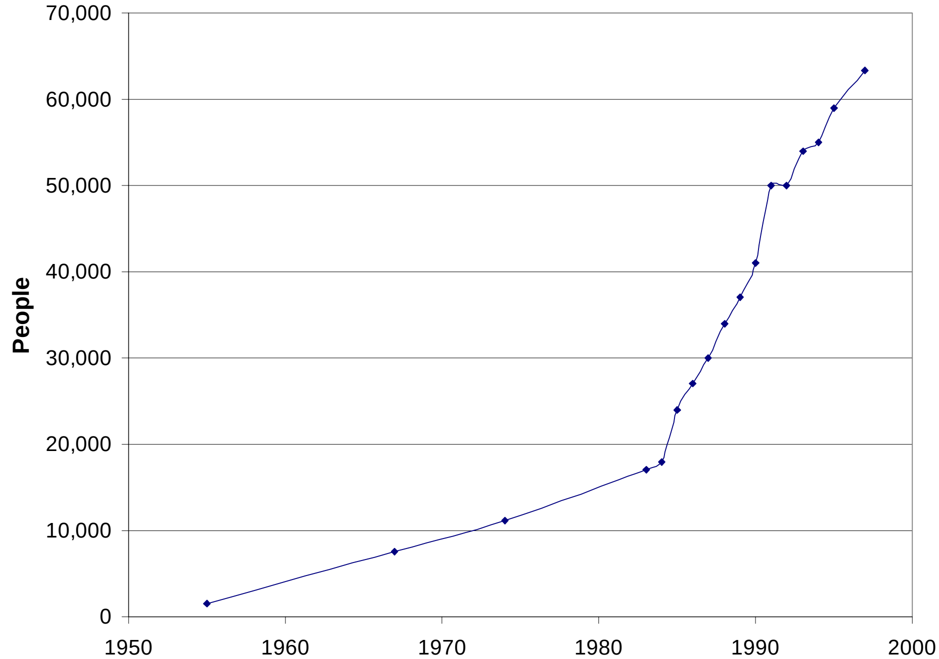

Figure 152: Stay-over Tourists
In the mid nineteen-eighties ecotourism boomed on Bonaire. This occurred simultaneously with a groundswell of international interest in ecologically sensitive travel, and with growing popularity for dive tourism[1]. Data sources are APPENDIX S, Table 45.

Ecotourism can take many forms. Indeed, there is no single definition for the phenomenon. Resource conservation, cultural heritage protection, biodiversity conservation, sustainable development, green management, environmental education, income sharing, local development, community-based initiatives, among others, are touted as benefits of ecotourism by some. The conservation component is described by Brandon and Margoluis (Brandon and Margoluis 1996:29):

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[1] In fact, the S-shape of this curve is one of the most common in nature. It is a logistic growth curve, which can be easily produced in simulation by an autocatalytic growth model (see Chapter X). In that model, a storage is gradually built by a linear flow of assets, as when infrastructure improvements like airport expansion or water / electric networks gradually improve the tourism product (1955-1985). Suddenly at some critical point, the existing storage begins to feedback and amplify the production of itself (1985-95?). Growth can continue until new limits are reached that constrain expansion. This process is intuitively understood by planners and developers, who know that tourism development can unexpectedly "take-off" after years of slow, incremental expansion, and fortunate positioning in the tourism market, after which it plateaus.

> The major underlying assumption of ecotourism is that visitors can provide the necessary economic incentives to achieve local conservation and development. In theory, ecotourism generates revenue which will be used to protect and conserve the biodiversity and natural resources that draw visitors to a particular site.

The cultural heritage component is included in Wallace's (Wallace 1996:122) definition:

> Ecotourism is travel to relatively undisturbed natural areas for study, enjoyment or volunteer assistance. It is travel that concerns itself with the flora, fauna, geology, and ecosystems of an area as well as the people (caretakers) who live nearby, their needs, their culture and their relationship to the land.

Community-based ecotourism is defined by Sproule (Sproule 1996:235) as:

> …ecotourism enterprises that are owned and managed by the community [which imply] that a community is taking care of its natural resources in order to gain income through operating a tourism enterprisie and using that income to better the lives of its members.

Growth limits and tourism policy

The mission statement of the *National Tourism Policy* of Bonaire captures many of these intentions:

> The overall objective for the development of tourism in Bonaire is to enable the people of Bonaire to benefit from the promotion and development of tourism by providing an optimum level of economic contribution consistent with the overall protection of Bonaire's environmental assets, cultural heritage, human resources and lifestyle (TCB 1995, see APPENDIX S).

The *National Tourism Policy* is a comprehensive plan for managing development, which attempts to limit lodging, foreign labor and natural resource exploitation (specifically coral reef contact with scuba divers). Growth limitation is a well-reasoned strategy for ecotourism destinations. However, popular consensus for limits can wane as growth slows. For that reason it is essential that the local population has been included in the benefits of growth, at all levels including ownership and management positions. In addition, the population should be informed and included in policy debates and decisions.

Emperical research can contribute to the popular discourse and negotiation of limits. One of the goals of this dissertation is to provide environmental education that can infuse the democratic and economic discourse, which is lively and productive on Bonaire, from my experience.

Figure 153: Washington Park Nature Tourism
Efforts are being made to diversify the Bonaire tourism product to other types of ecotourism, including birding and nature excursions.

The *National Tourism Policy* for Bonaire is an exceptional set of guidelines to manage economic development. Summarized in general terms (see the full text in APPENDIX Z), the *Policy* has two main goals, (1) to control, to restrict, to *limit* development growth in various ways (Table 17), and (2) to assure the *inclusion* of Bonairians in the economic benefits of development (Table 18).

Table 17: Growth Limits

Limits On:	Achieved With:
1) new lodging	1) unit caps and a new construction moratorium
2) lodging size	2) restrictions on large developments and incentives for small businesses
3) sprawl	3) zoning and land use planning
4) environmental impact	4) required impact studies for new lodging
5) coastal development	5) a moratorium on new construction on the coast
6) diving	6) monitored reefs and dive limits if necessary
7) park excursions	7) limited park visitation if necessary
8) dive shops	8) restricted permitting for shops
9) tourist types	9) tourism policy that promotes high-end market segments like scuba, birding, windsurfing, etc.
10) fast-food chains	10) policy that excludes multinational fast-food chains and promotes local and gourmet ethnic restaurants
11) cruise ships	11) low promotion for cruise and strict rules to limit cruise impact
12) yacht moorings	12) restrictions to constructed mooring sites
13) foreigner residents	13) strict policies for foreign labor and residence, which also limits the rate of population growth for the island as a whole

Table 18: Policies that Promote the Inclusion of Bonairians in Development

Policy Directive:	Achieved With:
1) investment incentives for Bonairians	1) small capital loans and technical advice for Bonairians who will invest in local tourism developments
2) tax holidays for Bonairians	2) exemptions for import duties and property taxes for Bonairian investors
3) building linkages	3) policy to promote links to other island industries, particularly agriculture, fisheries, handicrafts and other services
4) foreign labor limits	4) visa time limits, and restrictions to services that cannot be filled by Bonairians
5) training and education	5) training services for tourism jobs for all positions including management, and with education in primary and secondary schools directed toward the tourism industry

Figure 154: Cruise Ship Tourism

Another form of tourism diversification is cruise tourism, although the *National Tourism Policy* (APPENDIX Z) states that "Government will not actively seek to promote cruise tourism, or allocate funds for that purpose", at the same time maximizing "on-shore spending by cruise passengers." From an emergy perspective it is equally important that "cruise companies and/or their agents will be responsible for disposing of garbage generated by cruise ships visiting Bonaire, and will not be permitted to leave any garbage on the island. They will also be responsible for dealing with any pollution, accidental or otherwise, caused by cruise vessels." Besides this potential impact, the largest is in the expansion of the "downtown" district, which has grown substantially since the mid-eighties with several new "malls", and which will experience further growth if cruise is expanded. Cruise tourism was not analyzed for this study, but I suspect that it is comparable to the relatively high-intensity brand of ecotourism found on Bonaire. Cruise ships may not be out of proportion with other aspects of development on Bonaire. This is an empirical question that could be evaluated with emergy analysis.

If there is anything negative to say about the ecotourism policy on Bonaire, it is that it was not in place early enough. Ecotourism growth in the mid-eighties began without sound policy direction. As is all too common in economic growth around the world, impact studies are often conducted only *after* an intense period of rapid construction. In 1990 a *Structure Plan* was produced to provide "a development framework suitable to a small-island economy with a fragile physical and socio-economic environment (Island Government 1990:I-1)." The *Structure Plan* was followed in the early 1990s by the *Pourier Report* (Pourier 1992, see APPENDIX Y), and the *National Tourism Policy* (APPENDIX Z).

Emergy and the ecotourism product

It is not uncommon to view tourism as an export good. As other exports, tourism generates foreign currency earnings. In fact, it is the major source of foreign currency for the Bonaire economy. From the perspective of emergy accounting, this view is especially appropriate. Goods and services purchased from a tourism host country are purchased by foreigners who use the hotel facilities, eat the restaurant food, and take the goods with them. From that standpoint, the material products of tourism are consumed by foreigners, who happen to travel to the tourism destination to consume them.

What is the tourism product exported on the global market? Is it a T-shirt? Is it an hour diving on a reef? From the perspective of energy, materials, environmental goods, manufactured goods, and human services, what are the components of the tourism product that is exported? As for each of the subsystems described to this point, emergy accounting provides methods to identify the full inputs to an economic activity, and to calculate their contribution to work in that subsystem with the single currency of *emergy*. An emergy evaluation will include the important environmental inputs normally omitted by economic analysis. The emergy of the tourism product that is exported is equal to the total input emergies. The exported emergy is the sum of the inputs, both environmental inputs and human-made. The systems diagram in Figure 155 shows the inputs to the tourism sector on Bonaire.

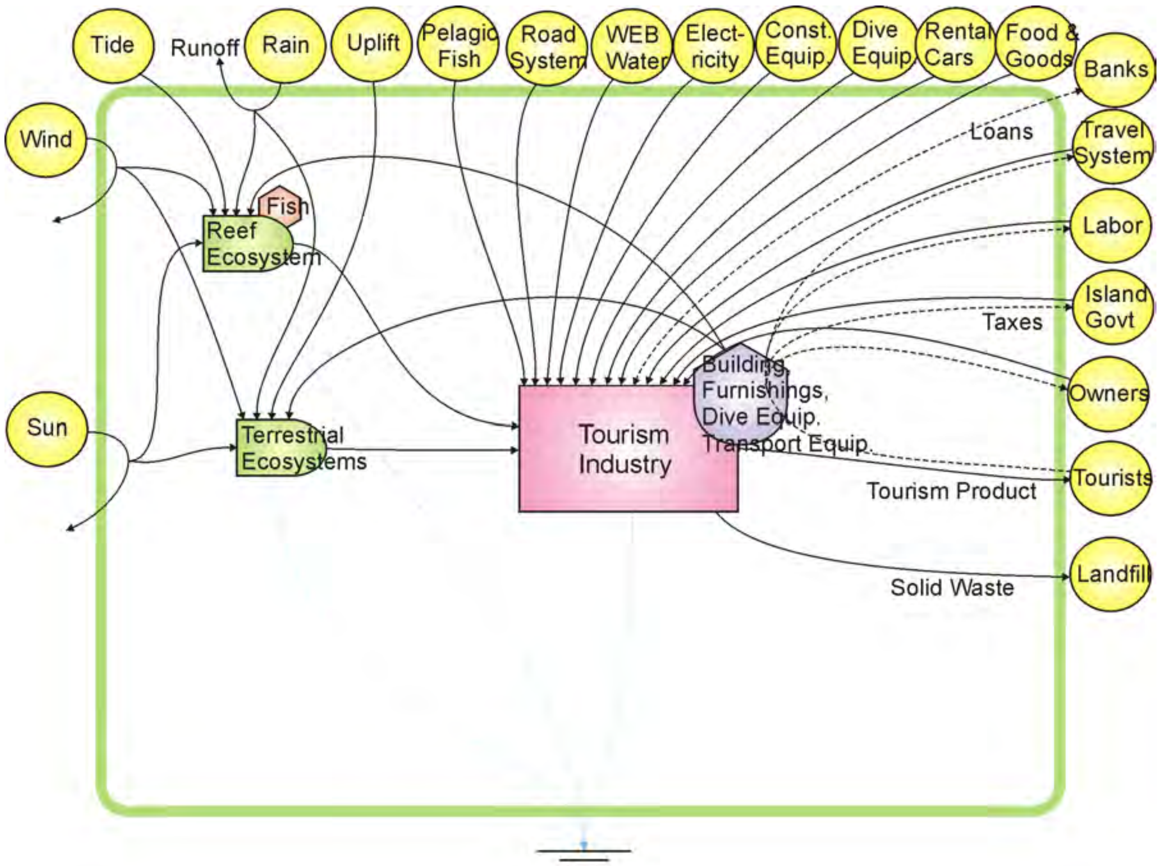

Figure 155: Ecotourism Systems Diagram
Ecotourism on Bonaire depends on many inputs (see emergy analysis in APPENDIX S). Some are environmental, but many are purchased from the international economy. Relative percentages are calculated and graphed in Figure 156.

Important emergy inflows to ecotourism are many and varied (Figure 156 and APPENDIX S). (1) Obviously *Travel* is an essential ingredient, and this value was estimated as 40% of emergy from the island airport. (2) *Services* is an estimate of all expenses for (mostly foreign) goods and services to maintain and promote the hotels. *Services* also includes the expenses paid to foreign airlines and tour operators. Money for these services goes out, but the emergy of the services is an input to the subsystem. (3) Imported goods (which include the emergy of *Shipping*) are represented in the emergy inflows from the *Retail* subsystem. (4) Tourism has a large labor force and the emergy inflow from *Labor* is substantial.

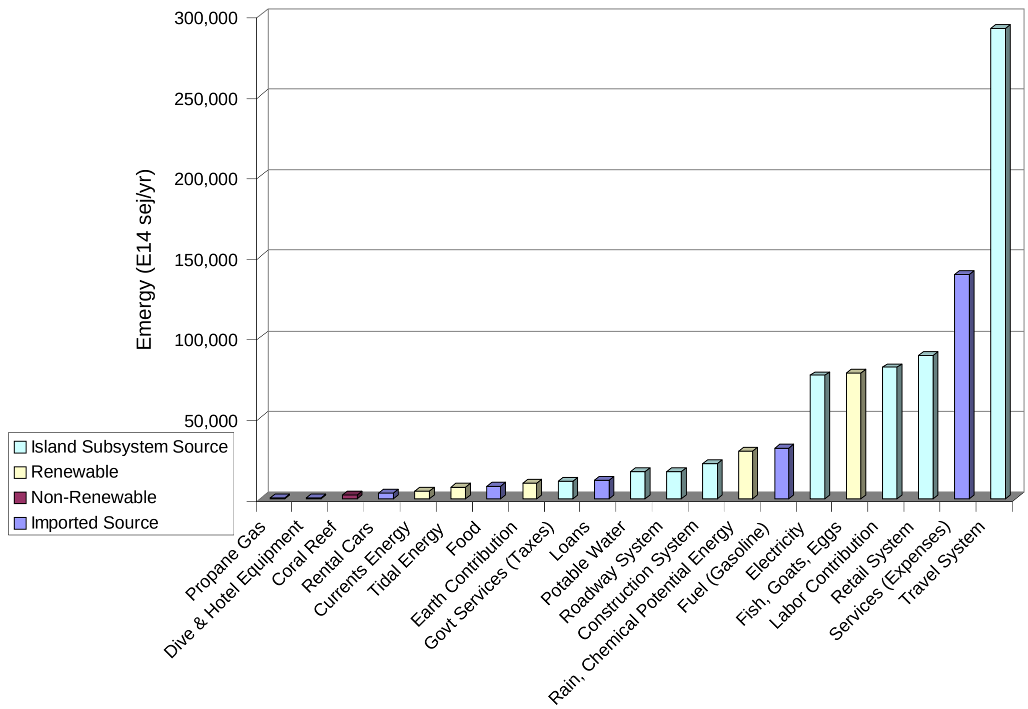

Figure 156: Annual Emergy Inflows to the Tourism Industry
There are many important emergy inflows to the ecotourism subsystem. Uncounted or undercounted by economic analysis, many essential ingredients are natural, renewable resources. Others are non-renewable resources from nature (fossil fuels or minerals). On Bonaire especially, many of the inflows to ecotourism are imported flows of goods and services. Finally, some sources to tourism are the outputs of other production subsystems on Bonaire, which themselves use renewable, non-renewable, and imported sources. See the following text for discussion of these inflows.

(5) Several important environmental inputs enter ecotourism, *Rainfall, Earth, Tide, and Currents*, and additionally *Fish, Goats, and Eggs*. The *Fish* input is surprisingly large, and signifies an important input for tourism and loss to the local economy. *Rain, Earth, Tide, and Currents* are the emergy sources for the terrestrial and marine ecosystems. They are calculated on an aerial basis. In other words, the larger the area associated with tourism, the larger the environmental basis. Before the Marine Park, Bonairians fished from boats directly on the reefs, but this is no longer legal. The production of fish on the reef has therefore been captured by the tourism industry. Part

of the marine environment has also been captured by shipping from the harbor, the salt works, and the oil terminal. Part is still captured by households as they fish from the rocks, or otherwise use the coasts. It was estimated that half of the environmental emergies of the marine ecosystems should be included in the tourism total.

(6) The high *Electricity* and *Gasoline* inputs to Bonaire's tourism industry indicate the "developed" nature of the ecotourism product. (7) Other obvious and important inputs are *Construction*, the *Roads* used by tourists and establishments, *Fresh Water*, *Loans*, and the *Island and Central Governments* that assure private property.

The sum of these emergy inputs is a total, which represents the emergy in the tourism export good. In other words, it is the emergy quantity that is exported when tourism is consumed by foreign tourists. This total leaves the island in return for foreign currency. It is 970,586 E14 sej/yr, which is the highest total for all export industries (Figure 171, CHAPTER 14).

On a *per establishment* basis, however, tourism emergy inflows and storages are not high. Unlike the other export industries, there are many establishments that compose the tourism industry. Ranked among all production subsystems on Bonaire, tourism lies somewhere in the middle (Figure 172). This places tourism in the center of the two "web" drawings of production hierarchy on Bonaire (Figure 104 and Figure 108).

Tourism intensity and sustainability

In emergy analysis, the *intensity* of development is a calculated measure that can be compared to alternative development choices in order to estimate the impacts that a development choice is likely to have on an economy and ecology. This type of approach was applied by Brown and Murphy (Brown and Murphy 1993:3D1-3D27) in evaluating ecotourism at two resorts in Papua New Guinea and Mexico:

> If a development's intensity is much greater than that which is characteristic of the surrounding landscape, the development has greater capacity to disrupt existing social, economic, and ecologic patterns

> (Brown 1980, Odum 1980). If it is similar in intensity it is more easily integrated into existing patterns. For example, because of the differences between a heavily urbanized area and an undeveloped wilderness area, the appropriate intensity of development in each environment is much different (Brown and Murphy 1993:3D7).

Notice that this measurement does not suggest "sustainability." This point should be clearly made. The term sustainability has been so broadly applied in the literature that it is of little analytic value. In human history, human activity has been supported by the fluctuating use of renewable and slow-renewable resources (see the extensive discussion in CHAPTER 16). In recent human times, human society has been subsidized by the capture and use of non-renewable resources (specifically fossil fuels and metals). If sustainability refers to renewable and slow-renewable resources, then human activity on Bonaire would need to return to pre-contact densities of less than 1200 people, living as horticulturists (CHAPTER 3, Figure 9). On the time-scale of millenia, this is the "sustainable" human pattern. However, in the time-scale of the 150 year fossil fuel pulse that we are now riding, sustainability has a very different measure. In this context, it could better refer to human activity that does not further tax existing ecosystems, and/or threaten the renewable and slow-renewable resources upon which we also depend (such as fresh water, topsoil, forests, and coral reefs).

Figure 157: Lodging for Higher-end Dive Tourists
Ecotourism on Bonaire combines reef eco-management with luxury accommodations for higher-end dive tourists. This brand of ecotourism obviously requires a substantial construction industry (as already discussed), and significant water, electric, and waste management. Ecotourism of this sort has a relatively high subsystem intensity ratio. However, intensity ratios are used as relative measures. Investment that matches an existing intensity of development, in principle, will not disrupt existing social-economic systems. Intensity ratios must always be considered in this context of existing intensity (see discussion in text).

Subsystem *intensity ratios* are defined here as the ratios of subsystem emergy inputs divided by the total environmental emergies entering the island. This places each subsystem on an equal environmental basis. In other words, it is assumed that the numbers of establishments have self-organized to be appropriate for the spatial and environmental scale of Bonaire, and thus each subsystem (species, niche) is supported by the total system environmental emergy[2]. Figure 158 depicts the intensity ratios for the production subsystems on Bonaire.

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[2] An island of this size would not have two, or three electric power plants. It is not efficient in energy or emergy terms. An island the size of Cuba or Puerto Rico, on the other hand, could support multiple power plants. Likewise, an island of this size can

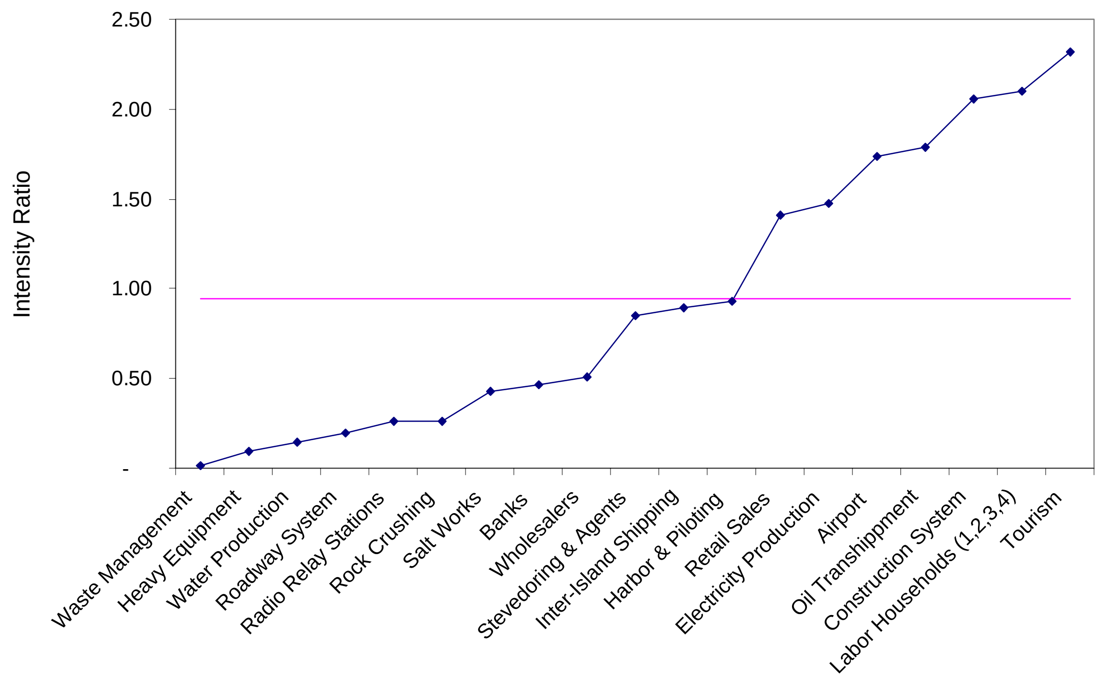

Figure 158: Subsystem Intensity Ratios
Intensity ratios measure the ratio of economic subsystem emergy inflows to the inflows of environmental sources. The average ratio is shown in light blue as 0.94. The related industries of tourism and construction are the highest intensity subsystems. These are relative and not absolute measures that can compare, for instance, the entire construction subsystem with the single oil transshipment terminal, and find that their intensities are similar. The average intensity ratio (0.94) can be used as a guideline for the approval of future establishments that are intended to minimize environmental stress.

Figure 158 displays a range of intensity ratios. While the related industries of tourism and construction are high, this is only in a relative sense that draws comparisons with other subsystems on the island. For instance, perhaps obviously, the intensity ratio for the oil refinery on Curacao would be far greater than these numbers. The intensity ratios for Bonaire permit comparisons between diverse production subsystems (like

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efficiently support only one oil transshipment terminal. On the other hand, an island of this size can support over 100 retail "snacks." This number was not proscribed, but has self-organized on Bonaire to be appropriate to emergy flows. Therefore, the intensity tourism or construction) with single site industries (like the salt works or transshipment terminal). The value of these ratios is in providing guidelines for the approval of new establishments. If such indices were calculated *before* tourism development had begun, they could have been used to guide development to a lower intensity, with perhaps less disruption. As it is, tourism development still ranks close to other existing industries, however, there are probably few Bonairians who would say that tourism has not transformed the island along at least a few dimensions, i.e., congestion, crime, inflation, or others. It is suggested here that if tourism development had been managed to match existing intensities that existed prior to development, these few negative effects would not have been felt.

As stated in the quotation above from Brown and Murphy, "If a development's intensity is much greater than that which is characteristic of the surrounding landscape, the development has greater capacity to disrupt existing social, economic, and ecologic patterns." Obviously this is a *relative* measurement, one that places establishments within the context of the existing system. For example, a 1000 room hotel in New York City would not be disruptive to the existing ecological-economic system, but the same hotel on Bonaire would dramatically transform the existing environmental-economic relationships that currently exist. If one professed goal of ecotourism is to minimize the impacts of development activity, then development should match a scale appropriate to the extant host site. The next section will compare five existing hotels on Bonaire and use these principles to suggest an appropriate scale for hotel establishments.

Five hotels comparison

Five anonymous hotels were extensively interviewed and compared. Emergy inputs were calculated for each. There is a range of hotels on Bonaire, from small to

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ratio should be calculated against the total environmental emergy, which contributed to the emergence of the retail subsystem on Bonaire.

large. An attempt was made to interview hotels near both ends of this continuum, and in-between.

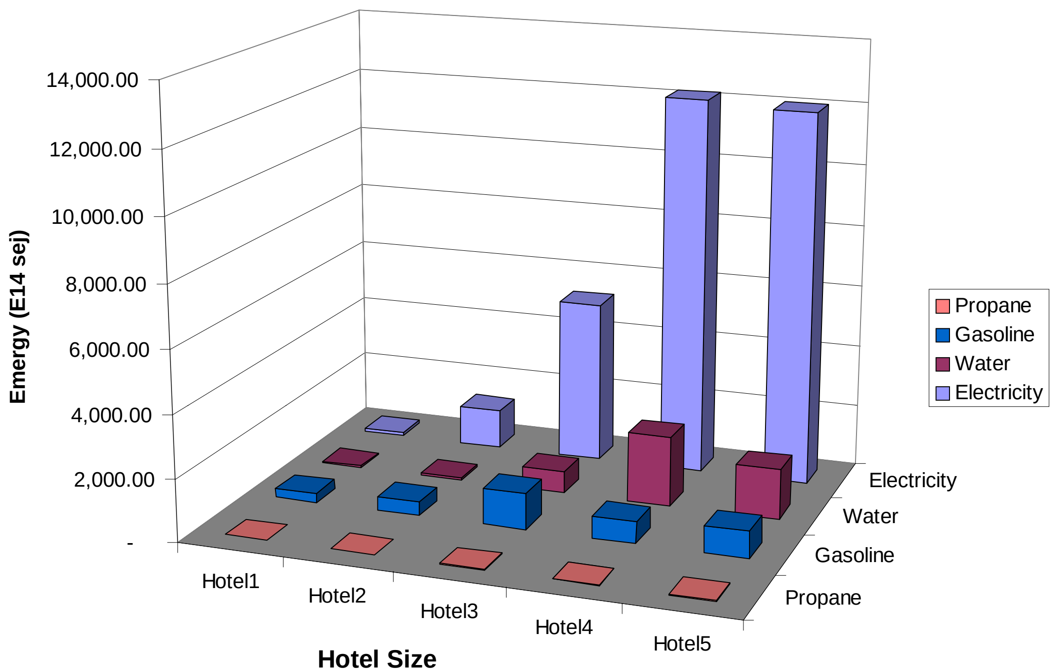

Figure 159: Hotel Emergy Inflows from Utilities
Electricity is the largest utilities input for large hotels. However, gasoline is the largest emergy inflow for smaller dive-oriented hotels. Recognize that these are *emergy* and not money inputs, and therefore indicate the relative work that each contributes to the tourism product. Electricity is a higher-transformity energy source, because it is produced by combining fuels with high-technology generators. The output electric power is a very flexible and versatile form of energy, appropriately matched to urban settings. Fresh water normally has a high emergy value because it is the product of the work of natural systems to evaporate seawater and converge rainfall into usable concentrations. Fresh water on Bonaire is especially valuable because it is instead a fossil fuel product, manufactured in the desalination plant.

The hotels are compared first on emergy inflows from utilities (Figure 159). This comparison can convey the relative sizes of these five establishments using familiar measurements, without revealing their identities.

Figure 160: Coastal Hotel Properties
Some of the coastal tourism development of Bonaire is seen from this aerial shot. The environmental contribution to any development project (sometimes called its ecological footprint) extends well beyond the immediate site. Near the top of the picture can be seen the electricity and water plant. That infrastructure supports all others on Bonaire, and is powered by oil from Curacao's refinery.

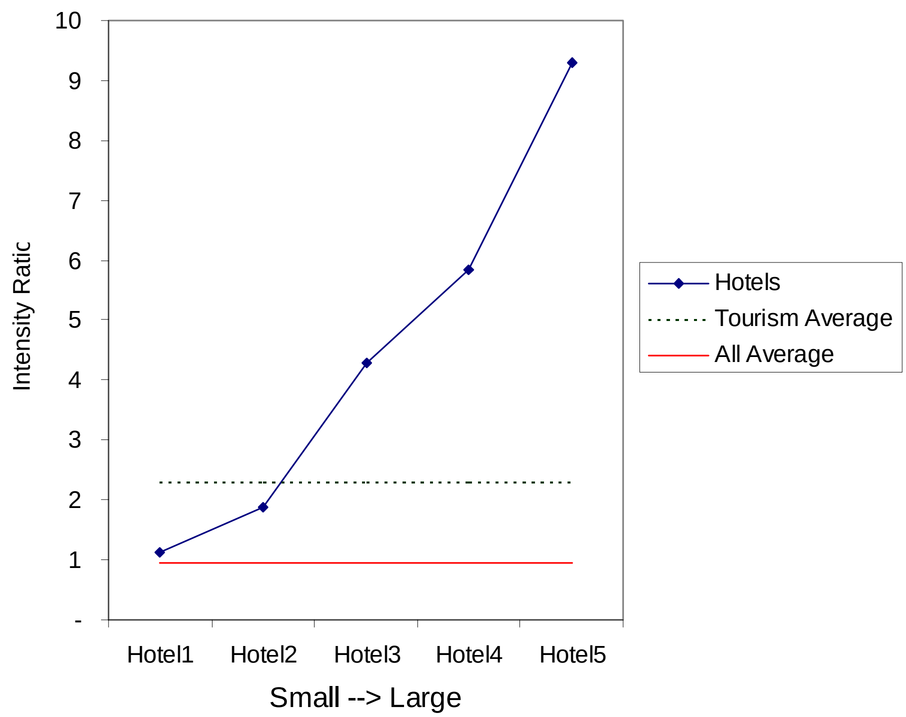

Figure 161: Intensity Ratios of Hotels
Intensity Ratios were calculated for the five hotels interviewed. Intensity ratio might suggest an ideal or appropriate hotel size for hotel developments on the island. "All Average" is the average intensity ratio for all subsystems on Bonaire (0.94). Values are calculated in Table 44 in APPENDIX S.

Figure 161 displays the intensity ratios for five hotels. The intensity ratios show an obvious pattern of increase with hotel size. Recall that the subsystem intensity ratio compares the contribution of purchased goods and services to the contribution of natural, domestic ecosystems. Intensity ratios can suggest a development size that is appropriate for an existing economy. The average intensity ratio for production subsystems on Bonaire is 0.94, and for the total tourism subsystem it is 2.32.

As stated above, one goal of ecotourism should be to match the scale of new development to the existing intensity of development, a rainforest in some contexts, or an urbanizing tropical desert island in another. In the case of ecotourism on Bonaire, therefore, hotels with intensity ratios of approximately 2.32 or less would be appropriate. This suggests that any future developments should be somewhere between Hotel1 and Hotel2 in scale.

Many Bonairians have a sense of the desirable scale for development on Bonaire, which is remarkably similar to the results of my analysis. They can also give concrete examples of the unforeseen costs of over-scaled development, such as lost access to swimming areas for kids. Many people spoke of their desire that Bonaire not change too much, that the tranquility of the island not be lost, as many have seen from travels to Curacao, Aruba or St. Maarten. Many are wary of mass tourism, which is a tempting option for some of the existing, larger hotels that are having financial difficulty in the dive tourism market. Others, however, simply believe that the more the better. A common heard slogan is "more tourists is much better" (*"mas turista, mas mihó"*). This woman (58) expressed some of the positive feelings toward tourism, which is commonly combined with the hope that the island will stay as peaceful as it is.

> Bonaire wants more tourists. More tourists, much better yes. Because Bonaire is a beautiful island. Everybody likes Bonaire. Because of that we expect more tourists, it's much better for us if the tourists can stay longer, or go, and every year come back. They like it. Every year, they go to another place, they go to Curacao, or Aruba, somewhere else, or Saint Maarten, wherever, but they liked Bonaire, they come back again. There are tourists that have come for 20 years. The same ones, they come regularly. Because they like it. [They like it a lot. It's a beautiful island.] Bonaire is a quiet island, tranquil and everybody is caring. But we expect it to stay like that also.
>
> *Bonèiru ke mas turista. Mas turista, mas mihor si. Pasó, Bonèiru ta un isla bunita. Ahh tur hende ta gusta Bonèiru. Wèl, dor d'esei nos ta spera mas turista, mas mihó pa nos e turistanan por keda mas tantu, òf nan ta bai, despues di kada aña, e mesun hende 'a bin bèk. Nan a gusta. Tur aña, lugá nan bai un otro kaminda, nan bai Kòrsòu òf Aruba òf otro kaminda, òf Sint Maarten, unda ku ta, nan a gusta Bonèiru, nan t'ei atrobe. Tin turista k'a bin binti aña. E mesun ... 'Geregeld' (= regularly) nan 'a bini. Pasó nan gusta. [Aha?] Si. [Nan ta gust'é hopi. E ta un isla bunita.] Bonèiru ta un isla ketu, trankil i tur hende ta kariñoso. Pero nos ta spera pa e keda asina tambe.*

Hopefully, development indices such as the intensity ratio can suggest policy that will maintain the standard of living that residents desire.

Inclusion policies and employment

Inclusion is a very important issue to Bonairians, and it deserves special attention. The *National Tourism Policy* includes some strong and probably controversial statements about employment and emigration. It is a stated goal to:

> Maximize job opportunities for Bonaireans and other qualified Antilleans at all levels of skill and responsibilities in the tourism sector by expanding training opportunities for nationals already working in, or potentially interested in entering the tourism industry and by limiting the validity of work permits of expatriates in cases where suitable qualified Antilleans are not available to such reasonable periods of time as are required for the training of local counterparts. Bonaire's labor policies should seek to encourage Bonaireans and other qualified Antilleans living elsewhere, to consider taking up job positions in Bonaire…
>
> …Application for work permits for expatriates will not be entertained in cases where suitably qualified Bonaireans or Antilleans are available to fill the vacant positions. Where applications for work permits are granted they will be limited to the periods of time required for the training and succession of local counterparts.

These provisions are critical if Bonairians are to be given a chance to grow expertise locally, and therefore participate fully in the benefits of tourism development.

Does the present tourism industry offer desirable employment opportunities for Bonairians? It is well recognized that management positions in foreign-owned hotels around the world are often not available to the native-born. One tourism textbook makes this general statement:

> Another concern among host countries has been that a foreign-owned hotel allows limited opportunity for local employees to reach positions of responsibility. International hotel chains usually have a core expatriate management team of three in a 100-room hotel, five in a 250-room hotel, and eight in a 350-room hotel. Some management contracts will stipulate that within, say, three to five years the management team must be made up of locals (Mill and Morrison 1985:238).

Furthermore, the hotel industry produces many jobs that are undesirable or demeaning to many Bonairians, such as housekeeping. This leaves some hotels even less integrated into the island social-economics, with foreigners hired at both ends of the pay scale, and Bonairians occupying the middle.

This woman (42) and hotel waitress made these points clear:

> I think if kids, when they finish, they need to look into the way of entering hotels, or look…[The kids? For work?] Yeah. Because there's hardly any Antillians in hotels. They look for all foreign people to bring to Bonaire. Bonaire itself has kids that can do it. [Yes.] They need to have the taste for it, you know, the "will"…Don't let people from outside come…We ourselves can do it. [Yeah. There's a school here?] Yeah. A *'hotelvakschool'*(?) But the kids don't need to learn papers. They need to go follow a *'stage'* (work experience program, intern program). The internship is very important. One month in restaurants, one month in bars, one month in kitchens. That way is much easier, you know? Don't get a kid that come's to do the *'stage'*, take them and say, go clean the table, and the chair. Let them do it…(tape out) [Yeah. there's a *'stage'* at school now for kids?] No. Not yet. Now we have *'stage'* yeah, but from Holland. They come to do internships from Holland here to Bonaire. [A lot of Dutch kids, they come to do internships with you at the hotel?] Yes. [And that's good, or you want more kids from Bonaire…?] Yeah, more kids. School…more kids come, come to come grow up…come to get ahead. Because we have a lot of kids that have the capacity to succeed with tourism. [Tom agreeing] But all hold back. I don't understand the fear they have to face the people, you know? Talking with people. They can do it. They can do it.
>
> It's really beautiful, a hotel job. Really beautiful work to attend to the tourists. You get your annoying people, people argue sometimes … there's happy people, there's people that don't like this or that. I explain to them, talk with them, don't give the guests an angry face. Sometimes there's people at work, they have problems, you know. At home. They come to work with the problem. So the tourists say, what's up? Problems need to stay at home, so work is calm. Although you don't want to laugh, but don't let the tourists see you with problems. That goes on a lot here (on Bonaire). Bonairians, a lot. People go (to work) with problems…from home … ARGUING. Not good. [Leave it at home] Yes. Leave it at home. Come to the hotel in a good mood. (someone comes to door)
>
> [So you told me that kids should go work in the hotels?] Yeah. There's a lot of kids that can go work. [And you work with people from Venezuela, Santo Domingo, …] All. All. Everywhere. Venezuela, Columbia, Holland…everywhere. [Is it good, do you think it is good for foreigners to come work, or…?] No. I prefer the Bonairians (*yu di tera*). Because they need to do it. They can do it. Kids of this land can do it. But yeah, if they don't want to?! [Are there more kids now, that work in hotels, compared to 10 years ago?] No. There's not a lot. There's not really a lot. [And in all the jobs…in the hotel, Bonairians, they work what types of jobs? All the…?] Yeah, all. Ok, in the kitchen, bar…In the kitchen the majority of them are Venezuelan, or Colombian, or Santo Domingans. Yeah. In the

bar it is possible there's Bonairans themselves. From Bonaire. In the rooms there's, the majority are Colombian or Santo Domingan. Yeah. [And the onwers, or the bosses, are they Bonairians?] No, Dutch (*makamba*). There's Dutch bosses…there's…the majority there's Bonairian bosses, very few. [But the Bonairians, they can do it?] Yes, they can. They can do it. Yes. They can do it. [Yeah, you know] They need to do it yeah.

Mi ta kere sí ku, muchanan ku, ora kaba nan mester buska moda di drenta hotèlnan, òf buska ... [E mucha? Pa trabou. Pa traha.] Si. Pasó no tin kasi Antiyano pa den hotèlnan. Nan ta buska tur hende afó trese Bonèiru. Bonèiru mes tin mucha ku por hasi'é. [Si.] Nan mester tin e smak…No laga e hendenan bin djafó bin .... Nos mes por hasi'é. [Uhun. Tin un skol aki?] Si. Un 'hotelvakschool'. Pero e muchanan no mester siña di papel. Nan mester bai kore 'stage'. I e 'stage' 'a mas importante. Un luna den restorant, un luna den bar, un luna den kushina. Asina mas fásil, no. No kue un mucha ku bin 'stage', kue bis'é, bai limpia e mesa k'e stul. Lag'e hasi p'e (END OF TAPE). [Si. Tin e 'stage' na skol awor aki pa mucha?] Nò. [Nò?] Ainda nò. Awor aki nos tin 'stage' si, pero di Hulanda. Nan ta bin 'stage' di Hulanda aki na Bonèiru. [Hopi mucha di Hulanda, nan ta bin ... ku 'stage' traha ku señora na hotèl?] Si. [I ah e ta bon òf señora ta ... señora ke mas hende di Bonèiru?] Si. Mas hende. Mas mucha. Skol ... mas mucha bin, bin pa bin krese ... bin pa bai dilanti. No laga nos so bini. Pasó, nos tin hopi mucha ku tin kapasidat pa huza ku turismo. Pero ???? Mi nos sa ta miedo nan tin di enfrentá e persona, bo sa kon? Papia k'e persona. Nan por hasi'é. Por hasi'é.

Ta masha bunita un trabou di hotèl. Un hotèl bo ... Masha bunita trabou pa bo atendé ku turista. Bo ta hañábo ku hende 'vervelend', bo sa, hendenan rabiá tin ora ... tin hende kontentu, tin hende ku n' ta gusta esaki ... Mi ta splika nan .... papia ku nan ... no trata nan ku kara rabiá. Tin be tin hende di trabou, nan tin problema, no? Na kas. Na ta bin trabou k'e problema. Anto e turista 'a bisa ????? Problema mester keda kas, anto trabou bin kontentu. Ounke ku bo n' ke hari, pero no laga e turista mira ku bo tin problema. E kos ei 'a pasa hopi 'ki riba. Hend'i Bonèiru, hopi. [Si? Hopi 'ki riba?] Kemen, aki, no. Aki riba Bonèiru, no. Hende ta bai ku nan problemanan kas, mané rabiá. Nò. [Lag'é na kas.] Si. Lag'é na kas. Bin hotèl kontentu. (Someone knocks at the door and she attends).

[Si. Señora a bisámi .... Señora ta kere e muchanan mester bai traha na hotèl?] Si. Tin hopi mucha ku por bai traha. [Uhun. I ah ... Si, señora ta traha ku e hende di Venezuela, di Santo Domingo, di ...?] Tur. Tur. [Tur kaminda?] Tur kaminda. Venezuela, Colombia, Hulanda .. tur kaminda. [I ah e ta bon, señora ta kere e ta bon pa e strañero ta bin traha, òf señora ...?] Nò. Mi ta preferá e yu di tera. [Si? Preferá yu ti tera.] Si. Pasó tin ku por hasi'é. Nan por hasi'é. Yu di tera mes por hasi'é. Pero ya, si nan n' ke! [Aha. Tin mas yu .. mas mucha awor .. na ta trah' den hotèl, kompará ku dies aña pasá? Antes?] Nò. No tin hopi. [Nò, no tin hopi.] No tin hopi hopi hopi. [I den tur e trabou ... Ah den hotèl, hende di Bonèiru, nan ta

> *traha ki sorto di trabou? Tur e ...?] Si, tur. Bon, den kushina, bar ... Den kushina mayoria di nan ta di Venezuela, òf Colombia òf di Santo Domingo. Si. Den bar por ta tin Bonèriano mes. Di Bonèiru mes. Na kamber tin .. mayoria di nan ta Colombia ku Santo Domingo. Si. [Ah, si. I ah e doño, òf e hefe ... ta di Bonèiru?] Nò, makamba. Tin makamba hefe ... tin ... mayoria tin Bonèiriano hefe. Masha poko. [Pero hende di Bonèiru, nan por?] Si, nan por. Por hasi'é. Si. Por hasi'é [Uhun. Si, no? Despues.] Nan mester hasi'é si.*

Other comments I heard about hotel work from employees were (1) low pay, and dependence on tips, which are irregular during the year, (2) short lunches, which means that the employee cannot make it home for lunch (a common work routine, with two-hour siestas often taken by other retail stores at noon), (3) six day work weeks, and (4) too many hotels, diluting the market and reducing the profitability for waitressing, bartending, etc.

Airport

The most important emergy inflows to the airport subsystem are (1) fuel and (2) purchased services, primarily from Curacao for the refining and delivery of fuel. While exact quantities were not available, it was estimated that the international airport on Bonaire depends on fuel imports of approximately 3 million gallons per year (see emergy analysis in APPENDIX T). In one sense, airports are gas stations for planes. Fuel, with its high-emergy return, is a great benefit to any economy because industries that use it can "fuel" other industries. Industries that can use fuel, such as airports, electric plants, desalination plants, and others, have a high net emergy that can drive other systems. Other important emergy inflows are (3) foreign aid, (4) the runway concrete and subbase, (5) electricity, and (6) a significant labor contribution of 165 persons.

Figure 162: Airport with ALM and KLM Aircraft

Important storages for the airport subsystem are (1) the airport runway itself, (2) a percentage of the storages of government (the airport is a government industry, managed by private firms), (3) the airport terminal and equipment, (4) the storage of foreign aid that has built and widened the runway, and (5) the storage of money estimated for the airport.

On a *per establishment* basis, the airport has the second highest emergy inflows for an industry, behind the oil transshipment terminal, and it is fourth in storage emergies.

CHAPTER 13
STATES AND STATE GOVERNMENT ON BONAIRE

Bonairians are governed by a state political-economic system. Anthropologists have studied the origins of states. States originally and independently emerged from chiefdoms in a few conducive world regions:

> The formation of a state is the result of a number of interrelated events feeding back on one another in complex ways. Ecological and historical circumstances, population pressure, long-distance trade, warfare and military organization, conquest, internal competition between groups, the maintenance of private property and the privileges of elite classes, and the necessity for more integrated management of public works such as irrigation all may play a role in the emergence of the state (Nanda 1991:349).

Ancient states may be characterized by a few essential features and processes:

> The state is a form of politically centralized society whose governing elites have the power to compel subordinates into paying taxes, rendering services, and obeying the law…
>
> As the governing elites compel subordinates to pay taxes and tribute, provide military or labor services, and obey laws, the entire process of intensification, expansion, conquest and stratification, and centralization of control is continuously increased or "amplified" through a form of change known as positive feedback. Where modes of production could sustain sufficient numbers of peasants and warriors, this feedback process recurrently resulted in states conquering states in the emergence of preindustrial empires involving vast territories inhabited by millions of people. (Harris 1987:210)

This simple equation of states--polities formed from monopolies on military force, law, and taxation, directed to the intensification of economic production--continues to apply to states today:

1. The Police/Military. The police/military apparatus of the state provides the coercive force, or threat of force, which guarantees that laws are obeyed, taxes are paid, and service is provided.
2. Laws and Courts. Laws apply to many spheres of life, but in the majority they assure rights to "private property" in its many forms. Legal contracts permit the exchange of property. Deeds assure ownership. Buying, selling--these activities

are defined by laws and protected by the coercive force of the state police/military. Acquiring property by other means is labeled theft, which is considered illegal and can lead to incarceration. Legal judgement is pronounced in state courts, and parties are bound by court decisions.

3. Taxes and Finances. Taxes support the government and political elites. In this day of nuclear arsenals and fossil fuel states, political elites use taxes to control greater military and natural assets than ever before. The activity of managing state tax revenues has broadened into a complex financial role of state accounting, money supply maintenance, and interest rate control--the so-called fiscal and monetary policies of a government.
4. Intensification of Production. In authoritarian states and ancient kingdoms the government is direct owner of key assets for economic production--land, minerals, forests, water rights, etc. Taxes (assured by police and legal coercion) are used by government elites to amplify economic production. Intensive production of domesticated foods can support larger populations. Large populations directed to further intensifications or military expansion are autocatalytic features (positive feedback) of state growth, within environmental limits.

Two other complementary features of state governments have been greatly amplified in recent times, as economic production has shifted from agrarian to mercantilism and then industrial capitalism.

5. Promotion of Industry. In industrial states, the ownership and control of productive natural assets is no longer the monopoly of political elites, but is rather shared by political and corporate elites. Government and industry form strategic alliances of mutual support in the production of goods and services. The success of industry expands the government tax base, technology base, and police/soldier base. Governments use their police/military and legal systems to facilitate industry success. This autocatalytic relationship is the engine of capitalist expansion when natural resources are available.
6. Wage Labor Force. Industry requires a free wage labor force. From the perspective of industry and the government, the ideal wage labor force is skilled, healthy, motivated, unorganized, unarmed, docile, mobile, and fully dependent on the market for its livelihood. From the perspective of the labor force in democracies, the elected officials of government should promote public welfare. These two perspectives are largely but not wholly incommensurable. In tax-supported social welfare states like the Netherlands, Germany, Switzerland, Austria, and France, public welfare is advanced with public education, health programs, job assistance, and pension plans. The resulting labor force is skilled, healthy, and dependent on the market, though perhaps less docile and unorganized than industry would prefer. It may be that the successes of social welfare states of the last half-century are ultimately the result of plentiful oil and gas to feed economies. It will be interesting to see if this century brings a reversal or retraction by social welfare governments and industry to features 1 through 4 above, leaving labor to fend for itself.

States and State Elites

Is there a "storage" of people (elites) within contemporary states (as there is within privately owned corporations)? The first states were ruled by powerful hereditary elites, known variously as monarchs, kings, queens, emperors, etc. These elites "owned" the wealth of the state and could dispose of it as they wished. Their families were permanently a part of the state. In systems terms, this storage of people was within the state, and their assets intermingled with the state. See Archaic States for further discussion.

In the 19th century in Europe, state monarchs were stripped of this totalitarian power in revolutions and reform movements. Not withstanding the popular ideology of freedom and democracy, this may have ultimately been due to the emergence of competing elites in industry. Since at least the 17th century in Holland, Britain and elsewhere, capitalists had emerged with economic power that rivaled the state, at times in direct competition with it.

Since the 19th century, the role of states has increasingly been transformed to the promotion of industry (per #4 above). Government and industry form strategic alliances of mutual support in the production of goods and services. In democracies today, elected officials occupy temporary positions in state bureaucracies. In theory, they may not directly benefit from the assets of the state. However, with the mutualistic relationship that exists between state and industry, political elites are surrounded by opportunities to multiply their personal asset storages. Many parlay their positions into great wealth, either in office or after they leave office.

But in fact, the super-elites of this day are no longer the heads of state. They are instead the owners of transnational corporations, whose territories span many states, whose personal assets exceed those of state elites, and whose durability (turnover times) are yet to be judged. Transnationals cannot exist independent of states, but form alliances with states when it is expedient. They continue to depend upon the ancient functions of states, to assure private property, to defend it with police and militaries, and to tax citizens to support themselves. The synergism between state and transnationals serves both.

The State on Bonaire

Figure 163: Politicians and the Assets of Government
The Island Government administration building, which houses personnel, records and record-keeping hardware of government.

Several administrative, policy-making, and management offices constitute the government apparatus of Bonaire (Table 19). Bonaire is governed by three state bodies, the "Island" government of Bonaire, the "Land" government of the Netherlands Antilles, and the final political authority of the Kingdom of the Netherlands. The state offices that govern Bonaire fit the state pattern defined above, collecting taxes, monopolizing force, managing legal claims, promoting industry, and providing for welfare. Because of the three tiered nature of political authority on Bonaire, some of these functions are performed locally, others by the Netherlands Antilles, and still others by the Netherlands:

Table 19: Features of the State on Bonaire

State Feature	**Government Office**	**Feature on Bonaire**	**Material Assets**
Police/ Military	Police Station (Land)	Island and Land governments provide the police and airport security on Bonaire. The Netherlands government provides the umbrella of international military force. In recent years on Bonaire, emergent inequality and emigration to the island have resulted in increased crime (mainly theft) and therefore an expanded demand for a police presence.	• Weapons • Prison • Police Cars
Laws and Courts	Justice and Public Prosecutor (Land) Legal Affairs Office (Island)	Legal Affairs and the Courts are provided by the three tiers of government. State prosecutors and judges are appointed in the Land tier.	• Courts • Laws • Legal Deeds
Taxes and Finances	Tax Inspection and Collection (Land) Financial Office (Island and Land) Customs (Land) Central Bank (Land)	Taxes are collected by tax inspectors and collectors, and by the island customs officers. State finances are managed by the Finance office and the Central Bank. Under pressure from the IMF and Dutch government, the island governments have intensified efforts to asses and collect taxes on Bonaire. This has resulted in the "voluntary" reallocation of land, away from residents and farms and toward foreigners, Antillean emigrants, and industry.	• Bank offices and records • Tax Office • Customs Office • Records and record-keeping equipment • Money supply
Intensifica-tion of Production	Harbor and Piloting (Island) Public Works (Island) Water & Electric (Island, semi-)	Production is intensified by a functioning harbor and piloting service, airport, land management, desalinated water, electricity, and public roads.	• Piers and Tugboats • Roads • Airport • Water & Electric Plant
Promotion of Industry	Economic Affairs (Island) Land and Zoning (Island) Land Registry (Land)	Industry is promoted by the Economic Affairs office, by land and zoning management, and by the services provided under the previous heading (ports, roads, airport). In recent years on Bonaire, the government has exerted its control over lands--for mining stone	• Offices • Land records and registries

State Feature	Government Office	Feature on Bonaire	Material Assets
		and sand, for building roads, for solid waste management, and over coastal waters, which are managed as a diver's marine park.	
Wage Labor Force	Fire Department (Island) Labor and Social Affairs (Island and Land) Public Education (Island and Land) Health and Hygiene (Island) Agriculture Extension (Island) Welfare and Civil Rights (Island)	Bonaire has inherited features of the Dutch social welfare state. Several government offices are directed to ensuring public welfare. These include the Fire Department, Labor Office, Public Education, Health and Hygiene, Agriculture Extension, and the Welfare and Civil Rights offices.	• Fire Equipment • Offices • Schools • Health Lab and Field Testing • Agriculture Extension center • Welfare records and record keeping

The State Equation and Financial Aid

One mechanism that the Netherlands government has used on Bonaire to assure and promote the six functions of the state outlined in the previous section has been financial aid. Current policies of financial aid to Bonaire began after the reorganization of island governments in the 1950s gave Bonaire the new authority to solicit aid funds, and gave the Netherlands a new and eager political-economy to mold. Financial aid has been targeted to a number of the subsystems previously discussed. This section will identify briefly some of the destinations of financial aid and their respective contributions to development.

Wage Labor Force

Labor Households. Financial aid directed to support households and wage labor has come in several forms. The major aid recipients are schools and house construction. A very significant portion of Dutch funding has been for the construction of housing projects (Figure 164). Most of the financial aid for subsidized housing came in the 1980s and 1990s.

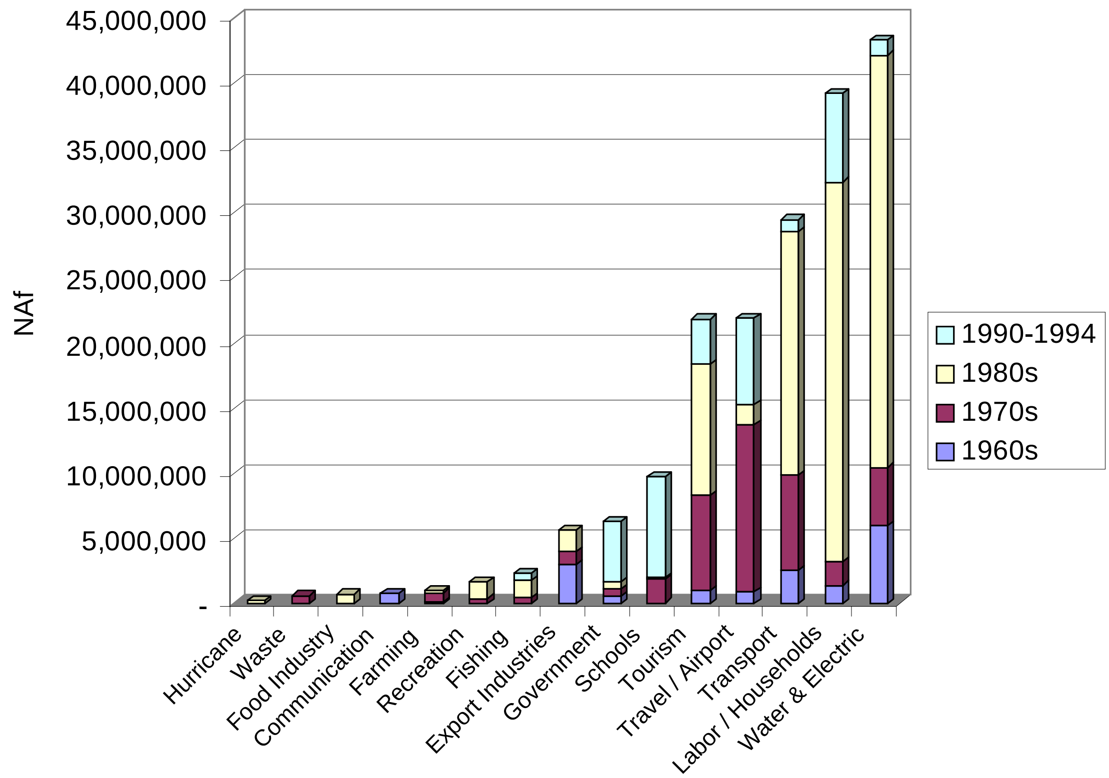

Figure 164: Financial Aid
The purpose of this graph is to present a broad outline of the financial aid that has come to Bonaire in the past 3 decades from three major sources--the Dutch government, the EEC, and the UNDP. The graph has been compiled from several data sets and must therefore contain some errors, however as a relative indicator of funding targets and history it is very valuable. These values are unadjusted NAf (1994 $1 = 1.78 NAf).

Promotion of Industry

Some private industry has been directly promoted with financial aid. The *indirect* promotion of industry on Bonaire is arguably one of the intentions of all the remaining aid combined.

Export Industries. Financial aid to the export industries has been chiefly Dutch funds to expand and industrialize the salt-making capacity of Bonaire. Dutch aid was spent to build a large pier for loading salt, and to expand the salt works. This effort has resulted in a successful commercial venture now owned by Akzo Nobel, a multinational chemical company and the world's largest producer of salt.

Fishing and Farming. Much of the aid that is presented separately under Fishing and Farming could instead have been included under Export Industries. Most of the Fishing money was for a maraculture project in the 1980-90s that failed, and in an aborted attempt to commercialize the local fishing industry in the 1970s. Some of the funding for Farming was in support of aloe farming in the 1960s that also failed. These products were each intended for export, but are grouped separately because of their special interest.

Tourism. Financial aid was provided to a few hotels, restaurants, and the yacht harbor, to create or improve these assets. Aid was also provided for producing marketing materials, which could be funneled into the international tourism marketing networks.

Intensification of Production

The building of infrastructure with financial aid has lead economic development on Bonaire.

Transport. Transport refers to the system for movement of people and bulk goods. On Bonaire financial aid has been paid for the construction of roads and wharves/piers. Financial aid for roads or wharves is funding for transport technologies. In Figure 164 the financial aid for schools is primarily funds for school buildings and equipment.

Travel. Bonaire saw significant financial aid for the construction of airport runways and terminal in the 1970s and again in the 1990s. As the largest single aid target of the 1970s, it was recognized early that much of Bonaire's "development" potential depended on an extensive airport subsystem.

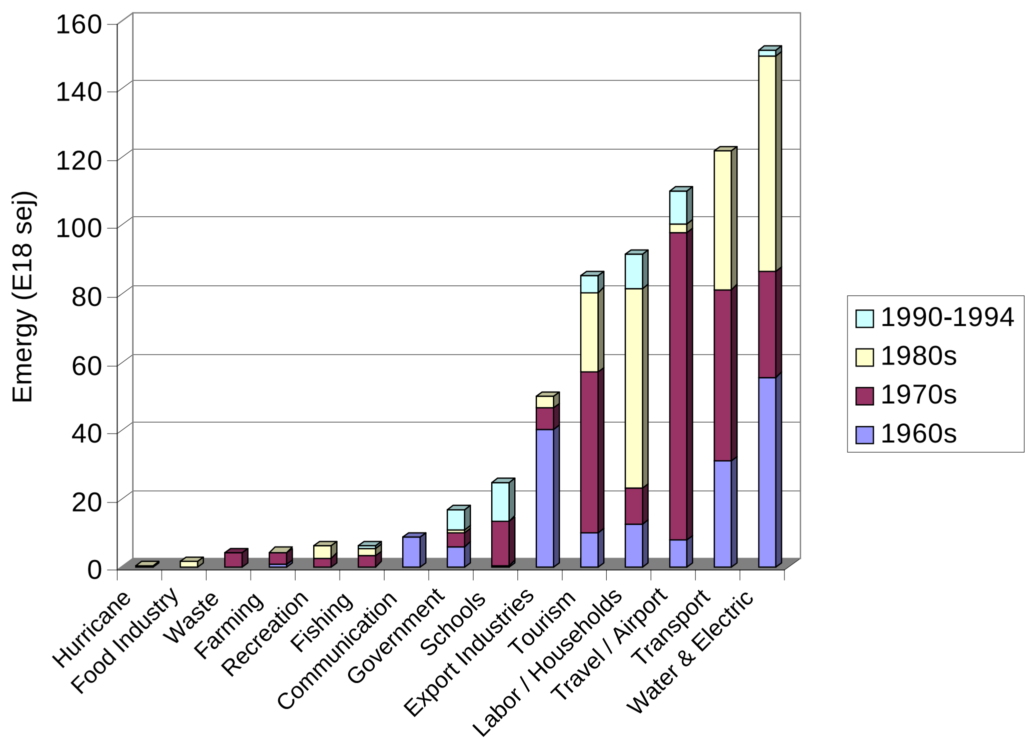

Figure 165: Financial Aid Emergy
Like adjusting dollar amounts to "real dollars", translating money amounts to emergy can account for currency inflation, and allow comparisons between years or decades. Unlike economic currency adjustments that are market driven, however, emergy adjusts for the reduction in currency "buying power" by basing currency values on the flow of emergy through an economy. The totals in this graph are based on the emergy/$ estimates from (Odum 1996a:313-4).

Government. Financial aid came to the government of Bonaire in the 1960s and 1970s for the purchase of large tracts of public land. This land is now the sites of the Washington-Slagbaai National Park, the BOPEC transshipment terminal, the large antenna farms, the salt works, and large tracts of natural thorn forest held in reserve. Financial aid has also come to Bonaire for the purpose of developing long-range economic planning, called the Bonaire Structure Plan. Tax reform was also sponsored by financial aid, in order to improve the revenue generating capabilities of the state, a critical component of IMF structural adjustment programs.

Water and Electric. A critical component for contemporary development has been the reliable delivery of electricity and water. Indeed, one of the first driving forces for electric power on Bonaire was the establishment of the now defunct garment factory of the 1950s (Hartog 1978:90). Additionally, on Bonaire (and Curacao and Aruba) it was early recognized that fresh water was a limiting factor to economic growth. Water and electricity have been the largest recipients of financial aid on Bonaire.

Construction

While construction is not listed here as a separate category, it is implied that much financial aid enters the construction subsystem (see Construction Subsystem, in CHAPTER 11). This subsystem uses specialized storages of technology and labor for the production of storages for the other subsystems. In other words, construction equipment and training are needed in the building of houses, roads, wharves, airports, etc. As financial aid enters Bonaire for building schools, for example, it also maintains the storages of specialized construction equipment owned by construction companies. Of the 185 million NAF of aid that entered Bonaire, approximately 100 million was used in construction projects of one kind or another. The table below breaks down those numbers.

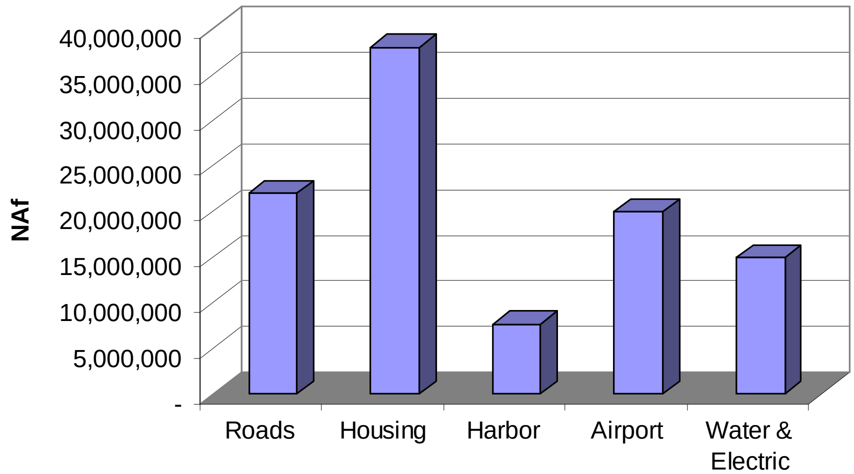

Figure 166: Aid for Projects with Construction Components

The State Equation, Land and Taxes

Taxation is an ancient and enduring form of state finance. In contemporary states, taxation has served to finance the state features previously listed, police and military, courts, public welfare, and state-sponsored intensification projects, such as road building, hydroelectric dams, water and power plants, public harbors, etc. In addition, tax rate management provides a leverage that governments can use to allocate and re-allocate the many valuable state assets (especially land) to meet the other state goals (of intensifying production, promoting industry, etc.)

One of the professed intentions of IMF structural adjustment has been to force governments to increase tax revenues (and thus repay international loans). In the Netherlands Antilles and Bonaire this policy was felt in the 1990s (see Structural Adjustment Programs, CHAPTER 3). In the first part of the last decade revenues from tax collection jumped 132% (Table 20). The specific tax increase most dearly felt by Bonairians was the leap in Land Tax collection by 459%.

The Land Tax rate for both *Erfpact* (Long Lease) and *Propiedat* (Private Property) is identical, and is calculated as a percentage of the assessed value of the plot (0.575% w/o house, 0.69% w/house). See Table 21 and Table 22 for descriptions of land categories on Bonaire.

Table 20: Total Island Tax Revenues ('1000 NAf)

Tax Type	1990	1991	1992	1993	% Change
Land Tax	429	716	1,451	2,398	459%
Profit Tax	2,031	2,609	1,513	8,366	312%
Income Tax	1,372	1,231	1,801	2,210	61%
Wage Tax	7,330	8,071	9,747	12,489	70%
Room Tax	338	727	1,051	2,147	535%
Car Tax	888	974	1,096	1,102	24%
Total Tax	12,388	14,328	16,659	28,712	132%

Land on Bonaire has always been unequally organized, with superior and inferior plots for agriculture and fishing, and with differences between Playa and its surroundings. It would be misleading to picture a homogeneous economic and ecological landscape shared equally by the island population. Economic hierarchy is the legacy of colonialism and slavery, and Dutch persons have controlled key interests in government and trade. Contemporary market capitalism has reproduced similar hierarchy in hotels, export industries, and others. However, in the past, with an economy fueled substantially by renewable natural resources (sun, wind, rain, goats, sorghum, fish), wealth differences within the majority population were relatively small.

Development has produced a new logic for economic and ecological hierarchy. Vast new sources of energy, materials, goods and services are entering the island with development and significant reorganization is occurring. As a service workforce emerges, as foreign managers and laborers migrate in, and as the *pensionados* arrive, competing uses for land now exist. Reallocation of land is occurring, and taxation and the market are the new means of its re-organization.

Reasons for the Land Tax increase are twofold. First, as proximate cause, island-wide property assessments had not been performed on Bonaire for many years, and the existing assessed values were generally well below current market prices. But secondly, and more to the point, the economic situation on Bonaire has changed significantly and the "market" for land itself has been transformed. The "market price" for long lease and private property jumped wildly and unevenly in the 1980s and 1990s. Sea front land, hillside lands with a view, town land, and desirable *kunuku* land in the "country" were re-assessed at great value.

Consider a hypothetical example. If 30 years ago a piece of land with a house near the sea was valued at 4,000 NAf, then the owner would pay 27.6 NAf/yr in taxes. It is not inconceivable that the same land today could be assessed at 400,000 NAf. The taxes on that land would now be 2,760 NAf/yr. For an owner that makes only 10-20,000 NAf/yr this is a significant increase.

The net effect of this process is to pry many Bonairians from desirable coastal, town, hillside or *kunuku* locations. If sly foreign interests do not prevail in the transaction, Bonairians may see a cash windfall from selling their private property or in transferring their *erfpact* (when a house is present). They may now need to relocate themselves at the current market rate, but they may indeed come out ahead in cash terms.

What do they loose? An obvious loss is the freedom to choose where to live. Land and household and location may have been in a family for many generations and may represent an advantage. Easy access to town, to *mondi*, or to the sea may be lost. For willing sellers this is not an issue, but for those less willing there may simply be no option.

Higher taxes, like inflation, can erase apparent income gains for households. While this effect was not measured for this study, it is known from interviews that the new tax burden for households is substantial.

The full effect is a new hierarchy in the landscape, with town and coast and hillside covered with foreigners and wealthy Antilleans. This perhaps both intensifies production and promotes industry. The most desirable lands on the island are now available for acquisition by the economic elites that the island economy wants to attract.

The familiar recipe for structural adjustment, also called the "Washington Consensus", is a smaller government workforce and the privatization of governmental infrastructures, such as the utilities for water, electricity, sewage, and others. Another common component is new taxes, or in Bonaire's case the renewed enforcement of old laws.

There are four land types on Bonaire. Table 21 and Table 22 describe and compare them. Three types are government owned, and one is private property.

Table 21: Land as Property (Part I)

	Government	
	Huurgrond	**Gov't Plantations**
Description	• This land is reserved for agriculture • Biggest percentage of land on the island • Only Antilleans can get *huurgrond* • A person holds the "book" in their name • Book holder can build a wood house only (no permanent dwelling)	• Columbia, Karpata, and Washington-Slagbaai National Park • Govt is holding on to Columbia and Karpata and currently will not let people use it (except for goat foraging)
Cost:	• 4 NAF/yr for 10,000 m2 (.0004 cents NAF/m2/yr)	
Cost Comparison	Rent 1 hectare lot = .4 NAF/yr	
Tax	None	

Table 22: Land as Property (Part II)

	Government	**Private**
	Erfpact **(Long Lease)**	***Propiedat*** **(*Eigendom*)** **(Private Property)**
Description	• Most houses are built on this land • Must be a resident and working for 3 years • Estimate 80% Antilleans and 20% Foreign born, in past was 95% Antillean • In high demand with 800 people waiting per year, in past was 300 people per year • In one year you must begin to build on land • Currently not making more available because infrastructure is too expensive • Lease for 60 years, review after 20 • All the big hotels are built on *erfpact* as a concession to build • BOPEC, AKZO, TWR, and Radio Naderland are all on *erfpact* • It is the smallest percentage of usable land on the island (excluding Govt plantations?)	• Large pieces from plantation land sales of 1868 • Small pieces created during WWII, none since then • Old plantations are Bolivia, Lima (with BelNem properties), Santa Barbara (with Sabadeco and Santa Barbara properties), and Bakuna • Second largest land type on the island, though some large pieces are less desirable
Cost	Ground Rent • 300 NAF/yr (average) • 60-300 NAF/yr for 1000 m2 (6-30 cents/m2)	Buy Land (some quotes) • Sabadeco - 55 NAF/m2 (140 lots sold • Santa Barbara - 92-125 NAF/m2 • Lagoon Hill - 65 NAF/m2 • Playa Pabou - 55 NAF/m2 • Antriol *kunuku* - 20 NAF/m2 (14,000 m2)
Cost Comparison	Rent 1 hectare lot = 60-300 NAF/yr	Buy 1 hectare lot = 100,000 NAF/yr
Tax	*Grondbelasting* (Land Tax) • .575% w/o house • .69% w/ house • Based on assessed values of land • New assessment had been done 3 years prior • Had not been done in 30 years • Values were assessed far higher, and taxes went up by 500% at times • If prior assessment was 2000 NAF, pay 13.8 NAF/yr • If new assessment is 200,000 NAF, pay 1380 NAF/yr • Brought down government in 1993 • Assessments were lowered some	

Electricity Production

Water and electricity are produced at the *Water en Energie Bedrijf Bonaire N.V.* (WEB) (Figure 167). It is a government owned, privately operated, water and power plant. In 1995, the WEB used diesel generators burning gasohol to produce 6 MW of electricity on average.

Figure 167: Water and Electric Plant

An emergy analysis of electricity production is in APPENDIX U. By far the major input to electricity production is fuel to run generators, and the services associated with fuel production, transport, etc. Massive foreign aid was poured into this project from the Dutch government (Figure 164). It was apparently recognized early that any hopes for economic development on the island depended on available electricity and fresh water. These foreign aid inflows are prorated over the turnover time of the plant, and constitute important emergy inputs. Major storages in the subsystem are (1) the high technology generators, (2) storage tanks, and (3) the electricity delivery hardware. For both total emergy inflow and *per establishment* inflow, electricity production is located in the top third of subsystems in emergy storage and flow.

Water Desalination

Water on Bonaire is desalinated from seawater. This energy intensive means of water production has fueled economic expansion. Without desalination, fresh water would restrict the human population of the island. The WEB currently (1995) uses both vapor compression distillation and multiple-effect distillation (MEP) to produce fresh water directly from seawater.

Figure 168: WEB from Above

Water from the WEB desalination plant is pumped high up the hill behind me to storage tanks to produce water pressure for the island.

The major emergy input to water production is electricity from the WEB electricity plant (APPENDIX V). In fact, the water and electricity plants are combined into one site. Water produced from vapor distillation uses the boiler steam from the electric plant. By contrast, multi-effect distillation uses electric power to force seawater through membranes to produce fresh water.

Transformities (emergy/energy ratios) were calculated for water and electricity produced on Bonaire. For most emergy analyses, transformities are values calculated from previous analyses. This is often adequate. However, on Bonaire, it was expected that electricity, and especially water would have larger transformities due to the high fuel requirements of desalination. The electricity transformity was computed as 3.2 E5, about twice the emergy of other electricity generation systems. The transformity of desalinated water is 2E6, which is high compared to other desalination plants, and far larger than transformities for other water management methods (Buenfil 2000).

As with the electricity plant, another important emergy inflow is financial aid for construction. Boiler water is the third largest input, followed by labor.

On a *per establishment* basis, the inputs to water production are in the middle of establishments. Total emergy is in the lower third. These numbers are rather low and are perhaps due to the analytic division that was drawn between water and electricity at WEB.

These large transformity values ripple through the Bonaire economy, effecting each of the other emergy analyses that use water and electricity. The emergy values calculated from these transformities are larger than they would be elsewhere in the world. In emergy terms, all water is *not* created equal when it is produced with high fossil fuel desalination. The desalinated water of Bonaire reflects the high emergy inputs that make the island livable for so many. On Bonaire (and Curacao and Aruba) fossil fuel replaces the work of mountain ranges, cold fronts, ocean currents, etc., that do the work of producing reliable rains elsewhere.

Waste Management

Waste management on Bonaire is of growing concern to many Bonairians. With the last few decades of growth, it has become clear that solid waste management is now required. In past years of lower population density and fewer imports, there was less solid waste to manage. It is true that at low densities, the solution to pollution is dilution. Nature can process most solid waste, either by decomposition and recycling materials or by sequestering. Strong tradewinds or dumping have historically moved much of island solid wastes into the sea, where high wave energy and powerful currents could disperse solids.

Figure 169: Landfill Waste to be Buried

One of the costs of development is that emergy must be fed back to manage ecosystems. The impacts of high intensity purchased emergies is that stress is placed on natural systems. One form of stress is additional solid waste. The response by the Bonaire government has been to landfill the waste.

An emergy analysis of the Bonaire landfill is in APPENDIX W. Emergy inputs to the landfill are relatively low. The largest input is labor, followed by fuel for solid waste transport.

The State as a Subsystem

The Bonaire State was not evaluated as a subsystem in a separate emergy analysis. Pieces of the state (some recently privatized) have been analyzed separately, including water & electric, solid waste, the port, roadways, and the airport. This constitutes much of the emergy contribution that is controlled by the government elites and bureaucracy. Some important state features were however not analyzed. This is due in part to the difficulty of collecting data in the time-span of my fieldwork. These missing components would have improved this dissertation analysis, but my time and energy limits were reached. If this analysis had been completed, additional information would have included, per the following design:

Estimates of Emergy Inputs to Government

This scheme could be used to collect numbers for an emergy analysis of government on Bonaire. Data would be collected on buildings, equipment, and personnel and emergy values would be calculated, as it was for other subsystems.

Police/Military

Buildings and Structures

- Prison
- Police Station

Mechanical Equipment, Technologies, Records

- Weapons
- Police Cars
- Dutch Marine Ship
- The large nations today continue to produce their own weapons, or contract private companies to produce weapons for them. Such weapons (aircraft carriers, nuclear bombs, etc.) should be considered a co-product of the state. The monopoly over the legitimate use of force is a defining feature of a state. Bonaire does not produce any of its own weapons, and therefore a weapons transformity cannot be calculated here.

Personnel

- Police Persons
- Marines
- Support Staff

Laws and courts

Buildings and Structures

- Courthouse
- Justice and Prosecutor Offices
- Legal Affairs Office

Mechanical Equipment, Technologies, Records

- Records for Taxes, Banking, Customs, Accounting, and Legal Deeds of Ownership. Per state model, these records are essential to financing the state apparatus, and have been since the earliest state bureaucracies. They might therefore be considered a co-product of the state, which feeds-back to reinforce its own production.
- Record Keeping Equip
- Records (Legal Deeds)
- Laws - These records are the product of the state bureaucracy, and are produced at great effort. They are not being produced on Bonaire, but are "imported" from the NA, and from the Netherlands. Copies are sent to Bonaire, and they would have a much lower transformity.

Personnel

- Judges
- Prosecutors
- Support Staff

Taxes and finances

Buildings and Structures

- Tax Inspection Office
- Financial Offices
- Customs Office
- Land Registry
- Central Bank

Mechanical Equipment, Technologies, Records

- Records (Many))
- Record Keeping Equip
- Money Supply

Personnel
- Finance Persons
- Banking Officers
- Tax Inspectors
- Customs Officers
- Property Appraisers
- Support Staff

Intensification of production

Buildings and Structures
- Public Works Office
- Harbor and Piloting
- Roadways
- Airport

Mechanical Equipment, Technologies, Records
- Harbor and Piloting Equip
- Airport Equipment

Personnel
- Harbor Personnel
- Airport Personnel
- Support Staff

Promotion of industry

Buildings and Structures
- Economic Affairs Office
- Land and Zoning Office

Mechanical Equipment, Technologies, Records
- Land Records and Registry

Personnel
- Economics Personnel
- Support Staff

Wage labor force maintenance

Buildings and Structures
- Fire Department
- Labor Office
- Schools
- Health and Hygiene
- Agriculture Extension
- Welfare and Civil Rights

Mechanical Equipment, Technologies, Records
- Fire Equipment
- Health Lab and Testing
- Agriculture Extension Equipment
- Welfare Records and Record Keeping
- School Equip and Books

Personnel

- Fire Personnel
- Labor Office personnel
- Teachers and Staff
- Doctors, Nurses, Technicians
- Agriculture Extension Personnel
- Welfare Office Personnel
- Support Staff

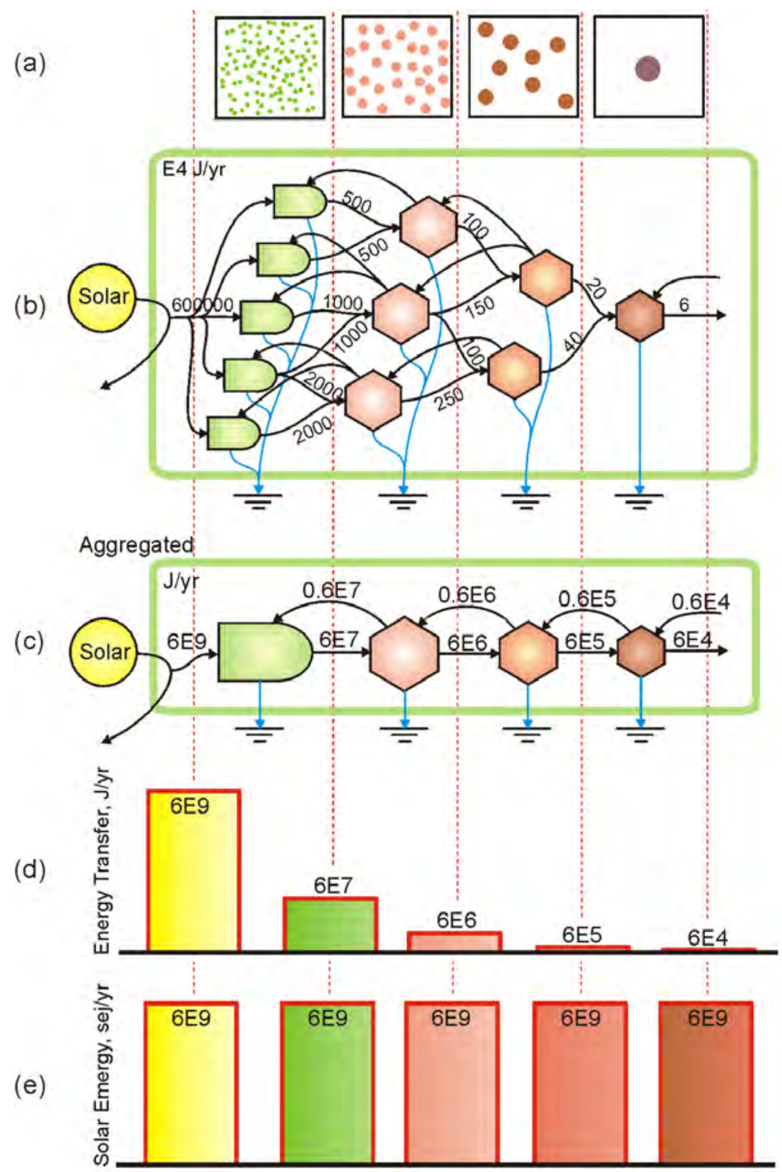

Figure 170: Energy Transformation Hierarchy
Adapted from (Odum, et al. 1998:23). (a) Spatial view of units and territories, (b) Energy network including transformation and feedback, (c) Aggregation of energy networks into an energy chain, (d) Bar graph of energy flows for the levels in an energy hierarchy, (e) Bar graph of *emergy* flows for the levels in the same hierarchy. The emergy flow is the same at each pathway, but the energy flow decreases at each step.

The preceding four chapters have presented emergy analyses of many productions subsystems on Bonaire. Interpretations and discussion can now be presented.

Constructing Web Hierarchy with Emergy Flows, Emergy Storages and Unit Counts

Total subsystem emergies are compared in Figure 171. Perhaps surprisingly, the largest emergy flows do not support the oil transshipment subsystem (transshipped oil is not added to the emergy inflow) or even the tourism subsystem, as defined. The largest inflows enter households. Households use water, electricity, and purchased goods and services. They control natural emergies in *kunuku*s and assets (houses, automobiles, etc.). But the determinant factor is that there are over 3000 total households on Bonaire.

As explained in CHAPTER 10, a web of production subsystems can be constructed for Bonaire that is analogous to an ecosystem web (Figure 170b). In an ecosystem hierarchy, more energy is used and degraded at the base of the food web, but less emergy is captured *per individual* organism because there are numerous small individuals at the base, and fewer larger individuals further to the right in the web (Figure 170a).

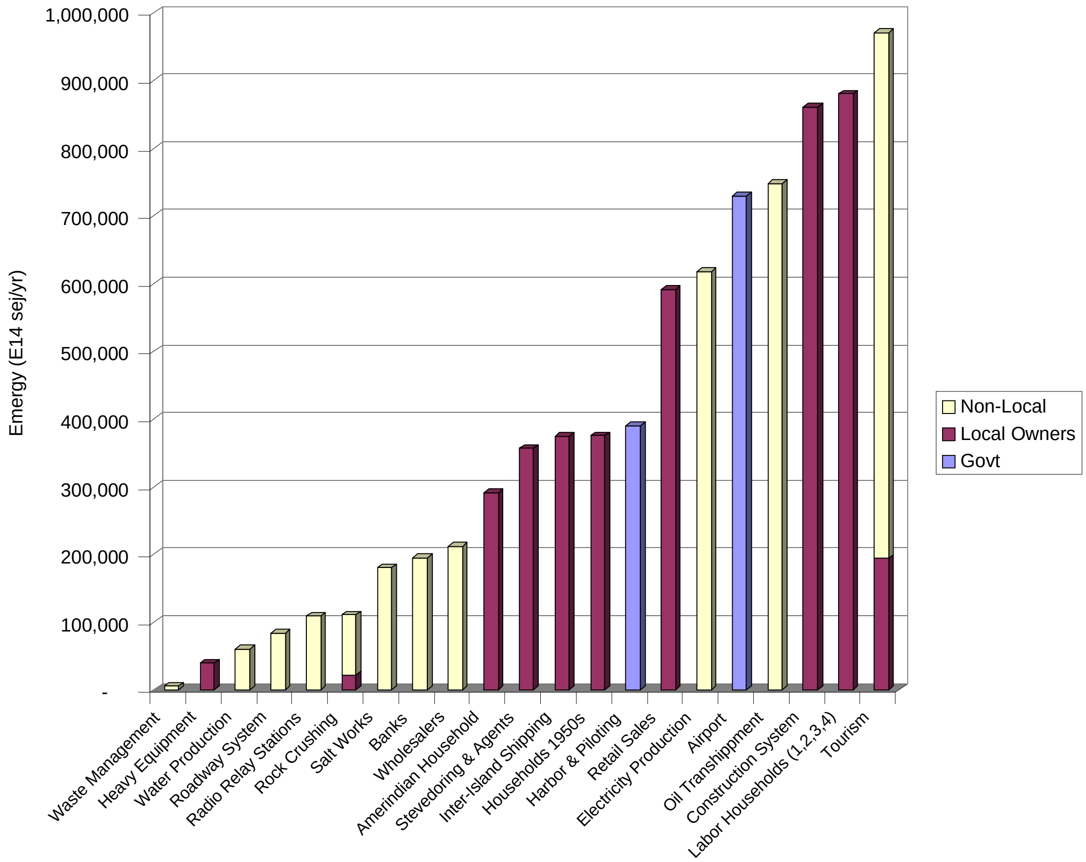

Figure 171: Total Annual Emergy Inflows
These values were calculated in the preceding chapters. Note especially the relatively high positions of tourism, construction, retail sales, and stevedoring. These are the major growth industries associated with development since the mid-eighties.

In Figure 171, after households, tourism and the construction subsystem capture the largest emergy flows. The next three subsystems with high energy/emergy needs are single industries, the airport, oil transshipment terminal, and the electricity plant. Others follow, see Figure 171.

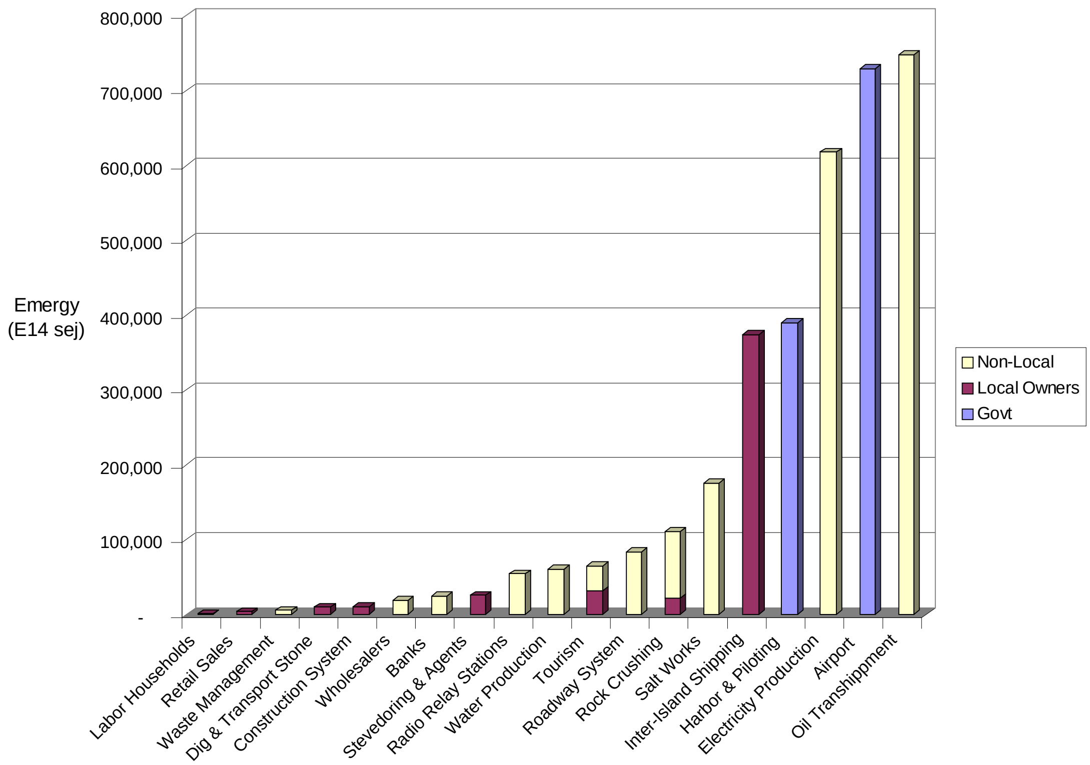

Figure 172: Emergy Inflows *Per Establishment*
The total emergy inflows from Figure 171 were divided by the numbers of establishments to produce this bar graph.

As one moves up trophic levels, energy is less and emergy is concentrated in fewer organisms. Humans are at the apex of most natural food webs the world over. On top of that web we can model an additional web of households and production subsystems. This web was depicted in the web drawings in CHAPTER 10 (Figure 104 and Figure 108) and in Figure 178, Figure 179, Figure 180, and Figure 181. The arrangement of subsystems in that web was determined by the hierarchy in Figure 172. Subsystems on the left of Figure 172 exist in great number and capture less emergy per establishment. Subsystems on the right are few or one, and capture much emergy per subsystem. This is analogous to an ecosystem web. Figure 174 and Figure 175 are counts of individuals within subsystems. Dividing the emergy totals in Figure 171 by the numbers in Figure 175 produced the graph in Figure 172. A subset of that table is Figure 173, which shows the *locally owned* production subsystems.

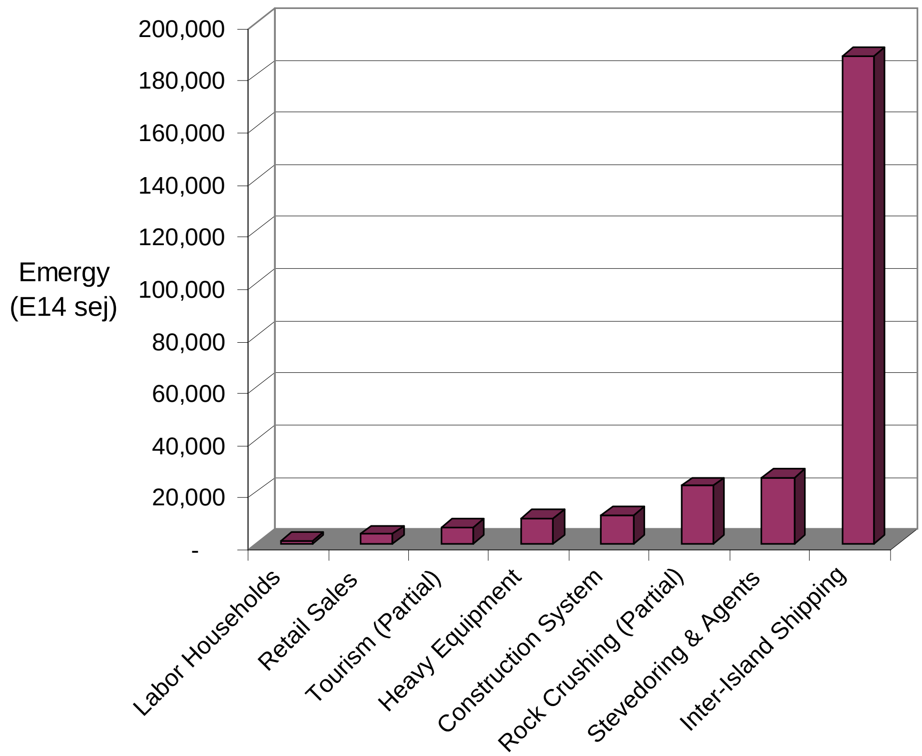

Figure 173: Annual Emergy Inflows per Locally Owned Establishment

Storages *per establishment* produce a similar hierarchy. Differences are the large storages associated with roadways, the salt works, airport, harbor, and the money storages in banks. Perhaps *storages* produce a better hierarchy model than flows. In ecosystems, and in landscape, weather, stellar and microcosm systems, fewer units of largest storage occur in nature, many units with smaller storage and faster turnover times occur at another extreme, and intermediate numbers with intermediate storages fall in-between.

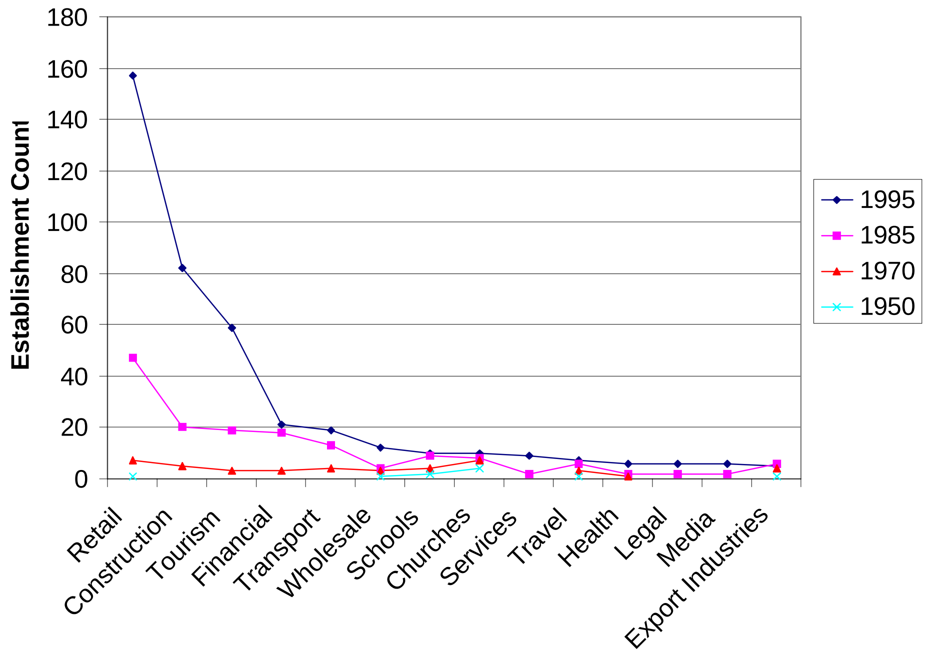

Figure 174: Count of Production Subsystems
The Labor Household System is omitted with its count of 3000-plus individuals (but see Figure 175, Figure 176, and Figure 177). These numbers come from the Chamber of Commerce and Labor Office on Bonaire and they are admittedly imperfect, especially the historical data. Values for the years past might have been higher and there are surely some industries that were omitted. The intention of this graph, however, was to identify the trend of subsystem complexification which appears to be evident, even with possible corrections.

This pattern appears in approximate terms for Bonaire. The subsystems with one instance have the largest inflows and largest storages. The two subsystems with the smallest inflows per unit occur in greatest number. Storage values are also low for each. Remaining subsystems closely follow this pattern, with some exceptions (which could be the product of my subsystem category definitions).

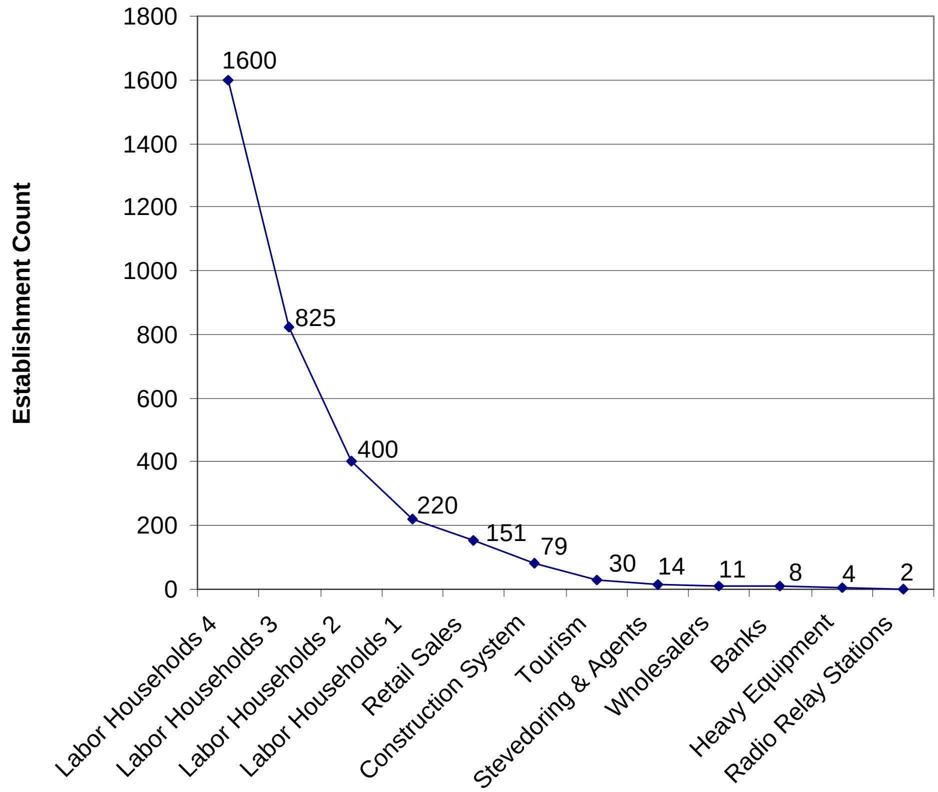

Figure 175: Count of Production Subsystems (from Emergy Analyses)
These counts differ some from Figure 174 and have a slightly different organization into types (species). The Labor Household subsystem is broken into four types (species) per Figure 176. The act of grouping companies into types was made on the basis of function and was judged along several dimensions simultaneously. As any human pattern recognition activity (whether in language, speech, vision, or science) the categories are constructions. All science relies on this innate human capacity, and systems science is no different. Where science differs from other human activity, perhaps, is in its professed intention to entertain all debate or disagreement, to refine or discard proposed analytic models. Where complex systems science differs from reductionist science, according to Holling, is that debate and contention persist, perhaps without ever reaching final consensus or universal approval.

It is a hypothesis that species within a trophic level must be different enough from each other that they do not directly compete. They do not suffer competitive exclusion, or their niche spaces do not overlap. An indication that the subsystem 'species' on Bonaire do not compete directly with one another is the differences in unit counts. In fact it may be expected that unit counts, like energy, may differ from one another exponentially. Refer back to Figure 174 and Figure 175. If those two curves are placed on log scale they form straight lines, which are consistent with exponential curves. This principle is used to propose the "4-household species" model in Figure 175 and Figure 176.

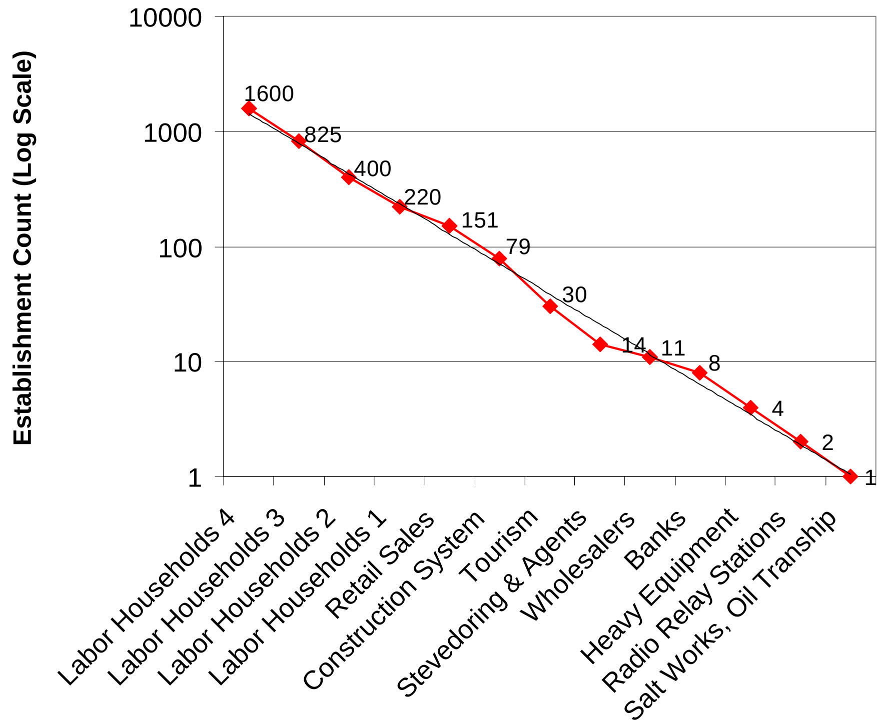

Figure 176: Log Count of Production Subsystems (from Emergy Analyses)
The single Labor Households subsystem was broken into four (species) types per this graph. Specifically, the 3140 households were fit to this trend line that was formed by the other subsystems. This hypothetical division is intended to suggest that there might be four recognizably different species, classes, scales, niches for households, that labor households are not all alike but form themselves into general lumps of functional specialization. This is a hypothesis.

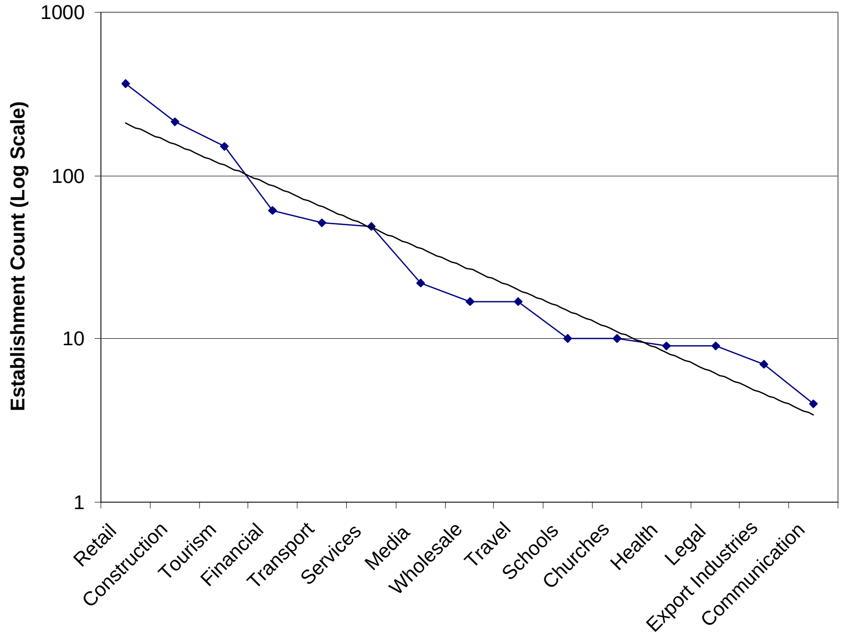

Figure 177: Number of Subsystems (Historical Count, Log Scale)

Energy Hierarchy and Sociocultural Self-Organization

A fundamental principle of ecosystem succession (and perhaps ecosystem evolution) is that a food web in late succession captures more available energies. A forest captures more sun, wind and rain for useful work than does a newly plowed field. A short grassy meadow with shallow topsoil holds less water, captures less wind energy, reaches fewer nutrients in rock, and attracts fewer animal species carrying seeds or doing other work. In contrast, a climax food web with diversity of plant and animal life (Figure 170b) captures and holds available energy and nutrients. Diversity and hierarchy capture additional energies, which reward the emergence of diversity and hierarchy. This is a classic self-organizing autocatalytic process, which has no beginning or end, no chicken or egg, but is simultaneous and emergent.

