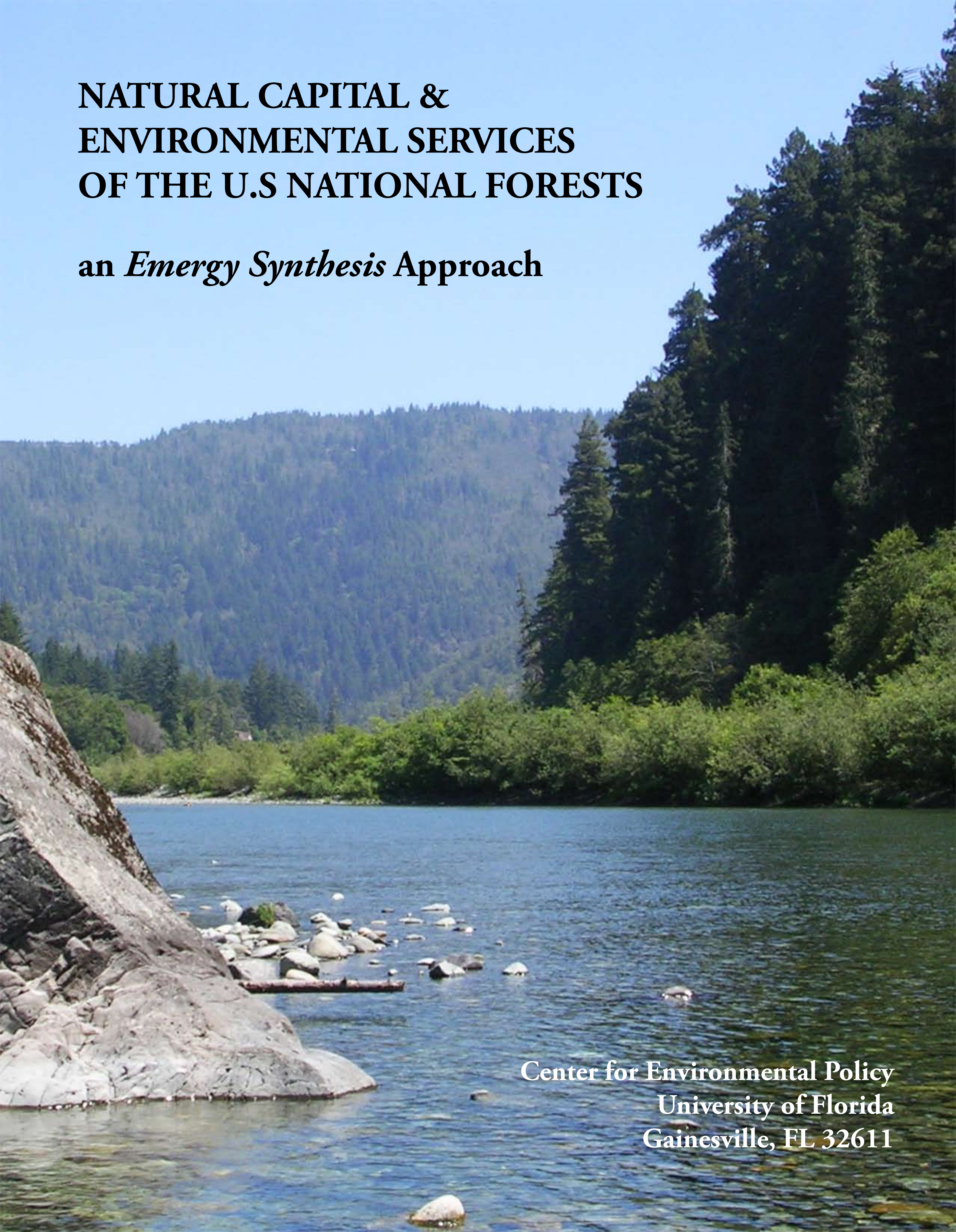
NATURAL CAPITAL & ENVIRONMENTAL SERVICES OF THE U.S NATIONAL FORESTS

an *Emergy Synthesis* Approach



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EVALUATION OF NATURAL CAPITAL AND ENVIRONMENTAL SERVICES OF U.S. NATIONAL FORESTS USING EMERGY SYNTHESIS

FINAL REPORT

By

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EXECUTIVE SUMMARY

Using the environmental accounting system, emergy synthesis, the value of the "Natural Capital" and "Environmental Services" of the U.S. Forest Service (USFS) were quantified on an energetic basis (ca. 2005). Emergy evaluation was done by quantifying all the energy flows required to create a system component or flow and placing it in a common unit, the solar emjoule (sej). Solar emjoules were also expressed in monetary equivalents called "emdollars" (em$) using a conversion factor based on the ratio of total emergy driving the USA economy divided by the Gross Domestic Product (GDP). In this way, emergy, generally an unfamiliar concept, and emjoules, equally unfamiliar units, were expressed in more familiar units and directly comparable to monetary scales of value.