Humans use culture in ecosystems in the same way. In ancient societies, human groups have self-organized functional specializations (diversity) which have captured additional ecosystem energies (CHAPTER 16). This cultural hierarchy sits atop ecosystem food webs (transforming them in the process). Archaic state societies made tremendous use of stone and later metals to literally reshape landscapes to capture energy/emergy unavailable to non-human ecosystems, and to steal energies from competing large carnivores and herbivores. Humans literally reshaped the food webs that supported themselves, and added new emergies never before available to them. This self-organizing process may be the same process observed in succession and evolution.

With the self-organization of fossil fuel use, humans have captured the greatest additional energy sources that the biosphere has ever seen (with the exception of an occasional asteroid). The (simultaneous) cause and effect is the functional specialization that has increased to capture and use available emergies. Additional energies do not simply build new human structure atop natural ecosystems, but instead transform natural systems in fundamental ways.

Extensive fossil fuel use has come to Bonaire in only the last half century. With widespread fuel use (especially with ecotourism development) has come the emergence of economic functional specialization and hierarchy. This is clearly shown in Figure 174, in which small and middle-size business formation has risen dramatically. The sequence of drawings, Figure 178, Figure 179, Figure 180, and Figure 181 attempts to depict this emergence.

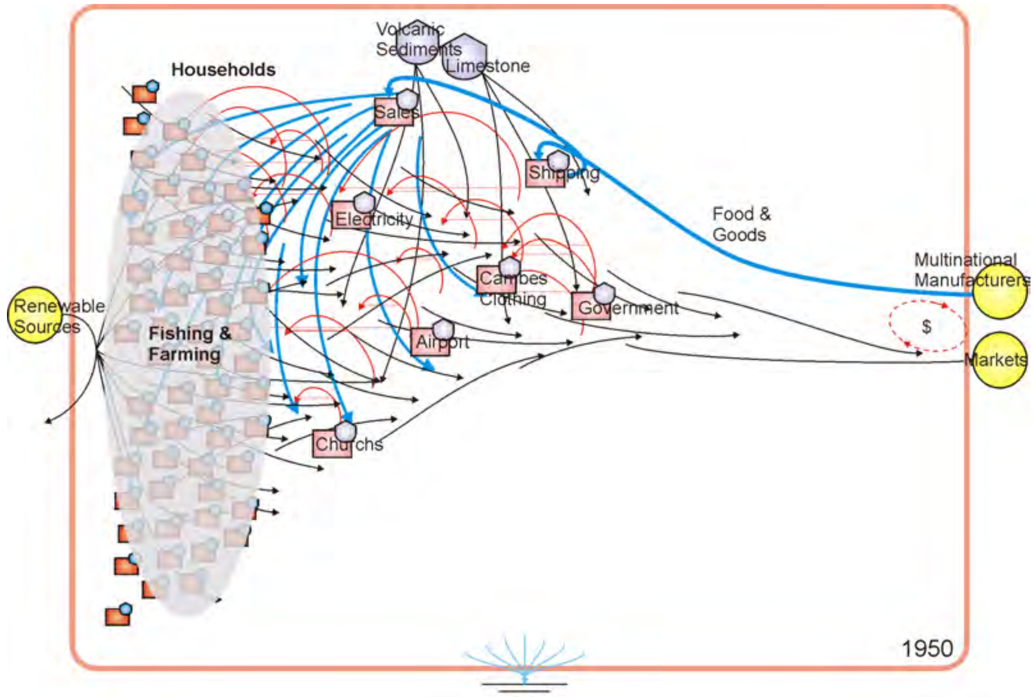

Figure 178: Social-Economic Web 1950
In 1950 Bonaire's future was changed by a new constitution and status with the Kingdom of the Netherlands. Dutch financial aid began to flow in, building infrastructure in a port, airport, and roads (see CHAPTER 3 for further details).

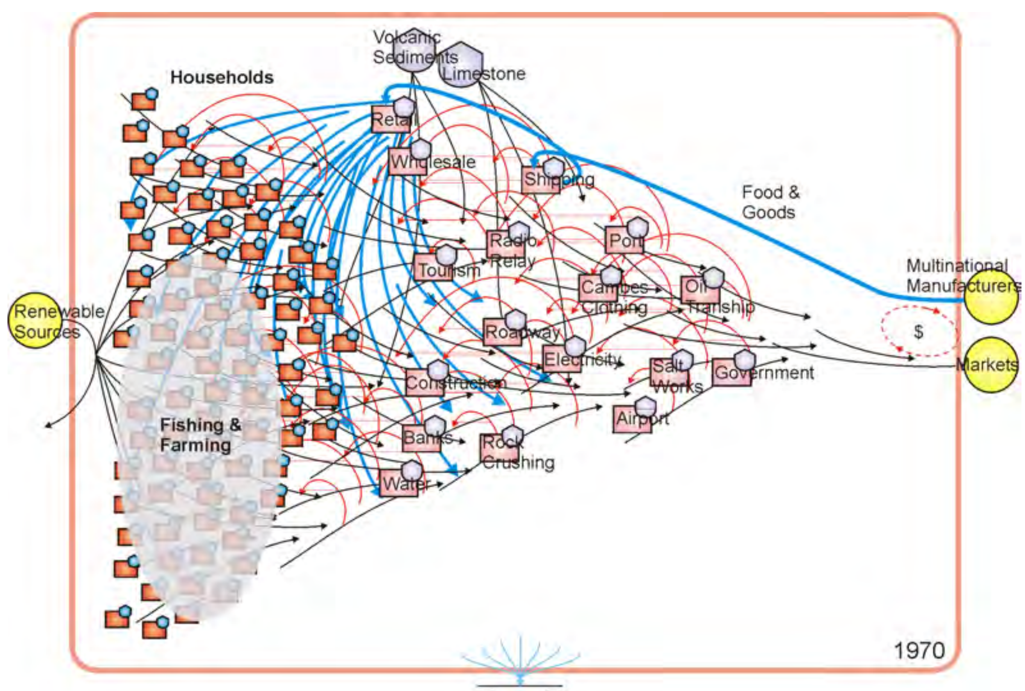

Figure 179: Social-Economic Web 1970
By the 1970s, several export industries moved to Bonaire. Construction industries were emerging in support. A new water and electric plant was built

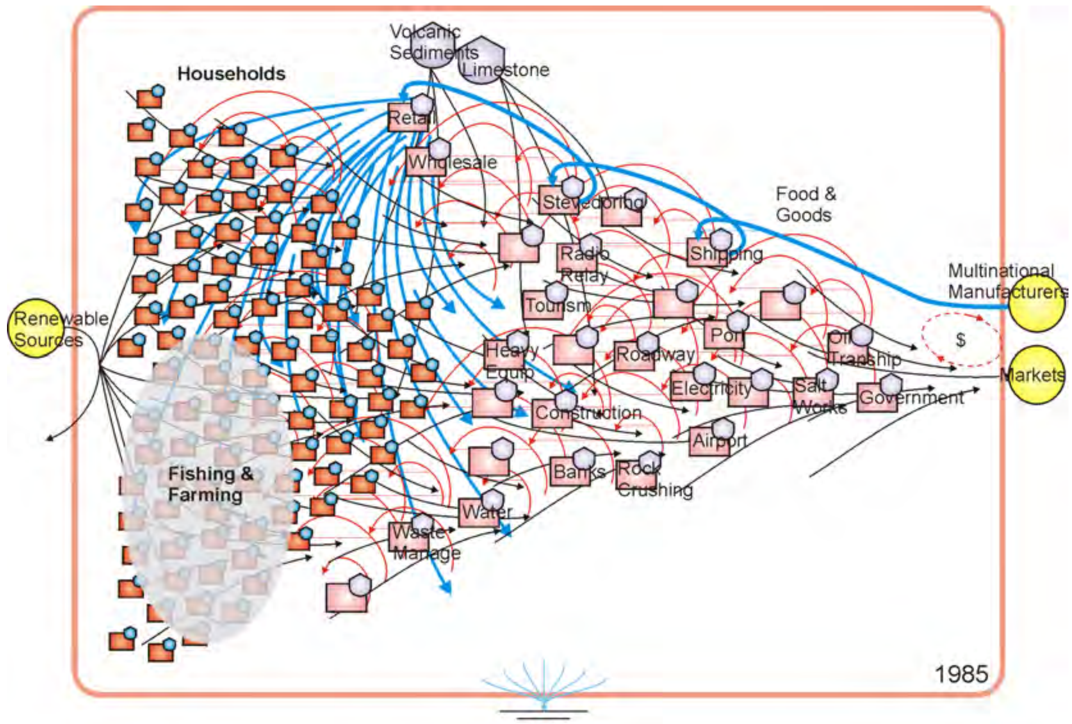

Figure 180: Social-Economic Web 1985
Bonaire's population had doubled since 1950, and much of the population was working for wages. Tourism was about to take-off, encouraged from within and without.

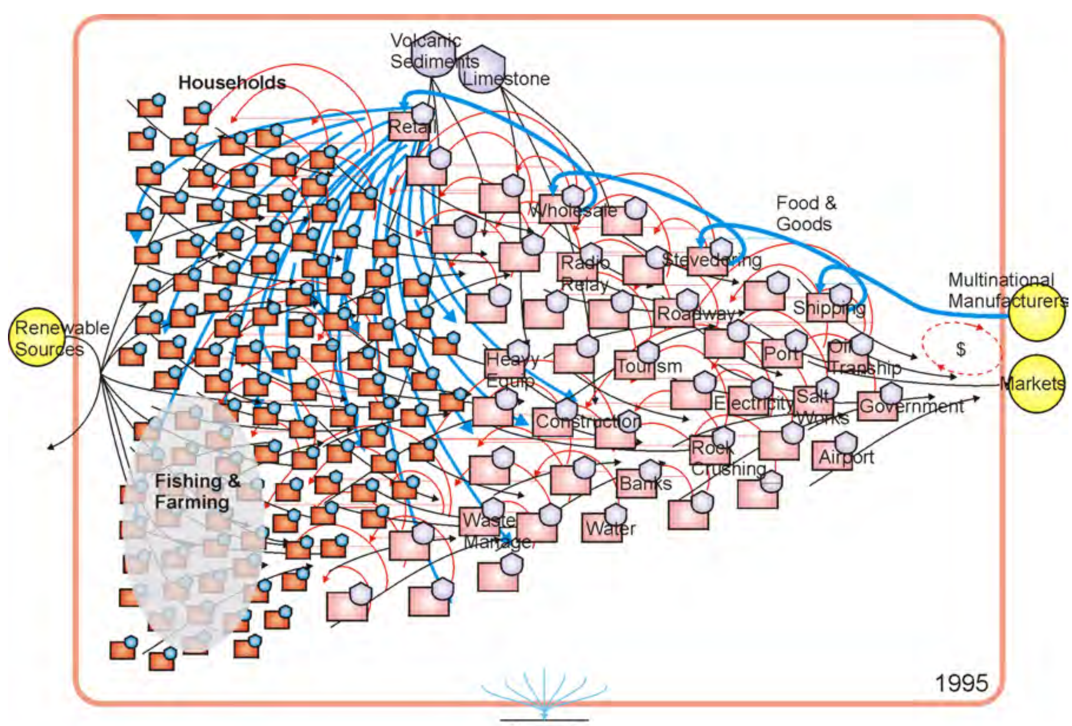

Figure 181: Social-Economic Web 1995

Per Figure 170d, ecosystem webs capture greater energies at their bases (to the left in systems diagrams), and transform energy into fewer and larger organisms, with less energy transferred to each organism in the hierarchy. At each step in the energy chain, emergy remains constant, per Figure 170e. This is definitional, emergy is defined in this way, as having an equal value at each transformation in an energy chain. *Transformities* are defined as the values that are multiplied by energy flows to equal constant emergies.

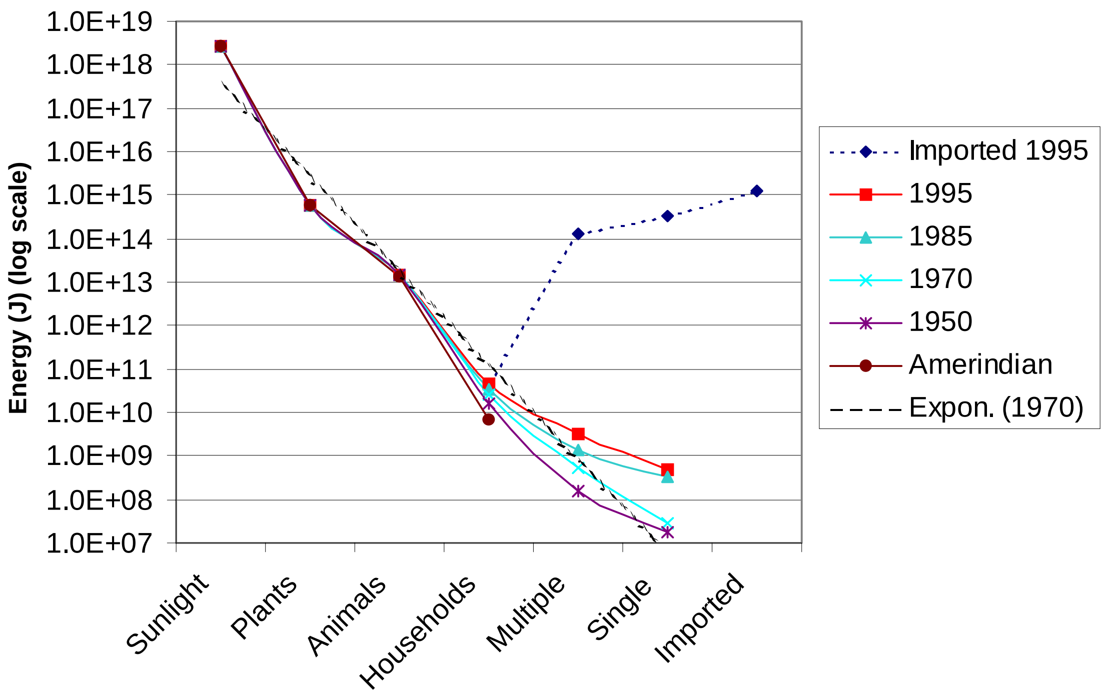

Figure 182: Energy Hierarchy
Households, Multiple, and Single represent the social-economic web from Figure 181. Components of (suggested) similar transformities have been aggregated to form a chain, as in Figure 170c.

Figure 182 depicts the energy hierarchy on Bonaire. Compare this hierarchy with Figure 170d. Note that in log scale it forms a straight line, which on a linear axis would create the same exponential drop-off seen in Figure 170d.

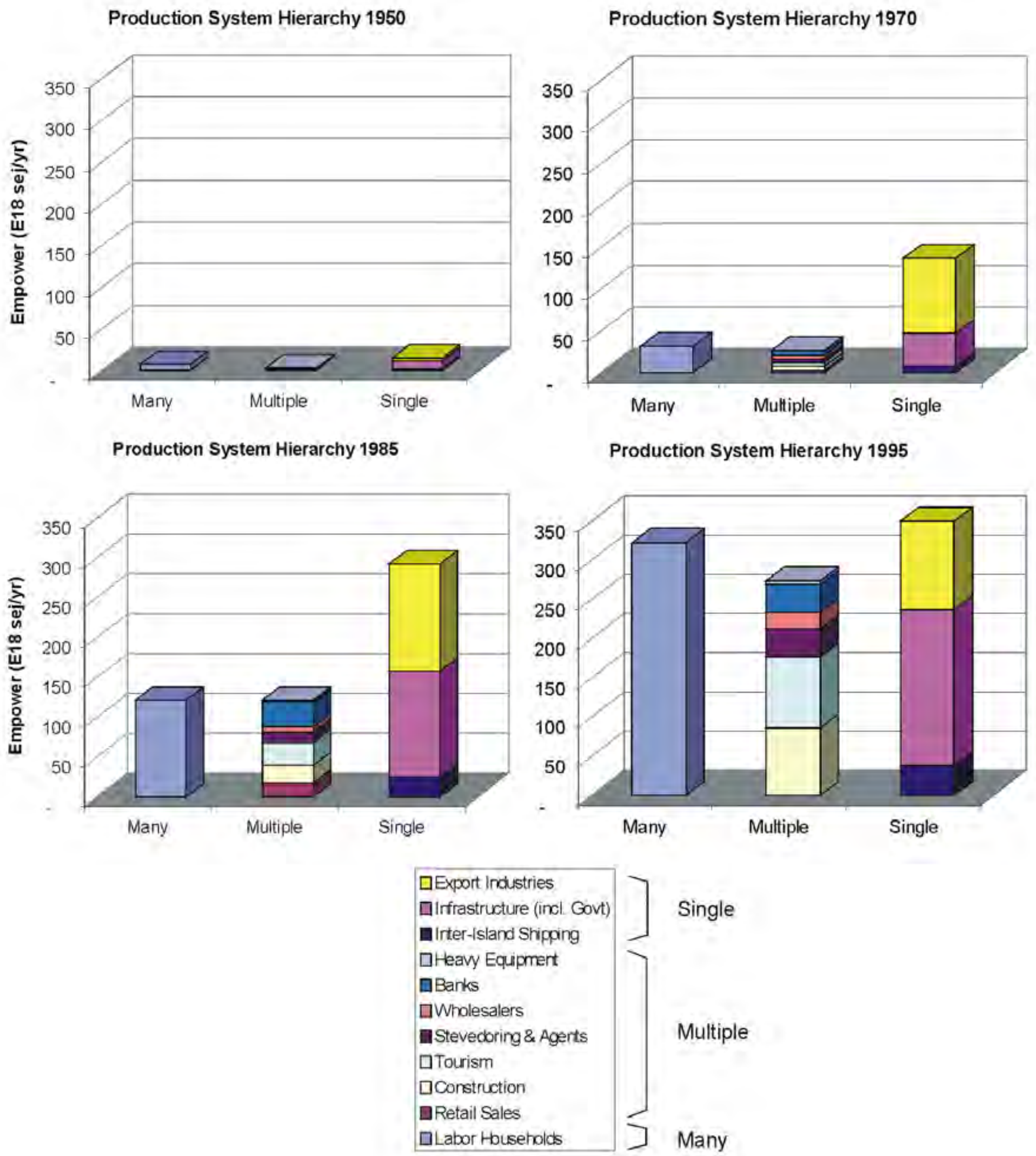

Figure 183: Production System Hierarchies
By the definition of emergy, the total emergies at each scale (many, multiple, single, in this case) are expected to be equivalent in a self-organized system that is maximizing empower (Figure 170e). If the three scales constructed for Bonaire are reasonable, it appears the island system is moving again toward maximum empower. In complex systems terms, these two points could be described as points on a surface with multiple stable states (Figure 185).

The human energy hierarchy of Figure 182 (Households, Multiple, and Single) is presented in detail in Figure 183. In Figure 183, these are *emergy* values and should be compared to Figure 170e. In other words, the emergies at each step in the emergy hierarchy should be equivalent. They nearly are in the 1950 graph and again in the 1995 graph. This series depicts the self-organization of Bonaire's economy in the last half-century. Note that this transformation was principally lead by energies entering the island in the export industries and into government. Prior to the tourism boom (beginning 1985), the economy had already dramatically expanded its population and the middle sector of supporting industries. This was again led by the doubling of imported emergies into export industries and infrastructure.

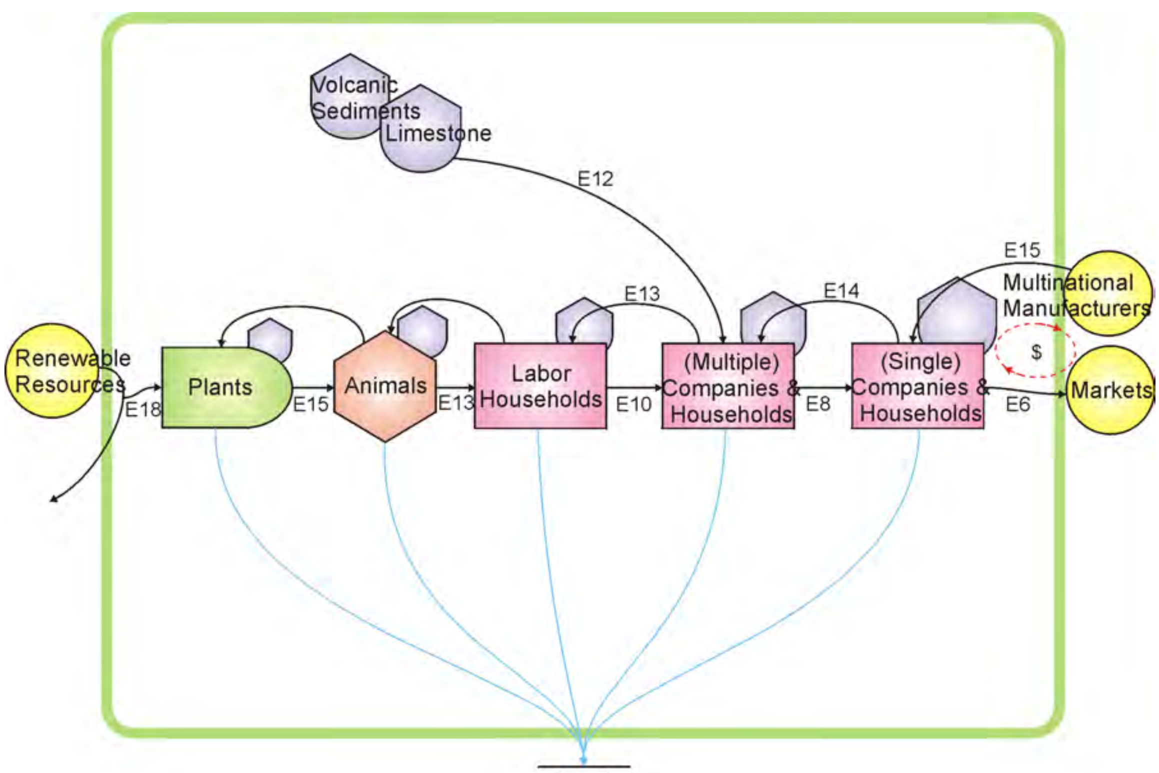

Figure 184: Aggregated Social-Economic Web 1995
Values are energy (J). Energy flows that move up the household hierarchy are only human labor energies. Compare them to Figure 170d.

The last graph in Figure 183 (1995) shows increased emergies in all three levels, but especially in the "Many" and "Multiple" levels. This is due to an exploding population and the burgeoning of industries to support tourism development. While not shown in this graph, additional emergy inputs are now also entering the ecosystem levels of the hierarchy (to the left of these bar graphs), in the form of Marine Park management, the National Park management, and work from the agricultural extension office.

Implications of this graph sequence might be that Bonaire has reached a population size equivalent with its current development, and should not further expand its population. In addition, it can be expected that more middle industries will appear with greater specialization.

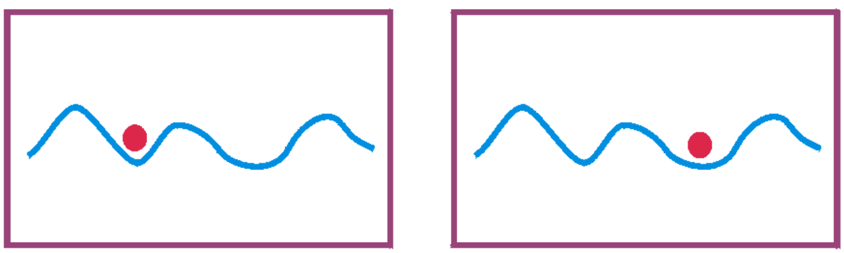

Figure 185: Multiple Stable States
A surface and ball have been used by complex systems scientists to represent multiple stable states in systems. Disturbances to a system (such as the arrival of large export industries and government infrastructure to an island) can push the system out of a current stable state to another stable state.

Finally, some general observations can be made. Unlike other nations that possess fossil fuels or mineral resources within their boundaries, Bonaire must import the great majority of its driving energy. Therefore, as shown in Figure 184, it tends to grow from the top down. Energy enters the economy via transport industries that are controlled from abroad and via local monopolies (government and private). In economies that possess the resources naturally, it might be that development would occur with a more uniform energy signature (Figure 170d).

Alternatively, it may be that growth is always led by an uncoordinated and asymmetrical expansion as in Figure 183. If that is the case, the years 1950 and 1995 in Figure 183 might represent alternative periods of relative emergy equilibrium, in which the island system is self-organized for maximum empower. Complex systems scientists have rejected the idea of single ecosystem equilibrium (climax), replaced by models of multiple stable states, often with pulsing or oscillating behavior between states (Figure 185). This may be indeed what is observed for Bonaire.

SECTION III: ISSUES AND DISCUSSION

The next seven chapters will discuss the theoretical framework applied to the preceding Bonaire case study. Other authors might have placed this text before the Bonaire case, however I feel that systems ecology is best broached by example. With now intuitive understanding of systems thinking, general principles and positions can be elaborated, clarified, detailed and evaluated.

This last section deals with the issues of emergy analysis, evolution, complex systems, self-organization, hierarchy and scale, which are all raised by the dissertation fieldwork and analysis that has preceded it. This section is referenced many times by the prior two sections, and thus also serves as a *defacto* appendix to them.

CHAPTER 15
SYSTEMS RESEARCH FOR UNDERSTANDING CULTURAL AND ECOLOGICAL DYNAMICS

> We now know that far from equilibrium, new types of structures may originate spontaneously. In far-from-equilibrium conditions we may have transformation from disorder, from thermal chaos, into order. New dynamic states of matter may originate, states that reflect the interaction of a given system with its surroundings. We have called these new structures dissipative structures to emphasize the constructive role of dissipative processes in their formation (Prigogine and Stengers 1984:12).

A Science of Complex Systems[1]

Recently the ecologist C.S. Holling has discussed the conflict between "two streams of science" and the confusion it creates for politicians and the public (Holling 1995:12-16, see also Holling 1993:553-4). One stream is experimental, reductionist, and narrowly disciplinary. It is familiar to us as the scientific ideal. The less familiar stream is interdisciplinary, integrative, historical, analytical, comparative, and experimental at appropriate scales. Examples given of the first form are molecular biology and genetic engineering. The second form is found in evolutionary biology and systems approaches in populations, ecosystems, landscapes, and global dynamics. One stream is a science of parts, the other a science of the integration of parts.

Anthropology has held itself up to the first stream ideal of science. But the first stream ideal does not always produce the results in anthropology that proponents and critics alike have demanded. Our knowledge of detail is incomplete at societal scales, and prediction can fail. Disproof by experiment is unlikely even with "natural experiments." And unanimous agreement over results is almost never reached. One

[1] This chapter became the basis for (Abel 1998).

response by anthropologists has been to shrink temporal and spatial scales, and hold fast to the ideal. To let the requirements of the scientific methods of this first stream of science structure our research. Anthropologists are often dissatisfied with such restrictions on our object of study, but see little alternative if anthropology is to become a mature science.

But science itself is always evolving. Many anthropologists, both proponents of science and critics, are unaware of the constructive critiques now coming from the mature disciplines of science, from the "hard" sciences. For over twenty years scientists like Holling and Nobel Prize chemist Ilya Prigogine (Prigogine 1980, Prigogine and Stengers 1984) have been arguing that the first stream of science is limited to certain problem sets. They contend that a science of complexity has fundamentally different features, and is the proper approach to other problem sets. Much of the subject matter of anthropological inquiry, it will be shown, is commonly addressed in problem sets of the second type. In fact, anthropologists long have argued their case for understanding cultures in terms that sound remarkably like those advocated by the new science of complexity. We have been fighting to resemble the ideal of science, while a second form is coming to look like us.

Points for Anthropology

Holling identifies a number of characteristics of the integrative stream of science. It incorporates technologies and results from reductionist, experimental science, but does not expect disproof by experiment, and ultimate agreement by the scientific community. Models are multivariate and multi-scaled, and testing of alternative hypotheses is done by planned and unplanned interventions into whole systems in case studies, with the evaluation of the integrated consequence of each alternative. Multiple lines of converging evidence are used to argue for one hypothesis over another in a process of peer assessment and judgment.

While these ground rules for research might be revolutionary in the physical sciences, anthropology has long been forced by our subject into this type of science. Case study ethnographies are our hallmark. Experimental disproof is difficult and uncertainty is high. Peer assessment, judgment, and argument--not final agreement--are the norm. We view cultures as integrated wholes, with systemic interrelationships of parts. We make cross-cultural comparisons, extracting multiple lines of converging evidence to bolster our arguments. Each of these characteristics we have been forced to adopt in order to deal with the complexity of culture, and culture-environment interactions.

In addition to these shared fundamentals, the second stream of science incorporates features that are less familiar to anthropologists. In the study of ecosystems or global systems, biota and environment are seen to affect one another at multiple scales and in profound ways. The geophysical environment is not a fixed background for living organisms, it structures and is structured by the presence of life. Only ecosystems-ecological anthropologists have attempted to incorporate this type of insight, and we have been tough critics of ourselves and that effort. Larger scale human-ecosystem interactions were once thought, by anthropologists (and ecologists), to be homeostatic in the short term, and linear and progressive in cultural evolutionary terms. More recently however, advances in theory and research have greatly modified the understanding of the nonlinear dynamics and thermodynamics of biogeophysical evolution (Prigogine 1980, Wicken 1987, Depew and Weber 1995), and of ecosystems (O'Neill, et al. 1986, Holling 1986, Holling 1995, Ulanowicz 1986, Ulanowicz 1996, Odum 1983, Odum 1996a), and ecological anthropologists have just begun to make use of the new insights (cf. Adams 1988, Park 1992, Acheson and Wilson 1996, South 1990, Ehrenreich, et al. 1995, Gumerman and Gell-Mann 1994, Kohler 1992).

Anthropologists have made some use of multiple scale analysis in the study of culture. We have recognized the need to move away from studying communities as isolates, and toward placing them within global relationships (Bennett 1988, DeWalt and Pelto 1985, Moran 1990). But the study of scale and hierarchy in ecosystems analysis is far more robust than this, and should prove invaluable for understanding the structure and function of human-environment and human-human relationships. The multi-scale, hierarchical relationships that exist in ecosystems require sophisticated methodologies of analysis and ecologists are committed to computer modeling as a central tool. This too diverges from the first stream of science in which modeling is only one tool among many, and anthropologists, specifically, have made little use of computer modeling, especially of the types used now to study complex systems (Lansing’s work is suggestive of the possibilities (Lansing 1991)).

Finally, the expectations and goals of science as advocated by Holling's second stream diverge from the first, and again seem to echo anthropology's past and suggest a future. The new stream of science is only weakly predictive. The nature of the dynamics of complex systems makes this so. Surprise and uncertainty are expected, and are important structuring features of evolution in nature. A science of complex systems is then "retrospective and historical" (or retrodictive) in nature. An ecosystem is a “moving target", constantly evolving at multiple spatial and temporal scales. Our knowledge of a system is always incomplete, and surprise is inevitable. We can hope to understand a system’s evolution after the fact, but prediction and control, as with biological evolution, is by its nature impossible. Long branded a failing of functionalist and cultural evolutionary theoretical frameworks, incomplete predictability is seen as a fundamental property of complex natural systems.

Comparing Ecological and Social Systems

Ecologists, chemists, physicists, and others from the "hard" sciences, have been eager to apply insights from the new science of complexity to understanding social systems (Allen 1982, Costanza, et al. 1993, De Greene 1993, Dyke 1988, Eldredge and Grene 1992, Forrester 1987, Garfinkel 1987, Geyer 1991, Gunderson 1995, Harvey and Reed 1994, Holling 1995, Iberall 1985, Iberall 1987, Jantsch 1982, Kahlil 1986, Lancaster 1989, Loye and Eisler 1987, Maruyama 1982, Nicolis 1989, Odum 1983, Odum 1996a, Ulanowicz 1996). There is a great need for anthropologists to enter into the debate on these issues. Well established anthropological theory could greatly contribute to better interdisciplinary theory building, and participation by anthropologists would eliminate the tendency to reinvent theory, or to choose a long discredited path. Anthropology represents arguably the best source for social theory that can be applied to this effort. Of the social sciences, anthropology has the time depth, the comparative data, and the bent for evolutionary-ecological-economic thinking that is necessary.

Research by Gunderson, et al. (Gunderson 1995), in Holling's edited volume, is an example of the way ecological systems theory has been applied to social systems. Their understanding of function, hierarchy, and scale in nature is fascinating, incorporating Holling's now well known theory of ecosystem function (Holling 1986) with hierarchy theory (Allen and Starr 1982, O'Neill, et al. 1986) into a general model of the dynamics of adaptive systems[2]. In the article, their complex adaptive systems model is

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[2] In the model, systems in nature continually cycle through the four phases of Exploitation, Conservation, Release (or Creative Destruction), and Reorganization. In ecosystems, r-strategists in the Exploitation phase give way to K-strategists in the Conservation phase. However, as interconnectedness increases, conditions become ripe for chance events such as fire, storm or pest to Release stored nutrients and organized carbon. In the final phase there is Reorganization of (some) released capital and movement towards a next Exploitation phase. Adaptive four phase cycles occur in nature that is hierarchical in space and time. Semi-autonomous levels of adaptive cycles interconnect variables that share similar speed and size relationships. Slow and large levels set the conditions at which faster and smaller levels exits. However the

applied to understanding rigidity and change in government wildlife management institutions. They review some relevant social change theories from the social sciences, searching for, and finding, theories or components of theories that appear to mesh with their position.

While this approach seems reasonable, it is too problem specific, focusing on change in management institutions, and omitting the cultural, ecological, and evolutionary context of those institutions. Their choice of social theories is eclectic, settling on theory that is surprisingly un-ecological, temporally small-scaled, and spatially restricted to western style bureaucratic management (i.e., institution and organization theory, risk and decision making). Their theory of complex adaptive systems incorporates a large body of well-studied ecosystem function and process into a general, nomothetic model of system organization and change. It deserves to be wed to nomothetic social theory that is founded on equally well-studied models of cultural process and function. It is at that point that social change theory can then contribute to understanding the specific problems of resource management they wish to address.

Where's the Ecology?

When the social is borrowed into physical and biological models, it is usually accomplished with cultural models of the familiar, of "entrepreneurs", and "bureaucracy", and "management." The social theory adopted by Gunderson, et al. (Gunderson 1995), and by most other ecologists, other scientists, and policy makers who have ventured into the game of applying theories of complexity to social systems, is surprisingly un-ecological and un-evolutionary. Most often defective human values, uninformed management decisions, undemocratic political systems, or uneducated voters are

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relationship between levels is not simply uni-directional. Fast and small variables in chance conditions can have significant effects on slower levels at critical times in the identified as cause. Anthropology offers, instead, scientific models of social behavior, of which there are now several approaches that explicitly link social behavior to material-ecological conditions.

Ecologists need the insights of anthropologists for understanding the latent functional and ecological relationships that exist between human culture and the environment and between person and person. Anthropologists, on the other hand, need better understanding of ecological processes from the sub-disciplines of ecology that specialize in complex ecosystem dynamics. O'Neil et al. (O'Neill, et al. 1986) make a lucid argument for the power of both ecosystem and community forms of ecology, and the evidence for the vitality of these two traditions is in the great volume of research that they continue to generate. Many of the criticisms of ecosystems models in anthropology (Vayda 1975, Vayda 1983, Vayda 1986, Orlove 1980, Smith 1984) were made prior to the incorporation of recent complex systems thinking into ecology, and no longer apply[3].

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four phase cycle. An example is insect outbreak that may significantly alter a forest structure if a particular threshold condition has been reached in the forest.

[3] (1) Homeostatic Systems. A one-time emphasis on equilibrium systems with homeostatic negative feedbacks has been rejected. It is replaced by a focus on evolving patterns of informed thermodynamic flow. (2) The “Calorific Obsession.” This criticism is made against single-scale, individual selection, with ingestible calories as the primary limiting factor. Systems of human-environment relations with complex organization at multiple evolving scales have many different limiting resource types—energetic and material. (3) Units of Analysis. Larger “units” in some systems theories (political system, ecosystem, belief system) have been designated from an eclectic set of criteria. The boundaries of dissipative structures are marked by proximate free energy gradients (Wicken 1987), and the energetic “negotiation” of those boundaries is continuous. (4) Typology. Typological or essentialist criticisms of biological systems theory are made principally against deterministic succession models in ecology (Simberloff 1980). Nonequilibrium thermodynamics restricts the determinacy of classical dynamics to limited applications, and replaces it with indeterminacy and evolution in biological and physical processes. (5) Functional Tautologies. Functional explanation needs to be supported by consequence laws at the level of theory (Winterhalder 1984). Evolutionary theory can produce consequence laws for hypothesis testing (ibid.), and an expanded evolutionary theory (Depew and Weber 1988) (Depew and Weber 1995) addresses evolution at multiple scales, not just individual organisms, which applies it to societal analysis.

While some difficulties with ecosystems ecology may remain, Winterhalder (Winterhalder 1984:304) suggests that often critiques have aimed more to advance alternative perspectives (community ecology, evolutionary biology, formalist economics, Marxist economics) than to condemn energy or ecosystem studies per se. Contemporary ecosystems ecology, that now incorporates complex systems thinking, could be applied in anthropology, not only to questions of subsistence production, but to existing models of political and social organization. Ecological models of function and structure have the potential to inform cultural evolution, political economy, ecosystems anthropology, and other traditions, as we can inform theirs.

Evolutionism in Anthropology

Anthropology's original and most enduring approach to building analytic models begins with the contrast between cultures, in ethnographic cases, which creates the perspective to identify cultural process, structure, and function. Evolutionism in anthropology was born from this comparative method in the late nineteenth century era of Darwin. Under the criteria of the first stream of science, cultural evolution has endured its share of criticism. Lack of specific predictability, properly narrow and controlled experimental design, or immediate applicability to policy problem-solving have been vulnerable spots. These objections themselves are challenged by the second stream of science, in which prediction, control, and simple solutions do not prevail.

At the turn of the century, cultural evolutionary theory began to loose supporters, until it was revitalized by Steward (Steward 1955) and White (White 1949, White 1959). This history parallels the fortunes of biological evolutionary theory, which interestingly had declining influence on twentieth century biologists until it was revised in the Modern Synthesis of the 1940’s and 1950’s (Depew and Weber 1995). Since that time, cultural evolutionary theory has fractured into Evolutionary Ecology (Smith and Winterhalder

1992), Life Histories / Sociobiology (Chagnon 1988, Hill and Hurtado 1996), Coevolution / Cultural Darwinism (Cavalli-Sforza and Feldman 1981, Rindos 1985, Rindos 1986, Boyd and Richerson 1985, Dunnell 1989, Durham 1991), and a line that more directly follows from Service, Morgan, Tylor, Steward and White which is still called Cultural Evolution (Johnson and Earle 1987).

Cultural evolutionary theory of this last form is an analytic tradition within the second stream of science. A recent example of this tradition is The Evolution of Human Societies (Johnson and Earle 1987)[4], which embodies the positives and pitfalls of this stream of science in anthropology. Following the style of argument employed by prior cultural evolutionists like Steward (Steward 1955) and Service (Service 1975) and Harris (Harris 1977), the authors utilize case studies of existing and past societies to build arguments for understanding structure and function in cultures, and the processes that create change.

What emerges from the comparison and contrasting of cases is a number of hypothesized relationships[5]. The results of their analysis is to produce explanatory

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[4] Johnson and Earle (Johnson and Earle 1987) is better recognized as a fusion between cultural evolution and political economy. Their book incorporates political-economy's concerns with asymmetrical economic and political power into a theoretical framework that is cultural evolutionary and ecological. Other anthropologists have done the inverse, adopted ecological and evolutionary thinking into a principally political-economic framework, in what has been labeled "political ecology" (i.e., (Schmink and Wood 1987), (Greenberg 1994)). The heart of the functional relationships within the political ecology model are those of political economy, specifically the forces/relations of production, the labor theory of value, and others. The model has been expanded by applying it to contemporary and historical cases in which human-ecological relationships are clearly central to a problem, such as "land tenure" or "environmental quality", however the core functional concerns with the relations of production remain. Johnson and Earle (1987), in contrast, is first and foremost ecological and evolutionary in the tradition of Harris, White, Steward, etc.

[5] Clearly the authors entered the exercise with theoretical models. It is impossible to begin any human activity without models of the world. Two questions are important here. First, how much detail of the final models existed before the investigation began, and how much emerged from the data itself. And second, were other models tried on the data and then rejected based on the relative merits of the analysis. Bringing to bare alternative models to a problem, evaluation of the results, and choosing among

models that functionally relate human social organization[6], with human political and economic activities, with human subsistence activities, and with human demography[7]. From the context of those models can be generated functional explanations for other questions, such as Holling's resource management dilemmas. Such social-functional models, that use multiple lines of converging case study evidence, are appropriate and acceptable arguments in the second stream of science, constrained by the real limits to generating understanding in complex systems.

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competing explanations are the hallmarks of the second stream of science as advocated by Holling.

[6] The criticism by anthropologists of functionalism in anthropology has been an important part of our debate (e.g., Friedman 1974, Hallpike 1973, Orans 1974, Gilman 1981), and reflects many of the criticisms of biological evolutionary theory (Gould and Lewontin 1979) and ecosystem theory (Simberloff 1980). The re-orientation of science that is evolving out of the science of complexity (Prigogine and Stengers 1984, Depew and Weber 1995) has deflected much of the debate, and will be discussed here further.

[7] Johnson and Earle (1987) settle on a population pressure (or stress model) of cultural evolution, the merits of which have been debated for many years in the literature (Cohen 1977, Cowgill 1975, Harris 1979, Haas 1982). The stress of growing populations, it is argued, effects subsistence strategies and technologies, which structure and reflect political-economic and social structural features of a culture. The realization of these relationships is evidenced in their case studies, and, as would be expected, is manifest in variation across cultures, dependent on the vagaries of ecology and history. They repeat a number of anthropology’s long argued, and generally well-argued, hypothesized causal relationships (Harris 1979, Boserup 1965, Cohen 1977, Carneiro 1970, Service 1971, 1975), and contribute new insights to that body of theory, although many issues still remain. One is the use of population limits or carrying capacities in constructing evolutionary arguments. Anthropologists have long known that raw population figures are only important in the context of existing economic and technological conditions. However, in addition, many slow- or non-renewable environmental resources can also alter the capacity of an ecology to support a human population. A once supported population size may, over time, come under greater, and greater stress as stores of natural resources are consumed. Population pressure, therefore, is another “moving target” with many limiting factors that may come into play under countless chance historical circumstances. Rather than focusing on population density per se, on some elusive human total (holding technology constant), cultural evolutionists should be constructing or reconstructing a more thorough environmental context, using ecological understanding of how ecosystems (with humans) function and change. The “environment” in “ecological” anthropology must become a dynamic environment, and so with that, we should be applying theoretical models that represent the dynamics of systems. See further discussion in section, Population Pressure and Self-Organization. Another fascinating correction to population pressure models is presented in Keegan (1995).

Contemporary cultural evolutionists eschew "progress" in function, pointing to the political-economic inequality in culture change which has emerged from the control over productive resources by elites (Harris 1979, Johnson and Earle 1987). World Systems theorists further expand the scope of power asymmetries that cross-cut and integrate cultures into world scale models (Wallerstein 1974, Sanderson 1995). These insights are significant improvements over earlier progressivist and neocolonial social theory, and are the results of extensive empirical research.

An "Arrow in Time": Direction and Teleology Reexamined

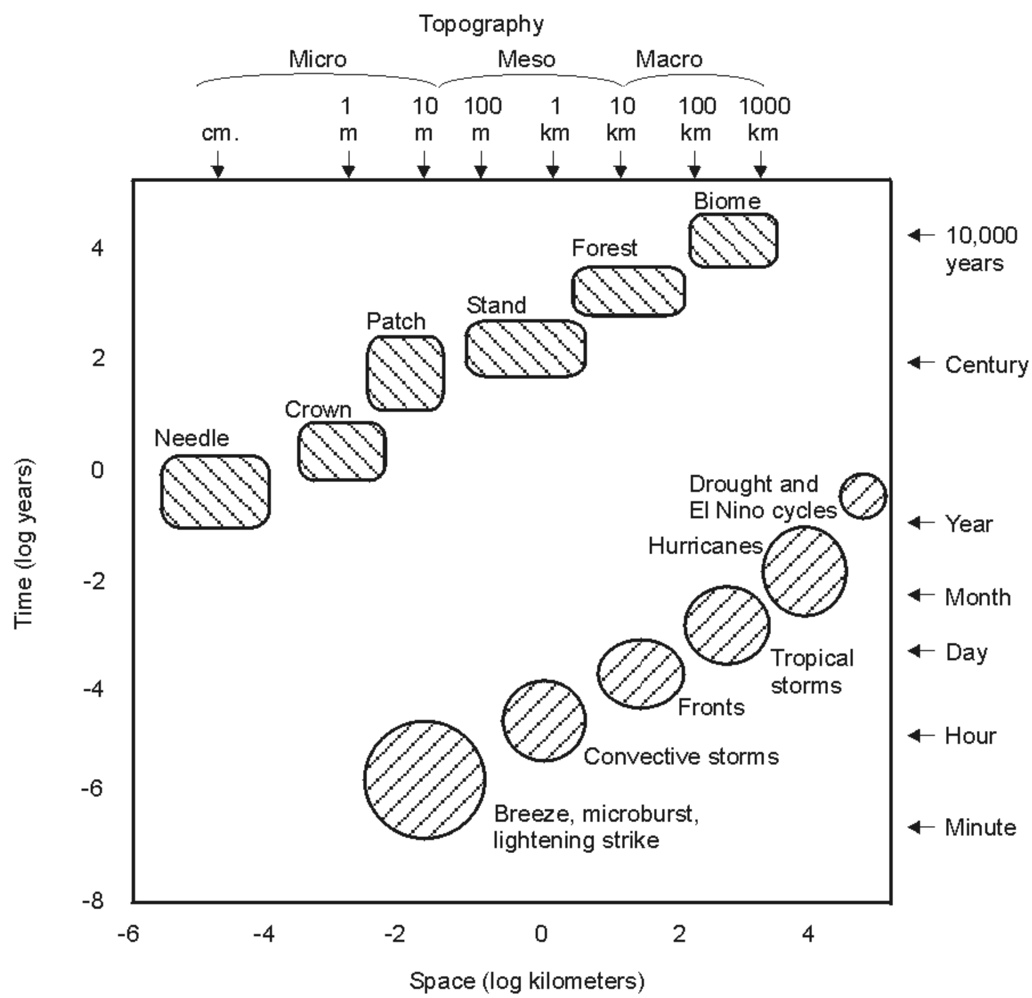

Figure 186: Hierarchy and Scale in an Ecosystem
Based on Holling (1995:23).

While these approaches have improved analytic models of direction and function in culture, recent developments in complexity theory (Depew and Weber 1995, Prigogine and Stengers 1984, Bechtel and Richardson 1993, Salthe 1985), in biological evolution (Eldredge 1985, Ereshefsky 1992, Mishler and Donoghue 1991, Wicken 1987), and in ecosystems thinking (Holling 1986, Holling 1995, Johnson 1988, Johnson 1992, Odum 1983, Odum 1988, Odum 1996a, Odum 1996b, Odum and Pinkerton 1955, Odum, et al. 1995, O'Neill, et al. 1986, Ulanowicz 1986, Ulanowicz 1996) have argued for function in nature at multiple evolving scales. As in Holling's model of ecosystems, it is argued that function exists in semi-autonomous scales of objects and relationships with similar temporal and spatial characteristics (Figure 186). Biogeophysical processes are argued to self-organize into scales that continuously evolve through patterns of destruction and renewal (Figure 187).

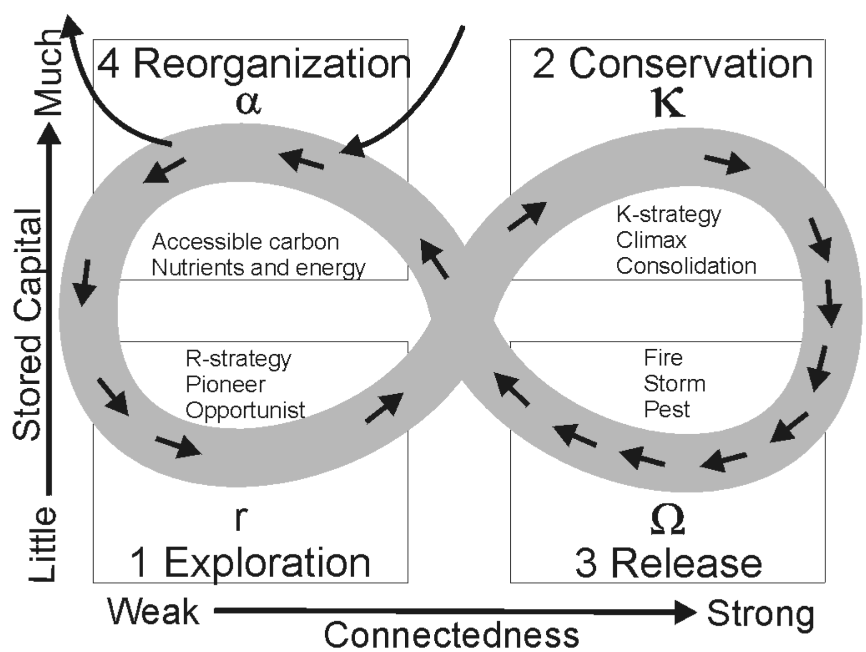

Figure 187: Holling's Diagram of Ecosystem Processes
Based on Holling (1995:22).

With these kinds of insights, there has been renewed interest in the function of nature evolving. Is there functionality, as in White's model, in a scaled and complex nature? In the current research into complex systems, perhaps the most profound conclusion is that nature displays a thermodynamic “arrow in time” (Prigogine and Stengers 1984). Change in nature is irreversible, constructive, and indeterministic due to the Second Law dissipation of energy. While this is intuitive (watching a plant grow in time-lapse or two liquids form a solution), classical Newtonian dynamics held that time was, in theory, reversible, that nature was finally deterministic, and that outcome could be reduced to the knowable behavior of basic elements of matter. The unarticulated belief in determinism and reducibility in nature has been long a part of our cultural and scientific ethos, and continues to structure much of scientific endeavor.

However, this picture of nature has been abandoned by physicists and chemists in many problem sets. It has been replaced by a model of nature that has structure and is self-organized by the dissipation of energy into what Prigogine calls "dissipative structures." Dissipative structures are the result of the incessant dissipation of energy in open systems. The existence of energy gradients leads nature to create structure. While this may sound teleological, philosophers and scientists have re-addressed the issue of teleology in nature. O'Grady and Brooks (O'Grady and Brooks 1988), for example, distinguished between goal-seeking behavior (teleological), end-directed behavior (teleonomic), and end-resulting behavior (teleomatic). While "teleological" describes human behavior, nature expresses itself also in teleomatic and teleonomic behavior. "Teleomatic" behavior is said to be the result of the existence of matter and energy, as in gravity, entropic decay, or reaction gradients. It produces end-states, but it is not purposeful, and there is no "control." "Teleonomic" behavior is the result of evolved internal controlling factors that determine the end-states of processes, as in homeostasis, ontogeny, and reproduction.

Since Darwin, great effort has been made to understand the origin of life, evolution, and development in terms other than teleology. In recent years each of these issues have been addressed by applying the teleomatics of nonequilibrium thermodynamics (Eigen and Schuster 1979, Eigen 1982, Wicken 1987, Depew and Weber 1995, Ho and Saunders 1984, Kauffman 1990). In each case, end-directed behavior can be understood to be the product of the end-resulting, teleomatics in nature. The picture that emerges is one in which both physical and biological nature is both creative and in flux, driven by the dissipation of energy. Change is incessant, and the "pause" of species formation, for example, is the event that requires explanation. This differs from explanations of stability and change resulting from simple chance, the happenstance coming together of two nucleic acids, then three, leading to a functional strand of DNA, or the monkey jumping on a typewriter and writing Hamlet if given long enough. Nature as depicted in nonequilibrium thermodynamics is inherently self-organizing and hierarchical. It is argued that matter forms into structures that facilitate the dissipation of energy. Biological life accelerates this process. Cultural life further so.

The Fourth Law?[8]: Maximum Empower

The thermodynamics of this self-organizing process was first discussed by Lotka (1925) and was taken up by systems ecologists (Odum 1983, Ulanowicz 1986) and now

[8] Lotka suggested that his "law of evolution" be considered a Fourth Law of Thermodynamics: "Evolution proceeds in such direction as to make the total energy flux through the system a maximum compatible with the constraints" ((Lotka 1925:357), quoted in (Depew and Weber 1995:409)). H.T. Odum has followed Lotka's work with his principle of Maximum Empower: "In the competition among self-organizing processes, network designs that maximize empower will prevail" (Odum 1996a:16). Empower is the flow of emergy per time, and emergy is defined as: "Available energy of one kind previously required directly and indirectly to make a product or service" (Odum 1996a:13). Emergy is a currency for representing the work that was necessary in the production of a product or service. It represents the energy em-bodied in that product or service. It is therefore a shorthand means for situating matter and energy within a system. Emergy is the currency that Odum recommends in his brand of ecological economics, called *Environmental Accounting* (Odum 1996a).

by complexity theorists (Johnson 1992, Wicken 1987, Weber, et al. 1988). An early promoter of these issues, H.T. Odum has elaborated his position on the energetics of ecosystems and general systems, responding to the surge of research in complex systems in the last 10 years (Odum 1983, Odum 1988, Odum 1996a, Odum 1996b, Odum, et al. 1995, Odum and Odum 2000). In Figure 188, one of Odum's systems diagrams depicts the self-organization of dissipative structures, with the formation of autocatalytic feedback ("reinforcing pump"). Nature is understood to organize itself at multiple scales by using energy and materials to build structure, which function to feedback and amplify their capture and use. This autocatalytic relationship has been argued by many researchers since Lotka to be a basic organizing principle in the emergence of life, and the overall organization of nature.

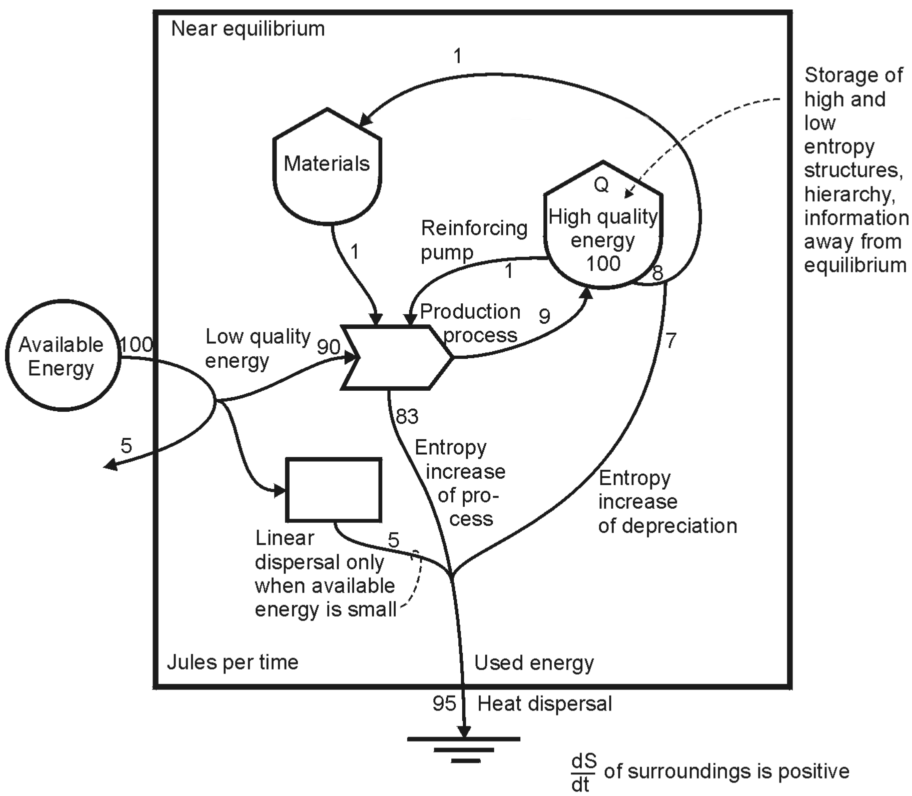

Figure 188: Odum's Diagram of Self-Organization
Typical energy flows in one unit of a self-organizing system on a source limited from the outside to a steady flow. Drawing is based on (Odum 1995:313).

Odum calls this natural phenomenon the Maximum Empower Principle (Odum 1996a:16, see Hall 1995), which is defined in two ways. The first definition addresses the topic of Prigogine's dissipative structures, "Self-organizing systems disperse energy faster, maximizing the rate of entropy production by developing autocatalytic dissipative structures" (Odum 1996a:21). His second definition is the inverse, and emphasizes the constructive side of natural systems, "Self-organizing systems develop autocatalytic storages to maximize useful power transformations" (Odum 1996a:20). Over time, this process has lead to the evolution of biogeophysical systems that capture, use, and dissipate more of the available solar and earth deep heat energy. This tendency towards increasing dissipation gives nature a directionality that it has lacked in the Newtonian worldview that has long dominated our scientific and popular ethos. More recently it has been shown that this process does not proceed gradually or linearly or lead to equilibrium, but rather it creates fluctuating patterns that we can observe of rapid energy dissipation followed by longer periods of renewal and storage.

What's Evolutionary about Cultural Evolution?

> Whatever else may happen, we are reasonably certain that evolutionary theory will remain incomplete as long as self-organizational and dissipative phenomena are kept at a distance (Depew and Weber 1995:479)).

Anthropologists working in the tradition of cultural evolution have had difficulty linking their work to biological evolutionary theory (Blute 1979, Dunnell 1980), in particular, to the “hardened” Evolutionary Synthesis of this half century, dominated by population geneticists. The advances of complexity theory achieve the inverse, they link biological evolution to a more general definition of evolution, one facet of which is the evolution of culture within ecosystems. Depew and Weber (Depew and Weber 1995) have evaluated the implications of complexity for evolutionary theory. The scope of their review is vast, spanning many disciplines, which suggests the fertility of interdisciplinary research. The essence of the argument can be summarized.

Complexity theory offers plausible explanations for many of the current challenges to the Evolutionary Synthesis, and it does so within the “basic assumptions” of the theoretical model. Neutral selection, molecular clocks, selfish DNA, hierarchical selection, the emergence of life, the complex genome, ecological succession, punctuated equilibrium--each of these issues has been difficult and cumbersome at best to articulate with the Synthesis and its exclusive concern with natural selection at the scale of organisms. Complexity theory places organisms within a rendering of nature that is hierarchical and self-organizing at multiple temporal and spatial scales. Physical selection (“survival of the stable”) and chemical selection (“survival of the efficient”) are related to natural selection by these processes (Depew and Weber 1995:408). In this context, the evolution of life is not a “frozen accident”, but an explicable elaboration of a basic theme, although irreducibly and historically contextualized. Not surprisingly still, life is expected to be further organized into species and ecosystems that exhibit global, emergent properties.

Cultural evolution since its beginnings has addressed itself to the emergence of social properties. Patterns of social self-organization and historic re-organization have been the focus of numerous case study-driven evolutionary scenarios. Using case studies of pre-historical, historical, and extant human groups, anthropologists produced evolutionary typologies (i.e., band, tribe, chiefdom, state) and processual models which have aimed to relate them. Recent processual models of cultural evolutionary change, such as Johnson and Earle’s (Johnson and Earle 1987), have emphasized the interplay between the human-ecological environment, human demographics, technological innovation, and political-economics. The emergence of novel cultural phenomena (but not the means of evolutionary transmission and selection so heavily emphasized by the biological evolution of the Synthesis) has been the dominant focus of explanatory theoretical models. Examples of emergent properties of culture that have occupied cultural evolutionists include the following:

- The emergence of food production technologies and domestication.
- The emergence of labor specialization.
- The emergence of private property.
- The emergence of large, permanent human social groups.
- The emergence of social inequality, related to the asymmetrical control of the productive resources and technologies by factions within a society.
- The emergence of organized warfare and specialized coercive military/police institutions.
- The emergence of markets and the expansion of trade.
- The emergence of political chiefs and chiefly lineages.
- The emergence of institutionalized religion and religious specialists.
- The emergence of irrigation agriculture.
- The emergence of legal/financial/monetary technologies.
- The emergence of state bureaucracy.
- The emergence of modern world systems, and supranational legal/financial institutions.

As emergent cultural behaviors have been identified and situated historically, cultural evolutionists have worked to relate cultural patterns into functional-ecological explanatory models. Cultural evolutionists have asked why cultural properties have emerged, what ecological, demographic, technological, and economic factors might have set the stage for their appearance, and how cultural properties functionally interrelate with others. They have attempted to explain emergent cultural properties in material ways, which is similar to the methods ecologists use to describe ecosystem function and organization, and the transitions between multiple, functionally stable ecosystem states.

Some anthropologists have recently sought to improve cultural evolutionary theory by strengthening ties to biological evolution (Boyd and Richerson 1985, Cavalli-Sforza and Feldman 1981, Rindos 1985, Rindos 1986, Durham 1991). The direction of this effort has been heavily influenced by population genetics. Unfortunately, this component of the Synthesis is arguably the most reductionist. The anthropology that it spawns is equally reductionist, intent on decomposing symbolic culture into traits that can be manipulated by mathematical formulation. This is occurring in anthropology at a time when the synthesis has come increasingly under pressure, and an expanded synthesis is emerging that emphasizes the developmental, ecological, hierarchical, integrative, and historical aspects of nature. This version of cultural evolutionary theory appears to be moving in the opposite direction.

This is particularly unfortunate considering the ease of fit between the long-standing version of cultural evolutionary theory, e.g. Johnson and Earle (Johnson and Earle 1987), and this expanded synthesis. The evolutionary theory emerging from the science of complexity does not require structures analogous to genes at multiple physical, chemical, ecosystem, or cultural scales. To the contrary, the evolution of language and culture have tremendously flexible capacities for information storage that are qualitatively different from genetic representation. Cultural evolutionary theory, in the tradition of Johnson and Earle (Johnson and Earle 1987), that emphasizes emergent cultural and structural properties, exhibiting internal dynamics and organization, and integrated to ecological systems by the self-organizing processes of energy capture and dissipation is a better match to an evolving Darwinism. The next chapter will demonstrate these principles with select case studies from Johnson and Earle (Johnson and Earle 1987).

Cultural Evolution from an Ecology of Complexity

> In all the scales of the known universe, from atomic processes to the stars, pulsing oscillations appear to be the norm (Odum 1996a:16).

Anthropologists and other scientists are beginning to apply complex systems theory to social theory. The biological and physical scientists have approached the problem from numerous perspectives and with uneven degrees of social science sophistication (Allen and Starr 1982, Costanza, et al. 1993, De Greene 1993, Dyke 1988, Eldredge and Grene 1992, Forrester 1987, Garfinkel 1987, Geyer 1991, Gunderson 1995, Harvey and Reed 1994, Holling 1995, Iberall 1985, Iberall 1987, Jantsch 1982, Kahlil 1986, Lancaster 1989, Loye and Eisler 1987, Maruyama 1982, Nicolis 1989, Odum 1983, Ulanowicz 1996). Archaeologists have recently become interested (Kohler 1992, Gumerman and Gell-Mann 1994), especially for applying the non-linear, or pulsing dynamics of complex systems to understanding the collapse of state societies (Tainter 1988, Yoffee 1988). Fewer cultural anthropologists have found use for complexity (Lansing 1991, Acheson and Wilson 1996, Park 1992, Carneiro 1982), and their works often reflect the mathematical components of the model, missing the potential value of its thermodynamic and ecological underpinnings.

In cultural anthropology, R.N. Adams (Adams 1988) produced a groundbreaking and extensive synthesis of much of complexity theory with anthropology, particularly into cultural evolutionary theory and into political anthropology. His book is perhaps the most thorough discussion to date, but falls short on some accounts. Adams has attempted to incorporate many of the issues raised by complexity theory, which include Lotka's energy principle, dissipative structures, hierarchical organization, and others. His is an effort to extend complexity theory into the obvious next-frontier--human culture. He chooses, however, to concentrate his theory building on the emergence of political power and social hierarchy, and does not pursue his own arguments into detailed analysis of human-environment relationships and the complex ecological context of culture. By this strategy, he misses some important opportunities to better utilize the implications of ecological theory for cultural evolution.

While Adam's research program is insightful and fertile, the synthesis can be improved by more completely and thoroughly integrating understanding of larger-scale ecosystem structure and function, within which human organization occurs. More specifically, the critical issue that needs to be incorporated is resource capture, use, and re-use in ecosystems with humans.

Natural Resource Use and Re-Use in Ecosystems with Humans

According to Odum (Odum 1983), global environmental systems self-organize around renewable energy use, which originates with solar energy and earth deep heat, and which fuels weather and geologic systems, and ultimately ecosystems. This self-organization results in ecosystems that exhibit pulsing between storage and release of energy in the form of nutrients, biomass, populations and information (Odum 1996a, Odum 1996b, Odum, et al. 1995). This storage and release occurs at multiple spatial and temporal scales. From our human scale, therefore, we perceive some storages as renewable, such as fresh water in lakes, or annual grasses, or seasonal insect populations. Other storages, however, we perceive as slow-renewable, like topsoil, or forest trees, which can be consumed by intensive human use, fire, flood, or some other action, and require many years to return[9]. At our scale we often call these disasters, but it is becoming increasingly recognized that pulsing is a part of self-organizing ecosystems on a larger scale, as in the many known fire-adapted ecosystems. Other storages we perceive as non-renewable, such as fossil fuel, or metals (although these too are part of renewable geologic cycles at a larger time scale). All life, at any scale, is said to organize around these renewable, slow-renewable, and non-renewable stores of energy and resources.

Slow-renewable resources have set real limits to the growth of human populations in pre-history and historical times (Odum and Odum 2000, Adams 1982, Debeir, et al. 1991, Perlin 1991, Hardin 1993). Important resources are topsoil, wood,

[9] It may be difficult for some to think of topsoil as a resource that is consumed. But topsoil is an organic product in ecosystem growth, and its nutrients can be captured and removed by farming, unless explicitly replaced.

metals, stone, reefs, and others. The consumption of these storages of solar and earth energy have been implicated in the expansion of state societies, in their collapse (Culbert 1988, Tainter 1988), or less dramatically, in the waves of use and abandonment of landscape by swidden agriculturalists, pastoralists, or hunter-gatherers. Humans are not alone in being constrained by resources. Put more generally, pulses at larger and smaller temporal and spatial scales will limit the size of all biological populations. This occurs locally to human populations, and has also occurred more globally at times (i.e., plague, drought, earthquakes, El Niño, hurricanes). The human difference is that at short temporal scales (in evolutionary time) we have modified our ability to capture and use additional environmental storages of resources, and our global population size has pulsed to its current large number.

Understanding environmental resources in these terms provides a more thorough model of ecological dynamics for cultural evolutionists. It indicates motive for human movement on the landscape, and for resource intensification when movement is not possible or undesirable. This dynamics produces a different picture of the environment, one far from homeostatic, one that should be expected to put stress on human populations from time to time. Under the stress of pulses from scales both slower and faster than human temporal scale, resource intensifications would at times be in great demand. With resource intensifications comes population growth and the "closing of doors" to prior, lower-density strategies like hunter-gathering, which since Boserup (Boserup 1965) has been central to cultural evolutionary thinking about the environment.

Framing now the issue of resource use and population growth in terms of self-organization and dissipative structures leads to another perspective on this important relationship between humans and resource use in cultural evolution. As defined in the Maximum Empower principle above, and observed in autocatalytic growth cycles, systems that use energy to build structure are often "rewarded" by gaining access to more energy. Human action in agricultural intensification builds structure that captures more energy by utilizing storages of slow-renewables like topsoil, non-renewables like phosphate and oil, and renewable energy. Our use of storages makes possible the capture of more energy for growing more of us. The human-agriculture ecosystem is energetically rewarded and expands to cover more landscape because it taps resource storages that were previously unused. In macro energetic terms, this human system incorporates or replaces other systems because it captures and dissipates more energetic resources.

Where are the limits? The limits are in the storages. Netting (Netting 1993) has shown in great detail the incredible diversity and ingenuity of smallholder farmers in capturing slow-renewables and renewable resources, and their efforts to maintain them. These elaborate systems have evolved because of the limits imposed by natural ecosystems. New production strategies and technologies have been the human response to limits, and they have come in two principal forms. The first is the intensive use of human labor. However, the obvious limit to that strategy is that it rewards the production of new labor, more people, which eventually pushes on the limits of the landscape to expansion. The other complementary strategy is to capture additional storages of resources, which requires new technologies, and is slower in coming due to chance events and prior technologies. This century especially has shown the greatest return to this strategy, to the point that we are now essentially "eating oil" (Green 1978). However, other technologies have been extremely important historically in gaining access to new resources, particularly plows for access to deeper soils, axes for opening up forest topsoil to farming, draught animal technologies, water delivery systems, storage facilities, iron and steel smelting, and others.

Does cultural evolution lead to more energy per person? Cultural evolution should not produce more energy that is captured and controlled by each culture member. The capture and use of resources is systemic, and results in more people, some with less energy than members of less complex cultural systems. According to this theoretical model, the teleomatics of nature have resulted in the emergence of life, which has now resulted in the emergence of human culture. The emergence of both was entirely unpredictable from the start, and both exist only in an historical context that channels any future evolution.

Does this argue for the progressive and inevitable rise of civilization in energetic terms? Again no, for the increased capture and use of resources by humans has been a halting process, not continuous, following environmental pulses at larger scales, and technology induced human pulses and contractions. Dissipative structures are argued to evolve only because they can. Odum contends that we are currently entering a period of contraction, in energetic terms, due to diminishing returns on fossil fuel use, and there is no evidence that a new technology can give nearly the same return that oil did in its years of high energetic return (Odum and Odum 2000). It is expected now that improved efficiency, materials recycling, and a concentration on maintaining renewable resources will need to be the strategy for a desirable standard of living.

Understanding science and government in terms of analytic models of cultural evolution does not lead to political or academic inaction or resignation. To the contrary, it should be clear by now that the application of complexity theory to evolution, both biological and cultural, suggests the indeterminacy of nature, and the central role of chance and action. Appreciation of the physical limits to growth is sobering, but it is essential for directing science and society to deal with the fuller nature of our world social and ecological dilemmas. Appreciation of the functional interrelationships within culture, and between culture and environment, is needed to frame the debate and inform decision making.

Science-minded anthropologists (and other scientists) continue to be influenced by the methods associated with the reductionist stream of science, and by the expectations of mechanistic explanations and control, to focus on simple problems with single or very few independent variables, essentially to abandon the study of the organization of emergent variables (such as economic sector organization, or human-environment dynamics), which for many years sustained anthropology and set it apart from other sciences.

Complexity theory and its expanded evolutionary synthesis can be integrated into cultural evolution and ecological anthropology. Theory building of the type best known to cultural evolutionists, of mounting processual arguments based on case study evidence, is not an evolutionary dead end. The type of science now emerging from the study of complex systems indicates that anthropology has much to contribute to the interdisciplinary study of complexity in natural systems.

CHAPTER 16
EVOLUTION IN CULTURAL AND NATURAL SYSTEMS: APPLYING SYSTEMS MODELING TO HUMANS AND CULTURE

This chapter will demonstrate with case study examples some key issues introduced in the previous chapter. Theories of cultural evolution synthesize the archaeological, historical, and ethnographic records to construct nomothetic explanations of recurrent cultural patterns and processes (Harris 1979:78). General systems models that can negotiate this body of knowledge should be preferred over those that cannot. The process of forcing systems modeling to incorporate the data and theory of cultural evolution enriches both. Cultural evolution gains a firmer foundation in the processes of biogeophysical change and self-organization. Systems modeling gains processual explanations of culture change, which uncover the infrastructural variables (demographic, technologic, economic, and environmental) that stubbornly channel or curb the directions of change.

This chapter follows closely *The Evolution of Human Societies: From Foraging Group to Agrarian State* (Johnson and Earle 1987), and other works in cultural evolution and world systems theory. It augments that body of work with systems models, which translate language through rigor into visual images that cannot be muddled by words, or hedged against specificity. Consider this discussion within the explosion of research into the self-organization of complex systems as dissipative structures. Complex systems research has invigorated the long tradition within ecology that explored the energetics of ecosystems, the cycling of nutrients, food webs, and other important systemic relationships that relate life to the energetics of the biosphere. The natural extension of this research is to place the evolution of human cultures within this picture of nature evolving.

By producing general explanations for like patterns of culture found apart in time and space, and with reasoned scenarios of circumstance and process that explain the empirical evidence of cultural complexification from foragers to chiefdoms to states, cultural evolution is a natural partner to systems ecology (Odum 1983), perhaps the paramount general, and synthetic theoretical framework. The sections that follow will in brief describe and illustrate with systems models the general cultural forms identified by cultural evolutionists. It will start with family level foragers, to be followed by local groups, chiefdoms, states, and world systems. By the end, an argument will be made for the inclusion of key ingredients of the cultural soup--material assets, technologies, and the social hierarchy created by the people that control them--in systems models of culture, people and nature. These ingredients are the analytic components of the preceding Bonaire case study.

Family Level Foragers

The oldest forms of human social groups were families, which aggregated and disaggregated with other families in search of resources (Figure 189). This smallest form of human organization has also been referred to as bands, as foragers, or as hunter/gatherers.

Plants and Animals

As depicted in the drawing above, Family-Level Groups subsist on foraging for natural plants and animals. Human foragers are essentially top consumers in a food web of un-domesticated plants and animals. Humans use shared technologies and a division of labor to produce complex foraging strategies that have made humans the most flexible foragers the world has ever seen, allowing humans to thrive in a greater variety of niches than any other animal.

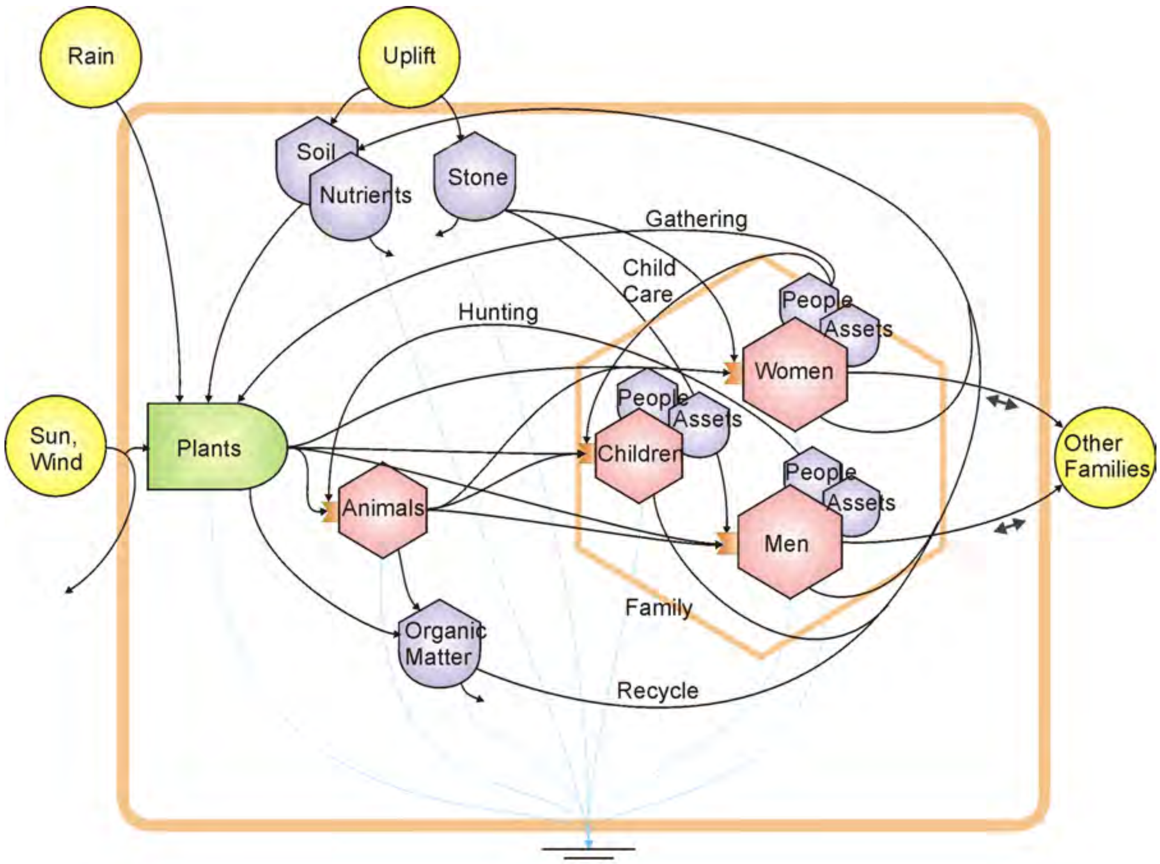

Figure 189: Family Level Foragers
Foragers have population densities of one or less per square kilometer. Foragers are egalitarian, with social hierarchy found only in age grades. The sexual division of labor produces a hint of economic diversity.

Storages of Natural Resources

Note especially the important role of some environmental storages. Specifically, soil and nutrients are shown to be created from stone as it is uplifted, used in the growth of plants and animals, and then recycled back into the storages of nutrients (with some natural loss to leaching, etc., represented by the heat sink under the drawing). Stone is also a critical element in the production of stone tools for Family Groups. It is well known that particular types of stone are valued for their strength and flaking characteristics, and were often traded great distances.

Sources and Storages as Limiting Factors

Stone for tools, soil nutrients, and fresh water from rain can be limiting factors on Family Group densities, meaning they can restrict the size of Family Groups and the permanence of their residence. Family foraging and horticultural groups are known to pulse a location, consuming storages of natural resources in a year or more, before moving on to another location, allowing the first to recycle and recover its productivity.

Assets

Private ownership of assets like digging sticks, bow & arrow, skin bags, etc. is recognized, but access to the materials and technologies for producing them is available to all. As all top consumers, Family Groups have significant feedback effects within their ecosystem, but relatively speaking there is much less modification of the natural environment than is found in Local Groups, and certainly in Chiefdoms and States.

Social Hierarchy

Family-Level Groups exhibit very little social and economic differentiation (compare to Local Groups, Chiefdoms, etc.). A division of labor by sex and age is common, and occasionally temporary leaders are chosen to lead work tasks. Family groups do not differentially control access to environmental resources (as do sedentary populations who's members differentially own the rights to land or domestic animals). The little social hierarchy that exists (in terms of control over resources) is found between children and adults, with adults owning tools, and controlling the labor of children, due to their greater strength, skill, and knowledge.

Cultural Models

All humans use language to produce models that explain the world. These models are constantly being negotiated, retold, relearned, and enculturated into young members. Cultural models recount the ecstatic and the mundane, the sacred and the profane. Probably the most resilient cultural models are those that encode practical knowledge for subsistence gathering, i.e., models for tool production, for foraging strategies, and for the division of labor. Cultural models provide a coherent explanation for the existent form of social hierarchy and division of labor. All members of human societies contribute to the negotiated production and maintenance of cultural models, which explain and interpret their worlds. These culturally learned life strategies are represented by the division of labor (here into men and women), and by socioeconomic hierarchy (here between children and adults), depicted by the vertical (top to bottom) and horizontal (left to right) differentiation of human consumers, respectively. With more complex cultural forms, both the division of labor and socioeconomic hierarchy increase.

Recycle

Recycle is a vital process within any system. In ecosystems, nutrients are recycled in the decomposition of organic matter and its return to the soil. From the soil those nutrients can be bound again into living organic matter. This work is performed by nature in ecosystems with Family-level groups. As human modification of the ecosystem becomes more intensive (with Local Groups, Chiefdoms, etc.), humans must do more of the recycle work to maintain the productivity of ecosystems.

Heat Sink

All ecosystems in nature are open systems, requiring constant inputs of energetic resources to maintain their structure against depreciation--the universal process referred to as the Second Law of Thermodynamics. In other words, without energetic inputs, all things will wither away. This depreciation is represented by the heat sink symbol, which is connected to everything in the system, and records the rate of natural decrease over time. The energy flux within any system is depicted by the flow from Source symbols (circles) to this Heat Sink symbol. The system that self-organizes between source and sink is a dissipative structure. This understanding of nature's Second Law is creative. Cultural and environmental systems are ultimately the product of the self-organization of nature in the dissipation of energy. A cultural system and its supporting environment will not exist without the constant energy flux that creates them.

Case Study: !Kung San Family Level Foragers

The !Kung San, like many human groups, have a rigid sexual division of labor, with women doing most of the gathering, food preparation and child care, and men doing hunting and some complementary gathering. There does exist a limited socioeconomic hierarchy by age, with men and women controlling more resources and manufactured goods than children.

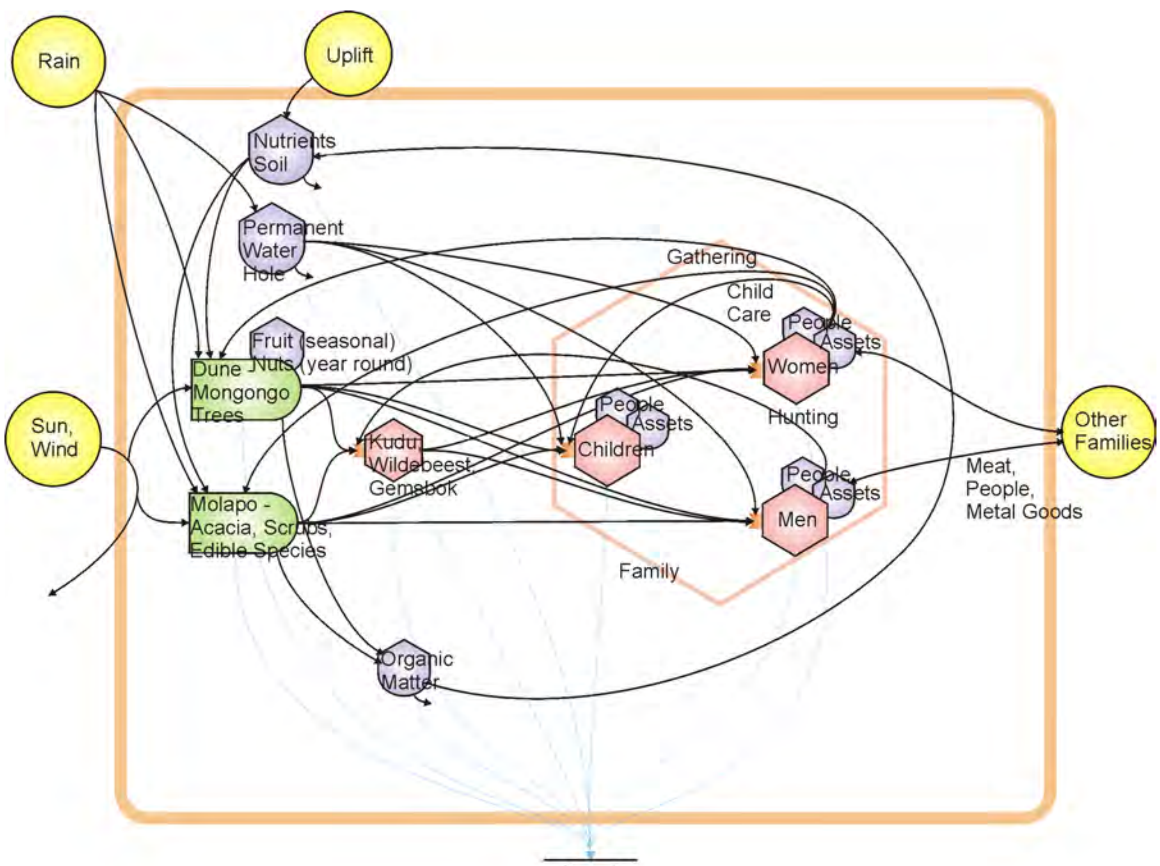

Figure 190: !Kung San Foragers
Contemporary human groups incorporate, or nest, some degree of age and sex hierarchy and diversity within additional scales of diversity.

Water is a limiting factor in the !Kung San environment. The !Kung San will disperse in the wet season, and aggregate in camps in the dry season around the few permanent water holes.

Table 23: Storages of !Kung San Foragers[1]

	Natural Assets	Other Assets	Human Biomass	Assets' Primary Function
Women	None	Digging Stick, Skin Bags, Food Processing Tools	1-2 People	Gathering Fruits & Mongongo Nuts, Manufacturing canteens, etc., Food Preparation, Child Care and Education
Men	None	Bow & Arrow, Knife, Eggshell Canteen, Poison, Spear, Snares	1-2 People	Hunt Animals, Some Gathering, Manufacturing hunting goods, Child Education
Children	None	Some crude versions of above	1-3 People	Carry Goods, Relay Messages, Process some Foods, Some Foraging and Hunting

Local Groups

Local Groups live and subsist in units larger than individual families. Population densities are usually low, but can on occasion be quite high when natural resources are

[1] Note on table formats in this chapter. The rows are distinguishable human groups, i.e. men, women, children, villages, elites, non-elites, etc. The first 3 columns are types of assets that exist in the sociocultural system, i.e., natural assets (when controlled by person or persons), other physical assets, and human biomass. The 4th column contains some critical ecological functions of these assets within the human system. Often the assets function is a "feedback" from right to left in a systems diagram, however the flow of the human assets may also be from left to right, signifying a convergence of resources to a human group with greater transformity. For Chiefdoms and States, one additional column will appear in the aggregate drawings, which refers to the additional

highly productive. On average, densities are above one person per square mile, which is higher than Family-Level Group densities.

Domesticated Plants and Animals

Local Groups have a subsistence base that often includes domesticated plants and animals, in addition to wild foods when available. Domestication requires labor for activities like burning, clearing, planting, manuring, and the herding of animals. Land must be prepared for planting, and crops must be weeded and harvested.

Social Hierarchy

Ownership and control of land for gardens and of animals is publicly recognized. Due to chance and the uneven distribution of natural environments, some families may gain greater access to resources. This incipient inequality or hierarchy among Family Groups is a pattern that is amplified in Chiefdoms and Archaic States, and is represented in Figure 191 by the relative positions of family groups in the left-to-right systems diagram.

Lineages

Local Groups are composed of Lineages, which themselves are made up of Family Groups. Family Groups within Lineages are related to each other by kinship (which has many forms, including fictive kin). Lineages usually control access to land for planting, water resources, and grazing land. This creates inequality or hierarchy among lineages, and is represented by the differential position of lineages within the Local Group in the left-to-right systems diagram.

Public Ceremonies

Local Groups have more elaborate public ceremonies than do Family-Level Groups. Public ceremonies are used to establish and re-establish lineage identity and

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storage on the drawings. This storage and column are labeled Division of Labor / Diversity, which was discussed previously.

membership. They are used to maintain regional intergroup relations in order to obtain allies in war, marriage partners, and exchange goods.

Charismatic Leader

Often charismatic leaders emerge (sometimes called headmen or Big Men), who will organize intensive labor, hunting, or raiding activities. They achieve their status by example and by persuasion, and their actions often involve public ceremonies. They are represented in the left-to-right systems diagram at the apex of the social hierarchy. This is because of the large feedback effect they have in controlling labor parties for the intensified production that is necessary to support the higher density Local Groups.

Cultural Models

Cultural models among Local Groups include beliefs about lineage memberships (often using fictive kinship structures), about social hierarchy, about private property, and about leaders. They also contain very valuable models to explain animal domestication and agriculture. Important knowledge about planting, care, and harvesting, and about herding must be maintained and enculturated into young group members.

Case Study: "Highland" Yanomamo Local Group Village

The Yanomamo live in a region that is more productive than the family-level foragers (!Kung San). This is due primarily to the differences in driving energies entering the system from outside the boundaries drawn here, specifically, the greater rainfall (although the Guiana highlands occupied by the Yanomamo are cooler and dryer than the lower altitude Amazon basin areas).

The Yanomamo grow swidden gardens of plantains, manioc, and yams, and they plant peach palm trees. Access to gardens and good hunting grounds attach the Yanomamo to a particular broad landscape. Peach palms and plantains especially are "capital improvements" that are valuable storages of resource that are controlled by individual Yanomamo families, and defended by the Yanomamo village. In recent years, access to nodes of exchange with outsiders have further tied the Yanomamo to more "valuable" regions of the forest.

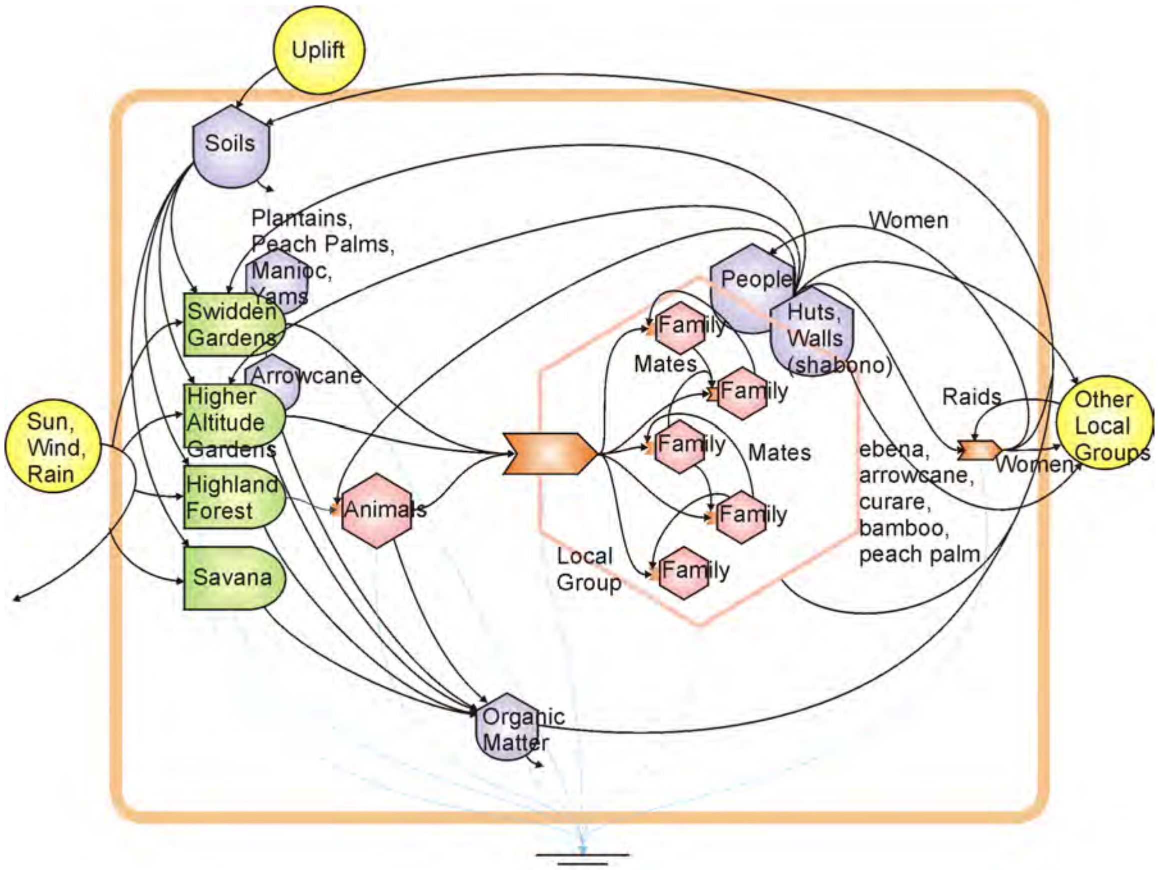


Figure 191: "Highland" Yanomamo Family and Village Local Group

Within a region, the Yanomamo use slash-and-burn to clear gardens every few years, and will then move to a new site allowing a garden to return to long fallow. This pulsing of the rainforest to capture natural stores of ecosystem resources is an important productive strategy for the Yanomamo, on a par with any more recognizable technological innovation.

Social hierarchy among the Yanomamo is minimal, although with gardening there exists the potential for differentially productive families.

The village as a whole produces a few important assets. The most important is the protective wall (shabono) that surrounds the village. At a slightly higher population density (above 1 person per square mile), and with a landscape of differentially "valuable" or productive regions, the Yanomamo occasionally fight to displace or eliminate some of their neighbors. Walls protect villagers against deadly raids. Raiding, in turn, fosters the formation of villages for defense and for alliance in subsequent raiding-parties.

Chiefdoms

Chiefdoms are regional polities with population desities that are characteristically high, about 25 persons per square mile. They exhibit social hierarchy or stratification, which is explained in terms of kinship distance from a chief or chiefly lineage. Differential control of productive resources distinguishes chiefdoms from simpler societies.

Irrigation Agriculture

Complex chiefdoms were often founded on irrigation agriculture, or some other critical economic resource that could potentially be controlled by an elite segment of society. Irrigation is a labor intensive form of agriculture. Irrigation is used with domesticated crops like maize, which were domesticated from successional plants that have more net production and typically produce more biomass. Intensive irrigation systems take the place of natural ecosystems. However, without the work of natural ecosystems for recycling nutrients, for building soil structure, holding soil moisture, etc. the irrigation agriculture system required heavy labor inputs in soil preparation, manuring, erosion control, etc. Even with these efforts, an irrigation agriculture system cannot maintain the resilience that the natural ecosystem has to perturbation or "surprise", and wide-spread collapse would have been a real and devastating possibility (maybe inevitability) that could have followed an insect outbreak, severe storm, or even less dramatic event. Chiefdoms were prone to collapse, and while collapse may have had many proximate causes, perhaps more often than not the ultimate cause was environmental.

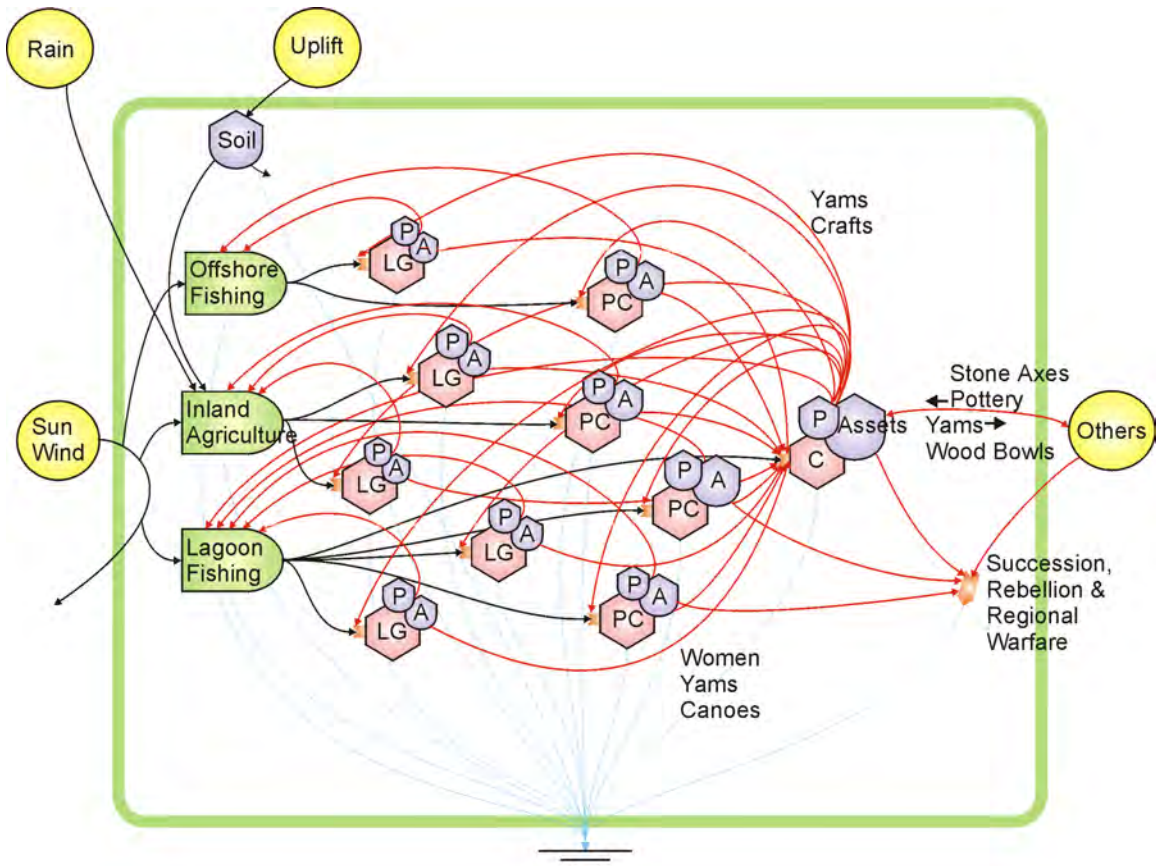


Figure 192: Trobriand Islanders Simple Chiefdom
Chiefdoms may span a variety of environmental niches with local groups (LG) occupying each. Petty Chiefdoms (PC) control perhaps the superior zones, with the paramount chief's (C) local group in control of the best terrain. Each local group has storages of people (P) and assets (A).

Plants and Animals

Natural ecosystems would have remained interstitially or on the fringes of large irrigation agriculture systems. They would have been important for seed sources when fields were left fallow. They would have supplied hard woods for tools and construction.

And they would have supported wild game. However, due to the productivity of irrigation agriculture for producing human foodstuffs, natural ecosystems would have been selected against by humans who were using water delivery technologies to intensify production for themselves. With the solar and ecosystem energies going to produce more humans, there would have been an equivalent reduction in other top consumers.

Table 24: Storages of the Trobriand Islanders

	Natural Assets	**Other Assets**	**Human Biomass**	**Assets' Primary Function**
Local Groups	Access to all immediate Local Group resources, but restricted by crowding of other Local Groups	Houses, Storehouses, Canoes, Tools, Pottery (imported) Stone Axes (imported), Symbolic wealth items	100's of People	Intensively grow crops or fish for selves and Chiefs, Build large trading canoes, Contribute wives to Chiefs, Fight warfare with other Local Groups or Chiefdoms
Local Groups w/Petty Chiefs	Same as above, but usually(?) more productive niches supporting larger Local Groups	Same as above, but with large public stores of yams owned by the Petty Chief and used to support canoe building and ceremonies	100's of People	Intensively grow crops or fish for selves and Chief, Finance Local Group to build large trading canoes, Build canoes, Contribute wives to Chief, Fight warfare with other Local Groups or Chiefdoms
Local Groups w/Chief	Same as above	Same as above, but with larger stores of yams for canoes and ceremonies Also large stores of crafts made by Chief's wives	100's of People	Intensively grow crops or fish for selves, Finance Local Groups with yams and crafts from Chief's wives to build large trading canoes, Build canoes, Fight warfare with other Local Groups or Chiefdoms for conquest, succession, rebellion

Lineages

With the emergence of storable foods, privately owned fields, warfare, external trade, and managed water networks there developed the potential for permanent social inequality or hierarchy to appear (or maybe better said, social hierarchy emerged synergistically with storable foods, private farms, irrigation, population stress, etc.). Lineages formed social groups of kin who cooperated in the control of land or water resources. These groups are depicted here forming hierarchy within a chiefdom in terms of their differential ability to control valuable resources. Food storages generally came under the control of a (petty) chiefly lineage, which might use both service and ritual to maintain their position at the apex of a petty chiefdom social hierarchy. Ritualized redistribution of stored foodstuffs was often used to reward industrious service to the chiefdom.

Social Hierarchy

Social hierarchy was further elaborated in complex chiefdoms, in which a single region would contain several competing and cooperating petty chiefdoms that recognized one chiefdom as the paramount chiefly lineage. The paramount chiefly lineage customarily controls a vast store of foodstuffs, to which each of the petty chiefdoms contribute. This paramount chief conducts regional ritual services in elaborate redistribution events. Complex chiefdoms are known to have produced the first known monumental architecture, which was often in the form of raised ritual platforms with elaborate storage areas for foodstuffs. These would have been the sites of rituals which would have reinforced the roles and positions of chiefs and their lineages.

Redistribution

Irrigation agriculture generally produces foods that can be stored for long periods, distributing the risks of food shortage among a large population. The ritual redistribution of food storages is a critical leverage of chief power. Legitimized by Cultural models, chiefs may reward or punish lineages that support his/her demands for labor or warriors.

Archaic States

Archaic States exhibit the first appearance of a hereditary sub-group of elites, which is not responsible for its own production of food and goods. You will see in the Inka aggregate diagram that there is not a direct line from natural production (plants and animals) to this elite group. Compare this with Chiefdoms, in which even the village of the paramount chief was responsible for its own production of basic goods.

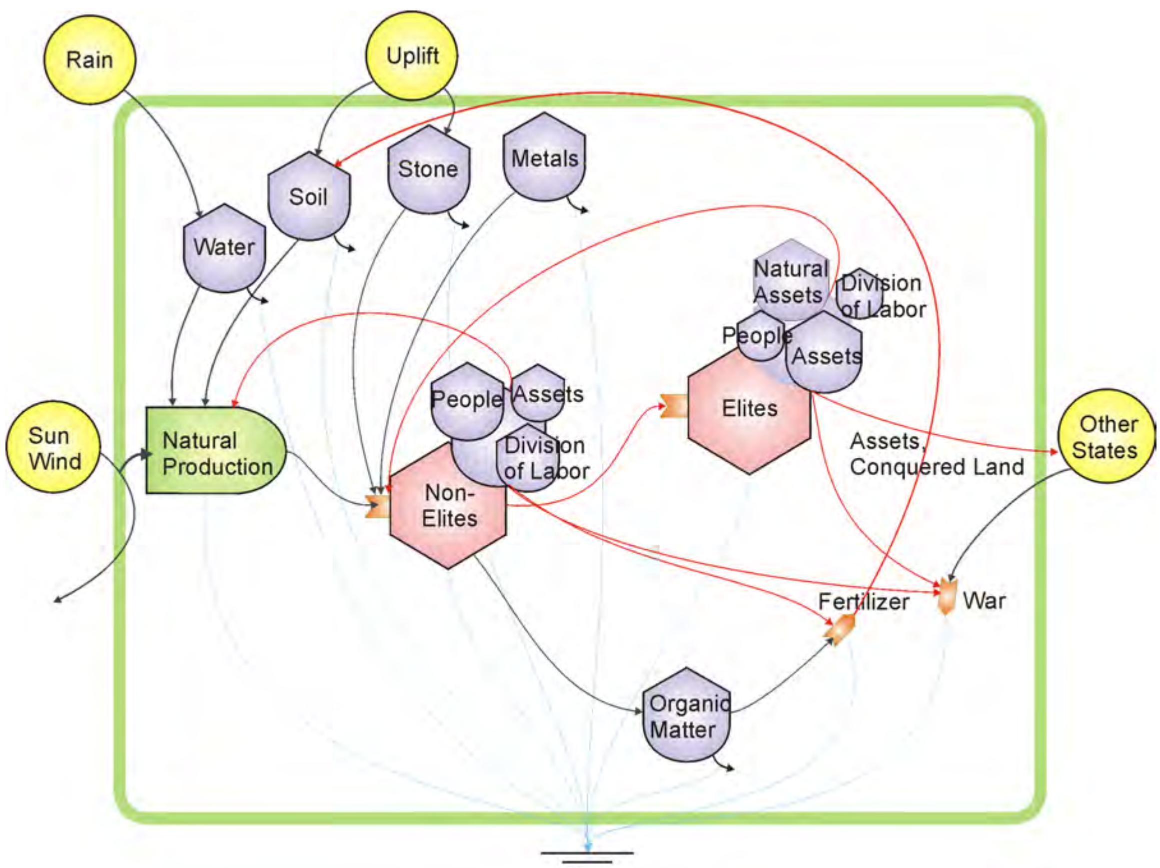


Figure 193: Archaic State

Case Study: Inka Empire (1463-1532)

Archaic States like the Inka have a hereditary sub-group of Elites, which is not responsible for its own production of basic goods. The Elites are supported by "staple taxes" of goods from Non-Elites, consisting of food and goods. You can see that there is not a direct flow from Natural Production to Elites, but instead Elites rely on the harvesting and manufacture of natural goods by Non-Elites. Elites capture these goods via feedbacks of services (financing public works) and coercion. In the drawing, production by the Non-Elites is split, with some building storages for the use of Non-Elites, but with much going directly to Elite storehouses.

Table 25: Storages of Inka Empire

	Division of Labor / Diversity	Natural Assets	Other Assets	Human Biomass
Non-Elites	Medium, Irrigation Farmers w/ Archipelago Strategies, Emerging Specialist Groups	Small Landholdings (Taxed for in Staple Goods), Llamas, Alpacas, Crops	Tools, Food Storages, Food Houses, Crafts	11 million people
Elites	Specialized bureaucrats, Religious, Military, and Ruling royalty	Land/Soil, Mines, Water storages	Irrigation systems, Roads, Monuments, Palaces & Walls Storehouses, Weapons, Crops, Crafts	100's-1000's of people

While the majority of the population is engaged in food production (as in chiefdoms), states are the first social forms that exhibit marked specialization among Non-Elite producers, referred to in this drawing by the tank for Division of Labor. There is also specialization among the bureaucracy of Elites, and they too have a Division of Labor tank.

Inka Elites control valuable, concentrated assets. Elites have rights to all mines, to land allocation, to irrigation systems, to roads, palaces, storehouses, food, weapons, and others. They use the staple taxes of the Non-Elites to finance large projects that intensify the production of these assets and enhance their control over production.

Archaic states possess the first large, standing armies of military specialists. Elites use taxes to finance standing armies, which can be used for coercion within the state, for defense of elite privilege and private property, and for the expansion of the state.

Inka Elites

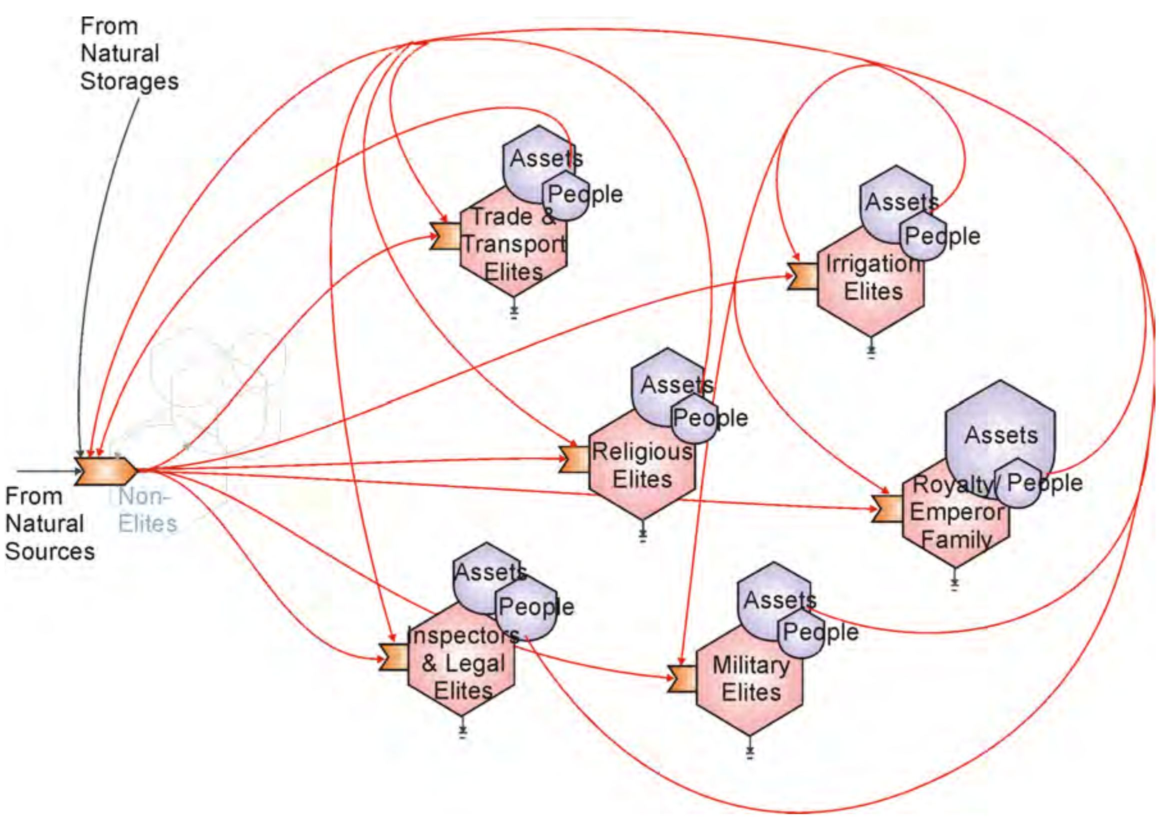


Figure 194: Inka Elites

Some comments can be made about the larger assets controlled by Elites. Fortresses, palaces, city walls, can usefully be viewed as technologies. We commonly perceive a fortress to be the living quarters for elites. However, just as a plow or machine is understood to be a tool used by people to intensify production or physical motive power, a fortress is first of all a technology for surviving military sieges. Similarly a road is a common object that can better be recognized as a technological innovation for moving bulk goods, including soldiers. Another important large-scale technological innovation is an irrigation network. Each of these technologies was evolved to great success among the Inkas.

Table 26: Storage of Inka Elites

	Natural Assets	**Other Assets**	**Human Biomass**	**Assets' Primary Function**
Royalty / Emperor Family	Land, Quarries, Mines,	Palaces, Walls, Food Storehouses, Quarries, Mines,	1-10's of people	Maintain / Re-create Roles and Responsibilities in System of Elites
Irrigation Elites	Land/Soil, Cut Stone	Irrigation Systems, Land Projects, Terraces, Water systems	10's of people	Maintain / Re-create Farm Communities & Farm Production System
Military Elites	Conquered Lands	Fortresses, Weapons, Armor	10's of people	Maintain / Re-create Property Rights, Capture & Defend Resources
Trade & Transport Elites	Land, Ports	Roads, Bridges	10's of people	Move Goods From/To Non-Elites
Religious Elites	Land	Monumental Architecture, Shrines	10's of people	Maintain / Re-create Worldviews
Legal Elites	Land	Land Surveys, Land Records, Courts, Storage Houses	10's of people	Maintain / Re-create Property Rights & Tax Obligations

Inka Non-Elites

With Archaic States there emerged specialized, Non-Elite producers. Among the Inka, these were separate communities that were established and supported by the Inka. For example, craft/pottery specialists were physically located within the capital city of Cuzco, and supported entirely by stores of food collected by Elites as taxes. Other specialized occupations were metallurgists, stonemasons, soldiers, and some domestic servants.

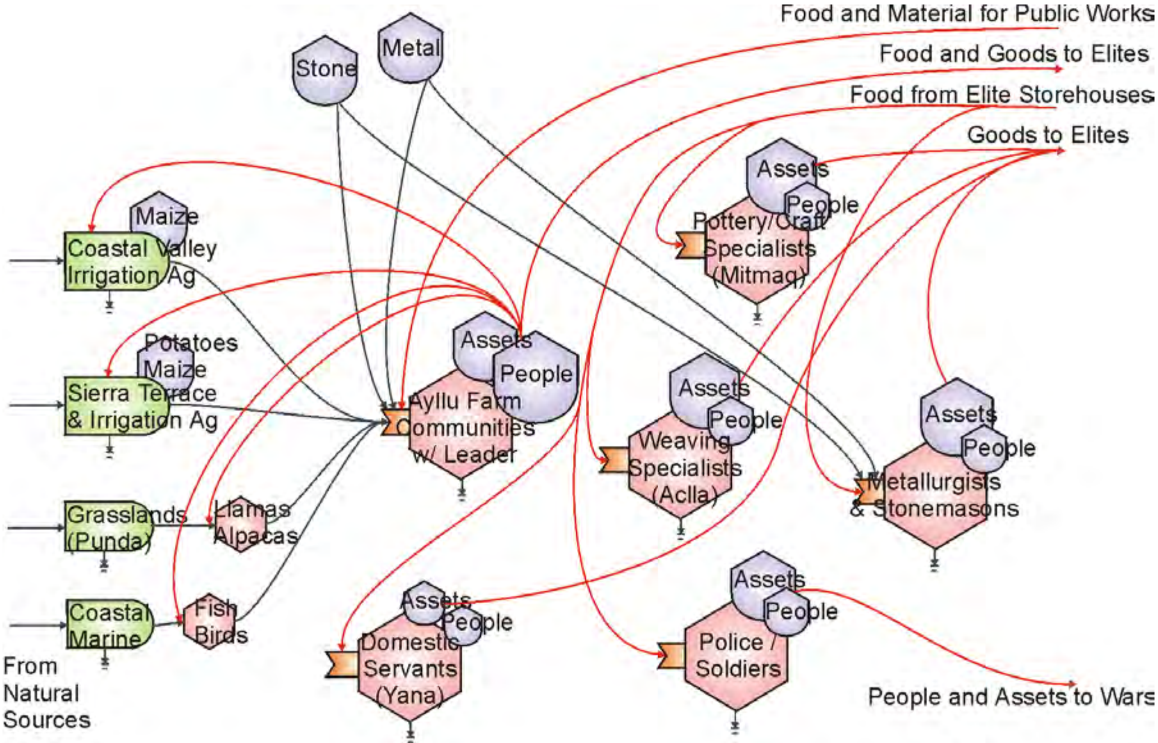


Figure 195: Inka Non-Elites

Table 27: Storages of Inka Non-Elites

	Natural Assets	Other Assets	Human Biomass	Assets' Primary Feedback Function
Farm Communities w/ Leader	Land (in Archipelago), Llama & Alpacas, Firewood,	Tools, Storehouses, Houses	11 million people	Intensively Grow Crops, Build Public Works

	Natural Assets	Other Assets	Human Biomass	Assets' Primary Feedback Function
(Ayllu)	Crops/Seeds, Fodder, Fertilizer			and Land Reclamation Projects, Mine Metals
Weaving Specialists (Aclla)	Little or no land (resettled people on Inka land), Raw Materials	Goods (cloth), Storehouses, Facilities, Tools	1000's of people	Produce Cloth and Garments for Elites
Pottery/Craft Specialists (Mitmaq)	Little or no land (resettled people on Inka land), Raw Materials	Goods (pottery) Storehouses, Facilities, Tools	1000's of people	Produce Pottery and Wood Products for Elites
Metallurgists & Stonemasons	Little or no land (resettled people on Inka land), Raw Materials. Transport Animals (Llamas)	Goods, Storehouses, Facilities, Tools	1000's of people	Cut stone, Build Walls, and Irrigation Works, Make Metal Goods for Elites
Police / Soldiers	Land, Conquered Land	Weapons, Armor, Living Facilities	1000's of people	Enforce Property Laws, Conquest and Defence
Domestic Servants (Yana)	Little or no land	Houses, Tools	100's of people	Work for Elites

Modern States and World Systems

With the emergence of World Systems, the organization of production has extended its boundaries outside of political state boundaries. Multinational corporations and international lending agencies are very visible examples of extra-national entities, however, world systems have a long history that began with expansive archaic state systems, and flourished with colonialism.

Wallerstein defines a World System in political-economic terms:

> …as one in which there is extensive division of labor. This division is not merely functional--that is, occupational--but geographical. That is to say, the range of economic tasks is not evenly distributed throughout the world-system. In part this is the consequence of ecological considerations, to be sure. But for the most part, it is a function of the social organization of work, one which magnifies and legitimizes the

> ability of some groups within the system to exploit the labor of others, that is, to receive a larger share of the surplus (Wallerstein 1974:349).

Since Wallerstein's original writing, others have adopted the concept in their own writings (Sanderson 1995). For the discussion that follows I will emphasize the geographical characteristic of world systems, and attempt to place the concept in systems ecological terms.

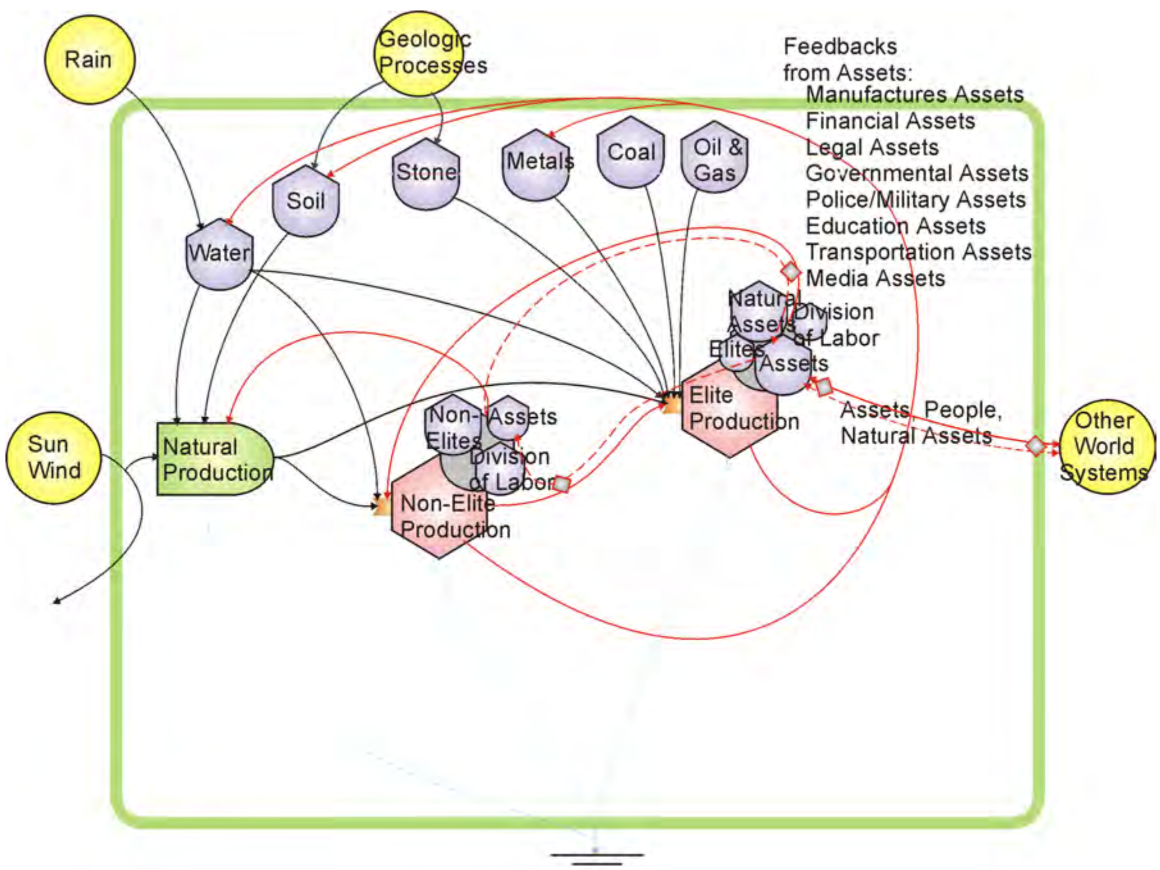


Figure 196: A World System
This diagram design is adapted for Bonaire in Figure 95.

A World System is a social arrangement of people and nations that forms a system with a core and a periphery. Core and periphery have been defined in various ways. I would define them as follows. The core is a region or nation with an advantage in production technologies and assets, which is surrounded by a periphery that supplies primary commodities (raw materials, i.e., oil, coal, iron ore, etc.) to the core.

This pattern appears within large states, and is extended beyond the borders of large states to capture the primary production of smaller and weaker nations. Early World Systems emerged via mercantile colonialism with cores in Holland, then Spain, and then England (CHAPTER 3). However, in more recent years as direct colonialism has disappeared, the fundamental means of world systems formation has been via advantages in economic / legal / financial assets that are mostly located in the core, and that are defended by military specialists, also located and supported by the core.

World Systems today might be the US and its periphery (the Americas, Middle East, some African states, others), the EEC and its periphery (Africa, Middle East, India, now much of Eastern Europe, Australia, Indonesia), Japan and its periphery (Micronesia, Malaysia, S. Korea, Australia, the Philippines, the Middle East), China and its periphery (North Korea, Mongolia, India, the Indochina Peninsula, the Middle East) (Figure 202). Until the 1980s, the Soviet Union represented the second major world system of Russia and its periphery (Eastern Europe, its internal periphery of Siberia, and other states, Afghanistan, others). The fate of the Soviet political world system remains to be seen, but considering the fact of contracting world resources it is most likely that further disintegration will occur there, and within other world systems that are organized around political nation states. For example, the US political system is currently decentralizing itself, abdicating control and responsibility for public works to state governments, who have less of a resource base to manage them. At the same time, however, the extra-national world economic / legal / financial systems are becoming increasingly hierarchical, with greater concentration of the remaining world assets among powerful elites. This pattern is defended in the name of "efficiency", but it is better characterized as the perpetuation of the system processes of rapid capture and use of world productive assets. This emerging structure is less responsive to the political demands of world populations of non-elites. In ecosystems, this pattern of rapid net production (of biomass) is usually associated with early succession, but is not sustained as an ecosystem self-organizes to make full use of available resources. Whether the near future will tend toward increasing hierarchicalization, or toward decentralization is impossible to predict. The long-term future however will move toward decentralization as the resource base that supports it (primarily fossil fuel) flattens out and contracts.

Table 28: Storages of a World System

	Division of Labor / Diversity	**Natural Assets**	**Other Assets**	**Human Biomass**
Non-Elites	Very High, Thousands of specializations and significantly unique economic strategies	Little or none, Small land holding	House, Car, Household goods, Stocks, Savings	6 Billion People
Elites	Medium, Specialized Financial Elites, Industry and Agriculture Elites, Legal Elites, Government Elites, Military/Police Elites, Education, Transportation and Media Elites	Agriculture Land, Waterways, Fossil Fuels, Minerals, Raw Materials, National Lands and Waters, Forests, Mining	Factories, Buildings, Equipment, Roads, Shipping, Bases, Communication, Weapons, etc.	100,000's of people

Modern State and World System Elites

Over time, elite merchants in archaic states were superceded by financial elites and transportation elites in modern states. Monarchies have gradually fallen, to be replaced by a new class of political and military elites. New technologies have co-evolved with industry elites, media elites, education elites, and legal elites.

Contemporary states are in fact the most specialized and hierarchical that the world has ever seen.

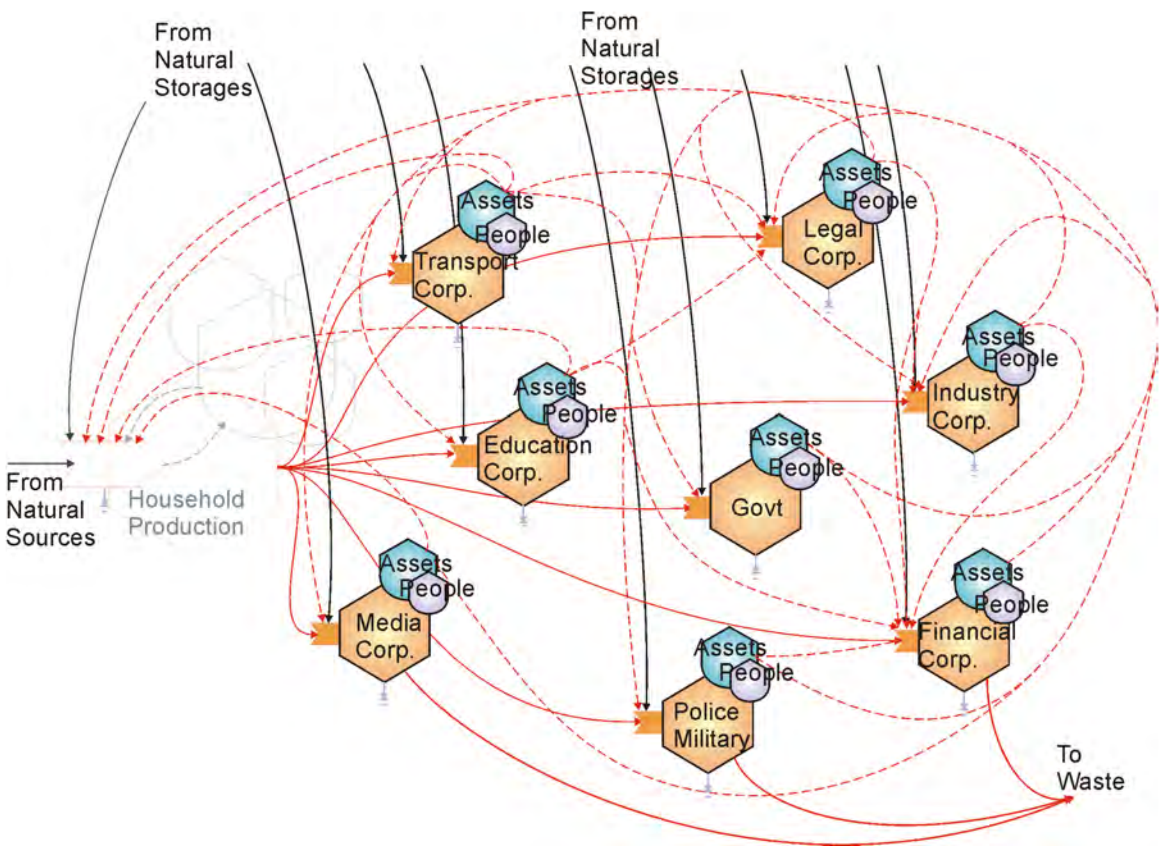


Figure 197: World System Elite Corporate Production
There are no world system elites on Bonaire. This structure can be invisioned for the Core countries in Figure 94, Figure 95, Figure 96, Figure 133, and Figure 134. Dotted lines here were intended to represent flows of goods and services combined with a counter-current of money. This convention was abandoned elsewhere for the customary approach of a goods and services flow and a separate counter-flow of money.

Industry Elites.

Productive technologies are vital to human groups, from foragers to modern states. They are defined here as the techniques for producing the food, goods and services (excepting military) that people use. This information is learned and must be transferred from generation to generation. It may be shared by all culture members. However, as cultures become more structurally complex, that information may be controlled by subgroups, indeed it may define those groups (as knowledge for smelting metals has been controlled by specialist lineages who achieved power and prestige by way of that skill, or as disciplines like medicine or law or graduate studies jealously defend access to special training). Productive technologies have great resilience to disturbance, and should be expected to be long-lived (as stone flaking techniques, farming strategies, or engineering technologies have had long continuous histories).

Table 29: Storages of World System Elites

	Natural Assets	**Other Assets**	**Human Biomass**	**Assets' Primary Function**
Financial Elite	Land (Banks)	Banks, Electronic Storage and Transfer, Lending Agencies, Insurance Agencies	xx People	Maintain / Create the Financial Technologies for the Ownership and Transfer of Private Properties
Industry & Agriculture Elite	Fossil Fuels, Raw Materials, Agricultural Land	Factories, Machinery,	xx People	Maintain / Create the Agriculture and Industry Production Systems
Legal Elite	Land (Courts)	Courthouses, Deeds, Laws, Databases, Repositories	xx People	Maintain / Create Property Rights & Tax Obligations, Settle Property Claims, Punish Violence within the State
Government Elite	National Lands and Waters, Forests, Mining	Public Utilities, Govt Buildings	xx People	Maintain / Create Policies that Intensify Production, incl., Allocate Natural Resources to Industry, Provide Public Utilities, Roads
Police / Military Elite	Land (Bases)	Bases/Stations, Weapons, Jails	xx People	Monopolize Force, Defend/Capture Markets & Natural Resources, Defend Property Rights
Education Elite	Land (Schools)	Schools, Books, Faculty	xx People	Maintain / Create / Justify Social Hierarchy, Control Access to Specialized Skills and Statuses, Transmit Specialized Skills

	Natural Assets	Other Assets	Human Biomass	Assets' Primary Function
Transportation Elite	Land (Roads)	Roads, Vehicles, Storage & Distribution Facilities	xx People	Maintain / Create Transportation Networks & Transport Vehicles (Supertankers, Airlines, etc.)
Media Elite	Land (Studios)	Radio & TV Stations, Film Studios	xx People	Intensify Consumption / Production of Goods, Structure Public Opinion

Military Elites

Police/military technologies have been distinguished from other technologies as a separate category because of the uniqueness of their purpose. These technologies have the special purpose of coercion or force, which has had an important role in the evolution of cultural forms. Military technologies were probably important for spacing of forager groups. With chiefdoms and states, military technologies became a means of increasing access to the basic resources of production, land (sunlight, soil, water) and later fossil fuels and metals. Besides the obvious use of force between groups, military/police technologies have played important roles within societies in relation to all the other cultural storages defined here. The threat of force or sanction, in terms of legal codes backed up by force, maintains the structure of social hierarchy. Financial codes (backed up by force) have made markets and trade networks possible. And private property (backed up by force) has lead to the concentration of capital resources in the hands of a few (which is part of the definition of social hierarchy, and which has spurred growth when it was energetically possible, but has lead to abuses in times of resource stagnation or contraction).

World System Non-Elites

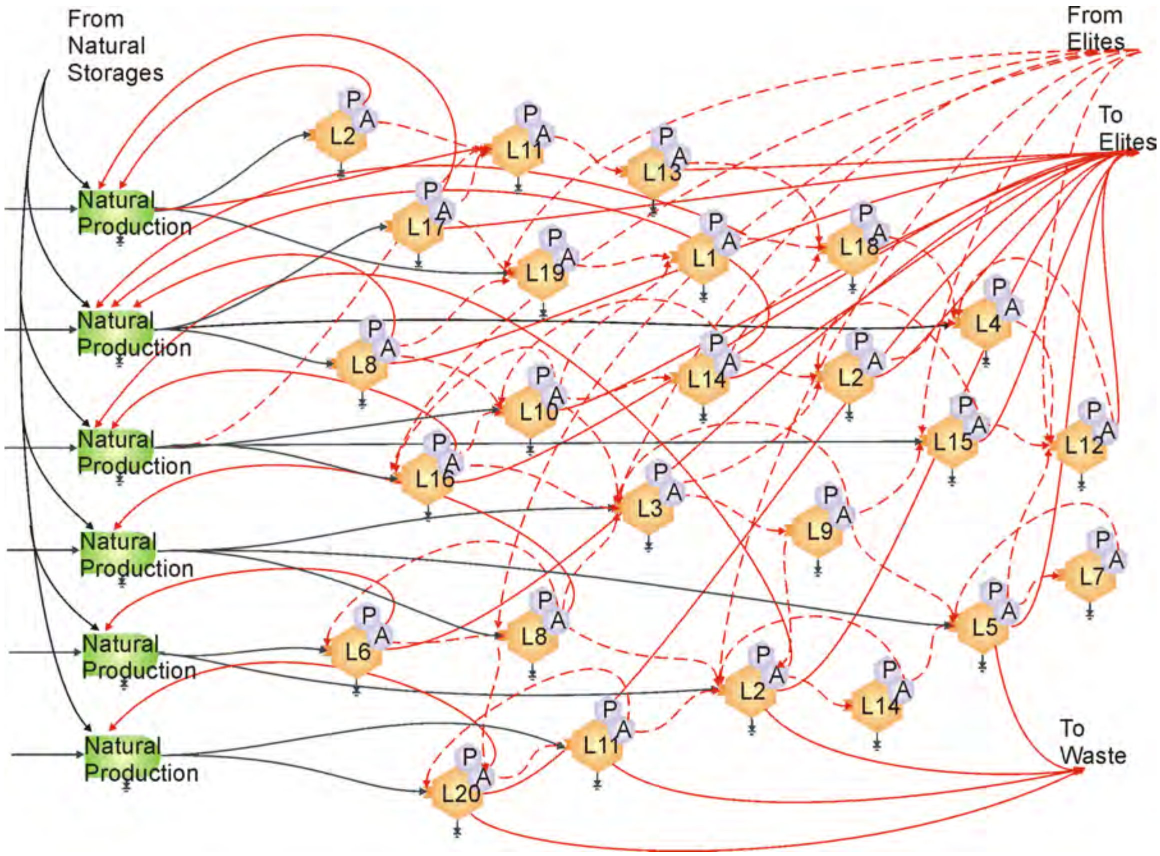


Figure 198: World System Non-Elite Occupational Groups
This diagram design of diversified and specialized non-elite labor is used widely in the preceding Bonaire case study, Figure 104, Figure 108, Figure 110, Figure 135, Figure 178, Figure 179, Figure 180, and Figure 181, and compare with the Inka case in Figure 195.

Table 30: Storages of World System Non-Elites

	Division of Labor / Diversity	Natural Assets	Other Assets	Human Biomass
Non-Elites, Wage Laborers	Thousands of specializations and significantly unique economic strategies	Little or none, Small land-holding	House, Car, Household goods, Stocks, Savings	6 Billion People

State and World System Summary

Social Structural Hierarchy

Social structural hierarchy is represented in Figure 196 by the two separate consumers (Non-Elites and Elites), and by the Division of Labor storages. Non-Elites and Elites are distinguished mainly by their differential control over resources or assets that are used in production. Elites own or control the capital and natural assets that are essential to production processes. Individual non-elites are understood to control some assets. However, by current assessments ((U.S. Congress 1986), (Rothchild 1995)), the super-elites (0.5% of US households) own 40% of the America's wealth. The elite 10% owns around 75% of the nation's wealth. If these numbers were modified to recognize the important energetic contribution of natural resources to production, these numbers might be even more extreme, considering the vast Natural Assets of forests and waterways and mineral and fuel deposits that are controlled by government and corporate elites.

Division of Labor

Division of labor is described further in the two detail diagrams for Non-Elites and Elites. Here division of labor (in two parts) is represented by a storage symbol, following the method of representing ecosystem diversity as a storage. Generally stated, division of labor and social structural hierarchy have increased when the use of energetic resources have increased. Division of Labor and Social Structural Hierarchy have several dimensions.

(1) Following an ecosystems design example, it can be said that greater hierarchical position is equated with greater control over resources and system processes (more control means higher position in the hierarchy), (2) Also as with ecosystems, with increasing hierarchy there is a smaller number of individuals (corporate groups), (3) As in ecosystems, with increasing hierarchy there are longer

turnover times (for corporate groups) (i.e., lineages or corporations that last for generations), and (4) With greater total energetic resources there is a greater division of labor (greater niche complexification).

Assets

Assets are the material products of human production. They are physical storages with varying turnover times, and diverse functions. Some assets feed back into the production of other assets. Others provide the shelter or transportation used by people. One type of assets storage, which has historically been very important in the creation of structural hierarchy, is the storage of food. Control of food storages was important among chiefdoms and early states, and remains today a final instrument of coercion or control that can be used within states and world systems. As social hierarchy increases with chiefdoms and states, the discrepancy becomes tremendous between the assets controlled by labor and those controlled by elites. Indeed, this becomes the defining characteristic in the social hierarchy. In particular, elites come to control the Natural Assets that are the energy sources for production, the limiting and essential ingredients of the productive system.

People

Finally, the last important human/cultural storage is the storage of people themselves. In plants, wood is a storage of organic matter that makes possible the processing of sunlight into more organic matter while dissipating energy as unusable heat. With animals, their physical biomass (organized by evolution within ecosystems, and replicated by genetic information) is again a storage of structured organic matter that processes other organic matter into useful work and dissipated heat, feeding-back important controls in the ecosystem structure. The storage of human biomass does the same.

Simply stated, the larger this human storage gets, the more energy needed to maintain it. As ecosystem (or biosphere) energies pulse and begin to contract, there is stress on this storage of people to shrink with them. As energetic resources contract, humans are in the unique position of being able to modify the production process to increase efficiency and to consume other stored assets. This short-term solution may stave off famine for some time while alternative energy sources are sought, or while population size decreases more gradually (non-catastrophically). Current world systems are in a precarious situation with the growth of fossil fuel use slowing down. This means that the storage of people (world population density) will be forced to slow its growth, and eventually contract in this century, as world fuel reserves contract. Currently the world population growth rate is slowing (Figure 214). The important question now is whether human-cultural systems will contract catastrophically, or whether there will be a "prosperous way down" (Odum and Odum 2000). Of special interest for this drawing, it can be noted that the People storage for Non-Elites is much larger than the people storage for Elites.

Storages and Pulsing

In dissipative structures theory, when an energy gradient exists between a storage and a sink, or between a source and a sink, self-organization will occur which has the effect of hastening the dissipation of energy. The process is creative and has lead to the evolution of life on earth. The process of self-organization is inherent in the thermodynamics of inorganic and organic matter and energy. Some complexity researchers, like Jeffrey Wicken, have argued that the emergence of life on earth is a result of this inherently creative process. The biosphere is charged by the energy gradient between our sun and the earth's surface, and between earth deep heat and the surface. Solar and deep heat energy have lead to the emergence of complex ecosystems, which capture, use, and dissipate energy.

Self-organization often leads to pulsing patterns that have been called chaotic, but which are better seen as the building of energetic storages followed by their autocatalytic consumption and dissipation. One example is a fire-controlled ecosystem that builds up biomass, and is then swept by fire, releasing nutrients and reseeding the forest. Another is the pulsing consumption of vegetation by locus. Another is the pulsing consumption of solar energy stored in oceans by the formation of hurricanes. It is expected that this pulsing pattern would also be observed with the storages that are important to the evolution of culture, discussed above. It is well known that horticulturists who use slash-and-burn planting will occupy an area only long enough to consume the storages of nutrients that have gradually built up and then move on.

On a larger scale, chiefdoms and states rose and collapsed between the environmental storages of soil and wood and water built by natural ecosystems, and stone raised by uplift. As expansionary states cleared forests and intensively grew domesticated crops, they tapped storages that synergistically lead to human-natural systems with storages of assets, structural diversity, more complex military and productive technologies and, above all, more people. Some specific functional relationships between storages are discussed in the other (detail) pages. However, it can be said in summary that with time these human-culture systems were simultaneously exhausting storages of topsoil, wood, etc., which eventually would lead to the collapse of the existing self-organized chiefdom or state.

On a much larger scale, modern states and world systems have been pulsing the storages of fossil fuels that were built over millennia. Human productive technologies have made it possible to access this energy gradient, and the self-organization that has resulted has been remarkably creative, unpredictable from the start, but understandable after the fact. The consumption of fossil fuel storages have lead synergistically to the creation of storages of assets, people, structural diversity, military technologies, and more productive technologies. Again, some functional interrelationships are described in the detail drawings. These storages all interact with each other and with other environmental storages in the self-organization of natural and cultural systems in the dissipation of energy.

Initial Conditions, Competition for Resources, and the Self-Organization of World Systems

US-Americas Cold War System

As discussed in the Modern States and World Systems section, a World System is here defined as a core of production technologies and assets, which is surrounded by a periphery of primary commodity producers. This pattern appears within large states (the US has internal peripheries of certain states that produce primary goods), and is extended beyond the borders of large states to capture the primary production of "third world" nations. World Systems first emerged with mercantile colonialism, but its fundamental structure has been perpetuated by the economic / legal / financial technologies that are mostly located in the core, and that are defended by military specialists, also located and supported by the core.

Figure 199 is a diagram that depicts the US-Americas Cold War World System. During the Cold War era there was plentiful fossil fuel to support the emergence of a number of large and internally well-integrated world systems (Figure 200). In the US-Americas system in Figure 199 you can see five geographical regions organized into a world system.

Each region has its own renewable and non-renewable energy source. Each region has a production symbol representing plant and animal production. And each region has an aggregated, consumer symbol of people and culture. In Figure 199, some of the regions have additional people/culture symbols, which represent additional social hierarchy of elites who concentrate and control highly productive cultural assets. This general design was employed to depict the position of Bonaire within a world system in Figure 94.

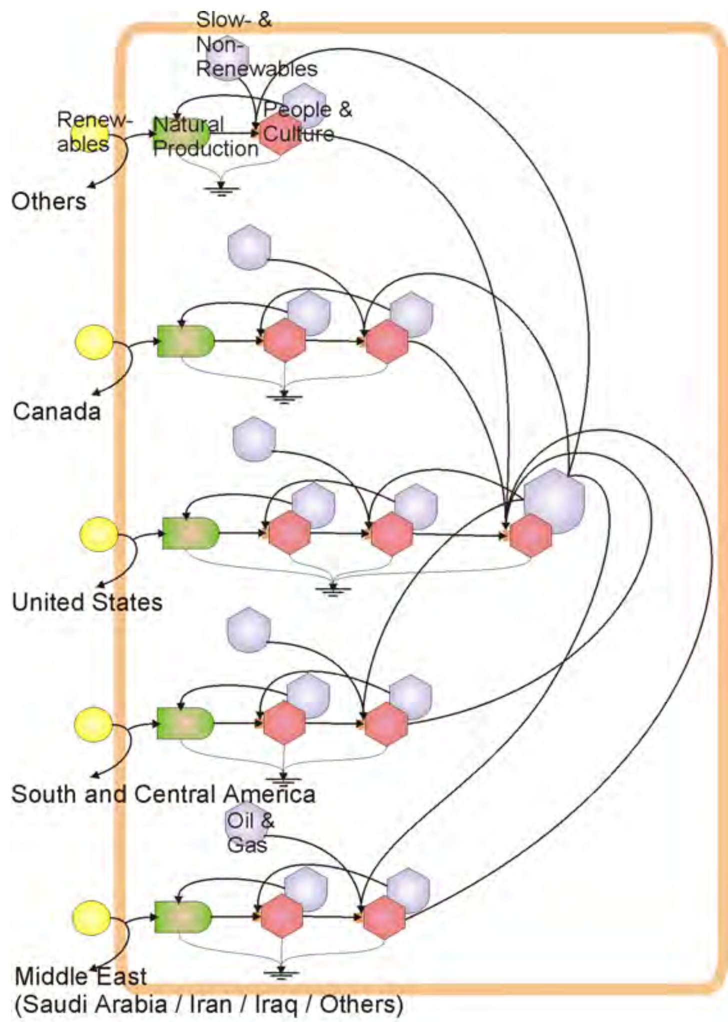


Figure 199: US-Americas Cold War System
The system oversteps national boundaries, and ties nations together via the exchange of high-emergy primary commodities moving to the core (US), and secondary commodities moving to the periphery. See Figure 94 for a similar diagram that includes Bonaire.

In Figure 199, between each of the geographical regions there is exchange of people, assets, technologies, and ideas. In the US-Americas System, the United States has gained an added structural hierarchy of elites who control valuable productive cultural assets. It is understood that this ascendancy of one region over others can occur for many reasons, and that its perpetuation is dependent on available renewable and non-renewable resources and the technologies to use them.

With this system design, it is only necessary for one region to possess a small initial advantage, after which autocatalytic processes will lead to its expansion, and the accompanied "underdevelopment" of the other regions in the system (Figure 201). In the US-Americas system, the US possessed a number of advantages in time and space: proximity to Europe, earlier conquest and settlement by Europeans, natural ecosystems well suited to European-style intensification, large stores of forest wood, metals, coal, oil and gas, and following World War II, the elimination of many of the impediments to its economic expansion into former European peripheries in South and Central America and Canada.

The Cold War World

Figure 200 shows five world systems that existed to varying degrees during the Cold War. Each of these systems can be envisioned, as in Figure 199, to be composed of a core region surrounded by a periphery of primary commodity producers. Not shown are lines of trade connecting the world systems. While trade may or may not have existed between cold war world systems, it was less substantial and it did not have this characteristic asymmetry of manufactured-out, primary commodities-in.

It is important to recognize that not all world regions are parts of these world systems. It takes a great deal of energy to organize and maintain the structure of any world system. Countries or regions can be captured by one and then another world system, or they may be essentially outside of all. The vital region of the Middle East has been unable to form its own system, but has not been exclusively captured by any of the others, and is therefore said to be shared by all.

Different designs are used by each of the systems to maintain their organization. However, as stated above, most today use economic / legal / financial assets that are defended by military specialists. "Lending" of monies to national governments is a common practice that forces participation in world markets, which are controlled by the cores. Another common design is for core corporations to physically locate themselves in foreign countries. The recent rioting against Chinese businesspeople in Indonesia is evidence of this design in the China System.

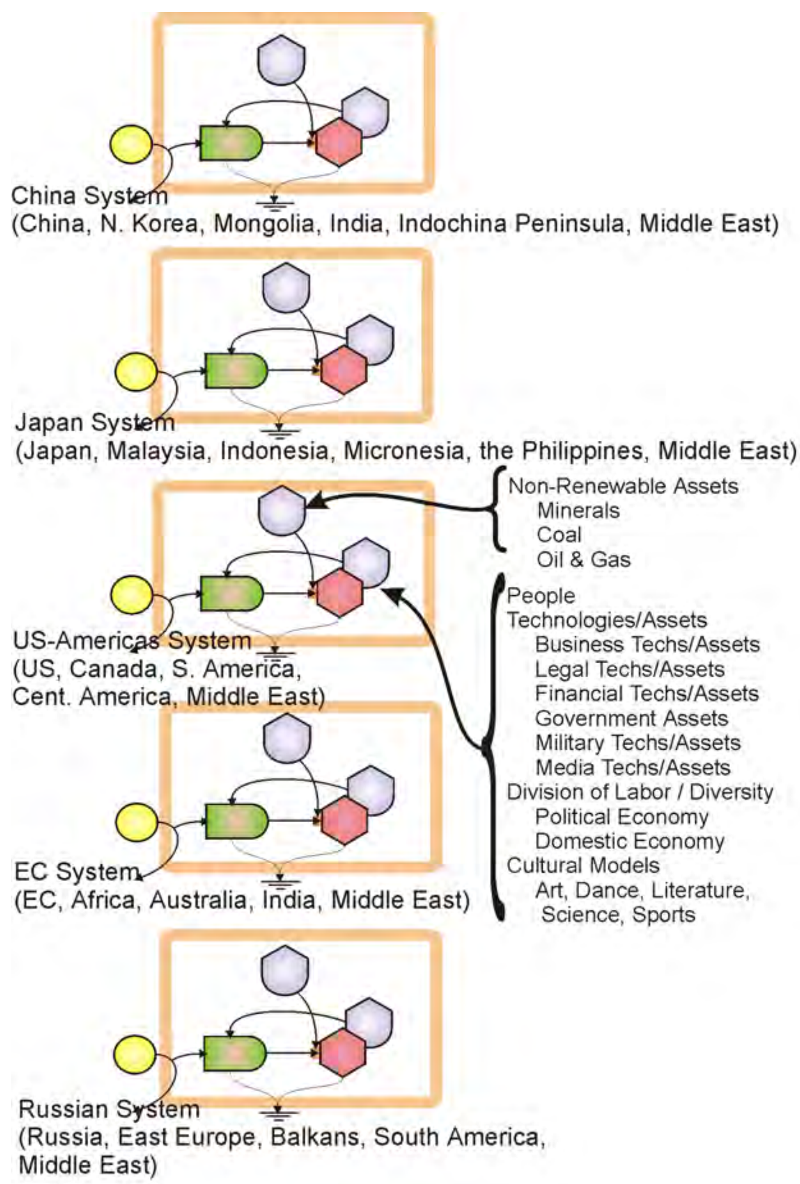


Figure 200: Cold War World
If systems boundaries can be identified by gradients of emergy flow (i.e., far more goods pass within these systems than between them), then perhaps five world systems existed during the Cold War years. In each of these systems, self-organization produced typical

system patterns of hierarchy and feedback. Non-renewable fossil fuels have dominated the inputs to human systems in this century. Note that the US-Americas System in this diagram is an aggregated representation of the larger diagram in Figure 199.

World System Simulation Results

A simple simulation was produced from Figure 199, with some slight modifications. Figure 201 shows a typical simulation run from this design. This run was obtained by "charging" the Non-Renewables in Nation 3 with slightly more initial resources and the Non-Renewables in Nation 2 with slightly more still. This might be equivalent to a small initial advantage in coal assets in one world region over another. The results show a rapid expansion of people and culture in Nation's 2 and 3 and the "underdevelopment" of region 1.

Wallerstein addresses this issue of initial advantage:

> Thus if, at a given moment in time, because of a series of factors at a previous time, one region has a slight edge over another in terms of one key factor, and there is a conjuncture of events which make this slight edge of central importance in terms of determining social action, then the slight edge is converted into a large disparity and the advantage holds even after the conjuncture has passed (Wallerstein 1974:98).

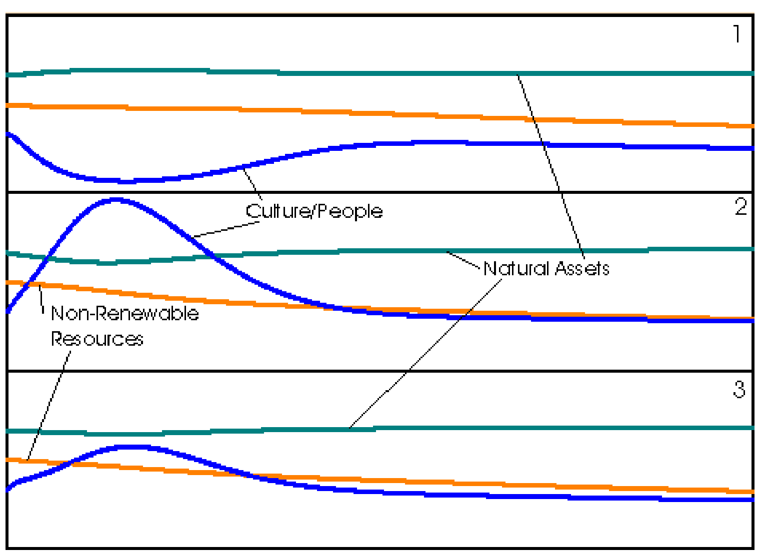


Figure 201: Simulation Run
These three runs represent three nations. Each nation has initial endowments of natural resources and cultural assets. As they come into competition with one another, initial conditions can generate large effects.

Very similar results were generated in other ways. One was to expand (with a positive growth rate) the population size and cultural assets ("People and Culture") in one region relative to another. Another was to initialize the renewable resources with different values for the different regions. The first case might equate to an initial edge in technologies or population. The second might equate to an initial advantage in untapped natural storages, as in the European conquest of the New World. Odum describes the situation well in a section from Systems Ecology entitled “International Trade and World Maximum Power.”

> When a country through balance of money payments causes more embodied energy to flow from an underdeveloped resource area to a developed urban center, the [total] world system may be compelled to maximize power, even if the effect on the country supplying resources is to make it subordinate and with a lower economic standard of living.
>
> When energy levels in the world are sufficiently high, the underdeveloped area cannot break off its balance of payments mechanism and impose trade on an embodied energy principle because the central dominant countries in the world hierarchy have enough feedback power through military, economic sanctions, intellectual influence, and other control mechanisms to maintain the economy as part of the world pattern, even though it subordinates the less developed area. As energies decline, however, and as transportation and military spheres of influence decline, more and more countries can become self-sufficient again, with a higher relative standard of living. Maximization of world power will be done with less centralized hierarchy. (Odum 1983:568)

Current World Systems

With the instability in the Soviet World System, an impediment to further expansion and organization in the west has been diminished. Figure 202 shows how the Japan System, the US-Americas System, and the EC System may be merging into a new larger system.

It is suggested that increasing concentrations of multinational economic / legal / financial / and military assets are making this possible. Multinational corporations, financial institutions (IMF, World Bank), legal bodies (UN International Court of Justice (UNICJ), UN Security Council), and military domination by the US are important components of this new scale of organization.

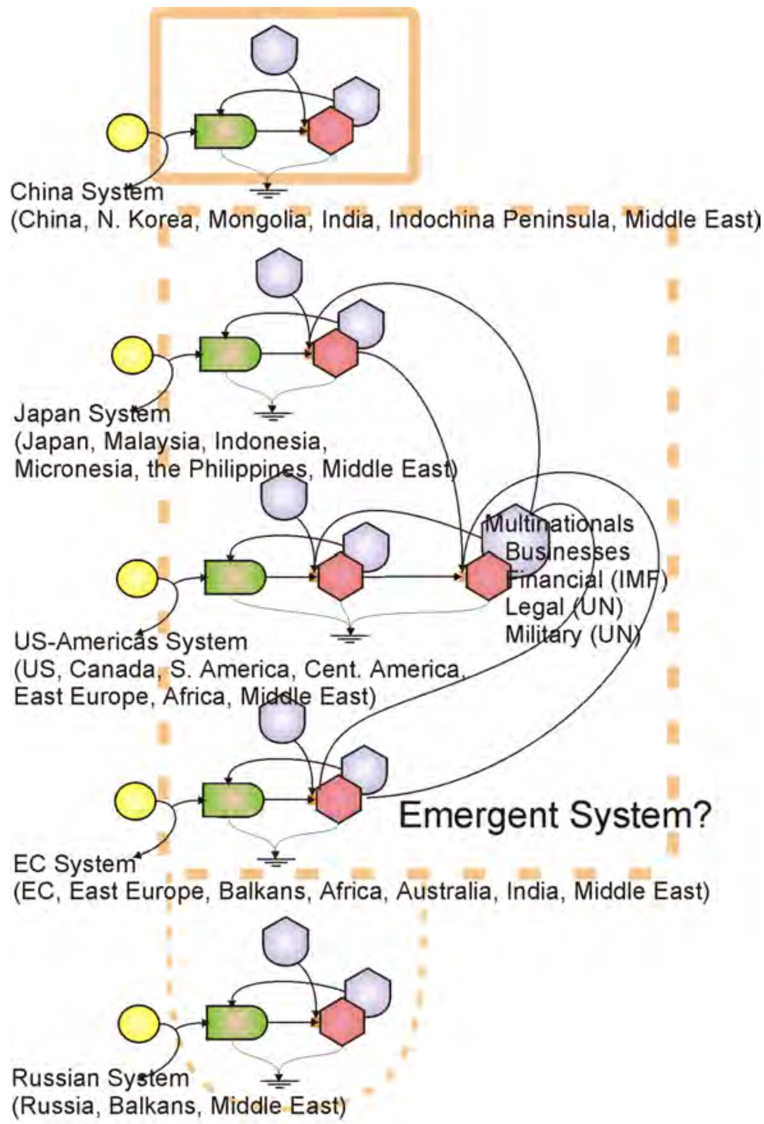


Figure 202: Current World Systems
Following the collapse of the Soviet Union, it might be that the pattern of five Cold War systems is being (temporarily?) replaced by a pattern with fewer, larger, and more hierarchical systems based on the economic model of free market capitalism.

Idealized Future World Systems?

Figure 203 shows one hypothesized future. In this drawing, only three monolithic systems remain. This is the expectation of many world leaders and economists; proponents of worldwide free market economics. Whether or not the reformed Russian system, and even the China system, could stay out of the larger free market system is unclear to those who favor this scenario.

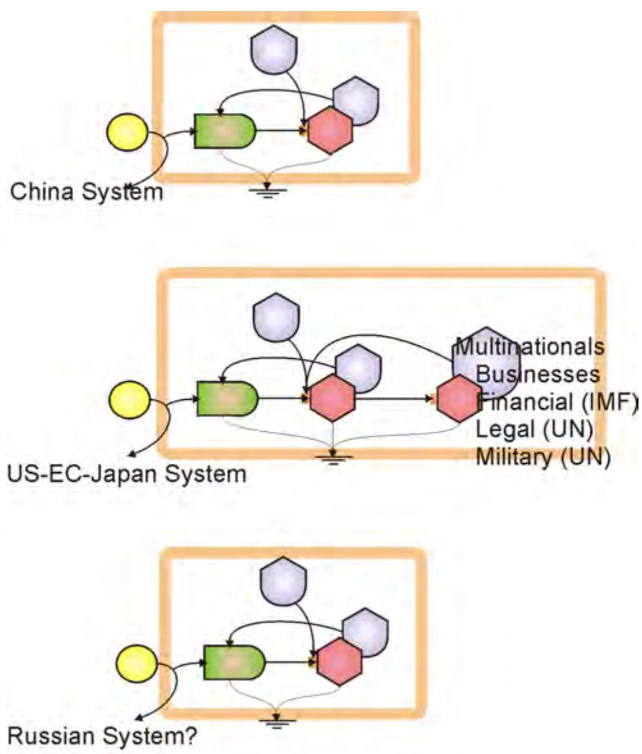


Figure 203: Idealized Future World Systems?
One future might be that continued self-organization will result in one, two, or three world systems, each based on a capitalist free market design. This seems unlikely since the non-renewable fossil fuel energy basis of these systems is contracting and the "growth"-paradigm of market capitalism is therefore unsustainable.

However, general principles of systems designs should be considered. It is proposed that, thermodynamically, systems self-organize as they form dissipative structures (Prigogine and Stengers 1984), or conversely stated, as they maximize empower ((Odum, et al. 1995), (Odum 1996a)). As they self-organize, a great deal of energy and resources may be expended in the production and maintenance of structure. For example, in ecosystems, the maintenance of diversity or structure has a high energy cost, but is repaid by the capture of additional available energies.

In human World Systems, a great deal of energy must also be expended for the maintenance of a system. The creation of the current world systems rode the expanding wave of fossil fuel use. Those resources are finite and will become less available to "fuel" world systems in this new century. Likewise, past world systems used the (then) new technologies of trans-ocean travel, markets, and militaries to gain access to vast storages of renewable energies like wood, topsoil, and salt, and non-renewable metals, and later coal. Those vast storages underwent similar declining returns.

Actual Future?

Figure 204 shows an alternative hypothesized future. As depicted in CHAPTER 17, if the total use of oil and natural gas is peaking, then it is possible that the energy necessary for further world system self-organization will become unavailable. In an alternative future there might be similar attempts to build vast world systems, but with ever-growing regions of the world becoming unarticulated from any of the large systems. These regions would loose access to the major supplies of oil, gas, and coal. They would therefore be unable to support their larger populations. Civil war or smaller conflicts would be a likely result, with battle-lines drawn by a resurgence of racism, ethnicity, or regionalism. New small states might emerge, or even chiefdoms, which would exhibit many of the characteristics of historic chiefdoms.

Are World Economies Already Running on Less?

If one considers measurements such as net emergy yield ((Odum 1983), (Odum 1996a)), or energy return on investment (EROI) (Hall, et al. 1986), then an increasing proportion of the world's energy sources are currently being spent just to capture the remaining storages of energy. In other words, even with increased gross use of world energy, the net available energy/emergy for the rest of the economy is shrinking. One could argue that the current world systems have actually been running on less energy since the 1970s.

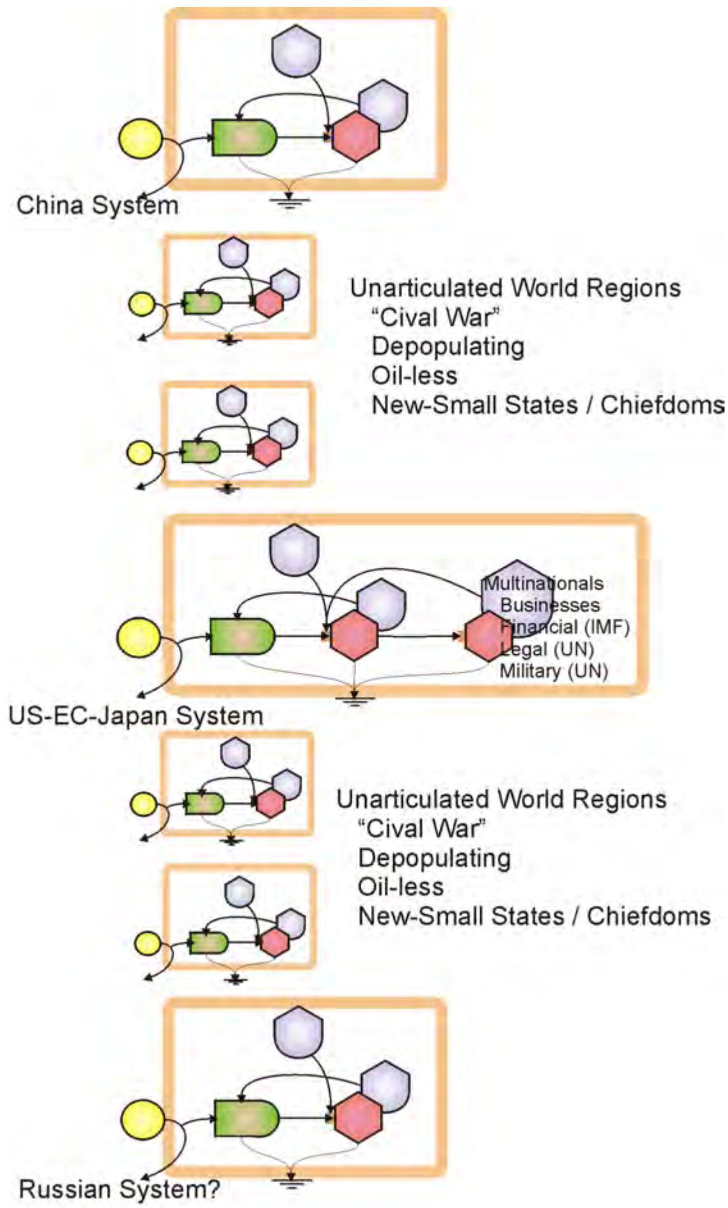


Figure 204: Actual Future?
Instead of one, two, or three dominant capitalist world systems, it seems reasonable that shrinking fossil fuel storages will result in more numerous and smaller systems world-wide.

The collapse of the Soviet Union (and Yugoslovia, and other civil wars in Somalia, Rwanda, Kosovo, etc.) may ultimately be the result of contracting energy sources available to run human economic systems. In this light, the current demand for the "efficiency" of the free market may be another response to living with less.

If that were the case, the current expansion of the US-Americas world system, and possible integration with the EC System and Japan System would appear to be inexplicable. However, these events may be a temporary result of the collapse of the Soviet System, and do not signal a new round of world economic expansion. The Soviet collapse both eliminated a military deterrent to the expansion of the "free market" systems around the world, and it released potential peripheries from the old eastern block states. In that event, a temporary windfall might be expected in the west, followed by a return to the slowing of growth experienced in the 1980s and early 1990s. The slowdowns in Asian markets and in Brazil and elsewhere could be suggestive of world trends to come.

Hierarchy and Convergence in Markets

Permanent *markets* were an important technological innovation in world pre-history and deserve special discussion. Over prehistoric and historic time their value to communities or regions has grown. The technological innovation of *money* amplified their usefulness by permitting transactions extended in time and space. Today world systems are shaped around international market exchange, buttressed by legal, financial, and military technologies.

Spatial convergence is a ubiquitous process in self-organizing systems. Dispersed rainfall is concentrated by landscapes into streams and rivers, which feedback to shape the landscape and provide high quality services to a region (like breeding areas for fish and water sources for large animals). Storms are concentrations of atmospheric moisture and temperature gradients, which deliver water and wind energy in pulses to ecosystems.

In human production systems, from families and local groups to states and world systems, people concentrate dispersed goods and services and feed back high emergy products. If feedback is not sufficient to maintain or amplify production in a system it will not persist. This autocatalytic relationship of concentration and feedback is a general design principal in self-organizing systems.

The emergence of markets in our human past is an occurrence of this process. The early markets in pre-history were agreeable locations for exchange. Exchange means that goods are concentrated into a point in time and space, from which they are then again dispersed. The service that is provided is convergence. Dispersed and diverse goods from an ecologically and temporally diverse countryside are brought together to produce a mix. That mix might supplement shortages in one region with harvests from another, or it might simply produce a more balanced diet. In later market towns, exchange might concentrate the raw goods that a specialist craftsperson or factory would require. Towns are the *products* of this convergence process, the effect and not the cause.

The next four figures support a brief discussion of that process, and examples of the goods and services that historically were converged and fed back.

Early Markets

Early markets appeared in Chiefdoms and small States (Figure 205). They converged goods from perhaps 10's to 100's of kilometers. Markets appeared after significant regional agricultural intensification and specialization had occurred. They were not needed and were not formed by Foragers or Local Group Collectivities.

Table 31: Trade Goods in Early Markets

Converged	Diverged
Regional crops Raw salt Preserved meats, live animals	Balanced Diet Processed foods, requiring dispersed ingredients Craft goods Refined salt

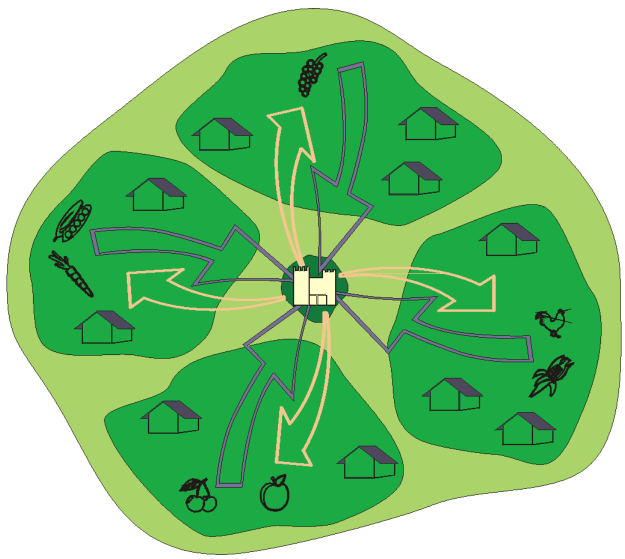


Figure 205: Early Market
This figure depicts the concentration of diverse and dispersed goods to a center of exchange (perhaps defended by a fortress), from which a mix of goods could be dispersed again to the countryside.

Ancient Towns

Ancient towns were supplied by States or regions within States. They converged goods from perhaps 100's of kilometers (Figure 206).

Table 32: Trade Goods in Ancient Towns

Converged	Diverged
Regional crops Lumber Metal Ores Preserved meats, live animals Raw salt	Balanced Diet Processed foods, requiring dispersed ingredients Metal goods and weapons Craft goods Refined salt

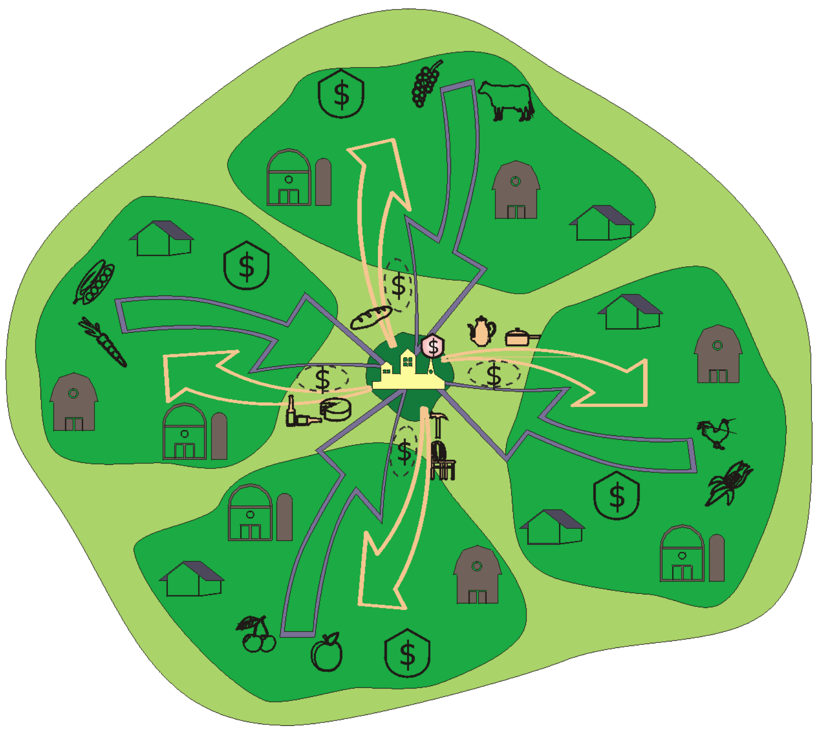


Figure 206: Ancient Towns
Ancient towns used the technology of money to extend transactions in time. As agricultural production intensified, markets encouraged diversification. Ancient towns supported specialists like metalworkers, who required high emergy inputs (metal ores, fuel wood) to produce a service for many.

Factory Towns

Factory towns were supplied by World Systems, States or regions within States.

They converged goods from perhaps 100's to 1000's of kilometers (Figure 207).

Table 33: Trade Goods in Factory Towns

Converged	Diverged
Regional crops Lumber Metal Ores Coal Oil (later) Preserved meats, live animals Raw salt	Balanced Diet Processed foods, requiring dispersed ingredients Metal goods and weapons Manufactured goods Transport vehicles Wooden goods Refined salt

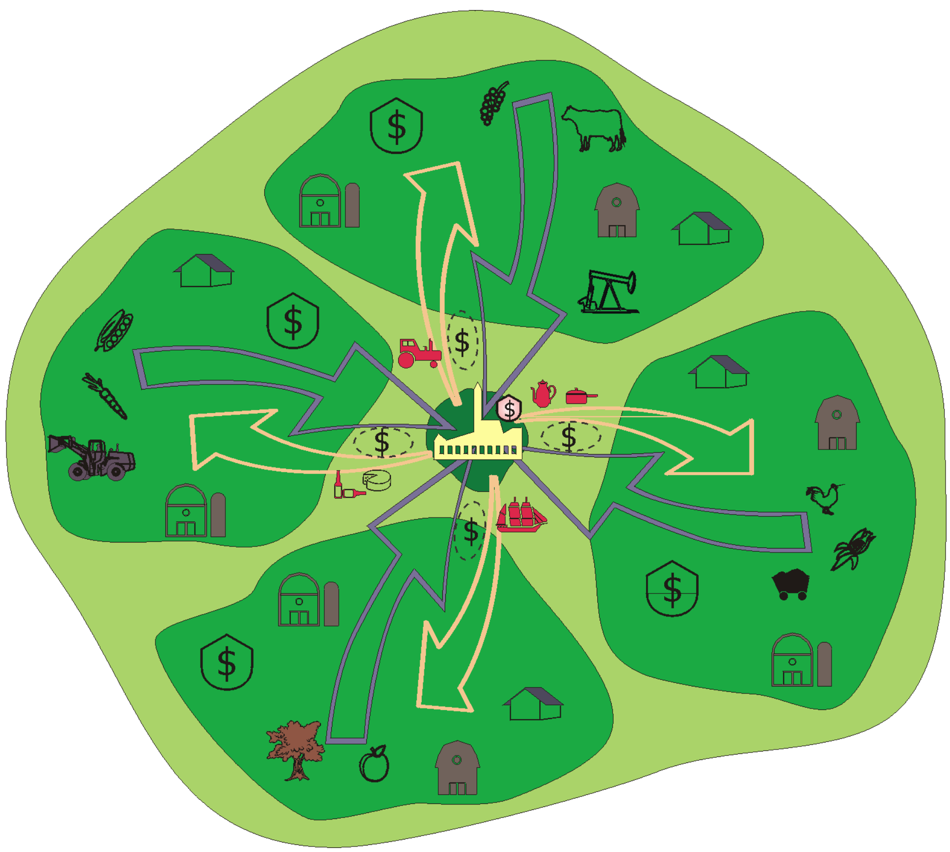


Figure 207: Factory Towns
Industrial factory towns used fossil fuels to amplify the role of market towns in the regional production system.

World Systems

World Systems today converge resources (primary commodities) from great distances. These goods include a wide array of minerals. Oil, natural gas, and coal are converged into cores, from which secondary commodities are produced and exported. It could be said that the Caribbean is a periphery to the US-EC-Japan world system (Figure 94, CHAPTER 8). In the diagram below you can see that this system crosses oceans and thus national boundaries (Figure 208).

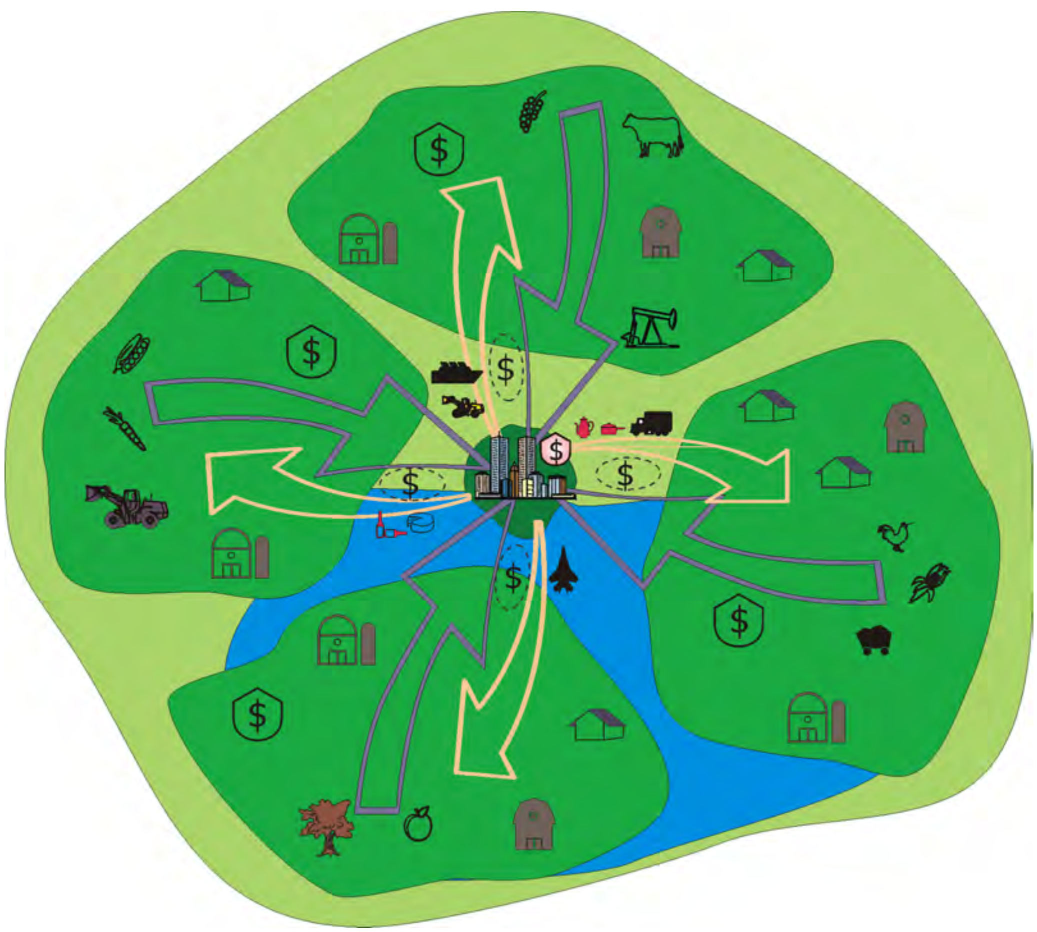


Figure 208: World System
World Systems concentrate goods and services within states and across nation boundaries.

Table 34: Trade Goods of World Systems

Converged	Diverged
Regional crops Lumber Metal Ores Coal Oil, Natural Gas (later) Preserved meats, live animals Chemicals	Balanced Diet Processed foods, requiring dispersed ingredients Metal goods and weapons Manufactured goods Transport vehicles Wooden goods Pharmaceuticals

CHAPTER 17
LIMITED RESOURCES AND THE RISE AND FALL OF WORLD CIVILIZATIONS

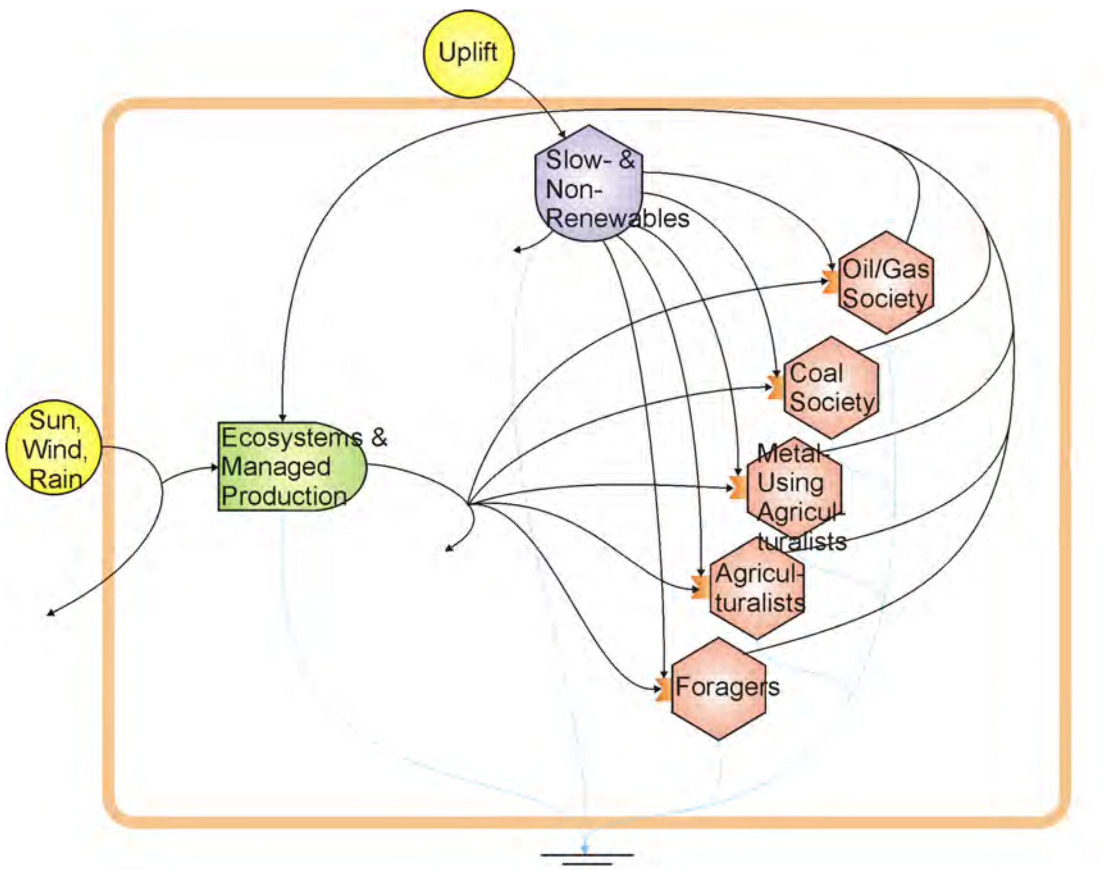


Figure 209: Aggregated Diagram of Cultural Evolution

The previous two chapters discussed the evolution of cultural storages within environmental limits. In order to test these principles and generate some predictions, a simulation was produced. This simulation demonstrates that a very simple model of culture, people and nature that emphasizes finite and limiting resources can generate reasonable approximations to the historical rise and fall of world civilizations. The limiting resources are slow-renewable and non-renewable sources (stone, metals, coal, oil and gas) used in the economic strategies of past and present societies. Humans have innovated technologies for millennia, which have increasingly made greater use of these high quality natural resources. As they have become depleted they instigate stress and even collapse which may lead to further rounds of innovation and expansion of population and assets.

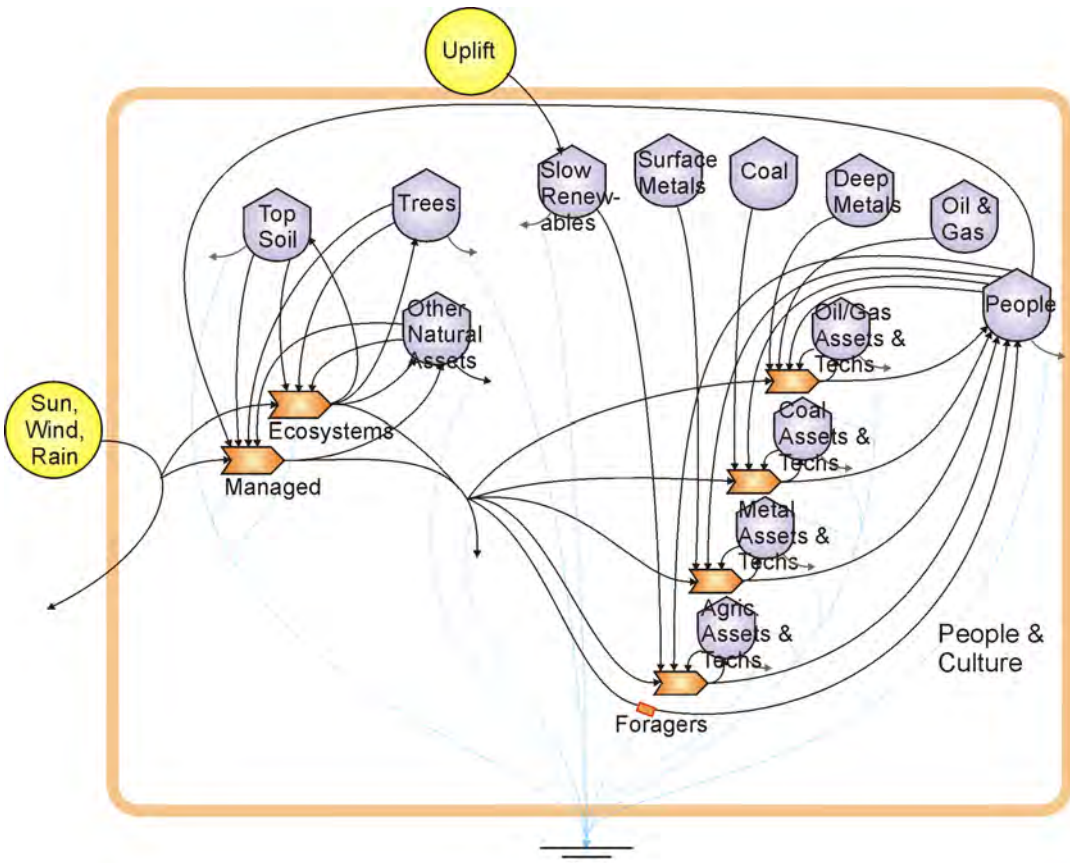


Figure 210: Evolution Simulation Details

The collapse of complex human-environmental systems is being explored by anthropologists in light of research into the dynamics of complex systems ((Tainter 1988), (Yoffee 1988)). While many factors are implicated in the rise and fall of complex systems, environmental energetics should arguably be the first issue addressed and understood.

This simulation is a world scale simulation. Its focus is technological innovations and world population size, and it should be understood that the trends shown are world trends, i.e., some regions may be in contraction at times when world totals are in expansion, and vice versa.

Figure 209 is a model of culture, people, and nature that is proposed to capture the material and demographic essence of the historic and prehistoric evolution of cultures. Figure 210 contains the detailed diagram for simulation. Simulation runs follow in Figure 211, Figure 212, and Figure 213. Simulation code is in APPENDIX DD.

Each simulation run is intended to be illustrative. Simulation runs produce different (often surprising) results when initial conditions and efficiencies are varied. The intention is to demonstrate the process of self-organization associated with people, culture and limited energetic resources.

Environmental Production

As experiments, a number of simple designs for representing the production of nature were simulated. I settled on a design with the two-production units and product flows, one managed by people and one for ecosystems, for the following reasons:

1. This design shows explicitly that trees and topsoil are created as a product of natural ecosystems. In other words, storages of trees and topsoil are products of production within natural ecosystems and must be replenished within natural ecosystems (fallowed fields, etc.)
2. This design makes it possible to show that increasing the storages of People or Assets/Technologies will cause decreased storages of Trees, Topsoil and Other Natural Assets.
3. This design can exhibit pulsing in nature if the draw into Managed is great enough, which is a reasonable outcome of over-cutting trees or of clearing too much area for crops.
4. This design permits the separation of Trees and Topsoil with long turnover times from the other products of natural production which would have shorter turnover times.
5. This design combines the outflow from Managed production with the outflow from Ecosystem production into a single flow source of natural yield from which humans can draw all natural assets. This keeps the two pathways from competing to the exclusion of one of them.

People and Culture

The energy storages of Slow-Renewables, Surface Metals, Coal, Deep Metals, and Oil & Gas are oversimplified to make a point. They are intended to represent valuable new energy/emergy sources that are tapped by new technologies and that are finite and will become limiting over time to any population that depends on them. I believe that innovation is both pushed by population stresses (almost imperceptible at first), and is self-propelling (see below).

In calibrating the model, an attempt was made to represent the relative efficiencies of the different production systems, with Oil & Gas societies supporting the largest populations on ecosystem resources, because they are using high-energy storages to replace ecosystem energies. Another way to see it is that the calibration ratios are equivalent to the land area needed per person. This works out to roughly:

Table 35: Efficiency Calibrations

Calibrations	**Societies**
14,000:1	Foragers
800:1	Agricultural Societies
400:1	Agricultural Societies that use Metals
200:1	Coal Societies
100:1	Oil and Gas Societies

Thus, the population density differences between Foragers and Oil & Gas Societies would be 140 to 1. This number may be off by an order of magnitude. There are a number of other corrections that could be included (i.e., the habitable surface area of the world has been increased with technological innovations). To reiterate, the purpose of this simulation is to demonstrate general processes, and it is not intended to be empirically precise.

Other Initial Storage and Flow Values

For calibration, initial storage and flow values were chosen to be within orders of magnitude. For example, with 520,000 units of biomass you might expect 500 units of human storage.

Some calibrations were determined from turnover times of the storages. Turnover time was calculated by dividing the storage value by its inflows.

Table 36: Turnover Time Calibrations

Storages	Turnover Times
TopSoil	40 yrs
Trees	200 yrs
Other Natural Assets	10 yrs
Agriculture Assets/Techs	20 yrs
Metal Assets/Techs	40 yrs
Coal Assets/Techs	100 yrs
Oil & Gas Assets/Techs	200 yrs
People	50 yrs

Cultural Evolution Simulation Results

Figures 3, 4, and 5 show the results of 3 different runs of the simulation. Distinct yet comparable results were obtained by changing initial values of important variables, i.e., increasing the initial world storages of coal, or reducing the calibrated "efficiency" of the agricultural consumption system. The results of each run were similar in most respects however. The simulations were given an initial "kick" by calibrating for a positive rate of population growth. In each run the agricultural system took-off first, followed by the metal-using agriculturalists, followed by coal societies, followed by oil & gas societies, per their "efficiency" calibrations. In each run the storages of slow- or non-renewable resources were drawn down in turn (Figure 211.2). In each run the storages (trees, topsoil, other) of natural assets were drawn down as human populations increased (Figure 211.3). In each run the world population rose together with total world assets and with shrinking natural storages. And in each run the world population declined as storages of non-renewable sources and natural storages shrank to a critical level.

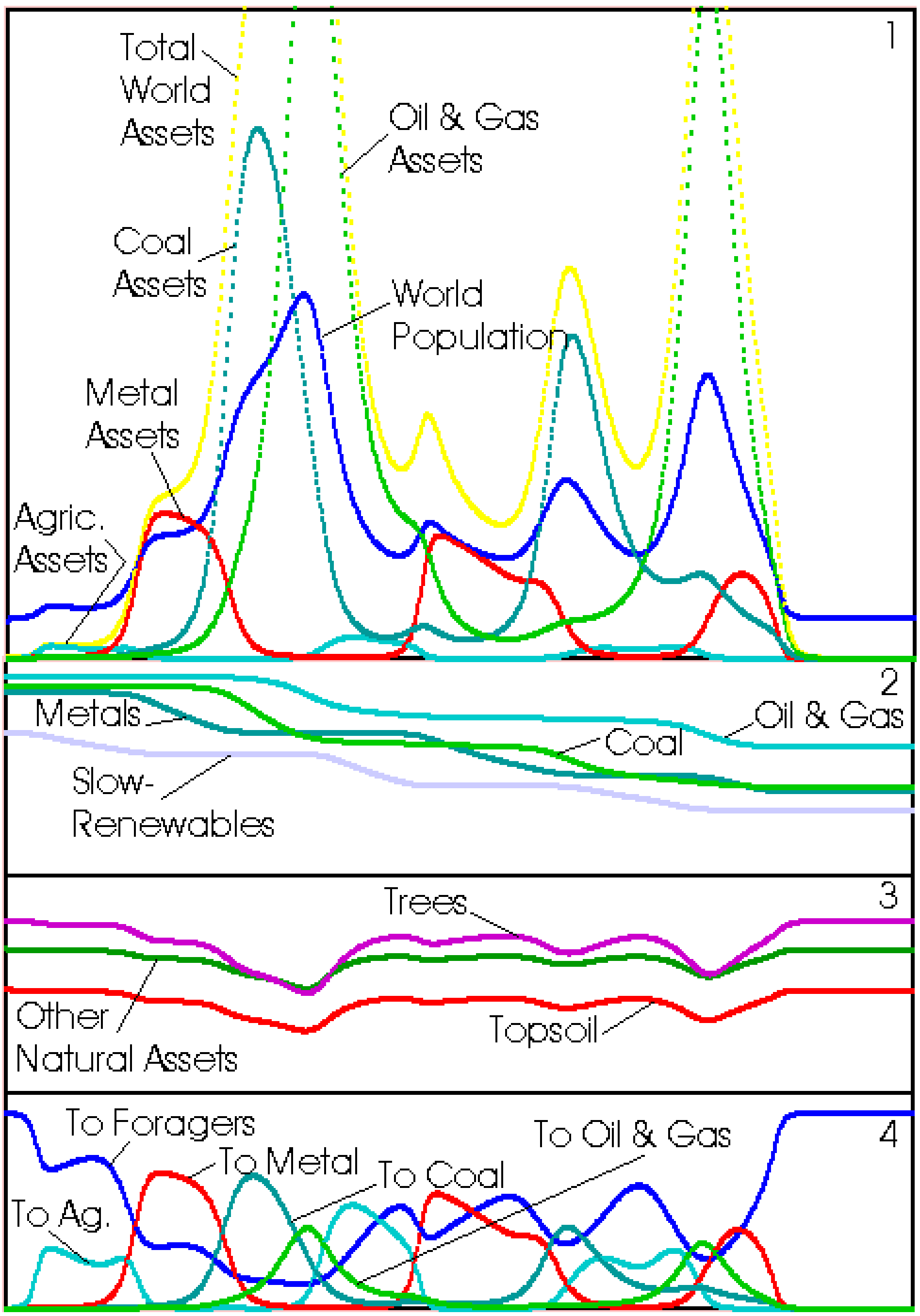


Figure 211: Simulation Run 1

One obvious difference between the three runs is that in runs 1 and 3 both population and world assets pulsed more than once. This interesting result suggests that a critical threshold of population, assets, and environmental storages was reached prior to the depletion of storages of non-renewables. At that point a collapse can occur, followed by rebuilding, and then a final collapse due to depletions of non-renewables.

Figure 211.4 shows the percentage of renewable resources that is being consumed in each human consumption system. Initially all resources going to people and culture travel along the Forager pathway. As the assets of the agricultural society grow the flow is shared by both. This means that both consumption strategies are present simultaneously, i.e., foragers and agriculturalists are co-existing. With time, metal-using agriculturalists replace early agriculturalists. Foragers persist however as a viable pathway.

This simulation is highly simplified. It could be made more realistic by adding recycles of metals, and by increasing the speed at which slow-renewables rebuild themselves. This would change the ending state of the model from Foraging to a mix of foragers and agriculturalists. This will be further explored in another paper.

Sustainability of the Agriculture Consumption Pathway

Of these five human systems and their required Storages of resources, probably the most difficult to understand is Agriculture and its requirement for various slow-renewable resources. However, there have always existed slow-renewable storages that could at times become limiting factors to agriculturalists.

Netting (Netting 1993:144) identifies several relevant factors to "sustainable" agriculture for which we do not have adequate long-term data:

1. Physical: soil degradation through erosion, weathering, compaction; diminished water supply, flooding, salinization; *depletion of non-renewable energy sources* (emphasis mine). Smallholders' techniques…may in fact be highly developed, and

their use of fossil fuels minimal, but environmental deterioration owing to climatic perturbations or gradually increasing overuse may become apparent.
2. Chemical: decline in soil-nutrient status…
3. Biological: loss of biodiversity; declining ecosystem stability and resilience. *Only groups of low-density foragers or shifting cultivators in large ecosystems may pose no threat to biological diversity* (Schelhas n.d.) (emphasis mine)…

Whether or not agriculture is ultimately "sustainable" in some form or another is not an essential theoretical component to the simulation being discussed here (although it remains a fascinating and unanswered question). What is important to recognize however is that agriculturalists often face limiting factors in their production systems. These limiting factors will often be the "depletion of [slow]-renewable energy sources", "decline in soil-nutrient status", or "declining ecosystem stability and resilience."

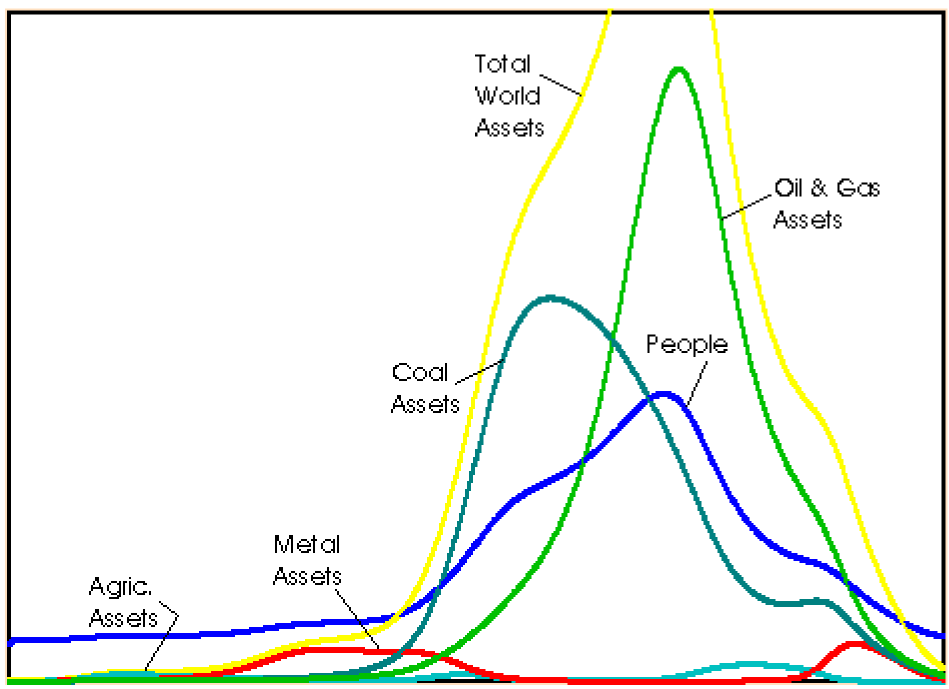


Figure 212: Simulation Run 2

These limiting factors, represented in the model as the slow-renewable storage, would have put stress on pre-historic agriculturalists at times. The threat of famine and population decline was probably often an important ingredient in the acceptance of innovative techniques that moved agriculturalists toward the use of non-renewable storages. These techniques today dominate our consumption systems.

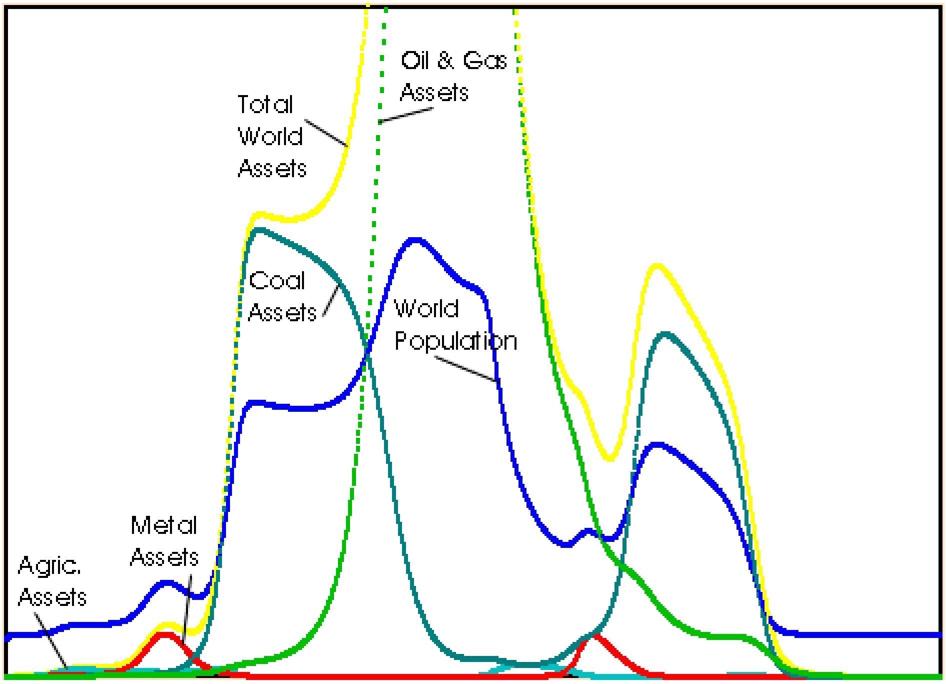


Figure 213: Simulation Run 3

Population Pressure and Self-Organization

This simulation for the evolution of cultures can be compared to a population pressure model of cultural evolution, which has been debated for many years ((Boserup 1965), (Cohen 1977), (Cowgill 1975), (Harris 1979), (Haas 1982), (Johnson and Earle 1987)). In the population pressure model, intrinsic pressures for population expansion force societies to make the choice for technological intensifications over harsh methods of birth control, even when intensifications have labor or caloric costs associated with them. Incrementally, in this way, population pressure pushes for new technological innovations. This iterative process has lead to contemporary intensive consumption systems, according to the model.

The preceding simulations suggest a subtle but important difference. In the simulations, the cultural transformations observed were initiated by a small intrinsic population growth rate. However, once technological innovations occurred, they pushed population sizes higher, which pressed on renewable and non-renewable resources, which pressed on technological innovations, which allowed further population expansion, which again pushed/pulled technology, and so on, with systemic feedbacks between nature, technologies and populations. In fact, this sequential accounting of events does disservice to the simulation, because the events in fact occurred simultaneously, or near enough. If these events are therefore understood as a systemic process of self-organization, no "prime mover" is required.

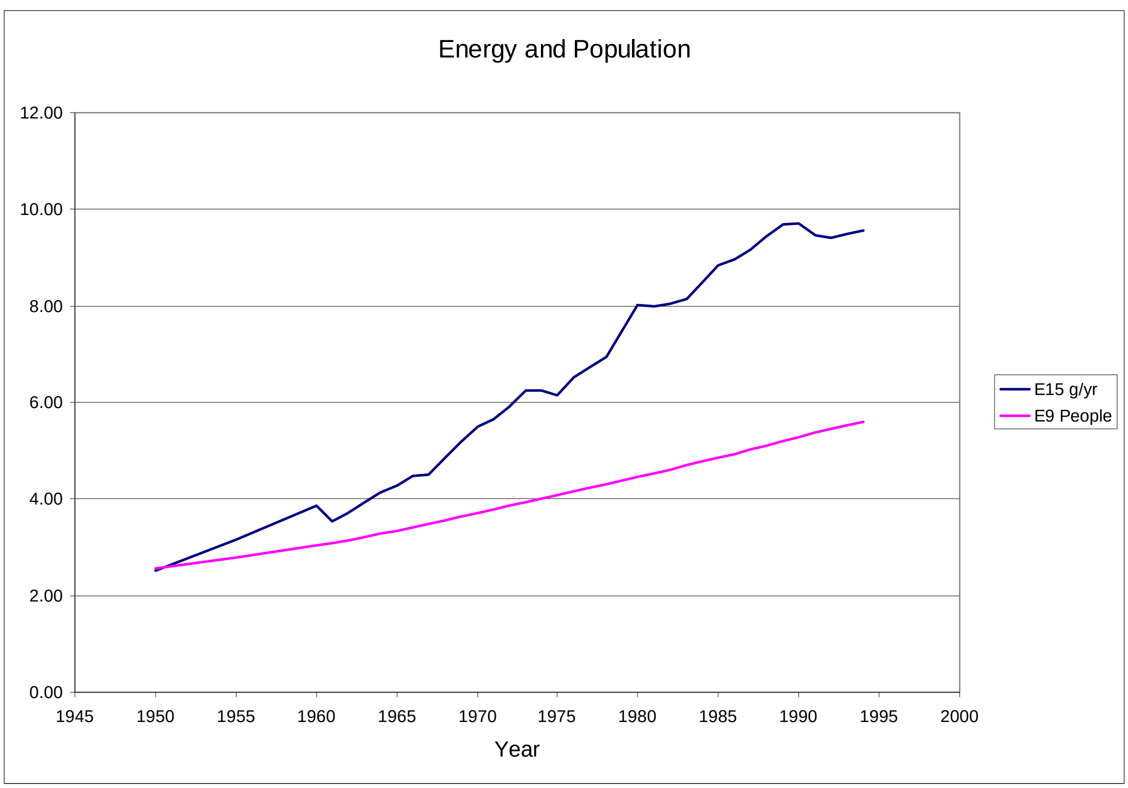


Figure 214: World Energy Consumption and Population Growth
Absolute values of energy use and human population continue to grow. Energy is E15 grams of combined oil, coal, and gas. The rate of world population growth surprised the UN by slowing in the 1990s (UN 1996***). Values are from Clark () and UN ().

Another feature of this simulation that warrants special discussion is the pervasiveness of autocatalytic designs. In far-from-equilibrium systems, like ecosystems, biological organisms, or single cells, autocatalytic designs prevail (Prigogine and Stengers 1984). In an autocatalytic design, the reproduction of a system requires feedback from itself. In the simulation, the ecosystems, economic systems, and people, all use feedbacks from themselves in their own production. This design leads to the non-linear expansions and contractions observed in the simulation. In the new science of complexity, the self-organization of autocatalytic, dissipative structures is a general model for evolution at multiple spatial and temporal scales (Depew and Weber 1995).

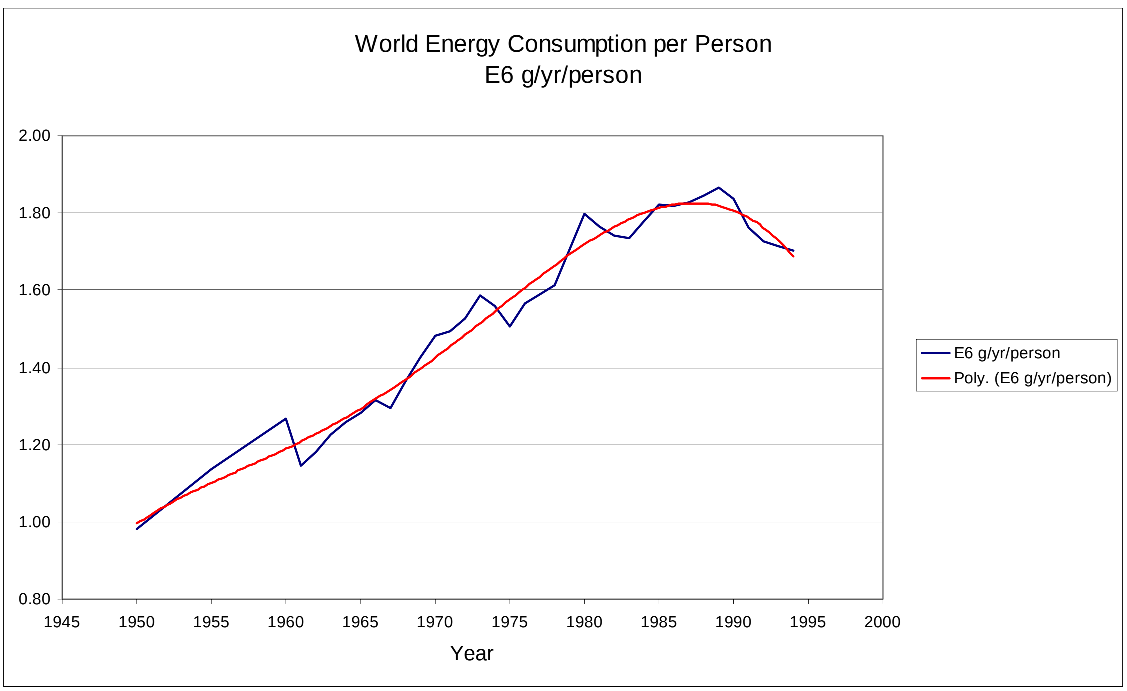


Figure 215: World Energy Consumption per Person
While absolute values of energy use and population continued to grow, the energy consumption per person flattened out in the 1980s and is shrinking. If energy resources ultimately drive all economies, this should coincide with a reduction in *world* standard of living. This may indeed be occurring, although masked by the collapse of the Soviet Union and resulting surge in resource capture by the west.

Finally, many geologists believe that world oil production will peak within the next few decades (Figure 214). At the same time, the UN has reported that world population growth is slowing--down to 1.48% per year between 1990 and 1995, compared to 1.72% per year between 1975 and 1990 (UN 1996***) (Figure 215). These events are consistent with the simulation.

The last growth industries of the post-industrial capitalist economies

In this century, the fossil fuel economy has lead to the production of industrial assets (super-tankers, oil platforms, factories, utilities, militaries, etc.), and to the elites who own and control them. These assets in turn produce consumer commodities and services, which are exchanged with workers for their labor. This relationships is autocatalytic, since greater stores of elite assets can feed back to capture more fossil fuel sources, which combined with labor can create more assets. The market adjusts itself when most limitations appear, producing substitutes or improving efficiency. The ultimate limiting factor, however, is fossil fuel, for which there is still no known substitute to match current emergy yields, and certainly nothing to match the yields that were achieved 30 years ago in the boom years of the world industrial economies.

Over the past 30 years, the emergy yield of fossil fuels has been in decline. In these years, world elites have sought to expand their assets, in competition with one another. This has become more difficult with contracting emergy yield from fossil fuels. One current solution is to continue to extract labor from non-elites in exchange for commodities that, however, require less emergy to produce. The following is a list of consumer commodities currently being produced by world elites. These commodities are grouped by the characteristic that makes them useful to elites for extracting labor from non-elites even when the return of goods and services to non-elites does not amplify household production the way it once did, i.e., is less valuable to households.

Inelastic demand

Commodities with inelastic demand are desirable to consumers almost regardless of price. Food, education, health care, drugs, have an inelastic demand. Multinational corporations have successfully captured the production of these goods, which were once produced on a more local or community basis (hospitals, food, university education), or which were once a smaller part of people's lives (drugs, genetic engineered foods) but which are now being amplified by commercial advertisements.

1. Health care
2. Pharmaceuticals
3. Hospitals
4. Education
5. Food (ADM, etc.)
6. Genetic Engineering

Addictive Products

The commodities of this category also exhibit an inelastic demand curve once a consumer has become addicted. These commodities take advantage of the human capacity for physical or behavioral addiction. Once a person is addicted, a person will continue to purchase the product almost regardless of the cost to themselves.