Much of the natural capital and many of the environmental services of the USFS do not have market values. Emergy synthesis quantifies the value provided by the environment as well as the storages within the environment on an energetic basis, independent from market valuation. Emergy synthesis can establish values for everything, from glaciers to endangered species, on a common baseline, the energy required to make them. These values are external to the economic system, and while comparable, in many cases are not directly transferable. That is to say, emdollar values, for the most part, do not and probably should not, be used to value things within a monetary value system by suggesting that emdollar value is equivalent to prices derived from market actions.

The United States Forest Service System

The United States Forest Service (USFS), part of the US Department of Agriculture, is responsible for 155 National Forests and 20 Grasslands totaling 192.7 million acres of public land in 44 states and Puerto Rico. National forests cover about 5% of the total area of the United States. In addition, they comprise roughly a quarter of all "natural" habitats in the US and are vital for the survival of many endangered and threatened species. Virtually every habitat type of the US is contained within USFS lands, from the Redwoods of northern California to the prairie-potholes of North Dakota.

The USFS is organized into nine regions throughout the country and these nine regions are further divided into 600 ranger districts. The regions are numbered 1 through 10 but in 1965, region 7 was combined with region 9 to form the Eastern Region and the number 7 was dropped from the continuum. The emergy evaluation of the USFS was conducted by evaluating each region and then summing results to obtain overall values for the USFS as a whole.

Emergy Flows Supporting the USFS

Emergy evaluation of the National Forest Systems first evaluated the flows of energy, materials and services driving the system including renewable, nonrenewable and purchased flows. Since much of the energy driving the forest system is environmental and varies spatially throughout the USA, the emergy evaluations were conducted by USFS region and then summed for the USFS as a whole. The annual emergy driving the USFS was dominated by renewable environmental flows and when converted to emdollars were equal to about $^{em}\$$42.7 billion (10^{9}) in 2005. Nonrenewable resource flows from within the USFS system that were used (soils and organic matter) totaled $^{em}\$$89.2 million. Imported emergy in the form of energy, goods and services (fuels, electricity, labor, etc) when expressed in emdollars totaled $^{em}\$$9.4 billion. By far the largest imported emergy in 2005 was the emergy in tourists visiting National Forests which totaled $^{em}\$$13.3 billion.

Exports, those with and without market values, that originate from USFS lands represent environmental subsidies to the USA economy. They were quantified using emergy and amounted to about $^{em}\$$263.7 billion in 2005, of which clean water accounted for about 40% and fossil fuels and minerals for about 37%. The remaining 23% was composed of wildlife, hydroelectric power, wood biomass and numerous other smaller "products". By comparison, the economic values of these exports were \$69 billion.

Emergy Value of USFS Assets

The assets or storages of matter, energy, and information of the USFS were evaluated grouping into four categories including: environmental assets (such as forest biomass, water, soils, organic matter, etc.) economic assets (roads, machinery, buildings etc.) geologic assets (fossil fuels and minerals) and cultural assets (Indian artifacts and critical species). In addition to these assets, biodiversity and genetic resources were also evaluated. Environmental assets within the USFS totaled over $^{em}\$$5.7 trillion (10^{12}) in 2005, while economic assets totaled 84 billion. The emergy in geologic assets when expressed as emdollars was $^{em}\$$5.7 trillion. Native American artifacts, were estimated to be $^{em}\$$11.4 trillion in value. The emergy values of the genetic resources on USFS lands were the largest storage of natural capital equal to over $^{em}\$$154.1 quadrillion (10^{15}) while biodiversity was valued at over $^{em}\$$209.1 trillion. Endangered species on USFS lands were valued at $^{em}\$$32.7 trillion. While controversial, these values underscore the importance of the Forest Service's role in protecting genetic resources and biodiversity.

Comparison of USFS Emdollar Values With Economic Values

For comparison with economic values, the natural capital of the USFS was grouped into two categories: capital having market values and capital having no market value. Natural capital for which market values could be generated included forest resources, minerals, water, etc. The economic values of these totaled over \$2.7 billion while the emergy derived emdollar values were about 2.5 times the market value or $^{em}\$$9.4 billion. Natural capital with no market values totaled over $^{em}\$$2.8 quintillion (10^{18}) of which the emergy value of geologic formations represented over 94% of this total.

Environmental services were also grouped into those with and those without market values. Environmental services for which market values could be generated included research information, water supply, wildlife hunting and fishing, carbon sink, etc. The economic values of these totaled about $177 billion while the emergy derived emdollar values were about 8.2 times the market value or about em$1.4 trillion. Environmental services without market values were estimated to be worth about em$52.3 billion, the largest of which was the ground water recharge , totaling em$42.7 billion and followed by clean air valued at em$6.9 billion.