1. Illegal drugs
2. Cigarettes, Coffee
3. Gambling, lotteries
4. Stock marketing (gambling)
5. Video Games
6. Pornography
7. Prostitution

Low or no Material Inputs

In the current world economy that is running on contracting emergy returns, these products are easier to produce because they require less emergy for their production. Compared to a tractor, for instance, software or entertainment require less emergy per copy (they are very easy to copy and move and sell), they are used for a shorter period of time (sometimes only hours), and they perform no physical work for consumers. Antiques require no material inputs because the assets were long ago spent for their creation.

1. Computer software
2. Entertainment - Movies, Music, Sports, TV
3. Antiques

Commodities that Directly Amplify the Capture of Assets by Elites

These commodities are the essence of the autocatalytic processes that create elites. Elites lend their stores of assets to smaller scales, which use the assets to do work, but which must repay the assets plus interest. Lending and insurance are the industries-supreme for creating hierarchy in a growth economy. In a contracting world they will be less effective because currency will loose its value as it moves less emergy.

1. Lending, other Banking services
2. Insurance
3. Telecommunications, Internet, Satellites (lower cost)

Defense of Private Property / Coercion

As the economy is squeezed by contracting emergy yield from fossil fuels, more people are marginalized, and the gap between rich and poor increases. In this environment, theft becomes more likely and consumers are more willing to pay for security in defense of their remaining private property. Elites are in support of this solution because it shifts the blame to the first victims of contraction and postpones any structural changes.

1. Police
2. Private security
3. Prisons
4. Legal Services

Maintenance of World System Inflows

Of all the commodities produced by elites, these are the most critical to maintaining world systems. These commodities assure control of remaining natural resources needed by the cores for their reproduction. Some assets permit coercion on an international scale (military, weapons, debt, monopoly). Others make possible the movement of valuable primary commodities and other goods (shipping, telecommunications, and roads). Finally, other commodities make it possible for elites to physically move their consumption into the periphery (tourism).

1. Military
2. Weapons
3. International Banking - Loans/Debt
4. Telecommunications
5. Shipping
6. Roads
7. Tourism

CHAPTER 18
E*M*ERGY ACCOUNTING AS AN ALTERNATIVE ECONOMICS

Emergy analysis, as conducted in the case study of Bonaire, presents an alternative ecological-economic worldview to current macroeconomics. The preceding discussion of cultural evolution exposed functional relationships within human-ecosystems that are reasoned and explicable in the trajectories of human history and world systems self-organization. In that light, it is now possible to expound upon the constrasting worldviews of emergy and macroeconomics. The macroeconomic worldview does not address explicitly the issues of power, force, and inequality (social hierarchy). These issues in contrast are highly determinant in a cultural evolution model, and I would argue, they are inescapable in any model that addresses the complex nature of human-ecosystem relationships, emergy analysis resolutely included.

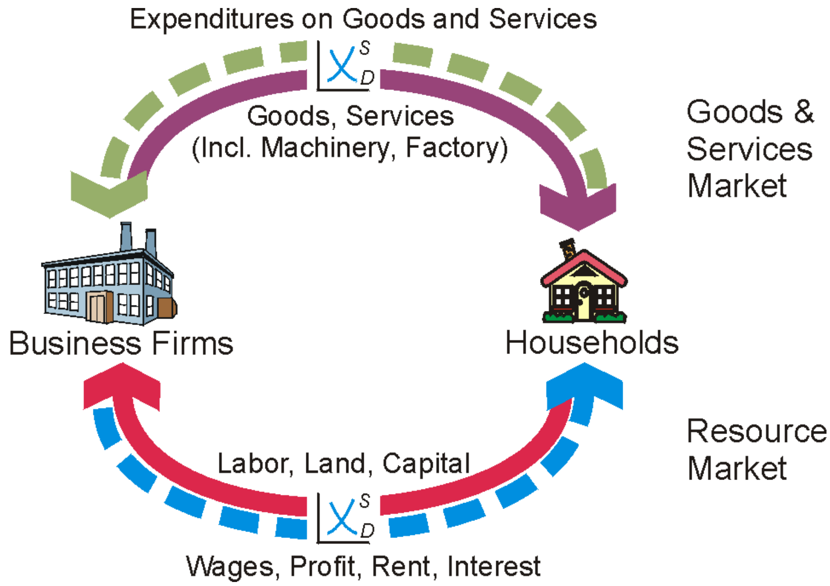


Figure 216: The Circular Flow of Income
This basic model can be found in every macroeconomics textbook. The assumptions of the model should be examined from the systems perspective. Dotted lines represent money flows.

Macroeconomics and Environmental Accounting

A common diagram in Macroeconomic textbooks is the "Circular Flow of Income" (Figure 216). It depicts the relationship between Business Firms and Households in a market economy. In its simplest form, Households provide labor, for which they receive wages from Business Firms. This is depicted in the lower flow of Figure 216. Business Firms supply Goods and Services, for which they receive payment from Households. This is depicted in the top flow of Figure 216.

In addition to labor, however, "Households" are also said to provide land, capital, natural resources, and other assets, which are exchanged in a "Resource Market" for profit, rents, interest, etc. (lower flow of Figure 216).

Furthermore, in addition to household goods and services, "Households" are also said to purchase various fixed goods (machinery, factories, equipment, raw material stocks, etc.) in the "Goods and Services Market" (upper flow of Figure 216).

While it might be a useful logical category for economists, the term "Households" is an odd assortment of both persons and assets. The assets of a "Household" may include the physical assets of a Firm. They also include storages of natural resources, which are owned or controlled by the "Household."

This leads to two shortcomings of the diagram. First, the term "Business Firms" has no physical reality, but is rather an abstract nexus of interactions between "Households." Second, the term "Households" is in fact both households and industries and the owners of each.

Figure 217 expands the "Households" of the first diagram into the physical hierarchy of households and corporations (and their owners). This diagram splits the (lower) flow of land, labor and capital. Here simple households supply labor, and the "Owners" of businesses supply labor, land, capital and other assets to the "Resource Market." In exchange, simple households receive wages, while the Owners receive profits, interest, and rents. This diagram also splits the (upper) flow of goods and services. Here simple houses receive household goods and services, while the Owners also receive fixed goods such as machines, equipment, buildings, etc. which they purchase in the "Goods and Services Market."

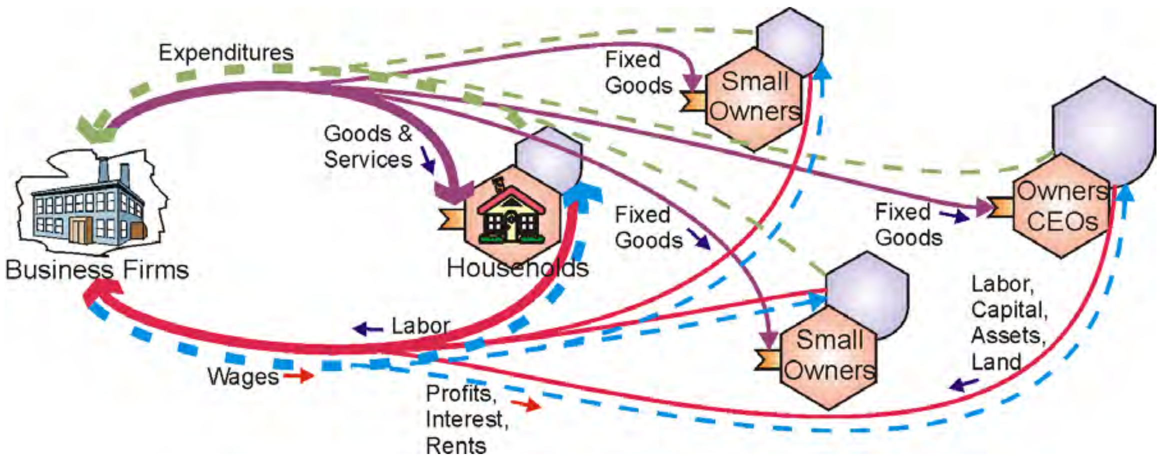


Figure 217: A Hierarchy of "Households"
A society is composed of family groups and their assets in households. Households can be placed into a web or hierarchy of production.

Figure 218 completes the transformation of Figure 216 into a systems diagram. The abstract "Business Firms" figure is eliminated, since the physical presence of a Firm is logically located with its Owner. A firm does not exist without ownership and management. Owner and firm are co-occurring components of an economy (see Production Subsystems on Bonaire, CHAPTER 10). The logic of ownership is that owners gain security, power and prestige from the control of productive assets, which they feedback to amplify production (when possible) and defend their positions in socioeconomic hierarchies. This fundamental principle of economic intensification is known from chiefdoms, archaic states, and contemporary states (see CHAPTER 16 for detailed discussion).

The systems diagram finishes the story by depicting natural assets and their location in the hierarchies of ecosystems and the biosphere. It adds renewable sources (sun, wind, rain), natural production (crops, timber, etc.), and non-renewable sources (metals, fossil fuels, etc.) that drive any ecosystem or economy. The absence of these sources from the macroeconomic diagram belies the minor role they play in the economist's model.

It is the control of physical assets that places people into the social hierarchy. Moving from left to right in the hierarchy, labor is combined with assets to produce new goods. As depicted in this diagram, the assets may be renewable natural products, nonrenewable storages, or secondary goods from the economy. High-emergy goods are concentrated into storages on the right, which will have powerful feedback effects over large territories.

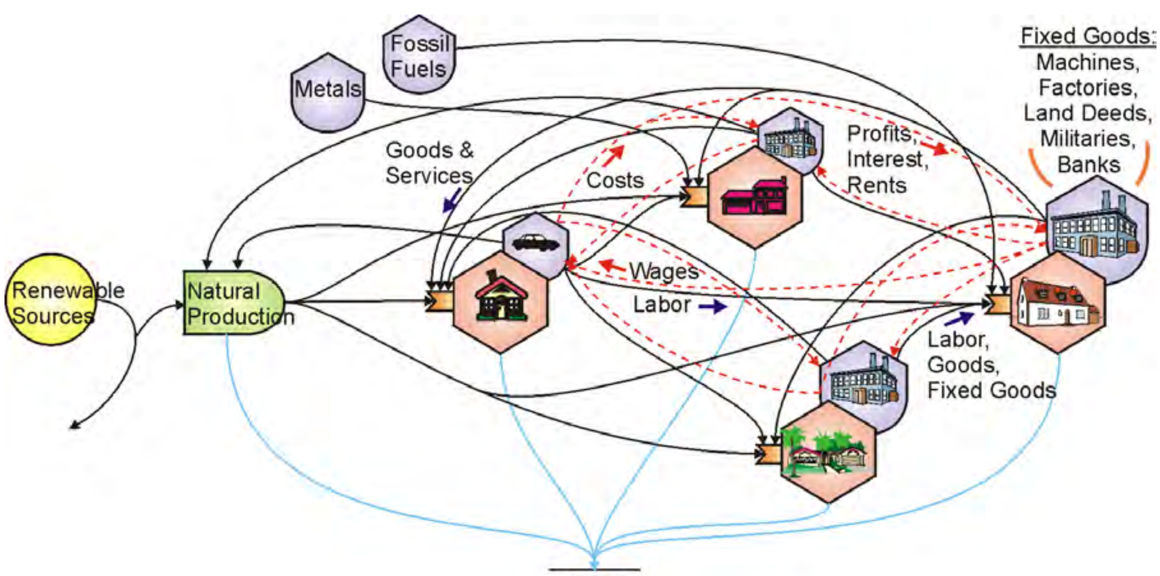


Figure 218: Flows of Emergy and Income
Humans are parts within ecosystem wholes. They should be modeled within those systems in order to identify the natural resources that drive the system.

Some critical storages of assets in state systems are machines, factories, legal deeds, militaries, and banks (Figure 218). Legal deeds to land and property are important assets preserved in government storehouses. These guarantees are backed by the coercive force of the courts and state military apparatus (see CHAPTER 13, States and the State Government on Bonaire). Banks provide loans, which are another critical component of the economic system. Money is concentrated into banks, from which loans are granted at interest.

New Assumptions for an Ecological-Economic Model

1) "Labor" is mislabeled as a "resource" in the resource market. Labor is a product of ecosystems, not a source. People are themselves top consumers in ecosystem hierarchies, the natural systems upon which economies are constructed. Generally speaking, in ecosystems, plants capture available energies to produce plant biomass, and animals (including humans) consume plant and animal biomass. In a web of ecosystem life there are also feedbacks between producers and consumers which can both amplify the capture of available natural resources, and amplify the useful work performed with those resources.

People and their economies tap additional sources of energy that amplify the production in an ecosystem. These sources are the ancient storages of fossil fuels and mineral concentrations. Fossil fuels, minerals, and the renewable natural sources (sun, wind, rain, etc.) are the driving energies of ecosystems with humans. Human's and their labors are product, not source, albeit a product that has the ability to feedback and amplify the capture of energetic sources when they are available.

2) Natural resources are not a market commodity like any other. They are, as stated in 1, the energetic sources that drive an ecosystem with humans. Natural resources like sun, wind, and rain are potential and kinetic energy sources. Carbon sources like crops, wood, hydrocarbon fuels (coal, gas, oil), and animals are storages of

chemical bonds that can be broken to release energy and do work. Veins of metal ore in the ground are the products of millenia of geological work, and the work of concentrating those ores created potential energy sources that have been captured by cultures with metalworking technologies.

Solar energy and the geologic energy of present and past millenia place finite limits on the quantities of stored natural resources. An economic model that depicts nature as a substitutable market good ignores these basic facts of thermodynamics and physical chemistry. It unrealistically assumes that there is always a substitutable market good to replace any depleted source. This is an unfortunate and dangerous "basic assumption" of economic theory. It contrasts with an ecological-economic model, which holds that natural resources, and not the market, are the fuel of any economy. The political-ideology of unlimited growth divides the economic from the ecological-economic worldview. Ecological-economic models recognize energetic limits in the biogeophysical world.

Gross Domestic Product, GDP

Money moves in countercurrent to goods and services within an economic system. From the perspective of environmental accounting however, the driving forces of the system are not the money, but are instead the high emergy sources and storages that flow into the system. These are depicted in Figure 219 as Renewable Sources, trade from Other States, and the storages of Metals and Fossil Fuels. These flows constitute a knowable and finite flow of emergy into a system each year. GDP measures the money that circulates in countercurrent to these flows.

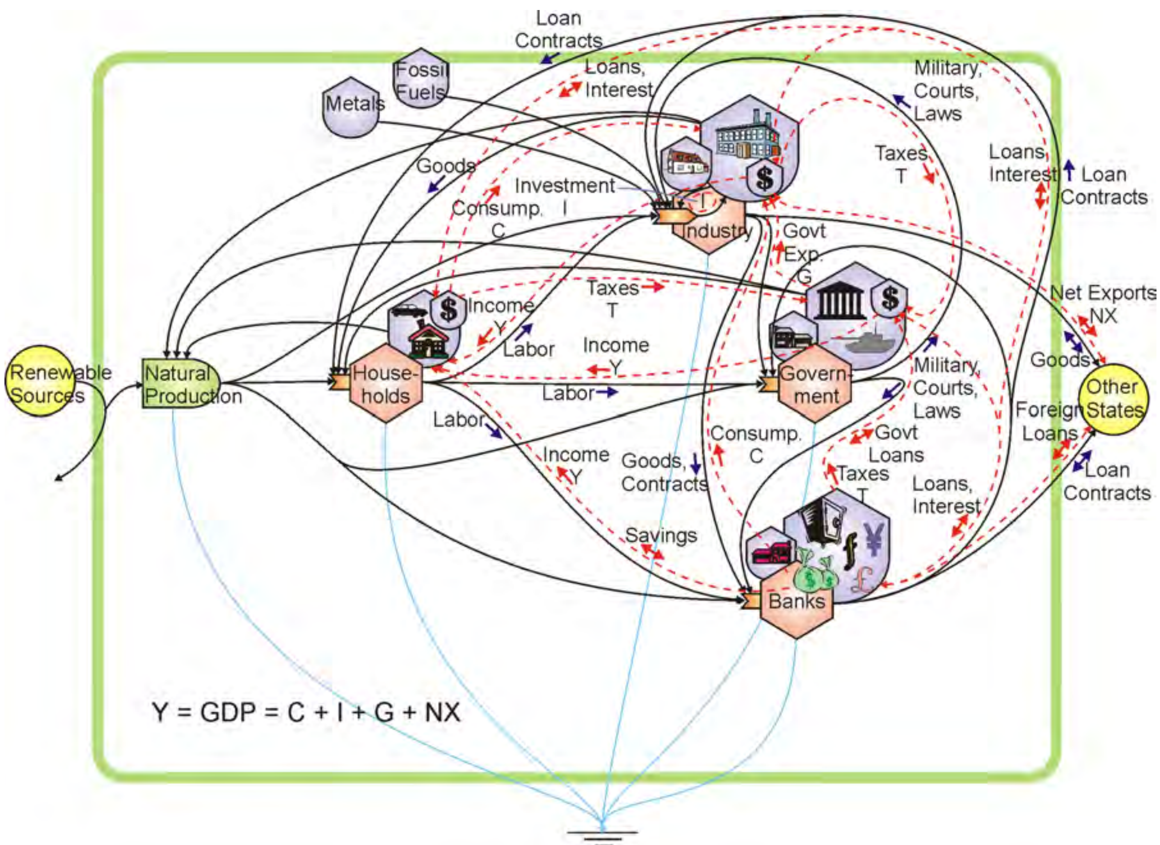


Figure 219: GDP and Emergy in a Nation
This diagram expands on the discussion in the previous section. Here you see the same hierarchy of households and owners. In this diagram the owners have been subdivided into Industry, Government, and Financial elites and the assets they control. It is now possible to represent the flows of currency in the GDP model. Gross Domestic Product (GDP) is said to equal the sum of Consumption (C), Investment (I), Government Expenditures (G), and Net Exports (NX). This diagram differs from an economist's model by depicting the functional relationships between government, industry and financial institutions, as they reinforce the production of each other. For example, the role of banks as the suppliers of international currency is shown. Banks depend on secure and durable storage technologies from industry, and on the legal, judicial, and coercive institutions of government (APPENDIX X)

The buying power of the money in an economy can be calculated by dividing the emergy use by the money expended for final purchases in an economy (the GDP). This index, called the emergy/money ratio, may be used to compare national economies, and to calculate appropriate exchange rates. Emergy/money ratios were calculated for Bonaire and the Netherlands Antilles, and compared with known values for other nations (Table 13).

Land-Based Industries, Law, Property, and Coercive Force

In systems modeling to date, the ownership or control of natural assets has not been well elaborated, though it arguably should be. This is due to the structural-functionalist bias that will be discussed (CHAPTER 21).

Defended, legal rights to ownership of land-based natural assets is a defining feature of state societies. Most people today would consider the right to purchase land to be inalienable. It is such a part of our worldview that it is difficult to recognize the physical assets of the state apparatus that make it possible.

What are the state assets that make ownership possible? What function does ownership fulfill in a national system? Figure 220 is a simple Nation model, in which people use cultural assets to capture natural resources to support themselves. In Figure 221, this simple model is expanded to expose two important examples of land-based industries--timber plantations, and oil wells.

In both of these industries, the systems model is drawn to depict the physical assets and the people who control them. The Oil industry relies on oil rigs, pipelines, trucks, and other equipment, which are owned by individuals or corporate groups of individuals. These are shown in Figure 221, along with the storage of crude oil that is produced.

The oil industry sells its oil to the main economy for money (depicted by the red dotted line in countercurrent). The industry relies on purchased labor, goods and services, which flow as a solid line from the main economy to the oil well interaction symbol. Another solid line flows from the main economy to the oil wells with two labels. The labels are "Legal Deeds to Land" and "Property Rights, Defended by Force."

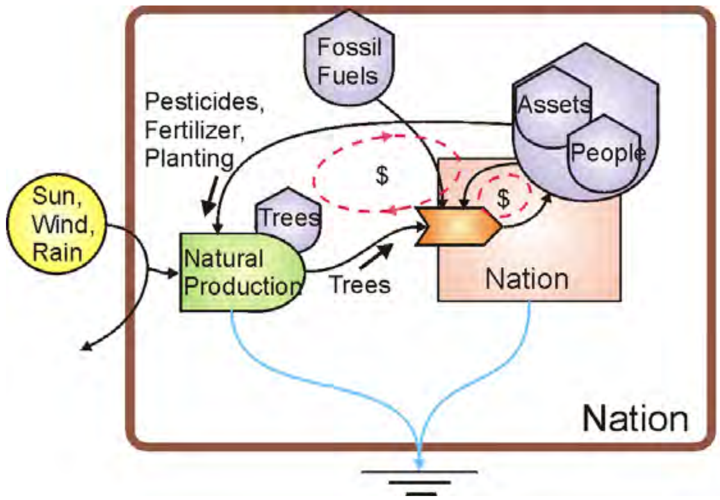


Figure 220: A Simple Nation Model
This model shows a nation with the sources and storages that drive economic production.

State governments control access to land. States control the recording of legal deeds to land ownership. Legal state records are kept under security. These services require storage buildings and a bureaucracy of legal specialists.

One other critical service is provided by states. Property rights must be defended by force. States control a monopoly on the legitimate use of force. Judicial systems and domestic military regiments (called police) provide the threat of force that assures legal rights to land that are expressed in legal deeds.

States tax the owners of land. It can be argued that they tax landowners for the services that assure land ownership. State taxes for land usually reflect the market value of the land. If oil is found beneath the land, the taxes are higher. Land with oil beneath is valuable land and can be sold on the market at a high price.

Plantation land is not unlike oil well land. It is even more obvious that plantation land itself is a good to be bought and sold on the market. The taxes paid on land cover the government services that assure private property.

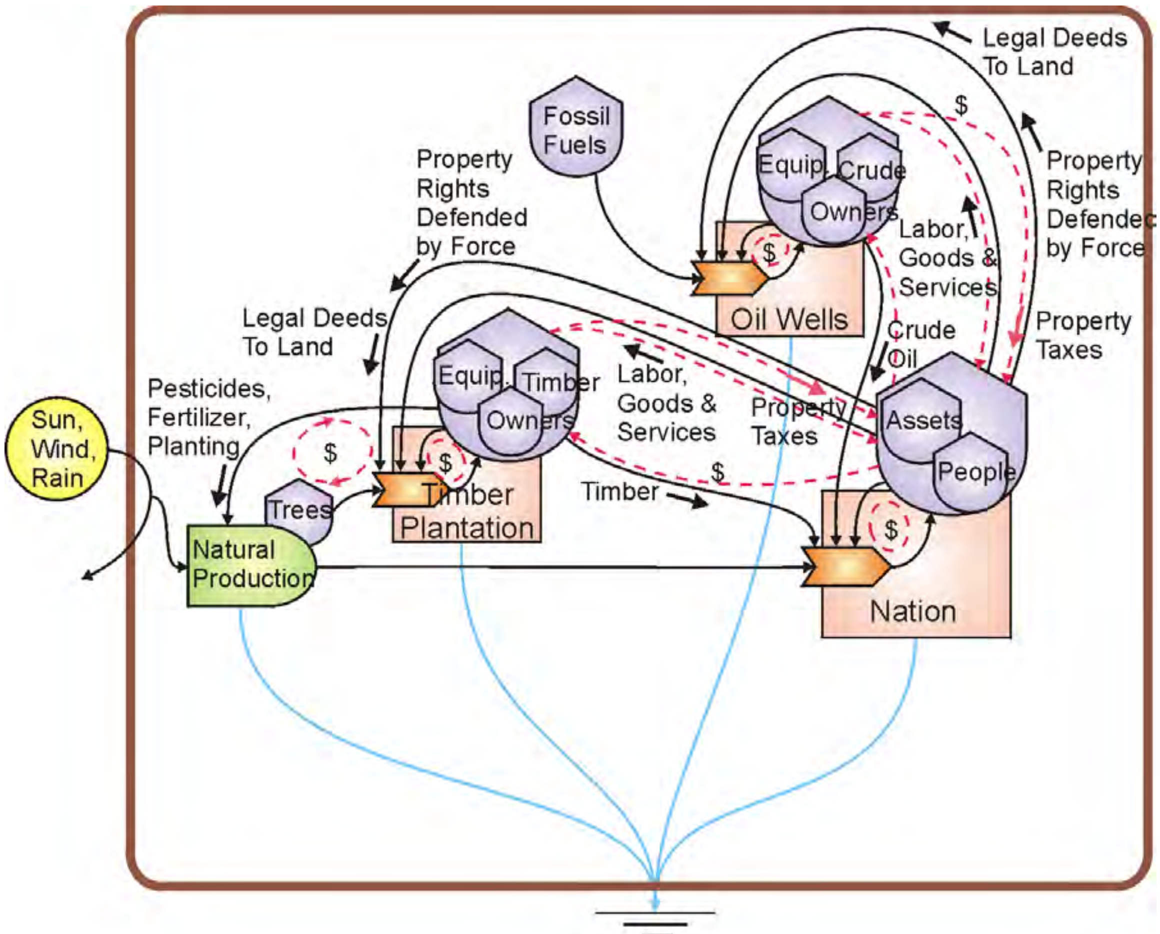


Figure 221: Nation and Land Based Industries
This figure expands on the first. Two production subsystems are shown, a timber plantation and oil wells.

Some Generalizations. All private property, not just wells or plantations, require the coercive force of legal and police assets to assure ownership. This service is included in the taxes paid for a good. With land-based industries this service is of paramount importance because it is essential to the production of the product.

Within nations, the guarantee that land (or any property) can be exclusively controlled is called private property. Between nations, the guarantee that states have exclusive control to land is called sovereignty. The example of the Iraq-Kuwait crisis in the 1990s is a demonstration that extra-national bodies are sometimes determined to guarantee national sovereignty by coercive force, just as national governments guarantee private property by force. This is not always the case, as the history of state warfare and conquest has shown. The fact of NATO intervention in the Iraq-Kuwait crisis suggests that Kuwait has been, and continues to be, part of an extra-national world system that includes the US and other NATO countries.

An alternative way to evaluate the emergy of the legal-military service to guarantee private property might be sought. If the emergy of the legal-military apparatus can be converted to emergy, it could be divided on an area basis to determine emergy/area within a state. This value could be compared to the emergy/money of taxes paid on land. It might be determined that landowners are getting a high emergy value for their tax dollars, at the expense of small landowners and the main economy.

CHAPTER 19
SOCIOCULTURAL SELF-ORGANIZATION

At this point it is now possible to restate a number of core issues of evolutionary and ecological anthropology in the terminology of systems ecology.

Diagramming Sociocultural Systems

Anthropologists have had much to say about the related concepts of culture and sociocultural system. Here they will not be rigorously defined, and there will be no attempt to review that extensive literature. In brief, however, consider these two simple system designs.

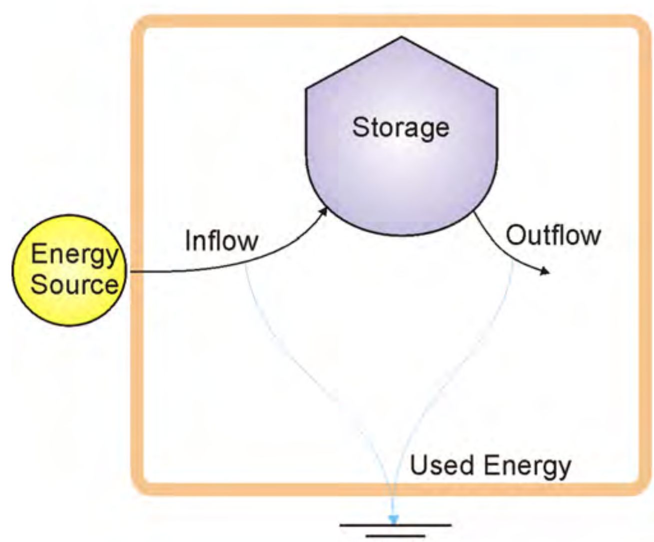


Figure 222: Linear Flows and Storage

Figure 222 is a model of linear flow and storage. Figure 223 is an autocatalytic system, which also has flows and storages, plus a feedback flow and an interaction symbol. Storage compartments in a systems diagram represent concentrations of a quantity (of matter, energy, structure, information or emergy, depending on the diagrammer's intentions). Ecosystems have many storages such as those of air, water, nutrients, plants, and animals. Storages are concentrations of a quantity, and any concentration is an energy source able to drive opportunistic pathways, i.e., has the potential to make things happen. For instance, storages of leaf litter on a forest floor support populations of microbes that decompose and recycle nutrients back to soils and eventually plants. Storages of refined oil represent energy to drive world systems.

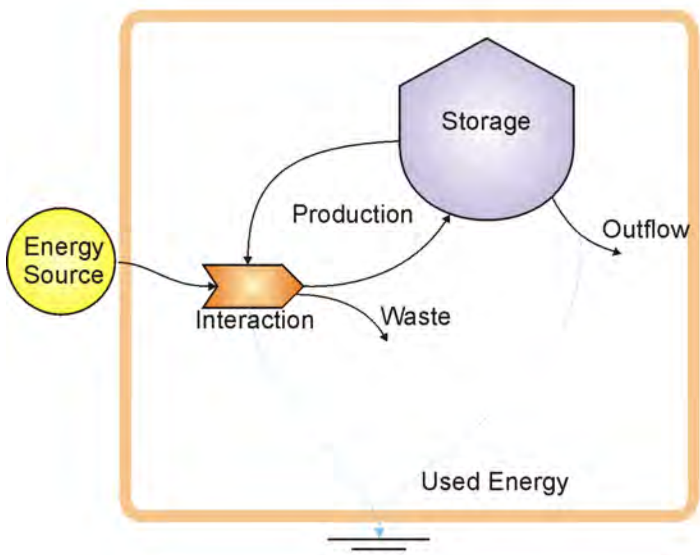


Figure 223: Autocatalytic Module

Autocatalytic Modules

Some storages appear in nature without direct feedback from themselves (but perhaps with feedback from some other component in the system). Many storages, however, have direct feedback into their own production. All living organisms have storages that operate in this way. A plant builds storages of leaves and stems that capture more energy to grow and maintain more leaves and stems. Non-living storages also form autocatalytic designs. Hurricanes grow because concentrations of warm ocean water create convection currents of air and water between sea and upper atmosphere. These currents begin to rotate around a center. This rotating structure dissipates heat more quickly to the upper atmosphere, and as it does it pulls more heat from the seas, building more structure, and so on. This self-organizing, autocatalytic system will grow within the limits of its solar energy source. Many chemical reactions are also autocatalytic, where the presence of a chemical is required for its own synthesis. Within the chemistry of biological organisms (organic chemistry), a great number of autocatalytic and cross-catalytic chemical pathways have evolved by natural selection.

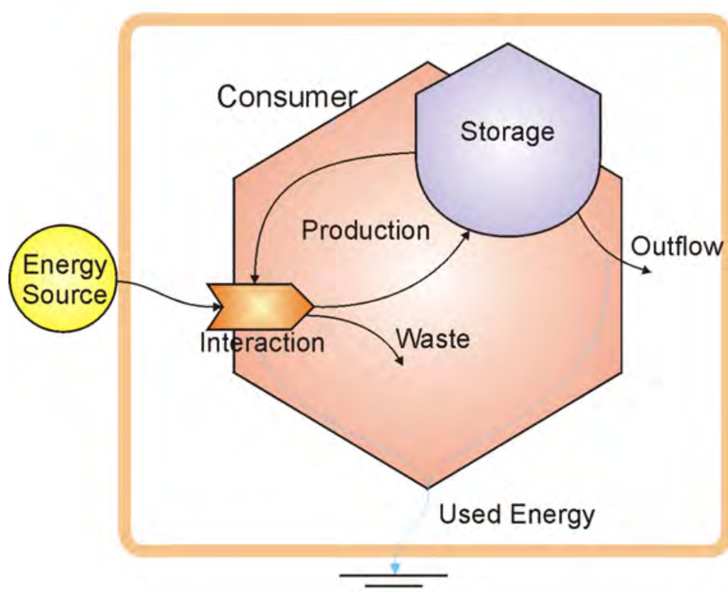


Figure 224: Consumer Module

Depreciation and Heat Sink

From the Second Law of Thermodynamics, we know that all concentrations are continuously degraded (depreciated), and that nothing in nature is permanent unless energy is added to maintain it. Energy concentrations shrink as they depreciate (or as they drive other processes). This is represented by the outflows in Figure 222, Figure 223, and Figure 224. When energy is either concentrated or depreciated it is transformed. No transformation is 100% efficient, and potential energy is lost as heat. This is represented by the flows of used energy to the heat sink.

Producers and Consumers

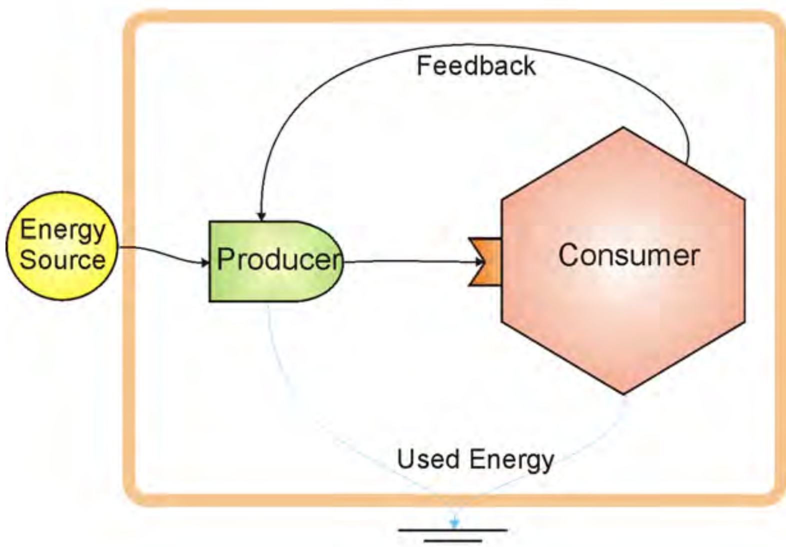


Figure 225: Producers and Consumers

It is common in systems diagrams to distinguish between Producers and Consumers. In ecosystems, producers are usually plants, which capture solar energy and produce living biomass. Consumers are usualy animals which eat plants or other consumers, building biomass and recycling nutrients back to nature. Internally, plants and animals are complex configurations of chemical reactions, which can be represented by interactions, storages and flows. This complex configuration can be aggregated into a simple system of single interaction, single storage, and autocatalytic production. See Figure 224, which has only a slight modification from Figure 223. This design captures the fundamental fact that a consumer eats to grow and replenish itself, in order to live to eat another day.

The next diagram (Figure 225) shows a producer and consumer within a single system. In this simple model, producers (plants) capture solar energy and build biomass. Those producers are later eaten by consumers. Consumers feedback nutrients to soils. They provide also other feedbacks such as the dispersal of seeds throughout an ecosystem.

The Primacy of Infrastructure vs. Sociocultural Self-Organization

Turning now to the production and maintenance of culture and sociocultural systems, consider this extensive quotation from *Cultural Materialism: The Struggle for a Science of Culture* (Harris 1979:71-73):

> As I have said…, infrastructure, structure, and superstructure constitute a sociocultural system. A change in any one of the system's components usually leads to a change in the others. In this regard, cultural materialism is compatible with all those varieties of functionalism employing an organismic analogy to convey an appreciation of the interdependencies among the "cells" and "organs" of the social "body."
>
> The conceptualization of the interrelationships in question can be improved by introducing a distinction between system-maintaining and system-destroying interdependencies. The most likely outcome of any innovation--whether it arises in the infrastructure, structure, or superstructure--is system-maintaining negative feedback, the dampening of deviation resulting either in the extinction of the innovation or in slight compensatory changes in the other sectors, changes which preserve the fundamental characteristics of the whole system. (For example, the introduction of progressive federal income taxes in the United States was followed by a series of privileged exemptions and "shelters" that effectively dampened the movement toward eliminating extremes of wealth and poverty.) However, certain kinds of infrastructural changes (for example, those which increase the energy flow per capita and/or reduce reproductive wastage) are likely to be propagated and amplified, resulting in positive feedback throughout the structural and superstructural sectors, with a consequent alteration of the system's fundamental characteristics. Cultural materialism denies that there is any similar class of structural or superstructural components whose variation leads as regularly to deviation amplification rather than to negative feedback.

Harris's verbal model of feedback and sociocultural systems should be compared to the systems diagrams in Figures 5-8. In Figure 226, the sociocultural system is shown as a "consumer" that is dependent on the natural production of the biosphere. This dependence is final, and ultimately determines the fate of a sociocultural system.

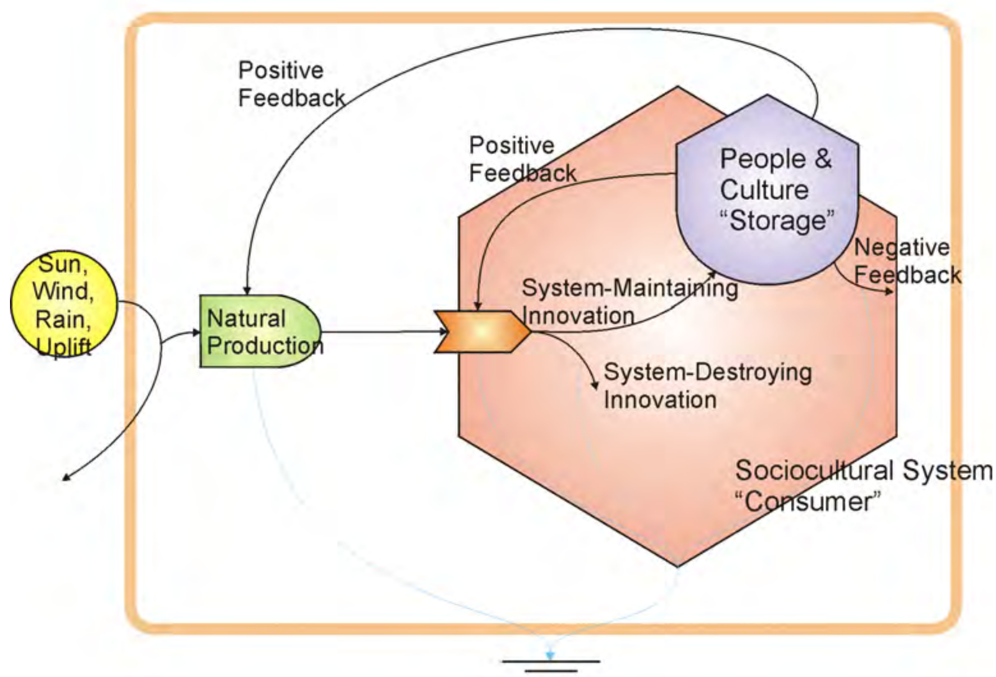


Figure 226: Sociocultural System

In this diagram, the People and Culture "Storage" feeds back to capture the inflow of energy and materials that it needs to maintain itself. If innovations appear that can increase the flow of energy and materials into the sociocultural consumer, then feedback is positive. Positive feedback, as Harris says, can fundamentally alter the systems characteristics. In systems modeling terms, it means that the storage can grow in size and structure.

The People and Culture "Storage" may grow when feedback is positive. Positive feedback is direct feedback to its own production. It is autocatalytic. Some innovations produce storages which are capable of feeding back to amplify the production of themselves. For example, technological innovations produced machines for burning oil, which could then be used to pump more oil from the ground, which could be burned in machines to pump more oil, etc. Cultural innovations that do not feedback and maintain or expand the storages of people and culture will not be selected when there are alternatives that do.

Feedback can be both positive and negative. Negative feedback can maintain a system at a steady state, or can slow the growth of a storage. If the People and Culture “Storage” begins to grow, negative feedback will drain the storage until a new steady state is reached. System-maintaining innovations are constantly replenishing the storage, with negative feedback balancing inflow with outflow.

Can a self-maintaining, autocatalytic system grow indefinitely, simply by feeding back innovations that amplify its own production? Clearly not. From this diagram it can be seen that the system is dependent on inputs from nature that are finite. It cannot be forgotten that sociocultural systems capture and use the products of natural production, and natural production is limited by the ultimate sources of sun, wind, rain, and finite storages of other natural resources like fossil fuels.

Infrastructure

The Infrastructure is those cultural innovations that are directly related to the goal of capturing and using biosphere energies. Examples are agricultural innovations, power production technologies, markets, financial technologies, etc. Sociocultural systems depend on natural production from the biosphere for their maintenance, reproduction, and growth. Cultural materialists insist that innovations in the infrastructure will determine to a degree the nature of other components within a sociocultural system. Stated in reverse, cultural innovations that effect belief systems or the division of labor, for example, which do not feedback to reinforce the infrastructure will be “selected against” in favor of innovations that do. Therefore the infrastructure has primacy in determining the nature of a sociocultural system.

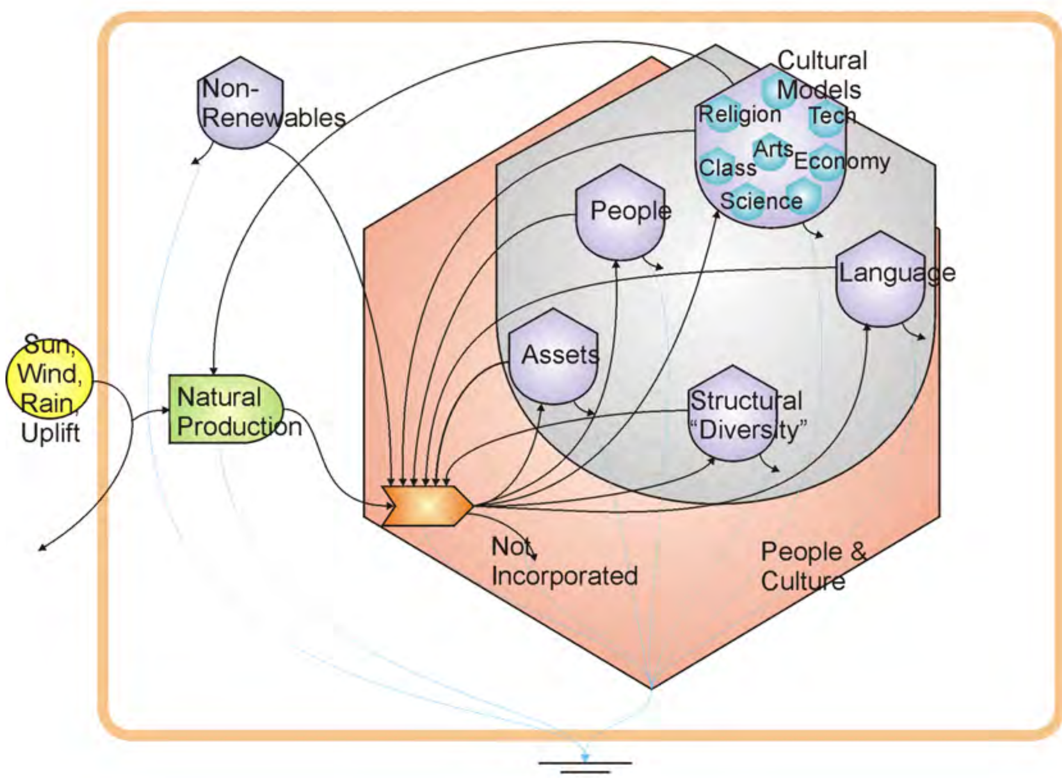


Figure 227: Components of a Sociocultural System

Figure 227 provides a more detailed look within a sociocultural system. Many designs were considered, but this design was the most effective. For discussion sake, some general comparisons can be made to cultural materialist analytic categories. The storage of Assets and Technologies plus the storage of People are roughly equivalent to the Etic Infrastructure. Here is the stuff of production and reproduction, the human creators and the tools we use to extend our reach, both feeding back to recreate themselves and the sociocultural whole. The storage of Structural “Diversity” is roughly equivalent to the Etic Structure for the Cultural Materialist. The flows to and from cultural models is the Etic Superstructure. Lastly, within the storages labeled Cultural Models and Language are the Emic Infrastructure, the Emic Structure and Emic Superstructure. Cultural models and language have the largest turnover times on average, while flows of behaviors, speech, ideas and actions have the shortest.

Consider the continuation of this extensive quotation from Cultural Materialism:

> The causal priority of infrastructure is a matter of the relative probability that systemic stasis or change will follow upon innovations in the infrastructural, structural or superstructural sectors. Cultural materialism, unlike classical structural-functionalism, holds that changes initiated in the etic and behavioral modes of production and reproduction are more likely to produce deviation amplifications throughout the domestic, political, and ideological sectors than vice versa. Innovations initiated in the etic and behavioral structural sectors are less likely to produce system-destroying changes; and innovations arising in the emic superstructure are still less likely to change the entire system (due to their progressively remote functional relationships with the crucial infrastructural components). To take a familiar example: during the late 1960s many young people believed that industrial capitalism could be destroyed by a "cultural revolution." New modes of singing, praying, dressing, and thinking were introduced in the name of a "counterculture." These innovations predictably had absolutely no effect upon the structure and infrastructure of U.S. capitalism, and even their survival and propagation within the superstructure now seems doubtful except insofar as they enhance the profitability of corporations that sell records and clothes (Harris 1979:71-73).

In terms of the discussion and diagrams here, simultaneous innovations in all the storages of a sociocultural system which amplify the capture and use of environmental resources are likely to be “selected for” and incorporated into the system. However, if the storages do not reinforce each other, the innovation is unlikely to amplify production and therefore to be incorporated. As an extreme example, consider the idea that energy could be created by using black holes to connect directly to galactic cores. Such a contention could not be reinforced by existing assets and technologies and would therefore be selected against.

On the other hand, suppose technologies had appeared 100 years ago that could create mechanical energy by burning geologic storages of hydrocarbons, once the decaying organic matter of primordial ecosystems. It would be expected that new structural diversity (division of labor) and cultural models would appear that reinforce the selection of this technology. And so they have.

Or, similarly, if cultural models appear which explain existing neo-liberal free market economics as a “scientific” inevitability, those cultural models will be reinforced. They improve the efficiency of an economic technology that has proven to be history’s incomparable producer of goods, structure builder, fertility enhancer, and dissipater of energy.

In other words, the only final limiting storage in sociocultural systems is the store of assets and technologies capable of amplifying the production of itself and other storages. The other storages are mutable when energy is available, but in themselves do not tap wholly new energy sources.

Turnover Time

Some time is always needed to propagate a new division of labor, train laborers, and share cultural models. These inertias are real and will restrict the speed at which sociocultural systems can transform themselves. However, in each case, with time, it should be expected that structure and cultural models will come to amplify the production technologies and assets of a sociocultural system.

A point to emphasize is that no storages are static. Even when a system appears to be changing little, its storages are depreciating and must be replenished. This fundamental principle of nature is called the Second Law of Thermodynamics, or “Time’s Arrow." Storages are like whirlpools in a stream, which appear to have structure and form, but that are ever-changing as new water molecules reproduce that structure. Likewise, all sociocultural storages are constantly depreciating, and must be replenished by production anew.

Continuing with Harris’s quotation:

> Nothing in this formulation of the probabilistic outcome of infrastructural changes warrants the inference that structure or superstructure are insignificant, epiphenomenal reflexes of infrastructural factors. On the contrary, structure and superstructure clearly play vital system-maintaining roles in the negative feedback processes responsible for the conservation of the system. Productive and reproductive processes are functionally dependent on etic domestic and political organization, and the entire etic conjunction is functionally dependent on ideological commitments to values and goals that enhance cooperation and/or minimize the costs of maintaining order and an efficient level of productive and reproductive inputs. It follows from this that ideologies and political movements which lessen the resistance to an infrastructural change increase the likelihood that a new infrastructure will be propagated and amplified instead of dampened and extinguished. Furthermore, the more direct and emphatic the structural and superstructural support of the infrastructural changes, the swifter and the more pervasive the transformation of the whole system.
>
> In other words, although I maintain that the probability is high that certain kinds of changes in the modes of production and reproduction will change the system, I also maintain that functionally related changes initiated simultaneously in all three sectors will increase the probability of systemic change. Indeed, it would be irrational to assert that ideological or political struggle could not enhance or diminish the probability of systemic changes involving all three sectors. But the crucial question that separates cultural materialism from its rivals is this: to what extent can fundamental changes be propagated and amplified by ideologies and political movements when the modes of production and reproduction stand opposed to them? Cultural materialism holds that innovations are unlikely to be propagated and amplified if they are functionally incompatible with the existing modes of production and reproduction--more unlikely than in the reverse situation (that is, when there is an initial political and ideological resistance but none in the modes of production and reproduction). This is what cultural materialists mean when they say that in the long run and in the largest number of cases, etic behavioral infrastructure determines the nature of structure and superstructure (Harris 1979:71-73).

This crucial question, "to what extent can fundamental changes be propagated and amplified by ideologies and political movements when the modes of production and reproduction stand opposed to them?", has thus been restated in the language of systems ecology. The answer given is the same, and as explained above, it is found in the energetics of ecosystems and their integral relationship with sociocultural systems.

Selection at Multiple Scales within Sociocultural Systems

> The maximum-power principle…suggests that natural selection operating on a variety of system designs tends to select those that generate maximum useful power. Systems that gain more power have more energy to maintain themselves and their habitat and to overcome any other shortages or stresses and are able to predominate over competing units. To maximize power, the energies stored tend to be fed back to pumps, gates, diversity, and so on to accelerate the inflow of more energy either from the same source or from other sources. In other words, systems that survive tend to develop autocatalytic units because that design processes energy in a competitive way, automatically increasing the inflow from the energy source when it is possible (Odum 1983:141).

"Reinforcement" and "feedback" are two everyday terms. Reinforcement is commonly thought of as encouragement or support. Feedback is some sign of approval or disapproval. A teacher might give feedback to a student on a paper. Reinforcement might be an encouraging word, a cash reward, or a sturdy new wall.

For systems ecologists, feedback reinforcement will refer ultimately to an energetic reward for a system design. As discussed in CHAPTER 15, nature self-organizes to "select" for system designs that utilize and dissipate energy faster while maximizing useful power transformations. As explained in the quotation above, "systems that gain more power have more energy to maintain themselves and their habitat and to overcome any other shortages or stresses and are able to predominate over competing units (Odum 1983:141)."

Storages and Flows

The systems diagram (Figure 227) depicts a sociocultural system, and its interactions with the biosphere. This very simple model highlights important storages within a sociocultural system (see Table 37 and CHAPTER 16 for examples of sociocultural storages). Storage compartments in a systems diagram represent concentrations of matter and energy. Ecosystems have many storages such as those of air, water, nutrients, plants, and animals. Storages are concentrations of a quantity, and any concentration is an energy source able to drive opportunistic pathways. We know that all concentrations depreciate, and that nothing in nature is permanent unless energy is added to maintain it. As concentrations depreciate they drive other processes until they reach the background temperature, represented by the heat sink in a systems diagram.

Table 37: Storages within a Sociocultural System

Storages	**Average Turnover Times**

Assets and Technologies
• Food
• Technologies and Material Assets for:
    • Shelter and Clothing
    • Food Production
    • Utilities - Water, Power, Sewage
    • Economic - Financial, Legal
    • Military / Police
    • Transportation
    • Media
    • Schools
    • Government
    • Reproduction
	10 Years

Structural "Diversity" • Division of Labor • Class • Kinship • Age Grades • Sexual Division of Labor	40 Years
People • Men, Women, Children	60 Years

Cultural Models for:
• Technologies and Assets listed above
• Structural "Diversity" listed above
• Superstructure
    • Religion
    • Arts
    • Science, Etc.
	100 Years

Language	500 Years

Autocatalytic Modules

In Figure 227, the production function for the sociocultural system is shown to be autocatalytic for each storage. In other words, the process that creates each storage requires input (feedback) from itself for its creation. The arrow leaving the interaction symbol and flowing into each storage depicts the inflow to each storage. The arrow leaving each storage and ending back at the interaction symbol represents the feedback. This reward loop, this autocatalytic design, is found throughout nature, from physical chemistry, to weather, to learning theory, to genetics. As above, “systems that survive tend to develop autocatalytic units because that design processes energy in a competitive way, automatically increasing the inflow from the energy source when it is possible (Odum 1983:141).” It should be quickly added that another key phrase here is “tend to develop." Linear pathways (pathways without feedback) that flow into a storage are also important when the storage is low. These pathways are thought to be replaced by autocatalytic designs when energy is available, because that design can amplify production, and dissipate energy more quickly.

Interaction and the Production of Sociocultural Systems

In Figure 227, all the storages are linked to the same interaction symbol. This design indicates that each storage is necessary in the capture and use of environmental inputs to sociocultural systems. The feedback from each of the storages contributes to maximum power for the sociocultural system. In plain English, behaviors, speech, material assets, technologies, social structural design, division of labor, human anatomy and physiology, and belief systems or cultural models are retained within a sociocultural system if they feedback in combination to enhance the sociocultural system’s ability to capture and utilize energetic resources. As above, “The maximum-power principle…suggests that natural selection operating on a variety of system designs tends to select those that generate maximum useful power (Odum 1983:141). Outputs that do not enhance this final end are not incorporated into the system (as shown in the drawing); rather they are selected against. Outputs that are not incorporated at one point in time may later reappear and be selected in the future.

Sociocultural Systems within Ecosystems

Both the sociocultural system configuration and the environmental inputs are dynamic, constantly forming and reforming in the energy flux of an open natural system. This point needs to be emphasized: sociocultural systems exist within larger systems of ecosystems and the biosphere. These systems are open systems, forming and reforming within the flux of free energy gradients. Sociocultural systems have important feedback effects on the larger ecosystem. This is represented in the diagram by the feedback line from the sociocultural storages to the producer labeled “natural production.” Again in plain English, we live in a world in which we humans have modified the biosphere for our own needs. Examples are agriculture, silviculture, domestic animals, landscape changes, water recycling, fuel use, and countless others. Feedback from sociocultural systems modifies natural production to increase and assure natural outputs that are useful to itself. The actions of humans ripple through ecosystems and the biosphere, effecting those systems and ultimately sociocultural systems again. In this way both culture and nature are highly dynamic, neither the static backdrop for the other, yet intimately joined in the most fundamental way. Sociocultural systems are first and foremost material systems, which co-evolve (self-organize) with nature. To understand the evolution of cultures, one must proceed by thoroughly understanding these material processes which define all natural systems.

Turnover times

The dynamics of sociocultural systems is greatly affected by turnover times. Turnover time is the average residence time of any quantity within a storage. For example, the average lifespan of any human within the “people storage” is approximately

50 years. If not another person were born in the world, the earth would remain inhabited by humans for 50 years at least. Turnover time is equivalent to average lifespan for living things. But it is a more general term, because it refers to the length of time that a quantity remains in a particular state and concentration.

For comparison, the average turnover time of material assets produced by people is probably less than a human lifespan. Machetes rust away, food storages degrade, books decompose, houses collapse, computers stop working. In Table 37, the average turnover time of all material human assets is 10 years. This is a suggested averaged number of all assets aggregated into one storage, and can be separated into several storages with different turnover times if desired.

Environmental storages similarly have turnover times. Some are much larger than human time scales, such as geologic storages within earth cycles. The concentration and storage of sediments into rock in the sedimentary cycle is one example. The millions of years in the formation of fossil fuels is another. Other environmental storages are much faster than human scales, such as the lifespans of small plants or animals.

Cultural Models

In Figure 227, other sociocultural storages are identified. A storage of “cultural models” or belief systems is shown farthest to the right. Following standard systems modeling conventions, this indicates that it has the longest turnover time (Table 37). In other words, cultural models on average are relatively slow to change. This is a hypothesis, but a reasonable one. Common sense tells us that systems of beliefs can be “behind the times.” Certainly individual beliefs or ideas have rapid turnover times. But articulated and shared models can have great duration, especially if they regard some feature of a sociocultural system that is of great value in the production and maintenance of that system. For that reason, cultural models that explain the process of agriculture or domestication have great longevity. Cultural models for technologies of food gathering and preparation are also widespread within a cultural system. In more recent times, cultural models for technologies of intensive production and distribution have had long turnover times. These technologies include financial technologies (markets), legal technologies, and military technologies, as has been discussed in elsewhere.

Other cultural models can be expected to have shorter turnover times and smaller areas of coverage. In Figure 227, storages of science (as different from technologies), art, and religion are shown to the left within the “cultural models” storage. It is suggested that models of these sorts are more quickly replaced within a sociocultural system. This is also a hypothesis, but it seems reasonable.

Structural Diversity is the last tank shown in the sociocultural system. As explained in CHAPTER 21, human organization, hierarchy, division of labor, and economic specialization are all ways to describe this characteristic of sociocultural systems. Structural diversity shares many similarities with species diversity within ecosystems. Both probably function to prevent competitive exclusion and to capture additional energies. Both however have high-energy costs, as specialization must be maintained, and pathways between units must be organized.

CHAPTER 20
HIERARCHY IN LANGUAGE AND CULTURE

Many systems researchers consider *information* to be a third fundamental entity separate from *matter* and *energy*. While this position has value, for example when considering DNA to be genetic *information*, its application to human culture is often muddled by our popular use of the term information in speech and cultural models.

Furthermore, or perhaps due to this confusion, use of the concept of *information* from information science can encourage idealist reasoning, which is incongruent with systems ecology or cultural materialist theoretic frameworks.

Further still, attempts to *quantify* the information content of a culture are in their infancy, and require greater participation by linguists and anthropologists, who can attempt to disassociate the object of study from the models and language used by researchers.

For these reasons, the proceeding five chapters proposed systems modeling techniques of people and culture that made little use of information theory. This position needs to be clarified and defended since it challenges the orthodoxy of general systems theory.

Hierarchy

Information theory can tell us something about parts and connections, but it does not recognize "qualities" of information and therefore information hierarchy. Human language and culture are hierarchical systems of unlike scales, some meaningful (i.e., morphology) and others not (i.e., phonology), some conceptual (cultural themes) and others processual (cultural models).

Both language and symbolic culture (which we create with language) can be interpreted with the systems principle of hierarchy. Hierarchy implies that there are multiple, nested scales in natural systems. Scales exist in part-whole relationships, with distinct properties at each scale, and additional emergent properties of the whole. Moving from left to right in a systems diagram, energy decreases, territory increases, convergence increases, and feedback effects increase.

Language

It has been long recognized that languages are multiple-scaled systems. Phonology, morphology, and syntax are nested parts, within a language whole. Each is a distinct system in itself.

Phonology

Phonological systems turn the stream of continuous human sound waves into recognizable sound units, which are the building blocks of the morphological systems. These sound units are constructed within a language by the conjunction of distinctive features.

The leftmost three-dimensional matrix in the drawing (Figure 228) represents this system of possible conjunctions of features. In fact, phonological systems have multiple-dimensions and might be better envisioned as a multi-dimensional space (which cannot be drawn). Examples of distinctive features in phonology are voicing, point of articulation, fricative, stop, and other manners. Each of these may form a distinctive feature in a language. When a language uses one distinctive feature or another, it uses that feature across a range of sounds in a systemic way. Phonology is therefore the study of a system of relationships, which constructs units from a continuum of human speech sound. These units are called phonemes.

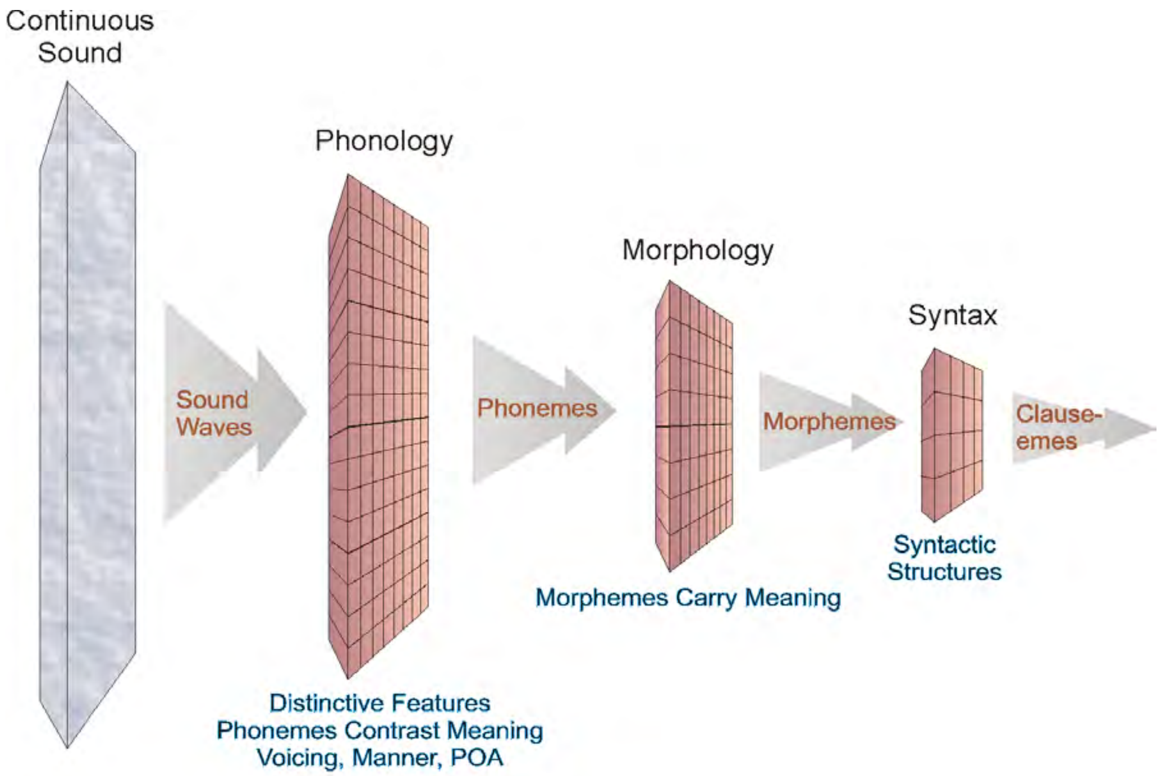


Figure 228: Hierarchy in Language

Morphology

Morphology is the patterning of phonemes into a system of meaningful units, called morphemes. Morphemes are patterned by semantic features into a multi-dimensional system, analogous to phonological systems. Languages that distinguish gender (as in English--he/she in pronouns, etc.) will exhibit that feature consistently and in structured ways. Only a subset of possible semantic features is utilized by any language, just as no language uses all possible distinctive features in its phonology.

Syntax

Syntactic systems are similarly structured into clause types and phrase types. A language is a system of these parts, phonology, morphology and syntax, which produces a whole--human communication.

Some other hierarchy concepts can be considered for languages:

Territory

Within a community of speakers, syntax has the largest spatial territory, while phonological systems have varieties across a region known as dialects. It is suggested that morphological variation is intermediate to the other two.

Time

Phonological systems change slowly over time, but they do change. Morphological systems are very resistant to change and shift more slowly. Syntactic shifts are slower still. The science of glottochronology reconstructs patterns of language change to judge the temporal histories of language splits and divergence. For instance, English is more closely related to Dutch than it is to German because it diverged from proto-English-Dutch at a later time (actually the history is even more complicated than that, including the Norman invasion of England and extensive contact with the Friese of northwestern Holland). Proto-Germanic was the earlier source for all four (English, Dutch, Friese and German).

Convergence

An infinite stream of human sound waves is conditioned by the phonological system of a language. Phonemes are the resulting product, which are then assembled by the morphological system. One or more phonemes compose each morpheme. Clauses are the structured products of morphemes. One or more morphemes form a clause.

Feedback

Phonemes condition each other by their proximity in a word or phrase. The simple past tense in English can be represented by allophones [-t] and [-d], dependent on the consonant that precedes them, as in /wak/ and /wakt/ (walk and walked), compared to /rab/ and /rabd/ (rob and robbed). This is feedback within the phonology system. Morphemes can also condition the phonemic shape of a word. Box becomes boxes, fox becomes foxes, but ox becomes oxen. The verb leave becomes left, not leaved*. This is feedback from the morphological system back to the phonological system.

Symbolic Culture

The definition of culture that I prefer is not limited to ideas and beliefs (symbolic culture, Figure 229). It includes also the material tools and behaviors that articulate human beings with nature (the infrastructure), and the social organizational features that relate humans to one another (the structure). These components of a culture are co-products of humanity (Figure 230). For the purpose of this discussion, however, I am comparing exclusively symbolic culture and language (Figure 228).

Cultural Themes

Cultural themes organize the infinite world into meaningful units. Within a culture, themes exhibit patterns that group concepts or objects together. A knife is grouped with a fork by a theme, call it "tools for meals." The knife and fork might also be grouped with a cup, but the relationship is not as strong. A refining of the knife/fork theme might be "tools for eating, not drinking, held in the hands, etc." The knife and fork may be grouped with a hammer as "hand-sized tools."

Other themes are more complex and difficult to define. A theme like "beauty", as in a "beautiful sunset", is constructed from many concepts, some physical, some emotional, some tactile, etc. Furthermore, the assertion that a sunset can be "beautiful" is not universal, but it the product of a symbolic culture. The continuum of the biogeophysical world is not perceived directly by people. Our symbolic culture teaches us how to interpret the perceptions that we experience with our senses.

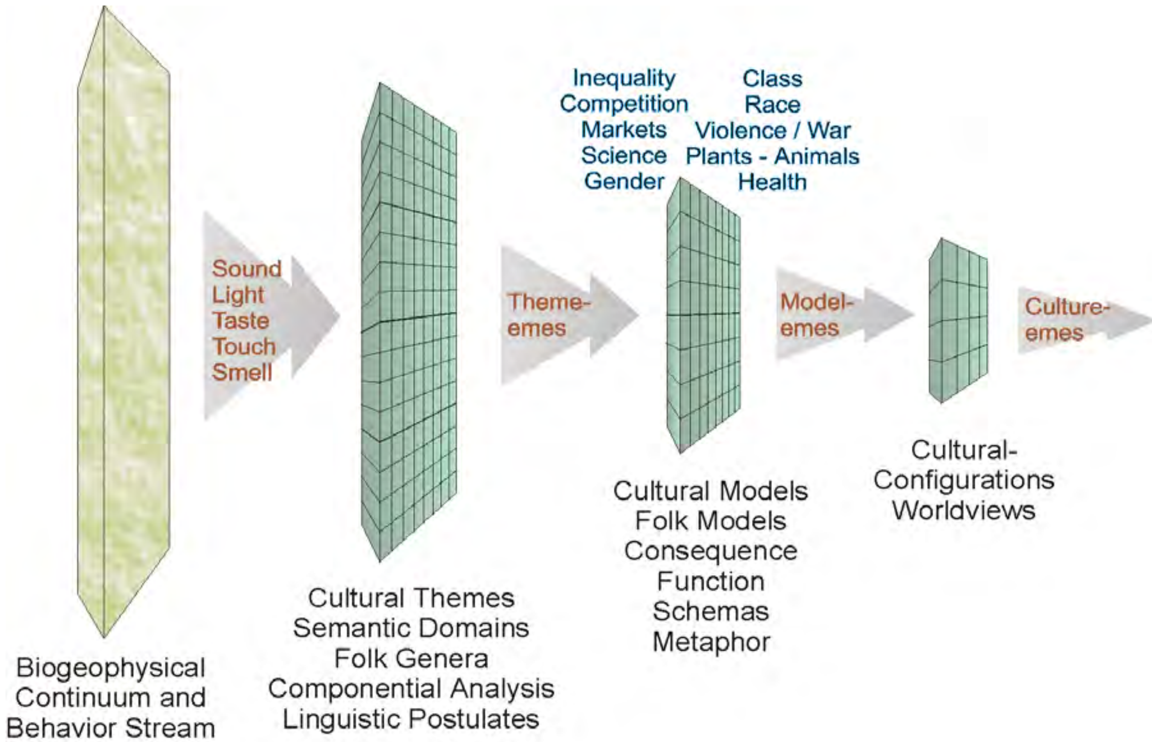


Figure 229: Hierarchy in Symbolic Culture

Cultural Models

Expectations, understanding, consequences, functions, these are the products of cultural models. Cultural models are beliefs about "how the world works" (the physical, emotional, ethical, cosmological, or other "worlds"). They express our expectations of "cause and effect." Cultural models are often borrowed from one semantic domain into another with metaphor, "her anger was boiling over."

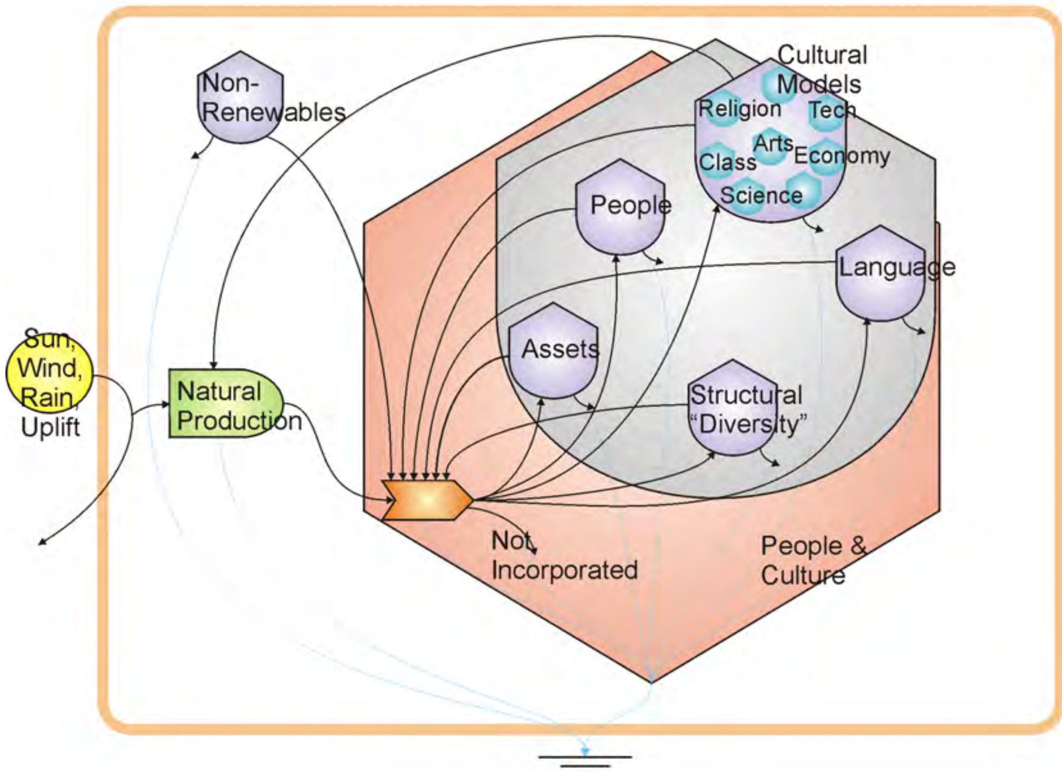


Figure 230: Components of Culture
In the definition used here, culture includes material assets, social structural diversity, cultural models, and language, and the interactions between these components, the natural environment, and the people that continuously produce and re-negotiate their forms. These components always co-occur. Not all of these components are shown in every drawing, but they should be assumed to exist wherever the word culture appears.

For important themes in a culture, there are multiple cultural models of explanation. Models of "health" are many, some biological, some spiritual, some astrological, others chemical, etc. There are cause-and-effect claims that come in countless varieties for this cultural theme of great relevance to people. Important models may cross many cultural themes. The model of "free market competition" permeates many themes, including sport, biology, racism, even "thinking" (IQ). Cultural models of "ethnicity" and "gender" are constructs that organize our expectations of human behavior. Cultural models about violence structure our tolerances and expectations of physical force. Cultural models of nature structure our behaviors towards it (her?). A jungle forager's models of plants and animals would surely be different from those of a farmer. Indeed, even the plant-animal distinction is the product of specific cultural models of nature.

Scientific models are cultural models that permeate and are permeated by other cultural models. As noted, the concept of natural selection has kindred models in economics, social theory, cognitive science, education, etc. Cultural models of "environmentalism" combine scientific models of ecology with models of social justice, spiritualism, life/death (when ecosystems are said to be "destroyed"), and others. In fact, all scientific models are situated within a political, economic, social, spiritual, etc. context, which structures the activities of science and its applications.

Ecological (and Social) Engineering

The concept of "engineering" is a product of western cultural models that emerged with the success of ancient mechanical technologies. Quantitative models appeared which refined the methods and reliability of technologies for constructing buildings, bridges, ships, tools, weapons, and countless other useful goods. In more recent years, "ecological" engineers applied mechanical analogies to nature. Ecological engineering has shed much of its mechanistic and reductionist beginnings, in favor of systems thinking, yet these themes remain, as does the overarching theme of engineering--control.

Ecological engineering competes with other cultural models for influence in the cultural soup. Opponents range from free-market capitalists, to aesthetic spiritualists, to right-wing militia, who each abhor the "control" of governments, or engineers. Ecological engineering (especially earlier "equilibrium" versions) has had proponents among conservatives seeking to assure the political-economic status quo. Scientists of all stripes are part of the symbolic milieu of cultural themes and models. Their ability to influence the world is not assured. They must re-negotiate their position continuously, as must all cultural models.

Science and Cumulative "Information"

To my mind it is doubtful that cultures evolve "information" storages that are progressively finer approximations of a single knowable reality. At times, scientific models are cumulative and self-correcting, however, we are well aware that the discipline of science is located in many other social-political-economic contexts, which shape the nature of the models produced. If cultural information does "accumulate", it is along countless dimensions, very few of which have anything to do with science. Instead, perhaps, very many of those themes have everything to do with the age-old processes of perseverance in a world of limits.

Language and Symbolic Culture

Language and symbolic culture facilitate the transmission of culture from one person to the next and from one generation to the next. In this sense there is an analogy to genetics. Indeed, as we know now that DNA is organized hierarchically, the analogy is even stronger. Like DNA, language and symbolic culture perform a thermodynamic function in self-organized systems. Genetics permits the replication of nature-tested physical-chemical pathways. Genetics further makes possible the production of eco-systems. These systems have processes and feedbacks at scales larger than individuals or species.

In analogous fashion, language and symbolic culture make possible the replication of human-cultural systems. As all systems, human-cultural systems self-organize within the open flows of energy to do "useful" work and to dissipate energy. Unlike all other systems with the exception of biological life, human-cultural systems use transmittable "memories" of their designs to reproduce themselves, at great energetic savings over continuous re-organization.

If we accept the principle that the genetic storehouse in systems increases and then levels off with time, what is the nature of the cultural models that also grow in volume, quantity, complexity or some other measure? Is a greater quantity of cultural models the "cause" of human expansion, or the "effect," or perhaps cause and effect together? Is the greater accumulation of genetic code the "cause", "consequence" or both of ecosystem complexification in evolutionary time?

Whatever the answer to this chicken and egg question, it is possibly moot, or less interesting than others. By modeling human-ecosystems (without genetic or cultural "information") we can still identify nature's contributions to human life-support systems. With or without the "text" of the story written in an ecosystem's genetic code, the principles of science can be applied to the system. Clear evidence of the genetic "script" of an ecosystem is the ecosystem itself. In like fashion, indirect evidence of human cultural codes everywhere surrounds us in the material and organizational products of human life.

Pragmatics - What's the payoff?

People use technologies in their quests for survival. Technologies are the most direct means by which humans contact the biogeophysical limits of nature. If science can facilitate the production of technologies, and therefore human contact with nature, then it serves a useful purpose for humans. Regardless of the quest for ultimate truth, science may (often only temporarily) improve the conditions of life for people.

Systems modeling is a form of science that offers one means towards that end. Dynamic models of complex systems have promise for some degree of prediction and control. It is important to remember, however, that within a culture there are many competing cultural models. These models might be about power or inequality or ethnicity or spirituality or cosmology. Each of these models may map well to an existing demo-techno-econo-environmental context, explaining life in terms that rival science for many culture members. The people of a culture will argue, persuade, negotiate, and disagree over the relevance of one model over another for explaining extant predicaments and offering solutions.

Where does a social scientist, a scientist of humanness, direct their efforts and attention. While that is an individual choice, my choice is directed by pragmatics. While language and cultural models are fascinating topics in their complexity and revelation, real problems in a world of limits can best be addressed by social science that focuses its attention on the technological articulation of human-environment conjunctions.

As a pragmatic social scientist that conducted fieldwork on Bonaire, I have addressed myself to the economic strategies and cultural technologies that articulate Bonairians with their material world, both local and global. In the process of learning Papiamentu, I wrote a preliminary phonology, and began a morphology and syntax. But they are not my first priority. The world today is asking questions about the impacts of humans on ecosystems, the pros and cons of economic development, third world population growth, and the human use of limited natural resources. A case study of the causes and consequences of economic development for individuals and an island nation has relevance to understanding and shaping similar events in countless settings around the world.

CHAPTER 21
HOW SYSTEMS ECOLOGISTS HAVE MODELED HUMANS AND CULTURE

A goal of this dissertation has been to utilize the general paradigm of systems ecology, as envisioned by Odum and his students, but to simultaneously agitate against that paradigm, and so to interject the models and purposes of an anthropologist. From this process emerged some practical approaches to fieldwork and analysis, and new tools for addressing some enduring theoretical concerns of anthropology.

This chapter will re-focus these lessons back on systems ecology in an effort to improve its usefulness for social scientists.

Structural-Functional vs. Evolutionary Models

The following is a review and discussion of current approaches to modeling ecosystems with humans from the perspective of systems ecology as practiced by Odum and others. Throughout the discussion there are suggestions for improvements to current approaches. The major points are summarized here:

1. Division of Labor / Diversity – The amount of economic specialization in past and present societies is a key component of the cultural-ecological dynamics within. This feature should be represented in models of ecosystems with humans. "Division of Labor" shares similarities with the "Diversity" concept in ecology.
2. Social Hierarchy / Inequality – The differential control of productive assets and resources by individuals or groups (Social Hierarchy) is another determinant feature in the self-organization of a sociocultural system. This feature and the first (Division of Labor) are indicative of a particular level of sociocultural integration within explanatory cultural evolutionary scenarios (per CHAPTER 21).
3. Individuals or Corporate Groups and their Assets vs. Economic Sectors and Institutions – The principle human units for analysis should be individuals or corporate groups, not institutions or economic sectors.
4. State or World System Context for all Contemporary Models – All modern day human "systems" must be understood first within the larger context of States or World Systems (see CHAPTER 8 and **Modern States and World Systems**, CHAPTER 16 for further discussion)

The drawings and discussions below will be compared with ethnographic cases and models of culture change (CHAPTER 16). Case studies of past and present cultures provide a penetrating lens for viewing our contemporary world. By comparing cultures at different time, place, size, and complexity, anthropologists have gained great understanding into the ecological and social processes that explain cultural stability and change. Applying these insights to systems modeling leads to suggestions for better modeling of ecosystems with humans.

The systems diagrams below are typical of the ways humans (with culture) have been conceptualized in systems ecology. The social theory that they embody is akin to structural-functionalist sociology (i.e., (Parsons 1951)) and anthropology (i.e., (Radcliffe-Brown 1952)), which were influential in the middle of this century, but which have since been much transformed or abandoned by social scientists. Structural-functionalists looked to social structure and the role of institutions in the maintenance of social systems. Social systems were often compared to organisms, and analogies made between institutions and organs within a body.

At their best, structural-functionalist models produced useful descriptions of a society’s internal functional relationships at a point in time. However, this ahistorical, anatomist’s view of society has certain problems. The boundaries and physical identity of a “social organ” are difficult to discern. "Social organs” were highly abstracted social objects, with names like education, government, or health, which are difficult to identify or operationalize.

Furthermore, the processes that relate social organs were expected to be homeostatic or system maintaining in nature. This politically conservative feature of structural-functionalism has been roundly criticized by social scientists. The conservatism of the mid-century sociocultural milieu, one that perhaps sought stability and ignored or de-emphasized social conflict, is implicated in the popularity of the structural-functionalist paradigm. However the inattention to historic or diachronic processes has emerged as a crippling problem with the approach. Structural-functionalists have been criticized for dealing poorly with culture change and evolution, and with political-economic conflict. As one sociology textbook summarizes:

> The functionalist approach has difficulty dealing with history and processes of social change. It fails to grasp the never-ending flow of action that occurs among people. Yet the real world consists of transition and flux. Moreover, the functionalist perspective tends to exaggerate consensus, integration, and stability while disregarding conflict, dissensus, and instability (Vander Zanden 1990:52).

It is not simply the matter that structural-functionalists did not incorporate all known social facts. All theories or models simplify reality for the sake of producing understanding. However, the absence of these particular, strategic ingredients has profound theoretical impact.

The structural-functionalist's static or synchronic view obscures the evidence that exists in history of the "processes" of social change. Those processes are brought to bold relief when histories are compared between cultures disparate in time and place. As Marvin Harris wrote in 1968:

> In effect, in order to assign priorities of functional order within a sociocultural organism, that is, in order to be able to describe its structure, we must simultaneously study its history and the history of similar organisms. From such a study there emerges a conception of how the parts of sociocultural systems relate to each other in general and specific terms, for we observe the phenomena of parallel and convergent development and note how the changes in one part are regularly succeeded by changes in another. Parallel and convergent evolution made manifest through comparative and diachronic anthropology is the anthropologist's equivalent of the physiologist's laboratory. To ignore the results of the natural experiments which constitute the stuff of history is to abandon all hope of understanding how sociocultural systems are put together in the present (Harris 1968:530).

While cultural evolutionists generally accept that there are functional relationships that exist between segments of a society, emphasis is placed on creating theories that can additionally explain the transformations of societies within historical scenarios and within their ecological contexts. This comparative-evolutionary approach has drawn many anthropologists to explanations that emphasize human-environmental interactions, technological innovations, human demography, and political-economic strategies. Details of this research strategy have been discussed in the previous chapters, and can be found in Harris ((Harris 1979), (Harris 1989), (Harris 1999)), and Johnson and Earle (Johnson and Earle 1987). Applying this evolutionary and ecological social theory from anthropology can improve systems modeling of ecosystems with humans.

A Need for More Space and More Context

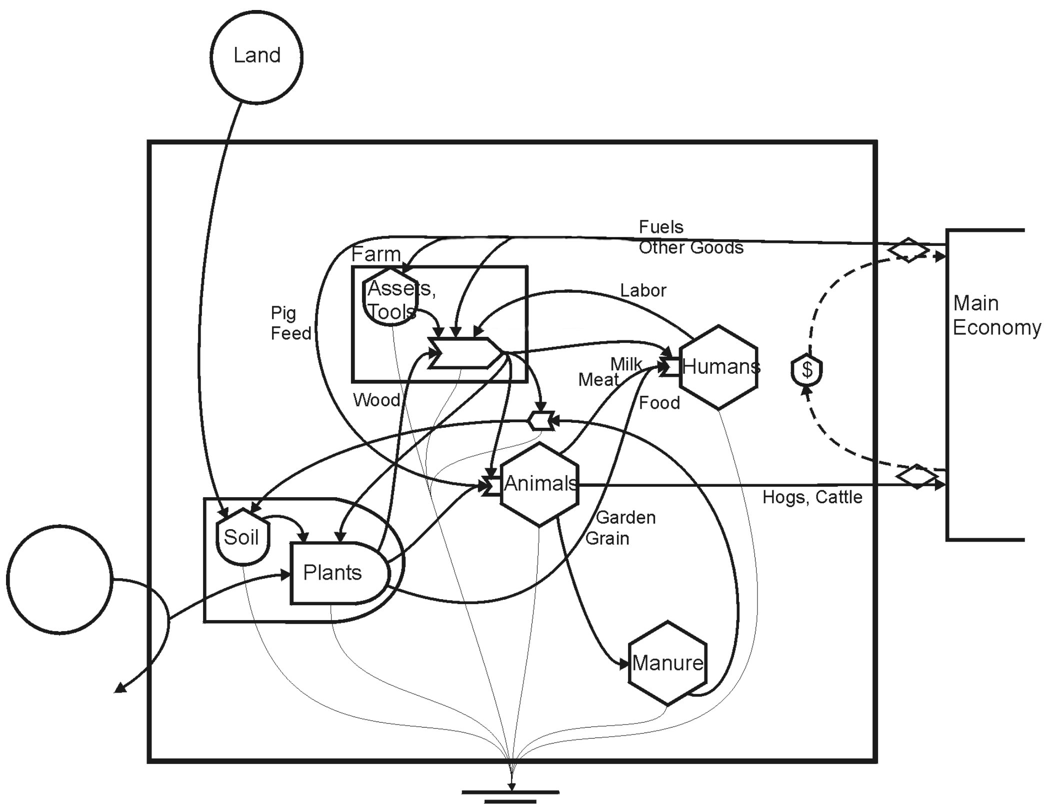


Figure 231: A Farm in Arkansas
Energy flows on Taylor farm, Arkansas. Based on (Burnett 1978 in (Odum 1983:527)). Compare this diagram with Figure 41 and especially Figure 108 and Figure 195. These drawings attempt to situate farming within its state context.

This systems diagram (Figure 231) (Odum 1983:527) depicts a farm in Arkansas. This diagram describes the functional ecological interrelationships between a farm, and a "main economy." In this type of diagram "Humans" are aggregated into a single top consumer. The diagram is useful for identifying the important interconnections within a human modified farm system, which can lead to better management of the farm.

However, if it is desirable to say anything else about farming, about this rural human niche, then this model is not sufficient. It is not explanation enough to picture this farm duplicated across a landscape. By modeling a single farm, this diagram cannot show the economic specialization among farmers, or the political and economic inequality between farmers and the "main economy." Furthermore, at this small scale, this model does not show the financial, legal and military specialization in the main economy, which makes this human settlement pattern possible. These are critical considerations for understanding how this high-energy Texas farm niche (which includes this particular farm) could come to exist.

When farm systems in other cultures are depicted, as in Figure 232 in Java (Odum 1983:515), the same can be said. While this is a useful snapshot of the complex interconnections that make a Java home garden work, it does not give any indication of why it exists.

It needs to be recognized that this Javanese farmer lives within the womb of an extremely specialized and hierarchical industrial state society. The Java state has set the essential human-environmental context for this Javanese farmer, eliminating violent struggles for land between village communities, and evolving a currency-based market system of exchange. From the model it can not be explained why the Javanese have home gardens, why they are not simply hunting and gathering in small groups spread on the landscape, or why they are not intensive agriculturalists working on irrigated fields to feed and clothe an archaic state bureaucracy and its army.

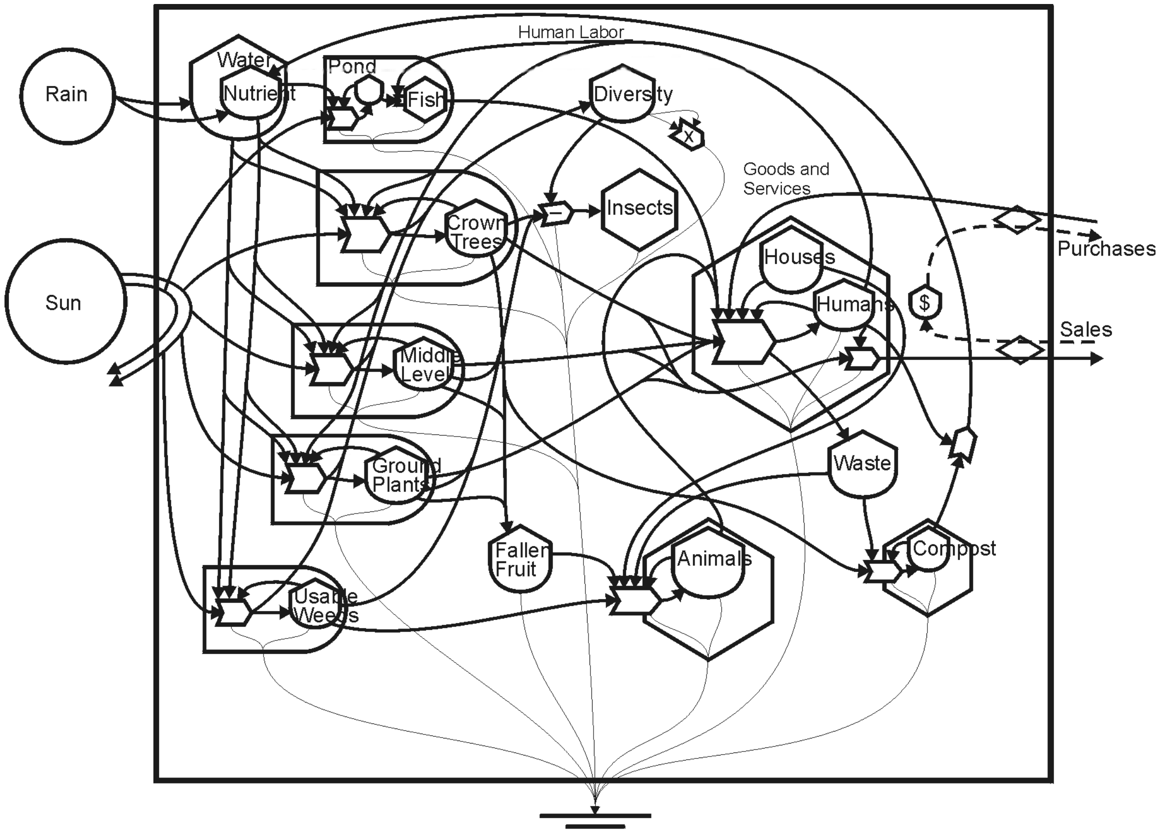


Figure 232: Java Home Garden
Dooryard garden system. Based on (Odum 1983:515)

Suggestions

Moving to a larger spatial scale to include many rural farmers, or an entire rural economic zone, would answer some of these concerns. And the results would have important theoretical implications for understanding States. In state societies, rural populations are known to exhibit marked specialization and marked economic hierarchy in terms of the assets that each participant controls. Sampling a large rural population within either of these state societies would no doubt uncover specialized farmer niches, rural transport niches, rural markets and shopkeepers, storage facility owners, and other functional needs that might be met by some of the farmers themselves, or by specialists. It is this specialization that has emerged as states have emerged, and which has lead to the capture and use of the greatest resource bases in history, and produced the largest human populations in history. For these reasons goat farming on Bonaire was situated within its state and world system context. Figure 41, Figure 108, Figure 178, Figure 179, Figure 180, and Figure 181 all depict farming as a diversified niche, within a wider and further diversified economy. This design also appears in the Inka (Figure 195) and State models (Figure 198).

Needing an Ecology that is Cultural Ecology

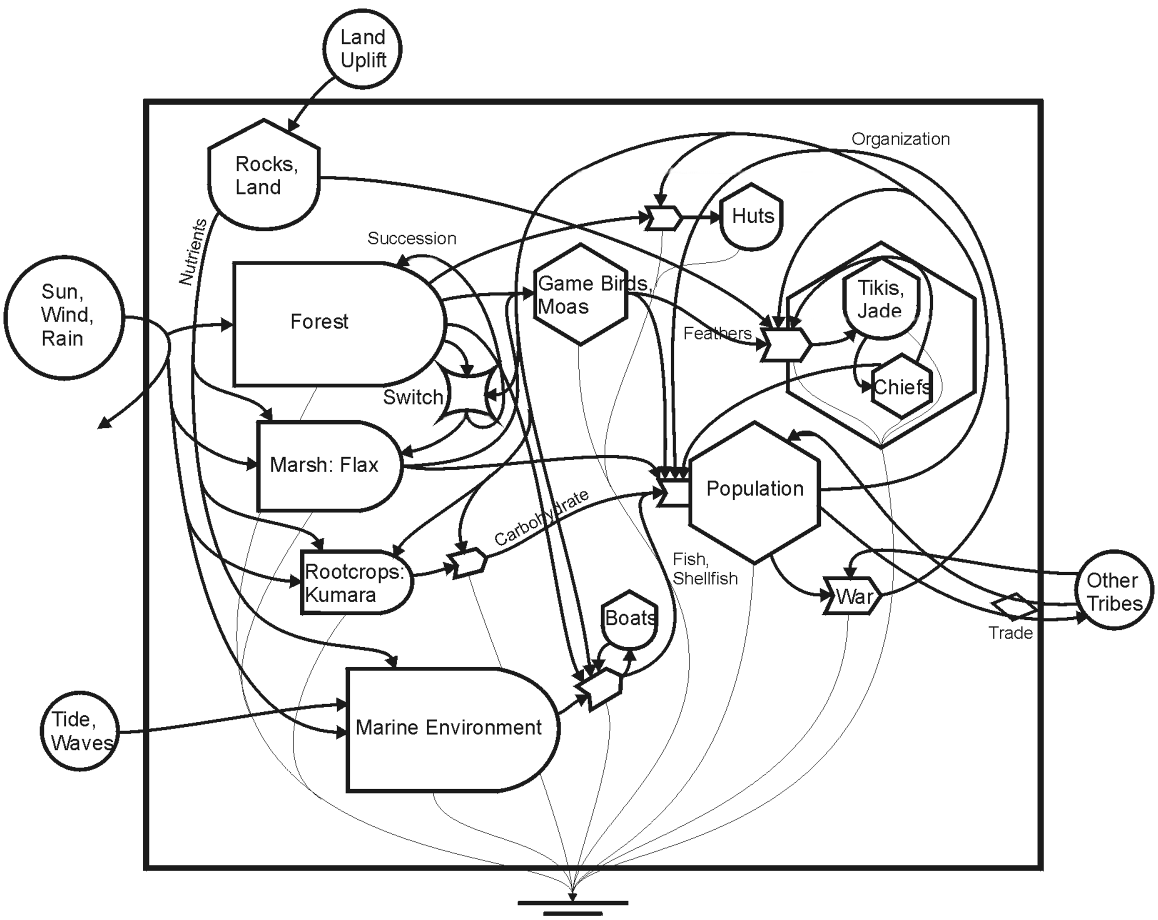


Figure 233: Maori Chiefdom
Early Maori culture in New Zealand. Based on (Odum 1983:512). Compare this diagram with Figure 192.

Many questions and interests can only be addressed at a larger spatial scale. This drawing (Figure 233) (Odum 1983:512) depicts the regional system of the Maori in

New Zealand. The Maori in prehistory and at contact were known to have been simple chiefdoms.

While the chief in a chiefdom represents the pinnacle of inequality, additional widespread social differentiation and emergent specialization was a defining and determinant feature of the Maori chiefdom (see **Chiefdoms**, CHAPTER 16). Chiefdoms like the Maori cover many productive environmental niches (marine, agriculture, forest, marsh), circumscribed by ocean and other chiefdoms, which has lead to specialization and inequality among villages confined within a crowded landscape. The "Chief", who is featured in the drawing, is only the most visible feature in a hierarchical and specialized social structure and intensified economic system. The important point is that this specialization and intensification is what is the ecological heart of the Maori chiefdom. It explains why and how the Maori became chiefdoms, and the limits to intensification and specialization explain perhaps why they did not become states.

While this next drawing, Figure 234, is admittedly simplistic by design, it can further illustrate some issues for making drawings at this larger scale.

Early state societies like Egypt evolved intensive farming and fishing strategies that produced food for the entire state (see Archaic States in CHAPTER 16). With the early Egyptian state there appeared an elite class of hereditary rulers, priests, legal experts, accountants, land surveyors, military specialists, etc. who were supported entirely by staple taxes from non-elite agriculturalists. Also with the early state there appeared highly specialized non-elites--stone masons, weavers, metallurgists, craftspeople, and full-time soldiers. Those specialists were supported by elites who fed them from the staple taxes they collected, in return for their valuable crafts (armor, weapons, storage pottery, cut stone, clothing, and elite valuables). Taxes were also used by the elites to feedback and finance large construction projects like irrigation systems, or large fishing boats, or to finance military campaigns that expanded the resource base of a state by capturing new resources in land, water, mines, trade routes, etc. In this drawing, a large assets storage should be associated with the elite class (the "Pharaoh" and the many other elite specialists), which could then be shown to feedback and support the huge population of agriculturalists and craft specialists. Related to that storage should be another, containing soldiers that defended elite privilege and coerced non-elites into cooperation in the state system.

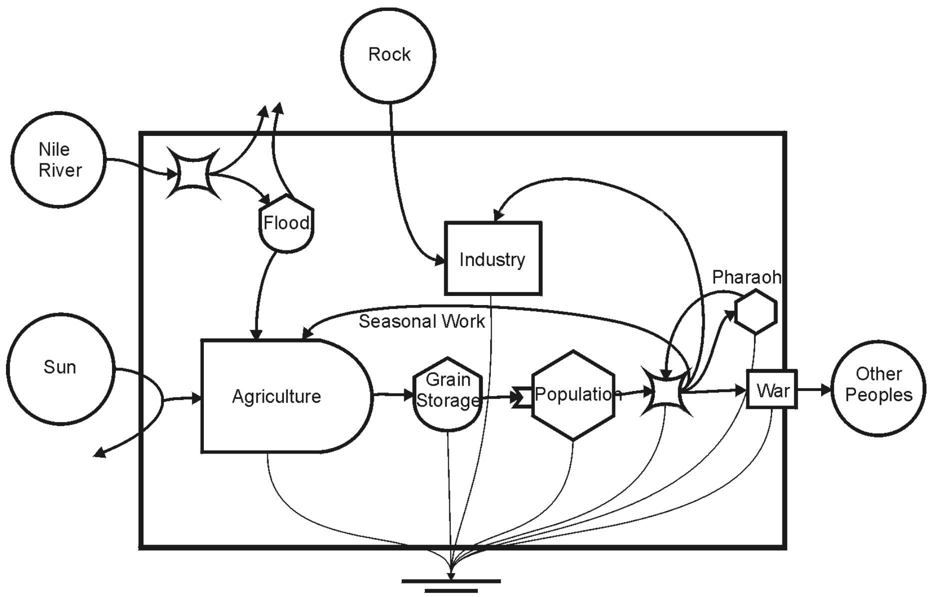


Figure 234: Egyptian State
The pyramids and energy modulation in ancient Egypt. Based on (Odum 1983:516). Compare this diagram with Figure 193, Figure 194, and Figure 195.

Suggestions

Social specialization and inequality should be shown in drawings of states or chiefdoms (see Chiefdoms, CHAPTER 16). The control of large storages of resources by elites appears to have been an important autocatalytic feedback in the intensification of agricultural production systems. Specialization can be depicted by showing separate consumer symbols for distinguishable economic groups (metallurgists, stone masons, farmers, etc.) (Specialization can also be depicted by a storage of Diversity/Division of

Labor). Inequality can be depicted by showing larger or smaller storages of assets (quantified when possible) associated with each of the consumers. It was the emergence of economic specialization within the "Population" that made the Egyptian system into such an intensive production system. That web of specialization (diversity) should be depicted. And it was the presence of a full-time standing police/army that made it possible to enforce elite privilege, inequality, private property rights, and other legal codes. The emergence of standing armies is another hallmark of the state and should be shown (see Archaic States, CHAPTER 16).

Modern States Need (Cultural) Ecology Too

This discussion of chiefdoms and archaic states improves our understanding of contemporary states and world systems. Through time, elite merchants in archaic states have been superceded by financial elites and transportation elites in modern states. Monarchies have fallen, but have been replaced by a new class of political and military elites. New technologies have co-evolved with industry elites, media elites, education elites, and legal elites. Contemporary states are in fact the most specialized and hierarchical that the world has ever seen.

However, in these two drawings of modern states (Figure 235, and Figure 236) (Odum 1983:537), (Odum 1996a:185), there is no depiction of the tremendous specialization and unequal control of resources that are characteristic cultural-ecological features of large polities, both historical and current.

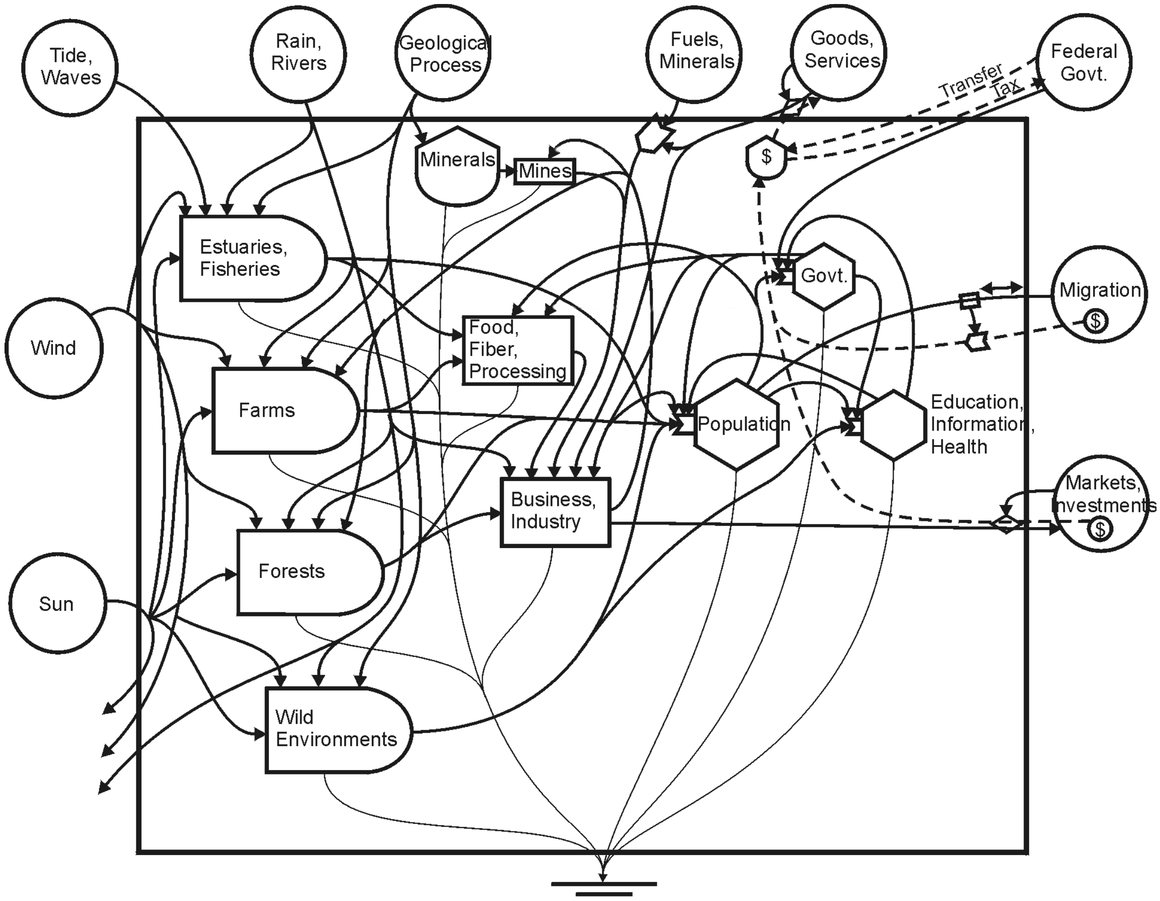


Figure 235: Modern State
Main features of regional systems of landscape and human settlement. Based on (Odum 1983:537). Compare this drawing with Figure 196, Figure 197, Figure 198, Figure 199, Figure 200, Figure 202, Figure 203, and Figure 204. For the Bonaire case, compare this diagram with Figure 104, Figure 108, Figure 94, Figure 95, and Figure 96.

Economic Sectors

The cultural differentiation that does exist in these drawings is "economic sectors" and "institutions." While diagrams that show economic sectors are valuable for identifying the connections between nature and technologies, they do not hint to the tremendous social hierarchy and specialization that co-evolved with the emergence of those economic sectors. They do not identify the owners of the technologies/assets who have accumulated storages of capital, and who are using that storage to feedback and build still more assets. The homogenous "Population" should be differentiated into elites and non-elites, with storages of the economic sector's assets associated primarily with elites.

Institutions

The social specialization that does appear in the drawings is government and education. These are sometimes called "institutions" and, once again, should be divided into elites and a large group of non-elites.

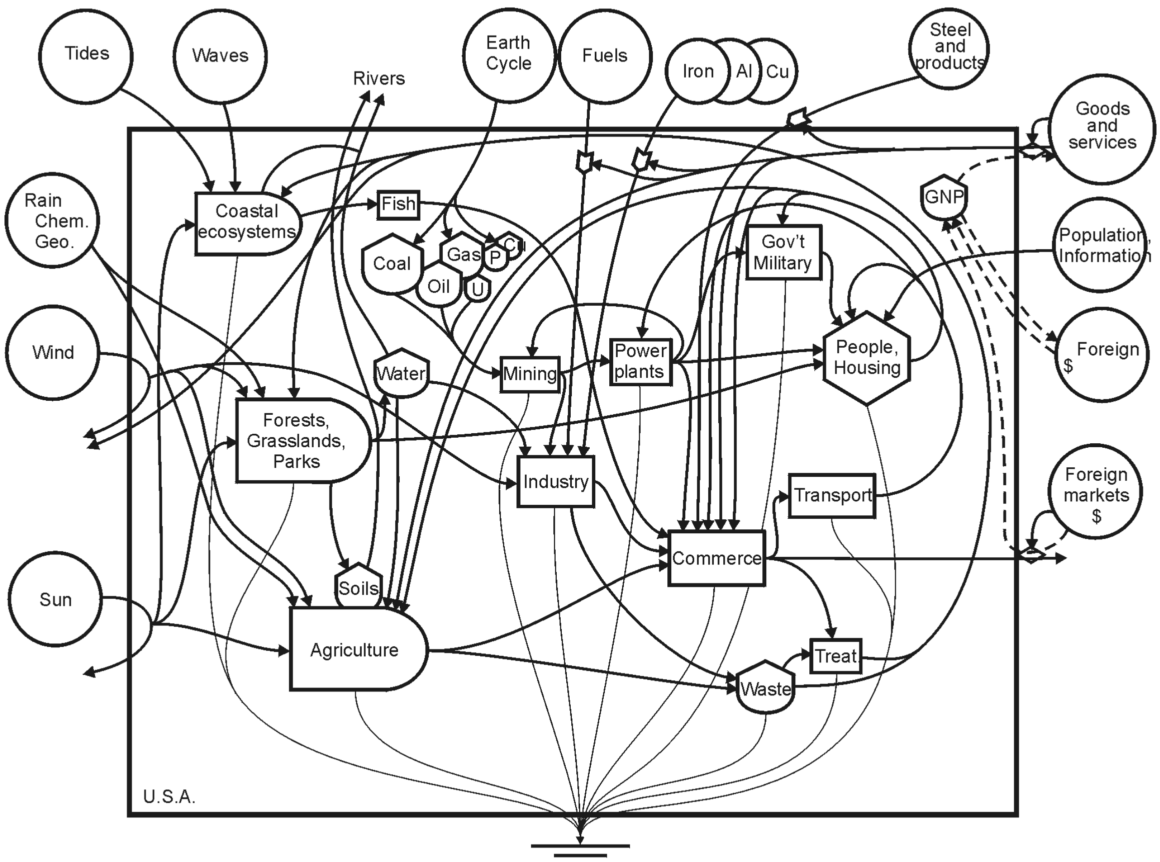


Figure 236: Institutions in the US
Emergy diagram for the United States. Based on Odum (1996:185). Compare this drawing with Figure 196, Figure 197, Figure 198, Figure 199, Figure 200, Figure 202, Figure 203, and Figure 204. For the Bonaire case, compare this diagram with Figure 104, Figure 108, Figure 94, Figure 95, and Figure 96.

Institutions are abstract entities that more commonly appear in non-ecological, structural-functionalist sociology (i.e., Weber) or in economics. In this type of functionalist social theory, the ephemeral "government" and "education" are analytic abstractions with little clear physical reality, that in the theory fulfill a societal function of "governing" or "educating", usually for the betterment of all. Institutions such as government, or religion, or education, or economy, or health, are highly abstracted theoretical constructs. So abstract, in fact, that they are arguably unrealistic and of dubious value for constructing social models. Finding "religion" or "health" among people and highways, operas and advertisements, is a far more difficult task than finding a functioning organ in a human body. Understanding the processes that brought it into being is more difficult still. Yet it is just that process that must be identified if we are to train our model to a useful scale and focus, if we are to identify determinant social actors, individuals and groups, and their relationships with their material environment. A materialist-ecological alternative is to re-organize this model into the physical "people" and "assets/technologies" themselves, that compose those "institutions" (see Modern States and World Systems, CHAPTER 16, for Bonaire also see Figure 108).

Information

While one method for representing our human-cultural adaptations is to use a storage of information (Odum 1983:537), it is unclear what that information refers to and how to quantify it. The alternative approach is to use social-structural diversity (division of labor) to represent cultural information. In other words, to represent cultural information in terms of what people do in the material-ecological world. In ecosystems diagrams without humans, genetic information is not usually directly represented. Instead, it is represented by the species diversity that composes the system. In the same way, human-cultural information can be represented by the specialization found in cultural systems. Certainly there is human "information" that is not realized in action or structure, but likewise we now know that there is a tremendous amount of genetic information that is not realized in an organism (so-called "neutral mutations"), but that may be incorporated in a later transformation of the species (see CHAPTER 20).

Summary of this Discussion and Critique

Abandoning institutionist, static functionalist, and non-ecological social theory will improve modeling of humans in ecosystems. Replacing it should be a social theory that is informed by anthropological research into the evolution of cultural systems. Only by empirical analysis of historic and pre-historic cases can we identify the important cultural-ecological processes that can then be modeled in systems diagrams.

What should be included in systems diagrams that contain humans? First of all, the sun-earth energy sources that charge the biosphere are included in all systems diagrams at the human scale. Next, ecosystems should be included since most of the resources used by cultural systems are produced by the work of natural systems. Next, natural storages of resources like fossil fuels, topsoil, or minerals should be depicted since they are another determining part of the human environment. Finally, humans should be depicted, in the ways discussed here, that identify the emergent patterns of social inequality and division of labor that are important systemic features of the evolution of cultural systems.

All of these items except the last are already being modeled in the diagrams shown here. Only the cultural-ecological representation needs to be modified. Examples of this last important feature can be seen in the other diagrams in CHAPTER 16.

What's In It for Anthropologists?

Interdisciplinary research is difficult. Anthropologists can identify weaknesses in social theory that has been adopted into ecological modeling. What can anthropologists gain from interdisciplinary research? While much anthropological research is "ecological", such as Cultural Ecology (Steward 1955), Culturology (White 1959), Cultural Materialism (Harris 1979), Human Ecology (Moran 1990), Evolutionary Anthropology (Winterhalder & Smith), and Political Ecology (Greenberg 1994) very little of that research has gone far enough in adopting the theoretical and methodological tools that ecology can offer. The "environment" has been represented in countless forms, usually homeostatic, usually single scaled, usually deterministic, and most often it is incompletely represented in theory, showing too much concern with human ingestible calories (the "calorific obsession"), and not enough with the entire biogeophysical system.

Another criticism is that materialist-ecological research in anthropology has often been theory-heavy, without enough empirical research to back it up. This is in part due to the relative youth of the discipline. It is also in part due to the lack of good methods and training available for anthropologists. And finally, maybe ultimately, it is also due to the complexity of human-environmental systems, which has only really been appreciated with the emergence of complex systems theory, and for which there have been very few tools available until recently.

This is where systems ecology can be most useful to anthropologists. Systems ecology incorporates the whole spectrum of biogeophysical environmental features mentioned above--the sun-earth energy sources that charge the biosphere, the world's ecosystems that capture and use those sources, and the storages (minerals, fossil fuels, topsoil) that are critical limiting factors in the human-environmental systems. By doing so, systems ecology can operate at the scale needed by anthropologists to better investigate global and regional problems that are facing us today, as well the traditional, smaller-scale concerns of anthropological research.

CHAPTER 22
CONCLUSIONS

Anthropologists talk about the need for multi-scaled research. That is research at the traditional scales of ethnography, but simultaneously at the scale of the larger region, or state, or national, or world context, and within both present and historic contexts. However, they often lack the methodological tools to accomplish this research goal.

This dissertation fieldwork spanned these scales. Data was collected on national trade and income. Regional industry owners, managers and civil servants were interviewed. An ecological ethnography of island farmers and households was produced, and a statistical survey of households was conducted. An environmental and demographic history began the dissertation and defined important constraints and potentials that were set by Bonaire's past.

From this data I performed analyses with a form of ecological economics known as "emergy analysis." Emergy is an alternative currency (a donor currency) that places all products of world ecosystems on one scale, based on the biogeophysical work that contributed to the production of that product. The emergy concept embodies the complex systems principles of hierarchy, scale, self-organization, dissipative structures, and others. It rests on second law thermodynamics, in which there are real material and energetic limits to growth and efficiency in natural systems. Unlike past interpretations of the second law, complex systems scientists see energy dissipation as a creative process that has resulted in the self-organization of ecosystems, geologic systems, weather systems, etc. and in the emergence of life.

When thinking about economic development on Bonaire (and many other tourism sites), what comes to mind is hotels, beach-front properties, and fragile reefs. However, in high-energy fossil fuel economies, the footprint of development is never confined to a spatially circumscribed development site. Development needs raw materials and processed goods. For typical development projects, natural resources are drawn from a wide domestic terrain of oil wells, bauxite mines, wood plantations, etc. None of these resources exist on Bonaire. The context of development on the island therefore clearly extends beyond its borders.

It was stated in the introduction that in addition to the historical and systems-descriptive explanatory account of the processes of change associated with ecotourism development on Bonaire a number of intermediate results are produced by this research which measure and explain:

(1) sustainability, with a measure called "percent renewable"
(2) the "underdevelopment" of Peripheries worldwide, including Bonaire in particular
(3) structural complexification of an economy as it has undergone 50 years of development activity
(4) why households in a development context would abandon farming for participation in the market
(5) why wages are low, or sometimes high, in a development context
(6) a recommended development size, with an index called "development intensity"

These results will be highlighted from top down in three scales. The first is the international and island scale, followed by the intra-island web of economic production, and then households and the production of labor. Ecotourism will then be singled-out for discussion. I will conclude with a final review of this project as methods research, with discussion of the value of systems and evolutionary research for cultural anthropologists.

Island and International Scale

Figure 237 is a systems diagram that depicts the emergy flows that drive the Bonaire economy. Both natural and human-made emergy sources are identified and evaluated (CHAPTER 8 and APPENDIX A).

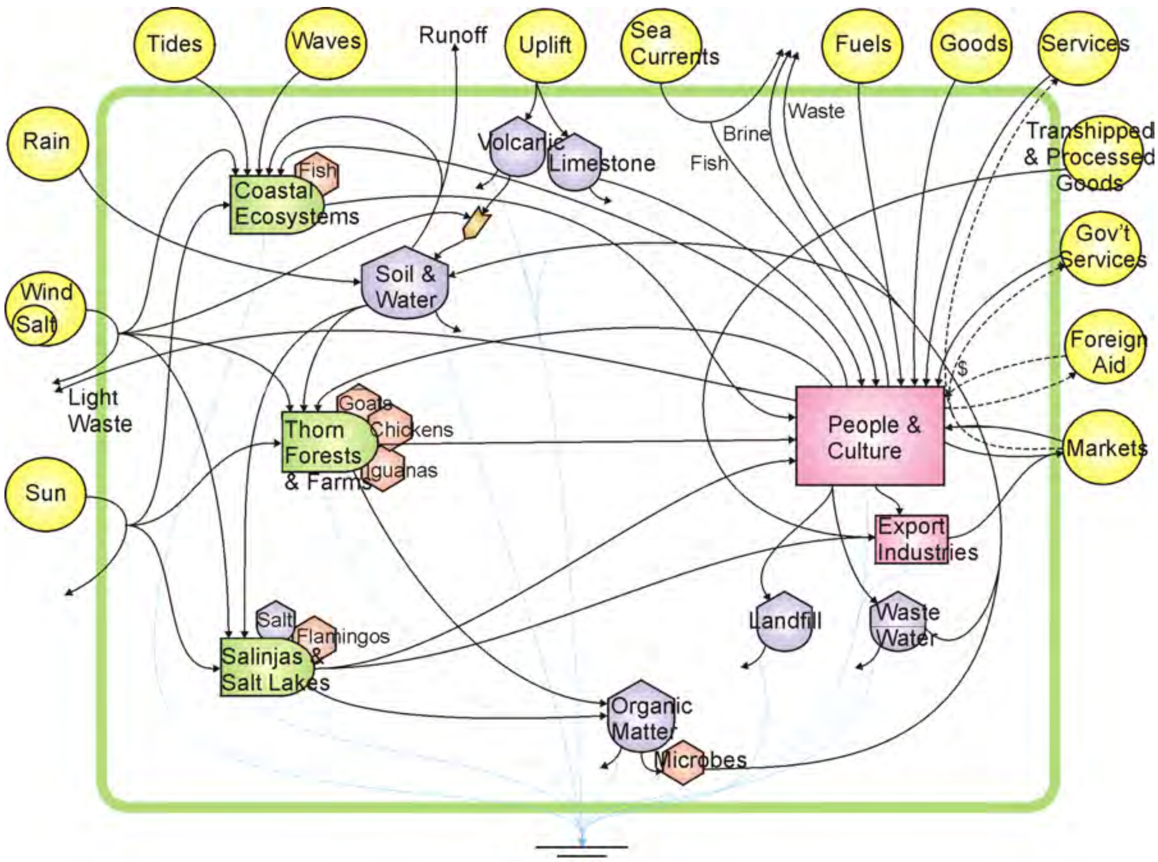


Figure 237: National Systems Diagram of Bonaire
In a national diagram, the aim is to identify important emergy sources (yellow circles) and storages (blue tanks), both renewable and non-renewable, and to briefly depict the island processes that use or produce them.

Figure 238 is an overview diagram that aggregates the first diagram into major flow categories, renewable resources (R), non-renewables and slow-renewables (N), fuels (F), goods (G), import dollars (I), import emergy in services (P2I), export dollars (E), export emergy in services (P1E), exported goods emergy (B), and gross domestic product (X). Note that the fuel flow (F) is greater than both the renewable (R) and non-renewable (N) environmental flows combined. Fuel is an especially valuable commodity for an economy because it is required for the heat engines of industry and transportation, for cooking, and for electricity, and because it yields much more emergy than it takes to produce it. This is called its net emergy yield, which today is 6 to 1, and which in the early days of oil use was 60 to 1, an emergy productivity gain that drove the boom years of the last Century (Odum 1996:140).

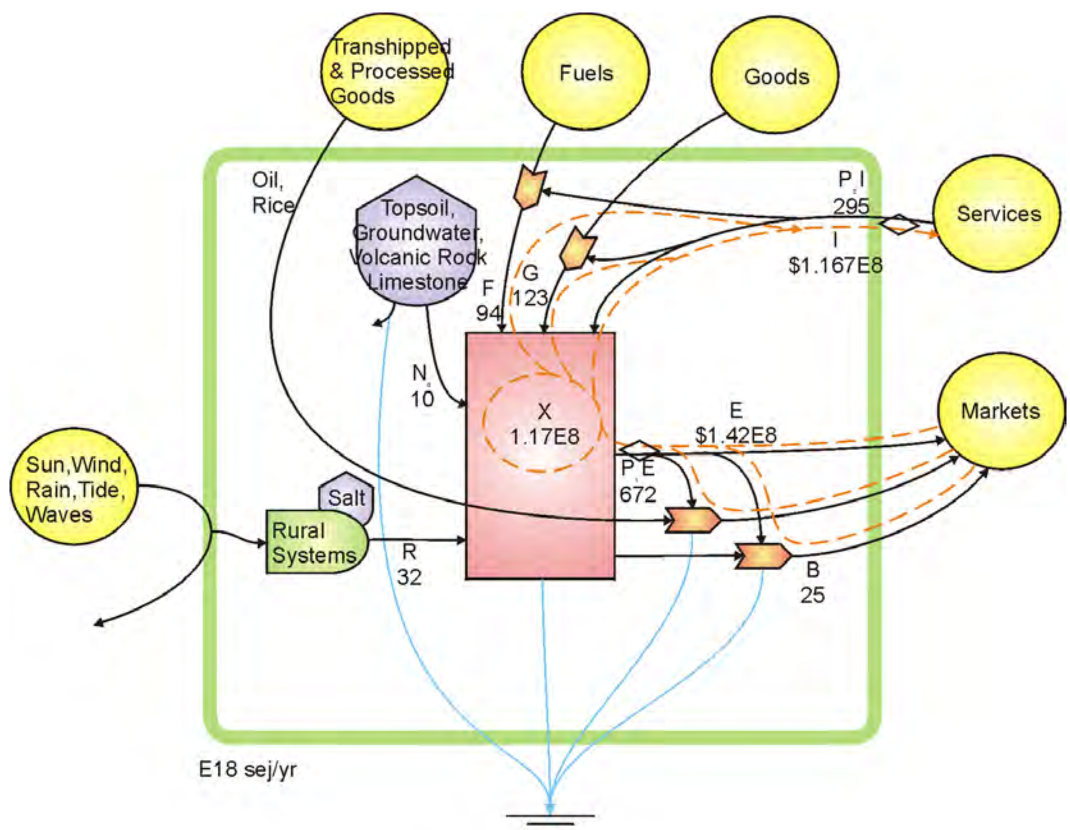


Figure 238: Overview Diagram of Bonaire, ca. 1995
Emergy flow values are in E18 sej/yr. Data values are from APPENDIX A, Table 2.

To an even greater extant on Curacao (and Aruba), the oil flow from Venezuela has for half a century fueled the economic development of the Netherlands Antilles as a whole. That fuel flow is the high-emergy input that supports the many services (including offshore banking) that are sold on the world market. While the Netherlands Antilles is not pumping crude itself, the direct proximity of the Maracaibo basin oil sources, and ownership of its refinery by Venezuela's national oil company (PDVSA), and the resulting flow of free and low-price refined oil into the N.A. economy have produced high net-emegy to run island economies. On Bonaire and the rest of the Netherlands Antilles, that emergy is "matched" in the economy with natural resources to produce growth.

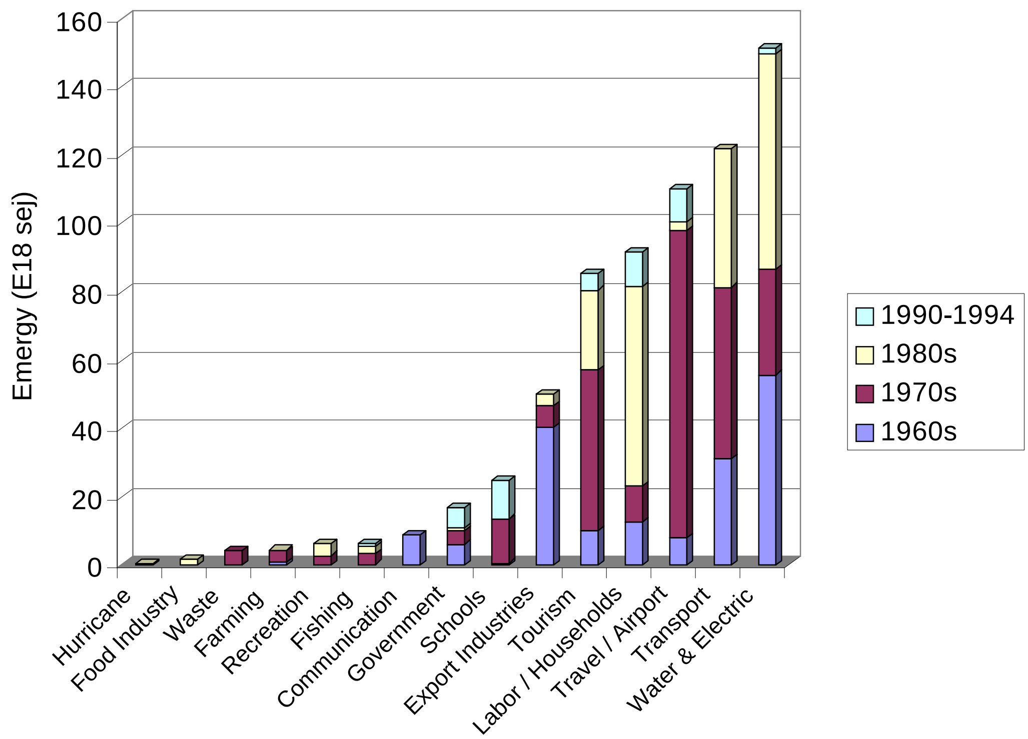


Figure 239: Financial Aid Emergy
Financial Aid destinations for Bonaire. These values are emergy values, calculated from money amounts via the emergy/$ estimates from (Odum 1996a:313-4). See Figure 165 and discussion.

The other important component for understanding the macro context of Bonaire's development growth is Dutch foreign aid in this century (see CHAPTER 13, The State

Equation and Financial Aid). As illustrated in Figure 239, there has been significant foreign aid to Bonaire in the second half of this last century. The great majority was directed to energy and water production, transport (road and harbor), airport, and other infrastructure. These key investments made it possible, in essence, for Bonaire to utilize the high-emergy fossil fuels from Curacao.

Table 38: Emergy Indices for Nations
Data values are from APPENDIX A, APPENDIX B, APPENDIX AA, and APPENDIX BB. Additional sources are (Odum 1996a), (Doherty, et al. 1991), (Braat 1987). See Table 13 and discussion.

	Amer-indian Bonaire	*Bonaire 1950s*	*Bonaire 1995*	*Nether-lands Antilles 1995*	*Nether-lands 1980*	*Puerto Rico*	*USA*
National Ecological economics							
1) Emergy Use / Person (E15 sej/person)	25	4	39	106	26.3	17	29
2) Empower Density (Emergy/m^2) (E10 sej/m^2)	7	12	127	1,906	1,000	736	70
3) Economic / Environmental Ratio (Average Investment Ratio)		0.56	12	169	3.3	46	7.1
4) Percent Environmental Emergy (Renew and Non-Renewable)	100%	64%	8%	0.59%	23%	2.1%	12%
5) Percent Renewable Emergy (Environmental Loading)	98%	63%	6%	0.37%	6%	1.6%	10%
Global Ecological economics							
6) Emergy / Money Ratio (sej/$) (E12 sej/$)		8.7	4.7	5.4	2.2	1.65	1.39
7) Exports / Imports (Emergy Yield Ratio, Y/F)		1.00	1.36	1.14	0.83	0.74	0.57

The indices produced in Table 38 are evidence to this process (CHAPTER 8, Summary Indices for Bonaire and the Netherlands Antilles). High emergy use per person, empower density, and economic / environmental ratios for the Netherlands Antilles (Curacao) are indicative of developed economies. The very low Percent Renewable contributions are indicative of large fossil fuel inputs. Finally, the high emergy/money ratios for the Netherlands Antilles and Bonaire indicate that they are peripheries in their world system.

Table 39: Percent Renewable Emergy (Environmental Loading)
This table shows the percent of emergy entering a region that is renewable. The remainder is supplied by non-renewable sources or is imported from external economies. World economies today are on average supported by 60% non-renewable emergy and 40% renewable. Additional values are calculated from (Odum 1996a). See Table 16 and discussion.

Country or State	Renew-able %	Country or State	Renew-able %
Netherlands Antilles	0.37%	Dominica	27%
West Germany	1.1%	Scotland	36%
Puerto Rico	1.6%	Japan	37.5%
Taiwan	4%	**World**	40%
Netherlands 1980	6%	Australia	48%
Bonaire	6%	Thailand	48%
Texas	6%	India	50%
Italy	9.5%	New Zealand	55%
USA	10%	Brazil	59%
Switzerland	12%	**Bonaire 1950s**	63%
Spain	12%	Ecuador	65%
Sweden	12.5%	Papua New Guinea	87%
China	13%	Liberia	92%
Mexico	23%	Alaska	92.5%
Soviet Union	24%	**Amerindian Bonaire**	98%

A particularly interesting comparative index in Table 38 is item 5, *percent renewable emergy*. Table 39 starts with my percent renewable calculations for Bonaire and the Netherlands Antilles, and brings in additional values for world regions that have been evaluated. The percent renewable values are calculated by dividing renewable emergy inflows by total emergy for a region. Notice that most regions of the world are highly subsidized by non-renewable emergies. This is particularly the case for the Netherlands Antilles and other refinery islands like Puerto Rico and Taiwan. Only 6% renewable and therefore 94% non-renewable emergy today supports Bonaire.

Sustainability

The percent renewable table has implications for the concept of sustainability. The term sustainability has been used uncritically by some. In human history, human activity has been supported by the fluctuating use of renewable and slow-renewable resources. In recent human times, human society has been subsidized by the capture and use of non-renewable resources (specifically fossil fuels and metals). If sustainability refers to renewable and slow-renewable resources, then human activity on Bonaire would need to return to pre-contact densities of less than 1200 people, living as horticulturists. On the time-scale of millennia, this is the "sustainable" human pattern.

In the time-scale of the 150-year fossil fuel pulse that we are now riding, the term sustainability can be applied to a different measure. In this context, it could usefully reference human activity that does not further tax existing ecosystems, and/or threaten the renewable and slow-renewable resources upon which we also depend (such as fresh water, topsoil, forests, and coral reefs). The long-term message of this table is however clear. Human systems worldwide are currently supported by 60% non-renewable emergies. The contraction of these finite sources as they are consumed will stress world economies and populations.

The Underdevelopment of Peripheries

The international context of Bonaire is described as a periphery within a world system that includes the U.S., the European Community, and Japan (see CHAPTER 8, Bonaire within the US-EC-Japan World System). Depicted in Figure 240, this system functions, in general terms, to converge primary commodities to a core of transnational corporations, and state governments, while diverging secondary commodities to the periphery, including Bonaire. Trade is what defines the system, and international trade is evaluated here with emergy accounting. Some results are shown in Figure 240.

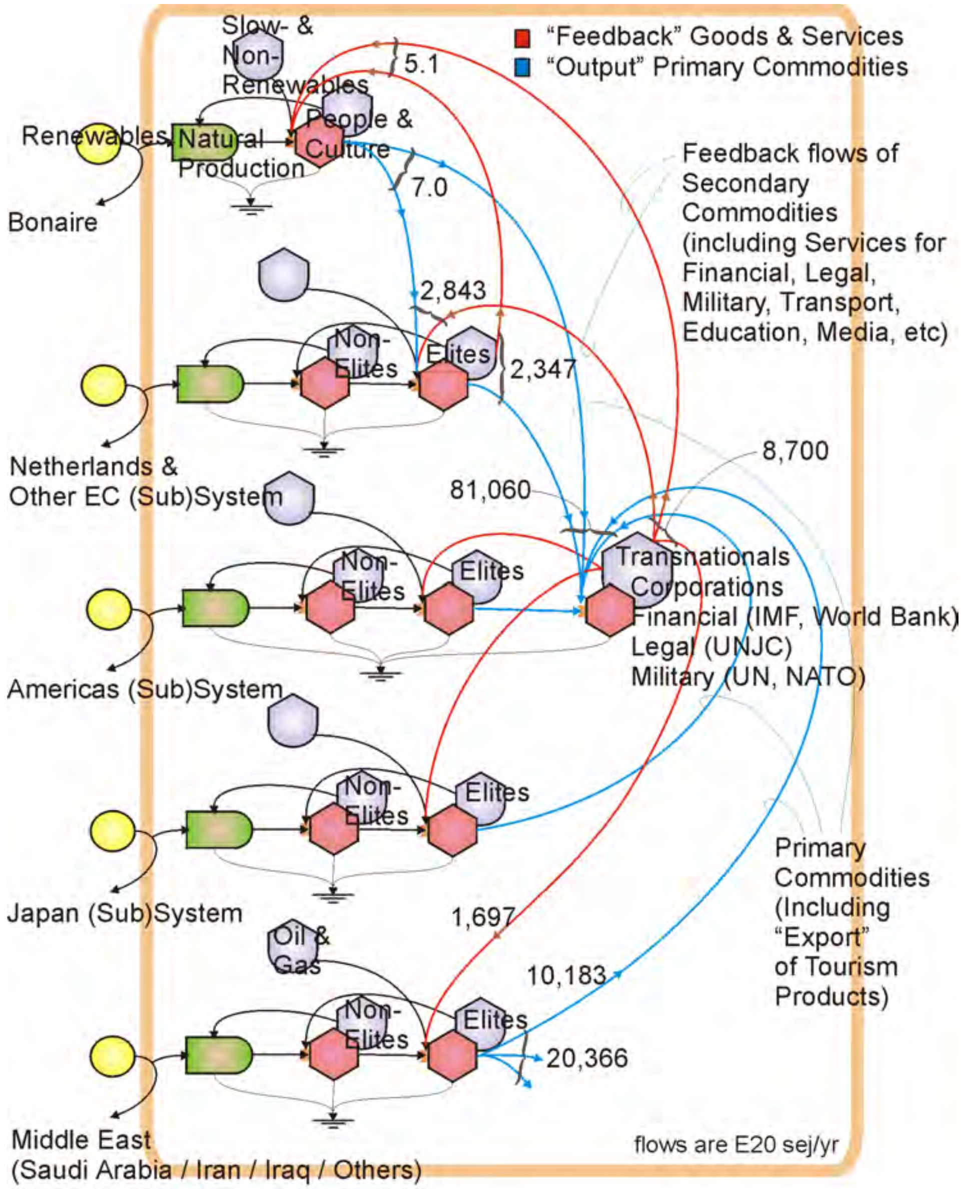


Figure 240: Bonaire within the US-EC-Japan World System
Note the asymmetry in emergy flows between imports and exports. As a Core nation, the US imports nearly ten times more emergy than it exports. As a Periphery, Bonaire exports significantly more emergy than it imports. This pattern defines the international relationships within a World System. See Figure 94 and related discussion.

While the exchange of goods and services travels in both directions between the periphery and the core, because of the high emergy value of primary commodities (like bauxite, phosphate, or old-growth timber), and because of free natural emergy subsidies in periphery economies, the core gains greater emergy wealth at the expense of the peripheries. Notice that Bonaire receives approximately 5 E20 sej/yr in exchange for 7 E20 sej/yr. Note that the U.S. receives 81,000 E20 sej/yr in exchange for 8,700 sej/yr, a 10-fold trade advantage. These numeric emergy values, therefore, offer on explanation for the "underdevelopment" of peripheries that many social and political scientist perceive and report in less quantitative terms. In other words, while the monetary exchange in trade is by definition equal, in emergy terms the core countries receive a substantial trade bonus at the expense of their peripheries, which does productive work in the core and deprives the periphery of that work.

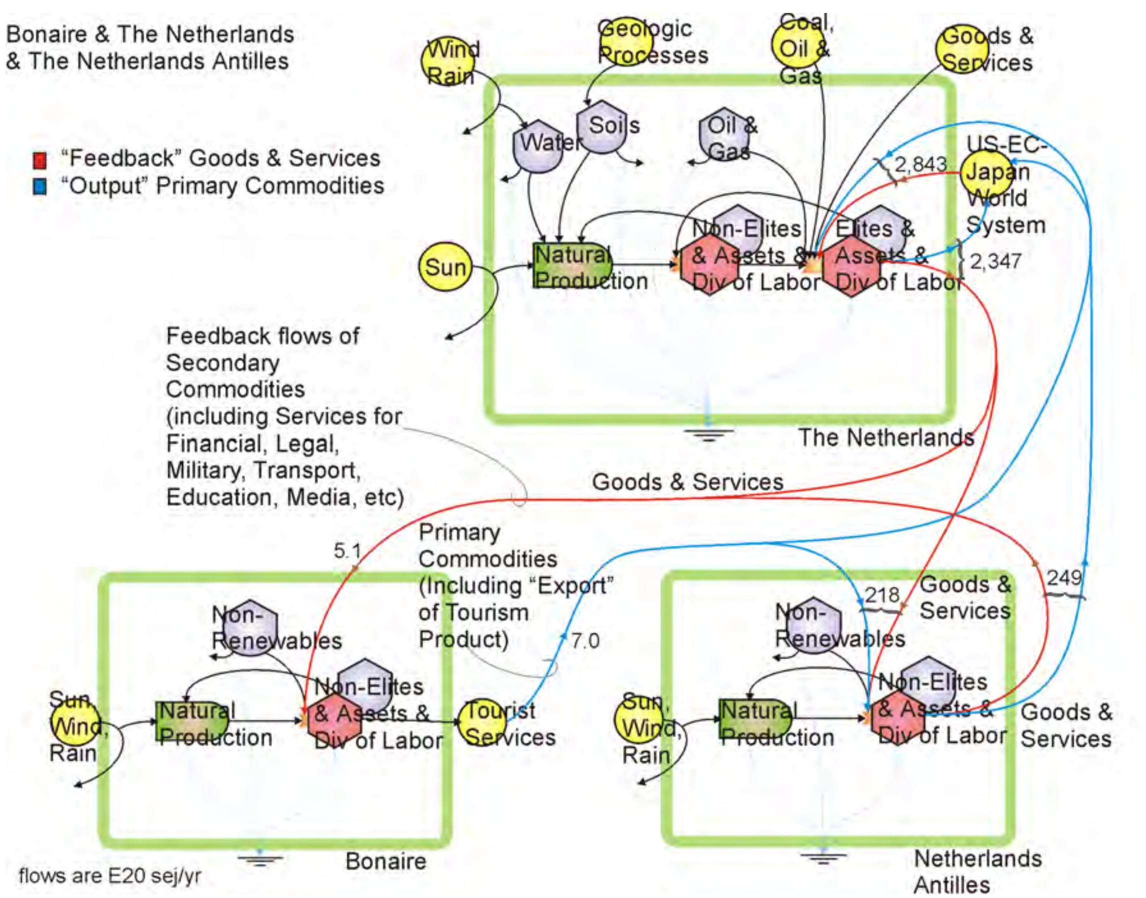


Figure 241: Bonaire in Dutch Context
The same general pattern of asymmetrical exchange is visible for Bonaire within its Netherlands Antilles and Netherlands context.

This asymmetrical relationship between core and periphery was also observed for trade with the Netherlands Antilles. While this expected pattern appeared for both the Netherlands Antilles and Bonaire, in these cases it occurred for both unexpected and expected reasons. As was expected, the tourism industry on Bonaire captures many renewable and non-renewable environmental resources and "exports" them to foreign travelers. This is a pattern that might be expected for "eco"-tourism worldwide. Rock to support hotel construction, expand airport runways, build roads, these are "exported" when foreign tourists consume tourism goods and services on Bonaire. In addition, the creation of the underwater Marine Park has meant that much of the renewable coral reef production of the island is also captured by the tourist industry. These products have been evaluated within the previous emergy analyses and included in the export totals in Figure 240, Figure 241, and Figure 238. Here you can see the relative magnitudes of emergy inputs to Bonaire from renewables, non-renewables, and purchased inputs of fuels, goods and services.

The renewable and non-renewable natural resource inputs are relatively small, due to the low natural productivity on the desert islands, and low mineral wealth. These values do not in themselves tip the emergy trade balance in favor of the core, and they are therefore not the reason that the islands are attractive to development investments. According to this analysis, the reason is oil.

What makes Bonaire and the Netherlands Antilles different from other eco-periphery regions is the oil refinery on Curacao. A large component of the tourism product exported from Bonaire is attributed to Venezuelan oil refined on Curacao. Specifically, the desalinated water, electricity, and international air services that make possible the high-end eco-dive tourism on Bonaire are direct products of high-emergy fossil fuel from Curacao. This emergy drives the many tourism services that are produced on Bonaire and exported to the world.

Intra-Island Web of Economic Production

The Structural Complexification of an Economy

At the intra-island scale, a new web of production has emerged on Bonaire during the last 50 years of economic development (CHAPTER 10 and CHAPTER 14). It is depicted in Figure 242. Households (on the left) are supported mainly by the market, with some input from fishing and farming. Households produce wage laborers that work for businesses (production subsystems shown on the right). As a Caribbean economy, a majority of material goods are imported. Those goods are brought by shipping (on the right) and progressively dispersed to retail outlets and eventually household (on the left).

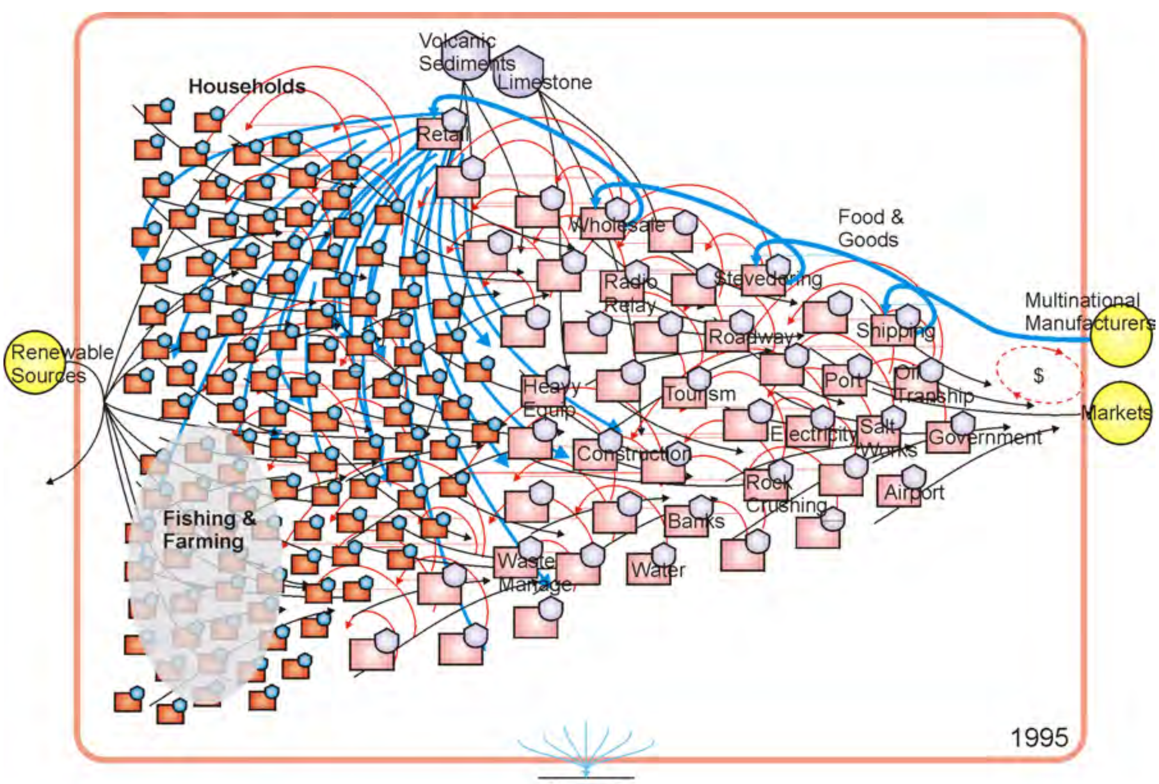


Figure 242: Web of Social-Economic Production
This diagram depicts a web of economic subsystems that were analyzed. The structure of the hierarchy is based on calculated emergy values. The diagram also emphasizes the hierarchy of household niches that exist on Bonaire. In state societies, households produce labor that is economically specialized, which produces not one but many labor economic niches. These niches differ in their ownership and control of assets, and this feature places the households in the hierarchy. See Figure 108 and discussion.

The systems diagram of Figure 242 can be aggregated to produce the diagram in Figure 243. Notice that the production subsystems on the right are companies *and* households. In the case of locally owned businesses, this refers to the inter-mingling of owner's households and business assets that work together to amplify both. The terms "many", "multiple", and "single" refer to the instances of a type of production subsystem. On Bonaire there is only one oil transshipment terminal, salt works, water and electric plant, harbor, airport, etc. These are "single." Today there are "multiple" hotels, restaurants, banks, wholesalers, retailers, constructions companies, etc. Finally, "many" household types are suggested for Bonaire.

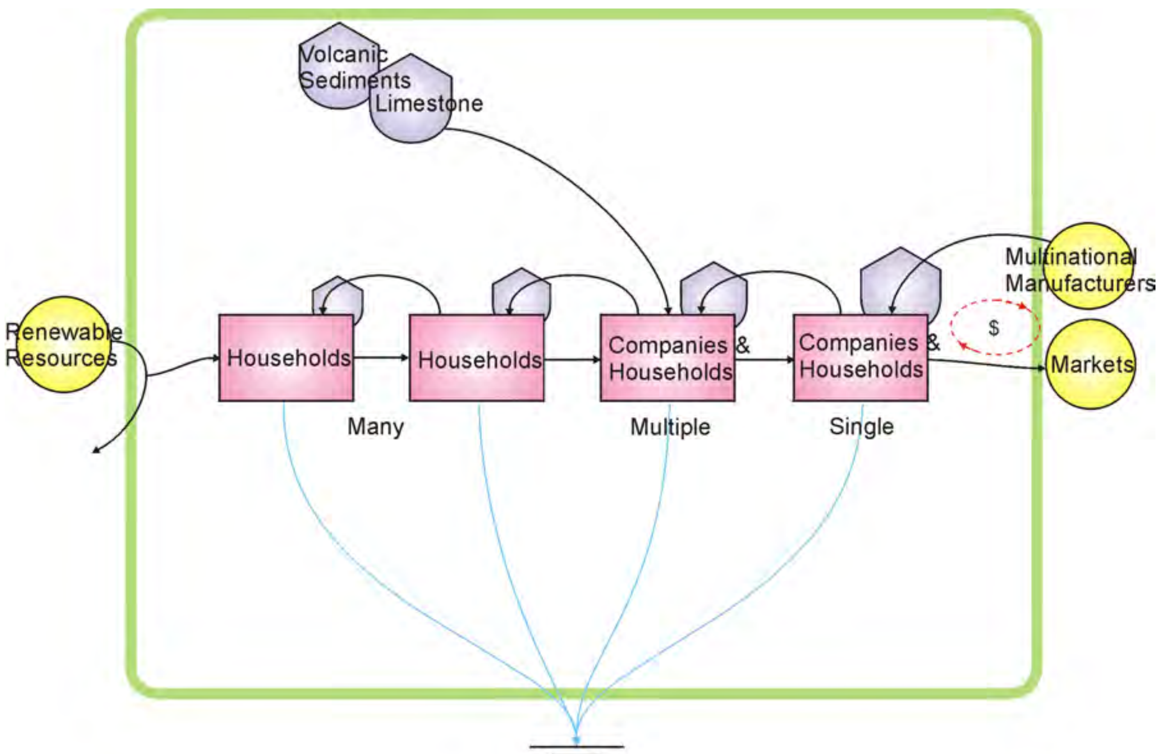


Figure 243: Aggregated Social-Economic System
Aggregated models simplify diagrams in order to accentuate the fundamental patterns and processes. See Figure 109 and discussion.

Emergy analyses were constructed for most of the island business types. Historical data of business openings was also collected. The results are assembled into Figure 244. The Y-axes are emergy flow per year (empower) and the x-axes show the categories just discussed.

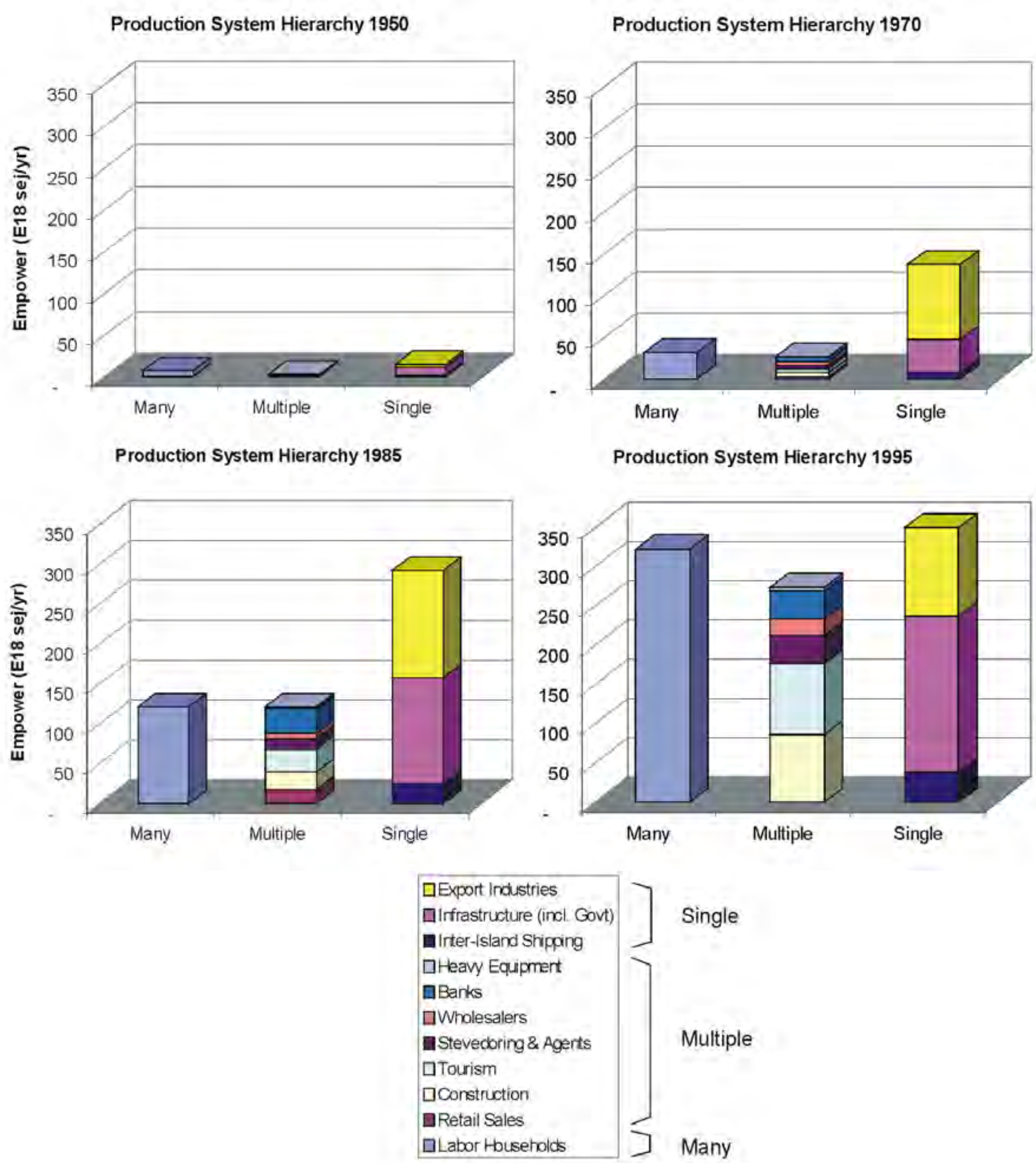


Figure 244: Production System Hierarchies

By the definition of emergy, the total emergies at each scale (many, multiple, single, in this case) are expected to be equivalent in a self-organized system that is maximizing empower (Figure 246e). If the three scales constructed for Bonaire are reasonable, it appears the island system is moving again toward maximum empower. In complex systems terms, these two points could be described as points on a surface with multiple stable states (Figure 245). See Figure 183 and discussion.

Perhaps surprisingly it can be seen that tourism has not lead economic growth on Bonaire. Emergy inflows increased first with the arrival of export industries and infrastructure funded by the Netherlands (1970). Island populations and various smaller support industries gradually appeared (1985). With the arrival of ecotourism since 1985, the middle scale of economic production has expanded dramatically, and with it the number of households and their emergy inflows.

In emergy terms, this economic growth has been fueled by a 30-fold increase in imported emergy flows. These new emergy sources attract households away from reliance on natural renewable sources like fishing and farming.

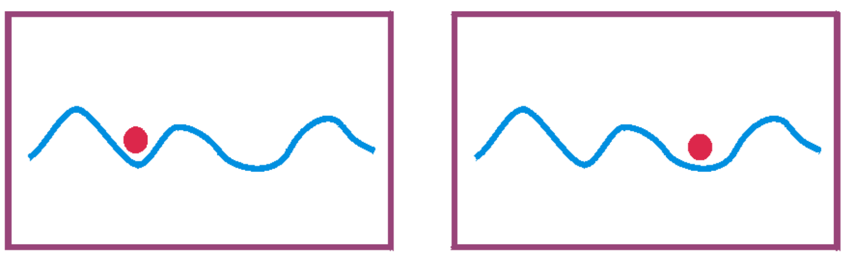


Figure 245: Multiple Stable States
A surface and ball have been used by complex systems scientists to represent multiple stable states in systems. Disturbances to a system (such as the arrival of large export industries and government infrastructure to an island) can push the system out of a current stable state to another stable state.

It is suggested that the first and last figures (1950s and 1995) possibly represent multiple stable states, depicted in this surface-and-ball diagram (Figure 245). In stable hierarchical systems, emergy flows at each scale are equal (Figure 246e), while energy flows decrease (Figure 246d). In an ecosystem, as shown in sections b and c in Figure 246, energy flows decrease at each step, while emergy flows remain constant.

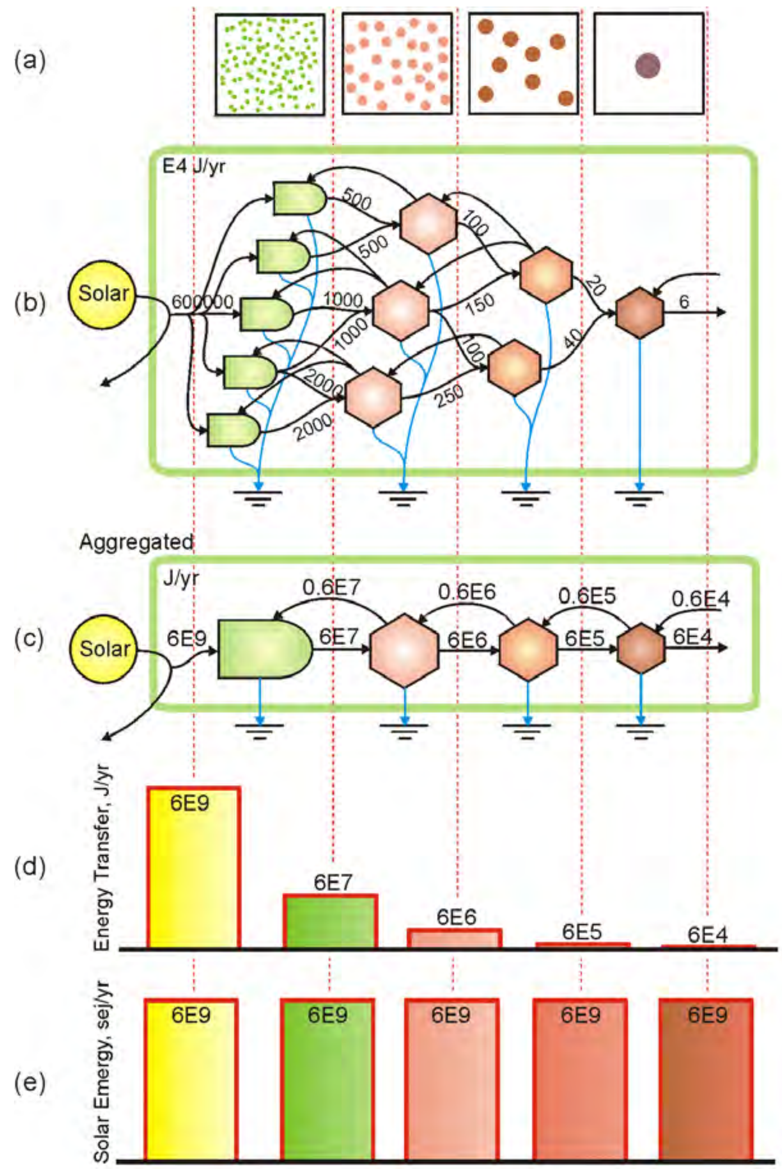


Figure 246: Energy Transformation Hierarchy
Adapted from (Odum, et al. 1998:23). (a) Spatial view of units and territories, (b) Energy network including transformation and feedback, (c) Aggregation of energy networks into an energy chain, (d) Bar graph of energy flows for the levels in an energy hierarchy, (e) Bar graph of *emergy* flows for the levels in the same hierarchy. The emergy flow is the same at each pathway, but the energy flow decreases at each step. See Figure 170 and discussion.

Using Stone and Sand

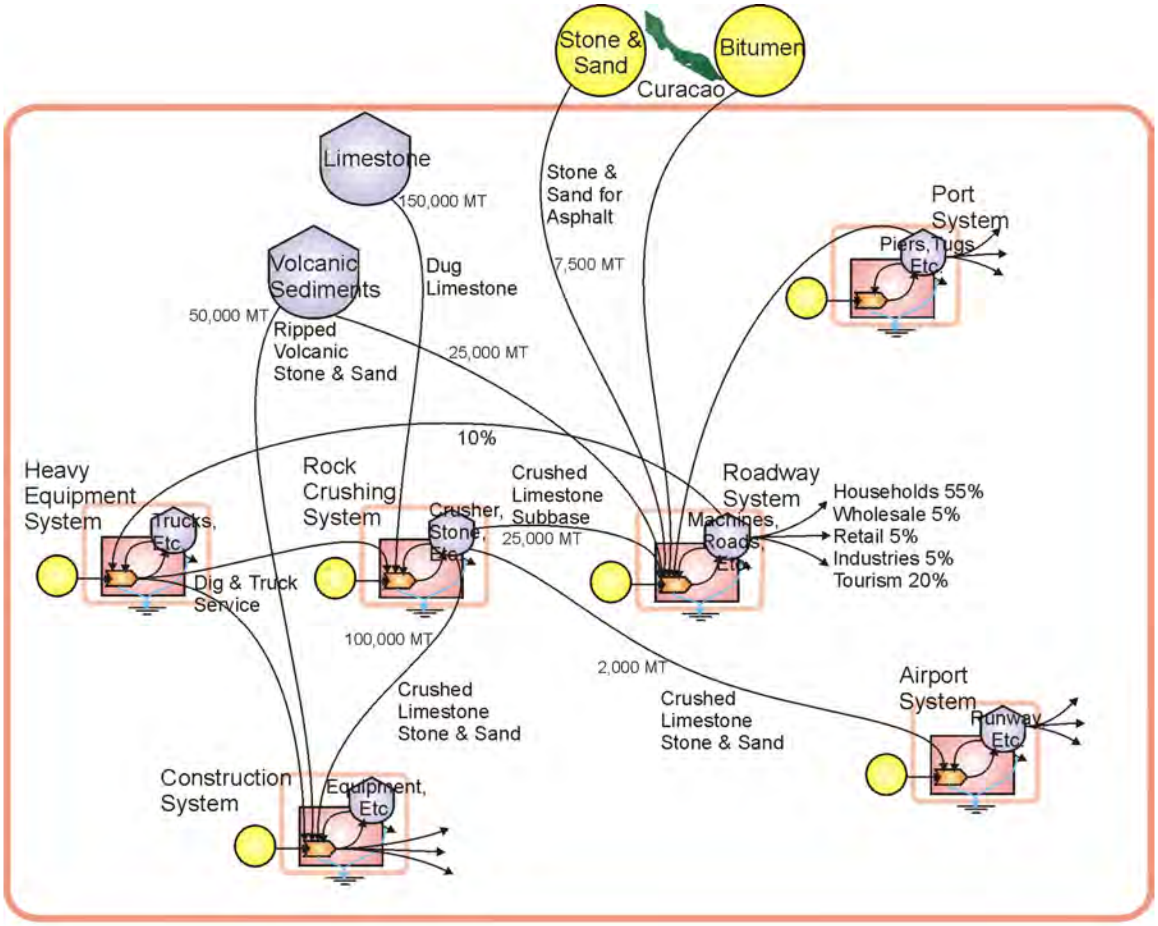


Figure 247: Stone and Sand on Bonaire
These production subsystems mine or use stone and sand from Bonaire. See Figure 110 and discussion.

The emergent web of production on Bonaire was analyzed in detail. One area of focus was businesses that use local resources to produce a product. Before research began, it was felt that if there were various and dispersed impacts of ecotourism development on Bonaire, those impacts would be associated with the activities of companies that depend on local resources. Such businesses are few on Bonaire, due to the low natural productivity of the island ecology and the absence of mineral wealth. The major non-renewable resource storage that Bonaire does indeed contribute to its development is rock and sand (Figure 247, see CHAPTER 11 for detailed discussion). Rock and sand are critical components in all construction. The airport runway, roads, piers, hotels and households all require heavy inputs of this island resource. This resource combined with fossil fuel and mechanical equipment has lead to industries for rock crushing, transport, road building, and all other construction.

Emergy analysis shows, not surprisingly perhaps, that the use of stone in these ways contributes more emergy to the Bonaire system than leaving it *in sutu* to support natural production. That is because it is "matched" with fossil fuel, a practically irresistible emergy source when it is available. It is therefore, also not surprising, that local Bonairians choose to participate in these industries. In fact, they are the businesses in which native Antilleans have had the greatest success as owners. This type of comparison (for evaluating whether or not to use a resource) is not trivial and should always be made when natural resources are captured by economic processes.

Households and the Production of Labor

Extensive ethnographic research was conducted at the household scale on Bonaire (Figure 248 and CHAPTER 5 and CHAPTER 6 for detailed discussion). Households can be modeled as a production subsystem (CHAPTER 7). Home, house, hearth is a nexus of kin on a site that offers support and security for the reproduction and nurturing of family. From a systems perspective, households produce people, which in a market economy is also wage labor. Labor is a *source* for the other human-economic subsystems.

A *house* is a critical asset in the formation of a household production subsystem. A contemporary house on Bonaire is a current version of ancient technologies for producing human shelter. A house is a technology for shelter, for family organization and cooperation, for child rearing, for protection, and for the storage of other vital personal assets (private property). Today households are locations for receiving electricity and water, and for waste removal. Furthermore, they are protected locations for the storage of useful personal assets, such as appliances, TVs, family deeds and titles, etc.

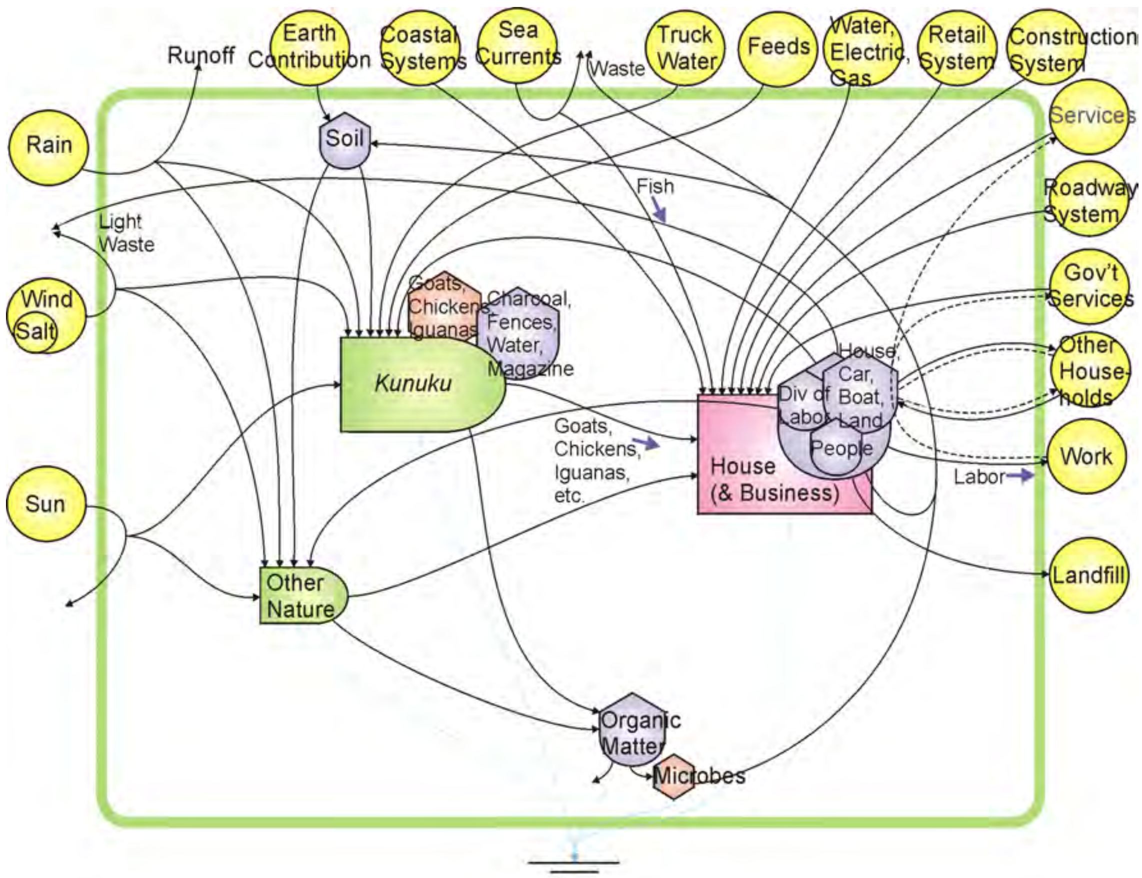


Figure 248: Household System
The green boundary defines the Household System, which can include *kunukus* or other natural production. See Figure 70 and discussion.

An additional critical asset for households is food. Households are the sites for raising and nurturing young and old alike, and a house, therefore, is a place to store preserved and fresh foods. Households are one of a few production subsystems on Bonaire that have an important natural/ecosystem source (Figure 248). Many households own *kunuku*s, which produce goats, chickens, or vegetables for family members. Furthermore, many households use coastal ecosystems as a natural source of fresh fish. These assets are produced by nature, and are procured by a household at no or very little monetary expense relative to their contribution to the household.

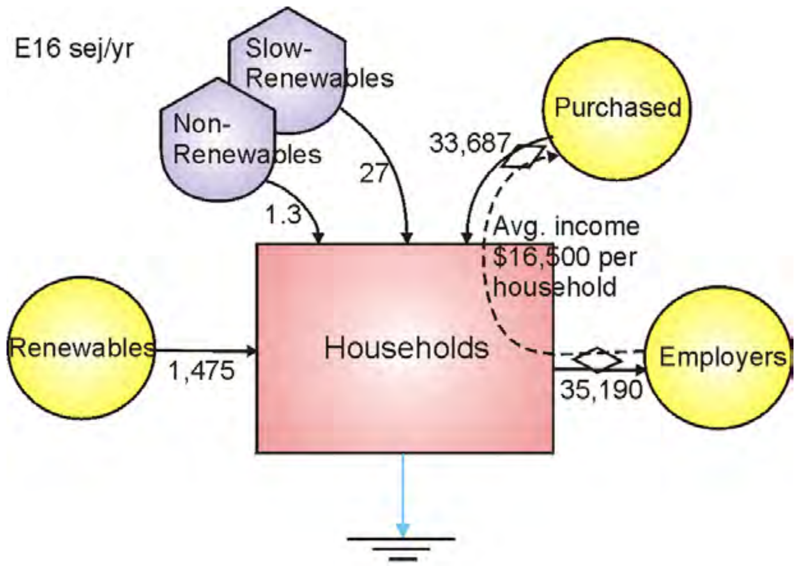


Figure 249: Household Emergy Flows Summary
See Figure 79 and discussion.

Farming or Wage Labor?

Figure 249 summarizes the emergy flows into an average household on Bonaire (CHAPTER 7). From this diagram it is clear that Bonaire households receive twenty times the supporting emergies from purchased goods. It is therefore not surprising that households, on Bonaire, almost without exception, are no longer farming and fishing for a living, but are largely dependent on the market. The question of why households in developing countries often abandon renewable economic strategies can thus be answered with this type of analysis.

Why are Wages Low (or High)?

This diagram (Figure 249) also indicates why households on Bonaire receive relatively high wages, when compared to other developing countries. In order to supply the required laborforce with emergy to maintain itself, the majority of emergy entering this household must be purchased. Bonaire households are not significantly subsidized by free environmental emergies as are other households throughout the world's peripheries. Wages must therefore be high enough to meet household needs for purchased goods.

It should be obvious that similar analyses can be conducted elsewhere in the world where purchased goods are less available, and renewable resources are much more productive. In such settings, wages paid to households can be pushed lower by employers because households are heavily subsidized by unpaid environmental production. This is a monetary bonus to foreign industries from core nations, which would pay more for their own country's labor, labor that does not support itself with free renewable resources.

Ecotourism on Bonaire

What is the tourism product exported on the global market (see Tourism section)? Is it a T-shirt? Is it an hour diving on a reef? From an emergy perspective, the exported tourism product is largely energy, materials, environmental goods, manufactured goods, and human services. Emergy accounting provides methods to identify the full inputs to an economic activity, and to calculate their contribution to work with the single currency of emergy. An emergy evaluation includes the important environmental inputs normally omitted by economic analysis. The emergy of the tourism product that is exported is equal to the total input emergies. The exported emergy is the sum of the inputs, both environmental inputs and human-made. The systems diagram in Figure 251 shows the inputs to the tourism sector on Bonaire (the yellow sources entering the ecotourism system).

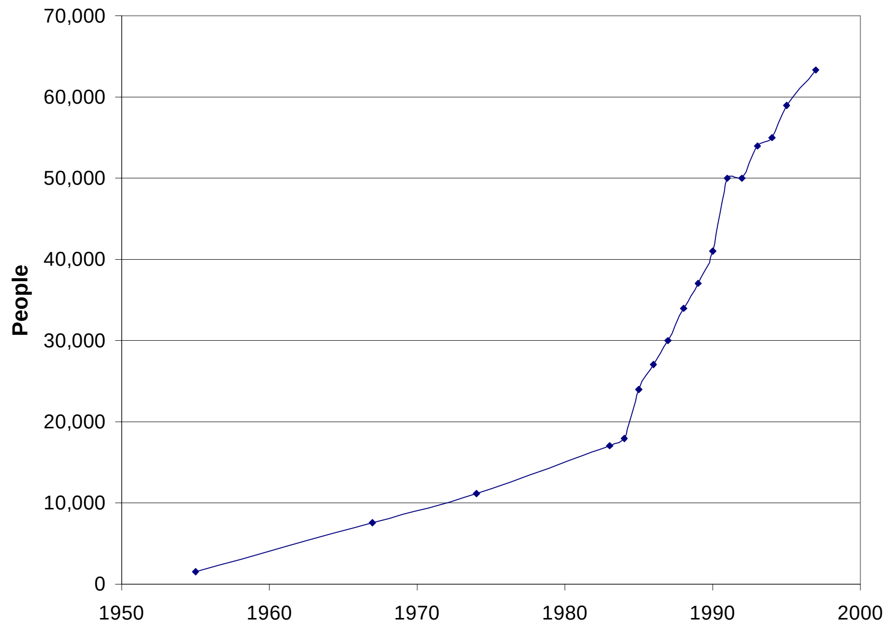


Figure 250: Stay-over Tourists
In the mid nineteen-eighties ecotourism boomed on Bonaire. This occurred simultaneously with a groundswell of international interest in ecologically sensitive travel, and with growing popularity for dive tourism.

Ecotourism can take many forms. Indeed, there is no single definition for the phenomenon. Resource conservation, cultural heritage protection, biodiversity conservation, sustainable development, green management, environmental education, income sharing, local development, community-based initiatives, among others, are touted as benefits of ecotourism.

Ecotourism development on Bonaire is directed by a *National Tourism Policy* (TCB 1995). This policy is a comprehensive plan for managing development, which attempts to limit lodging, foreign labor and natural resource exploitation (specifically coral reef contact with scuba divers). Growth limitation is a well-reasoned strategy for ecotourism destinations. However, popular consensus for limits can wane as growth slows. For that reason it is essential that the local population has been included in the benefits of growth, at all levels including ownership and management positions.

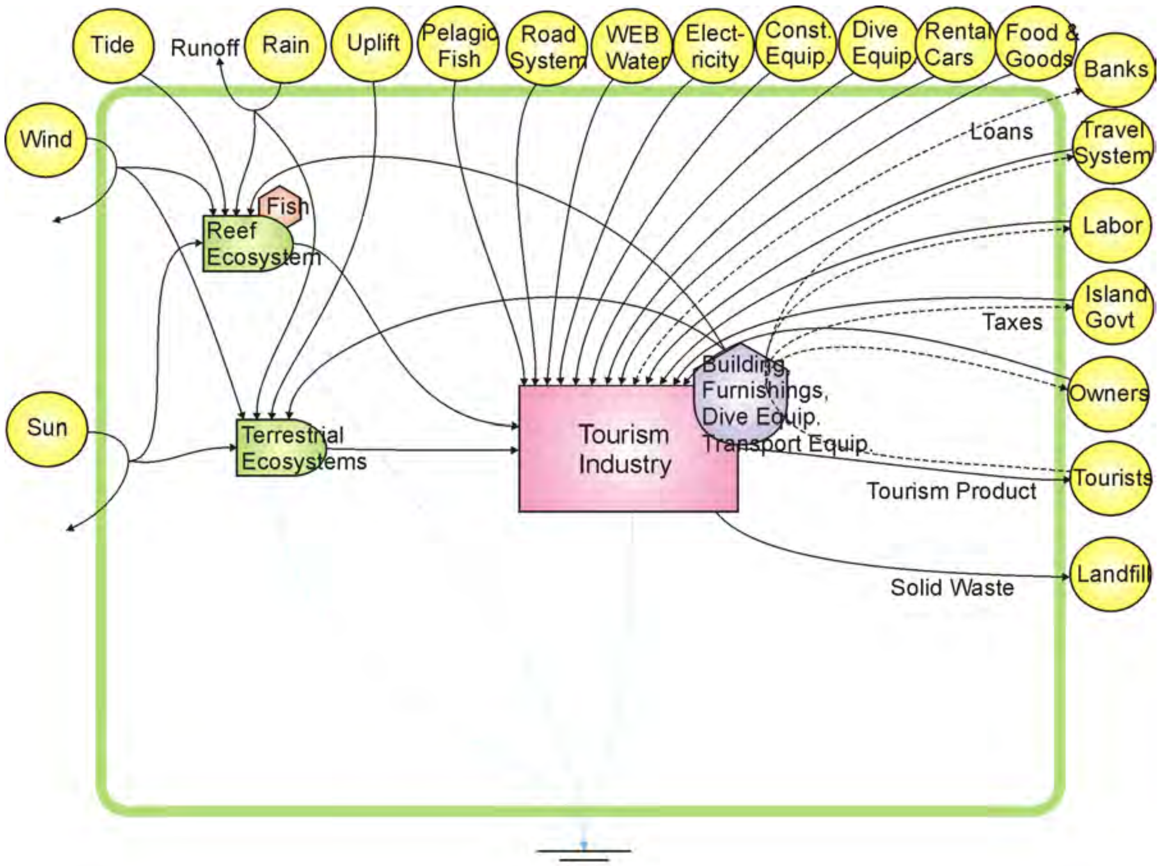


Figure 251: Ecotourism Systems Diagram
Ecotourism on Bonaire depends on many inputs. Some are environmental, but many are purchased from the international economy. See Figure 155 and discussion.

The *National Tourism Policy* for Bonaire is an exceptional set of guidelines to manage economic development. Summarized in general terms, the *Policy* has two main goals, (1) to control, to restrict, to *limit* development growth in various ways, and (2) to assure the *inclusion* of Bonairians in the economic benefits of development.

If there is anything negative to say about the ecotourism policy on Bonaire, it is that it was not in place early enough. Ecotourism growth in the mid-eighties began without sound policy direction. As is all too common in economic growth around the world, impact studies are often conducted only *after* an intense period of rapid construction. In 1990 a *Structure Plan* was produced to provide "a development framework suitable to a small-island economy with a fragile physical and socio-economic environment (Island Government 1990:I-1)." The *Structure Plan* was followed in the early 1990s by the *Pourier Report* (Pourier 1992), and the *National Tourism Policy* (TCB 1995).

What Size Development?

In emergy analysis, the *intensity* of development is a calculated measure that can be compared to alternative development choices in order to estimate the impacts that a development choice is likely to have on an economy and ecology. Subsystem *intensity ratios* are defined here as the ratios of subsystem emergy inputs divided by the total environmental emergies entering the island. This places each subsystem on an equal environmental basis.

In Figure 252, intensity ratios were calculated for five hotels on Bonaire. These hotels were chosen to represent the range of hotel establishments from small to large. It can be seen that only the first two hotels were below the average for all tourism establishments on Bonaire. Only the smallest hotel was close to the average of all businesses on the island.

As stated by Brown and Murphy (1993:3D7), "If a development's intensity is much greater than that which is characteristic of the surrounding landscape, the development has greater capacity to disrupt existing social, economic, and ecologic patterns." Obviously this is a *relative* measurement, one that places establishments within the context of the existing system. For example, a 1000 room hotel in New York City would not be disruptive to the existing ecological-economic system, but the same hotel on Bonaire would dramatically transform the environmental-economic relationships that currently exist. If one professed goal of ecotourism is to minimize the impacts of development activity, then development should match a scale appropriate to the existing host site.

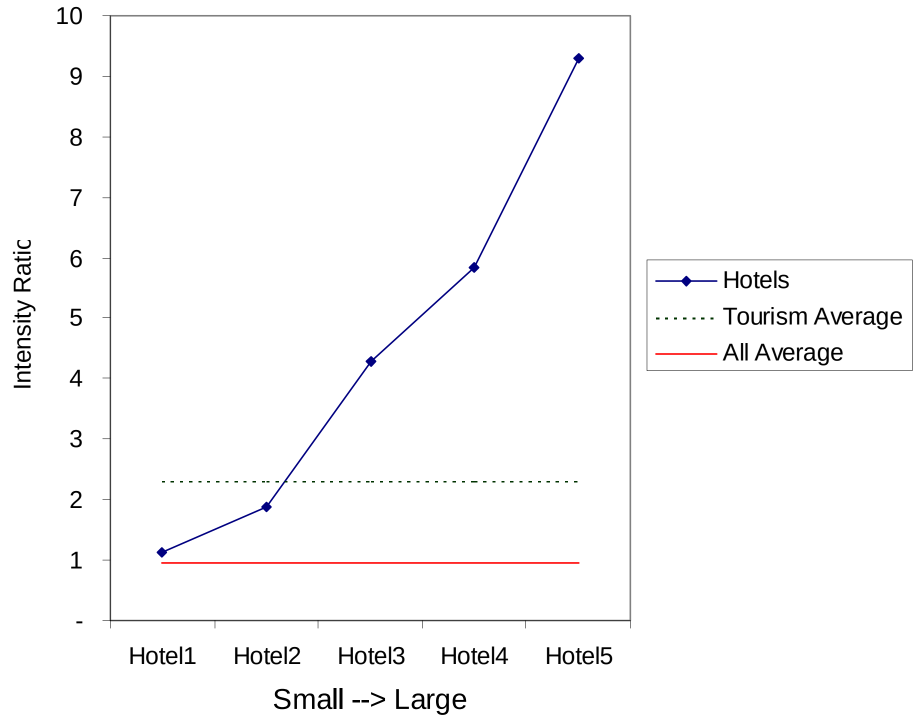


Figure 252: Intensity Ratios of Hotels
Intensity Ratios were calculated for the five hotels interviewed. Intensity ratio might suggest an ideal or appropriate hotel size for hotel developments on the island. "All Average" is the average intensity ratio for all subsystems on Bonaire (0.94). Values are calculated in Table 44 in APPENDIX S. See discussion with Figure 158 and Figure 161.

If this analysis had been done before ecotourism development had begun on Bonaire, it would have been recommended that establishment size be limited to hotels at the small range. It is argued that this would have limited disruptions to the pre-existing ecological-economic system.

Three Questions about Development

Why not farm?

Before research began I asked some very general questions about ecotourism and development on Bonaire. Are people being attracted by tourism resources to abandon multiple- (mixed-) strategies and to concentrate on wage work? What will they give up when they switch exclusively to wage labor? Are they giving up a sure thing of renewable resources for the precariousness of an uncontrollable (externally controlled) market?

This first question is now clearly answerable in the affirmative. According to the analysis of Bonaire households (CHAPTER 7), far more emergy is purchased by households than is captured from nature, either by fishing or farming. In other words, household members that work in the market for cash can better support themselves and family than could subsistence farmers or fishers. In emergy terms, the emergy available for purchase today on Bonaire far exceeds the emergy that can be foraged, fished, or farmed.

To be more specific, my original concern was that Bonairians are loosing access to sources of natural emergy production. By selling their land to *pensionados*, immigrants, or other Antilleans, whether due to the tax squeeze or attractive prices, are islanders not loosing valuable sources of emergy production? Similarly, if natural production is captured by the market, such as fish, iguana, or even goat, are Bonairians not the loosers? I was, therefore, surprised at the twenty-to-one emergy advantage of purchased goods and services entering households, and thus the apparent ability of households to survive independently of these natural products, under current world economic conditions.

Does dependence on the wage labor market leave households in uncontrollable or precarious situations? It is often argued that markets everywhere pose this threat to labor. Wage labor is always in danger of layoffs, downsizing, market fluctuations, recession, etc. It may be that Bonairians are both better protected and worse off in this regard. They are worse off because the world tourism industry is inconstant, prone to fads, and vulnerable to economic downturns. Vacation travel depends on a reliable flow of travelers with disposable income. Perhaps more threatening, it requires relatively cheap international transportation. As recent world oil supply fluctuations indicate, jet fuel availability and price are subject to the same market volatility that can threaten labor. In the longer run, if in the next ten or twenty years our world oil supply ceases to grow, passes the Hubbert Peak in other words (Hubbert 1971) (Youngquist 1997), both the demand and price of fuel will increase, which would probably restrict much vacation travel.

On the other hand, Bonairians are perhaps better off than some laborforces because the population of the island is still relatively low, and the island continues to support renewable subsistence resources. The reefs are in good shape, and goat farming remains a viable food source for islanders. As discussed previously, the "renewable" human density is smaller than the current population size and Bonairians require imported emergies, but natural production on the island can buffer the population against minor fluctuations in purchased emergy.

The Slow Bake?

If "developing" countries develop gradually, can they produce their own skilled labor, and can the rewards of development accrue to locals? In other words, if, on Bonaire, the ecotourism cake is allowed to slowly bake, will it rise to produce real wealth for the island population? Local wealth generation is a stated intention of the *National Tourism Policy*. However, the fact of development on Bonaire has not wholly matched the intent (CHAPTER 3). In the cases of foreign-owned export businesses, including some large hotels, there have been few instances of top managerial positions going to Antilleans, and especially Bonairians. In trade-related industries, the importance of imported goods and services gives large providers some leverage in the economy, which can be used to place foreign personnel. Finally, for locally owned industries, some but not all of the most lucrative economic niches have been captured by expatriate

Dutch, Americans, or other foreigners, or Antilleans from other islands, due to initial advantages in capital, in access to all forms of externals, and in skills.

If speed of development, therefore, is the major obstacle to Bonairian participation at management levels, the IMF and Dutch government are practicing policy that is problematic (see Structural Adjustment Programs and following sections). Once ecotourism emerged as a potential growth industry on Bonaire, that growth was encouraged and amplified dramatically by Island and Antillean governments. These governments are in search of foreign currency earnings to service the seemingly bottomless public debt to international lenders, principally the Dutch government (a debt that in emergy terms is being overpaid, due to Bonaire's high emergy/money ratio, see Global ecological economics section, CHAPTER 8). Debt burden is arguably a policy that international lenders in core nations use to pressure periphery governments to export primary commodities in the pursuit of foreign exchange, rather than to develop industries locally for their use.

Tourism development has established transportation networks, regular shipping, more trucks on the island, and more heavy equipment, which have spun off related economic growth in construction. These industries have their own momentum now, and they continue to look for growth opportunities.

In the case of Bonaire, however, the development pump was well primed (see CHAPTER 14, Energy Hierarchy and Sociocultural Self-Organization). The Dutch, with their Antillean resource brokers, had already established the infrastructure that both facilitated and fueled ecotourism growth when it began. When emergy storages of any kind are built-up in natural or human systems they represent a potential source for the rapid production of some output. This pulsing behavior in nature occurs, for example, when locus outbreaks rapidly consume vast storages of plant matter, or when hurricanes dissipate marine storages of summer heat. Perhaps on Bonaire, ecotourism development was the process that is consuming natural and human storages of rock, reef, construction industries, roads, harbors and airports, all storages that are now being drained in their use to produce an ecotourism product.

Ecotourism as a Wedge?

Is ecotourism the wedge, the foothold, for capitalist penetration and resource extraction from previously unexploited world regions? Is it the new best strategy for opening up heretofore-untapped environmental resources for international consumption? The follow-up question is whether ecotourism will have any longevity, and therefore whether the eco-principles of environmental management will hold up for any length of time. Or will it some day be better to view ecotourism as the wedge that was driven into new environments, attracting capital, and thus establishing the infrastructure that spins off additional exploitations of available resources.

At least in the Bonaire case, it can now be seen that ecotourism was not the first step toward development activity. On Bonaire, infrastructure in roads, airport, water, electricity, and harbor were first injected into the island from the Dutch context. In fact, "injected" is too strong a term. According to Klomp (Klomp 1986), international investment in infrastructure was vigorously sought after by Bonaire's politicians of the day, who were rewarded for success with political office. While the consequences of development were surely unforeseeable to the island population as a whole, there was general consensus that development was a common good. Some would say that this attitude was due to the attraction of higher wages, but it can just as easily be assumed that Bonairians at the time could recognize that their life choices were improved by the real work that a good harbor, paved roads, fresh water, or electricity can do in an economy.

On Bonaire, ecotourism has appeared *after* this development wedge was driven into the farmer-fisher economy of the island (see CHAPTER 14, Energy Hierarchy and

Sociocultural Self-Organization). Furthermore, the resources extracted have been only partially island resources, and partially Venezuelan oil.

It may be that this conceptualization of ecotourism as a wedge for penetrating untapped environments is still reasonable for other world regions. Low development areas may indeed be desirable locations for ecotourism to capture environmental resources for international market consumption. Perhaps the general process is the same, whether on Bonaire or a rainforest ecotourism site, but the order of events of market penetration may vary. Ecotourism then infrastructure, infrastructure then ecotourism, the process is perhaps more simultaneous, or synergistic. The effect is essentially identical, untapped natural resources are opened up to consumption by world markets, and hosts, in exchange, become often willing participants as consumers of global manufactured goods.

Will exotic environments remain ecotourism sites, or will they gradually metamorphose into the common fare of mass tourism plus other development activity once ecotourism has established a beachhead? This question will remain open, and, for settings like Bonaire, time will tell.

Summing Up - Theory and Methods

How does this research project compare in theory and methodology to other forms of ecology, evolution, and systems ecology. Some general points can be made.

Other Ecologies

Compared to population ecology or community ecology, which focus principally on biotic organisms, and the relationships between one or two or a few species, the systems ecology that underlies this research analyzes whole ecosystems, and the biotic *and* abiotic processes that form them. Systems ecology therefore attempts to account for the flows and storages of matter and energy in ecosystems, geologic systems and climatic systems.

Systems ecologists focus on the dissipation of energy in the self-organization of ecosystems (see Natural Resource Use and Re-Use in Ecosystems with Humans, CHAPTER 15). Ecosystems are analyzed for their characteristics of energy and material flow and storage. Compared to other ecologists, systems ecologists are thus critically concerned with limits to natural resources, and the dynamics of ecosystems that use those resources. Systems ecologists, more than other ecologists, address issues such as limits to water supplies, topsoil loss and conservation, limited fossil fuel storages, and the structuring of ecosystems that results from energy and material potentials. In our current world of expanding human populations and shrinking energy, metal, soil and other resources, this brand of ecology seems especially relevant.

This dissertation research adopted systems ecology as a structuring theoretical framework. It therefore addressed particularly the energy and material flows that have channeled the historic and current development of Bonaire (CHAPTER 3). The result is an "ecological" study with perhaps less "biology" than some would look for. In its place, however, is a study that has theory and methods to address questions at small and large scales, even worldwide scales, and as well questions that concern natural resource control, allocation and limits, and further questions about the self-organization of systems that result from these limited resources (CHAPTER 7 - CHAPTER 19). These issues and spatial scales are the domains that many anthropologists today feel that they must address, and systems ecology should therefore be a valuable tool for us.

Other Evolutions

Compared to population genetics, molecular biology, evolutionary ecology, human ecology, or sociobiology, which are each structured by the natural selection model of individual and thus population reproductive fitness, the model of evolution that comes from systems ecology and complex systems theory identifies evolutionary processes at multiple scales from physical chemistry, to genes, to organisms, to ecosystems, to global systems and beyond (CHAPTER 15). Compared to other evolutionists, systems scientists see biological evolution as one instance of a general model of the self-organization of dissipative structures.

Evolutionary ecology and human ecology in anthropology principally focus on people, their success in the capture and control of resources, and their affected reproductive fitness. The scale of analysis is often the individual or kin group and immediate resource control. In contrast, the evolutionary model in complex systems science and systems ecology focuses the attention of the researcher to multiple simultaneous scales. As previously discussed, this makes relevant whole ecosystems and the storages and flows of countless potentially limiting natural resources. Furthermore, for anthropologists, it returns to consideration the comparative study of whole cultures, a practice that has a long history in anthropology via the paradigm of cultural evolution (CHAPTER 16).

Systems ecology fits well with the whole systems focus of cultural evolution. Both address whole system complexification and its causes. The model of self-organization and dissipative structures in systems ecology offers to improve cultural evolutionary models by eliminating the need for "prime movers" like population pressure.

This dissertation research adopted the evolutionary theoretical framework proposed by systems ecologists and complex systems theorists. With this approach, cultures were compared across time and space to produce some general systems models for both people and culture (CHAPTER 16, CHAPTER 19), which were widely applied to the Bonaire case study (CHAPTER 7 - CHAPTER 14)

Other Systems Ecologies

Compared to other systems ecologies, the approach that emerged from this dissertation research differs in some key features (CHAPTER 21). Systems ecology in the past has been influenced by structural-functionalism within anthropology and sociology. It has therefore emphasized stability, economic function, institutions, and cooperation.

This dissertation research deals directly with power, coercion, culturally constructed hierarchy, inequality, diversity, private property rights and ownership. The self-organization of hegemonic world systems via asymmetrical trading practices that favor cores of multinational corporations and governments has been an underlying theme (see Modern States and World Systems, CHAPTER 16). At smaller scales it argued that the control of productive resources by individuals is the organizing principle of island and regional ecological-economic systems (CHAPTER 10 and CHAPTER 14).

Systems theory has also exhibited the tendency to invoke idealist, "informational" explanations of phenomena that have no immediate, apparent material explanation (CHAPTER 20). Cultural materialists have called that practice "quitting early." In that regard, this dissertation has utilized comparative cultural evolutionary models of sociocultural dynamics to seek materialist explanations for the observed events of economic development on Bonaire. This effort to explain social events actually suits well the systems ecological emphasis on material and energetic causality.

Sum Up

To sum up, few other styles of social science can use quantitative ecological and evolutionary theory and methods to move between world systems, multinational elites and goat farmers on Bonaire. The research methods employed here can produce explanations that interconnect multiple spatial scales of sociocultural systems. It is hoped that the results will prove to be intellectually intriguing to anthropologists and other scientists. It is further desired that this case study can give Bonairians new ways to see their world--past and present, to direct development, and to plan for the future.

APPENDIX A
BONAIRE SYSTEM EMERGY ANALYSIS

EMERGY Flows of Bonaire, circa 1995

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	2.62E+18	J	1	262	1,914
2	Rain, Chemical Potential Energy	1.10E+15	J	15,444	1,701	12,415
3	Rain, Geopotential Energy	5.08E+12	J	8,888	5	33
4	Wind, Kinetic Energy	2.06E+16	J	584	1,200	8,762
5	Wave Energy	4.58E+14	J	25,889	1,187	8,664
6	Tidal Energy	8.62E+13	J	49,000	422	3,082
7	Currents Energy	2.70E+13	J	1.0E+05	270	1,969
8	Earth Contribution	5.46E+09	g	1.0E+09	546	3,984
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**2,939**	**21,450**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Plants	5.75E+14	J	51,078	2,939	21,450
10	Animals	1.29E+13	J	2.06E+06	2,645	19,305
11	Sorghum	2.92E+13	J	39,000	114	831
12	Vegetables	3.22E+11	J	39,000	1	9
13	Fruit	3.22E+10	J	39,000	0.1	1
14	Livestock Animals	1.35E+12	J	2.18E+06	294	2,145
RENEWABLE IMPORTED SOURCES:						
15	Fish Catch	5.30E+11	J	5.00E+06	265	1,936
	Total of Renewable Imported Sources				**265**	**1,936**
SLOW-RENEWABLE ISLAND SOURCES:						
16	Top Soil	1.80E+13	J	63,000	114	829
17	Groundwater and Dams	3.21E+11	J	617,760	20	145
18	Coral Reef	2.50E+07	g	1.0E+09	3	182
	Total of Slow-Renewable Sources				**136**	**993**
NON-RENEWABLE ISLAND SOURCES:						
19	Volcanic Rock	1.00E+09	g	4.50E+09	450	3,285
20	Limestone	4.00E+09	g	1.00E+09	400	2,920
	Total of Non-Renewable Sources				**850**	**6,204**

IMPORTED EMERGY:						
21	Goods	3.49E+10	g	3.52E+09	12,288	89,691
22	Fuel	1.43E+15	J	6.60E+04	9,414	68,713
23	Foreign Aid				2,280	16,645
24	Services of NA Govt	1.68E+06	$	5.36E+12	898	6,552
25	Services in Fuel Imports	3.72E+06	$	5.36E+12	1,990	14,525
26	Services in Other Imports	1.13E+08	$	2.36E+12	26,635	194,415
	Total Imports and Outside Sources				**51,224**	**373,896**
NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
27	Households				36,080	263,356
28	People (Maintenance 237/yr)	4.74E+10	J	7.61E+09	36,080	263,356
Total Emergy Inflows					**55,414**	
EMERGY OF EXPORTS:						
29	Salt Works (Environ.)				615	4,492
30	Tourism Product (Environ.)				847	6,182
31	Oil Transshipment (Environ.)				443	3,234
32	Antenna Arrays (Environ.)				675	4,925
33	Services in Exports	1.42E+08	$	4.72E+12	67,195	490,476
Total Emergy Outflows					**69,775**	

NOTES
Data from estimates, or from citations as shown.

Emergy/$ Ratios
Weighted Imports (USA 41.5%, EU 27.2%, Other 31.3%), 2.36E+12 sej/$
Bonaire Emergy/$ ratio, 4.72E+12 sej/$
Netherlands Antilles Emergy/$ ratio, 5.36E+12 sej/$

Areas
Land Area = 28,700 ha
Reef Area = 12,800 ha (200m line less than 1 mile from shore)
Total Area = 4.15E+08 m^2

NUMBERED FOOTNOTES

Footnotes for Items 1-18 see Natural Systems analysis (APPENDIX D).

NON-RENEWABLE ISLAND SOURCES:

Averaged Yearly Deliveries, estimated		*Average Dug*
Limestone to Rock Crushers =	150,000 MT	150,000 MT
Limestone to Construction =	100,000 MT	
Volcanic to Construction =	50,000 MT	50,000 MT
Limestone to Roadway =	25,000 MT	
Volcanic to Roadway =	25,000 MT	25,000 MT
Limestone to Port =	5,000 MT	
Limestone to Airport =	20,000 MT	
	375,000 MT Delivered	225,000 MT Dug

19) Volcanic Rock: Volcanic sediments are dug (ripped) from private lands and sold with owners consent; Volcanic stone and sand; Construction, 50,000 MT; Roadway, 25,000 MT, est.; Turnover time of stored rock in buildings and roads, 75yrs;
Total Mass (g) = ((50,000 MT)+(25,000 MT))(1E6 g/MT)/(75 yrs) = 1.0E+09g/yr

20) Limestone: Stone and Sand 150,000 MT, est.; Turnover time of stored rock in buildings and roads, 75yrs. Dykes in Salt Works, estimated mass 100,000 MT, turnover time 50 years.
Total Mass (g) = (((150,000 MT)/(75 yrs))+((100,000 MT)/(50 yrs)))(1E6 g/MT) = 4.0E+09g/yr

IMPORTED EMERGY:

21) Merchandise
Add 2% of Curacao's import value and quantity to Bonaire's. Re-imported to Bonaire from Curacao (see text for discussion).

Bonaire Merchandise Adjusted	1995 Value	1991 Quantity (kg)
Original Merchandise		
Curaçao	1.65E+09 NAf	4.34E+08 kg
Bonaire	5.37E+07 NAf	2.62E+07 kg
Adjusted Merchandise (incl. 2% re-imported from Curacao)		
Curaçao	1.62E+09 NAf	4.26E+08 kg
Bonaire	8.68E+07 NAf	3.49E+07 kg
Bonaire Merchandise =	34,908 MT	
Total Wt. (g) =	3.49E+10 g/yr	

22) Fuel: Fuels on Bonaire. Despite repeated attempts, I could not persuade ISLA, the PDVSA refinery to release any fuel import numbers for Bonaire. Neither would the local importing company Bonoil. I therefore used interviews with end users and estimations to construct these figures below. See the subsystem analyses for details.

LABEL	QUANTITY	Unit	
The Port (Harbor and Piloting)	2,200,000	l/yr	diesel (tugboat fuel)
Construction Subsystem	850,000	l/yr	gas
Electricity Production	12,000,000	l/yr	gasahol (electric and water)
Roadway Subsystem	49,000	l/yr	gasoil and diesel fuel
Heavy Equipment Subsystem	165,000	l/yr	gas
Inter-Island Shipping	240,000	l/yr	diesel (ship fuel)
Stevedoring and Agents	83,000	l/yr	gas
Wholesalers	46,000	l/yr	gas
Retailers	625,000	l/yr	gas
Salt Works	175,000	l/yr	gas and diesel
Oil Transshipment	1,500,000	l/yr	gasahol and gas (electricity generators)
Household-Labor Production System	2,300,000	l/yr	gas (3 gallons/wk per car)
Radio Relay Stations	2,555,000	l/yr	gas oil (electricity generators)
Airport	12,000,000	l/yr	jet fuel (half ALM flights, few others)
Total =	34,788,000	l/yr	
Energy (J) =	1.43E+15	J/yr	(___l/yr)*(41E6J/l)

23) Foreign Aid: This value is included in the total services. It is shown here for information only. Foreign Aid, compiled from assorted Depos reports, and others. Total foreign aid (since 1960s) 1.83E+08NAF, unadjusted; Total foreign aid emergy 6,841,100 E14 sej, adjusted for yearly emergy/$ ratios (see The State Equation and Financial Aid in Government section).
Per year aid (30 years) 228,037 E14 sej

24) Services in NA Government: The services of the Netherlands Antilles government (Land) are purchased with national taxes. National taxes were not known, but were said to be approximately 10% of Island taxes of 30,000,000 NAf.
Services ($) = (3,000,000 NAf/yr)(1.79 NAf/$) = 1.68 E6 $/yr

25) Services in Fuel Imports: Value of oil used on Bonaire, 6,650,000 NAf, est (0.19 NAf/liter, wholesale). Emergy calculated with Curacao Emergy/$ ratio of 5.35E+12 sej/$.
Services ($) = (6,650,000 NAf/yr)(1.79 NAf/$) = 3,715,084 $/yr

26) Services in Other Imports Merchandise is estimated from known imports plus estimated Curacao re-imports. All other numbers are estimated from the Curacao numbers. These values are 5% of Curacao's. See discussion in text.

Goods and Services Due to:	**1995 Value**	**Services Emergy**
CURRENT ACCOUNT		
Merchandise	86,772,000	1.14E+20
Transportation	5,665,000	7.46E+18
Tourism	21,800,000	2.87E+19
Investment income	8,590,000	1.13E+19
Gov' t. n.i.e.	550,000	7.24E+17
Private remittances	13,660,000	1.80E+19
Other services	26,845,000	3.53E+19
Total	163,882,000	2.16E+20
CAPITAL ACCOUNT		
Private capital	36,450,000	4.80E+19
Gov't capital	2,000,000	2.63E+18
Total	38,450,000	5.06E+19
Total Flow =	202,332,000	2.66E+20
Total Service Costs =	1.13E+08 $/yr	

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

27) Households: See Household-Labor Production System analysis for details; Total production, 36,080 E14 sej

28) People (Maintenance 237/yr): Count, 14,218 people; 60yrs TT (Turnover Time of a person); Flow of persons per year, 237 persons flow = birth flow = death flow; 11,848 kg/yr (flow = 237 people * 50 kg/person / 60yr TT)

28a) Biomass Energy(J) Flux =(11,848 kg/yr)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 4.74E+10 J/yr (energy for maintenance of human population = birth = death)

EMERGY OF EXPORTS:

29) Salt Works (Environ.): Salt is the largest material export from Bonaire by far. It is evaluated in a subsystem analysis. The dollars paid for salt are included in the total export dollars. However, that money does not pay for environmental inputs, and it only pays for one-sixth of fuels. Those values are added together here.
Renewable emergy, 23,576 E14 sej/yr; Slow-renewable (topsoil), 13,449 E14 sej/yr; Non-renewable (limestone), 20,029 E14 sej/yr; Fuels, 4,483 E14 sej/yr (see Salt Works subsystem)
Total = 615 E16 sej/yr

30) Tourism Product (Environ.): Tourism is the largest export from Bonaire in terms of foreign exchange.
Renewable emergy, 51,003 E14 sej/yr; Slow-renewable (topsoil), 2,518 E14 sej/yr; Non-renewable (limestone), 1 E14 sej/yr; Fuels, 31,177 E14 sej/yr (see **Tourism**)
Total = 847 E16 sej/yr

31) Oil Transshipment (Environ.)
Renewable emergy, 4,396 E14 sej/yr; Slow-renewable (topsoil), 501 E14 sej/yr; Non-renewable (limestone), 0.1 E14 sej/yr; Fuels, 39,412 E14 sej/yr (see Oil Transshipment subsystem)
Total = 443 E16 sej/yr

32) Antenna Arrays (Environ.)
Two large antenna farms have been producing signal on Bonaire for 30 years. They are evaluated in a subsystem analysis.
Renewable emergy, 1,443 E14 sej/yr; Slow-renewable (topsoil), 26 E14 sej/yr; Non-renewable (limestone), 1 E14 sej/yr; Fuels, 65,996 E14 sej/yr (see Radio Relay Stations subsystem)
Total = 675 E16 sej/yr

33) Services in Exports: Besides merchandise and tourism export values that were known from (Central-Bank 1997), these values are estimated from the Curacao numbers. These values are 5% of Curacao. See discussion in APPENDIX C.

Exports		**Emergy/$ ratio of Bonaire**	
Bonaire		**4.72E+12**	
Goods and Services	**1995**	**Services**	
Due to:	**Value**	**Emergy/yr**	
CURRENT ACCOUNT			
Merchandise	11,309,000	3.17E+19	(CBS 1991)
Transportation	27,880,000	7.80E+19	(est. 5%)
Tourism	66,300,000	1.86E+20	(Central-Bank 1997)
Investment income	9,860,000	2.76E+19	(est. 5%)
Gov' t. n.i.e.	15,235,000	4.26E+19	(est. 5%)
Private remittances	8,465,000	2.37E+19	(est. 5%)
Intercomp. remittances	13,255,000	3.71E+19	(est. 5%)
Other services	57,160,000	1.60E+20	(est. 5%)
Total	209,464,000		
CAPITAL ACCOUNT			
Private capital	39,715,000	1.11E+20	(est. 5%)
Gov't capital	5,470,000	1.53E+19	(est. 5%)
Total	45,185,000		
Total Flow =	254,649,000	7.13E+20	
Total Service Costs =	1.42E+08 $/yr		

Services Balance Sheet	Dollars	Emergy
Total Service Imports =	1.13E+08 $	2.86E+20 sej
Total Service Exports =	1.42E+08 $	7.13E+20 sej
Difference =	-2.92E+07 $	-4.27E+20 sej
Difference (%) =	-26%	-60%

Table 2. Summary of Flows for Bonaire, circa 1995

Letter	*Item*	*Solar Emergy (E16 sej/yr)*	*Dollars/yr*
R	Renewable sources (rain + tide + fish)	3,204	
N	Nonrenewable sources flow within Bonaire	986	
N0	Dispersed Rural Source	986	
F	Imported Fuels and Minerals	9,414	
G	Imported Goods	12,288	
I	Dollars Paid for Imports		$1.167E+08
P2I	Emergy Value of Services and Other Goods Imports	29,522	
U	Total emergy used (N0+R+F+G+P2I)	55,414	
E	Dollars Received for Exports		$1.42E+08
P1E	Emergy Value of Services and Other Goods Exports	67,195	
B	Exported Products transformed within the island (Tourism Product, Salt, Transhipped Oil, Radio Signal)	2,580	
X	GDP, Netherlands Antilles 1994 (Europa 1998:2479)		$4.11E+09
	GDP, Bonaire (1994)		$1.17E+08
P2	U.S. emergy/$ ratio, used in imports	1.37E+12	
	World emergy/$ ratio, used in imports	3.8E+12	
	Weighted Imports (USA 41.5%, EU 27.2%, Other 31.3%)	2.36E+12	(EIU 1997:66)
	1990 Netherlands emergy/$ ratio, used in foreign aid, imports	2.2E+12	
P1	Bonaire Emergy/$ ratio	4.72E+12	

Footnotes to Table 2

P2	1960 Netherlands emergy/$	Odum 1986:313-14	
P2	1990 Netherlands emergy/$	Odum 1986:201	
X	GDP, Bonaire (1994, CBS 1996)	2.10E+08	NAf
		1.17E+08	$

Table 3. Indices for Bonaire, circa 1995

Item	*Name of Index*	*Expression*	*Quantity*	
1	Renewable emergy flow	R	3.20E+19	sej/y
2	Flow from indigenous nonrenewable reserves	N	9.86E+18	sej/y
3	Flow of imported emergy	F+G+P2I	5.12E+20	sej/y
4	Total emergy inflows	R+N+F+G+P2I	5.54E+20	sej/y
5	Total emergy used, U	U=N0+N1+R+F+G+P2I	5.54E+20	sej/y
6	Total exported emergy	P1E+B	6.97E+20	sej/y
7	Fraction emergy use derived from home sources	(NO+N1+R)/U	0.08	
8	Imports minus exports	(F+G+P2I)-(N2+B+P1E)	-1.85E+20	sej/y
9	Export to Imports (Island Yield Ratio = Y/F)	(N2+P1E+B)/(F+G+P2I)	1.36	
10	Fraction used, locally renewable	R/U	0.058	
11	Fraction of use purchased	(F+G+P2I)/U	0.92	
12	Fraction imported service	P2I/U	0.53	
13	Fraction of use that is free	(R+N0)/U	0.076	
14	Ratio of concentrated to rural (Island Investment Ratio = F/I)	(F+G+P2I+N1)/(R+N0)	12.22	
15	Use per unit area (4.15E8 m^2)	U/(area)	1.27E+12	sej/m2
16	Use per laborer	U/person	3.90E+16	sej/person
17	Renewable carrying capacity at present living standard	(R/U)*(person)	822	people
18	Developed carrying capacity at same living standard	8(R/U)*(person)	6,577	people
19	Ratio of use to GNP, Emergy/Dollar Ratio	P1=U/GNP	4.72E+12	sej/$
20	Ratio of electricity to use	(electric)/U	0.11	
21	Fuel use per person	fuel/population	6.62E+15	sej/person

Footnotes to Table 3

20 RATIO OF ELECTRICTY TO USE		
(___kWh/yr)*(860 Cal/kwh)*(4186 J/Cal)		
Electricity use 1995 (CBS 1996)	63,000,000	kWh/yr
Energy (J) =	2.27E+14	J/yr
Transformity of electricity =	2.72E+05	sej/j
	6.18E+19	sej

Table 4. Indices Comparison

Index	*Bonaire*	*Netherlands Antilles*	*Taiwan*	*Mexico*	*U.S.A.*	*P.N.G.*	*Brazil*	*Australi*	*New Zealand*	*World*	*Bonaire 1950s*	*Netherla 1980*
Emergy Use (E20sej/y)	5.5	220	1861	4818	66400	1205	17820	8850	791	188000	0.51	3702
GNP (E9$/yr)	0.12	4.1	99	185	2600	2.3	214	139	26	5000	0.006	166
Emergy/$ (E12sej/$)	4.72	5.3	1.9	2.6	2.6	51.79	8.4	6.4	3.0	3.8	8.67	2.2
Population (E6 people)	0.022	0.21	18	81.14	227	3.2	121	15	3.1	5044	0.014	14
Emergy Use/person (E15sej/per/yr	39.0	106	8	5.93	29	37.7	15	59	26	1.6	3.58	26.3
Environmental component of Emergy (E20sej/yr)	0.42	0.95	515		8240	997	10200	4590	438	80000	0.33	859
Economic component of Emergy (E20sej/yr)	5.1	219	1425		58160	208	7600	3960	353	188000	0.18	2843
Economic/ Environment	12.2	232	2.8		7.1	.21	.74	1.1	.8	2.35	0.56	3.3
Area (E10 m^2)	0.044	0.07	3.6	196	940	46.2	918	768	26.9	_	0.04	3.7
Population Density (people/Km^2	49.5	324	494	41.4	24.2	6.9	13.2	1.9	11.5	_	19.4	380
Emergy use/area (E11sej/m^2/y	12.7	297	52	2.0	7.0	2.61	2.8	1.42	2.49	_	1.17	100

Table 5. EMERGY Storages of Bonaire, circa 1995

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E18 sej)*	*Emdollar Value (1993 E6 US$)*
EMERGY STORAGES						
1	Hardwood Biomass	2.88E+16	J	5.11E+04	1,469	1,072
2	Limestone	1.16E+16	g	1.00E+09	11,623,500	8,484,307
3	Volcanic Sediment	7.75E+15	g	1.00E+09	7,749,000	5,656,204
4	Topsoil	1.94E+14	J	6.30E+04	12	9
5	Groundwater	1.15E+16	J	4.10E+04	471	344
6	Coral Reef	1.00E+12	g	1.00E+09	1,000	730
7	Livestock	2.70E+12	J	2.18E+06	6	4
8	Foreign Aid Storage				342	250
9	Harbor				35	25
10	Roadways				764	558
11	Houses				3,000	2,190
12	Economic Assets	2.35E+09	$	5.01E+12	11,756	8,581
13	People	1.71E+14	J	7.54E+07	12,869	9,394
14	People (person-years)	4.27E+05	per-	3.10E+16	13,223	9,652
15	Money Supply	4.99E+07	$	5.01E+12	250	182
	Total of Storages				**19,417,447**	14,173,319

Notes

1) Hardwood Biomass: Estimated Bonaire NPP, 57,505 MT, see Natural systems analysis; Turnover time of thornforest, 50 yrs, est.;

Total storage = (57,505 MT/yr)(50 yrs))*(.5 DW)*(1.0E+06 g/MT)*(4.78 kcal/g)*(4186 J/kcal) = 2.88E+16 J

2) Limestone: Bonaire average elevation, 45 m; Area of Bonaire, 2.87E+08m^2; Above sea level rock, 1.29E+10m^3; Estimate 60% is limestone, 7.75E+09 m^3; Estimate 40% is volcanic, 5.17E+09 m^3; 1.50 MT/m^3 est.