Emergy Evaluation of Osceola and Deschutes Forests

To demonstrate the application of the methodology at a smaller scale the flows and storages of two forests, Osceola Forest in Florida, and Deschutes Forest in central Oregon were also evaluated. Osceola National Forest is in North Central Florida and consists of 160,000 acres of predominately Slash Pine forest but also features hardwood and Cypress swamps and stands of Longleaf Pine. The Timucuan Indians inhabited the area for 12,000 years disappearing shortly after European contact. The Deschutes National Forest on the east side of the cascade Mountains in Central Oregon is managed in conjunction with the Ochoco National Forest and the Crooked River National Grassland. Deschutes comprises more than half of the combined area, 1.85 million acres of the total 2.5 million within the three management regions. The forest is generally dominated by pines, primarily Lodgepole and Ponderosa but also includes Spruce-Fir forests. This area was historically inhabited seasonally by the Umpqua Native Americans for over 10,000 years.

Deschutes Forest is about 12 times the size of Osceola Forest and has about 5 1/2 times the renewable environmental emergy driving it as compared to Osceola. When driving emergy is expressed as emdollars the total value of the renewable emergy driving Deschutes and Osceola Forests was em$386.1 million and em$70.2 million respectively. Imported emergy in the form of energy, goods and services when expressed in emdollars totaled em$1.3 million in Osceola and about em$33 million in Deschutes Forest. By far the largest imported emergy in both forests in 2005 was the emergy in visiting tourists, which totaled em$124 million in Deschutes and em$6.2 million in Osceola Forest. Exports from Deschutes Forest totaled nearly em$2.2 billion, of which the geopotential energy in water leaving the forest represented about 63% of the total. Harvested timber was em$38 million. On the other hand Osceola Forest exports totaled em$14.7 million of which harvested wood accounted for about em$8.9 million.

Summary

In all, the USFS annual budget allocation in 2005 was about $4.9 billion. When compared to environmental services obtained from USFS lands (em$1.5 trillion) the budget allocation is about 0.3% of the services and when compared to the values of natural capital the budget is miniscule. Total exports from Forest Service lands were estimated to be worth em$299.6 billion or more than 60 times the USFS annual budget in 2005. The value of endangered species found on USFS lands alone were estimated at nearly 6600 times the annual USFS budget, and if the values of biodiversity and genetic resources are included the annual budget appears diminishingly small in comparison.

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INTRODUCTION

Background and Concepts

Increasingly, government agencies like the US Forest Service (USFS) are being questioned regarding the costs and benefits of their annual monetary budgets. While it is relatively easy to account for monetary expenditures for goods and services that support forest operations and the returns that result from them, (e.g. timber or other material resources,) it is quite difficult to evaluate the less tangible environmental services or the natural capital inherent in the forests and grasslands that make up the Forest Service System. Society benefits from these environmental services and the natural capital from which they flow, yet in most monetary accounting schemes they are often not evaluated or if they are, given values based on human preferences.

In this research project we us the concepts and methods of systems ecology (Odum, 1983) and EMERGY (spelled with an "m") synthesis (Odum 1996) to evaluate natural capital and environmental services of the 191 million acres of the National Forest System of the U.S.A. Emergy synthesis is an overview systems approach to evaluating environmental resources and services that includes economic costs and benefits as well as societal and environmental non-market assets and values. We use the term synthesis instead of analysis because the approach is a synthesis, or combining elements into coherent wholes, instead of dissection as the term analysis implies. By evaluating complex systems using emergy methods, the major inputs from the human economy and those that are derived "free" from the environment can be integrated to analyze questions of public policy and environmental management holistically.

Emergy is the available energy of one kind previously required directly and indirectly to make a product or service, and its unit is the emjoule (see Table 1 for additional definitions) (Odum, 1996). Emergy can be used to evaluate, on a common basis, the contributions of complex systems or processes that have coupled hydrologic, geologic, ecological and economic components. For this reason, it is an ideal method for evaluating such complex systems as the US National Forest System, where societal and environmental systems are interacting.

Emergy synthesis is a scientifically based quantitative method for evaluating environmental assets and processes as well as economic products and services. It measures the work of environmental processes and sectors of the economy to produce goods and services on a common basis, the energy required directly and indirectly to produce them. The values obtained using emergy synthesis are independent of human preferences and do not rely on artificial markets or shadow pricing. However, emergy can be expressed in emdollars, defined as the dollars of gross economic product an emergy flow contributes (Odum, 1996). Since emergy is an unfamiliar unit of measure, it is often converted to dollars of economic product using a standard multiplier. The strength of emergy synthesis is its ability to evaluate directly both market and non-market goods and services, and when converted to dollars of economic product, it provides a powerful quantitative decision-making tool. Table 1 provides definitions for some important terms.