Limestone (g) = (7.75E9 m^3)(1.5 MT/m^3)(1E6 g/MT) = 1.16E+16g

3) Volcanic Sediment: Estimate 40% is volcanic, 5.17E+09 m^3

Volcanic (g) = (5.17 E9 m^3)(1.5 MT/m^3)(1E6 g/MT) = 7.75E+15g

4) Topsoil

Temperate forest org. mat., 17.50 MT/acre, (Odum 1996a:195); Estimate Bonaire org. mat. (5%) = 0.88 MT/acre, 0.35 MT/ha; Bonaire land area, 24,250 ha; Organic matter, 8.59+09g

Energy = (8.59 g)(5.4kcal/g)(4186 J/kcal) = 1.94+14 J

5) Groundwater: Porosity of Limestone, 0.10; Land Area, 2.87E+08 m^2;

Groundwater Storage Energy = (2.87E8 m^2)(0.10 porosity)(100m)(1e6g/m^3)(4 J/g) = 1.15E+16J

Storage, 2.87E+09 m^3; Inflow, 3.80E+06 m^3/yr, est. per Water Budget analysis, APPENDIX E; Turnover Time = 755 years (seems reasonable?)

6) Coral Reef: Total Reef, 1,000,000 MT, guess; 1.00E+12g

7) Livestock: Livestock Biomass, 337 MT; 2 yrs, avg turnover; 674 MT

Energy(J) =(674 MT)*(.2 dry wt)*(1E+06 g/MT)*(4.78 kcal/g)*(4186 J/Cal) = 2.70E+12 J

8) Foreign Aid Storage: Total Foreign Aid (40 yrs), 6,841,100 sej; 171,027 Financial Aid/Yr (40 years); Storage, 3,420,550 Yearly Aid x 20 (5% depriciation)

9) Harbor: Total Emergy Storage, 348,023 sej (see Port analysis)

10) Roadways: Total Emergy Storage; 7,644,011 sej (see Roadway analysis)

11) Houses: Total Emergy Storage, 30,000,000 sej (see Households analysis)

12) Economic Assets: Gross Domestic Product, 1.17E+08$/yr: GDP x 20 = 2.35E+09$ services, 5%/yr depreciation

Two Approaches to Evaluating the Emergy Storage in People

13) People: Populataion, 14,218 people; Average mass, 50 kg; Lifespan, 60 yrs; Biomass Storage, 42,654,000 kg
(42,654,000 kg/yr)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 1.71E+14J
Transformity People =6.34E+09sej/j, see Household-Labor Production System analysis

14) People (person-years): Population, 14,218 people; Average age, 30 yrs; 426,540 people-years; sej/Person-year = 3.10E+16 (Odum 1996a:195)

15) Money Supply: Money, 8.93E+08NAF; 4.99E+08$
Estimate Bonaire 10% = 4.99E+07$

APPENDIX B
THE NETHERLANDS ANTILLES SYSTEM EMERGY ANALYSIS

EMERGY Flows of the Netherlands Antilles, circa 1995

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	6.96E+18	J	1	696	5,083
2	Rain, Chemical Potential Energy	2.93E+15	J	15,444	4,518	32,975
3	Rain, Geopotential Energy	1.35E+13	J	8,888	12	88
4	Wind, Kinetic Energy	5.46E+16	J	584	3,188	23,273
5	Wave Energy	1.22E+15	J	25,889	3,153	23,012
6	Tidal Energy	2.29E+14	J	49,000	1,121	8,184
7	Currents Energy	7.16E+13	J	1.0E+05	716	5,230
8	Earth Contribution	1.45E+10	g	1.0E+09	1,450	10,580
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**7,805**	**56,970**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Plants	1.53E+15	J	51,078	7,805	56,970
10	Animals	3.42E+13	J	2.1E+06	7,024	51,273
11	Sorghum	7.75E+13	J	39,000	302	2,207
12	Vegetables	8.56E+11	J	39,000	3	24
13	Fruit	8.56E+10	J	39,000	0.3	2
14	Livestock Animals	3.58E+12	J	2.2E+06	780	5,697
RENEWABLE IMPORTED SOURCES:						
15	Fish Catch	1.41E+12	J	2.00E+06	282	2,057
	Total of Renewable Imported Sources				**282**	**2,057**
SLOW-RENEWABLE ISLAND SOURCES:						
16	Top Soil	1.37E+13	J	63,000	86	629
17	Groundwater and Dams	1.37E+13	J	617,760	845	6,170
18	Coral Reef	1.00E+08	g	1.0E+09	10	730
	Total of Slow-Renewable Sources				**941**	**6,872**
NON-RENEWABLE ISLAND SOURCES:						
19	Volcanic Rock	6.00E+09	g	4.50E+09	2,700	19,708
20	Limestone	1.20E+10	g	1.00E+09	1,200	8,759
	Total of Non-Renewable Sources				**3,900**	**28,467**

IMPORTED EMERGY:						
21	Merchandise	5.01E+11	g	3.52E+09	176,694	1,289,739
22	Oil Used on Islands	1.93E+17	J	6.60E+04	1,272,569	9,288,823
23	Foreign Aid, Dutch	1.31E+08	$	2.20E+12	28,797	210,195
24	Services in Imports	3.14E+09	$	2.36E+12	739,748	5,399,623
	Total Imports and Outside Sources				**2,189,011**	**15,978,184**
NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
25	Households				525,853	3,838,342
26	People (Maintenance 3,454/yr)	6.91E+11	J	7.61E+07	525,853	3,838,342
Total Emergy Inflows					**2,201,939**	
EMERGY OF EXPORTS:						
27	Goods Exported	1.71E+11	g	3.52E+09	60,221	439,570
28	Tourism Product Exported				153,830	1,122,843
29	Services in Exports	4.30E+09	$	5.36E+12	2,305,781	16,830,520
Total Emergy Outflows					**2,519,832**	
EMERGY PASSING THROUGH THE ECONOMY WITHOUT USE						
30	Oil Imported for Refining	6.35E+17	J	6.60E+04	4,191,991	30,598,474
31	Oil Exported after Refining	4.42E+17	J	6.60E+04	2,919,422	21,309,652

NOTES

In order to produce a rough emergy analysis for the Netherlands Antilles as a whole, I have extrapolated the environmental data from Bonaire on an area basis. This is acceptable for two reasons. First, the two Leeward Islands (Bonaire and Curacao) make up over 91% of the area. The majority of the natural environment is therefore similar to Bonaire's. Second, the great majority of emergy that enters the Netherlands Antilles system is clearly not renewable environmental emergy. As you will see below, Curacao and St. Maarten especially are very developed islands. Aruba is not a part of this evaluation, since politically it is a separate and equal unit in the Kingdom of the Netherlands. Another emergy analysis could be performed that includes Aruba, which would be reasonable based on history and shared geography. Aruba numbers are included below for information only.

Areas and Populations (EUROPA 1998)

Netherlands Antilles and Aruba	Area	Population	Density (km^2)
Curacao	44,400 ha	152,700	344
Aruba	19,300 ha	87,972	456
St Maarten	3,400 ha	36,231	1,066
St. Eustatius	2,100 ha	2,609	124
Saba	1,300 ha	1,466	113
Bonaire Land Area =	28,700 ha	14,218	50
	99,200 ha	295,196	298
	(without Aruba)	207,224	259

Areas and Populations			(EUROPA 1998)
Netherlands Antilles and Aruba	Area	Population	Density (km^2)
Totals			
Land Area =	79,900 ha	(without Aruba)	
Reef Area =	35,635 ha	(from Bonaire)	
Netherlands Antilles Total =	115,535 ha		
	1.16E+09 m^2		

Adjustment factor is 2.78, i.e. environmental estimates are 2.78 times the Bonaire estimates, proportional to area.

Emergy/$ Ratios
Weighted Imports (USA 41.5%, EU 27.2%, Other 31.3%), 2.36E+12 sej/$
Bonaire Emergy/$ ratio, 3.61E+12 sej/$
Netherlands Antilles Emergy/$ ratio, 5.35E+12 sej/$

NUMBERED FOOTNOTES

Footnotes for Items 1-18 see Natural Systems analysis (APPENDIX D).

NON-RENEWABLE ISLAND SOURCES:

19) Volcanic Rock: Volcanic sediments are dug (ripped) from private lands and sold with owners consent; Volcanic stone and sand use on Bonaire is Construction, 50,000 MT; Roadway, 25,000 MT, est.; For the Netherlands Antilles these values are multiplied by six. The population density of the Netherlands Antilles is 6 times that of Bonaire, and it seems reasonable that rock dug for human use should be equivalent to population. Turnover time of stored rock in buildings and roads, 75yrs;

Total Mass (g) = ((50,000 MT)+(25,000 MT))(1E6 g/MT)/(75 yrs)(6) = 6.0E+09 g/yr

20) Limestone: Stone and Sand 150,000 MT, est.; This estimate is also multiplied by six for the Netherlands Antilles. Turnover time of stored rock in buildings and roads, 75yrs

Total Mass (g) = (150,000 MT)(1E6 g/MT)/(75 yrs)(6) = 1.20E+10g/yr

IMPORTED EMERGY:

21) Merchandise
Below is calculated an emergy/mass ratio for a general "breadbasket" of imported merchandise Curacao. This same ratio is used with the Bonaire imports, in the Bonaire emergy analysis. Four values must be converted from mass to energy. See footnotes to this subtable below the table.

Imports			(CBS 1992)	
Section	**Quantity kg**	**Raw Units**	**Emergy/unit**	**Emergy**
Not Classified	23,000			
Animal & Veg. Oils/Fats	1,223,000	5.12E+12 J	2.00E+06	1.02E+19
Materials, No Fuels (Salt, Stone)	29,984,000	3.00E+10 g	1.00E+09	3.00E+19
Miscellaneous Mnf.	157,481,000	1.57E+11 g	1.80E+09	2.83E+20
Chemicals	24,671,000	2.47E+10 g	1.00E+09	2.47E+19
Mineral Fuels, Lubricants, Etc.	3,435,000	1.56E+14 J	6.60E+04	1.03E+19
Manufactured Goods	118,295,000	1.18E+11 g	1.80E+09	2.13E+20
Beverage and Tobacco	9,680,000	4.05E+13 J	6.00E+04	2.43E+18
Food and Live Animals	138,613,000	5.80E+14 J	2.00E+06	1.16E+21

Machinery & Trans. Equip.	18,037,000	1.80E+10 g	1.80E+09	3.25E+19
	501,442,000	5.01E+11		1.77E+21
		Emergy/mass ratio =	3.52E+09	sej/g

Animal & Veg. Oils/Fats
Energy (J) = (1,223,000 kg)*(1000 g/kg)*(5 Cal/g)*(20%)*(4186 J/Cal) = 5.12E+12 J/yr

Mineral Fuels, Lubricants, Etc.
Energy (J) = (3,435,000 kg)/(1000 kg/MT)*(1.0838e7 kcal/MT)*(4186 J/kcal) = 1.56E+14 J/yr

Beverage and Tobacco
Energy (J) = (9,680,000 kg)*(1000 g/kg)*(5 Cal/g)*(20%)*(4186 J/Cal) = 4.05E+13 J/yr

Food and Live Animals
Energy(J) = (138,613,000 kg)*(1000 g/kg)*(5 Cal/g)*(20%)*(4186 J/Cal) = 5.80E+14 J/yr

22) Oil Used on Islands:
Fuels in the NA
The EIU reports that oil imports and exports to the Netherlands Antilles were as listed below. Oil is refined at the Coastal Oil plant on Aruba and the PDVSA plant on Curacao. Refined oil is fed directly into the economies of the Netherlands Antilles, generating electricity, providing jet fuel to airports, gas for cars. The bulk of the oil entering the NA is refined and then exported. However, great quantities of oil are easily available for consumption on the islands. It does seem reasonable that the total below is about 100 times greater than the amount I had estimated for Bonaire. The oil necessary to run the two refineries, feed the two international airports, and fuel the total population that is 20 times greater than Bonaire's could easily be 100 times the fuel use on Bonaire.
Per ((EIU 1997):61) Imports to the Netherlands Antilles in 1995 were 14 MTOE (million ton oil equivalents). Exports were 9.75 MTOE. Of the remaining 4.25 MTOE, 1.25 MTOE were consumed in the refining processes or as losses. The remaining 3 MTOE were otherwise consumed within the Netherlands Antilles to run their economies. The entire 4.25 MTOE is a contribution to the economies, not only the 3 MTOE that directly supports them. Without consumption of the oil in refineries there would not be the remainder available for everything else.
Energy (J) = (4.25E6 MT)(4.54E10 J/MT) = 1.93E+17 J/yr

The value of this petroleum is estimated from known import and export values and quantities from 1991 ((CBS 1991)). It is reported that 17.9 MTOE were imported, with a value of 2,769 million NAf. This is (2.769E9 NAf)/(1.79E7 MT), which is approximately 155 NAf/MT. Exports were 12.7 MTOE at 2,414 million NAf , which is approximately 190 NAf/MT. With these two estimates the value of the oil that is consumed on the islands can be estimated. The oil that is consumed or lost in the refining processes is calculated at the import value, 155 NAf/MT. The refined oil that runs the economies is calculated at the export value, 190 NAf/MT.
Services value of remaining oil ($) = (155 NAf/MT)(1.25E6 MT) + (190 NAf/MT)(3 E6 MT) = 763,750,000 NAf

23) Foreign Aid, Dutch
This value is included in the total services. It is shown here for information only. Dutch Aid, 1997 is 234,300,000 NAF, (Central-Bank 1997)
Aid Service ($) = (234,300,000 NAf)/(1.79 NAf/$) = 1.31E+08$
Emergy/$ ratio of Netherlands = 2.20E+12sej/$

24) Services in Imports ((Central-Bank 1997))
Notes: (a) This emergy/money ratio was calculated from the weighted values of the US and Netherlands emergy/money ratios, the main trading partners of the Netherlands Antilles, (b) The

Balance of Payment data are from the Central Bank (Central-Bank 1997), (c) Trade statistics are from (CBS 1991). I was only able to obtain the trade data for this earlier year. While I could have used the Balance of Payment data from this year also, I chose to use the 1995 data from the year of the study. Balance of Payment data from 1991 were similar to 1995, so I assumed that the trade statistics were also similar. These results are very general approximations, which is acceptable for emergy analyses. (d) There are two components to an emergy inflow of purchased goods. "One is the emergy contained in the available energy that is brought in. The other is the emergy that supported the human services…These are entirely separate sources and must be evaluated separately (Odum 1996a:81)." These emergy values are calculated in APPENDIX P, (e) The oil quantity values are from the (EIU 1997:61) and are for the year 1995. Again, the data presented is from different years, which sacrifices some accuracy in exchange for the production of an overall summary of trade.

Netherlands Antilles	**Emergy/$ ratio of Imported Services = 2.36E+12 (a)**			
	Balance of Payments		**Imports/Exports**	
Goods and Services Due to:	**1995 (b) Value (NAf)**	**Services Emergy (sej)**	**1991(c) Quantity (kg)**	**Goods (d) Emergy (sej)**
PETROLEUM IMPORTS/EXPORTS			(e)	
Oil Refined and Exported	2,768,801,000	3.64E+21	14,000,000,000	4.19E+22
(Passes through economy uncounted)				
Oil Used on Islands				
Curacao	763,750,000	1.01E+21	4,215,000,000	1.26E+22
Bonaire	6,650,000	8.75E+18	35,000,000	1.05E+20
CURRENT ACCOUNT				
Merchandise	2,545,300,000	3.35E+21		
Curaçao	1,637,064,000	2.16E+21	429,905,520	1.51E+21
Bonaire	70,236,000	9.25E+19	30,565,480	1.08E+20
Windward Islands	838,000,000	1.10E+21		
Transportation	113,300,000	1.49E+20		
Tourism	397,200,000	5.23E+20		
Curaçao	268,400,000	3.53E+20		
Bonaire	21,800,000	2.87E+19		
Windward Islands	107,000,000	1.41E+20		
Investment income	171,800,000	2.26E+20		
Gov' t. n.i.e.	11,000,000	1.45E+19		
Private remittances	273,200,000	3.60E+20		
Intercomp. remittances				
Other services	536,900,000	7.07E+20		
Total	4,048,700,000			
CAPITAL ACCOUNT				
Private capital	729,000,000	9.60E+20		
Gov't capital	40,000,000	5.27E+19		
Total	769,000,000			
Total Flow =	5,588,100,000	6.96E+21		1.43E+22
Total Service Costs =	3.14E+09 $/yr			

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

25) Households: See Household-Labor Production System analysis for details; Bonaire Household emergy inflows are 36,080 E16 sej.

Netherlands Antilles (calculated) = (36,080 E16 sej)(207,224 people NA)/(14,218 people Bonaire) = 525,853 E16 sej (proportional to population)

26) People (Maintenance 3,454/yr): Count, 207,224 people; 60yrs TT (Turnover Time of a person); Flow of persons per year, 3,454 persons flow = birth flow = death flow; 172,687 kg/yr (flow = 3,454 people * 50 kg/person / 60yr TT)

26a) Biomass Energy(J) Flux =(172,687 kg/yr)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 6.91E+11 J/yr (energy for maintenance of human population = birth = death)

EMERGY OF EXPORTS:

27) Goods Exported: Total Merchandise 170,902,000 kg ((CBS 1991))

28) Tourism Product Exported

Tourism	Receipts (NAF)	Emergy	
Curaçao	314,100,000	4.81E+20	(proportional to Bonaire/NAf)
Bonaire	66,300,000	1.02E+20	(see Tourism subsystem)
Windward Islands	624,200,000	9.56E+20	(proportional to Bonaire/NAf)
		1.53E+21	

29) Services in Exports ((Central-Bank 1997))
Notes: (a) By *mass*, Bonaire's (non-oil) merchandise exports actually exceed Curacao's. That is because Bonaire exports about 300,000 tons per year of salt from the Akzo Nobel salt works. In 1995, Bonaire and Curacao also exported rice under the EU null tariff agreement, and Curacao exports stone to Bonaire and chemicals from the petroleum industry. (b) I am showing that tourism exports a material component in addition to tourism services (foreign exchange earnings). While it might appear that tourism has no exported material component, tourism is an "invisible export" good because the material product of the industry is consumed by foreigners, albeit on domestic soil.

Netherlands Antilles	**Emergy/$ ratio of Netherlands Antilles services = 5.35+12**			
	Balance of Payments		**Imports/Exports**	
Goods and Services Due to:	**1995 Value (NAf)**	**Services Emergy (sej)**	**1991 Quantity (kg)**	**Goods Emergy (sej)**
PETROLEUM IMPORTS/EXPORTS				
Oil Refined and Exported	2,740,172,000	2.38E+22	9,750,000,000	2.92E+22
(Passes through economy uncounted)				
Oil Used on Islands				
Curacao				
Bonaire				
CURRENT ACCOUNT				
Merchandise	377,100,000	1.13E+21	(a)	
Curaçao	289,300,000	8.65E+20	170,902,000	6.02E+20
Bonaire	11,300,000	3.38E+19	252,622,000	8.90E+20
Windward Islands	76,500,000	2.29E+20		
Transportation	557,600,000	1.67E+21		
Tourism	1,004,600,000	3.01E+21		(b)
Curaçao	314,100,000	9.40E+20		7.51E+20
Bonaire	66,300,000	1.98E+20		1.59E+20
Windward Islands	624,200,000	1.87E+21		1.49E+21

Netherlands Antilles	Emergy/$ ratio of Netherlands Antilles services = 5.35+12			
	Balance of Payments		Imports/Exports	
Goods and Services Due to:	**1995 Value (NAf)**	**Services Emergy (sej)**	**1991 Quantity (kg)**	**Goods Emergy (sej)**
Investment income	197,200,000	5.90E+20		
Gov' t. n.i.e.	304,700,000	9.11E+20		
Private remittances	169,300,000	5.06E+20		
Intercomp. remittances	265,100,000	7.93E+20		
Other services	1,143,200,000	3.42E+21		
Total	4,018,800,000	1.62E+22		
CAPITAL ACCOUNT				
Private capital	794,300,000	2.38E+21		
Gov't capital	109,400,000	3.27E+20		
Total	903,700,000			
Total Flow =	7,662,672,000	2.29E+22		2.85E+21
Total Service Costs ($) =	4.30E+09 $/yr			

EMERGY PASSING THROUGH THE ECONOMY WITHOUT USE

30) Oil Imported for Refining: Amount is 14,000,000 MT ((EIU 1997):61)
Energy(J) =(14,000,000 MT)*(1.0838e7 kcal/MT)*(4186 J/kcal) = 6.35E+17 J/yr

31) Oil Exported after Refining: Amount is 9,750,000 MT ((EIU 1997):61)
Energy(J) = (9,750,000 MT)*(1.0838e7 kcal/MT)*(4186 J/kcal) = 4.42E+17 J/yr

Table 2. Summary of Flows for Netherlands Antilles, circa 1995

Letter	*Item*	*Solar Emergy (E16 sej/y)*	*Dollars*
R	Renewable sources (rain + tide + fish)	8,087	
N	Nonrenewable sources flow within the Netherlands Antilles	4,841	
N0	Dispersed Rural Source	4,841	
N1	Concentrated Use	-	
N2	Exported without Use	-	
F	Imported Fuels and Minerals	1,272,569	
G	Imported Goods	176,694	
I	Dollars Paid for Imports		$3.14E+09
P2I	Emergy Value of Services and Other Goods Imports	739,748	
E	Dollars Received for Exports		$4.30E+09
P1E	Emergy Value of Services and Other Goods Exports	2,305,781	
B	Exported Products transformed within the island (Merchandise Goods & Tourisim Product)	214,051	
X	GDP, Netherlands Antilles 1994 (Europa 1998:2479)		$4.11E+09
P2	U.S. emergy/$ ratio, used in imports	1.37E+12	
	World emergy/$ ratio, used in imports	3.8E+12	
	Weighted Imports (USA 41.5%, EU 27.2%, Other 31.3%)	2.36E+12	
	1990 Netherlands emergy/$ ratio, used in foreign aid, import	2.2E+12	
P1	Netherlands Antilles Emergy/$ ratio	5.36E+12	

Footnotes to Table 2

P2	1960 Netherlands emergy/$	Odum 1986:313-14	
	1990 Netherlands emergy/$	Odum 1986:201	
	Weighted Imports (EIU 1997:66)	Percent of Imports	Emergy/$ ratio
	USA percent of imports	41.5%	1.37E+12
	EU percent of imports	27.2%	2.2E+12
	Others	31.3%	3.8E+12
	Weighted average =		2.36E+12

Table 3. Indices for Netherlands Antilles, circa 1995

Item	*Name of Index*	*Expression*	*Quantity*	
1	Renewable emergy flow	R	8.09E+19	sej/y
2	Flow from indigenous nonrenewable reserves	N	4.84E+19	sej/y
3	Flow of imported emergy	F+G+P2I	2.19E+22	sej/y
4	Total emergy inflows	R+N+F+G+P2I	2.20E+22	sej/y
5	Total emergy used, U (leaves out salt)	U=N0+N1+R+F+G+P2I	2.20E+22	sej/y
6	Total exported emergy	B + P1E	2.52E+22	sej/y
7	Fraction emergy use derived from home sources	(NO+N1+R)/U	0.0059	
8	Imports minus exports	(F+G+P2I)-(N2+B+P1E)	-3.31E+21	sej/y
9	Export to Imports	(N2+P1E+B)/(F+G+P2I)	1.15	
10	Fraction used, locally renewable	R/U	0.0037	
11	Fraction of use purchased	(F+G+P2I)/U	0.99	
12	Fraction imported service	P2I/U	0.34	
13	Fraction of use that is free	(R+N0)/U	0.0059	
14	Ratio of concentrated to rural	(F+G+P2I+N1)/(R+N0)	169.32	
15	Use per unit area (1.43E9 m^2)	U/(area)	1.91E+13	sej/m2
16	Use per laborer	U/person	1.06E+17	sej/person
17	Renewable carrying capacity at present living standard	(R/U)*(person)	761	people
18	Developed carrying capacity at same living standard	8(R/U)*(person)	6,088	people
19	Ratio of use to GNP, Emergy/Dollar Ratio	P1=U/GNP	5.36E+12	sej/$
20	Ratio of electricity to use	(electric)/U	0.03	
21	Fuel use per person	fuel/population	2.95E+18	sej/person

Footnotes to Table 3

20 RATIO OF ELECTRICTY TO USE		
(___kWh/yr)*(860 Cal/kwh)*(4186 J/Cal)		
Electricity use 1994 (CBS 1995)	738,000,000	kWh/yr
Energy (J) =	2.66E+15	J/yr
Transformity of electricity =	2.73E+05	sej/j
	7.24E+20	sej

APPENDIX C
MACROECONOMIC DATA FOR BONAIRE

There are two methods for calculating GDP in an economy. The Income Approach measures the yearly flow of money to the owners of assets. The Expenditure Approach measures the money spent by persons for goods and services. These two flows of money are said to be equal because they are measuring two sides of the same process, gross economic production in an economy.

I will focus on the expenditure approach to GDP for the economies of Bonaire and the Netherlands Antilles.

Expenditure Approach

The expenditure approach measures GDP by adding together the expenditures on goods and services purchased by households (called consumption, C), by the government (G), by (net) foreigner's (NX), and by the owners themselves (called investment, I).

GDP = C + G + NX + I = Income to Owners (Y)

Table 40: GDP by Expenditure Approach
Figures for the 1990 Netherlands Antilles (NA) are from (CBS 1995:88). Bonaire 1990 GDP is from (CBS 1994b:9). Netherlands Antilles 1994 GDP is from (EUROPA 1998:2479). Bonaire 1993 is from (CBS 1996). See Table 41 for a breakdown of Bonaire's GDP. All figures are in million NAf.

	NA 1990	**Bonaire 1990**	**NA 1994**	**Bonaire 1993**
C	2,177		2,793	
G	835		1,071	
I	792		1,016	
NX	(599)		(769)	
GDP	3,205	138	4,111	210

Table 40 shows two known GDPs for both Bonaire and the Netherlands Antilles. From Figure 219, consumption (C) is the flow of money from households to industry for the purchase of goods. The flow of emergy (goods and services) is in the opposite direction. In the Investment (I) flow, the owners of one industry purchase the products of another industry. In emergy terms, investment is the work of maintenance against depreciation (from the Second Law of thermodynamics), in which work must be performed to maintain a storage of assets (the factory building, machines, records, etc.). Both households and industries also purchase loans of money from banks, for which they must pay interest. The loan itself, the legal contract, is the material good, and it is stored in the high security infrastructure of banks.

Government expenditures (G) are the purchases of goods from industry. Government assets are courthouses, tanks, toilets, and canons--the countless material goods that make possible the service and force of government. These assets are purchased from industry, often with borrowed money. Governments therefore also purchase loans from banks at interest.

Net exports (NX) measures the loss or gain in currencies due to international trade. It indicates, therefore, not the total flow of imports or exports, but the difference between the two. In countercurrent is the net goods and services flow into an economy.

The GDP therefore, not only measures the flow of money in a economy, but it tracks the flows of goods and services from one sector to another. Figure 219 adds to this equation the functional relationships that exist between the elites of government, industry, financial institutions, and households, which form a hierarchy of production, joined by the flows of material goods and services.

The Sectoral Origin of GDP

The expenditure approach to GDP may be refined by identifying the sector from which the expenditure/purchase was made. This is called the sectoral origin of the GDP. It depicts the destinations of monetary flows in the economy.

Table 41: Sectoral Origin of GDP
Figures for the 1990 Netherlands Antilles (NA) are from (CBS 1995:86). Bonaire 1990 figures are from (CBS 1994b:9). Netherlands Antilles 1994 figures are from (EUROPA 1998:2479). Bonaire 1993 figures are from (CBS 1996). All figures are in million NAf.

Sector	**NA 1990**	**Bonaire 1990**	**NA 1994**	**Bonaire 1993**	**Bonaire Major Contributor**
Agriculture, fishing & mining	24	10	36		Salt works
Manufacturing	215	5	245	9	
Public utilities	101	6	121	11	WEB
Construction	218	7	207	22	Houses & Hotels
Wholesale & retail trade	697	13	866		Households
Restaurants & hotels	216	13	216	21	Tourism
Finance and other business services	677	28	952	37	Tourism
Transport, storage & communication	345	27	613	56	Airfares, Port
Social & personal services	359	16	374	22	
Imputed bank charges	(176)	(11)	(250)		
Government services	529	23	731	34	
GDP	3,205	138	4,111	210	

This gives a reasonable GDP for Bonaire at the time of my study. It will be used to calculate the Emergy/money ratio for Bonaire. The sectoral numbers provide general measures for the services produced in portions of the Bonaire economy. In emergy accounting, money is paid to people for the services provided. In the case of the wholesale and retail sector, the money paid to that sector measures the services provided by that sector, not the emergy in the goods that are sold. That emergy is an additional measure based on the energetic sources that contributed to the production of the good.

Emergy Sources Flowing into the Bonaire Economy

The emergy sources that are driving the Bonaire economy are flowing into the economy in many forms. Some are natural and renewable, such as the sun, wind, rain, and tides. Many others are produced by the outside economies of the world and enter Bonaire as trade imports.

Import statistics are available in a few forms. For the Netherlands Antilles, statistics of imports and exports are produced by the Centraal Bureau voor de Statistiek (CBS). These numbers are compilations of customs data, and therefore include some physical measure of the goods (usually mass), in addition to the value of the goods.

A complementary source of trade data is the Balance of Payments report from the Central Bank of the Netherlands Antilles. There are many flows of currency other than trade expenditures that move between nations. This money pays for "services", such as investment income, or ship handling, or tourism. Emergy accounting views services as an emergy flow into or out from an economy. Services move in counter-current to the money that pays for them. If money goes out, services are coming in. Converted to emergy, an inflow of services represents the work done in the foreign economy to produce the service. See APPENDIX B, Items 24 and 29 for details of imports and exports to the Netherlands Antilles, respectively.

Missing Numbers

There are some important patterns of un-, under-, and over-reporting in the trade statistics for Bonaire and the Netherlands Antilles. In some cases data can be supplemented from other sources. In others, estimations can be made from known figures.

Imports to Bonaire

For this study of Bonaire, one critical under-reporting is the omission of trade between Curacao and Bonaire. Movement of goods between the islands is considered a "free circulation" and customs statistics are not kept. The import statistics that do exist for Bonaire are direct imports from foreign ports of origin.

To remedy this, I have added a percentage of Curacao's imports of merchandise to Bonaire's. While Bonaire has approximately 10% of the population of Curacao, it does not have the heavy industry of the larger island, or the substantial offshore banking sector. I am therefore estimating that 2% of the merchandise imports to Curacao are re-exported to Bonaire. These numbers are added to the known imports to Bonaire to give Bonaire a rough approximation of 5% of total merchandise (see Table 42). For emergy analysis this will be sufficient to produce estimations of driving emergy sources. If any values are found to be especially important to the analysis, they may be investigated further.

Table 42: Bonaire Merchandise Adjusted
Bonaire's merchandise imports are adjusted to reach 5% of the total merchandise trade reaching the islands (by value). Note that by mass this is approximately 7.6%. Similar adjustments were made in APPENDIX A.

	1995 Value (NAf)	1991 Quantity (kg)
Original Merchandise		
Curaçao	1,653,600,000	434,248,000
Bonaire	53,700,000	26,223,000
Adjusted Merchandise (incl. 2% re-imported from Curacao)		
Curaçao	1,620,528,000	425,563,040
Bonaire	86,772,000	34,907,960
Bonaire's percent of total =	5.1%	7.6%
Percent directly shipped =	61.9%	75.1%

Fuels

Perhaps the most critical under-reporting for the analysis of the Netherlands Antilles, including Bonaire, is the absence of good data on oil imports and oil use. The islands of the Netherlands Antilles are powered by oil from the oil fields of Venezuela. No coal or natural gas is employed. In the trade statistics, only fuel imports to Curacao are available, Bonaire imports are "free circulation" re-imports from Curacao. On Curacao the imported oil is destined for the PDVSA refinery. That oil is refined and the majority is exported. Export data shows the quantity and values of petroleum products leaving Curacao. Unfortunately, these figures give no indication of the volume of oil that stays behind to power the refinery and additionally the economies of Curacao and Bonaire. While trade statistics indicate the earnings to the islands, they do not reveal the volume of oil that remains.

Fortunately, rough estimates of these numbers have been collected from elsewhere. For 1995 it is reported that petroleum imports were 14 million tons oil equivalent (MTOE) to the Netherlands Antilles (EIU 1997:61). Of that amount, 4.25 MTOE were consumed by the Netherlands Antilles economy. Energy to run the refinery plus losses amounted to 1.25 MTOE, which leaves 3 MTOE to power other production subsystems on Curacao and around the Netherlands Antilles.

An attempt must be made to estimate the monetary value of these petroleum imports that remain on Curacao to power the economies of the Netherlands Antilles. That value represents the services provided by the Venezuela economy in getting oil to the market. In 1991, the Curacao refinery received 17.9 MTOE, with a value of 2,769 million NAf (CBS 1991). This computes to approximately 155 NAf/ton. If 4.25 MTOE remain on Curacao, the value of services for that oil is about 465 million NAf. This value is an invisible "service" contribution to the Curacao economy. With total non-oil merchandise imports to Curacao of 1,570 million NAf in 1995 (Central-Bank 1997), this additional service input is very significant, and together total about 2 million NAf in service inflows for the emergy analysis.

Estimating the fuel use on Bonaire was difficult. With no import figures available, an attempt was made to construct a value by summing the known use of fuel on Bonaire. See the Bonaire System analysis for details (APPENDIX A). The number that was constructed is 35,000 Tons, which is approximately 1% of the 3 million tons retained from the flow through Curacao. Bonaire has 10% of the population of Curacao, but less industry and a far smaller port and airport. This estimate of 1% seems reasonable. The hidden "services" inflow to Bonaire associated with the refined oil is approximately 6.65 million NAf, added to a total non-oil input of 202 million NAf.

Un-Reported Trade

Finally, a significant portion of total imports and exports to Bonaire are not available. The Central Bank figures for Services imports (besides Tourism) were not available. This includes transportation, investment income, transfers, and the capital account figures. These figures were estimated as 5% of Curacao's. See APPENDIX B.

APPENDIX D
NATURAL SYSTEMS EMERGY ANALYSIS

EMERGY Flows of Natural Systems on Bonaire

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sei)*	*EmDollar Value (1993 US$)*
RENEWABLE SOURCES:						
1	Sunlight	2.62E+18	J	1	262	191
2	Rain, Chemical Potential Energ	1.10E+15	J	15,444	1,701	1,242
3	Rain, Geopotential Energy	5.08E+12	J	8,888	5	3
4	Wind, Kinetic Energy	2.06E+16	J	584	1,200	876
5	Wave Energy	4.58E+14	J	25,889	1,187	866
6	Tidal Energy	8.62E+13	J	49,000	422	308
7	Currents Energy	2.70E+13	J	1.0E+05	270	197
8	Earth Contribution	5.46E+09	g	1.0E+09	546	398
					2,939	
RENEWABLE PRODUCTION WITHIN BONAIRE:						
9	Mondi Plants	5.75E+14	J	51,078	2,939	2,145
10	Mondi Animals	1.29E+13	J	2.06E+06	2,645	1,930
11	Sorghum	2.92E+13	J	39,000	114	83
12	Vegetables	3.22E+11	J	39,000	1.3	1
13	Fruit	3.22E+10	J	39,000	0.1	0
14	Livestock Animals	1.35E+12	J	2.18E+06	294	214
15	Reef Fish	9.11E+12	J	2.00E+06	1,822	
SLOW-RENEWABLE RESOURCE USE FROM WITHIN BONAIRE						
16	Top Soil	5.15E+12	J	63,000	32	24
17	Groundwater and Dams	3.21E+11	J	617,760	20	14
18	Coral Reef	1.00E+07	g	1.0E+09	1	1
					53	
NON-RENEWABLE SOURCES FROM WITHIN BONAIRE:						
19	Volcanic Rock	5.00E+06	g	4.5E+09	2.3	2
20	Limestone	5.00E+06	g	1.0E+09	0.5	0
					3	

NUMBERED FOOTNOTES

RENEWABLE SOURCES:

1) Sunlight: Land Area, 28,700ha; Reef Area, 12,800ha; Total Area, 4.15E+08m^2; Solar Radiation, 180 kcal/cm^2/yr (Budyko (1974)) (also called Insolation, radiation reaching the

ground); Ground Reflection, 0.20 (Ground reflection of Solar Radiation without absorption, expressed as a fraction); (Fraction absorbed, (1 - 0.2 = 0.8))
Energy(J) = (Total area)*(Avg insolation)*(Fraction absorbed) =(4.35E8m^2)(180 kcal/cm^2/yr)(1E4cm^2/m^2)(1-0.2)(4186 J/kcal) = 2.62E+18

2) Rain, Chemical Potential Energy: Gibbs free energy of rainwater relative to seawater, 4940 J/kg; Land Area, 2.87.E+08m^2; Shelf Area, 1.28.E+08m^2; Lac Bay, 2.0 E+07m^2; Rain (land), 0.53 m/yr (CBS 1990); Evapotrans rate, 0.95 (est. 95% of rain is ET); Chemical potential energy over LAND is (land area)(Evapotrans)(rainfall)(Gibbs no.)
Land chemical rainfall energy = (2.87E8 m^2)(.95)(.53m)(1000kg/m^3)(4.94E+03J/kg) = 7.14E+14 J
Chemical potential energy over SHELF is (reef area)(rainfall)(Gibbs no.); Freshwater in the ocean makes density gradients and drives current
Shelf chemical rainfall energy = (1.28E8 m^2 + 2.0E7 m^2)(.53m)(1000kg/m^3)(4.94E+03J/kg) = 3.87E+14 J
Total rain chemical potential energy =1.10E+15 J

3) Rain, Geopotential Energy (Not added into total, double counting with chemical energy): Area, 4.35.E+08 m^2; Rainfall, 0.53 m; Avg Elev, 45 m; Runoff rate, 0.05 (1.0 - ET);
Energy(J) = (area)(% runoff)(rainfall)(avg elevation)(gravity) = (2.59E8m^2)(.05)(1000kg/m^3)(45m)(9.8m/s^2) = 5.08E+12 J/yr

4) Wind, Kinetic Energy:
Evaluating Landscape Use of Wind Kinetic Energy (Odum calculation)

Wind Kinetic Energy, D = r * C * V^3 Joules/m^2/second
Where r is air density (1.3 kg/m^3) and the velocity is in meters per second (mps).
m/s = 0.22 * Miles per hour.

Winds observed over land are about 0.6 of the wind that the pressure system (geostrophic wind) would generate in the absence of the friction.
V = (10/6) * wind observed over land (v)

The drag coefficient C is about 1.0 E-3 for ordinary winds of 10 meters per second (m/s) or less, but increases to 4.0 E-3 at wind velocity of 50 m/s in hurricanes

The emergy contributed is the power dissipation D times an appropriate transformity for the wind velocity.

Land and Shelf area =	4.35E+08 m^2
Average annual wind velocity (v) =	6.3 m/s
Geostrophic wind (V) = (10/6)(v) =	10.5 m/s
Drag coefficient used (C) =	0.0010
Air density =	1.3 kg/m^3
Average wind transformity =	584 sej/J
Seconds in a year =	3.14E+07 s/yr
1 Joule =	1.00E+00 kg m^2/s^2

D = (1.3 kg/m3)(1.0 E-3)((10.5 m/s3)^3)(3.14 E7 s/y) = 4.73E+07 J/m^2/y
D (*mondi*) = D * area = (4.73E7 J/m^2/y)(2.4E8 m^2) = 2.06E+16 J/y

5) Wave Energy: Wave heights and shore lengths (van Duyl 1985:10-11)
Wave height, 1.5 m (estimate); Shore length, 20 km (perpendicular to waves);

F = ma, kg*m/s^2, nt
m = (density, kg/m^3)*(volume, m^3)

volume = (wave height squared, m^2)*(shore length, m)
a = gravity, 9.8m/s^2
v, velocity of falling water = SQRT((shoaling depth)*(gravity))
Wave energy = F*v, kg*m/s^2 * m/s, (kg*m^2/s^2)/s, J/s

Wave energy = (((density of seawater)(volume))(gravity))(SQRT((shoaling depth)(gravity))(fraction of energy at shore, 1/8)

Wave energy = (((1025 kg/m^3)((1 m)^2*(2E4 m)))(9.8 m/s^2))(SQRT((0.75 m)(9.8 m/s^2))1/8

Wave energy = 1.45E+08 J/s
Conversion, s/yr = 3.15E+07 s/yr
Wave energy = 4.58E+15 J/yr
Wave energy absorbed (10%) = 4.58E+14J/yr (90% of wave energy reflected by rock coast)

6) Tidal Energy: Cont Shlf Area, 1.28E+08 m^2; Lac Bay, 2.0E+07 m^2; Avg Tide Range, 0.30m ((Rooth 1965)); Density of Sea Water, 1025kg/m^3 (Odum 1983); Tides/year = 730tides/yr

Tidal Energy(J) = (shelf area)*(90% absorbed)*(tides/y)*(mean tidal range)^2*(density of seawater)*(gravity)
Tidal Energy = (1.48E8 m^2)*(0.9)*(730 tides/yr)*(.30 m)^2*(1025 kg/m^3)*(9.8m/s^2) = 8.62E+13 J/yr

7) Currents Energy: Oceanic swell moving from the east to west. Assume a water current of 0.25 m/s (0.5 knot) with 10% absorbed, sweeping over the NE Coastline (25 km). Shelf area, 1.28E+08 m^2; NE quarter shelf area, 3.20E+07 m^2; Distance in axis of current, 25,000 m (about 25 km of NE Coast shoreline is perpendicular to current)

Kinetic energy over the shelf:
KE = 1/2 mv^2
(1/2)*((volume of water, m^3)*(density, kg/m3))*(velocity, m/s)^2
(1/2)*(6.4E7 m^2)*(100 m avg. depth)*(1025 kg/m3)*(.51 m/s)^2 =4.27E+11 J (= kg m^2/s^2)

Rate of replacement turnover from velocity and entry cross section:
((velocity, m/s)*(conversion, s/yr))/(distance in axis of current, m)
((0.51 m/s)*(3.154E7 s/yr))/(25,000 m) = 632.40 times per year
Energy absorbed: (8.53E11J)*(9,826 /yr)*(.1, absorbed) = 2.70E+13J/yr

8) Earth Contribution: Estimated as the land use per year. Land is lost by erosion-runoff and especially by solution of karst structure (calcium carbonate). Transformity, 1E9 sej/g, for average earth cycle (Odum 1996:310)

Karst structure lost:
Yearly rainfall = 0.53 m^3/yr
Depth of percolation = 20 m^2 (20m x 1m, area of rainfall measure .53m^3)
Calcium in solution = 40 ppm, g/m^3
Limestone dissolved? = 2.5 (= 100/40, so 2.5g of limestone dissolved to release 1g calcium?)
Land area =2.17E+08 m^2

(.53 m^3/yr)/(20 m^2, percolated through)*(40 g/m^3)*(100/40 limestone dissolved?)*(2.17E8 m^2)
Karst structure lost = 5.75E+08 g/yr

Erosion-runoff lost:
Yearly runoff = 9 mm/m^2 (from Water balance, est.), 0.09 m/m^2
Suspended solids = 250 ppm, g/m^3 (estimate)

Erosion rate (clay solids) = 22.5 g/m^2
Land area = 2.17E+08 m^2
Total erosion-runoff lost = 4.88E+09 g/yr

Total Karst and erosion lost = 5.46E+09 g/yr

RENEWABLE PRODUCTION WITHIN BONAIRE:

9) *Mondi* Plants
265 g/m^2 (est. NPP for low prod. Woodland and Plant Prod = 2,650,000 g/ha high prod. Desert Scrub, from Ludwig 1986:6), 57,505 MT/*mondi*

Net primary production in arid environments can be usefully correlated with rainfall. Rutherford (1980) in (Louw and Seely 1982):117 reports that .5 mg NPP / g annual rainfall (5 kg/ha / mm rainfall) is a good estimate up to an annual rainfall of about 600 mm. For Bonaire, with 530mm annual rainfall, this equals 265 g/m^2 NPP (2650 kg/ha NPP).

Noy-Meir (1973) concludes that average annual net above-ground primary production varies between 100 and 400 g/m^2 for arid and between 250 and 1000 g/m^2 for semi-arid communities. ((Louw and Seely 1982):121).
With these numbers, an estimate of 265 g/m^2 for Bonaire again seems reasonable, although it is expected that production would be variable from year to year.

Assuming that all emergy inputs to this system are necessary for the production in the *mondi*, a transformity can be calculated for *mondi* plants. Using rain as the input emergy (to avoid double counting), the transformity of 51,078 is calculated for *mondi* plants, which could be reasonable considering the large quantity of hardwood quality plant matter that is aggregated here.

Caloric content per unit mass = 4.78 kcal/g (E.P. Odum 1971)
Energy(J) = (57,505 MT)*(.5 DW)*(1.0E+06 g/MT)*(4.78 kcal/g)*(4186 J/kcal) = 5.75E+14 J

9a) Plant Detritus: 51,755 MT (90% of NPP, in deserts)
Energy(J) = (51,755 MT)*(.5 DW)*(1.0E+06 g/MT)*(4.78 kcal/g)*(4186 J/kcal) = 5.18E+14 J

10) *Mondi* Animals: Animals, 3,214MT (sum of below three items)
Energy(J) (3,214 MT)*(.2 DW)*(1E+06 g/MT)*(4.78 Cal/g)*(4187 J/Cal) = 1.29E+13 J

10a) Invertebrates: Animals, 115kg/ha/yr, which is 2,496 MT
Energy(J) = (2,496 MT)*(.2 DW)*(1E+06 g/MT)*(4.78 Cal/g)*(4187 J/Cal) = 9.99E+13 J

10b) Small Animals: Animals, 33kg/ha/yr, which is 716 MT
Energy(J) = (716MT)*(.2 DW)*(1E+06 g/MT)*(4.78 Cal/g)*(4187 J/Cal) = 2.87E+12 J

10c) Birds of Prey: Animals, 0.1kg/ha/yr, which is 2.2 MT
Energy(J) = (2.2MT)*(.2 DW)*(1E+06 g/MT)*(4.78 Cal/g)*(4187 J/Cal) = 8.68E+09

11) Sorghum: (transformity 3.9E4 from (Odum 1996a):311, for Cornstalks); Ag. Prod, 6 MT/ha (for temperate grassland NPP, Whittaker 1975, in Odum et al 1987, Mississippi); 2100 MT (total NPP on (350 ha of sorghum)(6 MT/ha))
(total area *Mondi* (23,950 ha) + Farms (3000 ha))(2100 MT)(1E6 g/MT) = 77.9 kg/ha
Energy(J) = (2100 MT)*(1.0E+06 g/MT)*(3.32 kcal/g)*(4186 J/kcal) =2.92E+13 J

12) Vegetables: Ag. Prod, 200kg/farm (est., vegetables / farm);100 MT (total on 500 farms)
Energy(J) = (100 MT)*(.2 DW)*(1.0E+06 g/MT)*(16120 J/g) = 3.22E+11 J

13) Fruit: Ag. Prod, 20 kg/farm (est., vegetables / farm); 10 MT (total on 500 farms)

Energy(J) = (__ MT)*(.2 DW)*(1.0E+06 g/MT)*(16120 J/g) = 3.22E+10 J

14) Livestock Animals:
L'stock Prod = 300 MT (25,000 goats and 5,000 sheep @ 20kg / 2 yr lifespan)
5.3 MT (1,000 donkeys @ 80kg/15 yr lifespan)
11.7 MT (500 pigs @ 100kg / 3 yr lifespan)
20 MT (20,000 chickens, 40/farm, @ 1kg/1yr lifespan)
(300 MT)+(5.3 MT)+(11.7 MT)+(20 MT) = 337 MT

Energy(J) = (117)*(.2 dry wt)*(1E+06 g/MT)*(4.78 kcal/g)*(4186 J/Cal) = 1.35E+12 J

Transformity of livestock is calculated by assuming that they consume 10% of *mondi* vegetation. If the *mondi* vegetation requires the total emergy of the system (rain), then livestock require 10%, or 286 E16 sej/j. This gives a livestock transfromity of 2,118,673.

15) Reef Fish: Total Reef Emergy, 1,822 E16 sej/yr, per Coastal Systems analysis; Average Reef Fish transformity, 2.00E+06 sej/j;
Calculated Energy of fish = (1,822 E16 sej/yr)/(2.0 E6 sej/j) = 9.11E+12 J/yr
Calculated Mass of fish = (9.11 E12 J/yr)/((.2 dry wt)*(1E+06 g/MT)*(4.78 kcal/g)*(4186 J/Cal)) = 2,277 MT

SLOW-RENEWABLE RESOURCE USE FROM WITHIN BONAIRE

16) Top Soil: Erosion-runoff , 22.5 g/m^2 clay solids, est, see Note 8.
Energy(J) = (22.5 g sed/m^2)*(0.07 g OM/g sed)*(3.6Kcal/g)*(4187 J/Kcal)*(2.17E7 m^2, Area) =5.15E+12 J/yr

17) Groundwater and Dams: Chemical potential of fresh water is (fresh water)(Gibbs no.); Groundwater to Farms, 30,000 m^3/yr and Dam reservoir Water to Farms, 35,000 m^3/yr (see water budget analysis); 65,000 m^3/yr total
Fresh water energy (J) =(65,000 m^3)*(1000kg/m^3)*(4.94E+03J/kg) = 3.21E+11 J/yr

18) Coral Reef:), mass of reef storage lost per year to human activities, 10 MT/yr, est.
Mass(g) = (10 MT/yr)*(1E6 gm/MT) = 1.00E+07 g

NON-RENEWABLE SOURCES FROM WITHIN BONAIRE:

19) Volcanic Rock: 5 MT/yr (est, low density human use)
Mass(g) = (5 MT/yr)*(1E6 gm/MT) = 5.00E+06 g

20) Limestone: 5 MT/yr (est, low density use)
Mass(g) =(5 MT/yr)*(1E6 gm/MT) = 5.00E+06 g

APPENDIX D2
COASTAL SYSTEMS ANALYSIS

Annual EMERGY Flows of the Coastal Systems of Bonaire

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*Emdollar Value (E3*
OFFSHORE = Island Shelf and Coast - Area: 1.28 E8 m^2						
RENEWABLE ISLAND SOURCES:						
1	Sunlight	7.72E+17	J	1	7,716	563
2	Rain, Chemical Potential Energy	3.24E+14	J	15,444	50,050	3,653
3	Wind, Kinetic Energy	6.05E+15	J	584	35,323	2,578
4	Wave Energy	3.97E+14	J	25,889	102,659	7,493
5	Tidal Energy	7.45E+13	J	49,000	36,512	2,665
6	Currents Energy	2.70E+13	J	1.00E+05	26,976	1,969
7	Earth Contribution	1.61E+09	g	1.00E+09	16,059	1,172
8	Migratory Birds	5.00E+09	J	2.00E+06	100.0	7
	Total of Renewable Sources (Wave+Currents+Tide+Earth)				**182,206**	**13,300**
RENEWABLE PRODUCTION WITHIN BONAIRE:						
9	Reef Fish	9.11E+12	J	2.00E+06	182,206	13,300
IMPORTED EMERGY FOR FISHING INDUSTRY:						
10	Deep Water Pelagic Fish	5.30E+11	J	5.00E+06	26,522	1,936
11	Boats	3.56E+07	g	6.70E+09	2,385	174
12	Fuel	1.07E+14	J	63,000	67,695	4,941
13	Parts and Services	1.50E+06	$	5.36E+12	80,396	5,868
14	Fishers (Labor)				14,588	1,065
	Total Imports and Outside Sources				**191,588**	**13,984**
FISH CATCH AND TRANSFORMITY AFTER FISH LANDINGS:						
15	Pelagic Fish from Fishers	5.30E+11	J	3.61E+07	191,588	13,984
16	Fish Outlet Emergy				20,529	1,498
17	Fish on Sale from Outlets	5.30E+11	J	4.00E+07	212,116	15,483

INSHORE - Estuaries and Beaches - Area: 2E7 m^2

RENEWABLE ISLAND SOURCES:

18	Sunlight	1.21E+17	J	1	1,206	88
19	Rain, Chemical Potential Energy	5.06E+13	J	15,444	7,820	571
20	Wind, Kinetic Energy	9.45E+14	J	584	5,519	403
21	Wave Energy	6.20E+13	J	25,889	16,041	1,171
22	Tidal Energy	1.16E+13	J	49,000	5,705	416
23	Earth Contribution	2.51E+08	g	1.0E+09	2,509	183
24	Rooi Run-in, chemical potential	8.73E+11	J	41,068	359	26.2
25	Rooi Run-in, total N (g)	1.98E+05	J	9.0E+08	2	0.130
26	Rooi Run-in, total P (g)	2.19E+04	J	8.1E+09	2	0.130
27	Rooi Run-in, Organic load (COD)	7.74E+12	J	62,400	4,832	352.7
28	Migratory Birds	5.00E+09	J	2.0E+06	100	7.30
	Total of Renewable Sources (Wave+Organic Run-in+Tide+Earth				**29,087**	**2,123**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

29	Boats	5.00E+06	g	6.7E+09	335	24.45
30	Fuel	1.07E+13	J	63,000	6,716	490.2
31	Parts and Services	3.65E+03	$	5.4E+12	195	14.26
32	Fishers (Labor)				3,647	266
	Total Imports and Outside Sources				**10,893**	**795**

RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

33	Conch, Other Shellfish and Fish	1.47E+10	J	2.0E+06	3	0.22

NOTES

Offshore - Island Shelf and Coast - Area: 1.28 E8 m^2
Inshore - Bay Estuary and Beaches Area: 2E7 m^2

Offshore Fraction of Total = 0.294253
Bay Fraction of Total = 0.045977
Offshore Fraction of Marine = 0.864865
Bay Fraction of Marine = 0.135135

NUMBERED FOOTNOTES

OFFSHORE - Island Shelf and Coast

RENEWABLE ISLAND SOURCES:

Footnotes for Items 1-5, 7, see Natural Systems analysis ()

6) Currents Energy: Total Currents Energy is focused on Shelf and Coast, 2.70E+13 J

8) Migratory Birds: Migratory population, 10,000 (estimate 10,000 migratory sea birds, half year); 1 kg (estimate 1 kg/bird, lives 4 years); 1,250 kg (flow of 10,000 birds, half year, with TT of 4 years)

Bird Energy(J) = (1,250 kg)(.2 dry wt)(1E+03 g/kg)(4.78 kcal/g)(4186 J/Cal) = 5.00E+09 J

RENEWABLE PRODUCTION WITHIN BONAIRE:

9) Reef Fish: These estimates are back calculated from total reef emergy. For information only. It would be interesting to compare them with other biomass estimates for the reefs. Total Renewable Reef Emergy, 182,206 E16 sej/yr; Average Reef Fish transformity, 2 E6 sej/j

Calculated Energy of fish = (182,206 E16 sej/yr)/(2 E6 sej/j) = 9.11 E12 J/yr

Energy(J) = (__MT)*(.2 dry wt)*(1E+06 g/MT)*(4.78 kcal/g)*(4186 J/Cal)

Calculated Mass of fish = (9.11 E12 J/yr)/((.2 dry wt)*(1E+06 g/MT)*(4.78 kcal/g)*(4186 J/Cal)) = 2,277 MT

IMPORTED EMERGY FOR FISHING INDUSTRY:

10) Deep Water Pelagic Fish: Deep water fish are outside the border of the Bonaire system as defined, and are therefore considered as an "imported" source. Fishing sources are primarily (Leendertse and Verbeek 1986:78) and (Roullot 1980)
Catch is 10,000 kg/yr (per fulltime fisher); Full-time Fishers are 52 boats (boats over 24 ft, with inboard engines);Total Catch (Full-time Fishers) is therefore estimated as 520,000 kg/yr; Part-time Fishers, 200; Part-time Catch estimate is 1,000 kg/yr (est. 10% of full-time fishers); Total Catch (Part-time Fishers) is therefore estimated as 200,000 kg/yr;

Total Catch (dry weight, 0.2) = (520,000 kg/yr + 200,000 kg/yr)*(0.2 dw) = 144,000 kg/yr

Energy (J) = (144,000kg)(1000g/kg)(4 kcal/g)(4186 J/kcal)(22% protien) = 5.3 E11 J/yr

11) Boats: Full-time fishers 52; 156 MT (est. 3 MT each for inboard boats over 24 feet)
Part-time fishers 200 MT (est. 1 MT each for small outboard boats)

Total Wt. (g) = (356,000 kg)*(1000g/kg)/(10 Yrs. dep) = 3.56E+07 g/yr

12) Fuel: 200 l/engine/week, estimate average (50 gallons/wk), which is 2,620,800 l/yr

Energy (J) = (2,620,800 l/yr)*(41E6J/l) = 1.07E+14 J/yr

13) Parts and Services: Gasoline is 1 NAF/liter which is 2,620,800 NAF/yr; Parts estimate, 50,000 NAF/yr

Services Total = (2,620,800 NAF/yr + 50,000 NAf/yr)/(1.78 NAf/$) = 1,500,990 $/yr

14) Fishers (Labor): Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 100 fishers (est. from 52 full-time, 200 part-time)

Emergy/yr = (100 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 14,588 E14 sej/yr

FISH CATCH AND TRANSFORMITY AFTER FISH LANDINGS:

15) Pelagic Fish from Fishers Transformity = (191,588 E14 sej/yr) / (5.3 E11 J/yr) = 3.61 E7 sej/J

16) Fish Outlet Emergy: Approximately five major fish outlets (combined wholesalers/retailers); 4,106 E14 sej/Household (est. affluent 2)

Fish Outlet Emergy (sej) = (4,106 E14 sej/Household)(5 Households) = 20,529 E14 sej/yr

17) Fish On Sale from Outlets = (212,116 E14 sej/yr) / (5.3 E11 J/yr) = 4 E7 sej/J

INSHORE - Bay Estuary and Beaches

RENEWABLE ISLAND SOURCES:

Footnotes for Items 18-23, see Natural Systems analysis ()

24) Rooi Run-in, chemical potential: Rooi measurements were evaluated because it was thought that they might be important. The numbers suggest that they are relatively less important. Gibbs free energy of rainwater relative to seawater, 4940 J/kg; Run-in water estimated as 4.42 mm, which is 4.42E+06 mm^3/m^2/yr; Drainage estimate is 4,000 ha, which is 4.0E+07 m^2

Energy = (4.94J/g)(1E6g/m^3)(4.42 E6 mm^3/m^2/yr)(4.0E+07 m^2)/(1E9 mm^3/m^3) = 8.73E+11 J/yr

25) Rooi Run-in, total N (g): Rooi total N: 80 mg-at/m^3 average concentration at surface, Ecuador study

Total N (g) = (80 mg-at/m3)(.001 g-at/mg-at)(14 g/g-at)(1.77E5 m3/yr) = 1.98E+05 g/yr

Solar transformity of marine nutrient nitrogen, 9.0 E8 sej/g was derived from world annual emergy flux divided by world oceanic nitrogen flux.

26) Rooi Run-in, total P (g): Rooi total P: 4 mg-at/m^3 average concentration at surface, Equador study

Total P (g) = (4 mg-at/m3)(.001 g-at/mg-at)(31 g/g-at)(1.77E5 m3/yr) = 2.19E+04 g/yr

Solar transformity of marine phosphate phosphorus, 8.1 E9 sej/g was derived from world annual emergy flux divided by world oceanic phosphorus flux. Nitrogen and Phosphorus are cycle by-products representing the same emergy.

27) Rooi Run-in, Organic load (COD): Runoff estimate is 185 kg/ha/yr; Runoff to Sea (est 50% of total runoff) 92.5 kg/ha/yr; Lac Bay drainage land area estimate is 4,000 ha

Runoff to Bay (total) = (4,000 ha)(92.5 kg/ha/yr)/(1000 kg/MT) = 370 MT/yr

Energy = (370 MT/yr)(1E6g/MT)(5kcal/g)(4186 J/kcal) = 7.74E+12 J/yr

28) Migratory Birds: Migratory population, 10,000 (estimate 10,000 migratory sea birds, half year); 1 kg (estimate 1 kg/bird, lives 4 years); 1,250 kg (flow of 10,000 birds, half year, with TT of 4 years)

Bird Energy(J) = (1,250 kg)(.2 dry wt)(1E+03 g/kg)(4.78 kcal/g)(4186 J/Cal) = 5.00E+09 J

IMPORTED EMERGY AND TECHNOLOGY SOURCES:

29) Boats: Part-time fishers 50 fishers (est); 50 MT (est. 1 MT each for small outboard boats);

Total Wt. (g) = (50,000 kg)*(1000g/kg)/(10 Yrs. dep) = 5.00E+06 g/yr

30) Fuel: 100 l/engine/week, estimate average (50 gallons/wk), which is 260,000 l/yr

Energy (J) = (260,000 l/yr)*(41E6J/l) = 1.07E+13 J/yr

31) Parts and Services: Gasoline is 1 NAF/liter which is 260,000 NAF/yr; Parts estimate, 50,000 NAF/yr

Services Total = (260,000 NAF/yr + 50,000 NAf/yr)/(1.78 NAf/$) = 174,220 $/yr

32) Fishers (Labor): Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 25 fishers (est. from 100 part-time)

Emergy/yr = (100 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 3,647 E14 sej/yr

RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

33) Conch, Other Shellfish and Fish: Total Catch, 20,000 kg/yr (est.)

Energy (J) = (20,000kg)(0.2 dw)(1000g/kg)(4 kcal/g)(4186 J/kcal)(22% protien) = 1.47E+10 J/yr

APPENDIX E
WATER BUDGET EMERGY ANALYSIS

Water Budget of Bonaire						
Notes	*Items*	*Quantity*	*Units*	*Transformity*	*Units*	*Emergy (E17)*
1	Rainfall	7.51E+14	J	15,444	sej/J	116
2	Evaporation	3.57E+14	J	32,514	sej/J	116
3	ET	3.57E+14	J	32,514	sej/J	116
4	Groundwater	1.88E+13	J	617,760	sej/J	116
5	Runoff to Dams	3.76E+11	J	617,760	sej/J	2.32
6	Runoff to Salt Lakes	9.20E+12	J	617,760	sej/J	56.86
7	Runoff to Sea	9.20E+12	J	617,760	sej/J	56.86

NUMBERED FOOTNOTES

Surface Area of Bonaire is 2.87E+08 m^2; Salinas and Salt Lakes area is 2.20E+07m^2 ((Rooth 1965):14); Land Area of Bonaire is 2.65E+08 m^2

1) Rainfall is 530 mm/yr; Total Yearly Rainfall on Bonaire is (area)*(rainfall)
Volume rainfall = (2.87E8 m^2)(0.53 m) = 1.52E+08 m^3 water/yr (152,110,000 m^3/yr)
Chemical Potential Energy of Rain = (Volume)(Gibbs No.)
Energy (J) = (1.52E8 m^3)*(1000 kg/m^3)*(4.94E+03 J/kg) = 7.51E+14 J

Rainwater to Houses (Cisterns)	
To Cisterns (per House or Farm) =	20 m^3/house/yr
For all Households (500) =	10,000 m^3/yr

Evaporation + Evapotransporation (ET) is estimated to be 95% of Rainfall
Evap. + ET = (530 mm/yr)(95%) = 503.5 mm/yr
Remaining = 26.5 mm/yr

2) Evaporation is 50% est. of 503.5 mm/yr, which is 251.75 mm/yr
Total Evaporation from Bonaire = (2.87E8 m^2)(0.25 m) = 7.23E+07 m^3 water/yr (72,252,250 m^3/yr)
Chemical Potential Energy of Evaporation = (7.23E7 m^3)(1000 kg/m^3)(4.94E+03 J/kg) = 3.57E+14 J/yr

3) ET is 50% est. of 503.5 mm/yr, which is 251.75 mm/yr
Total ET from Bonaire = (2.87E8 m^2)(0.25 m) = 7.23E+07 m^3 water/yr (72,252,250 m^3/yr)
Chemical Potential Energy of ET = (7.23E7 m^3)(1000 kg/m^3)(4.94E+03 J/kg) = 3.57E+14 J/yr

4) Groundwater is estimated to be 50% of the remaining 26.5 mm/yr, or 13.25 mm/yr
Estimated total groundwater = (2.87E8 m^2)(0.01325 m) = 3.8E6 m^3 water/yr (3,802,750 m^3/yr)

Chemical Potential Energy of Groundwater = (3.8E6 m^3)(1000 kg/m^3)(4.94E+03 J/kg) = 1.88E+13 J/yr

Destinations of Groundwater Outflows		
Wells To *Kunuku*s (per Farm) =	50	m^3/farm/yr
For all Farms (500) =	25,000	m^3/yr
Wells To Goats / Sheep (per Farm) =	10	m^3/farm/yr
For all Farms (500) =	5,000	m^3/yr
To Support *Mondi* =	730,550	m^3/yr (remainder of groundwater flow)
Loss to Wetlands or Sea =	3,042,200	m^3/yr (80% of groundwater flow)

The remaining water (13.25 mm/yr) is estimated to be surface runoff
Estimated runoff = (2.87E8 m^2)(0.01325 m) = 3.8E6 m^3 water/yr (3,802,750 m^3/yr) to Dams, Salt Lakes, and Sea. Runoff is split in thirds between Dams, Salt Lakes, and Runoff to Sea

5) Runoff to Dams is a small but important amount, estimated to be 2% of remaining 13.25 mm (0.27 mm/yr)
Estimated total groundwater = (2.87E8 m^2)(0.00027 m) = 76,055 m^3 water/yr
Chemical Potential Energy of Groundwater = (76,055 m^3)(1000 kg/m^3)(4.94E+03 J/kg) = 3.76E+11 J/yr
Flow per Dam (est. 500 dams) = 152 m^3/yr/dam

Dam Water Use (Outflows)		
To Goats / Sheep (per farm) =	40	m^3/farm dam/yr
For all Farms (500) =	20,000	m^3/yr
To Vegetables (per farm) =	30	m^3/farm dam/yr
For all Farms (500) =	15,000	m^3/yr
To Groundwater =	40	m^3/farm dam/yr
For all Farms (500) =	20,000	m^3/yr
To Evaporation =	40	m^3/farm dam/yr
For all Farms (500) =	20,000	m^3/yr

6) Runoff to Salt Lakes is estimated to be half of remaining runoff (6.49mm/yr)
Total Flow to all Salt Lakes = (2.87E8 m^2)(0.00649 m) = 1,863,348 m^3 water/yr
Chemical Potential Energy of Lake Runoff = (1,863,348 m^3)(1000 kg/m^3)(4.94E+03 J/kg) = 9.20E+12 J/yr

7) Runoff to Sea is estimated to be the other half of remaining runoff (6.49mm/yr)
Total Flow to Sea = (2.87E8 m^2)(0.00649 m) = 1,863,348 m^3 water/yr
Chemical Potential Energy of Sea Runoff = (1,863,348 m^3)(1000 kg/m^3)(4.94E+03 J/kg) = 9.20E+12 J/yr

APPENDIX F
HOUSEHOLDS SYSTEM EMERGY ANALYSIS

EMERGY Flows of Households Subsystem, 1995

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
(MONDI & KUNUKUS)						
1	Sunlight	1.05E+18	J	1	10,464	763,820
2	Rain, Chemical Potential Energy	4.40E+14	J	15,444	67,880	4,954,769
3	Rain, Geopotential Energy	2.03E+12	J	8,888	180	13,162
4	Wind, Kinetic Energy	8.20E+15	J	584	47,907	3,496,897
5	Wave Energy	1.83E+14	J	25,889	47,371	3,457,720
6	Tidal Energy	3.44E+13	J	49,000	16,848	1,229,776
7	Currents Energy	1.08E+13	J	1.0E+05	10,766	785,807
8	Earth Contribution	2.18E+09	g	1.0E+09	21,780	1,589,782
	Total of Renewable Sources (Mondi & Kunukus)				**117,274**	**8,560,134**
(HOUSE & OTHER)						
1b	Sunlight	2.70E+17	J	1	2,700	197,115
2b	Rain, Chemical Potential Energy	1.13E+14	J	15,444	17,518	1,278,650
3b	Rain, Geopotential Energy	5.24E+11	J	8,888	47	3,397
4b	Wind, Kinetic Energy	2.12E+15	J	584	12,363	902,425
5b	Wave Energy	4.72E+13	J	25,889	12,225	892,315
6b	Tidal Energy	8.87E+12	J	49,000	4,348	317,361
7b	Currents Energy	2.78E+12	J	1.0E+05	2,778	202,789
8b	Earth Contribution	5.62E+08	g	1.0E+09	5,621	410,266
	Total of Renewable Sources (House & Other)				**30,264**	**2,209,067**
	Total of Renewable Sources (Rain + Tide + Currents + Earth)				**147,538**	**10,769,201**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
(MONDI & KUNUKUS)						
9	Mondi Plants	2.30E+14	J	51,078	117,274	8,560,134
10	Mondi Animals	5.13E+12	J	2,056,417	105,546	7,704,120
11	Sorghum	2.92E+13	J	39,000	11,382	830,808
12	Vegetables	3.22E+11	J	39,000	126	9,178
13	Fruit	3.22E+10	J	39,000	13	918
14	Livestock Animals	9.44E+11	J	2,178,982	20,570	1,501,475
	Total of Renewable Production (Mondi & Kunukus)				**254,911**	**18,606,633**
(HOUSE & OTHER)						
9b	Mondi Plants	5.93E+13	J	51,078	30,264	2,209,067
10b	Mondi Animals	1.32E+12	J	2,056,417	27,238	1,988,160
	Total of Renewable Production (House & Other)				**57,502**	**4,197,227**
	Total of Renewable Production				**312,413**	**22,803,860**

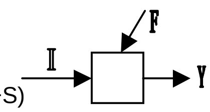
SLOW-RENEWABLE ISLAND SOURCES:						
(MONDI & KUNUKUS)						
15	Top Soil	2.06E+12	J	63,000	1,295	94,542
16	Groundwater and Dams	1.28E+11	J	617,760	792	57,783
17	Coral Reef	3.99E+06	g	1.0E+09	40	2,913
	Total of Slow-Renewable Sources (Mondi & Kunukus)				**2,127**	**155,238**
(HOUSE & OTHER)						
15b	Top Soil	5.31E+11	J	63,000	334	24,398
16b	Groundwater and Dams	3.31E+10	J	617,760	204	14,912
17b	Coral Reef	1.03E+06	g	1.0E+09	10	752
	Total of Slow-Renewable Sources (House & Other)				**549**	**40,061**
	Total of Slow-Renewable Sources				**2,676**	**195,300**
NON-RENEWABLE ISLAND SOURCES:						
(MONDI & KUNUKUS)						
18	Volcanic Rock	2.00E+06	g	4.50E+09	90	6,554
19	Limestone	2.00E+06	g	1.00E+09	20	1,456
	Total of Non-Renewable Sources (Mondi & Kunukus)				**110**	**8,011**
(HOUSE & OTHER)						
18b	Volcanic Rock	5.15E+05	g	4.50E+09	23	1,691
19b	Limestone	5.15E+05	g	1.00E+09	5	376
	Total of Non-Renewable Sources (House & Other)				**28**	**2,067**
	Total of Non-Renewable Sources				**138**	**10,078**
IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:						
20	Construction System				541,056	39,493,161
21	Roadway System				46,344	3,382,758
22	Cars and Trucks	4.41E+08	g	6.70E+09	29,527	2,155,248
23	Travel (Airport) System				440,172	32,129,314
24	Retail System (Food & Goods)				399,623	29,169,526
25	Fish Catch	4.24E+11	J	4.04E+07	171,278	12,502,065
26	Buildings	8.34E+08	g	9.26E+07	772	56,376
27	Gasoline	9.40E+13	J	6.30E+04	59,193	4,320,661
28	Potable Water	3.09E+12	J	1.39E+06	43,060	3,143,073
29	Electricity	4.50E+13	J	2.73E+05	122,783	8,962,228
30	Propane Gas	7.30E+11	J	4.80E+04	350	25,577
31	Retail Services	1.09E+07	$	2.36E+12	256,494	18,722,195
32	Financial Services (Loans)	1.55E+06	$	2.36E+12	36,600	2,671,513
33	Education Services	1.09E+06	$	4.72E+12	51,415	3,752,895
34	Health Care Services	8.16E+05	$	4.72E+12	38,561	2,814,672
35	Legal Services	1.36E+05	$	4.72E+12	6,427	469,112
36	Travel Services	1.09E+07	$	4.72E+12	514,147	37,528,954
37	Media Services	8.98E+05	$	4.72E+12	42,417	3,096,139
38	Telecommunication Services	1.12E+05	$	2.36E+12	2,649	193,324
39	Other Services (Expenses)	8.53E+06	$	2.36E+12	200,907	14,664,710
40	Govt Services (Taxes)	9.61E+06	$	4.72E+12	453,843	33,127,233
	Total Imports and Outside Sources				**3,457,616**	**252,380,736**
NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
41	Structure	2.00E+02	N	1.80E+18	3,607,968	263,355,317
42	Household Assets	1.00E+13	J	3.61E+07	3,607,968	263,355,317
43	People (Maintenance 237/yr)	4.74E+10	J	7.61E+09	3,607,968	263,355,317
TOTAL EMERGY INFLOWS					**3,607,968**	

OUTPUT AND TRANSFORMITIES:

44	Labor Services, Average	5.44E+07	$	6.63E+12	3,607,968	263,355,314
Total Emergy Outflows					**3,607,968**	
45	Emergy Use per Person				254	18,523
46	Emergy Use per Household				1,091	79,642
47	Emergy Use per Laborer				586	42,738

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
G Manufactured *goods* brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + G + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + G + S)/(N + R)	23.0
Yield Ratio = Y/F	Y/(M + G + S)	1.04
Goods & Service/Free	(G + S)/(N + R)	22.6
Goods & Service/Resource	(G + S)/(N + R + M)	16.2
Nonrenewable/Renewable	(N + M)/R	0.4
Developed/Environmental	(N + M + G + S)/R	23.8

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area is estimated to be divided as follows:

Island Area =	28,700 ha		
Salinjas and Salt Lakes =	2,200 ha	8%	((Rooth 1965):14)
Towns =	800 ha	3%	(estimate)
Planted/Plantable =	1,750 ha	6%	((Westermann and Zonneveld 1956):45)
Salt Works =	2,850 ha	10%	((Nobel 1995))
Total *Mondi* Land =	21,100 ha	74%	

Farms are estimated to be 500, of 6 hectares each. That is 3,000 ha, which includes the planted area above, plus *mondi* hectares, equaling 3,000. Many farms contain *mondi* land within their fences.

Fenced Farms Total Area =	3,000 ha	10%	(included in *Mondi* and planted)
Farms =	500 farms		
Mondi/Farmer =	42 ha / farmer		
Fenced Farm Avg. =	6 ha		(average, 6 hectares / farm)
Total Goats =	25,000 goats		((Westermann and Zonneveld

		1956):46)
Total Sheep =	5,000 sheep	((Westermann and Zonneveld 1956):46)
Total Chickens =	20,000 chickens	
Donkeys =	1,000 donkeys	
Pigs =	500 pigs	

Estimate that tourism captures 50% of the shelf around Bonaire, 30% of shelf contributes to households;

Cont Shlf Area = (12,800 ha)(30%)(10,000 m^2/ha) = 38,400,000 m^2

Estimate that towns cover 800 ha on Bonaire (about 3%), of which 80% is house plots.

Town House Plot Area = (800 ha)(80%)(10,000 m^2/ha) = 6,400,000 m^2

Estimate that 80% of *mondi* land is *kunuku* and *mondi* used by households.

Kunuku and *Mondi* Area = (21,100 ha)(80%)(10,000 m^2/ha) = 168,800,000m^2

Kunuku/*Mondi* Portion = 0.4067470 (use this for houses that have *kunuku*s)
Town and Shelf Portion = 0.1079518
Combined Household and *Kunuku* Fraction of Total = 0.5146988
Approximately 51% of Bonaire input emergy is land in *kunuku*s and *mondi*, plus town land for houses, plus shelf area not captured by tourism or industry. These are the environmental inputs to households.

Island Total Population = 14,218 ((Land Government 1998))
Workforce = 6,162 (Extrapolated from 1992 Labor Force Survey ((CBS 1993b)) and Labor Office ((Labor Office 1993)))
Total Households = 3,307 (Extrapolated from 1992 Labor Force Survey ((CBS 1993b)))
Working Persons per Household = 1.86 (Economic Strategies Survey) (1.7, Playa, 2.8, Rincon)

NUMBERED FOOTNOTES

Footnotes for Items 1-10, 15-19 see Natural Systems analysis (APPENDIX D).

Footnotes 11-13 are 100% of island production entering households. See island analysis (APPENDIX A).

14) Livestock Animals: Total production is 1.35 E12 J, see island analysis. Estimate that 30% is captured by restaurants. That leaves 70% for households = (1.35E12 J)(70%) = 9.44E11 J

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

20) Construction System: Many old houses on Bonaire have been renovated in recent years and re-occupied. However these 1995 estimates may still be unrealistic. It might have been better to add the newly occupied houses to the houses built in more recent years, especially to the last decade of new construction. Yet, given the inaccuracy of the population count in the 1992 census, this even redistribution of the population into additional houses in each year bracket might actually yield the most accurate numbers.

Occupied Houses (CBS 1993b:363))	1992		1995, estimates
Built before 1940 =	582	19%	644
Built 1940-59 =	442	15%	489
Built 1960-69 =	375	13%	415
Built 1970-79 (FKB begun 1973) =	548	18%	606
Built 1980-84 =	451	15%	499
Built After 1985 =	558	19%	618

Unknown =	32	1%	35
Households =	2,988		3,307
55 Year per year average =	54		60
FKB houses per year since 1973 =	50		50
Private per year since 1973 =	4		10

	One House	Houses	Total Emergy
FKB House Emergy =	7,702	X 50 =	385,124
Private House Emergy =	15,405	X 10 =	155,932
			541,056

FKB House Emergy = (7,702 E14 sej/house)(50 houses) = 385,124 E14 sej/yr
Private House Emergy = (15,405 E14 sej/house)(10 houses) = 155,932 E14 sej/yr
Total emergy from construction industry into households = 541,056 E14 sej/yr

21) Roadway System: Total Per Year Emergy from Roadway Subsystem, 84,261 sej/yr. Estimate that 55% of all road traffic on Bonaire by tonnage is regular household car or truck traffic; (84,261 E14 sej/yr)(55%) = 46,344 E14 sej/yr

22) Cars and Trucks: All vehicles (Ontvanger Kantoor, June 30, 1995): Personal Cars, 3888; Motorcycles, 289; Busses, 21; Taxis, 20; Government, 108; Caterpillars/Loaders, 59; Trucks, 1557(all types, pickups to heavy dump trucks); Total, 5942

Vehicles owned by households (estimate) = (3888 personal cars)+(519 trucks)(1/3) = (4,407 vehicles)(2 MT)(1E6 g/MT)/(10 yrs dep) = =4.41E+08g/yr

23) Travel (Airport) System: Total Services, 733,618 E14 sej/yr, per Airport Subsystem

Estimate 60% to Households = 440,172 E14 sej/yr

24) Retail System: Total Services, 666,028 sej/yr, per Retail Sales Subsystem; Estimate 60% to Households = 399,617; (Estimate 30% to Island Industries = 199,808; Estimate 10% to Government = 66,603)

25) Fish Catch: Total fish catch estimated 720,000 kg/yr (see Coastal analysis (APPENDIX D2)). To Hotels/Restaurants, 20% estimate. Remainder to households.

Fish Catch (J) = (720,000 kg/yr)(80%)(1000 g/kg)(20% DW)(4 kcal/g)(4186 J/kcal) = 4.24 E11 J/yr

26) Buildings: Concrete, 10 MT (est., per building); Houses, 4170;

Total Buildings (g) = (10 MT)(4170 houses)(1E6 g/MT)/(50 yrs dep) = 8.34 E8 g/yr

27) Gasoline: 10 l/engine/week, est.; 4,407 vehicles

Energy (J) = (10 l/engine/wk)(52 wks/yr)(4,407 vehicles)(41E6 J/l) = 9.40E+13 J/yr

28) Potable Water: Water use per house per year = 150 m^3 (Per Economic Strategies Survey); Total households, 4,170;

Energy (J) = (150 m^3)(4,170)(1000 g/m^3)(4.94E3 J/g) = 3.09E+12J/yr

29) Electricity: Electricity use per house per year, 3,000 kWh/yr (Per Economic Strategies Survey); Total households, 4,170 households

Energy (J) = (3,000 kWh/yr)(4170)(860 Cal/kWh)(4186 J/Cal) = 4.50E+13J/yr (27%of WEB output, seems reasonable)

30) Propane Gas: Propane use per house per year, 4,500 liters/yr (Per Economic Strategies Survey); Total households, 4,170 households

Energy (J) = (4,500 l/yr)(4,170)(1000 l/m^3)(3.89E7 J/m^3) = 7.30E+11J/yr

The following services are calculated as percentages of the average household income. Average yearly household income, $16,459 (from 1.86 personal incomes/household). All percentages of expenses calculated from the Breadbasket Survey ((CBS 1994a)). Assume purchase approximately equals income:

31) Retail (Goods): 20% of Expenses/Income;
Retail goods services = ($16,459)(20%)(4,170 households) = 10,885,228 $/yr

32) Financial Services (Loans): 1% of Expenses/Income + car loan (with 5,942 estimated personal vehicles, can estimate can estimate half are new with loan payments); Estimate $525/yr paid in interest on car loan
Financial Services = ($16,459)(1%)+(5,942 vehicles)(50%)($525 loan interest/yr) = $1,553,228

33) Education Services: 2% of Expenses/Income
Education services = ($16,459)(2%)(4,170 households) = 1,088,523$/yr

34) Health Care Services: 1.5% of Expenses/Income
Health care services = ($16,459)(1.5%)(4,170 households) = 816,392$/yr

35) Legal Services: 0.25%of Expenses/Income
Legal services = ($16,459)(0.25%)(4,170 households) = 136,065$/yr

36) Travel Services: 20 %of Expenses/Income
Travel services = ($16,459)(2%)(4,170 households) = 10,885,228$/yr

37) Media Services: 1.65% of Expenses/Income
Media services = ($16,459)(1.65%)(4,170 households) = 898,031$/yr

38) Telecommunication Services: Total = 200,000 NAF/yr, est., 112,400 $/yr

39) Other Services (Expenses): From Economic Strategies Survey; Gasoline, 1,833,312 NAF (0.80 NAF/liter); Water, 8,132,188 NAF (13 NAF/m^3); Electric, 4,269,986 NAf (2.93 kWh/NAF); Propane, 835,644 NAF (big bottle, 1325 liters for 59 NAF); Machines, 100,000 NAF/yr, estimate
Total Other Services = ((1,833,312 NAf)+(8,132,188 NAf)+(4,269,986 NAf)+(835,644 NAf/yr)+(100,000 NAf/yr))/(1.79 NAf/$) = 8,526,175 $/yr

40) Govt Service (equivalent to services in estimated taxes):
Land Tax = 2,398,000 NAF (CBS 1995)
Wage Tax = 12,489,000 NAF (CBS 1995)
Income Tax = 2,210,000 NAF (CBS 1995)
Taxes($) = 9,608,514 $/yr
If island household total income, 54,426,140 $/yr (Table 43); Wage plus Income Tax, 8,260,838 $/yr; "Average" Total "Income" Tax is therefore 15% (which seems reasonable)

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

41) Structure: Household Niches = 200 est., different types of household production; (Note 41 and 42 are both very rough guesses)

42) Household Assets: Energy (J) =1.00E+13 J/yr (wild guess, need to try to evaluate)

43) People (Maintenance 237/yr): Count, 14,218 people; 60yrs TT (Turnover Time of a person); Flow of persons per year, 237 persons flow = birth flow = death flow; 11,848 kg/yr (flow = 237 people * 50 kg/person / 60yr TT)

43a) Biomass Energy(J) Flux =(11,848 kg/yr)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 4.74E+10 J/yr (energy for maintenance of human population = birth = death)

OUTPUT AND TRANSFORMITIES:

44) Labor Services Income, Average: Household total income, 54,426,140 $/yr; Total Emergy Inflows, 3,607,851 sej/yr

45) Emergy Use per Person: Total Emergy Inflows, 3,607,851 E14 sej/yr: Population, 14,218; Emergy per Person = 254 E14 sej/person

46) Emergy Use per Household: Total Emergy Inflows, 3,607,851 E14 sej/yr; Total Households, 3,307; Emergy per Household = 1,091 E14 sej/household

47) Emergy Use per Laborer: Total Emergy Inflows, 3,607,851 E14 sej/yr; Total Workforce, 6,162; Emergy per Laborer = 586 E14 sej/laborer

Table 43: Household Income Estimates
These 1995 estimates are extrapolations from the 1992 Census (CBS 1993b), adjusted for 1995 population.

Monthly Household Income	Yearly	House-holds	Totals	
250	3,000	309	927,883	
750	9,000	421	3,786,583	
1,250	15,000	455	6,822,672	
1,750	21,000	499	10,483,035	
2,250	27,000	409	11,052,728	
2,750	33,000	325	10,732,063	
3,250	39,000	216	8,426,000	
3,750	45,000	176	7,931,356	
4,250	51,000	111	5,683,286	
4,750	57,000	85	4,861,154	
5,500	66,000	132	8,705,729	
6,500	78,000	65	5,055,600	
7,500	90,000	47	4,195,943	
8,500	102,000	24	2,435,694	
9,500	114,000	15	1,685,200	
20,000	240,000	17	4,093,603	
		3,307	96,878,529	NAF
			54,426,140	$
			3,828	$/person
			16,459	$/household

APPENDIX G
HEAVY EQUIPMENT SYSTEM EMERGY ANALYSIS

EMERGY Flows of Heavy Equipment Subsystem

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	6.03E+14	J	1	6	440
2	Rain, Chemical Potential Energy	2.53E+11	J	15,444	39	2,854
3	Rain, Geopotential Energy	1.17E+09	J	8,888	0.1	8
4	Wind, Kinetic Energy	4.73E+12	J	584	28	2,014
5	Wave Energy	1.05E+11	J	25,889	27	1,992
6	Tidal Energy	1.98E+10	J	49,000	10	708
7	Currents Energy	6.20E+09	J	1.0E+05	6	453
8	Earth Contribution	1.25E+06	g	1.0E+09	13	916
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**68**	**4,931**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	1.32E+11	J	51,078	(68)	(4,931)
10	Mondi Animals	2.96E+09	J	2,056,417	(61)	(4,438)
	Total of Renewable Production				**(128)**	**(9,369)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.18E+09	J	63,000	1	54
12	Groundwater and Dams	7.38E+07	J	617,760	0	33
13	Coral Reef	2.30E+03	g	1.0E+09	0	2
	Total of Slow-Renewable Sources				**1**	**89**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.15E+03	g	4.50E+09	0	4
15	Limestone	1.15E+03	g	1.00E+09	0	1
	Total of Non-Renewable Sources				**0**	**5**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Trucks and Loaders	2.60E+07	g	6.70E+09	1,742	127,153
17	Fuel	6.82E+12	J	6.30E+04	4,298	313,731
18	Parts	1.00E+07	g	6.70E+09	670	48,905
19	Roadway Contribution				8,426	615,047
20	Services (Expenses)	1.50E+05	$	2.36E+12	3,528	257,507
21	Loans	1.12E+04	$	2.36E+12	265	19,332
22	Govt Services (Taxes)	8.69E+04	$	4.72E+12	4,103	299,514
23	Labor Contribution				6,794	495,896
	Total Imports and Outside Sources				**29,826**	**2,177,087**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

24	Owner Households	11,525	841,225
	Total Non-Renewable Production within Subsystem	**11,525**	**841,225**

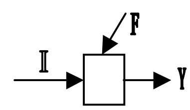
Total Emergy Inflows **41,420**

OUTPUT AND TRANSFORMITIES:

25	Emergy per Load Delivered				1.33	97
26	Services Income (?)	1.05E+06	$	3.93E+12	41,420	3,023,337
27	Emergy Attracted per Laborer				1,010	73,740
28	Emergy Attracted per Unit				10,355	755,834

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	433.3
Yield Ratio = Y/F	Y/(M + S)	1.39
Service/Free	S/(N + R)	1.0
Service/Resource	S/(R + N + M)	0.6
Nonrenewable/Renewable	(N + M)/R	1
Developed/Environmental	(N + M + S)/R	3

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area is company lands, for storing equipment, etc: Estimate 10 ha, (100,000 m^2);

Fraction of Total = 0.0002410

NUMBERED FOOTNOTES

Footnotes for Items 1-15 see Natural Systems analysis.

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Trucks and Loaders: Estimate Trucks (60) at 3 MT each, which is 180 MT (1560 trucks total on Island); Loaders and Caterpillars (20) at 4 MT each, which is 80 MT (60 caterpillars/loaders on island); 10yrs (Yrs of depreciation)

Total Wt. (g) = (180 MT + 80 MT)(1E6 g/MT)/(10 Yrs.) = 2.60E+07 g/yr

17) Fuel: 40 liters/engine/week, estimate

Energy (J) = (40 l/engine/week)(260 engines)(52 weeks/yr)(41E6J/l) = 6.82E+12 J/yr

18) Parts: Parts at 10 MT/yr

Parts (g) = (10 MT/yr)(1E6 g/MT) = 1.00E+07 g/yr

19) Roadway Contribution: Total Per Year Emergy from Roadway Subsystem is 84,261 E14 sej/yr (see Roadway analysis); Est. 10% for Stone and Sand Transport, which is 8,426 E14 sej/yr; i.e., estimate that 10% of all road traffic on Bonaire by tonnage is truck traffic, moving sand and stone. This service is vital to all construction activities on the island. Total loads est. >16,000 per year.

20) Services (Expenses):
Estimate gasoline use is 166,400 liters, at 1 NAf/liter is 166,400 liters. Estimate parts costs of 100,000 NAf/yr

Services total ($) = (166,400 NAf/yr + 100,000 NAf/yr)/(1.79 NAf/$) = 149,717 $/yr

21) Loans: Estimate loans for equipment is 200,000 NAf, loan for 20 vehicles (principal and interest, est.); 10yr loan

Loans($) = (200,000 NAf)/(10 yrs)/(1.79 NAf/$) = 11,240 $/yr

22) Govt Services (Taxes): Land tax on average is 0.15 NAf/m^2. Profit taxes are high (compared to US standards) of 37%-45%, in 1992. It is estimated that these local businesses do not have any tax protections (tax holidays) like the big hotels. Estimate 37% tax rate. Profit before taxes for the entire sector is estimated at 377,243 NAf/yr (rough estimate, see 26 below).

Land Tax = (100,000 m^2)(0.15 NAf/m^2, est) = 15,000 NAF
Profit Tax = (377,243 NAf/yr)(37%) = 139,580 NAF
Taxes($) = (15,000 NAf/yr + 139,580 NAf/yr)/(1.79 NAf/$) = 86,874 $/yr

23) Labor Contribution: Emergy of 100 Persons for 1 Year = 51,159 E14 sej (see Household analysis); Full-time Laborers, 42; 260 wrk days/yr, 8 hrs/day

Labor emergy (sej) = (41 people)(51,159 E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 6,794 E14 sej/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

24) Owner Households

Company	Total
Dehema (Heavy Equipment) N.V.	14
Obersi Heavy Equipment Rental & Transport N.V.	10
Damascus Construction (E.Z.)	9
Associated Transport Company (Bonaire) N.V.	8
Total Employees =	41

From ((Bonaire 1995)) and ((Labor Office 1993))

Emergy inflows to household, 8,644 E14 sej/Household (est. affluent). Each household owns 3 businesses, est average

Total emergy (sej) = (8,644 E14 sej/yr/household)(4 households)/(3 businesses) = 11,525 E14 sej/Households of Owners

OUTPUT AND TRANSFORMITIES:

25) Emergy per Load Delivered: Average truck load is 12 MT/load; Total tonnage moved is estimated as: Total Limestone (150,000 MT dug, 2 trips, to crusher, to consumer) 300,000 MT moved; Total Volcanic is 75,000 MT ripped and delivered

Total Loads = (300,000 MT + 75,000 MT)/(12 MT/load) = 31,250 loads/yr
Emergy/load = (4.14E+18 sej)/(31,250 loads/yr) = 1.33E+14sej/load

26) Services Income (?): Estimate average income for transport per load Sand and Stone is 5 NAF/MT (consumer prices are 14 NAF/ton stone, 34 NAF/ton sand). With 12 tons per load, which comes to 60 NAf/load, estimate

Service ($) = (31,250 loads/yr)(60 NAf/load)/(1.79 NAf/$) = 1,053,750 $/yr
Profit (20 %, est.) = 210,750 $ (before taxes)

27) Emergy Attracted per Laborer: Total Emergy Inflows, 41,420 E14 sej/yr; Total Laborers, 41

Emergy per Laborer = (41,420 E14 sej/yr)/(41 Laborers) = 1,010 E14 sej/yr/laborer

28) Emergy Attracted per Unit: Total Emergy Inflows, 41,420 E14 sej/yr; Total Units = 4

Emergy per Unit = (41,420 E14 sej/yr)/(4 Companies) = 10,355 E14 sej/yr/unit

APPENDIX H
CONSTRUCTION SYSTEM EMERGY ANALYSIS

EMERGY Flows of Construction Industry

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	7.23E+16	J	1	723	52,799
2	Rain, Chemical Potential Energy	3.04E+13	J	15,444	4,692	342,496
3	Rain, Geopotential Energy	1.40E+11	J	8,888	12	910
4	Wind, Kinetic Energy	5.67E+14	J	584	3,312	241,721
5	Wave Energy	1.26E+13	J	25,889	3,274	239,013
6	Tidal Energy	2.38E+12	J	49,000	1,165	85,008
7	Currents Energy	7.44E+11	J	1.0E+05	744	54,318
8	Earth Contribution	1.51E+08	g	1.0E+09	1,506	109,893
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**8,106**	**591,714**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	1.59E+13	J	51,078	(8,106)	(591,714)
10	Mondi Animals	3.55E+11	J	2,056,417	(7,296)	(532,543)
	Total of Renewable Production				**(15,402)**	**(1,124,257)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.42E+11	J	63,000	(90)	(6,535)
12	Groundwater and Dams	8.86E+09	J	617,760	55	3,994
13	Coral Reef	2.76E+05	g	1.0E+09	3	201
	Total of Slow-Renewable Sources				**57**	**4,196**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Sediments	6.67E+08	g	4.50E+09	30,000	2,189,781
	Total of Non-Renewable Sources				**30,000**	**2,189,781**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

15	Manufactured Goods	3.76E+09	g	1.80E+09	67,689	4,940,803
16	Trucks and Equipment	6.00E+07	g	6.70E+09	4,020	293,431
17	Fuel	3.50E+13	J	6.30E+04	22,028	1,607,870
18	Sand and Stone Transport				16,570	1,209,516
19	Crushed Sand and Stone	1.00E+11		7.70E+07	76,951	5,616,829
20	Housing Foreign Aid				30,513	2,227,251
21	Services (Imported Goods)	6.70E+06	$	2.36E+12	157,796	11,517,987
22	Services (Local Goods, Loans, Taxe	4.05E+06	$	4.72E+12	191,172	13,954,178
23	Labor Contribution				157,019	11,461,257
	Total Imports and Outside Sources				**723,759**	**52,829,122**

NON-RENEWABLE PRODUCTION FROM WITHIN SUBSYSTEM:

25	Owner Households				162,381	11,852,595
	Total Imports and Outside Sources				**162,381**	**11,852,595**

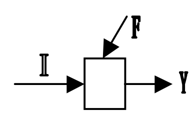
Total Emergy Inflows **924,303**

OUTPUT AND TRANSFORMITIES:

26	FKB House	3.23E+04	$	2.38E+13	7,703	562,228
27	Private House		$		15,405	1,124,457
28	Large Hotel		$		231,076	16,866,852
29	Construction Sector Income	2.00E+07	$	4.62E+12	924,303	67,467,408
30	Emergy Attracted per Laborer				859	62,683
31	Emergy Attracted per Unit				11,700	854,018

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
G Manufactured *goods* brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + G + S)/(N + R)	19.0
Yield Ratio = Y/F	Y/(M + G + S)	1.28
Service/Free	(G + S)/(N + R)	18.4
Service/Resource	(G + S)/(N + R + M)	11.7
Nonrenewable/Renewable	(N + M)/R	6
Developed/Environmental	(N + M + G + S)/R	93

NOTES

Data comes from interviews with owners, laborers, from estimates, or from citations as shown.

Land area is house and hotel plots, construction company lands, and stone and sand mining lands. Estimate 1200 ha, of which 800 ha is houses, hotels, and other buildings, and 400 ha is for volcanic stone/sand mining. The remaining 600 ha of an estimated 1000 ha of stone/sand mining is counted in the Rock crushing and Roadways systems.

Fraction of Total = 0.0289157

NUMBERED FOOTNOTES

Footnotes for Items 1-13 see Natural Systems analysis.

NON-RENEWABLE ISLAND SOURCES:

14) Volcanic Sediments: Volcanic sediments are dug (ripped) from private lands and sold with owners consent; Stone and Sand, 50,000 MT, est.; Turnover time of stored rock in buildings and roads, 75 yrs

Mass (g) = (50,000 MT)(1E6 g/MT)/(75 yrs) = 6.7E+08g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

15) Manufactured Goods
Two years of "highlights" of manufactured goods. Note that most are goods destined for construction.

Article	Quantity '91 (kg)	Value '91 (NAf)	Quantity '94 (kg)	Value '94 (NAf)
Articles Of Rubber N.e.s.		253,000	50,000	841,000
Veneers, Plywood Boards,"Improved"	396,000	270,000	186,000	658,000
Wood Manufactures N.e.s.	199,000	880,000	199,000	736,000
Paper And Paperboard	117,000	266,000	69,000	266,000
Articles Made Of Paper Pulp,of Paper	48,000	310,000	168,000	1,081,000
Furnishing Articles of Textile Fabrics		1,982,000	16,000	186,000
Lime, Cement And Materials	9,673,000	2,119,000	78,000	156,000
Clay Construction Materials		753,000	248,000	486,000
Glassware	37,000	783,000	16,000	94,000
Iron Bars, Rods, Angles, Sections	153,000	123,000	493,000	825,000
Plates And Sheets Of Iron Or Steel	518,000	676,000	58,000	115,000
Iron And Steel Wire (excluding Wire Rod)	5,000	160,000	41,000	12,000
Tubes,pipes And Fittings Of Iron Or Steel	790,000	1,591,000	37,000	159,000
(Finished) Struct. Parts of Iron, Steel, Al	84,000	1,233,000	64,000	455,000
Metal Containers For Storage And Trans.	2,000	77,000	1,123,000	1,971,000
Nails, Screws, Nuts, Bolts, Stapels, etc.	48,000	312,000	26,000	139,000
Tools For Use In Hand Or In Machines	33,000	623,000	8,000	142,000
Household Equipment Of Base Metal	15,000	1,306,000	44,000	428,000
	12,118,000	13,717,000	2,924,000	8,750,000
Average quantity =	7,521,000 kg			
Average Value =	11,233,500 NAF			

Estimate 50% inputs to housing industry, 30% to hotels, 20% to other industries

Construction goods (g) = (7,521,000 kg)(50%)(1000 g/kg) = 3.76E+09g/yr

16) Trucks and Equipment: Trucks (400), 800 MT (estimate, 1560 trucks total on Island); Heavy Equipment (10) = 100 MT (estimate, 60 catipilars/loaders on island); Turnover time, 15yrs (Years of depreciation)

Total machines (g) = (400 trucks)(2 MT each)+(10 heavy equip)(10 MT each)(1E6 g/MT) = 6.00E+07g/yr

17) Fuel: 40 liters/engine/week, estimate;
Total fuel (J) = (40 liters)(410 engines)(52 weeks/yr)(41E6 J/l) = 3.50E+13J/yr

18) Sand and Stone Transport: Truck load = 12 MT/load (est); Volcanic sediments, 50,000 MT; Crushed limestone, 100,000 MT; Emergy per load, 1.33E+14 sej/load (from Heavy Equipment Subsystem analysis)
Emergy total =((150,000 MT/yr)/(12 MT/load))(1.33+14 sej/load) = 1.66E+18 sej

19) Crushed Sand and Stone: Crushed Limestone, 100,000 MT; Turnover time of stored rock in buildings and roads, 75yrs
Mass (g) = (100,000 MT)(1E6 g/MT)/(75 yrs) = 1.0E+11g/yr

20) Housing Foreign Aid
Services input to the housing sector over a 30 year period; Emergy values are calculated with the Emergy/$ ratio appropriate for the year of funding, per (Odum 1996a):313-314

Funding Type		Real NAF	Emergy (E14 sej)
Lower Income Housing	1967	1,375,900	126,583
Lower Income Housing	1972	735,500	51,485
Infrastructure 50 Low Income Homes	1972	98,800	6,916
Lower Income Housing	1977	1,025,100	45,104
Public Transport (Purchase Busses)	1981	840,000	22,680
Build 25 Middle Class Houses	1981	3,000,000	81,000
Hotel Management Negotiations	1982	17,519	438
Project 60 Houses Bonaire	1983	2,552,822	61,268
Build Clubhouse Rincon	1984	99,307	2,185
Build 34 Houses in Amboina (1st Phase)	1985	1,600,000	32,000
Build 116 Houses in Amboina (2nd Phase)	1986	7,000,000	133,000
Self Construction Project II FKB?	1986	5,250,000	99,750
Build 150 Houses Phase 1	1988	7,749,486	135,616
Self Construction Project II FKB	1989	1,000,000	16,300
FKB Build 100 Houses	1991	6,425,000	95,733
Primary Divisions of Public Housing	1993	390,000	5,343

Total Emergy = 915,400 E14 sej
Per year aid (30 years) = (915,400 E14 sej)/(30 yrs) = 30,513 E14 sej/yr

21) Services (Imported Goods): Fuel, 852,800 liters (see note 17); at 0.8 NAf/liter; manufactured goods, 11,233,500 NAf/yr
Service fuel ($) = (852,800 liters)(0.8 NAf/liter)/(1.79 NAf/$) = $383,419
Service goods ($) = (11,233,500 NAf/yr)/(1.79 NAf/$) = $6,313,227
Total services ($) = $6.7E6/yr

22) Services (Local Goods, Loans, Taxes)
Sand and Stone, 25 NAf/MT (14 NAF/ton stone, 34 NAF/ton sand); Construction sector income, 22,000,000 NAf/yr (CBS 1996); Profit estimate, 20% (4,400,000 NAf/yr); Profit tax ranges from 37%-45% in 1992)
Service ($) = (150,000 MT)(25 NAf/MT)/(1.79 NAf/$) = $2,107,500
Taxes on Const. Companies
Land Tax = (0.15 NAF/m^2, est.)(12,000,000 m^2) = 1,800,000 NAf

Profit Tax = (4,400,000)(37%)/(1.79 NAf/$) = $909,497
Taxes($) = $1,925,843
Loans to Const. Companies, 500,000 NAF/yr (estimate, principal and interest); 20yr loan
Loan Service ($) = (500,000 NAf/yr)/(20 yrs)/(1.79 NAf/$) = $14,050
Total Service ($) = $4,047,393

23) Labor Contribution; Three estimates of laborers in construction: 542 (CBS 1994:40); 1,283 (Labor Office Bonaire 1995); 1,404 Per my "Construction" definition; Averaged Laborers (from these three labor numbers), 1,076; Emergy of 100 Persons for 1 Year, 61,439 E14 sej (see Household-Labor Production System analysis); Full-time Laborers, 1,076 persons, 260 wrk days/yr, 8 hrs/day
(1,076 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 157,019 E14 sej

NON-RENEWABLE PRODUCTION FROM WITHIN SUBSYSTEM:

25) Owner Households; 4,106 E14 sej/Household (est. affluent 2) (see Household analysis); Companies in construction or related, 79 Households; Owners of land for dirt mining, 10 households (1% of household output, est.); Owners average 2 businesses each
Emergy (sej) = ((79 owners)+(10 dirt owners * 1%))(4,106 E14 sej/household)/(2 businesses/household) = 162,381 E14 sej/Households of Owners

OUTPUT AND TRANSFORMITIES:

One Year Construction Estimates for Housing and Hotels	
FKB Houses =	50 houses/yr (FKB)
Private Houses =	20 houses/yr (est) (wt as 40 FKB houses)
Hotels =	1 hotel/yr (est) (wt as 30 FKB houses)
Total, in equal units =	120 equivalent FKB house units

26) FKB House: FKB Cost Labor and Materials, 57,500 NAf (builder estimate, $32,315); Total Emergy Inflows, 924,298 sej/yr
One FKB house (sej) = (935,774 sej/yr)/(120 units) = 7,702 sej per FKB house unit

27) Private House: Estimate twice size of FKB House, 15,405 sej per house

28) Large Hotel: Estimate 30 times FKB House (7,702 sej)(30 units) = 231,076 sej per Hotel

29) Construction Sector Income
Construction income (Bonaire) = 22,000,000 NAF/yr (CBS 1996)(1.79 NAf/$) = $12,364,000

30) Emergy Attracted per Laborer: Total Emergy Inflows = 924,298 sej/yr; Total Laborers = 1,076
Emergy per Laborer = (924,298 sej/yr)/(1,076 Laborers) = 859 sej/yr/laborer

31) Emergy Attracted per Unit: Total Emergy Inflows = 924,298 sej/yr; Total Units = 79
Emergy per Unit = (924,298 sej/yr)/(79 Companies) = 11,700 sej/yr/unit

APPENDIX I
ROCK CRUSHING SYSTEM EMERGY ANALYSIS

EMERGY Flows of Rock Crushing Industry

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	3.01E+16	J	1	301	21,999
2	Rain, Chemical Potential Energy	1.27E+13	J	15,444	1,955	142,706
3	Rain, Geopotential Energy	5.84E+10	J	8,888	5	379
4	Wind, Kinetic Energy	2.36E+14	J	584	1,380	100,717
5	Wave Energy	5.27E+12	J	25,889	1,364	99,589
6	Tidal Energy	9.90E+11	J	49,000	485	35,420
7	Currents Energy	3.10E+11	J	1.0E+05	310	22,633
8	Earth Contribution	6.27E+07	g	1.0E+09	627	45,789
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**3,378**	**246,548**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	6.61E+12	J	51,078	(3,378)	(246,548)
10	Mondi Animals	1.48E+11	J	2,056,417	(3,040)	(221,893)
	Total of Renewable Production				**(6,418)**	**(468,441)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	0.00E+00	J	63,000	-	-
12	Groundwater and Dams	5.92E+10	J	617,760	366	26,701
13	Coral Reef	4.02E+02	g	1.0E+09	0	0
	Total of Slow-Renewable Sources				**366**	**26,701**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.15E+05	g	1.00E+09	1	84
15	Limestone	2.00E+09	g	1.00E+09	20,000	1,459,854
	Total of Non-Renewable Sources				**20,001**	**1,459,938**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Steel	3.33E+05	g	1.80E+09	6	438
17	Machines	1.97E+06	g	6.70E+09	132	9,618
18	Fuel	2.01E+12	J	6.30E+04	1,266	92,385
19	Sand and Stone Transport				33,136	2,418,669
20	Loans	5.62E+03	$	2.36E+12	132	9,666
21	Taxes	4.43E+05	$	4.72E+12	20,910	1,526,298
22	Services (Stone)	4.22E+05	$	4.72E+12	19,909	1,453,204
23	Labor Contribution				1,751	127,781
	Total Imports and Outside Sources				**77,241**	**5,638,059**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

24	Owner/Manager Households	14,435	1,053,634
	Total Non-Renewable Production within Subsystem	**14,435**	**1,053,634**

Total Emergy Inflows	**115,421**	

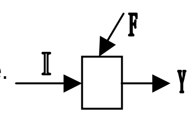
OUTPUT AND TRANSFORMITIES:

25	Crushed Stone	1.50E+11	g	7.69E+07	115,421	8,424,880
26	Services (Stone/Sand Price)	2.11E+06	$	5.48E+12	115,421	8,424,880
27	Emergy Attracted per Laborer				9,618	702,073
28	Emergy Attracted per Unit				115,421	8,424,880

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and miner when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	3.3
Yield Ratio = Y/F	Y/(M + S)	1.5
Service/Free	S/(N + R)	1.5
Service/Resource	S/(R + N + M)	1.4
Nonrenewable/Renewable	(N + M)/R	1.5
Developed/Environmental	(N + M + S)/R	5.4

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area estimate that limestone and volcanic mines cover about 4% of the island: Fifty percent of that area is counted here, 500 ha, (5,000,000 m^2), and the remainder is calculated with the Construction system (400 ha, volcanic rock), and with the Roadway system.

Fraction of Total = 0.0120482

NUMBERED FOOTNOTES

Footnotes for Items 1-14 see Natural Systems analysis.

15) Limestone: Approximately 150,000 MT limestone is crushed per year. Turnover time of stored rock in buildings and roads, 75 yrs

Mass (g) = (150,000 MT)(1E6 g/MT)/(75 yrs) = 2.0 E9 g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Steel: Misc, 10MT; 30yrs (Yrs of dep)

Total Wt. (g) = (10 MT)(1E6 g/MT)/(30 yrs) = 3.33E+05 g/yr

17) Machines: Large Crusher, 10 MT; Small Crusher, 5 MT; Big Excavator, 4 MT; Trucks (2), 3 MT (3 MT each, used half the year); Loaders (2), 6 MT (3 MT each); Generator, 1 MT; Backup Generator, 1 MT; 15yrs (Yrs of dep)

Total Wt. (g) = ((10 MT)+(5 MT)+(4 MT)+(2)(3 MT)+(2)(3 MT)+(1 MT)+(1 MT))/(15 yrs) = 1.97E+06 g/yr

18) Fuel: Diesel Fuel; 39,000 l/yr (half of 78,000 l/yr, both plants); Gas Oil (Generators), 10,000 l/yr (half of 20,000 l/yr, both plants)

Energy (J) = ((39,000 l/yr)+(10,000 l/yr))(41E6 J/l) = 2.01E+12 J/yr

19) Sand and Stone Transport: Truck load, 12 MT/load; Crushed Limestone (x 2 trips), 150,000 MT; Total Limestone and Volcanic stone, 300,000 MT; 1.33E+14 sej/load, from Heavy Equipment Subsystem analysis

Total Loads (sej) = (300,000 MT)/(12 MT/load)(1.33 E14 sej) = 3.31E+18 sej

20) Loans: 500,000 NAF, loan for equipment (principal and interest, est.); 50yr loan

Loans ($) = (500,000 NAf)/(1.79 NAf/$)/(50 yrs) = 5,620 $/yr

21) Taxes:

Land Tax = (5,000,000 m^2)(0.15 NAf/m^2, est) = 750,000 NAF

Profit Tax = 37,724 NAF (5%?)

Taxes($) = ((750,000 NAf)+(37,724 NAf))/(1.79 NAf/$) = 442,701 $/yr

22) Services (Stone): Stone/Sand Dlvd, 5 NAF/MT; 150,000 MT delivered

Services ($) = (150,000 MT)/(5 NAf/MT)/(1.79 NAf/$) = 421,500 $/yr

23) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household-Labor Production System analysis); Full-time Laborers, 12 persons, 260 wrk days/yr, 8 hrs/day (12 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 1,751 E14 sej/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

24) Owner/Manager Households: Owned 80% by Antillen, N.V., and 10% each by two Bonairian truck transport company owners Antillen, N.V. is owned by Dutch company, K.V.S.(Kon. Volken Stevin, Rotterdam); 8,644 E14 sej/Household (est. affluent); 1 manager + 2 managers w/ 3 businesses

Households = (1 household + 2/3 households)(8,644 E14 sej/households) = 14,435 E14 sej/Households of Managers

OUTPUT AND TRANSFORMITIES:

25) Crushed Stone: 150,000 MT/yr

Energy (g) = (150,000 MT/yr)(1E6 g/MT) = 1.5E+11g/yr

26) Services (Stone/Sand Price): 25 NAF/MT, average
Service ($) = (150,000 MT/yr)(25 NAf/MT)/(1.79 NAf/$) = 2,107,500$/yr

27) Emergy Attracted per Laborer: Total Emergy Inflows, 115,421 E14 sej/yr; Total Laborers, 12
Emergy per Laborer = (115,421 E14 sej/yr)/(12 Laborers) = 9,618 E14 sej/yr/laborer

28) Emergy Attracted per Unit: Total Emergy Inflows = 115,421 E14 sej/yr; Total Units = 1
Emergy per Unit = (115,421 E14 sej/yr)/(1 Company) = 115,421 E14 sej/yr/unit

APPENDIX J
ROADWAY SYSTEM EMERGY ANALYSIS

EMERGY Flows of Roadway System

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	1.49E+16	J	1	149	10,868
2	Rain, Chemical Potential Energy	6.25E+12	J	15,444	966	70,497
3	Rain, Geopotential Energy	2.89E+10	J	8,888	3	187
4	Wind, Kinetic Energy	1.17E+14	J	584	682	49,754
5	Wave Energy	2.60E+12	J	25,889	674	49,197
6	Tidal Energy	4.89E+11	J	49,000	240	17,497
7	Currents Energy	1.53E+11	J	1.0E+05	153	11,181
8	Earth Contribution	3.10E+07	g	1.0E+09	310	22,620
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**1,669**	**121,795**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	3.27E+12	J	51,078	(1,669)	(121,795)
10	Mondi Animals	7.30E+10	J	2,056,417	(1,502)	(109,615)
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	2.93E+10	J	63,000	18	1,345
12	Groundwater and Dams	1.82E+09	J	617,760	11	822
13	Coral Reef	5.68E+04	g	1.0E+09	0.57	41
	Total of Slow-Renewable Sources				**30**	**2,209**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock for Subbase	3.33E+08	g	4.50E+09	15,000	1,094,891
15	Limestone	2.84E+04	g	1.00E+09	0.3	21
	Total of Non-Renewable Sources				**15,000**	**1,094,911**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Steel	3.33E+05	g	1.80E+09	6	438
17	Roadmaking Machines	3.97E+06	g	6.70E+09	266	19,399
18	Fuel	2.01E+12	J	6.30E+04	1,266	92,385
19	Natural Gas	2.58E+09	J	4.80E+04	1.2	90
20	Limestone for Asphalt (Imported)	1.00E+08	g	1.00E+09	1,000	72,993
21	Port Services (Limestone shipped)				381	27,824
22	Bitumin	6.21E+11	J	6.30E+04	391	28,549
23	Limestone Subbase (Local Crushed	3.33E+08	J	7.69E+07	256	18,722
24	Truck Transport of Stone and Sand				6,351	463,578
25	Foreign Aid, Roads				25,181	1,838,043
26	Loans	5.62E+03	$	2.36E+12	132	9,666
27	Govt Service (Taxes)	2.11E+05	$	4.72E+12	9,968	727,571
28	Services (Imported Stone, Sand)	3.82E+05	$	5.36E+12	20,466	1,493,869
30	Labor Contribution				1,896	138,430
	Total Imports and Outside Sources				**67,562**	**4,931,555**
Total Emergy Inflows					**84,261**	

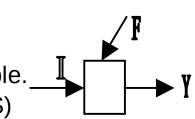
OUTPUT AND TRANSFORMITIES:

31	New Road per Year (5 km, est.)	9.90E+09	g	8.51E+08	84,261	6,150,470
32	Mass of Road, Outflow	1.04E+10	g	8.11E+08	84,261	6,150,470
33	Services Income (?)	2.81E+05	$	3.00E+13	84,261	6,150,470
34	Emergy Attracted per Laborer				6,482	473,113
35	Emergy Attracted per Unit				84,261	6,150,470

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and min when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic systen
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	4
Yield Ratio = Y/F	Y/(M + S)	1.2
Service/Free	S/(N + R)	3.8
Service/Resource	S/(R + N + M)	3.5
Nonrenewable/Renewable	(N + M)/R	10
Developed/Environmental	(N + M + S)/R	40

NOTES

Data comes from an interview with the plant manager, from estimates, or from citations as shown.

There are 210 km of paved roads (EIU 1997:63). This gives a land area of approximately 1,470,000 m^2 (210 km x 7m), est).
Stone/Sand mining for road subbase material, and asphalt aggregate, 100 ha (of the total estimated 1000 ha (500 ha in Rock Crushing, 400 ha in Construction).
Total Land area = (1,470,000 m^2)+(1,000,000 m^2) = 2,470,000 m^2

Fraction of Total = 0.0059518

NUMBERED FOOTNOTES

Footnotes for Items 1-13 see Natural Systems analysis.

14) Volcanic Rock for Subbase: Ripped Volcanic Rock, 25,000 MT, est (see discussion in Rock Crushing Subsystem); Turnover time of stored rock in buildings and roads, 75 yrs
Subbase Mass = (25,000MT)(1E6g/MT)/(75yrs) = 3.33E+08 g/yr
Transformity = 4.50E+09 sej/g, for volcanic-sedimentary (Odum 1996:50)

15) Limestone: Island limestone is calculated as a fraction of the total island use. Limestone for the roadway is delivered from the rock crushing industry, via Curacao. It is imported emergy from an island technology source, see Limestone Subbase (number 23)

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Steel: (10MT)(1E6 g/MT)/(30yrs depreciation) = 3.33E+05 g/yr

17) Roadmaking Machines: (___kg)(1000g/kg)/(Yrs. dep); Asphalt Maker, 20 MT; Bitumin Htr(2), 6 MT; Bitumin Stg(8), 8 MT; Trucks (8), 9 MT (3 MT each, used half the year); Loaders (3), 9 MT (3 MT each); Paving Mch., 2 MT; Rollers (4), 4 MT (1 MT each); Generator, 1 MT; Bckup Genertr, 1 MT;
Total Machines = (59,500 kg)(1000g/kg)/(15yrs) = 3.97E+06 g/yr

18) Fuel: (___l/yr)*(41E6J/l); Diesel Fuel, 39,000 l/yr (half of 78,000 l/yr, both plants);
Diesel fuel = (39,000 l/yr)(41E6 J/l) = 1.60E+12 J/yr
Gas Oil (Generators), 10,000 l/yr (half of 20,000 l/yr, both plants)
Gas Oil = (10,000 l/yr)*((41E6 J/l) = 4.10E+11 J/yr
Total Energy (J) = 2.01E+12 J/yr

19) Natural Gas for Rollers: 50 bottles/yr at 1,325 l/bottle is 66.25 m^3
Energy (J) = (66.25m^3)*(3.89E7 J/m^3) = 2.58E+09 J/yr

20) Limestone for Asphalt (Imported): (___MT/yr)*(1E6 g/MT) Imported from Tafelberg, Curacao; 7,500 MT/yr, est., used for making Asphalt; Turnover time of stored rock in buildings and roads = 75 yrs, est.
Energy (g) = (7,500MT/yr)(1E6 g/MT)/(75yrs) = 1.00E+08 g/yr

21) Port Services (Limestone shipped): Emergy per Load = 7.62+15 sej/load (see The Port (Harbor and Piloting) analysis); Loads per year, est. 5;
Total = 3.81E+16 sej/yr

22) Bitumin: (___l/yr)*(41E6 J/l) (for oil), 4,000 Gallons/yr; 3.7843 l/gallon, 15,142 l/yr;
Energy (g) = (15,142 l/yr)*(41E6 J/l) = 6.21E+11 J/yr

23) Limestone Subbase (Local Crushed): (25,000 MT/yr)*(1E6 g/MT), est., used for road subbase foundation; Turnover time of stored rock in buildings and roads, 75 yrs, est.
Energy (g) = (25,000MT/yr)(1E6 g/MT)/(75yrs) = = 3.33E+08 g/yr

24) Truck Transport of Stone and Sand:Truck load 12 MT/load (est), Total Limestone and Volcanic stone, 57,500 MT,Total Loads (57,500 MT)/(12 MT/load) = 4,792 loads/yr
Emergy per load = 0.82 E14 sej/load, per Heavy Equipment Subsystem analysis
Emergy total = (1.33E14 sej/load)(4,792 loads) = 6,351 E14 sej

25) Foreign Aid, Roads: Services input to road building over a 35 year period (synthesized from various Depos reports ((DEPOS 1987))((DEPOS 1995))).
Emergy conversion per Odum (1996:313-14)

Funding Type		Real NAF	(E14 sej)	Donor
Roads Kralendijk Environs	1958	456,900	64,880	NL
Road Rincon-Kralendijk	1958	600,000	85,200	NL
Road Antriol-Lagun	1962	792,000	95,040	NL
Road Airport-Lima-Sorobon	1967	363,700	33,460	NL
Road Rincon-Karpata	1972	1,853,300	129,731	NL
Road Airport-Lima-Sorobon	1972	586,300	41,041	NL
Road Kralendijk-Sorobon	1972	1,436,900	100,583	EEG
Road Repair (Phase 2)	1981	7,015,800	189,427	NL
Road Repair Bonaire (Phase 3)	1986	3,237,500	61,513	NL
Road Repair Bonaire (Phase 4)	1987	4,470,400	80,467	NL

Total Emergy (E14 sej) = 881,342
Per year aid (35 years) = 25,181 E14 sej

26) Loans: (___NAF)(1.79NAf/$); 500,000 NAf, loan for hardware (principal and interest, guess); 50 yr loan
Loans($) = (500,000 NAf)(1.79 NAf/$)/(50 yrs) = 5,620 $/yr

27) Govt Service (equivalent to services in estimated taxes):
Land Tax (if taxed road land) = (0.15 NAf/m^2)(2.47E6 m^2 road) = 570,500 NAF
Profit, 100,000 NAf/yr (guess); Profit tax 5%
Profit Tax = (500,000 NAf/yr)(.05) = 5,000 NAf/yr
Total Taxes = 375,500 NAf/yr
Taxes($) = 211,031 $/yr

28) Services (Imported Stone, Sand): Delivery from Curacao Port Services, 3,000 $/trip (port fees, 5 per year, estimate); Stone/Sand Dlvd, 20 NAF/MT; 7,500 MT/trip
Stone/Sand Dlvd = (3,000 $/trip)(5 trips)+(7,500 MT/trip)(20 NAF/MT)/(1.79 NAf/$) + (25,000 MT local)(20NAF/MT)/(1.79 NAf/$) = $380,300
Bitumin Dlvd, 4,000 gallons/yr, 0.80 NAF/gallon
Bitumin Dlvd = (4,000 gallons/yr)(0.80 NAf/gallon)(1.79 NAf/$) = $1,798
Total services = $382,098

29) Parent Company Contributions (did not use this, for information only)
De Antillen, N.V., is owned by Royal Volker Wessels Stevin (KVWS), which is a multinational construction company, with its home office in Rotterdam. KVWS has over 12,500 employees in seven countries. Shareholder's equity amounted to NLG 844 million in 1998.Total Employees, 12,500 people; Bonaire Employees, 13 people

30) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 13 full time, 260 wrk days/yr, 8 hrs/day
(13 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 1,896 E14 sej/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

Owner Households

Owned by K.V.S. (Kon. Volken Stevin, Rotterdam); Owners are long line of companies going back to the Netherlands, no owners on Bonaire

0 E14 sej/Households of Owners

OUTPUT AND TRANSFORMITIES:

Roadway Notes:
Roads improved and asphalted (1933) (estimate 30 km x 20 feet, Playa Roads, Rincon-Playa)
Resurface Playa Roads, Rincon-Playa Road (1958) (about 80 km)
Remaining Roads till 1995 (about 120 km, 210 km total)
Total surfaced roads on Bonaire, 210 km (EIU 1997:63)

Two measures of road emergy were calculated, giving similar results:

31) New Road per Year (5 km, est.): Road mass (asphalt and subbase) 30 kg/sq.ft; 66,000 sq.ft./km; 5 km/yr, est.;

Mass (g) = 9.90E+09 g/yr = (30 kg/sq ft)(66,000 sq.ft/km)(5 km/yr)(1000 g/kg)
Emergy per gram = 7.78E+08 sej/g (compare McGrane 1994:37, 3.23E9 sej/g)

32) Mass of Road, Outflow: Road mass (asphalt and subbase) 30 kg/sq.ft.; 66,000 sq.ft./km; 210 km paved roads (EIU 1997:63); 40 years depreciation

Mass (g) = 1.04E+10 g/yr = (30 kg/sq ft)(66,000 sq.ft/km)(210 km)(1000 g/kg)/(40 yr)
Emergy per gram = 7.41E+08 sej/g (compare McGrane 1994:37, 3.23E9 sej/g)

33) Services Income (?) 500,000 NAF, est., could be much higher

Service ($) = (500,000 NAf)/(1.79 NAf/$) = $281,000

34) Emergy Attracted per Laborer: Total Emergy Inflows = 84,261 E14 sej/yr; Total Laborers = 13

Emergy per Laborer = (84,261 E14 sej/yr)/(13 Laborers) = 6,482 E14 sej/yr/laborer

35) Emergy Attracted per Unit: Total Emergy Inflows = 84,261 E14 sej/yr; Total Units = 1

Emergy per Unit = (84,261 E14sej/yr)/(1 Company) = 84,261 E14 sej/yr/unit

Estimated Road Usage (for other subsystems analyses):

Households 55%
Tourism = 20%
Stone and Sand Transport = 10%
Retail = 5%
Wholesale = 5%
Export Industries = 5%
I.e., estimate that 55% of all road traffic on Bonaire by tonnage is regular household car or truck traffic

APPENDIX K
INTER-ISLAND SHIPPING SYSTEM EMERGY ANALYSIS

EMERGY Flows of Inter-Island Container Shipping and Delivery

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*Emdollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	1.75E+15	J	1	17.5	1,278
2	Rain, Chemical Potential Energy	7.35E+11	J	15,444	113.6	8,290
3	Rain, Geopotential Energy	3.39E+09	J	8,888	0.3	22
4	Wind, Kinetic Energy	1.37E+13	J	584	80.2	5,851
5	Wave Energy	3.06E+11	J	25,889	79.3	5,786
6	Tidal Energy	5.75E+10	J	49,000	28.2	2,058
7	Currents Energy	1.80E+10	J	1.0E+05	18.0	1,315
8	Earth Contribution	3.64E+06	g	1.0E+09	36.4	2,660
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**196.2**	**14,323**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	3.84E+11	J	51,078	196.2	14,323
10	Mondi Animals	8.59E+09	J	2,056,417	176.6	12,891
	Total of Renewable Production				**372.8**	**27,214**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	3.44E+09	J	63,000	2.2	158
12	Groundwater and Dams	2.14E+08	J	617,760	1.3	97
13	Coral Reef	2.50E+06	g	1.0E+09	25.0	1,825
	Total of Slow-Renewable Sources				**28.5**	**2,080**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	3.34E+03	g	4.5E+09	0.2	11
15	Limestone	3.34E+03	g	1.0E+09	0.0	2
	Total of Non-Renewable Sources				**0.2**	**13**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Ships and other Assets	6.24E+07	g	6.70E+09	4,181	305,200
17	Deisel Fuel	9.84E+12	J	6.30E+04	6,199	452,496
18	WEB Water	1.37E+10	J	1.39E+06	191	13,914
19	Electricity	1.05E+11	J	2.73E+05	288	20,989
20	Agent and Stevedoring Services				106,179	7,750,274
21	Port Services (Bonaire)				18,944	1,382,744
22	Services (Parts, Maintenance, etc.)	2.09E+06	$	2.36E+12	49,138	3,586,706
23	Services (International Shipping)	7.36E+06	$	2.36E+12	173,317	12,650,892
24	Loans	9.37E+03	$	2.36E+12	221	16,110
25	Govt Services (Taxes)	2.32E+05	$	4.72E+12	10,937	798,338
26	Labor Contribution				2,918	212,969
	Total Imports and Outside Sources				**372,512**	**27,190,631**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

27	Owner Households				5,762	420,612
	Total Imports and Outside Sources				**5,762**	**420,612**
Total Emergy Inflows					**378,872**	

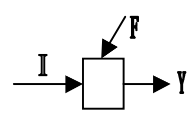
OUTPUT AND TRANSFORMITIES:

28	Emergy per Gram of Goods Moved	1.00E+11	g	3.73E+08	373,109	27,234,261
29	Shipping Convergence(?)	1.00E+02	J	3.73E+17	373,109	27,234,261
30	Services Income (?)	3.06E+06	$	1.24E+13	378,872	27,654,874
31	Emergy Attracted per Laborer				18,944	1,382,744
32	Emergy Attracted per Unit				378,872	27,654,874

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	62.22
Yield Ratio = Y/F	Y/(M + S)	1.00
Service/Free	S/(N + R)	19.51
Service/Resource	S/(R + N + M)	10.68
Nonrenewable/Renewable	(N + M)/R	1.77
Developed/Environmental	(N + M + S)/R	60.72
Empower Density	sej/ha/yr	9.22E+09

NOTES

Data comes from an interview with an owner, from estimates, or from citations as shown.

Land area is house and hotel plots, construction company lands, and stone and sand mining lands, est about 1-2% of the island surface: Land Area, 10 acres, (40,470 m^2); Shelf Area, 25,000 m^2 (100 m x 250 m coastline) = 65,470 m^2

Fraction of Total = 0.0001578

NUMBERED FOOTNOTES

Footnotes for Items 1-12 and 14-15 see Natural Systems analysis.

13) Coral Reef: Total reef lost estimated due to piers and shipping, 50 MT; Years of reef consumption, 20 yrs;
Loss per year = (50 MT)(1E6 g/MT)/(20 yrs) = 2.50E6 g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Ships and other Assets: Ships(2); 2,000 MT (each ship, est.); 50yrs (Yrs dep)
Mass (g) = (2,000 MT/ship)(1E6 g/MT)/(50 yrs) = 4.00E+07g/yr
Trucks: 2MT (each, est.); No. of Trucks, 10; 10yrs (Yrs of dep)
Mass (g) = (2 MT/truck)(10)(1E6 g/MT)/(10 yrs) = 2.00E+06g/yr
Chasis: 2MT (each, est.); No. of Item, 80; 10yrs (Yrs of dep)
Mass (g) = (2 MT/chasis)(80)(1E6 g/MT)/(10 yrs) = 1.60E+07g/yr
Containers: 40 Containers (25'), 1MT (each, est.); 25 Containers (40'), 2MT (each, est.); 10yrs (Yrs of dep)
Mass (g) = ((1 MT/small)(40 containers)+(2 MT/large)(25))(1E6 g/MT)/(10 yrs) = 4.01E+06g/yr
Warehouses: Steel, 80 MT (est.); Aluminum, 20 MT (est.); 50yrs (Yrs of dep)
Mass (g) = (80 MT+20 MT)(1E6 g/MT)/(50 yrs) = 4.02E+05g/yr
Total Ship and other Assets = 6.24E+07g/yr

17) Deisel Fuel: 20,000 l/month (Diesel)
Fuel (J) = (20,000 l/month)(12 months/yr)(41E6 J/l) = 9.84E+12 J/yr

18) WEB Water: 3,000 NAF/month; 13 NAF/m^3;
Energy (J) = ((3,000 NAf/month)(12 months/yr)/(13 NAf/m^3))(1000 g/m^3)(4.94E3 J/g) = 1.368E10 J/yr

19) Electricity: 10,000 NAF/yr (est., in warehouse); 2.93 kwh/NAF
Energy (J) = (10,000 NAf/yr)(2.93 kWh/NAf)(860 Cal/kWh)(4186 J/Cal) = 1.05E+11J/yr

20) Agent and Stevedoring Services: Estimate 1/2 of all stevedoring performed at Kralendijk Port; Total Services, 363,906 E14 sej/yr; Subtract 40% already fed-back from Agents, 151,548 E14 sej/yr (see Stevedoring and Agents analysis); One-half of remainder, 106,179 E14 sej/yr

21) Port Services (Bonaire & Curacao): Total services, 395,479 E14 sej/yr (see The Port (Harbor and Piloting) analysis); 5% already fedback
Total = (395,479 E14 sej/yr)(5%) = 18,944 E14 sej/yr

22) Services (Parts, Maintenance, etc.): Estimate expenses for parts, maintenance, etc. by subtracting estimated costs from estimated income
Expenses are Freight Income minus Profit minus Taxes and Wages
Total value of imports, 136,380,000 NAf; Freight income estimated to be 20% of imports value
Freight income (20%) = (136,380,000 NAf)(20%) = 27,276,000 NAf, estimate
Inter-Island Freight Portion estimate 20% of freight income go to Inter-island shipping (the rest to international shipping) = (27,276,000)(20%) = 5,455,200 NAf,
Estimated Income = (5,455,200 NAf)/(1.78 NAf/$) = 3,064,719 $/yr

Estimated Profit (20%), 612,944 $/yr;
Expenses ($) = 3,064,719 $/yr - 612,944 $/yr = 2,451,775 $/yr;
Taxes($), 231,557$/yr, Wages ($), 134,880 $/yr
Remaining Expenses = 231,557 $/yr - 134,880 $/yr = 2,085,338 $/yr

23) Services (International Shipping); These services come from the International countries and are paid for as freight costs. This portion of costs is paid to Curacao for transfer services, etc. Total value of imports, 136,380,000 NAf; Freight income estimated to be 20% of imports value
Freight income (20%) = (136,380,000 NAf)(20%) = 27,276,000 NAf, estimate
International Freight Portion estimate 80% of freight income go to Inter-island shipping (the rest to inter-island shipping) = (27,276,000)(80%) = 21,820,800 NAf,
Estimate 60% of international shipping is via Curacao, 13,092,480 NAf,
Estimated Services for International Shipping = 7,355,326 $/yr

24) Loans: = 500,000 NAF, loan for ship, etc (principal and interest, est.); 30yr loan
Loans($) = (500,000 NAf)/(1.79 NAf/$)/(30 yrs) = 9,367 $/yr

25) Govt Service (equivalent to services in estimated taxes):
Land Tax = (0.15 NAf/m^2)(65,470 m^2) = 6,071 NAF
Profit, 1,097,169 NAf/yr (est., see #30); Profit tax 5%
Profit Tax = (1,097,169 NAf/yr)(.37) = 405,953 NAf/yr
Total Taxes = 412,023 NAf/yr
Taxes($) = 231,557 $/yr

26) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 20, est, 260 wrk days/yr, 8 hrs/day
(20 people)(61,439 E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 2,918 E14 sej/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

27) Owner Households; Locally owned companies have assets that are intermingled with owner's household assets, and which contribute to the production of the owners and families. This is reflected by counting the assets of a locally owned company as one portion of the total household assets. Stated conversely, the household assets are a critical contribution to the formation and maintenance of the company. Either way, the total assets storage feedsback and amplifies the production of the household and company. 8,644 E14 sej/Household (est. affluent 1) (see Household analysis); 2 affluent households, averaging 3 businesses each
Emergy (sej) = (2 owners)(8,644 E14 sej/household)/(3 businesses/household) = 5,762 E14 sej/Households of Owners

OUTPUT AND TRANSFORMITIES:

27) Emergy per Gram of Goods Moved: Tonnage shipped per year, estimate 400 tons per trip from Curacao, 250 trips per year
Mass (g) = (400 MT)(250 trips/yr)(1E6 g/MT) = 1.00E+11g/yr

28) Shipping Convergence(?): I have no idea how to calculate this. But the concept is very important to systems thinking, and seems to demand some representation. Shipping (and other forms of transportation) serve the vital function of convergence of goods to a center. What is the emergy value of that act of convergence? Diesel fuel spent in a random cruise has should have one transformity. Fuel spent in the act of convergence should be much higher?
100J

29) Services Income (?): Estimate that the total Services cost per Container is 5,000 NAF per 20' Container. Estimate 5,000 containers/yr are shipped (100,000 MT/yr at 20 MT/container);

Total services paid for shipping = (5,000 NAf)(5,000 containers) = 25,000,000 NAf/yr
Second income estimate is 27,276,000 NAf/yr, from note 23 above
Estimate that the inter-island portion of the freight cost is 20%, so 5,455,200 NAf/yr income
Inter-Island Freight Cost (est. 20%) = (27,276,000)(20%)/(1.79 NAf/$) = $3,064,719

Balance Sheet for Import Services
If 25,000,000 NAF is a good estsimate of total services paid for imports…

Inter-Island Freight Cost (est. 20%) =	$2,808,989	20%
Wholesalers Services (per analysis) =	$4,166,667	27%
Retail Services (per analysis) =	$2,916,667	19%
Agents and Stevedoring (per analysis) =	$6,153,900	40%
$13,850,177		
Total Services Paid ($) =	$15,323,596 (25,000,000 NAF)	
Total Accounted for =	$13,850,177	
International Shipping =	$1,473,418	10% (too low?)
	(assign balance to international shipping)	

30) Emergy Attracted per Laborer: Total Emergy Inflows, 378,817 sej/yr; Total Laborers = 20
Emergy per Laborer = (378,817 sej/yr)/(20 Laborers) = 18,944 sej/yr/laborer

31) Emergy Attracted per Unit: Total Emergy Inflows = 378,817 sej/yr; Total Units = 1
Emergy per Unit = (378,817 sej/yr)/(1 Companies) = 378,817 sej/yr/unit

APPENDIX L
PORT SYSTEM EMERGY ANALYSIS

EMERGY Flows of the Port Subsystem

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	3.92E+16	J	1	392	28,599
2	Rain, Chemical Potential Energy	1.65E+13	J	15,444	2,542	185,518
3	Rain, Geopotential Energy	7.60E+10	J	8,888	7	493
4	Wind, Kinetic Energy	3.07E+14	J	584	1,794	130,932
5	Wave Energy	6.85E+12	J	25,889	1,774	129,465
6	Tidal Energy	1.29E+12	J	49,000	631	46,046
7	Currents Energy	4.03E+11	J	1.0E+05	403	29,423
8	Earth Contribution	8.15E+07	g	1.0E+09	815	59,525
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**4,391**	**320,512**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	8.60E+12	J	51,078	(4,391)	(320,512)
10	Mondi Animals	1.92E+11	J	2,056,417	(3,952)	(288,461)
	Total of Renewable Production				**(8,343)**	**(608,973)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.18E+09	J	63,000	1	54
12	Groundwater and Dams	7.38E+07	J	617,760	0	33
13	Coral Reef	2.50E+07	g	1.0E+09	250	18,248
	Total of Slow-Renewable Sources				**251**	**18,336**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.15E+03	g	4.50E+09	0.1	4
15	Limestone	1.15E+03	g	1.00E+09	0.0	1
	Total of Non-Renewable Sources				**0.1**	**5**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Steel Reinforcing	1.25E+06	g	1.80E+09	23	1,642
17	Concrete in Piers	2.14E+07	g	9.26E+07	20	1,449
18	Tugboats (2)	2.00E+08	g	6.70E+09	13,400	978,102
19	Fuel	9.02E+13	J	6.30E+04	56,826	4,147,883
20	Inter-Island Shipping				112,032	8,177,485
21	Agents and Stevedoring				162,195	11,839,015
22	Foreign Aid (Construction Piers)				10,179	743,028
23	Loans	5.62E+03	$	2.36E+12	132	9,666
24	Services (Fuel, Tugboats)	1.47E+06	$	2.36E+12	34,618	2,526,833
25	Labor Contribution				1,459	106,484
	Total Imports and Outside Sources				**390,883**	**28,531,588**
Total Emergy Inflows					**395,525**	

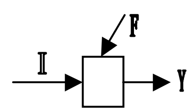
OUTPUT AND TRANSFORMITIES:

26	Output to Stevedoring and Agents (20%) =				79,034	5,768,897
27	Tanker into Bopec Port (1) =				1,333	97,307
28	Cruise Ship into Port (1) =				76	5,560
29	Inter-island Freight (1) =				15	1,112
30	Other Freight Ship (1) =				76	5,560
31	Salt Ships into Salt Pier (1) =				305	22,242
32	Services Income (?)	10,428,305	$	3.79E+12	395,525	28,870,441
33	Emergy Attracted per Laborer				39,517	2,884,449
34	Emergy Attracted per Unit				395,169	28,844,486

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	84.2
Yield Ratio = Y/F	Y/(M + S)	1.01
Service/Free	S/(N + R)	72.0
Service/Resource	S/(R + N + M)	18.5
Nonrenewable/Renewable	(N + M)/R	3.1
Developed/Environmental	(N + M + S)/R	89

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area is estimated as, 10 ha, (100,000 m^2), coastline at 250m, by 200m of reef and shelf (50,000 m^2)

Fraction of Total = 0.0003614

NUMBERED FOOTNOTES

Footnotes for Items 1-12 and 14-15 see Natural Systems analysis (APPENDIX D).

13) Coral Reef: Total reef lost estimated due to piers and shipping, 500 MT; Years of reef consumption, 20 yrs;

Loss per year = (500 MT)(1E6 g/MT)/(20 yrs) = 2.50E7 g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Steel Reinforcing: Misc, 100MT (Steel reinforced concrete); 80yrs (Yrs of dep)

Total Wt. (g) = (100 MT)(1E6 g/MT)/(80 yrs) = 1.25E+06 g/yr

17) Concrete in Piers
Cement pier built (67 x 11 meters) (1950): 1,692 cubic meters total, estimated; 181 kg/cubic meter concrete; Pier turnover time, 80 yrs

Mass per year = (1,692 m^3)(181 kg/m^3 concrete)/(80 yrs) = 3.83E+06g/yr

Concrete Transformity 9.26E7 sej/g ((Doherty and Brown 1993))

Roll-on Roll-off Pier (1972?) (900,000 NAF, Dutch) (Dimensions est 20 x 100 meters): 3,445 cubic meters total, estimated; 181 kg/cubic meter concrete; Pier turnover time, 80 yrs

Mass per year = (3,445 m^3)(181 kg/m^3 concrete)/(80 yrs) = 7.79E+06g/yr

New pier, for cruise ships, etc. (132 x 17 meters) (1973) (2,500,000 NAF, EEC): 4,336 cubic meters total, estimated; 181 kg/cubic meter concrete; Pier turnover time, 80 yrs
Mass per year = (4,336 m^3)(181 kg/m^3 concrete)/(80 yrs) = 9.81E6 g/yr

Total Mass per year (g) = (3.83E6 g/yr)+(7.79E6 g/yr)+(9.81E6 g/yr) = 2.14E+07g/yr

18) Tugboats (2): Estimates: 2,000 MT per tugboat; Tug dimensions -120'x40'x20'; 4,000 HP; 2,000 LT displacement; 30,000 gallons fuel capacity; $6,000,000 each; 20 yrs depreciation

Mass machines (g) = (2,000 MT)(1E6 g/MT)/(20 yrs) = 2.00E+08g

19) Fuel: Estimate 110,000 liters per tank x 10 tanks per year x 2 boats

Energy (J) = (110,000 liters/tank)(10 tanks/yr)(2 boats)(41E6 J/l) = 9.02E+13 J/yr

20) Inter-Island Shipping: Total Shipping output, 378,871 E14 sej/yr (APPENDIX K); Estimate 40% feedback to Port, 151,548, E14 sej/yr; Subtract the 10% already fed forward to Shipping, 39,553;

Total input from Shipping = (378,871 E14 sej/yr)(40%) - (395,525 E14 sej/yr)(10%) = 111,996 E14 sej/yr

21) Agents and Stevedoring: Total Agenst & Stevedoring output, 363,906 E14 sej/yr (APPENDIX M); Estimate 50% feedback to Port, 181,953 E14 sej/yr; Subtract 5% already fed forward to Agents and Stevedoring; 5% already fed forward to Agents, 19,776 E14 sej/yr;

Total input from Agents & Stevedoring = (363,906 E14 sej/yr)(50%) - (395,525 E14 sej/yr)(5%) =162,177 E14 sej/yr

22) Foreign Aid (Construction Piers): Services input to piers over a 30 year period (synthesized from various Depos reports ((DEPOS 1987))((DEPOS 1995))); Funding is converted to emergy per ((Odum 1996a):313-314) to put values from different years on an even basis.

Funding Type	Real NAF	Emergy (E14 sej)	Donor

Funding Type		Real NAF	Emergy (E14 sej)	Donor
Supplementary Costs EEC Pier	1967	332,500	30,590	NL
Roll-on Roll-off Pier	1972	863,800	60,466	NL
Wharf	1972	2,319,200	162,344	EEG
Supplementary Costs Roll-on Roll-off Pier	1977	217,000	9,548	NL
Master Plan Harbor and Support	1988	2,424,937	42,436	NL
		Emergy (E14 sej) =	305,384	

Per year aid (30 years) = (305,384 E14)/(30 yrs) = 10,179 E14 sej

23) Loans: 500,000 NAF, loan for hardware (principal and interest, est.); 50yr loan
Loans($) = (500,000 NAf)/(1.79 NAf/$)/(50 yrs) = 5,620 $/yr

24) Services (Fuel, Tugboats): Tugboat Cost, 6,000,000 $, est; 25 years depreciation
Fuel (.80 NAF/l) = (2,200,000 l/yr)(0.80 NAf/l)/(1.79 NAf/$) = 983,240 $/yr
Tugboats per year (2) = ($6,000,000)(2)/(25 yrs) = 480,000 $/yr
Total Service Costs = 1,469,120 $/yr

25) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis (APPENDIX F)); Full-time Laborers, 10 full time, 260 wrk days/yr, 8 hrs/day
(10 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 1,495 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

Shipping Tonnage Data

(Island Government 1990):II-28		Freight	
Tankers =	82	4,600,000	GRT
Tourist Ships =	91		
Inter-island boats =	200	83,769	GRT
Freight Ships =	106	176,664	GRT
Salt Ships =	26	114,698	GRT
Total Shipping (1989) =	397	4,975,131	

(CBS 1994c):73			
Tankers (Bopec) =	186	7,422,000	GRT
Cruse Ships =	58		
Others (100 salt ships, etc) =	639	1,802,000	GRT
Total ships piloted into port =	883	9,224,000	GRT

GRT - Gross Registered Tons - A common measurement of the internal volume of a ship with certain spaces excluded. One ton equals 100 cubic feet; the total of all the enclosed spaces within a ship expressed in tons each of which is equivalent to 100 cubic feet.

Emergy is divided by GRT. This is reasonable because the use of tugs is proportional to tonnage, and most of the emergy is due to tugboats and tugboat fuel.

Estimates for 1995: Total Port emergy, 116,765 E14 sej/yr

Estimates for 1995		Freight	
Tanker into Bopec Port (1) =	200	7,000,000	GRT
Cruise Ship into Port (1) =	50	100,000	GRT
Inter-island Freight (1) =	250	100,000	GRT
Other Freight Ship (1) =	150	300,000	GRT

Estimates for 1995		Freight
Salt Ships into Salt Pier (1) =	100	800,000 GRT
Other Piloted boats =	200	
Total Shipping Estimate =	950	8,300,000 GRT

26) Output to Stevedoring and Agents = (395,525 E14 sej/yr)(20%) = 79,105 E14 sej/yr

27) Tanker into Bopec Port (1) = (316,420 E14 sej/yr)(7,000,000 / 8,300,000)/(200) = 266,860 E14 sej/ship

28) Cruise Ship into Port (1) = (316,420 E14 sej/yr)(100,000 / 8,300,000)/(50) = 3,812 E14 sej/ship

29) Inter-island Freight (1) = (316,420 E14 sej/yr)(100,000 / 8,300,000)/(250) = 3,812 E14 sej/ship

30) Other Freight Ship (1) = (316,420 E14 sej/yr)(300,000 / 8,300,000)/(150) = 11,437 E14 sej/ship

31) Salt Ships into Salt Pier (1) = (316,420 E14 sej/yr)(800,000 / 8,300,000)/(100) = 30,498 E14 sej/ship

Other Piloted boats = 200
Total Shipping Estimate = 950 8,300,000 GRT

32) Services Income (?): From GDP, Transport, storage and communication, 56,000,000 NAf ((Land Government 1998)): Estimate (guess) that it is distributed as below:

Airport (5%, est.) = 2,800,000 NAf
Passanger Fares (28%) = 15,866,667 NAf
Port (33%, est) = 18,666,667 NAf
Telecomm (33%, est) = 18,666,667 NAf

Port Income = (18,666,667)/(1.79 NAf/$) = 10,428,305 $/yr

33) Emergy Attracted per Laborer: Total Emergy Inflows = 395,525 E14 sej/yr; Total Laborers, 10
Emergy per Laborer = (395,525 E14 sej/yr)/(10 Laborers) = 39,553 E14 sej/yr/laborer

34) Emergy Attracted per Unit: Total Emergy Inflows = 395,525 E14 sej/yr; Total Units = 1
Emergy per Unit = (395,525 E14 sej/yr)/(1 Company) = 395,525 E14 sej/yr/unit

APPENDIX M
STEVEDORING SYSTEM EMERGY ANALYSIS

EMERGY Flows of Stevedoring and Shipping Agents

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	6.03E+14	J	1	6	440
2	Rain, Chemical Potential Energy	2.53E+11	J	15,444	39	2,854
3	Rain, Geopotential Energy	1.17E+09	J	8,888	0	8
4	Wind, Kinetic Energy	4.73E+12	J	584	28	2,014
5	Wave Energy	1.05E+11	J	25,889	27	1,992
6	Tidal Energy	1.98E+10	J	49,000	10	708
7	Currents Energy	6.20E+09	J	1.0E+05	6	453
8	Earth Contribution	1.25E+06	g	1.0E+09	13	916
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**68**	**4,931**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	1.32E+11	J	51,078	(68)	(4,931)
10	Mondi Animals	2.96E+09	J	2,056,417	(61)	(4,438)
	Total of Renewable Production				**(128)**	**(9,369)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.18E+09	J	63,000	1	54
12	Groundwater and Dams	7.38E+07	J	617,760	0	33
13	Coral Reef	8.05E+00	g	1.0E+09	0	0
	Total of Slow-Renewable Sources				**1**	**88**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.15E+03	g	4.50E+09	0	4
15	Limestone	1.15E+03	g	1.00E+09	0	1
	Total of Non-Renewable Sources				**0**	**5**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Trucks, Forklifts, etc.	6.00E+06	g	6.70E+09	402	29,343
17	Fuel	3.41E+12	J	6.30E+04	2,149	156,865
18	Parts	1.00E+06	g	6.70E+09	67	4,891
19	Inter-Island Shipping				151,549	11,061,949
20	Roadway System				4,213	307,523
21	Port System				39,548	2,886,708
22	Telecommunication Services	5.62E+04	$	3.80E+12	2,136	155,883
23	Services (International Shipping)	4.90E+06	$	2.36E+12	115,545	8,433,928
24	Other Services (Expenses)	4.30E+04	$	2.36E+12	1,014	74,004
25	Loans	1.12E+04	$	2.36E+12	265	19,332
26	Govt Services (Taxes)	4.30E+05	$	4.72E+12	20,326	1,483,676
27	Labor Contribution				12,254	894,468
	Total Imports and Outside Sources				**349,467**	**25,508,571**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

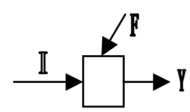
28	Owner Households				14,370	1,048,902
	Total Non-Renewable Production within Subsystem				**14,370**	**1,048,902**
Total Emergy Inflows					**363,906**	

OUTPUT AND TRANSFORMITIES:

29	Emergy per Day Services				997	72,774
30	Services Income (?)	6.15E+06	$	5.91E+12	363,906	26,562,497
31	Emergy Attracted per Laborer				4,332	316,220
32	Emergy Attracted per Unit				25,993	1,897,321

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	5078
Yield Ratio = Y/F	Y/(M + S)	1.04
Service/Free	S/(N + R)	2.3
Service/Resource	S/(R + N + M)	1.9
Nonrenewable/Renewable	(N + M)/R	0.2
Developed/Environmental	(N + M + S)/R	24

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area est, 10 ha, (100,000 m^2);

Fraction of Total = 0.0002410

NUMBERED FOOTNOTES

Footnotes for Items 1-15 see Natural Systems analysis.

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Trucks, Forklifts, etc.: Truck (1), 1MT (est.); No. of Trucks, 40 (est.); 10yrs (Yrs of dep)
Trucks, Forklifts (g) = (40 MT)(1E6 g/MT)/(10 yrs) = 4.00E+06 g/yr
Warehouse, Steel, 80 MT (est.); Aluminum, 20MT (est.)
Warehouse (g) = (80 MT + 20 MT)(1E6 g/MT)/(50 yrs) = 2.0E+06 g/yr
Total Wt. (g) =6.0E+06g/yr

17) Fuel: 40 l/engine/week, estimate
Energy (J) = (40 l/engine/week)(40 engines)(52 weeks/yr)(41E6 J/l) = 3.41E+12J/yr

18) Parts: Parts (mass), 10 MT/yr (estimate); 10 yrs dep
Parts (g) = (10 MT)(1E6 g/MT)/(10 yrs) = 1.00E+06 g/yr

19) Inter-Island Shipping: Total services, 378,871 E14 sej/yr (APPENDIX K); Estimate 40% is feedback to here
Inter-Island Shipping = (378,871 E14 sej/yr)(40%) = 151,548 E14 sej/yr

20) Roadway System: Total services, 84,261 E14 sej/yr (APPENDIX J); Estimate 5% used here
Roadway System = (84,261 E14 sej/yr)(5%) = 4,213 E14 sej/yr

21) Port System: Total services, 395,472 E14 sej/yr (APPENDIX L); Estimate 10% used here
Port system = (395,472 E14 sej/yr)(10%) = 39,547 E14 sej/yr

22) Telecommunication Services: Total, 100,000 NAF/yr, est.
Telecom Services ($) = (100,000 NAf/yr)/(1.79 NAf/$) = 56,200 $/yr

23) Services (International Shipping): These services come from the International countries and are paid for as freight costs. The services enter the Bonaire economy here and are spread outward from here.
Total value of imports, 136,380,000 NAf; Estimate 20% of values is freight costs, 27,276,000 NAf; Estimate 20% of freight costs go to Inter-island shipping, 5,455,200 NAf; Estimate remaining 80% is International Shipping, 21,820,800 NAf; Estimate 40% is Shipping Direct to Bonaire, 8,728,320 NAf
Services (International Shipping) = (8,728,320 NAf)/(1.78 NAf/$) = 4,903,551 $/yr

24) Other Services (Expenses)
Gasoline = (83,200 liters/yr)(0.8 NAf/liter) = 66,560 NAF
Parts = 10,000 NAF/yr, estimate
Total Other Services ($) = ((66,560 NAf)+(10,000 NAf/yr))/(1.79 NAf/$) = 43,027 $/yr

25) Loans: 200,000 NAF, loan for trucks, etc? (principal and interest, est.); 10yr loan
Loans($) = (200,000 NAf)/(10 yrs)/(1.79 NAf/$) = 11,240 $/yr

26) Govt Services (Taxes):
Land Tax = (100,000 m^2)(0.15 NAf/m^2, est.) = 15,000 NAF
Profit Tax = (2,028,991 NAf)(37%) = 750,727 NAF (37%-45%, 1992)
Taxes($) = (15,000 NAf + 750,727 NAf)/(1.79 NAf/$) = 430,338 $/yr

27) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis (APPENDIX F)); Full-time Laborers, 84 persons, 260 wrk days/yr, 8 hrs/day
(84 people)(61,439 E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 12,254 E14 sej/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

28) Owner Households: Some major Importing Companies: Kralendijk Port Services N.V. was created in 1993 to consolidate the stevedoring operations of many of the companies listed below.

Company	Open
Associated Transport Company (Bonaire) N.V.	10/28/74
Bonaire Cargo Handlers N.V.	4/1/85
Bonaire Express Services N.V.	1/1/87
Bonaire Heavy Equipment N.V.	8/9/89
Bonaire Stevedoring Company (Bosteco) N.V.	5/6/86
Bonaire Trading Services Center N.V. (under BTC, Service Center, Airport, Handelmij Bonaire)	1/18/80
C. Winkel & Zonen Bonaire N.V.	8/14/64
Don Andres	12/19/86
Kralendijk Port Services N.V.	7/7/93
N.V. Handelmaatschappij Bonaire (Bonaire Trading Company - BTC)	12/31/40
Rexport N.V.	11/24/89
Rocargo Services Bonaire N.V.	12/8/82
S.G. Soliana Imports (E.Z.)	1/1/50
SEL Maduro & Sons (Bonaire) N.V.	7/26/63

From ((Bonaire 1995)) and ((Labor Office 1993))

Total Owners/Directors, 14; Total Employees, 84 (estimate 6 per company in stevedoring); the households in this business sector are some of the most prolific in the business community. On average they own 4 businesses each. The total owner emergy is divided by 4; Households emergy, 4,106 E14 sej/Household (est. affluent 2)

Emergy (sej) = (4,106 E14 sej/household)(14 households)/(4 businesses/household = 14,370 E14 sej

OUTPUT AND TRANSFORMITIES:

29) Emergy per Day Services: Total Emergy divided by 365 days

Emergy per day (sej) = (363,905 E14 sej/yr)/(365 days) = 997 E14 sej/day

30) Services Income (?): Income per day, 30,000 NAF/day, estimate; 10,950,000 NAf, est., could be much higher; Summed total costs, 6,153,900 $

Service ($) = (10,950,000 NAf/yr)/(1.79 NAf/yr) = 6,153,900$/yr

Economic Balance Sheet
Total Profit = (6,153,900 $/yr)-(1,139,883 $/yr) = 5,014,017 $(divided by 14 companies, too small?)

31) Emergy Attracted per Laborer: Total Emergy Inflows, 363,905 E14 sej/yr; Total Laborers, 84

Emergy per Laborer = (363,905 E14 sej/yr)/(84 Laborers) = 4,332 E14 sej/yr/laborer

32) Emergy Attracted per Unit: Total Emergy Inflows = 363,905 E14 sej/yr; Total Units = 14

Emergy per Unit = (363,905 E14 sej/yr)/(14 Companies) = 25,993 E14 sej/yr/unit

APPENDIX N
WHOLESALERS SYSTEM EMERGY ANALYSIS

EMERGY Flows of Wholesalers of Food and other Goods

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	6.03E+14	J	1	6	440
2	Rain, Chemical Potential Energy	2.53E+11	J	15,444	39	2,854
3	Rain, Geopotential Energy	1.17E+09	J	8,888	0	8
4	Wind, Kinetic Energy	4.73E+12	J	584	28	2,014
5	Wave Energy	1.05E+11	J	25,889	27	1,992
6	Tidal Energy	1.98E+10	J	49,000	10	708
7	Currents Energy	6.20E+09	J	1.0E+05	6	453
8	Earth Contribution	1.25E+06	g	1.0E+09	13	916
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**68**	**4,931**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	1.32E+11	J	51,078	(68)	(4,931)
10	Mondi Animals	2.96E+09	J	2,056,417	(61)	(4,438)
	Total of Renewable Production				**(128)**	**(9,369)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.18E+09	J	63,000	1	54
12	Groundwater and Dams	7.38E+07	J	617,760	0	33
13	Coral Reef	2.30E+03	g	1.0E+09	0	2
	Total of Slow-Renewable Sources				**1**	**89**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.15E+03	g	4.50E+09	0	4
15	Limestone	1.15E+03	g	1.00E+09	0	1
	Total of Non-Renewable Sources				**0**	**5**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	International Shipping Services	7.36E+05	$	2.36E+12	17,338	1,265,545
17	Inter-Island Shipping Services				56,831	4,148,225
18	Stevedoring and Agents				7,185	524,451
19	Trucks, Freezers, Wharehouse	8.80E+06	g	6.70E+09	590	43,044
20	Gasoline	1.88E+12	J	6.30E+04	1,182	86,276
21	Potable Water	2.47E+09	J	1.39E+06	34	2,506
22	Electricity	1.05E+13	J	2.73E+05	28,755	2,098,890
23	Telecommunication Services	1.12E+05	$	2.36E+12	2,649	193,324
24	Other Services (Expenses)	5.92E+05	$	4.72E+12	27,955	2,040,507
25	Loans	2.81E+04	$	2.36E+12	662	48,331
26	Govt Services (Taxes)	3.19E+05	$	4.72E+12	15,049	1,098,461
27	Labor Contribution				23,050	1,682,451
	Total Imports and Outside Sources				**181,279**	**13,232,011**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

28	Owner/Manager Households				45,163	3,296,550
	Total Non-Renewable Production within Subsystem				**45,163**	**3,296,550**
Total Emergy Inflows					**226,510**	

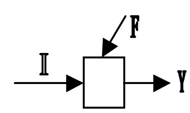
OUTPUT AND TRANSFORMITIES:

29	Services Income (?)	4.17E+06	$	5.44E+12	226,510	16,533,586
30	Emergy per Gram of Goods Moved	2.25E+10	g	1.01E+09	226,510	16,533,586
31	Emergy Attracted per Laborer				1,434	104,643
32	Emergy Attracted per Unit				20,592	1,503,053

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	2633.2
Yield Ratio = Y/F	Y/(M + S)	1.25
Service/Free	S/(N + R)	0.9
Service/Resource	S/(R + N + M)	0.8
Nonrenewable/Renewable	(N + M)/R	0.04
Developed/Environmental	(N + M + S)/R	4

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area is wholesale warehouse buildings, etc., estimate, 10 ha, (100,000 m^2);

Fraction of Total = 0.0002410

NUMBERED FOOTNOTES

Footnotes for Items 1-15 see Natural Systems analysis (APPENDIX D).

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Services (International Shipping): These services come from the International countries and are paid for as freight costs, 27,276,000 NAf; Estimate 20% of freight costs go to Inter-island shipping, 5,455,200 NAf; Estimate remaining 80% is International Shipping, 21,820,800 NAf; Estimate 40% is Shipping Direct to Bonaire, 8,728,320 NAf; Estimate 15% of Agent services to Wholesalers, 1,309,248 NAf

Services (International Shipping) = (1,309,248 NAf)/(1.78 NAf/$) = 735,797 $/yr

17) Inter-Island Shipping Services: Estimate that the services of inter-island shipping are divided between the three big users of shipping, wholesalers (15%), retailers (5%), Port system (40%) and Stevedoring (40%); Total services from shipping, 378,871 E14 sej/yr (APPENDIX K)

Wholesaler's percentage = (378,871 E14 sej/yr)(15%) = 56,831sej/yr

18) Stevedoring and Agents: Agents arrange for the shipping of goods to an island. They coordinate the receipt and packing of goods into containers on foreign ports. On arrival, the agents are responsible to assure that all freight and port services have been paid for, and to present the buyer with one bill. Stevedoring is the unloading and unpacking of goods on Bonaire. Agents and stevedoring services are partitioned in the same way shipping above, wholesalers (50%), retailers (30%), and export industries (20%); Total Est. Services from Agents, etc., 14,387 E14 sej/yr (APPENDIX M)

Wholesalers percentage = (14,387 E14 sej/yr)(50%) = 7,185 E14 sej/yr

19) Trucks, Freezers, Warehouse: Trucks, 22 (est. 4 for big stores, 2 for medium, 1 for small, 2MT each); Freezers and Refrigerators, 40MT (est.); 10yrs (Yrs of dep)

Total machines (g) = ((22 trucks)(2 MT/truck) + (40 MT, freezers))(1E6 g/MT)/(10 yrs) = 8.40E+06g/yr

Warehouse, Steel, 80MT (est.); Aluminum, 20MT (est.); 50yrs (Yrs of dep)

Mass (g) = (80 MT + 20 MT)(1E6 g/MT)/(50 yrs) = 4.02E+05g/yr

Total Wt. (g) = 8.80E+06 g/yr

20) Gasoline: 40 l/engine/week, est.; 22 trucks

Energy (J) = (40 l/engine/wk)(52 wks/yr)(22 trucks)(41E6 J/l) = 1.88E+12 J/yr

21) Potable Water: 500 m^3, est.

Energy (J) = (500 m^3)(1000 g/m^3)(4.94E3 J/g) = 2.47E+09 J/yr

22) Electricity: 1,000,000 NAF/yr, est. (200,000 NAF large stores, less smaller)

Energy (J) = (1,000,000 NAf/yr)(2.93 kWh/NAf)(860 Cal/kWh)(4186 J/Cal) = 1.05E+13 J/yr

23) Telecommunication Services: Total, 200,000 NAF/yr, est.

Services ($) = (200,000 NAf/yr)/(1.79 NAf/$) = $112,400

Parent Company(s) Contributions (not used, for information only):
Multinational companies (Albert Heijn, Del Monte, etc.) sign agency agreements with wholesalers. These agreements give the wholesalers exclusive distribution to a given product. These non-competitive contracts demonstrate the powerful control that the multinational exporters have over island importers. The prices charged are set by the manufacturers, and with no competition for the same product, the consumers have no choice but to pay them if they want the good. (Do wholesalers have to pay for contract?)

24) Other Services (Expenses): Gasoline, 36,608 NAF (0.80 NAF/liter); Water, 6,500 NAF (13 NAF/m^3); Electric, 1,000,000 NAf (2.93 kWh/NAF); Parts, 10,000 NAF/yr, estimate

Total Other Services = ((36,608 NAf)+(6,500 NAf)+(1,000,000 NAf)+(10,000 NAf/yr))/(1.79 NAf/$) = 591,847 $/yr

25) Loans: 1,000,000 NAF, loan for building, etc? (principal and interest, est.); 20yr loan

Loans($) = (1,000,000 NAf)/(20 yrs)/(1.79 NAf/$) = $28,100

26) Govt Service (equivalent to services in estimated taxes):

Land Tax = (0.15 NAf/m^2)(100,000 m^2) = 6,071 NAF
Profit, 1,491,667 NAf/yr (guess); Profit tax 37%
Profit Tax = (1,491,667 NAf/yr)(.37) = 551,917 NAf/yr
Total Taxes = 566,917 NAf/yr
Taxes($) = 318,607 $/yr

27) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis (APPENDIX F)); Full-time Laborers, 158; 260 wrk days/yr, 8 hrs/day

(158 people)(61,439 E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 23,050 E14 sej/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

28) Owner/Manager Households

Some major Wholesale Companies. "Wholesale food distribution in the Caribbean is mostly carried out by importer-distributors. There are usually only a few sizeable importer-distributors per island, and these companies usually act as manufacturers' agents." (USDA 1997:6) "Manufacturers" are multinational corporations, such as Albert Heijn, Heiniken, or Del Monte. "Under a typical agency agreement, the wholesaler is the exclusive distributor for a given product." (USDA 1997:7) "The largest wholesalers on [Caribbean] islands function as agents and offer the widest possible coverage, from the largest to the smallest retailers, to hotels, restaurants, and sometimes directly to individuals through warehouse sales. In many cases, the largest wholesalers on the islands are also the biggest retailers." (USDA 1997:15). This is the case of Cultimara Supermarket retail on Bonaire, which is a sister company to Consales N.V.

Company	Parent	Employees	Open
Consales (Bonaire) N.V.	Netherlands	35	10/3/63
Mansur Trading N.V.	Aruba	12	
Bon-Import N.V.	Venezuela	3	5/31/91
Tropical Flamingo N.V.	Venezuela	6	11/27/89
J.C. Herrera N.V.	Bonaire	14	
C. Winkel & Zonen Bonaire N.V.	Curacao	6	8/14/64
Korona Supermarket N.V.	Curacao	16	8/22/90
Progreso Minimarket	Venezuela	15	2/22/84
General Store Bonaire N.V.	Curacao	35	11/26/81
Caribbean Fasteners Bonaire N.V.	Hardware	3	12/14/89
Bonairean Eastern Store N.V.	China	13	6/10/86
		158	

From ((Bonaire 1995)) and ((Labor Office 1993))

Total Owners/Directors =11

Total Employees =158
4,106 E14 sej/Household (est. affluent 2); 11 Households
Owners/managers households = (4,106 E14 sej/household)(11 households) = 45,163 E14 sej/Households of Owners

OUTPUT AND TRANSFORMITIES:

29) Services Income (?): Goods pass through wholesalers without being used. Therefore the only money that goes to the wholesaler is the profit margin on the shipped goods; Value of Imported Goods, 75,000,000 NAF/yr; Percent Imported by Wholesalers, 50%(est.); Profit to Wholesalers, 7,500,000 NAF/yr (est. 20% added to value of goods);
Service ($) = (75,000,000 NAf/yr)(50%)(20%)/(1.79 NAf/$) = $4,166,667
Note: Per CBS 1996, the sectoral origin of wholesale and retail is 13,000,000 NAf. Almost twice the 7,500,000, which seems right (the difference goes to retailers).

30) Emergy per Gram of Goods Moved: Total Goods Imported, 45,000 MT; Estimate half through Wholesalers, 22,500 MT;
Mass (g) = (22,500 MT)(1E6 g/MT) = 2.25E10 g

31) Emergy Attracted per Laborer: Total Emergy Inflows, 226,510 E14 sej/yr; Total Laborers, 158
Emergy per Laborer = (226,510 E14 sej/yr)/(158 Laborers) = 1,434 E14 sej/yr/laborer

32) Emergy Attracted per Unit: Total Emergy Inflows = 226,510 E14 sej/yr; Total Units = 11
Emergy per Unit = (226,510 E14 sej/yr)/(11 Companies) = 20,592 E14 sej/yr/unit

APPENDIX O
RETAIL SALES SYSTEM EMERGY ANALYSIS

EMERGY Flows of the Retail Sales System

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	9.10E+15	J	1	91	6,644
2	Rain, Chemical Potential Energy	3.82E+12	J	15,444	590	43,097
3	Rain, Geopotential Energy	1.76E+10	J	8,888	2	114
4	Wind, Kinetic Energy	7.14E+13	J	584	417	30,417
5	Wave Energy	1.59E+12	J	25,889	412	30,076
6	Tidal Energy	2.99E+11	J	49,000	147	10,697
7	Currents Energy	9.36E+10	J	1.0E+05	94	6,835
8	Earth Contribution	1.89E+07	g	1.0E+09	189	13,828
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**1,020**	**74,457**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	2.00E+12	J	51,078	(1,020)	(74,457)
10	Mondi Animals	4.46E+10	J	2,056,417	(918)	(67,012)
	Total of Renewable Production				**(1,938)**	**(141,469)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.79E+10	J	63,000	11	822
12	Groundwater and Dams	1.11E+09	J	617,760	7	503
13	Coral Reef	3.47E+04	g	1.0E+09	0	25
	Total of Slow-Renewable Sources				**18**	**1,350**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.74E+04	g	4.50E+09	1	57
15	Limestone	1.74E+04	g	1.00E+09	0	13
	Total of Non-Renewable Sources				**1**	**70**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Wholesaler's Services				226,516	16,534,045
17	Roadway Services				4,213	307,523
18	Inter-Island Shipping Services				18,944	1,382,744
19	International Shipping Services	2.45E+05	$	2.36E+12	5,779	421,848
20	Trucks and Freezers	6.34E+07	g	6.70E+09	4,249	310,156
21	Buildings	5.03E+04	g	9.26E+07	0.047	3
22	Gasoline	2.58E+13	J	6.30E+04	16,225	1,184,334
23	Potable Water	9.88E+10	J	1.39E+06	1,377	100,527
24	Electricity	6.20E+12	J	2.73E+05	16,894	1,233,115
25	Propane Gas	8.81E+10	J	4.80E+04	42	3,087
26	Telecommunication Services	1.12E+05	$	2.36E+12	2,649	193,324
27	Other Services (Expenses)	8.72E+05	$	2.36E+12	20,539	1,499,218
28	Loans	9.33E+04	$	2.36E+12	2,200	160,555
29	Govt Services (Taxes)	3.70E+05	$	4.72E+12	17,471	1,275,267
30	Labor Contribution				99,493	7,262,227
	Total Imports and Outside Sources				**436,591**	**31,867,975**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

31	Owner Households	228,407	16,672,025
	Total Imports and Outside Sources	**228,407**	**16,672,025**

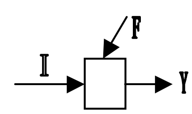
Total Emergy Inflows **666,038**

OUTPUT AND TRANSFORMITIES:

32	Services Income (?)	2.92E+06	$	2.28E+13	666,038	48,615,877
33	One Larger Store Income (?)	2.32E+04	$	4.72E+12	1,095	79,913
34	One Smaller Store Income (?)	3.86E+03	$	4.72E+12	182	13,319
35	Emergy per Gram of Goods Moved	4.50E+10	g	1.48E+09	666,038	48,615,877
36	Emergy Attracted per Laborer				977	71,284
37	Emergy Attracted per Unit				4,411	321,959

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	420
Yield Ratio = Y/F	Y/(M + S)	1.53
Service/Free	S/(N + R)	0.5
Service/Resource	S/(R + N + M)	0.2
Nonrenewable/Renewable	(N + M)/R	0
Developed/Environmental	(N + M + S)/R	2

NOTES
Data comes from interviews with owners, from estimates, or from citations as shown.

Land area est, 1 hectare per store, (1,510,000 m^2);

Fraction of Total = 0.0036386

NUMBERED FOOTNOTES

Footnotes for Items 1-16 see Natural Systems analysis (APPENDIX D).

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Wholesaler's Services: Assume that all the services produced by wholesalers are purchased by retailers. Total Est. Services from Wholesalers, 226,510 sej/yr (see Wholesalers analysis (APPENDIX N))

17) Roadway Services: Total Per Year Emergy from Roadways, 84,261 sej/yr (see Roadway analysis (APPENDIX J)). Est. 5% for Retail Sales, 4,213 sej/yr, i.e., estimate that 5% of all road traffic on Bonaire by tonnage is moving goods from wholesalers to retailers. This service is vital to all retail activity.

18) Inter-Island Shipping Services: Estimate that 5% of island retail business is arranged directly with foreign manufacturers and not through wholesalers. Therefore that portion of shipping services is directed to Retail sales. Total Est. Services from Shipping, 378,817 sej/yr (see Shipping analysis (APPENDIX O))

Retailers percentage = (378,817 sej/yr)(5%) = 18,944 sej/yr

19) International Shipping Services: These services come from the International countries and are paid for as freight costs, 27,276,000 NAf; Estimate 20% of freight costs go to Inter-island shipping, 5,455,200 NAf; Estimate remaining 80% is International Shipping, 21,820,800 NAf; Estimate 40% is Shipping Direct to Bonaire, 8,728,320 NAf; Estimate 5% of Agent services to Retailers, 436,416 NAf

International Shipping Services = (436,416 NAf)/(1.78 NAf/$) = 246,266 $/yr

20) Trucks, Freezers: Trucks, 302 (est. 1 truck per store, 2 MT each); Freezers and Coolers, 30MT (est., 200 kg machine per store, 151 stores); 10yrs (Yrs of dep)

Total machines (g) = ((302 trucks)(2 MT/truck) + (30 MT, freezers))(1E6 g/MT)/(10 yrs) = 6.34E+07g/yr

21) Buildings: estimate 10 MT concrete per building;
Mass (g) = (10 MT/store)(151 stores)(1E6 g/MT)/(30 yrs) = 5.03E+04g/yr

22) Gasoline: 40 l/engine/week, est.; 151 trucks

Energy (J) = (40 l/engine/wk)(52 wks/yr)(151 trucks)(41E6 J/l) = 2.58E+13J/yr

23) Potable Water: 500 m^3, large restaurants (est. 5%); 200 m^3, smaller restaurants and snacks (est.40%); 50 m^3, retail and small snacks (est. 55%)

Energy (J) = ((500 m^3)(151)(5%))+(200 m^3)(151)(40%)+(50 m^3)(151)(55%))(1000 g/m^3)(4.94E3 J/g) = 9.88E+10J/yr

24) Electricity: 1,721,400 NAF/yr, est. (80,000 kWh/yr, largest Retail food (w/coolers) (est. 5%); 10,000 kWh/yr, smaller retail and restaurants (est.65%); 3,000 kwh/yr, small snacks (est. 30%))

Energy (J) = ((80,000 kWh/yr)(151)(5%))+(10,000 kWh/yr)(151)(65%)+(3,000 kWh/yr)(151)(30%))(860 Cal/kWh)(4186 J/Cal) = 6.20 E12 J/yr

25) Propane Gas: 60,000 l/yr, large restaurants (est. 20%); 10,000 l/yr, smaller restaurants (est. 30%)

Energy (J) = ((60,000 l/yr)(151)(20%)+(10,000 l/yr)(151)(30%))(1000 l/m^3)(3.89E7 J/m^3) = 8.81E+10J/yr

26) Telecommunication Services: Total, 200,000 NAF/yr, est. (200,000 NAf/yr)/(1.79 NAf/$) = 112,400 $/yr

27) Other Services (Expenses): Gasoline, 502,528 NAF (0.80 NAF/liter); Water, 260,098 NAF (13 NAF/m^3); Electric, 587,509 NAf (2.93 kWh/NAF); Propane, 100,857 NAF (big bottle, 1325 liters for 59 NAF); Machines, 100,000 NAF/yr, estimate

Total Other Services = ((502,528 NAf)+(260,098 NAf)+(587,509 NAf)+(100,857 NAf/yr)+(100,000 NAf/yr))/(1.79 NAf/$) = 871,657 $/yr

28) Loans: 50,000 NAF, loan for larege stores (principle and interest, est.); 10,000 NAF, loan for smaller (70%) (principal and interest, est.); 20yr loan

Loans($) = ((50,000 NAf)(151)(30%)+(10,000 NAf)(151)(70%)/(20 yrs)/(1.79 NAf/$) = $93,348

29) Govt Service (equivalent to services in estimated taxes):

Land Tax = (0.15 NAf/m^2)(1,510,000 m^2) = 226,500 NAF

Profit, 1,166,667 NAf/yr (guess); Profit tax 37%

Profit Tax = (1,166,667 NAf/yr)(.37) = 431,667 NAf/yr
Total Taxes = 658,167 NAf/yr
Taxes($) = 369,890 $/yr

30) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis (APPENDIX F)); Full-time Laborers, 682; 260 wrk days/yr, 8 hrs/day

(682 people)(61,439 E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 99,493 E14 sej/yr

31) Owner Households

Retail Businesses. "The largest wholesalers on [Caribbean] islands function as agents and offer the widest possible coverage, from the largest to the smallest retailers, to hotels, restaurants, and sometimes directly to individuals through warehouse sales. In many cases, the largest wholesalers on the islands are also the biggest retailers." (USDA 1997:15). This is the case of Cultimara Supermarket retail on Bonaire, which is a sister company to Consales N.V.

"Below the level of supermarkets are the small shops. Known as 'colmados' in the Dominican Republic, counter shops' in the OECS, and 'Lo-Lo' in the French West Indies [and 'toko's or 'snacks' in the N.A.], these timy outlets may be only a few hundred square feet in size and generally offer a very limited range of items. They are usually family-run and have a neighborhood customer base. Though they sometimes offer perks such as store credit to their loyal customers, the main draw of these stores is convenience. On certain islands, there is literally at least one of these stores on every street corner and in every village, making it easy for anyone to shop there."

"Supermarket expansion is putting pressure on the smaller stores, which generally charge higher prices and offer less items than supermarkets. It also is putting pressure on the importer-distributors to lower prices and upgrade service, as supermarkets are not shy to do their own importation if they feel this will save them money. As one Caribbean wholesaler said, "Shipping is no longer a big mystery, and even the small supermarkets are bringing in two trailers a month." (USDA 1997:9)

Company	Employees	No. of Stores
Retail Goods	280	56
Restaurants, Snacks, Bakeries, and	402	95

Food Stores		
	682	151

From ((Bonaire 1995)) and ((Labor Office 1993))

Emergy inflows to household, 1,513 E14 sej/Household (est. not affluent, group 4, see Household analysis (APPENDIX F)); 151 Households

Total emergy (sej) = (1,513 E14 sej/yr/household)(151 households) = 228,407 E14 sej/yr

OUTPUT AND TRANSFORMITIES

32) Services Income (?): Goods pass through retail without being used. Therefore the only money that goes to the retailer is the profit margin on the shipped goods. Value of Imported Goods, 75,000,000 NAF/yr; Income to Retailers, 5,250,000 NAF/yr ; Per (CBS 1994b), the sectoral origin of wholesale and retail is 13,000,000 NAf. With 7,500,000 going to wholesalers (my estimate), that leaves 5,500,000 NAf for retail profit. That works out to 7% used here.

Service ($) = (5,250,000 NAf/yr)/(1.79 NAf/$) = 2,916,667$

33) One Larger Store Income (?): Estimate large stores (20%), make (60%) of income 700,000 $ (60%); 30 stores (20%)

Income ($) = (700,000 $/yr)(60%)/(30 stores) = 23,179 $/yr income for each large retail store

34) One Smaller Store Income (?) Estimate smaller stores (80%), make (40%) of income 466,667 $ (40%); 121 stores (80%)

Income ($) = (466,667 NAf/yr)(40%)/(121 stores) = 3,863 $/yr income for each smaller retail store

35) Emergy per Gram of Goods Moved: Total Goods Imported, 45,000 MT ((CBS 1992))

Mass (g) = (45,000 MT)(1E6 g/MT) = 4.5 E10g

37) Emergy Attracted per Laborer: Total Emergy Inflows, 666,028 E14 sej/yr; Total Laborers, 682

Emergy per Laborer = (534,121E14 sej/yr)/(682 Laborers) = 977 E14 sej/yr/laborer

38) Emergy Attracted per Unit: Total Emergy Inflows, 666,028 E14 sej/yr; Total Units = 151

Emergy per Unit = (666,028 E14 sej/yr)/(151 Companies) = 4,411 E14 sej/yr/unit

APPENDIX P
OIL TRANSHIPPMENT SYSTEM EMERGY ANALYSIS

EMERGY Flows of Oil Transhippment Terminal

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	3.92E+16	J	1	392.2	28,630
2	Rain, Chemical Potential Energy	1.65E+13	J	15,444	2,544.3	185,715
3	Rain, Geopotential Energy	7.60E+10	J	8,888	6.8	493
4	Wind, Kinetic Energy	3.07E+14	J	584	1,795.7	131,071
5	Wave Energy	6.86E+12	J	25,889	1,775.6	129,603
6	Tidal Energy	1.29E+12	J	49,000	631.5	46,095
7	Currents Energy	4.04E+11	J	1.0E+05	403.5	29,454
8	Earth Contribution	8.16E+07	g	1.0E+09	816.4	59,588
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**4,395.7**	**320,852**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	8.61E+12	J	51,078	4,395.7	320,852
10	Mondi Animals	1.92E+11	J	2,056,417	3,956.1	288,767
	Total of Renewable Production				**8,351.8**	**609,619**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.27E+09	J	63,000	0.8	58
12	Groundwater and Dams	7.89E+07	J	617,760	0.5	36
13	Coral Reef	5.00E+07	g	1.0E+09	500.0	36,496
	Total of Slow-Renewable Sources				**501.3**	**36,590**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.23E+03	g	4.5E+09	0.1	4
15	Limestone	1.23E+03	g	1.0E+09	0.0	1
	Total of Non-Renewable Sources				**0.1**	**5**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

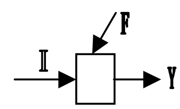
16	Tanks, Piers and other Assets	1.74E+09	g	6.70E+09	116,692	8,517,640
17	Gasahol (for Generators)	6.26E+13	J	6.30E+04	39,412	2,876,791
18	Roadway Contribution				843	61,505
19	Port Services (Tugboats)				266,829	19,476,583
20	Goods and Services	8.43E+06	$	2.36E+12	198,569	14,494,074
21	Construction Services	1.45E+06	$	5.70E+12	82,390	6,013,855
22	Central Govt Services (Profit Tax)	2.25E+05	$	5.36E+12	12,036	878,572
23	Island Govt Services (Ground Rent)	1.80E+04	$	4.72E+12	851	62,117
25	Labor Contribution				25,530	1,863,475
	Total Imports and Outside Sources				**743,151**	**54,244,612**
Total Emergy Inflows					**756,400**	**55,211,679**

OUTPUT AND TRANSFORMITIES:

26	Emergy Transhipping One Barrel				0.013	0.95
27	Bopec Services ($)	1.97E+07	$	4.72E+12	928,747	67,791,770
28	Emergy Attracted per Laborer				4,322	315,495
29	Emergy Attracted per Unit				756,400	55,211,679
30	Bopec Services	1.97E+07	$	3.85E+12	756,400	55,211,679

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local ivironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	152
Yield Ratio = Y/F	Y/(M + S)	1.02
Service/Free	S/(N + R)	144
Service/Resource	S/(R + N + M)	16
Nonrenewable/Renewable	(N + M)/R	9
Developed/Environmental	(N + M + S)/R	171
Empower Density	sej/ha/yr	7.08E+09

NOTES

Data comes from an interview with a terminal manager, from estimates, or from citations as shown.

Land Area, 106,900 m^2; Shelf Area, 100,000 m^2 (100 m x 1,000 m coastline)

Fraction of Total = 0.0004986

NUMBERED FOOTNOTES

Footnotes for Items 1-12, 14-15 see Natural Systems analysis (APPENDIX D).

SLOW-RENEWABLE ISLAND SOURCES:

13) Coral Reef: Total reef lost estimated due to piers and shipping, 1,000 MT; Years of reef consumption, 20 yrs;

Loss per year = (1,000 MT)(1E6 g/MT)/(20 yrs) = 5.00E7 g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Tanks, Piers and other Assets:
Tanks: Pits A, B, C, Processing Unit, and Unity Pit (23 Tanks); Mass of Tanks, Piping, etc., 100,000 MT (est. total mass); 30yrs (Yrs dep, est)

Tanks mass (g) = (50,000 MT)*(1E6 g/MT)/(30 Yrs. dep) = 1.67E+09 g/yr

Piers: Cement and Steel Piers (2); Piers (1) = 500 MT (each, est.); 40yrs (Yrs dep, est)

Piers mass (g) = (500 MT)*(1E6 g/MT)/(40 Yrs. dep) = 2.50E+07g/yr

Miscellaneous Others: Misc. Equipment, 500 MT (est.); 10yrs (Yrs dep, est)

Misc. mass (g) = (500 MT)*(1E6 g/MT)/(10 Yrs. dep) = 5.00E+07g/yr

Total Tanks and other Assets = 1.74E+09g/yr
Use transformity of machines, 6.7E9.

17) Gasahol (for Generators): 800 barrels/month

Fuel (J) = (800 barrels/month)(158.94 l/barrel)(12 months/yr)(41E6 J/l) = 6.26E+13 J/yr

18) Roadway Contribution: Estimate that 1% of all road traffic on Bonaire by tonnage is moving goods to transhippment terminal; per year Emergy from Roadways, 84,261 sej/yr (see Roadway analysis (APPENDIX J)); Est. 1% for Goods Transp. = 843 sej/yr

19) Port Services (Tugboats): Tankers into Bopec Port, 200 ships/yr; Tanker into Bopec Port (1), 1,334 E14 sej/ship (see Port analysis (APPENDIX L))

Total emergy = (200 ships/yr)(1,334 E14 sej/ship) = 266,860 E14 sej/yr

20) Goods and Services: Total expenses estimated, 15,000,000 NAF/yr

Total Expenses per Year = (15,000,000 NAf/yr)/(1.79 NAf/$) = 8,426,966 $/yr

21) Construction Services: Construction costs (1974), 102,915,000 NAf; Depreciation, 40 yrs turnover time; Emergy/$ Ratio from 1974 US, 5.70E+12sej/$ ((Odum 1996a):314)

Total Expenses per Year = (102,915,000 NAf)/(1.79 NAf/$)/(40 yrs) = 1,445,435 $/yr

22) Central Govt Services (equivalent to services in estimated taxes):

Land Tax (0%) = - NAF/yr (tax holiday)
Profit Tax (2%) = 400,000 NAF/yr, if profit is 20,000,000 NAf/yr, (paid to Central Govt)
Taxes($) = (400,000 NAf/yr)/(1.79 NAf/$) = 224,719 $/yr

23) Island Govt Services (Ground Rent, equivalent to services in estimated taxes)

Erfpacht (Ground Rent) = (0.30 NAf/m^2)(106,900 m^2)/(1.79 NAf/$) = 18,017 $/yr

24) Parent Company Contribution (PDVSA) (did not use this, for information only):
"Petroleos de Venezuela S.A. (PDVSA) is the leading exporter of oil to the US. The government-owned company boasts proved reserves of 72 billion barrels of oil--the most outside the Middle East--and 143 trillion cu.ft. of natural gas. Although PDVSA's exploration and production take place in Venezuela the company has refining and marketing operations in the Caribbean, Europe, and the US, as well as at home. Subsidiary CITGO Petroleum operates more than 15,000 gas stations in the US." (Hoover's Online).

Bonaire has no local owners of PDVSA. However, the fact of the foreign ownership by a transnational oil giant contributes vast expertise and assets. Total Assets, 48 billion dollars, 1998, Hoover's Online; total Employees, 50,821 people, 1998

25) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis (APPENDIX F)); Full-time Laborers, 90 persons, Contractors, 85, 260 wrk days/yr, 8 hrs/day
(175 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 25,530 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

26) Emergy Transhipping One Barrel: 1994 had 315 tankers, with 159,000 barrels/day throughput
Emergy per barrel = (756,431 sej/yr)/((159,000 barrels/day)(365 days/yr)) = 1.3 E12 sej/barrel transhipped

27) Services Income (?): Total income and profit values are unknown. If Yearly Expenses are 15,000,000 NAf/yr, profit might be 10,000,000 NAF/yr; Total Income would have to be 25,000,000 NAf/yr = $14,044,944

28) Emergy Attracted per Laborer: Total Emergy Inflows = 756,431 E14 sej/yr; Total Laborers = 175

Emergy per Laborer = (756,431 E14 sej/yr)/(175 Laborers) = 4,322 sej/yr/laborer

29) Emergy Attracted per Unit: Total Emergy Inflows = 756,431 E14 sej/yr; Total Units = 1

Emergy per Unit = (756,431 E14 sej/yr)/(1 Company) = 756,431 E14 sej/yr/unit

30) Services Income (emergy/$) = (756,431 E14 sej/yr) / (1.97E7 $/yr) = 3.85 E12 sej/$

APPENDIX Q
SALT WORKS EMERGY ANALYSIS

EMERGY Flows of Salt Works

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	2.10E+17	J	1	2,103.7	153,556
2	Rain, Chemical Potential Energy	8.84E+13	J	15,444	13,646.4	996,091
3	Rain, Geopotential Energy	4.08E+11	J	8,888	36.3	2,646
4	Wind, Kinetic Energy	1.65E+15	J	584	9,631.2	703,005
5	Wave Energy	3.68E+13	J	25,889	9,523.3	695,129
6	Tidal Energy	6.91E+12	J	49,000	3,387.1	247,230
7	Currents Energy	2.16E+12	J	1.0E+05	2,164.3	157,976
8	Earth Contribution	4.38E+08	g	1.0E+09	4,378.6	319,605
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**23,576**	**1,720,902**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	4.62E+13	J	51,078	(23,576.4)	(1,720,902)
10	Mondi Animals	1.03E+12	J	2,056,417	(21,218.7)	(1,548,812)
	Total of Renewable Production				**(44,795.1)**	**(3,269,715)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.80E+13	J	63,000	11,364	829,499
12	Groundwater and Dams	3.38E+11	J	617,760	2,085.1	152,195
13	Coral Reef	2.81E+03	g	1.0E+09	0.0	2
	Total of Slow-Renewable Sources				**13,449**	**981,696**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	6.55E+05	g	4.5E+09	29.5	2,152
15	Limestone	2.00E+09	g	1.0E+09	20,000	1,459,854
	Total of Non-Renewable Sources				**20,029**	**1,462,006**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

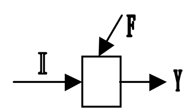
16	Loaders, Trucks, Wash Plant, etc.	1.26E+08	g	6.70E+09	8,431	615,389
17	Diesel and Gasoline	7.12E+12	J	6.30E+04	4,483	327,252
18	Electricity	3.60E+12	J	2.73E+05	9,814	716,345
19	Potable Water (for Cleaning)	1.82E+10	J	1.39E+06	254	18,504
20	Goods and Services	1.00E+06	$	2.36E+12	23,564	1,719,964
21	Construction Services	2.81E+05	$	1.03E+13	28,933	2,111,867
22	Government Services	2.32E+05	$	4.72E+12	10,937	798,304
23	Port Services				30,498	2,226,154
24	Labor Contribution				8,753	638,906
	Total Imports and Outside Sources				**125,666**	**9,172,685**
Total Emergy Inflows					**182,721**	**13,337,290**

OUTPUT AND TRANSFORMITIES:

25	Salt	4.00E+11	g	4.57E+09	182,721	13,337,290
26	Salt Works Services ($)	8.43E+06	$	4.72E+12	398,035	29,053,616
27	Emergy Attracted per Laborer				3,045	222,288
28	Emergy Attracted per Unit				182,721	13,337,290
29	Salt Works Services	8.43E+06	$	2.17E+12	182,721	13,337,290
Total Emergy Outflows					**580,755**	**42,390,905**

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	2.2
Yield Ratio = Y/F	Y/(M + S)	1.45
Service/Free	S/(N + R)	2.1
Service/Resource	S/(R + N + M)	2.0
Nonrenewable/Renewable	(N + M)/R	1.6
Developed/Environmental	(N + M + S)/R	7
Empower Density	sej/ha/yr	6.41E+06

NOTES

Data comes from an interview with an airport manager, from estimates, or from citations as shown.

Shoreline = 500m (length of coastline, est.)
Cont Shlf Area = 6.40E+06m^2 (estimate 5% of shelf)
Land Area = 2.85E+07m^2 (total land area)

Fraction of Total = 0.080230
Land Area Fraction = 0.0655172

NUMBERED FOOTNOTES

Footnotes for Items 1-10, 12-14 see Natural Systems analysis (**APPENDIX D**).

SLOW-RENEWABLE ISLAND SOURCES:

11) Top Soil: Shallow topsoil was removed or piled with limestone into dykes. Land surface area, 2.85E+07m^2; Depth = 3 cm, est.; Topsoil total, 8.55E+05m^3; Mass, 1 MT/m^3, est; depreciation of dykes, 50 yrs, est.

Topsoil mass = (2.85 E7 m^2)(.03 m)(1 MT/m^3) = 8.55E+05 MT

Energy (J) = (8.55 E5 MT)(1 E6 g/MT)(0.07 g OM/g sed)(3.6 kcal/g)(4186 J/kcal) = 9.02E+14 J

Topsoil loss = 9.02 E14 J/ 50 yrs = 1.80E+13 J/yr

NON-RENEWABLE ISLAND SOURCES:

15) Limestone

Dykes are the largest component of the salt works infrastructure. 100 km of dykes, made from earth; Dykes, 100,000 m^3 (100 km by 1 m^2, est); 1.0 MT/m^3, est.; Depreciation, 50 yrs, est.

Total mass limestone in dykes / yr = (100,000 m^3)(1 MT/m^3)(1E6 g/MT) / (50 yrs) = 2.00E+09g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Loaders, Trucks, Wash Plant, etc.:

Harvesting Equipment: Bulldozers (4), 80 MT (est. 20 MT each); Frontend Loaders (6), 120 MT (est. 20 MT each); Large Trucks (5), 100 MT (est. 20 MT each); Graders (2), 40 MT (est. 20 MT each); Total Large Harvest Equip, 340 MT; 5 yrs (Years of depreciation)

Total = 6.80E+07g/yr

Small Equipment: Backhoes (2), 10 MT (est. 5 MT each); Forklifts (2), 10 MT (est. 5 MT each); Pickups (13), 26 MT (est. 2 MT each); Total Small Equip, 46 MT; 3 yrs (Years of depreciation)

Total = 1.53E+07g/yr

Other Equipment: Wash Plant 100 MT est.; Conveyer Belt 500 MT est.; Total Other, 600 MT; 20 yrs (Years of depreciation)

Total = 3.00E+07g/yr

Pier: Cement and Steel Pier, 500 MT est.; 40 yrs (Years of depreciation)

Total = 1.25E+07g/yr

All Equipment = 1.26E+08g/yr

17) Diesel and Gasoline; Diesel Fuel, 45,000 NAf/yr (at 0.35 NAf/liter); 128,571 liters/yr Gasoline, 45,000 NAf/yr (at 1 NAf/liter); 45,000 liters/yr; 173,571 l/yr

Diesel and Gasoline = (128,571l/yr + 173,571 l/yr)*((41E6 J/l) = 7.12E+12J/yr

18) Electricity; 1,000,000 kwh/yr

Energy (J) = (1,000,000 kwh/yr)*(860 Cal/kwh)*(4186 J/Cal) = 3.60E+12J/yr

19) Potable Water (for Cleaning): Water, 4,000 NAf/month (13 NAf/m^3); 3,692 m^3/yr

Energy (J) = (3,692 m^3/yr)*(1000g/m^3)*(4.94E3 J/g) = 1.82E+10J/yr

20) Goods and Services: Frontend Loader (1), 500,000 $; Total Equipment, est., 5,000,000 $; Depreciation, 5 yrs, est. average;

Yearly Equipment and parts = 1,000,000 $/yr

21) Construction Services: Construction Costs (estimate), 20,000,000 NAF (Pier, Salt floor, dykes); Depriciation, 40 yrs turnover time;

Construction costs = 280,899 $/yr

Emergy/$ Ratio from 1964 US = 1.03E+13sej/$ 1964 (Odum 1996:314)

22) Government Services: Erfpacht (0.007 NAf/m^2) 199,500 NAF/yr; Land Tax (0%) NAF/yr (tax holiday); Profit Tax (2%?), 16,854 NAF/yr; Equipment Duty (5% + 6% emergency), 110,000 $/yr

Taxes($) = 231,547 $/yr

23) Port Services; Tankers into Bopec Port 100 ships/yr; Tanker into Bopec Port (1), 305 E14 sej/ship

Total = 30,498 E14 sej/yr

24) Labor Contribution: Employees, 60 persons (50 and 55); Emergy of 100 Persons for 1 Year, 61,439 E14 sej; 260 Eight hour work days/yr

Emergy/yr = (60 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 8,753 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

25) Salt: Mass salt exported, 400,000 MT/yr

Mass (g) = 4.00E+11g/yr

26) Salt Works Services ($): Saltworks Income, 15,000,000 NAf/yr, approx.

Total Income for both = 8,426,966 $/yr

Est. Profit (10%) = 842,697 $

27) Emergy Attracted per Laborer: Total Emergy Inflows = 182,721 sej/yr; Total Laborers = 60

Emergy per Laborer = (182,721 sej/yr)/(60 Laborers) = 3,045 sej/yr/laborer

28) Emergy Attracted per Unit: Total Emergy Inflows = 182,721 sej/yr; Total Units = 1

Emergy per Unit = (182,721 sej/yr)/(1 Company) = 182,721 sej/yr/unit

APPENDIX R
RADIO RELAY STATIONS EMERGY ANALYSIS

EMERGY Flows of Radio Relay Stations

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	1.29E+16	J	1	128.7	9,397
2	Rain, Chemical Potential Energy	5.41E+12	J	15,444	835.1	60,955
3	Rain, Geopotential Energy	2.50E+10	J	8,888	2.2	162
4	Wind, Kinetic Energy	1.01E+14	J	584	589.4	43,020
5	Wave Energy	2.25E+12	J	25,889	582.8	42,538
6	Tidal Energy	4.23E+11	J	49,000	207.3	15,129
7	Currents Energy	1.32E+11	J	1.0E+05	132.4	9,667
8	Earth Contribution	2.68E+07	g	1.0E+09	267.9	19,558
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**1,443**	**105,309**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	2.82E+12	J	51,078	1,442.7	105,309
10	Mondi Animals	6.31E+10	J	2,056,417	1,298.5	94,778
	Total of Renewable Production				**2,741.2**	**200,086**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	2.53E+10	J	63,000	15.9	1,163
12	Groundwater and Dams	1.58E+09	J	617,760	9.7	711
13	Coral Reef	4.91E+04	g	1.0E+09	0.5	36
	Total of Slow-Renewable Sources				**26.2**	**1,910**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	2.45E+04	g	4.5E+09	1.1	81
15	Limestone	2.45E+04	g	1.0E+09	0.2	18
	Total of Non-Renewable Sources				**1.4**	**99**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

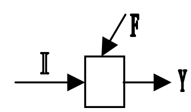
16	Antennas, Generators, Transmitters	6.75E+07	g	6.70E+09	4,525	330,273
17	Gas Oil (for Generators)	1.05E+14	J	6.30E+04	65,996	4,817,201
18	Goods and Services	2.81E+05	$	2.36E+12	6,619	483,136
19	Construction Services	1.40E+05	$	1.03E+13	14,466	1,055,934
20	Government Services	1.98E+04	$	4.72E+12	936	68,338
21	Labor Contribution				15,318	1,118,085
	Total Imports and Outside Sources				**107,860**	**7,872,965**
Total Emergy Inflows					**112,071**	**8,180,369**

OUTPUT AND TRANSFORMITIES:

22	Transmitted Signal	1.73E+13	J	6.46E+07	112,071	8,180,369
23	Radio Services ($)	6.91E+06	$	4.72E+12	326,435	23,827,408
24	Emergy Attracted per Laborer				1,067	77,908
25	Emergy Attracted per Unit				56,036	4,090,184
26	Radio Services	6.91E+06	$	1.62E+12	112,071	8,180,369
Total Emergy Outflows					**438,507**	**32,007,777**

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	73
Yield Ratio = Y/F	Y/(M + S)	1.04
Service/Free	S/(N + R)	28
Service/Resource	S/(R + N + M)	1
Nonrenewable/Renewable	(N + M)/R	46
Developed/Environmental	(N + M + S)/R	77
Empower Density	sej/ha/yr	5.25E+07

NOTES

Data comes from (RN 1994) and (TWR 1998), from estimates, or from citations as shown.

Land area is large terrain for antennas. One is located in the area of plantation Colombia, the other is located just north of the salt works: Land Area, 2,135,000 m^2

Fraction of Total = 0.0051462

NUMBERED FOOTNOTES

Footnotes for Items 1-15 see Natural Systems analysis (APPENDIX D).

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Antennas, Generators, Transmitters: Antennas (14 & 5), 1,900 MT (est., 10 MT/antenna) 30 yrs; Transmitters (2), 2 MT (est., 250 kW ABB, and 500 kW medium wave); Dsl Generators, 35 MT (est., 5 & 2 Diesel generators, 5 MT each); Misc equip, 5 MT (est.)

Antennas (g) = ((10 MT/antenna)(19 antennas)+(2 MT/transmitter)(2 transmitters)+(35 MT generators)+(5 MT misc))/(30 yrs) = 6.75E+07g/yr

17) Gas Oil (for Generators): 7,000 l/day (5000 & 2000)
Fuel (J) = (7,000 l/day)(365 days/yr)(41E6 J/l) = 1.05E+14J/yr

18) Goods and Services: 500,000 NAF/yr, est. total expenses
Total Expenses per Year = (500,000 NAf/yr)/(1.79 NAf/$) = 280,899 $/yr

19) Construction Services: 10,000,000 NAF (Two stations, est. 1960s construction costs); Depreciation, 40 yrs turnover time
Construction costs = (10,000,000 NAf)/(40 yrs)/(1.79 NAf/yr) = 140,449 $/yr
Emergy/$ Ratio from 1964 US = 1.03E+13sej/$ 1974 ((Odum 1996a):314)

20) Central Govt Services (equivalent to services in estimated taxes):
Erfpacht = (0.005 NAF/m^2)(2,135,666 m^2) = 10,678 NAF/yr
Land Tax (0%) = - NAF/yr (tax holiday)
Profit Tax (2%) = 13,822 $/yr, if profit is 691,111 $/yr (guess), (paid to Central Govt)
Total Taxes($) = (10,678 NAf/yr)/(1.79 NAf/$) + 13,822 $/yr = 19,821 $/yr

Parent Company Contributions (for information only
Two large antenna farms and transmitters on Bonaire, short wave and medium wave transmission.
Radio Nederlands Wereldomroep - Relay station for the Dutch International Radio Service. Radio Nederlands has a short wave transmitter in Flevoland, the Netherlands, and two relay transmitters, one on Bonaire (1964) and one on Madagascar (1972). The main targets for Bonaire's site are the Americas, West Africa, Australia and New Zealand. Radio Nederlands receives around 7% of the total Dutch state funding for public broadcasting.
TransWorld Radio (TWR) - a non-profit, non-denominational missionary organization broadcasting from nine worldwide locations: Albania, Bonaire, Cyprus, Guam, Monaco, Russia, Sri Lanka, Swaziland, and Uruguay. TWR has some 40 transmitters from 13 primary sites, and an international staff of over 1,000 people.

21) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 105 persons (50 and 55) full time, 260 wrk days/yr, 8 hrs/day
(105 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 15,318 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

22) Transmitted Signal: Transmitted Signal, 0.55 MW
Signal (J) = (0.55 MW)(8760 hr/yr)(1000 kWh/MWh)(860 Cal/kwh)*(4186 J/Cal) = 1.73E+13J/yr

23) Services Income (?): TWR total income (1997, 1998), 31,100,000 $ ((TWR 1998))
Sites world wide, 9 sites; Income per site, 3,455,556 $;Radio Nederland, 3,455,556 $, estimate same (or more); If Radio Nederlands generates the same income, total income for both, 6,911,111 $, est.

24) Emergy Attracted per Laborer: Total Emergy Inflows = 112,071 E14 sej/yr; Total Laborers = 105

Emergy per Laborer = (112,071 E14 sej/yr)/(105 Laborers) = 1,067 E14 sej/yr/laborer

25) Emergy Attracted per Unit: Total Emergy Inflows = 112,071 E14 sej/yr; Total Units = 2
Emergy per Unit = (112,071 E14 sej/yr)/(2 Company) = 56,036 E14 sej/yr/unit

26) Radio Services (emergy/$) = (438,507 E14 sej/yr) / (6.91 E6 $/yr) = 1.62 E12 sej/$

APPENDIX S
TOURISM INDUSTRY SYSTEM EMERGY ANALYSIS

EMERGY Flows of Tourism Industry

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	4.55E+17	J	1	4,551	332,191
2	Rain, Chemical Potential Energy	1.91E+14	J	15,444	29,522	2,154,868
3	Rain, Geopotential Energy	8.82E+11	J	8,888	78	5,724
4	Wind, Kinetic Energy	3.57E+15	J	584	20,835	1,520,828
5	Wave Energy	7.96E+13	J	25,889	20,602	1,503,790
6	Tidal Energy	1.50E+13	J	49,000	7,327	534,839
7	Currents Energy	4.68E+12	J	1.0E+05	4,682	341,754
8	Earth Contribution	9.47E+08	g	1.0E+09	9,472	691,409
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**51,003**	**3,722,869**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Plants	9.99E+13	J	51,078	(51,003)	(3,722,869)
10	Animals	2.23E+12	J	2,056,417	(45,903)	(3,350,582)
	Total of Renewable Production				**(96,906)**	**(7,073,452)**
RENEWABLE IMPORTED SOURCES:						
11	Fish, Goats, Eggs	2.14E+11	J	3.65E+07	78,005	5,693,775
	Total of Renewable Imported Sources				**78,005**	**5,693,775**
SLOW-RENEWABLE ISLAND SOURCES:						
12	Top Soil	1.78E+10	J	63,000	11	817
13	Groundwater and Dams	1.11E+09	J	617,760	7	499
14	Coral Reef	2.50E+08	g	1.0E+09	2,500	182,482
	Total of Slow-Renewable Sources				**2,518**	**183,798**
NON-RENEWABLE ISLAND SOURCES:						
15	Volcanic Rock	1.72E+04	g	4.50E+09	1	57
16	Limestone	1.72E+04	g	1.00E+09	0	13
	Total of Non-Renewable Sources				**1**	**69**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

17	Construction System				23,107	1,686,675
18	Electricity	2.81E+13	J	2.73E+05	76,549	5,587,549
19	Propane Gas	5.05E+11	J	4.80E+04	242	17,698
20	Fuel (Gasoline)	4.95E+13	J	6.30E+04	31,177	2,275,680
21	Potable Water	1.21E+12	J	1.39E+06	16,865	1,230,996
22	Dive & Hotel Equipment	6.70E+06	g	6.70E+09	449	32,766
23	Food	3.12E+12	J	2.50E+05	7,794	568,891
24	Beverages	1.53E+11	J	6.00E+04	92	6,700
25	Rental Cars	5.33E+07	g	6.70E+09	3,573	260,827
26	Retail System				99,906	7,292,382
27	Roadway System				16,852	1,230,094
28	Travel System				293,448	21,419,543
29	Loans	4.87E+05	$	2.36E+12	11,473	837,435
30	Govt Services (Taxes)	2.31E+05	$	4.72E+12	10,916	796,813
31	Services (Expenses)	5.90E+06	$	2.36E+12	138,998	10,145,852
32	Labor Contribution				102,118	7,453,899
	Total Imports and Outside Sources				**833,560**	**60,843,799**

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

33	Owner Households				50,133	3,659,328
	Total Non-Renewable Production within Subsystem				**50,133**	**3,659,328**

Total Emergy Inflows					**1,015,220**	

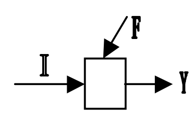
OUTPUT AND TRANSFORMITIES:

34	Emergy Inflow per Room per Week				23.0	1,677
35	Emergy Inflow per Person Night				2.7	198
36	Tourism Services ($)	37,247,191	$	4.72E+12	1,759,313	128,416,981
37	Emergy Attracted per Laborer				1,450	105,862
38	Emergy Attracted per Hotel				33,841	2,470,121
39	Tourism Services	37,247,191	$	2.73E+12	1,015,220	74,103,638

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
G Manufactured *goods* brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + G + S)/(N + R)	20
Yield Ratio = Y/F	Y/(M + G + S)	1.22
Service/Free	(G + S)/(N + R)	7
Service/Resource	(G + S)/(N + R + M)	12
Nonrenewable/Renewable	(N + M)/R	0
Developed/Environmental	(N + M + G + S)/R	8

NOTES
Data comes from interviews with five hotels (managers, chefs, and others), from estimates, or from citations as shown.

Estimate that 50% of the continental shelf production is captured by tourism. Arguably the marine park exists because if its value to the tourism industry. The remaining production from the shelf I have divided between households (30%) and government/industry (20%). Land area is hotels and restaurants: Land Area, 150 ha, (1,500,000 m^2); Shelf area is 6,400 ha (64,000,000 m^2).

Fraction of Total island production = 0.1578313
Land Fraction of Total = 0.0036145

NUMBERED FOOTNOTES

Footnotes for Items 1-10 and 12-16 see Natural Systems analysis (APPENDIX D).

RENEWABLE IMPORTED SOURCES

11) Fish, Goats, Eggs: Total Fish Energy; 5.30E+11 J/yr (island catch, see Coastal Systems (**APPENDIX D2**)); Hotels/Restaurants Fish, 1.06E+11 J/yr (est. 20% of total catch, higher?); Total Sheep/Goat Energy, 1.35E+12 J/yr (see Natural Systems (APPENDIX D)); Hotels/Restaurants Sheep and Goats, 1.35E+10 J/yr (est 1%, higher?); Eggs, 20,000 kg/yr (est. 550 eggs/day); Hotels/Restaurants use of eggs, (20,000 kg)(1000 g/kg)(25% dry weight)(4500 cal/g)(4.186 J/cal) = 9.42E+10 J/yr

Total Energy = 1.06E11 J/yr (fish) + 1.35E10 J/y (goats) + 9.42E10 J/yr (eggs) = 2.14E+11J/yr

17) Construction System: Large Hotel Construction (1), at 231,074 E14 sej, per Construction analysis (**APPENDIX H**); Large Hotels (5), which is 1,155,372 E14 sej; Medium Hotels (10 @ 60%), which is (231,074 E14 sej)(10 hotels)(60%) = 1,386,447 E14 sej; Small Hotels (15 @ 10%), which is (231,074 E14 sej)(15 hotels)(10%) = 346,612 E14 sej; Other Tourist Restaurants (5 @ 5%), which is (231,074 E14 sej)(5 tourist restaurants)(5%) = 57,769 E14 sej; Hotel/restaurant depreciation, 50 yrs

Total emergy from construction (sej) = (2,946,199 E14 sej)/(50 yrs) = 23,107 E14 sej/yr

This is 3% of Construction Industry output, which might seem a little low, but not considering the long house building boom, and when compared to Curacao's percent of construction GDP linked to tourism, 1% ((CTO 1992):19)

18) Electricity: Large Hotels (5), at 800,000 kWh each, which is 4,000,000 kwh/yr; Medium Hotels (10), at 300,000 kWh each, which is 3,000,000 kwh/yr; Small Hotels (15) at 40,000 kWh each, which is 600,000 kwh/yr; Other Tourist Restaurants (5), at 40,000 kWh each, which is 200,000 kWh

Total = 4,000,000 kwh/yr + 3,000,000 kWh/yr + 600,000 kWh/yr + 200,000 kWh = 7,800,000 kWh/yr

Energy (J) = (7,800,000 kwh)*(3.6E6 J/kwh) = 2.81E+13 J/yr
This is 17% of WEB output (low?); Compare to Curacao percent of public utilities GDP linked to tourism, which is 5% ((CTO 1992):19)

19) Propane Gas: Large Hotels (5), 1,000 bot each, which is 5,000 bottles/yr; Medium Hotels (10), 300 bottles each, which is 3,000 bottles/yr; Small Hotels (15), 20 bottles each, which is 300 bottles/yr; Other Tourist Restaurants (5) 300 bottles each, which is 1,500 bottles/yr; 1,325 liters propane/big bottle

Total = 5,000 bottles/yr + 3,000 bottles/yr + 300 bottles/yr + 1,500 bottles/yr = 9,800 bottles/yr, estimate

Energy (J) = (9,800 bottles/yr)(1,325 liters/bottle)/(1000 liters/m^3)(3.89E7 J/m^3) = 5.05E+11J/yr

20) Fuel (Gasoline): Dive Boats: Large Hotels (5), at 30,000 l/yr each, which is 150,000 l/yr; Medium Hotels (10), at 15,000 l/yr, which is 150,000 l/yr; Small Hotels (15), at 5,000 l/yr, which is 75,000 l/yr

Boat Total = 150,000 l/yr + 150,000 l/yr + 75,000 l/yr = 375,000 l/yr

Rental Cars: Estimate 40 l/engine/week; Estimate 400 rental cars/week

Car Total = (40 l/engine/week)(400 cars/week)(52 weeks/yr) = 832,000 l/yr

Total = 375,000 l/yr (boats) + 832,000 l/yr (cars) = 1,207,000 l, estimate

Energy (J) = (1,207,000 l/yr)(41E6J/l) = 4.95E+13 J/yr

21) Potable Water: Large Hotels (5), at 25,000 m^3, which is 125,000 m^3; Medium Hotels (10), at 10,000 m^3, which is 100,000 m^3; Small Hotels (15), at 1,000 m^3, which is 15,000 m^3; Other Tourist Restaurants (5), at 1,000 m^3, which is 5,000 m^3

Total = 125,000 m^3 + 100,000 m^3 + 15,000 m^3 + 5,000 m^3 = 245,000 m^3

Energy (J) = (245,000 m^3/yr)(1E6g/m^3)(4.94E3 J/g) = 1.21E+12 J/yr

This is 32%of WEB output. Compare to Curacao percent of utilities GDP linked to tourism = 5% ((CTO 1992):19)

22) Dive & Hotel Equipment: Large Hotels (5) at 5,000 kg each, which is 25,000 kg; Medium Hotels (10), at 3,000 kg each, which is 30,000 kg; Small Hotels (15), at 800 kg each, which is 12,000 kg; 10 yrs (Years of depreciation)

Total = 25,000 kg + 30,000 kg + 800 kg = 67,000 kg

All Equipment (g) = (67,000 kg)(1000g/kg)/(10 Yrs. dep) = 6.70E+06 g/yr

23) Food: Large Hotels (5) at 100,000 kg each, which is 500,000 kg; Medium Hotels (10) at 5,000 kg each, which is 50,000 kg; Small Hotels (15) at 800 kg each, which is 12,000 kg; Other Tourist Restaurants (5), at 20,000 kg each, which is 100,000 kg

Total = 500,000 kg + 50,000 kg + 12,000 kg + 100,000 kg = 662,000 kg

Energy (J) = (662,000 kg/yr)(1000 g/kg)(25% dry weight)(4500 cal/g)(4.186 J/cal) = 3.12E+12 J/yr

24) Beverages: Large Hotels (5), at 10,000 l/yr, which is 50,000 l/yr; Medium Hotels (10), at 1,000 l/yr, which is 10,000 l/yr; Small Hotels (15) at 500 l/yr, which is 7,500 l/yr; Other Tourist Restaurants (5), at 1,000 l/yr, which is 5,000 l/yr

Total = 50,000 l/yr + 10,000 l/yr + 7,500 l/yr + 5,000 l/yr = 72,500 l/yr

Energy (J) = (72,500 l/yr)(2.11E7 J/l)(10% alcohol) = 1.53E+11 J/yr

25) Rental Cars: Rental Cars (400), at 2 MT each, which is 800MT (estimate); 15yrs (Yrs of dep)

Total Wt. (g) = (800 MT)(1E6 g/MT)/(15 Yrs. dep) = 5.33E+07g/yr

26) Retail System: Retail Total Emergy is 666,028 E14 sej/yr (see Retail system (**APPENDIX O**)); Estimate that Toursim captures 15% of total retail production

Retail emergy (sej) = (666,028 E14 sej/yr)(15%) = 99,904 E14 sej/yr

Compare to Curacao percent of wholesale/retail GDP linked to tourism = 15% (CTO 1992)

27) Roadway System: Roadway Total Emergy is 84,261 E14 sej/yr (see Roadway system (**APPENDIX J**)); Estimate that Tourism captures 20% of total roadways

Roadway emergy (sej) = (84,261 E14 sej/yr)(15%) = 16,852 E14 sej/yr

Compare to Curacao percent of transport, storage, and communication GDP linked to tourism = 17% (CTO 1992)

28) Travel System: Travel Total Services emergy is 733,618 E14 sej/yr, per Airport Subsystem (**APPENDIX T**); Estimate that Toursim captures 40% of total service

Travel emergy (sej) = (733,618 E14 sej/yr)(40%) = 293,447 E14 sej/yr

29) Loans: Estimate loans of Large Hotels (5) are 1,000,000 NAF each, which is 5,000,000 NAF; Medium Hotels (10) are 400,000 NAF each, which is 4,000,000 NAF; Small Hotels (15) are 100,000 each, which is NAF 1,500,000 NAF; Other Tourist Restaurants (5) are 100,000 NAF each, which is 500,000 NAF; Car Rental Agencies (5) are 500,000 NAF each, which is 2,500,000 NAF; 30 yr loans; 5 yr auto loans

Loans = 5,000,000 NAf + 4,000,000 NAf + 1,500,000 NAf + 500,000 NAf + 2,500,000 NAf = 13,500,000 NAf, mortgage for hotel (principal and interest, est.)

Loans($) = (13,500,000 NAf)/(1.79 NAf/$) = 486,891 $/yr, Financed off the island

Compare to Curacao percent of Finance GDP linked to tourism = 8.5% ((CTO 1992):19)

30) Govt Services (Taxes):

Land Tax = (1,500,000 m^2)(0.15 NAf/m^2, est.) = 225,000 NAF

Profit Tax = (3,724,719 NAf)(5%) = 186,236 NAF (tax holidays for big hotels, normal profit tax is 37%-45%, 1992)

Taxes ($) = (225,000 NAf + 185,460 NAf)/(1.79 NAf/$) = 231,115 $/yr

Compare to Curacao percent of GDP linked to tourism = 5.5% (CTO 1990:19) (Other services incl. Gov't)

31) Services (Expenses): Estimate of expenses for Large Hotels (5) at 1,000,000 NAF each, which is 5,000,000 NAF; Medium Hotels (10) at 400,000 each, which is NAF 4,000,000 NAF; Small Hotels (15) at 100,000 NAF each, which is 1,500,000 NAF

Total expenses = 5,000,000 NAf + 4,000,000 NAf + 1,500,000 NAf = 10,500,000 NAF, estimate of which 1,207,000 NAf/yr is fuel costs

Total Service Costs = (10,500,000 NAF)/(1.79 NAf/$) = 5,898,876 $/yr

Foreign Tourism Operators

Tour operators can wield a great deal of influence over destinations. Operators have the ability to direct large numbers of tourists to particular destinations (Mill and Morrison 1985:239). "Overwhelmingly, transnationals have their home offices in developed countries. Approximately 80 percent of the hotels abroad are accounted for by companies headquartered in the US, France, and the UK. Most problems for the destination countries have resulted when the transnational corporations have had no financial investment in the hotels. Most overseas properties are operated without any foreign equity involvement, which is a trend that is increasing. Control is exercised through management contracts, or to a far lesser extent, through franchise agreements" (Mill and Morrison 1985:237).

32) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 700 persons (Hotels, Tourist Restaurants, Car Rentals), 260 wrk days/yr, 8 hrs/day

Labor emergy = (700 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 102,118 E14 sej

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

33) Owner Households: Foreign Owned, approx. 50-75% of Bonaire hotels

Another concern among host countries has been that a foreign-owned hotel allows limited opportunity for local employees to reach positions of responsibility. International hotel chains usually have a core expatriate management team of three in a 100-room hotel, five in a 250-room hotel, and eight in a 350-room hotel. Some management contracts will stipulate that within, say, three to five years the management team must be made up of locals (Mill and Morrison 1985:238).

Owner Households on Bonaire = Estimate 1/3 smaller hotels owned locally; 10 of 30 hotels, 10 Households

8 Owners at 4,106 E14 sej/Household (est. affluent 2)

2 Owners at 8,644 E14 sej/Household (est. affluent 1)

Owner household emergy = (4,106 E14 sej/household)(8 households) + (8,644 E14 sej/household)(2 households) = 50,133 E14 sej/Households of Owners

OUTPUT AND TRANSFORMITIES:

34) Emergy Inflow per Room per Week: Rooms available, 850 approximately;Total emergy is 1,015,175 E14 sej/yr
Emergy inflow per room = (1,015,175 E14 sej/yr)/(850 rooms) = 23 E14 sej/yr per room

35) Emergy Inflow per Person Night: Total Emergy Inflows, 879,486 sej/yr
Tourist Arrivals
Stay-over Tourists (1995) = 59,410 persons (Central-Bank 1997)
Cruise Toursts (1995) = 11,000 persons (EIU 1997)
Person Nights (1995) = 374,681 person nights (Central-Bank 1997)
Emergy per Person Night = (1,015,175 E14 sej/yr)/(374,681 person nights) = 2.71 sej/person night

36) Services Income: Foreign exchange receipts from tourism (EIU 1997); Total receipts is 66,000,000 NAF/yr
Services income ($) = (66,000,000 NAf/yr)/(1.79 NAf/$) = 37,092,000 $/yr

37) Emergy Attracted per Laborer: Total Emergy Inflows, 1,015,175 E14 sej/yr; Total Laborers, 700
Emergy per Laborer = (1,015,175 E14 sej/yr)/(700 Laborers) = 1,450 E14 sej/yr/laborer

38) Emergy Attracted per Hotel: Total Emergy Inflows = 1,015,175 E14 sej/yr; Total Units = 30
Emergy per Unit = (1,015,175 E14 sej/yr)/(30 Companies) = 33,839 E14 sej/yr/unit

39) Tourism Services (emergy/$) = (1,016,175 E14 sej/yr) / (3.72 E7 $/yr) = 2.73 E12 sej/$

Table 44: Intensity Ratios - Five Hotel Comparison
Total inflow emergies per hotel are divided by the per establishment total environmental inflows for the island (R+N). (R+N)/30 establishments = 13,966 sej/yr

	Total Inflows (E14 sej/yr)	Intensity Ratios (Total Inflows / 13,966 sej/yr)
Hotel 1	15,674	1.12
Hotel 2	26,289	1.88
Hotel 3	59,958	4.29
Hotel 4	81,543	5.84
Hotel 5	129,859	9.30

Table 45: Tourism Statistics

Year	Receipts (NAf)	Receipts (Mn NAf)	Arrivals - Stop over	Arrivals - Cruise	Citation
1955			1,555		Hartog (1978:100)
1967			7,512		Hartog (1978:100)
1974			11,102		Hartog (1978:100)
1982	12,000,000	12			EIU Country Profile 1988-89:58
1983	10,000,000	10	17,000		EIU Country Profile 1988-89:58
1984	5,000,000	5	18,000	3,000	EIU Country Profile 1988-89:58

Year	Receipts (NAf)	Receipts (Mn NAf)	Arrivals - Stop over	Arrivals - Cruise	Citation
1985	8,000,000	8	24,000	3,000	EIU Country Profile 1988-89:58
1986	11,000,000	11	27,000	3,000	EIU Country Profile 1992-93:70
1987	19,000,000	19	30,000	3,000	EIU Country Profile 1992-93:70
1988	25,000,000	25	34,000	8,000	EIU Country Profile 1992-93:70
1989	24,000,000	24	37,000	7,000	EIU Country Profile 1992-93:70
1990	30,000,000	30	41,000	4,000	EIU Country Profile 1996-97:62
1991	41,000,000	41	50,000	12,000	EIU Country Profile 1992-93:70
1992	45,000,000	45	50,000	23,000	EIU Country Profile 1996-97:62
1993	49,000,000	49	54,000	18,000	EIU Country Profile 1996-97:62
1994	58,000,000	58	55,000	12,000	EIU Country Profile 1996-97:62
1995	66,000,000	66	59,000	11,000	EIU Country Profile 1996-97:62
1996	75,800,000	76			Central Bank Annual Report 1997 Section 4.2.2.1
1997	79,100,000	79	63,378	20,357	Central Bank Annual Report 1997 Section 4.2.2.1, Tourists - Europa 1998

APPENDIX T
AIRPORT SYSTEM EMERGY ANALYSIS

EMERGY Flows of Airport Travel Subsystem

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	9.95E+14	J	1	10	726
2	Rain, Chemical Potential Energy	4.18E+11	J	15,444	65	4,709
3	Rain, Geopotential Energy	1.93E+09	J	8,888	0	13
4	Wind, Kinetic Energy	7.80E+12	J	584	46	3,324
5	Wave Energy	1.74E+11	J	25,889	45	3,286
6	Tidal Energy	3.27E+10	J	49,000	16	1,169
7	Currents Energy	1.02E+10	J	1.0E+05	10	747
8	Earth Contribution	2.07E+06	g	1.0E+09	21	1,511
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**111**	**8,136**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	2.18E+11	J	51,078	(111)	(8,136)
10	Mondi Animals	4.88E+09	J	2,056,417	(100)	(7,322)
	Total of Renewable Production				**(212)**	**(15,459)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.95E+09	J	63,000	(1)	(90)
12	Groundwater and Dams	1.22E+08	J	617,760	1	55
13	Coral Reef	3.79E+03	g	1.0E+09	0	3
	Total of Slow-Renewable Sources				**1**	**58**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Sediments	1.90E+03	g	4.50E+09	0.1	6
15	Limestone	1.90E+03	g	1.00E+09	0.0	1
	Total of Non-Renewable Sources				**0.1**	**8**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Airport Terminal Assets	5.50E+07	g	1.80E+09	990	72,263
17	Airport Equipment (Misc.)	6.67E+06	g	6.70E+09	447	32,603
18	Fuel	4.84E+14	J	6.30E+04	305,220	22,278,803
19	Sand and Stone Transport				413	30,151
20	Concrete and Limestone Subbase				7,082	516,901
21	Airport Foreign Aid (Construction)				36,706	2,679,296
22	Electricity	2.22E+12	J	2.73E+05	6,065	442,701
23	Potable Water	2.67E+10	J	1.39E+06	372	27,132
24	Services (Fuel & Goods)	6.58E+06	$	5.36E+12	352,288	25,714,468
25	Labor Contribution				23,925	1,746,342
	Total Imports and Outside Sources				**733,507**	**53,540,660**
Total Emergy Inflows					**733,619**	

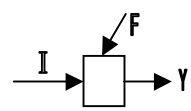
OUTPUT AND TRANSFORMITIES:

27	Airport Services	1.52E+06	$	4.72E+12	71,646	5,229,651
28	Emergy Attracted per Laborer				4,473	326,517
29	Emergy Attracted per Unit				733,619	53,548,861
30	Airport Services	1.52E+06	$	4.84E+13	733,619	53,548,861

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
G Manufactured *goods* brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + G + S)/(N + R)	6529
Yield Ratio = Y/F	Y/(M + G + S)	1.0
Service/Free	(G + S)/(N + R)	3813
Service/Resource	(G + S)/(N + R + M)	1.4
Nonrenewable/Renewable	(N + M)/R	2738
Developed/Environmental	(N + M + G + S)/R	6581

NOTES

Data comes from an interview with an airport manager, from estimates, or from citations as shown.

Land Area = 165,000 m^2 (total land area, 3300m x 500m est)

Fraction of Total = 0.0003976

NUMBERED FOOTNOTES

Footnotes for Items 1-16 see Natural Systems analysis (APPENDIX D).

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

Flights (Aircraft Movement) 1994 Annual Report
Aircraft Movements, Air Taxi, 1,050; General Aviation, 3,085; Military, 96; Govt/Local + Training Flights, 303;Total Aircraft Movements, 4,534; Revenues (estimated), 2,700,000 NAf/yr, est from informal reports; Annual Costs (estimated), 2,250,000 NAf/yr

16) Airport Terminal Assets: Airport Terminal, Steel =1000MT, est.;Jet Fuel Storage Tank, Steel =100MT, est.; Depreciation, 20 yrs

Total Steel = (1,100MT)(1E6 g/MT)/(20 yrs) = 5.50E+07g/yr

17) Airport Equipment (Misc.): Equipment is high loaders, stairs, air starter (start engines), air conditioning (for planes), ground power units (restart engines), baggage movers, 3 double cab trucks. Total equipment (estimate) =100MT (Total machines); 15yrs (Years of depreciation)

Total Wt. (g) = (100MT)(1E6 g/MT)/(15 yrs) = 6.67E+06g/yr

18) Fuel: Unfortunately this critical input to Bonaire's economy could not be obtained directly from Bonoil or Curoil. Curoil delivers jet fuel to storage tank near WEB. The fuel is for international flights, mainly the ALM flight to Miami. There is also an Air Aruba flight to Newark via Aruba. The KLM flight fuels in Caracas or Curacao. The Dash 8's fuel on Curacao. Avensa also fuels in Caracas. There are two big fuel trucks that hold 5000 US gallons/truck (load 600 gal/minute and 500 gal/minute). They keep one truck at the airport loaded. The ALM flight uses one truck of fuel for big flights.
The estimate below is calculated from estimated re-fueling of aircraft on Bonaire. AIR ALM has 2 flights daily from Miami; and, Thursday, Saturday and Sunday flights from Atlanta. Most flights connect through Curacao, although nonstops operate from Miami on Wednesdays and Saturdays and from Atlanta on Saturdays only. Big re-fueling trucks hold 5000 US gallons/truck. Miami-Bonaire flight uses one truck of fuel.
Flights
Total flights (1994), 4,534 flights/yr; General aviation, 3,085 flights/yr; ALM has 17 flights/week to Bonaire, 442 flights/yr (est. half refuel on Bonaire, more?); Estimate 1/2 truck/day for all other flights, 183 truckloads/yr (more?);

Fuel = (221 ALM truckloads + 183 truckloads other)(5000 gallons/truck) = 3,122,500 gallons/yr, estimate

Energy (J) = (3.7843 liters/gallon)(3,122,500 gallons/yr)(41E6J/l) = 4.84E+14J/yr (could be double?)

<u>Runway Construction</u>
1,500 kg/m^3 (est); Subbase (600 mm); Concrete slab (200 mm); Resurface (40mm)

	Total mass	Transformities	Emergy
Flamingo Airport opened (1955) (1000 x 20 m?) (900,000 NAF, from Island funds)			
Concrete slab =	6,140 MT	9.26E+07 sej/g	5.69E+17
Rock Subbase (54 lbs/square foot) =	19,949 MT	1.00E+09 sej/g	1.99E+19
Flamingo Airport lengthened (1750 x 30 meters) (1972) (7,320,000 NAF, EEC)			
Concrete slab =	11,028 MT	9.26E+07 sej/g	1.02E+18
Rock Subbase =	9,672 MT	1.00E+09 sej/g	9.67E+18
Flaming Airport lengthened (2400 x 45 meters) (1980)			
Concrete slab =	20,239 MT	9.26E+07 sej/g	1.87E+18
Rock Subbase =	26,452 MT	1.00E+09 sej/g	2.65E+19
Total =	93,481 MT	Total =	2.83E+19

Concrete transformity from (Doherty and Brown 1993)

19) Sand and Stone Transport: Truck load = 12 MT/load (est); Total Mass of Concrete/Limestone, 93,481 MT (see table above); Averaged over years construction, 25 yrs; Concrete/Limestone per year, 3,739 MT/yr; Emergy per load, 1.33 E14 sej/load (from Truck Transport analysis)
Emergy total =((3,739 MT/yr)/(12 MT/load))(1.33 E14 sej/load) = 4.13 E16 sej/yr

20) Concrete and Limestone Subbase: Total Mass of Concrete/Limestone, 93,481 MT (see table above); Total emergy input, 2.83E19 (see table above); Runway turnover time, 40 yrs
Emergy flow of runway = (2.83E+19 sej)/(40yrs) = 7.08 E17sej/yr

21) Airport Foreign Aid (Construction): Services input to the airport sector over a 30 year period (synthesized from various Depos reports((DEPOS 1987))((DEPOS 1995)))

Funding Type		Real NAF	Emergy (E14 sej)	Source
Expansion Airport	1967	750,000	69,000	NL
Airport Landing Electronics	1967	103,200	9,494	NL
Equipment Control Tower Airport	1972	208,900	14,623	NL
Study Landing Strip	1972	156,100	10,927	EEG
Landing Strip Airport	1972	7,320,000	512,400	EEG
Airport Terminal	1972	4,815,600	337,092	EEG
Management Airport	1972	93,800	6,566	EEG
Firefighting Equipment Airport	1972	247,200	17,304	NL
Flamingo Airport Roof	1987	520,000	9,360	NL
Airport Emergency Preparations?	1988	780,000	13,650	NL
Institute for Airport Traffic Problems	1988	233,894	4,093	NL
Airport Phase 1	1990	3,143,947	48,731	NL
Airport Phase 2	1993	3,500,000	47,950	NL
		Emergy (E14 sej) =	1,101,191	

Per year aid = (1,101,191 E14 sej)/(30 yrs) = 36,706 E14 sej/yr

22) Electricity: Electricity use per month, 51,500 kWh/mo
Energy (J) = (51,500 kWh/mo)(12 mo/yr)(860 Cal/kWh)(4186 J/Cal) = 2.22E+12J/yr

23) Potable Water: Water use per month, 450 m^3/mo
Energy (J) = (450 m^3/mo)(12 mo/yr)*(1000g/m^3)*(4.94E3 J/g) = 2.67E+10 J/yr

24) Services (Fuel & Goods): The airport is a government agency, and the employees are government employees. The Bonaire government probably does not pay for the fuel. It is "injected" into the Bonaire by Curoil and the Antillean airlines ALM. However, the services of production and delivery of the jet fuel, equivalent to the cost of the jet fuel, do enter the Bonaire economy, and are included here as inputs.
Fuel, 11,816,477 liters/yr (see above); 0.8 NAF/liter (estimate)
Service ($) = (11,816,477 liters/yr)(0.8 NAf/liter)/(1.79 NAf/$) = $5,312,688
Annual Operating Costs, 2,250,000 NAF/yr (see above)
Total Service ($) = $5,312,688 + (2,250,000 NAf/yr)/(1.79 NAf/yr) = $6,577,187

25) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 35 government (CBS 1994:40); 125 BTC employees (Labor Office Bonaire 1995), Air Aruba and Servensa, 4 (Labor Office), 260 wrk days/yr, 8 hrs/day
(164 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 23,925 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

27 Airport Revenues: Airport income reported to be 2,700,000 NAf/yr; Transport, storage and communication 56,000,000 NAf (CBS 1996); Indicates that airport revenues is about 5% (leaving 95% to passanger fares, port, and telecommunication, which seems reasonable)
Airport Income = (2,700,000 NAF/yr)/(1.79 NAf/$) = $1,516,854

28) Emergy Attracted per Laborer: Total Emergy Inflows = 733,618 sej/yr; Total Laborers = 164
Emergy per Laborer = (733,618 sej/yr)/(164 Laborers) = 4,473 sej/yr/laborer

29) Emergy Attracted per Unit: Total Emergy Inflows = 733,618 sej/yr; Total Units = 1
Emergy per Unit = (733,618 sej/yr)/(1 Company) = 733,618 sej/yr/unit

30) Airport Services (emergy/$) = (733,618 E14 sej/yr) / (1.52 E6 $/yr) = 4.84 E13 sej/$

APPENDIX U
WEB ELECTRICITY PRODUCTION SYSTEM EMERGY ANALYSIS

EMERGY Flows of Electricity Production

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	1.54E+16	J	1	154	11,220
2	Rain, Chemical Potential Energy	6.46E+12	J	15,444	997	72,780
3	Rain, Geopotential Energy	2.98E+10	J	8,888	3	193
4	Wind, Kinetic Energy	1.20E+14	J	584	704	51,366
5	Wave Energy	2.69E+12	J	25,889	696	50,790
6	Tidal Energy	5.05E+11	J	49,000	247	18,064
7	Currents Energy	1.58E+11	J	1.0E+05	158	11,543
8	Earth Contribution	3.20E+07	g	1.0E+09	320	23,352
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**1,723**	**125,739**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	3.37E+12	J	51,078	(1,723)	(125,739)
10	Mondi Animals	7.54E+10	J	2,056,417	(1,550)	(113,165)
	Total of Renewable Production				**(3,273)**	**(238,905)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	3.02E+10	J	63,000	19	1,389
12	Groundwater and Dams	1.88E+09	J	617,760	12	849
13	Coral Reef	2.50E+06	g	1.0E+09	25	1,825
	Total of Slow-Renewable Sources				**56**	**4,062**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	2.93E+04	g	4.50E+09	1	96
15	Limestone	2.93E+04	g	1.00E+09	0	21
	Total of Non-Renewable Sources				**2**	**118**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Steel	1.17E+06	g	1.80E+09	21	1,533
17	Machines	2.73E+06	g	6.70E+09	183	13,367
18	Fuel	4.92E+14	J	6.30E+04	309,960	22,624,818
19	Foreign Aid (Construction and Maint.)				14,145	1,032,489
20	Services (Fuel, Curacao)	5.40E+06	$	5.36E+12	288,978	21,093,315
21	Labor Contribution				3,209	234,265
	Total Imports and Outside Sources				**616,497**	**44,999,787**
Total Emergy Inflows					**618,277**	

OUTPUT AND TRANSFORMITIES:

22	Electricity	2.27E+14	J	2.73E+05	618,277	45,129,706
23	Services (Elec)	4.01E+06	$	1.54E+13	618,277	45,129,706
24	Emergy Attracted per Laborer				28,103	2,051,350
25	Emergy Attracted per Unit				618,277	45,129,706

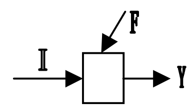
INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.

N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.

M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.

S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local inironment, nonrenewable and renewable.

F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)

Y *Yield* or output of the subsystem

Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	346
Yield Ratio = Y/F	Y/(M + S)	1.00
Service/Free	S/(N + R)	9.8
Service/Resource	S/(R + N + M)	0.1
Nonrenewable/Renewable	(N + M)/R	180
Developed/Environmental	(N + M + S)/R	358

NOTES

Data comes from interviews with two managers, from estimates, or from citations as shown.

Land area is the water and electric plant, water storage areas, and the areas covered with water and electric delivery equipment (pipes and electric wires, transformers, etc.). This area is estimated at 500 ha, divided by two between the water and electric subsystems. Land Area, 500 ha, (5,000,000 m^2); The reef area is estimated as the 250 meters of coastline beside the water and electric plant, and out 200 meters from the shore, divided by two between the water and electric subsystems. Total area is 2,550,000 m^2

Fraction of Total = 0.0061446

NUMBERED FOOTNOTES

Footnotes for Items 1-12 and 14-15 see Natural Systems analysis (APPENDIX D).

13) Coral Reef: Total reef lost estimated due to fuel barge and brine discharge, 50 MT; Years of reef consumption, 20 yrs;
Loss per year = (50 MT)(1E6 g/MT)/(20 yrs) = 2.5 E6 g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Steel: Estimate Pipes, 10MT; Tanks,15MT; Misc, 10MT; 30yrs (Yrs depreciation)
Total Wt. (g) = (10 MT + 15 MT + 10 MT)(1E6 g/MT)/(30 yrs) = 1.17E+06 g/yr

17) Machines: Generators(4), 40MT; Fuel Pumps, 1MT; 15yrs (Yrs depreciation)
Total Wt. (g) = (40 MT + 1 MT)(1E6 g/MT)/(15 Yrs) = 2.73E+06 g/yr

18) Fuel: 12,000,000 l/yr Deisel fuel (Gasahol)
Energy (J) = (12,000,000 l/yr)(41E6 J/l) = 4.92E+14 J/yr

19) Foreign Aid (Construction and Maint.): Services for construction and maintenance over a 30 year period

Dutch Funding (DEPOS)		Real NAF	Emergy/$ Ratios (E12 sej/$)	Emergy (E14 sej)
Water & Energy's 3rd Generator	1962	183,300	12	12,362
Electricity Installations	1967	3,760,200	9.2	194,417
Improvement Waterplant	1967	2,045,300	9.2	105,750
Expansion Water Supply System	1972	725,700	7	28,549
Prep. Expansion Water Supply System	1972	144,000	7	5,665
Expansion Water Supply Installations	1972	3,446,100	7	135,570
Supplementation Expansion Water Supply System	1978	150,000	4	3,372
Electricity Generation by Wind Turbines	1985	864,000	2	9,711
WEB Remaining Costs	1985	6,000,000	2	67,440
WEB Water and Electric	1985	12,500,000	2	140,500
WEB Water Pipes	1985	12,253,028	2	137,724
Energy Study	1990	114,000	1.55	993
Wind Turbine	1993	864,000	1.37	6,652
			Emergy (E14 sej) =	848,706

((DEPOS 1987), (DEPOS 1995), Emergy/$ ratios (Odum 1996a):312-13 (assumed Netherlands values similar to US))

Total Emergy 848,706 E14; Half for water, half for electric, 424,353 E14 sej over 30 years
Per year aid (30 years) = (424,353 E14 sej)/(30 yrs) = 14,145 E14 sej/yr

20) Services (Fuel, Curacao): Diesel Fuel (Gasahol) (l) = 12,000,000 liters
Service ($) = (12,000,000 liters)(0.80 NAf/liter)/(1.79 NAf/$) = 5,395,200$
Use Curacao transformity 5.35 E12 sej/$

21) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 22 full time, 260 wrk days/yr, 8 hrs/day
Labor emergy (sej) = (22 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 3,209 E14 sej

OUTPUT AND TRANSFORMITIES:

22) Electricity: 63,000,000 kWh/yr 1995, (Land Government 1998)
Energy (J) = (63,000,000 kWh/yr)(860 Cal/kwh)(4186 J/Cal) = 2.27E+14 J/yr

23) Services (Elec): (Land Government 1998), est. 2/3's of Utilities, 10,700,000 NAf
Service ($) = (10,700,000 NAf)(2/3)/(1.79 NAf/$) = 4,008,933 $

24) Emergy Attracted per Laborer: Total Emergy Inflows = 618,277 E14 sej/yr; Total Laborers, 22
Emergy per Laborer = (618,277 E14 sej/yr)/(22 Laborers) = 28,103 E14 sej/yr/laborer

25) Emergy Attracted per Unit: Total Emergy Inflows = 618,277 E14 sej/yr; Total Units = 1
Emergy per Unit = (618,277 E14 sej/yr)/(1 Company) = 618,277 E14 sej/yr/unit

APPENDIX V
WEB WATER PRODUCTION SYSTEM EMERGY ANALYSIS

EMERGY Flows of Water Production

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	1.54E+16	J	1	154	11,220
2	Rain, Chemical Potential Energy	6.46E+12	J	15,444	997	72,780
3	Rain, Geopotential Energy	2.98E+10	J	8,888	3	193
4	Wind, Kinetic Energy	1.20E+14	J	584	704	51,366
5	Wave Energy	2.69E+12	J	25,889	696	50,790
6	Tidal Energy	5.05E+11	J	49,000	247	18,064
7	Currents Energy	1.58E+11	J	1.0E+05	158	11,543
8	Earth Contribution	3.20E+07	g	1.0E+09	320	23,352
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**1,723**	**125,739**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM (GAIN AND LOST):						
9	Mondi Plants	3.37E+12	J	51,078	(1,723)	(125,739)
10	Mondi Animals	7.54E+10	J	2,056,417	(1,550)	(113,165)
	Total of Renewable Production				**(3,273)**	**(238,905)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	3.02E+10	J	63,000	19	1,389
12	Groundwater and Dams	1.88E+09	J	617,760	12	849
13	Coral Reef	2.50E+06	g	1.0E+09	25	1,825
	Total of Slow-Renewable Sources				**56**	**4,062**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	2.93E+04	g	4.5E+09	1	96
15	Limestone	2.93E+04	g	1.0E+09	0	21
	Total of Non-Renewable Sources				**2**	**118**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

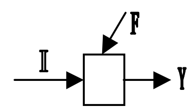
16	Steel	4.00E+06	g	1.8E+09	72	5,255
17	Machines	6.73E+06	g	6.7E+09	451	32,929
18	Boiler Water	4.38E+12	J	6.3E+04	2,759	201,416
19	Chemicals	5.40E+08	J	4.1E+07	224	16,318
20	Electricity	1.41E+13	J	2.7E+05	38,328	2,797,684
21	Construction / Maint. Foreign Aid				14,145	1,032,489
22	Labor Contribution				3,209	234,265
	Total Imports and Outside Sources				**59,189**	**4,320,357**
Total Emergy Inflows					**60,969**	

OUTPUT AND TRANSFORMITIES:

23	Water	4.39E+12	J	1.39E+06	60,969	4,450,276
24	Services (Water)	2.00E+06	$	3.04E+12	60,969	4,450,276
25	Emergy Attracted per Laborer				2,771	202,285
26	Emergy Attracted per Unit				60,969	4,450,276

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	33
Yield Ratio = Y/F	Y/(M + S)	1.03
Service/Free	S/(N + R)	9.8
Service/Resource	S/(R + N + M)	7.5
Nonrenewable/Renewable	(N + M)/R	0.34
Developed/Environmental	(N + M + S)/R	34

NOTES

Land area is the water and electric plant, water storage areas, and the areas covered with water and electric delivery equipment (pipes and electric wires, transformers, etc.). This area is estimated at 500 ha, divided by two between the water and electric subsystems. Land Area, 500 ha, (5,000,000 m^2); The reef area is estimated as the 250 meters of coastline beside the water and electric plant, and out 200 meters from the shore, divided by two between the water and electric subsystems. Total area is 2,550,000 m^2

Fraction of Total = 0.0061446

NUMBERED FOOTNOTES

Footnotes for Items 1-13 and 14-15 see Natural Systems analysis (APPENDIX D).

13) Coral Reef: Total reef lost estimated due to fuel barge and brine discharge, 50 MT; Years of reef consumption, 20 yrs;

Loss per year = (50 MT)(1E6 g/MT)/(20 yrs) = 2.5 E6 g/yr

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Steel: Estimate Pipes, 10 MT; Tanks, 100 MT; Misc, 10 MT; 30yrs (Yrs depreciation)

Total Wt. (g) = (10 MT + 100 MT + 10 MT)(1E6 g/MT)/(30 yrs) = 4.00E+06 g/yr

17) Machines: Vapor Comp(2), 50 MT; MED Machine, 40 MT; Intake Pumps, 3 MT; Fresh Water Pumps, 4 MT; Fresh Water Filters, 4 MT; 15yrs (Yrs depreciation)

Total Wt. (g) = (50 MT + 40 MT + 3 MT + 4 MT + 4 MT)(1E6 g/MT)/(15 Yrs.) = 6.73E+06 g/yr

18) Boiler Water: Steam at 130C, with 100C difference; 5,000 l/hr (5 m^3/hr?, 3 bars pressure);

Energy (J) = (5,000 l/hr)(8760 hr/yr)(1000 J/l/C)(100C) = 4.38E+12 J/yr (use transformity of oil)

19) Chemicals: Anti-Scaling Chemicals (Belgart - Organic Polymer?): Chemicals, 18,000 kg/yr; 1%? by atmc wt.; 0.1%? in chm.

Energy (J) = (18,000 kg/yr)*(1.0)*(.1)*(1000 g/kg)*(300 J/g) = 5.40E+08 J/yr
(used trnsfmty of phosphate rock?)

20) Electricity: 3,905,500 kwh required

Energy (J) = (3,905,500 kwh/yr)(860 Cal/kwh)(4186 J/Cal) = 1.41E+13 J/yr

21) Foreign Aid (Construction and Maint.): Services for construction and maintenance over a 30 year period

Dutch Funding (DEPOS)		Real NAF	Emergy/$ Ratios (E12 sej/$)	Emergy (E14 sej)
Water & Energy's 3rd Generator	1962	183,300	12	12,362
Electricity Installations	1967	3,760,200	9.2	194,417
Improvement Waterplant	1967	2,045,300	9.2	105,750
Expansion Water Supply System	1972	725,700	7	28,549
Prep. Expansion Water Supply System	1972	144,000	7	5,665
Expansion Water Supply Installations	1972	3,446,100	7	135,570
Supplementation Expansion Water Supply System	1978	150,000	4	3,372
Electricity Generation by Wind Turbines	1985	864,000	2	9,711
WEB Remaining Costs	1985	6,000,000	2	67,440
WEB Water and Electric	1985	12,500,000	2	140,500
WEB Water Pipes	1985	12,253,028	2	137,724
Energy Study	1990	114,000	1.55	993
Wind Turbine	1993	864,000	1.37	6,652
			Emergy (E14 sej) =	848,706

((DEPOS 1987), (DEPOS 1995), Emergy/$ ratios (Odum 1996a):312-13 (assumed Netherlands values similar to US))

Total Emergy 848,706 E14; Half for water, half for electric, 424,353 E14 sej over 30 years
Per year aid (30 years) = (424,353 E14 sej)/(30 yrs) = 14,145 E14 sej/yr

22) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 22 full time, 260 wrk days/yr, 8 hrs/day (half of 45 WEB workers on Water)

Labor emergy (sej) = (22 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 3,209 E14 sej

OUTPUT AND TRANSFORMITIES:

23) Water: Production, 888,000 m^3/yr, 1995, (Land Government 1998)

Energy (J) = (888, 000 m^3/yr)(1E6 g/m^3)(4.94 J/g) = 4.39E+12 J/yr

24) Services (Water): (Land Government 1998), est. 1/3's of Utilities, 10,700,000 NAf

Service ($) = (10,700,000 NAf)(2/3)/(1.79 NAf/$) = 2,004,467$

25) Emergy Attracted per Laborer: Total Emergy Inflows = 60,969 E14 sej/yr; Total Laborers, 22

Emergy per Laborer = (60,969 E14 sej/yr)/(22 Laborers) = 2,771 E14 sej/yr/laborer

26) Emergy Attracted per Unit: Total Emergy Inflows = 60,969 E14 sej/yr; Total Units = 1

Emergy per Unit = (60,969 E14 sej/yr)/(1 Company) = 60,969 E14 sej/yr/unit

APPENDIX W
WASTE MANAGEMENT SYSTEM EMERGY ANALYSIS

EMERGY Flows of Solid Waste Management

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	5.43E+14	J	1	5	396
2	Rain, Chemical Potential Energy	2.28E+11	J	15,444	35	2,569
3	Rain, Geopotential Energy	1.05E+09	J	8,888	0	7
4	Wind, Kinetic Energy	4.25E+12	J	584	25	1,813
5	Wave Energy	9.49E+10	J	25,889	25	1,793
6	Tidal Energy	1.78E+10	J	49,000	9	638
7	Currents Energy	5.58E+09	J	1.0E+05	6	407
8	Earth Contribution	1.13E+06	g	1.0E+09	11	824
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**61**	**4,438**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	1.19E+11	J	51,078	(61)	(4,438)
10	Mondi Animals	2.66E+09	J	2,056,417	(55)	(3,994)
	Total of Renewable Production				**(116)**	**(8,432)**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.07E+09	J	63,000	1	49
12	Groundwater and Dams	6.64E+07	J	617,760	0	30
13	Coral Reef	2.07E+03	g	1.0E+09	0	2
	Total of Slow-Renewable Sources				**1**	**80**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.03E+03	g	4.5E+09	0	3
15	Limestone	1.03E+03	g	1.0E+09	0	1
	Total of Non-Renewable Sources				**0**	**4**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Trucks	2.50E+06	g	1.8E+09	45	3,285
17	Potable Water	3.95E+09	g	1.4E+06	55	4,020
18	Fuel	1.15E+12	J	6.3E+04	723	52,791
19	Electricity	8.42E+10	J	2.7E+05	230	16,757
20	Services (Fuel & Electric)	3.10E+04	$	3.8E+12	1,178	85,985
21	Labor Contribution				4,085	298,156
	Total Imports and Outside Sources				**6,316**	**460,994**
Total Emergy Inflows					**6,378**	

OUTPUT AND TRANSFORMITIES:

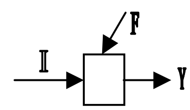
22	Sushi (Waste)	3.24E+13	J	1.97E+04	6,378	465,516

EMERGY VALUES OF WASTE:

23	Sushi (Paper Waste)	1.99E+13	J	3.49E+04	6,961	508,120
24	Sushi (Plastic Waste)	1.25E+13	J	6.60E+04	8,250	602,173
25	Emergy Attracted per Laborer				228	16,626
26	Emergy Attracted per Unit				6,378	465,516

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.



I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem

Name of Index	Expression	Quantity
Investment Ratio = F/I	(M + S)/(N + R)	102
Yield Ratio = Y/F	Y/(M + S)	1.01
Service/Free	S/(N + R)	84.9
Service/Resource	S/(R + N + M)	7.4
Nonrenewable/Renewable	(N + M)/R	14
Developed/Environmental	(N + M + S)/R	104

NOTES

Data comes from interviews with owners, from estimates, or from citations as shown.

Land area is landfill area, and area of buildings: Land Area, 9 ha, (90,000 m^2);

Fraction of Total = 0.0002169

NUMBERED FOOTNOTES

Footnotes for Items 1-15 see Natural Systems analysis (APPENDIX D).

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Trucks: Trash Trks (4), 16MT (est., 4 MT/truck); Pickups (3), 6MT (est., 2 MT/truck); Landfill Moover, 3 MT; 10 yrs (Yrs of dep)
Total Wt. (g) = (25 MT vehicles)(1E6 g/MT)/(10 yrs) = 2.50E+06g/yr

17) Potable Water: 800 NAF/yr (13 NAF/m^3)
Energy (J) = (800 NAf/yr)/(13 NAf/m^3)(1000 l/m^3)(41E6J/l) = 3.95E+09 J/yr

18) Fuel: Deisel fuel (Gasahol): 20,000 l/yr (trash and pickup trucks); 8,000 l/yr (landfill trucks);
Energy (J) = (28,000 l/yr)(41E6J/l) = 1.15E+12 J/yr

19) Electricity: 8,600 NAF/yr (2.72 kWh/NAF)
Energy (J) = (8,600 NAf/yr)(2.72 kWh/NAf)(860 Cal/kwh)(4186 J/Cal) = 8.42E+10 J/yr

20) Services (Fuel & Electric): Fuel (l), 28,000 liters; 0.8 NAf/liter; Electricity 8,600 NAf/yr
Fuel = 22,400 NAf/yr
Service ($) = ((28,000 liters)(0.8 NAf/liter)+(8,600 NAf/yr)+(22,400 NAf/yr))/(1.79 NAf/$) = 31,000 $/yr

21) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 28 full time, 260 wrk days/yr, 8 hrs/day
(28 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day)
= 4,085 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

22) Sushi (Waste); Total (MT), 2,660 MT/yr; Total emergy, 5,756 E14 sej/yr;
Energy (J) = 1.99E+13 J/yr + 1.25E+13 J/yr = 3.24E+13 J/yr

23) Paper (MT), 1,330 MT/yr (est., half of total)
Paper Energy (J) = (1,330 MT/yr)*(1E6 g/MT)*(15E3 J/g) = 1.99E+13J/yr

24) Plastic (MT) = 1,330 MT/yr
Plastic Energy (J) = (1,330 MT/yr)*(1E6 g/MT)*(9.4E3 J/g) =1.25E+13 J/yr

25) Emergy Attracted per Laborer: Total Emergy Inflows = 6,378 E14 sej/yr; Total Laborers = 28
Emergy per Laborer = (6,378 E14 sej/yr)/(28 Laborers) = 228 E14 sej/yr/laborer

26) Emergy Attracted per Unit: Total Emergy Inflows = 6,378 E14 sej/yr; Total Units = 1
Emergy per Unit = (6,378 E14 sej/yr)/(1 Company) = 6,378 E14 sej/yr/unit

APPENDIX X
BANKING SYSTEM EMERGY ANALYSIS

EMERGY Flows of Banking Subsystem

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E14 sej)*	*EmDollar Value (1993 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	6.03E+13	J	1	0.6	44
2	Rain, Chemical Potential Energy	2.53E+10	J	15,444	3.9	285
3	Rain, Geopotential Energy	1.17E+08	J	8,888	0.0	1
4	Wind, Kinetic Energy	4.73E+11	J	584	2.8	201
5	Wave Energy	1.05E+10	J	25,889	2.7	199
6	Tidal Energy	1.98E+09	J	49,000	1.0	71
7	Currents Energy	6.20E+08	J	1.0E+05	0.6	45
8	Earth Contribution	1.25E+05	g	1.0E+09	1.3	92
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**6.8**	**493**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Mondi Plants	1.32E+10	J	51,078	6.8	493
10	Mondi Animals	2.96E+08	J	2,056,417	6.1	444
	Total of Renewable Production				**12.8**	**937**
SLOW-RENEWABLE ISLAND SOURCES:						
11	Top Soil	1.18E+08	J	63,000	0.1	5
12	Groundwater and Dams	7.38E+06	J	617,760	0.0	3
13	Coral Reef	2.30E+02	g	1.0E+09	0.0	0
	Total of Slow-Renewable Sources				**0.1**	**9**
NON-RENEWABLE ISLAND SOURCES:						
14	Volcanic Rock	1.15E+02	g	4.5E+09	0.0	0
15	Limestone	1.15E+02	g	1.0E+09	0.0	0
	Total of Non-Renewable Sources				**0.0**	**0**

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16	Construction				5,546	404,804
17	Computers, Vaults, etc.	4.00E+07	g	6.7E+09	2,680	195,620
18	Electricity	3.60E+12	J	2.73E+05	9,814	716,352
19	Expenses, Taxes, and Other Liabilitie	7.13E+06	$	2.36E+12	167,981	12,261,407
20	Labor Contribution				11,671	851,874
	Total Imports and Outside Sources				**197,692**	**14,430,059**
Total Emergy Inflows					**197,712**	**14,431,498**

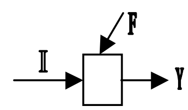
OUTPUT AND TRANSFORMITIES:

21	Services Income (?)	1.47E+06	$	1.35E+13	197,712	14,431,498
22	Emergy per Dollar Loaned				0.027	2.0
23	Emergy Attracted per Laborer				2,471	180,394
24	Emergy Attracted per Unit				24,714	1,803,937

INDICES

R Free *renewable* Emergy of environmental inputs from sources such as sun, wind, rain.
N Free *nonrenewable* resource Emergy from the local environment such as soil, forest wood, and minerals when used faster than produced.
M Purchased Emergy of *minerals*, fuels, and raw materials brought to an area by the economic system.
S Purchased Emergy in *services and labor*, the paid work of people.

I is (N + R), *Inputs* from the local invironment, nonrenewable and renewable.
F is (M + S), *Feedbacks* from the main economy, goods and services (M+S)
Y *Yield* or output of the subsystem



Name of Index	**Expression**	**Quantity**
Investment Ratio = F/I	(M + S)/(N + R)	28,719
Yield Ratio = Y/F	Y/(M + S)	1.00
Service/Free	S/(N + R)	28,717
Service/Resource	S/(R + N + M)	28,717
Nonrenewable/Renewable	(N + M)/R	0.02
Developed/Environmental	(N + M + S)/R	29,266
Empower Density	sej/ha/yr	1.98E+10

NOTES

Data comes from an interview with a bank manager, from estimates, or from citations as shown.

Land Area = 10,000 m^2

Fraction of Total = 0.00002410

NUMBERED FOOTNOTES

Footnotes for Items 1-15 see Natural Systems analysis (APPENDIX D).

IMPORTED EMERGY AND ISLAND TECHNOLOGY SOURCES:

16) Construction: Large Hotel Construction (1), 231,074 sej (per Construction analysis (APPENDIX H));3 Branch Offices, 138,645 sej (60% of hotel, est.) ; depreciation, 50 yrs

M&C Offices = (138,645 sej)/(50 yrs) = 2,773 sej/yr
Total Banking Sector (x2) = 5,546 sej/yr (est. doubled for other banks)

17) Computers, Telecom, etc.: All computers and equipment, 100 MT (est.); 5 yrs (Years of depreciation)
Equipment (g) = (100 MT)(1E6 g/MT)/(5 yrs) = 2.00E+07g/yr
Total Banking Sector (x2) = 4.00E+07 g/yr (est. doubled for other banks)

18) Electricity: 500,000kWh/yr, (est., data unavailable)
Energy (J) = (500,000 kWh/yr)(3.6E6 J/kWh) = 1.80E+12J/yr
Total Banking Sector (x2) = 3.6E12 J/kWh (est. doubled for other banks)

19) Expenses, Taxes, and Other Liabilities: M&C Banks, Total Expenses per Year = 126,894,000 NAF/yr, M&C Annual Report (1994:9); Total Branches in NA, 30;Total Branches on Bonaire, 3
Bonaire's Percentage = (126,894,000NAF/yr)/(30 branches)(3 branches on Bonaire)/(1.79NAf/$) = 7,128,876 $/yr
Total Banking Sector (x2) = 14,257,753 $/yr (est. doubled for other banks)

Parent Company Contributions (did not use this, for information only)
Maduro & Curiel's Bank is the largest in the Netherlands Antilles. It was started on Curacao in the early part of the last century. It is today 49% owned by the Scotiabank of Canada. The total assets of the bank in 1994 reached 2.039 billion NAF. The bank has over 30 branches in the Netherlands Antilles. The Scotiabank has assets of CDN $132.9 billion. The bank has 33,000 employees in 1,454 branches and offices in more than 40 countries. Each branch therefore is not an independent business entity, but has the weight of these assets behind it, making its existence and success possible.
Maduro & Curiel's total assets, 2.04E+09NAF (1.15E+09$); Scotiabank assets, 1.33E+11CDN $ (1.11E+11$); Total Branches, 1,484 branches

20) Labor Contribution: Emergy of 100 Persons for 1 Year = 61,439 E14 sej (see Household analysis); Full-time Laborers, 80, all banks, 260 wrk days/yr, 8 hrs/day
(80 people)(61,439E14 sej/100 people)(260wrk days/365 days/yr)(8hrs/24 hr/day) = 11,671 E14 sej/yr

OUTPUT AND TRANSFORMITIES:

21) Services Income (?): Loans, 1.31E+09 NAf/yr, M&C Annual Report (1994:9); Interest (10%); Bonaire Branches (3/30); Loan Life, 10 yrs, avg.
Income may be = (1.31E+09 NAf/yr)(10%)(3/30)/(10 yrs)(1.79 NAf/$) = $733,507
Total Banking Sector (x2) = $1,467,013 (est. doubled for other banks)

22) Emergy per Dollar Loaned: Loans, 1.31E+09NAf/yr (all M&C Loans); Bonaire Branches (3/30); Loan Life, 10 yrs, avg.
Emergy per Dollar Loaned = (197,711 E14 sej/yr)/((1.31E+09 NAf/yr)(3/30)/(10 yrs)/(1.79 NAf/$)) = 2.7 E12 sej/$

23) Emergy Attracted per Laborer: Total Emergy Inflows = 197,711 sej/yr; Total Laborers = 80
Emergy per Laborer = (197,711 sej/yr)/(80 Laborers) = 2,471 sej/yr/laborer

24) Emergy Attracted per Unit: Total Emergy Inflows = 197,711 sej/yr; Total Units = 1
Emergy per Unit = (197,711 sej/yr)/(8 Units) = 24,714 sej/yr/unit

APPENDIX Y
POURIER REPORT: ENGLISH VERSION SUMMARY

TEXT ON BONAIRE

Summary

In recent years, the economic development of the island territory of Bonaire has accelerated; the community is changing drastically throughout where until the eighties unemployment always forced the Bonairean to find work abroad. Since then, a work surplus has led to an influx of foreign workers.

Over a relatively short period of time, Bonaire changed from a community closed off from the outside world which depended on some agriculture, cattle rousing and fishing for marginal existence, to a service-based society powered by tourism in particular. Partly as a result of tourism, the most modern means of communication became attainable for the average Bonairean.

Tourism not only brought prosperity but also came with problems. Crime and drug use, for instance, are increasing. The rising cost of important matters such as homes and land make home ownership increasingly difficult. The lifestyle and culture of the people of Bonaire, in general, have suddenly come under heavy pressure.

Administrators are under pressure internally from the local problems demanding their attention, as well as, externally from foreign investors in particular; the situation calls for a policy framework to guide their decision making. A policy action plan should be included in this policy framework to co-direct the policy of cooperation between the Netherlands Antilles, the Netherlands and Bonaire.

The Executive Council of the Island territory of Bonaire recognized the necessity of a policy framework for social-economic development and decided to institute a committee. This committee was charged with drafting a report which was to indicate the premises for the social-economic development of the Island territory of Bonaire, as well as, the conditions for their implementation.

Based on its investigations, the Committee came to the following conclusions:

A. Bonaire possesses a unique product, her environment complemented by culture and historical monuments. This product lends itself admirably to building a tourism industry with a high added value for the Island territory provided it is protected and its quality is ensured. The development and exploitation of this product offer the Island territory of Bonaire new prospects for conducting a financial policy that is aimed now more than ever at gaining more independence and achieving more substance with regard to its autonomy as a result;
B. A Bonairean policy approach which centers on the environment can only have the desired results if it is supported by the entire population. Informational campaigns, school programs and community events that address the environment are indispensable along with legal measures with intrinsic regulations and sanctions. Moreover, this policy approach will only become accepted public opinion if the whole population shares in its benefits;
C. Making a choice for environment-based tourism means letting go to a certain extent of a policy that focused on the diversification of agriculture, cattle-raising and especially industry

and means channeling limited means and manpower to the tourism sector and the environmental product;

D. Making a choice for environmental tourism means, above all, foregoing the promotion of man-tourism and also limiting the increase of diving and the number of hotel rooms;
E. Important prior conditions must be heeded if the environment is to benefit the people of Bonaire and the government. It is essential that planning legislation is passed. However, factors such as good education, physical infrastructure, public health and low crime play an important part in making the environmental product economically productive;
F. The environmental product that Bonaire offers represents a value that increases all the time as it becomes more and more scarce around the world. The tourist is willing to pay for the enjoyment of this product. Government policy, therefore, must be aimed at conserving, protecting and improving this product, as well as, deriving optional benefit from the economic development that is generated by this environment-based tourism;
G. An important condition for giving substance to the policy approach outlined above and for realizing the economic potential, is the availability of an adequate functioning administrative system, which also includes the federal agencies that are important to the development of the Island territory. Furthermore, as representative of the people, the Island Council must strive more than up to now for optional public participation in the development, implementation, control and direction of policy;
H. The development cooperation between Bonaire, the Netherlands Antilles and the Netherlands must complement local development efforts. In the context of Bonaire this means that the development cooperation must supplement the development policy stated by Bonaire and therefore must also respond to Bonaire’s newly discovered development potential.

It is a fact that in nature conservation and protection, Bonaire leads the way in the region. Various governmental and regulatory measures are proof thereof. Increasingly, however, activities are taking place on the island that are or could detrimental to the environment or the rural character of the island. This is where the lack of policy view becomes apparent, a policy view which takes the environment as the core and starting point for socio-economic development. The majority of the population has always experienced the surrounding nature as a matter of course and has not always been able to value the environmental correctly because, for this majority, an attractive economic return has not been forth coming; because of the lack of policy vision, the majority of people remains uncertain as to which economic activities will to their and the island’s advantage.

Foreign investors and tourists, on the other hand, have become aware of the advantages of the environmental product on Bonaire and are profiting from it increasingly. And in this lies the heart of Bonaire’s socio-economic development. Because the environmental product on Bonaire is unique and increases in value day by day, the tourist can be asked to pay for enjoying this product. The compensation can increase to the extent that focused government policy ensures that this environmental product stays undamaged and even increases in value.

The Committee’s recommendations for the conservation, protection and strengthening of the environment are in the areas of planning, historic preservation, construction and housing regulations, as well as, limiting the growth of the number of hotel rooms and limiting the pressure on the environment generally by conducting a selective tourism policy.

The advantages of such a policy offer the government more financial independence, strengthen island autonomy and contribute to alleviating the financial and monetary problems of the Netherlands Antilles. The Committee’s proposals should contribute towards almost covering the usual duties in the island budget from local resources by 1998. For the time being, however, local efforts will probably be insufficient to finance the necessary big investments in infrastructure among other things. That is why complementary development aid remains necessary in the shape of program aid as recommended by the Committee.

Population must also be made more aware of the unique product at its disposal. This requires focused public education campaigns as well as education and training programs that address economic and administrative needs. It is important that the population itself enjoys the advantages directly with this new socio-economic approach. In doing so, one must strive to distribute the prosperity as widely as possible and for housing and construction that is affordable for the population. An informed public not only provides the community basis for environmental measures, but can also contribute to increasing the value of the environmental product through cultural expression, maintenance and beautification drives.

Conducting a socio-economic policy also requires the availability of an adequate administrative system, which assists the island authorities in the development, implementation, control and direction of policy. In the judgement of the Committee, the present government body unfortunately is understaffed in terms of quality. To strengthen it, local trained executives need to be recruited vigorously, taking remuneration and other social aspects into account. Assistance from the Netherlands offers temporary comfort, but is less desirable on account of efforts to give more substance to island autonomy and also on account of costs.

The following are some of the agencies or departments for which the Committee asks special attention:

- The Department of Planning, which still has to be established and which should play an important role in policy development.
- The Secretariat, the Departments of Finance and Personnel and the Public Works Agenda which are essential to a well-functioning government, particular for implementation and control.

The Committee asks attention, moreover the Federal Agencies on Bonaire. Their functioning cannot be viewed separately from the Island agencies and therefore they must also be included in the process of quality improvement. Some Federal Agencies such as Commerce, Industry and Employment (”HIW”) and Social Affairs are stuck in the decentralization process and because of this important tasks are not performed such as effective controls on prices and work conditions. The Committee considers it appropriate to conclude these matters promptly.

The Committee also would like to point out that a socio-economic policy centered on tourism must have a community basis that is as broad as possible. In this context, it is important that the Island Council also adopts and promotes the new policy view. In view of strengthening the democratic idea, the requirement for the Island Council to meet in public at least once a month should be included in article 106 of the Island Regulations Netherlands Antilles (”IRNA”). Such a regulation would keep the Island Council from staying inactive for lack of a quorum for long periods of time as far as public meetings are concerned, which also keeps the population deprived of information usually presented through this public forum.

The environmental product of Bonaire is of such great importance to the socio-economic development of the island that the Committee thought it should propose guarantees to prevent damage to this product as much as possible. The Committee recommends therefore that the Governor in his capacity as head of the Federal Government and applying article 68 of IRNA, instructs the administrator to present to the Governor any island regulations, decisions and decrees which affect the environment, within twice 24 hours after they have been determined.

In order to be able to implement the above, the Committee offers the following for consideration:

- the drafting of policy/action plan for the short, medium and long range to be based on the policies outlines in this report.
- adapting the existing public investment program, taking into account the operating expenses for the island budget.

These two tasks should be carried out within a period of three months after the publication of this report.

APPENDIX Z
NATIONAL TOURISM POLICY

Tourism Corporation Bonaire

INTRODUCTION
Bonaire is endowed with a variety of natural and cultural assets which, taken as a whole, provide the basis for the attraction of visitors from abroad and the development of tourism. These assets include outstanding marine resources, unspoiled natural scenery, a pleasant year-round climate, an uncrowded environment and a friendly, welcoming population.

These assets should be preserved and nurtured, not just because they are appreciated by visitors from other lands, but because they are valued by the present population and will be by generations yet to come.

The development and promotion of tourism is in the interest of the people of Bonaire, and will be encouraged in so far as it contributes to economic and social well-being by creating job opportunities for local people, generates receipts for local businesses, increases foreign exchange earnings and does not exceed the island's carrying capacity. Development which does not take careful account of environmental and human resource concerns could deplete or eliminate the very assets which makes Bonaire attractive to visitors and local residents alike.

Tourism in Bonaire should develop in a planned and orderly manner so as to provide the maximum benefit to the island and its residents, and to ensure that any adverse effects on the social, economic, cultural and general quality of life of the people of Bonaire, and the environment, are minimized.

The objective should be to achieve a managed growth path and a sustainable level of tourism development. This necessitates finding and striking the fine balance between the facilitation of tourism growth and the control of associated developments, bearing in mind that without careful conservation of Bonaire's primary tourism resources, it may cease to have a viable tourism product.

A comprehensive national tourism policy is therefore essential if tourism is to grow in an orderly way.

MISSION STATENENT
The overall objective for the development of tourism in Bonaire is to enable the people of Bonaire to benefit from the promotion and development of tourism by providing an optimum level of economic contribution consistent with the overall protection of Bonaire's environmental assets, cultural heritage, human resources and lifestyle.

GENERAL POLICY GUIDELINES
While this objective has to be adhered to by all those involved in the tourism sector, whether private sector or public sector, it is for the public sector to enact polices and to carry out programs to reach the stated objective.

To this end, Government will:

1. Encourage the orderly, fair and reasonable development of tourism resources within the context of a carefully planned and executed Tourism Development Plan.
2. Give full active support to the development of tourism activities which raise the wealth of Bonaire and its inhabitants.
3. Ensure a pattern of tourism development consistent with the protection and conservation of the island’s natural resources and attractions, particularly its offshore reefs and that also guarantees public access to the coastal zones. This to ensure locals and visitors’ access to dive sites, beaches and fishing areas.
4. Strive to continuously improve and upgrade the product which Bonaire has to offer to international and domestic tourism in order to consolidate a strong and competitive position in targeted overseas markets.
5. Encourage a balanced and diversified growth in the number, types, place of origin and travel motivations of visitors to Bonaire by stimulating well researched and financed marketing and promotion campaigns, and, while encouraging further expansion of the dive market, actively explore other leisure-oriented markets compatible with Bonaire's character and image.
6. Encourage a tourism development that caters to high quality – and specialty, non – mainstream tourists. (= boutique tourism)
7. Encourage the modernization and competitiveness of the accommodation sector.
8. Grant licenses and leases for new development only to bona-fide investors, with a demonstrated planning and delivery capability, who are willing to follow the guidelines set out in this policy statement.
9. Maximize job opportunities for Bonaireans and other qualified Antilleans at all levels of skill and responsibilities in the tourism sector by expanding training opportunities for nationals already working in, or potentially interested in entering the tourism industry and by limiting the validity of work permits of expatriates in cases where suitable qualified Antilleans are not available to such reasonable periods of time as are required for the training of local counterparts. Bonaire’s labor policies should seek to encourage Bonaireans and other qualified Antilleans living elsewhere, to consider taking up job positions in Bonaire.
10. Encourage Bonairean and Antillean ownership and management of tourism facilities and services, utilizing locally-available capital resources, and seek foreign capital only for those investments for which local funds and/or management capabilities are limited or not available.
11. Encourage a more intensive exploitation of the scope for linkages between tourism and other sectors of the local economy, particularly agriculture, livestock, fishery, handicraft and services.
12. Encourage ALM, as well as other airlines which currently service Bonaire, or which may service Bonaire in the future, to provide on a year-round basis reliable and convenient air service at a competitive price.
13. Facilitate the entry and exit of visitors at all ports of entry and strive to ensure that facilities are improved to keep pace with the demands of visitors and other passengers.
14. Exploit the positive effects of tourism on the socio-cultural fabric of Bonaire, while minimizing those aspects which may create potential conflicts or loss of cultural identity.
15. Create a better understanding among residents and public officials of the importance of tourism to the island's economy; and foster a spirit of continued hospitality and friendliness toward visitors.
16. Promote tourism in a manner that fosters visitors’ understanding and respect for the cultural and culture customs and ethnic traditions of local residents and for the delicate and varied ecology of the island.
17. Continue to work closely with the Caribbean Tourism Organization and the Caribbean Hotel Association and strengthen ties with other regional and international organizations involved in the areas of tourism, economic development and conservation.
18. Establish and implement the necessary institutional changes and legislation necessary for the attainment of the above policies and goals.
19. Consonant with the above, strive to strengthen the functions, capabilities and resources of Tourism Corporation Bonaire, which is the agency of the Bonaire tourism sector.

SPECIFIC POLICIES

New Hotel Development
The projected growth in tourist accommodation is far in excess of the development goals of the Tourism Strategic Master Plan and the Bonaire Tourism Structure Plan.

Beginning of first quarter, 1994 Government will impose an official moratorium on all new hotel and related tourist accommodation developments, including condominium and time sharing projects, for an initial period of seven years during which no new permits for such development will be issued.

In addition, all existing permits for new lodging developments, and extensions to existing properties will be reviewed and, where appropriate, renegotiated so as to ensure that the total number of lodging units is kept below 1600 units.

It is expected that this policy will result in a re-focussing from an emphasis on attracting large new projects to facilitating the upgrading of the existing tourism product and stimulating small business growth.

Investment in other viable tourism-related facilities, both by Bonaireans and overseas investors, will be encouraged provided such projects conform to the guidelines set out in this policy statement.

Physical Planning
The Bonaire Structure Plan (1990) presents a zoning plan for guiding land use development, including the designation of areas reserved for tourism and tourism-related facilities.

All proposals for development require planning approval and must be submitted in the first instance to the Legal Department to verify their conformance with the stipulated requirements of the structure plan.

Final approval is given by the Executive Council on the advice of the inter-departmental Planning Committee of which the tourist office needs to form part. Building permits are issued by the Public Works Department and will not be granted unless the project has been approved by the Executive Council (or Planning Committee). Project developers have the right to appeal with the island Parliament of Bonaire, this within 30 days after notice.

Protection of the Environment
All major development proposals must be accompanied by a thorough environmental impact study conducted by an independent, qualified expert. The Government or Tourism Corporation can submit a developers plan to an outside independent appraisal, this at the expense of the developer.

Effective 1994, coastal zone development will be stopped for a period of at least 5 years and only projects underway and with valid permits are allowed to be completed. This pending findings of baseline study of BMP on the subject marine environmental impacts in Bonaire's coastal area's.

The maximum permitted building height for tourist lodging projects is eleven meters (3-story), and eight meters (two-story) in environmentally-sensitive areas.

No building development is provided is permitted in the following conservation areas:

- Washington-Slagbaai Park
- the Lac area
- Klein Bonaire (check)
- and the designated linear beach park areas as defined in the Structure Plan.

Billboards
A permit is required for the erection of all advertising signs and billboards which must conform to certain specified standards.

Jet Skis
The operation of jet skis and similar high-powered marine craft is totally prohibited.

Bonaire Marine Park
The number of divers and other persons using the Marine Park will be monitored, and be limited, if necessary for the conservation of the coral reefs and the protection of the island's tourism industry. To preserve marine life especially on Bonaire's reefs, existing fishing laws regulating fishing in the proximity of the coastal area's should be strictly enforced.

Further research will be undertaken by the BMP to determine the precise carrying capacity of the park, whether in terms of the maximum number of users or the intensity of use by various categories of user. The annual admission fee payable by any person diving in the marine Park will be increased to $25 per diver per year as a direct contribution to the operation and maintenance of the park.

At the same time, there will be an intensified marketing effort to attract visitors to Bonaire for reasons other than diving.

Dive Shops
A permit is required by all operators of dive shops and similar establishments who must comply with the stipulated conditions governing the operation of such establishments as stipulated in the Marine Environment Ordinance. Government will carefully monitor, and, where necessary, control the number of dive shops permitted to operate in Bonaire, bearing in mind the finite carrying capacity of the Marine Park and the possible need to limit the number of dive visitors, or the number of dives per diver, or both, at some future date.

Government will establish a comprehensive legislation framework to govern the use Bonaire's marine resources for all other users. This legislation includes set charges for the various categories of users. Local users of marine resources are charged for the dollar amount in Antillean guilders. (local is defined as all persons who register Bonaire as their residence island).

Product Development
The Tourism Corporation and Government will continue to pursue a ”dive-plus” marketing strategy that will make Bonaire more competitive in existing and new dive markets while at the same time reaching out to new potential ”niche” markets in the general leisure markets in existing and new geographical markets.

Government will welcome and actively support proposals to upgrade and expand the current tourism product to appeal and cater to identified higher-end market segments such as birdwatching, windsurfing, fishing, snorkeling, cycling, family market, sailing, etc.

Investment
Investment in viable tourism projects, other than those pertaining to the accommodation sector, will be welcome, both from Bonaireans and overseas investors, although quite naturally Government will seek to stimulate and foster local investment.

Government will actively encourage Bonaireans to invest in tourist-related facilities such as restaurants, bars, entertainment facilities, watersport and other sports facilities and attractions, transportation and communications facilities, tour and travel operations, retail outlets, handicraft, etc. through the provision of small capital loans and technical advice from OBNA and other agencies.

In addition, Bonairean investors in approved projects can receive a tax holiday consisting of:

- full exemption from import duties for all construction materials including furniture, fixtures and equipment
- exemption from property taxes for up to eleven years
- a reduction of all income taxes down to two percent for up to eleven years.

For Bonaireans, the minimum capital investment needed to qualify for the above tax incentives will be reduced to Naf. 250,000 for approved projects in the tourism sector (excluding the accommodation sector).

Foreign owned companies that wish to qualify for tax incentives are required to establish Bonaire subsidiaries which include Bonairean citizens as directors and/or include a government nominee on their boards.

Tax incentives will no longer be offered for hotel on land development projects by foreign investors.

Tax incentives will continue to be offered for the renovation of existing hotel properties, whether owned by Bonaireans or overseas investors.

In this way, it is hoped to redirect financial mechanisms and incentives policy away from large new accommodation projects in favor of the promotion of small locally-owned and managed tourism-related businesses and the upgrading of existing accommodation establishments.

Tourism Linkages
It is intended that tourism will increasingly be utilized as a catalyst for the development of other economic activities in Bonaire, particularly agriculture, fisheries, handicrafts and other services, and Bonaireans will be encouraged to invest in such projects.

Condominium and Time Sharing Developments
No permits for new condominiums or time sharing projects will be issued before 2000 AD

Existing permits for such developments will be reviewed and renegotiated where appropriate.

In the intervening period, Government will make provision for the regulation of future condominium and time sharing developments. Government will need to be satisfied at the planning application stage as to the experience and competence of the proposed management company before approval is given.

Profits from the re-sale of condominium units will henceforth be subject to tax and owners of condominium units will be obliged to allocate a minimum number of weeks each year for renting.

Casino and Gaming Establishments
Government does not intend to issue any new additional licenses for casino operations in Bonaire, whether stand alone or part of a hotel establishment. The Governments policy is to have one ”low key type” casino for the whole island. The operation of coin-operated gaming machines other than in casinos is totally prohibited.

Fast Food Restaurant
No permits will be issued for high profile American style fast-food restaurants. Priority will be given to the establishment of high quality international, gourmet ethnic and local restaurants.

Cruise Tourism
Priority will be given to the development of land-based, as opposed to cruise tourism. In that respect, Government will not actively seek to promote cruise tourism, or allocate funds for that

purpose. Not more than one cruise ship will be permitted to dock at the port of Bonaire at any one time.

At the same time, every effort will be made to maximize on-shore spending by cruise passengers, and to seek to convert cruise visitors into future stay-over tourists. Cruise ships will be required to remain for a whole day and passengers are not allowed to take food and beverages off board.

In order to increase the revenue benefits from cruise tourism, Government will impose a passenger head tax of US$5 per manifested passenger on board all cruise ships calling at Bonaire from April 1, 1994. The headtax will be increased to US$10 at the beginning of 1995, this in accordance with CTO guidelines.

Cruise companies and/or their agents will be responsible for disposing of garbage generated by cruise ships visiting Bonaire, and will not be permitted to leave any garbage on the island. They will also be responsible for dealing with any pollution, accidental or otherwise, caused by cruise vessels. The Government of Bonaire will install a fine of up to $500,000 for those ships found guilty of polluting.

Yachts
Pending legislation on the charter yacht industry.
A mooring fee of US$ 15 per day will be charged at the beginning of 1994 for all anchoring yachts visiting Bonaire and not using the (private) Marina. Government will ensure that in due course adequate moorings are available and that suitable arrangements are made for the removal and disposal of garbage for a reasonable charge. (TCB awaiting legislation example of the BVI's).

Charter Boats
All operators of charter boats must have a license. Licenses are only issued for boats taking visitors for day or evening cruises.

Operators are not permitted to take hotel visitors on overnight cruises unless this is done by prior agreement with the hotels.

Live Aboard Dive Boats
No licenses will be issued for the operation of live Abroad Dive Boats.

Manpower Training
Government will ensure that the necessary and 'on-the-job' training is provided for Bonaireans wishing to work, or who are already working, in the tourism industry.

Assistance will be sought from national and international donor agencies in the fields of instruction and student training.

Developers will be required, as part of their project proposal, to introduce on an ongoing bases a program of 'in house' training and pre-opening training for their employees.

Government will institute a national certification program for all persons employed in the tourism industry in both the public and private sectors, so that eventually all posts are filled by qualified personnel.

Work Permits
Application for work permits for expatriates will not be entertained in cases where suitably qualified Bonaireans or Antilleans are available to fill the vacant positions.

Where applications for work permits are granted they will be limited to the periods of time required for the training and succession of local counterparts. The charges for work permits expatriates will be raised to Nafls 1000,- effective July 1994 and for renewal of permits to Nafls 400,-.

Tourism Education

Government will ensure that tourism-related subjects are introduced into the curricula of all islands primary and secondary schools so that school leavers are fully aware of the importance of tourism to the island economy and of career opportunities in tourism, both as employees and as owners/managers of tourism-related enterprises.

Public Awareness

Government will mount an ongoing program to increase public awareness of the role of that the community at large is expected to play in the development of the tourism sector including the reception of visitors and the maintenance of an unspoiled environment.

Government will continue to support the ”Tene Boneiru Limpi” campaign and other community programs geared towards preservation and enhancement of Bonaire’s cultural heritage and natural beauty.

Government will give top priority to the realization and implementation of an environmental protecting legislation, including an effective control mechanism and apparatus.

CONCLUDING STATEMENT

Tourism can, if carefully planned, managed and prompted, become the mainstay of the economy of Bonaire. The hospitality affects and embraces people of all walks of life, and the increasing economic benefits which it can bring will touch everyone. However, it is necessary to strike a balance between the economic benefits that may be brought by an ever increasing number of visitors and the possible negative impacts of this growth in tourism on the natural and cultural environment of Bonaire. The purpose of the National Tourism Policy is to ensure that this balance is achieved and that the island’s unique natural and cultural assets are preserved for the enjoyment of future generations of Bonaireans and visitors.

APPENDIX AA
BONAIRE 1950s EMERGY ANALYSIS

EMERGY Flows of Bonaire, circa 1955

Note	*Item*	*Raw Units*		*Emergy per Unit (sej/unit)*	*Solar Emergy (E16 sej)*	*Emdollar Value (1993 E3 US$)*
RENEWABLE ISLAND SOURCES:						
1	Sunlight	2.62E+18	J	1	262	1,914
2	Rain, Chemical Potential Energy	1.10E+15	J	15,444	1,701	12,415
3	Rain, Geopotential Energy	5.08E+12	J	8,888	5	33
4	Wind, Kinetic Energy	2.06E+16	J	584	1,200	8,762
5	Wave Energy	4.58E+14	J	25,889	1,187	8,664
6	Tidal Energy	8.62E+13	J	49,000	422	3,082
7	Currents Energy	2.70E+13	J	1.0E+05	270	1,969
8	Earth Contribution	5.46E+09	g	1.0E+09	546	3,984
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**2,939**	**21,450**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Plants	5.75E+14	J	51,078	2,939	21,450
10	Animals	1.29E+13	J	2.06E+06	2,645	19,305
11	Sorghum	2.92E+13	J	39,000	114	831
12	Vegetables	3.22E+11	J	39,000	1	9
13	Fruit	3.22E+10	J	39,000	0.1	1
14	Livestock Animals	1.35E+12	J	2.18E+06	294	2,145
RENEWABLE IMPORTED SOURCES:						
15	Fish Catch	5.30E+11	J	5.00E+06	265	1,936
	Total of Renewable Imported Sources				**265**	**1,936**
SLOW-RENEWABLE ISLAND SOURCES:						
16	Top Soil	5.15E+12	J	63,000	32	237
17	Groundwater and Dams	3.21E+11	J	617,760	20	145
18	Coral Reef	2.50E+07	g	1.0E+09	3	182
	Total of Slow-Renewable Sources				**55**	**400**
NON-RENEWABLE ISLAND SOURCES:						
19	Volcanic Rock	5.00E+06	g	4.50E+09	2	16
20	Limestone	5.00E+06	g	1.00E+09	1	4
	Total of Non-Renewable Sources				**3**	**20**

IMPORTED EMERGY:						
21	Merchandise	1.75E+09	g	3.52E+09	614	4,485
22	Fuel	7.13E+13	J	6.60E+04	471	3,436
23	Foreign Aid				114	832
24	Services Imports	3.94E+05	$	1.58E+13	623	4,549
	Total Imports and Outside Sources				**1,708**	**12,469**
NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
25	Households				1,804	13,167
26	People (Maintenance 237/yr)	1.86E+10	J	9.69E+06	1,804	13,167
Total Emergy Inflows					**4,970**	**36,275**
EMERGY OF EXPORTS:						
27	Aloe	6.40E+11	J	29,000	2	1
28	DiviDivi (Watapana) Pods	8.35E+11	J	29,000	2	1
29	Livestock	2.79E+11	J	2,169,497	60	25
30	Charcoal	2.71E+12	J	29,000	8	3
31	Fish	2.76E+11	J	5.00E+06	138	58
32	Salt	1.27E+08	g	4.00E+08	5	2
33	Emmigration	5.18E+09	J	2.67E+09	1,384	577
34	Services in Exports	254,353	$	8.67E+12	220	92
Total Emergy Outflows					**1,820**	**758**

NOTES

NUMBERED FOOTNOTES

Footnotes for Items 1-20 see Natural Systems analysis (**APPENDIX D**).
With a smaller population it is likely that Natural production was greater in those days and these numbers were probably somewhat larger.

IMPORTED EMERGY:

Unknown values are estimated as 5% of 1995. This is a gross estimate. It does however produce values that are in line with the values for exports that are known. The point of this analysis is to establish an order of magnitude baseline against witch to compare the current island values.

21) Merchandise: Estimate 5% of 1995 = 1.75E+09g/yr

22) Fuel: Estimate 5% of 1995 = 7.13E+13J/yr

23) Foreign Aid: Estimate 5% of 1995 = 11,402 E14 sej

24) Services Imports: Total Imports (1955) 710,000 NAf/yr (Hartog 1957:309)
394,444 $/yr

NON-RENEWABLE PRODUCTION WITHIN SUBSYSTEM:

25) Households: Estimate 5% of 1995 = 1,804 E14 sej

26) People (Maintenance 93/yr): Count, 5,581 people; 60yrs TT (Turnover Time of a person); Flow of persons per year, 93 persons flow = birth flow = death flow; 4,651 kg/yr (flow = 93 people * 50 kg/person / 60yr TT)

26a) Biomass Energy(J) Flux =(4,651 kg/yr)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 1.86+10 J/yr (energy for maintenance of human population = birth = death)

EMERGY OF EXPORTS:

Goats 5,950 Goats/yr exported ((Westermann and Zonneveld 1956:43), average 6 years)
Sheep 1,010 Sheep/yr exported ((Westermann and Zonneveld 1956:43), average 6 years)
Aloe 64,000 kg/yr ((Westermann and Zonneveld 1956:43), average 6 years)
Livestock (5950 Goats, 1010 Sheep) 69,600 kg/yr(@ 20 kg / 2 yr lifespan) ((Westermann and Zonneveld 1956:43), average 6 years)
Charcoal 185,000 kg/yr ((Westermann and Zonneveld 1956:43), average 6 years)
DiviDivi Pods 83,500 kg/yr ((Westermann and Zonneveld 1956:43), average 4 years)

27) Aloe: Energy(J) = (64,000 kg)(.5 DW)(1000 g/kg)(4.78 kcal/g)(4186 J/kcal) = 6.40291E+11J

28) DiviDivi (Watapana) Pods: Energy(J) = (83,500 kg)*(.5 DW)*(1000 g/kg)*(4.78 kcal/g)*(4186 J/kcal) = 8.35379E+11J

29) Livestock: L'stock Prod = 69,600 kg (6,000 goats and 1,000 sheep @ 20kg / 2 yr lifespan); Energy(J) = (69,600 kg)*(.2 DW)*(1000 g/kg)*(4.78 kcal/g)*(4186 J/Cal) = 2.79E+11 J/yr

30) Charcoal: Energy(J) = (185,000 kg)*(1000 g/kg)*(3.5 Cal/g)*(4186 J/Cal) = 2.71E+12 J/yr

31) Fish: No mass given in Hartog. Estimate price at about 1 NAf/kg; Export value, 68,983 NAf; L'stock Prod = 68,983 kg; Energy(J) =(69,600 kg)*(.2 DW)*(1000 g/kg)*(4.78 kcal/g)*(4186 J/Cal) = 2.76E+11 J/yr

32) Salt: 126,800 kg (Hartog 1957:307); Estimate the emergy/mass is 1/10th of current value

33) Emigration: Average Population in 1940-60 = 5,581, male = 2,402, female = 3,179 (Klomp 1986:194); Estimate of emigration is difference between male and female totals = 3,179 - 2,402 = 777 males ages 18-45 doing migrant work off the island (Curacao or Aruba refineries were popular, also shipping); If average off island work is for 30 years, then migrant flow is 26 men / year

Biomass Energy(J) Flux =(26 people/yr * 50 kg/person)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 5.18 E9 J/yr(energy for maintenance of human population = birth = death)

34) Services in Exports: Goats, 76,973 NAF/yr; Sheep, 16,425 NAF/yr; Aloe, 53,593 NAF/yr; Charcoal, 9,752 NAF/yr; DiviDivi Pods, 7,120 NAF/yr; Goat skins, 7,603 NAF/yr; Fish, 68,983 NAF/yr; Sand, 131 NAF/yr; Salt, 14,008 NAF/yr; Textile Products, 203,248 NAF/yr;

Total (NAf) = 457,836 1955 NAf (Hartog 1957:301)
Total ($) = 254,353 1955 US$ (if rate was 1.8 NAF/$)

APPENDIX BB
AMERINDIAN BONAIRE EMERGY ANALYSIS

EMERGY Flows of Bonaire, Amerindian

Note	Item	Raw Units		Emergy per Unit (sej/unit)	Solar Emergy (E16 sej)	Emdollar Value (1993 E3 US$)
RENEWABLE ISLAND SOURCES:						
1	Sunlight	2.62E+18	J	1	262	1,914
2	Rain, Chemical Potential Energy	1.10E+15	J	15,444	1,701	12,415
3	Rain, Geopotential Energy	5.08E+12	J	8,888	5	33
4	Wind, Kinetic Energy	2.06E+16	J	584	1,200	8,762
5	Wave Energy	4.58E+14	J	25,889	1,187	8,664
6	Tidal Energy	8.62E+13	J	49,000	422	3,082
7	Currents Energy	2.70E+13	J	1.0E+05	270	1,969
8	Earth Contribution	5.46E+09	g	1.0E+09	546	3,984
	Total of Renewable Sources (Rain+Tide+Currents+Earth)				**2,939**	**21,450**
RENEWABLE PRODUCTION WITHIN SUBSYSTEM:						
9	Plants	5.75E+14	J	51,078	2,939	21,450
10	Animals	1.29E+13	J	2.06E+06	2,645	19,305
11	Manioc	2.92E+13	J	39,000	114	831
RENEWABLE IMPORTED SOURCES:						
12	Fish Catch	1.06E+11	J	5.00E+06	53	387
	Total of Renewable Imported Sources				**53**	**387**
SLOW-RENEWABLE ISLAND SOURCES:						
13	Top Soil	5.15E+12	J	63,000	32	237
14	Groundwater and Dams	3.21E+11	J	617,760	20	145
15	Coral Reef	2.50E+07	g	1.0E+09	3	182
	Total of Slow-Renewable Sources				**55**	**400**
NON-RENEWABLE ISLAND SOURCES:						
16	Volcanic Rock	5.00E+06	g	4.50E+09	2	16
17	Limestone	5.00E+06	g	1.00E+09	1	4
	Total of Non-Renewable Sources				**3**	**20**
RENEWABLE HUMAN PRODUCTION WITHIN SUBSYSTEM:						
18	People (Maintenance 20/yr)	4.00E+09	J	7.62E+07	3,049	22,257
	Emergy Use per Person	1.20E+03	People		2.5	
	Empower Density (Emergy/Area)				0.000007	
Total Emergy Inflows					**3,049**	**22,257**

NOTES

NUMBERED FOOTNOTES

Footnotes for Items 1-17 see Natural Systems analysis (**APPENDIX D**).
With a smaller population it is likely that Natural production was greater in those days and these numbers were probably somewhat larger.

18) People (Maintenance 20/yr): Count, 1,200 people; 60yrs TT (Turnover Time of a person); Flow of persons per year, 20 persons flow = birth flow = death flow; 1,000 kg/yr (flow = 20 people * 50 kg/person / 60yr TT)

18a) Biomass Energy(J) Flux =(1,000 kg/yr)*(1000 g/kg)*(.2 DW)*(4.78 kcal/g)*(4187 J/Cal) = 4 E9 J/yr (energy for maintenance of human population = birth = death)

APPENDIX CC
POPULATION VALUES

Table 46: Bonaire Population Data

Year	Population	Citation
1500	1000	Havisar (1991:190)
1520	200	Estimate
1636	200	Estimate
1639	200	Estimate
1806	945	Klomp 1986:194
1816	1,135	(Westermann and Zonneveld 1956:41)
1826	1,049	
1828	1,476	
1833	1,348	
1847	1,955	
1850	2,159	
1855	2,397	
1857	2,647	Klomp1986:194
1860	2,903	
1865	3,453	
1867	3,833	Klomp 1986:194
1870	3,692	
1873	4,246	
1875	4,370	
1880	4,898	
1884	5,246	
1885	4,031	
1889	4,701	
1890	3,761	
1895	4,341	
1900	4,926	
1905	5,950	
1910	6,353	
1915	6,570	
1920	7,051	
1925	7,456	
1926	7,521	(Hartog 1957)
1927	5,216	
1928	5,166	
1930	5,733	CBS 1990
1935	6,028	
1940	5,616	CBS 1990

Year	Population	Citation
1945	5,798	
1948	4,995	(Hartog 1957)
1950	5,079	CBS 1990
1955	5,711	
1956	5,661	
1960	5,812	CBS 1990
1970	8,191	CBS 1990
1972	8,181	CBS 1990
1973	8,213	CBS 1990
1974	8,400	CBS 1990
1975	8,785	CBS 1990
1976	8,838	CBS 1990
1977	8,861	CBS 1990
1979	8,441	CBS 1990
1980	9,061	CBS 1990
1981	9,278	CBS 1990
1982	9,544	CBS 1990
1983	9,836	CBS 1990
1985	10,304	CBS 1990
1986	10,436	CBS 1990
1987	10,512	CBS 1990
1988	10,604	CBS 1990
1989	10,797	CBS 1990
1990	11,058	CBS 1993
1991	11,139	CBS 1993
1992	12,865	CBS 1993
1995	14,218	CBS 1996
1996	14,169	CBS 1996

Table 47: Netherlands Population Data

Year	Population (Millions)	Citation
-1500	10	Estimate, based on (TeBrake 1985)
1000	100	
1500	950	(Rotberg and Rabb 1987:102)
1550	1250	(Rotberg and Rabb 1987:102)
1600	1500	(Rotberg and Rabb 1987:102)
1700	1900	(Rotberg and Rabb 1987:102)
1750	1925	(Rotberg and Rabb 1987:102)
1795	2079	(Lee 1979:259)
1800	2100	(Rotberg and Rabb 1987:102)
1815	2292	(Rotberg and Rabb 1987:102)
1830	2613	(Rotberg and Rabb 1987:102)
1840	2860	(Rotberg and Rabb 1987:102)
1850	3049	(Rotberg and Rabb 1987:102)
1860	3309	(Rotberg and Rabb 1987:102)
1870	3580	(Rotberg and Rabb 1987:102)

1880	4013	(Rotberg and Rabb 1987:102)
1900	5104	(Rotberg and Rabb 1987:102)
1909	5858	(Lee 1979:259)
1920	6865	(Lee 1979:259)
1930	7936	(Lee 1979:259)
1940	8923	(Lee 1979:259)
1947	9625	(Lee 1979:259)
1987	14400	(Shetter 1987:41)
1994	15380	Europa 1998
1995	15451	Europa 1998
1996	15517	Europa 1998

APPENDIX DD
SIMULATIONS

Cultural Evolution Simulation Code

```
' ** Iterate calculations until t=Time
Start_Loop:
R(1) = Sun / (1 + (k(1) * N * Tr * Tp) + (k(2) * N * Tr * Tp * P))
J(1) = k(1) * R(1) * N * Tr * Tp
J(2) = k(2) * R(1) * N * Tr * Tp * P
J(3) = k(3) * R(1) * N * Tr * Tp * P
J(4) = k(4) * R(1) * N * Tr * Tp
J(5) = k(5) * N
J(6) = k(6) * R(1) * N * Tr * Tp
J(7) = k(7) * R(1) * N * Tr * Tp * P
J(8) = k(8) * Tr
J(9) = k(9) * R(1) * N * Tr * Tp
J(10) = k(10) * R(1) * N * Tr * Tp * P
J(11) = k(11) * Tp
J(12) = k(12) * R(1) * N * Tr * Tp
J(13) = k(13) * R(1) * N * Tr * Tp * P
J(14) = k(14) * R(2)
J(15) = k(15) * R(2) * A * S * P
J(16) = k(16) * R(2) * A2 * M * P
J(17) = k(17) * R(2) * A3 * C * P
J(18) = k(18) * R(2) * A4 * DMt * OG * P
J(19) = k(19) * R(2)
J(20) = k(20) * R(2) * A * S * P
J(21) = k(21) * A
J(22) = k(22) * R(2) * A * S * P
J(23) = k(23) * R(2) * A2 * M * P
J(24) = k(24) * A2
J(25) = k(25) * R(2) * A2 * M * P
J(26) = k(26) * R(2) * A3 * C * P
J(27) = k(27) * A3
J(28) = k(28) * R(2) * A3 * C * P
J(29) = k(29) * R(2) * A4 * DMt * OG * P
J(30) = k(30) * A4
J(31) = k(31) * R(2) * A4 * DMt * OG * P
J(32) = k(32) * R(1) * N * Tr * Tp * P
J(33) = k(33) * P
J(34) = k(34) * R(2) * A * S * P
J(35) = k(35) * S
J(36) = k(36) * R(2) * A2 * M * P
J(37) = k(37) * R(2) * A3 * C * P
J(38) = k(38) * R(2) * A4 * DMt * OG * P
J(39) = k(39) * R(2) * A4 * DMt * OG * P
R(2) = (J(12) + J(13)) / (1 + (k(14)) + (k(15) * A * S * P) + (k(16) * A2 * M * P) + (k(17) * A3 * C *
P) + (k(18) * A4 * DMt * OG * P))
```

```
' ** Increment storages by differences
dN = J(3) + J(4) - J(5)
dTr = J(6) - J(7) - J(8)
dTp = J(9) - J(10) - J(11)
dS = U - J(34) - J(35)
dM = -J(36)
dC = -J(37)
dDMt = -J(38)
dOG = -J(39)
dP = J(19) + J(22) + J(25) + J(28) + J(31) - J(32) - J(33)
dA = J(20) - J(21)
dA2 = J(23) - J(24)
dA3 = J(26) - J(27)
dA4 = J(29) - J(30)
```

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BIOGRAPHICAL SKETCH

Thomas Abel was born in Ohio in 1957 and grew up in Cocoa Beach, Florida. He received a Bachelors degree in Anthropology from the University of Florida in 1980, with emphases in ecological and linguistic anthropology. He then worked for six years at Kennedy Space Center on the Space Shuttle Program, first in Software Quality and later as a Computer Programmer. He received a Masters degree in Computer Science in 1985 from the Florida Institute of Technology.

In 1990 he received a second Masters degree, this time in Anthropology from the University of Florida, with speciazations in cognitive and linguistic anthropology. In the 1990s, he worked part-time as a computer programmer for the Graduate School and Department of Sponsored Research at the University of Florida. In that time he returned to his long interest of ecological and evolutionary anthropology, and began work with H.T. Odum and Mark Brown in the Department of Environmental Engineering. He qualified for a Ph.D., and started fieldwork on Bonaire in 1994. After 14 months of fieldwork he returned to Gainesville, where he has been working full-time as a computer programmer and writing his dissertation.