Different from other methods of energy analysis, emergy synthesis recognizes that each kind of energy has different quality (different transformity). Once transformed to emergy, flows of different energies, materials and services that are usually not comparable can be compared, summed or subtracted, and indices calculated that shed light on the sources of real wealth, losses due to impacts, and relative rates of use and exploitation. The techniques of systems ecology, including systems diagramming, aggregation, and simulation of macroscopic models of system properties provide potential for synthesis of complexity (Odum et al., 1998). The methods of emergy synthesis provide a quantitative decision making tool.

Background and Previous Work

Emergy Synthesis and Ecological Economics are emerging new fields of interest in environmental policy. The importance of these fields relates to valuing natural resources and the unmonied contributions of the environment to the economy. Over the past two decades faculty, students, and associates of the Systems Ecology Program and the Center for Environmental Policy in the Department of Environmental Engineering Sciences, University of Florida have developed and refined these theories of environmental value that are independent of human preferences. The theories and methods have been applied in wide array of systems to better understand issues related to resource management and to evaluate alternative solutions to policy questions. Table 2 lists previous research projects using emergy evaluations of resource management issues and questions.

Significance of the Research

All parties involved with Forest Service lands are concerned with finding solutions to the many social, economic, and environmental issues associated with their management. Trade offs between critical habitat and endangered species, quality and quantity of water resources, ecosystem services, aesthetic values and economic use are a few of the common issues recognized by agencies and the general public. While a common concern, is to insure the sustainability of these valuable ecosystems and the economic enterprises they support. As a result, methods for evaluation of management decisions should encompass environmental as well as economic systems and be able to evaluate the environmental consequences of management decisions that are guided by sometimes conflicting social values.

Emergy evaluations made to determine basic questions concerning the emergy characteristics of the USFS System provide a way to value resources and environmental services that is independent of human preferences and willingness-to-pay. Evaluation can guide land and water management in regard to developing new uses, controlling watersheds, and carrying nutrients and particles to receiving waters. Emergy synthesis may help define difficult choices on uses of water for drinking or recreation, retention of scenic resources, and conservation of breeding places for wildlife.

The results of this project allow the expression of ecological and economic values within a common framework and demonstrate an alternative valuing system and its applicability to environmental management decision making.

Strengths and Weaknesses of the Methods

The greatest strength in using emergy as a measure of value is that all things are put on a common scale that is objective and scientific. Products and processes in the economy of humanity and nature are valued according to what it took to make them or what they can do in use rather than what people think they are worth. This results in the ability to compare the effects of alternatives across broad and diverse categories of things. Because the economic and ecological consequences of social value choices are expressed on a common scale, emergy synthesis eliminates the uncertainty associated with the controversy over how to quantify and compare these different values.

Perhaps the greatest problem in using emergy synthesis is that it is a complex method that requires broad knowledge and special training by its practitioners. Emergy synthesis is also a fairly new methodology that at first received fierce opposition in the economic community. As the true relationship between our economy and its support environment has become more apparent, economists have become more open to new ways of thinking as illustrated by the development of a new field, ecological economics and the increased interest in alternative valuing systems.

A significant problem in using emergy synthesis is the fact that it is a "donor system of value". There are two general methods by which value can be determined (1) receiver based systems e.g. the market economy based on human willingness to pay and (2) donor based systems which are based on the production cost of goods and services (Odum, 1996). Donor based methods of determining value are not usually employed for the determination of value in western society where value is invariably associated with the subjective idea of utility to humans. Emergy synthesis is a donor based method for determining value. Since western society is more inclined to measure value from a receiver based perspective it has been difficult to alter this mind set for environmental management decisions that require a broader, integrative viewpoint. A main impediment to the use of emergy synthesis in decision making is society's reluctance to change value systems under the perceived notion that willingness-to-pay works in the market place, and therefore it can be made to work in the public policy arena.

Values determined by a donor method are based on objective facts and scientific principles. Both objective and subjective values can be determined using statistical methods with known limits of confidence and both measures are dependent on the accuracy of the information used in the determination. Donor based estimates of value are limited by the available information and these limits may be less confining than in the receiver based method since receiver based estimates of value are limited by the information available to the general public which is canvassed to obtain the value estimates.

Plan of Study

To place the values of the natural capital and environmental services of the Forest Service System in perspective, emergy synthesis of the main storages and the main ecological processes were performed. Using an eco-region approach to quantifying storages and processes, values were quantified for each of the nine forest service regions. In addition, each regional system's flows of purchased inputs, labor, and tourism activity were also evaluated. The data from the regions was summarized in an overall evaluation of the USFS system. This evaluation included the flows of renewable and nonrenewable inputs, purchased inputs and exports for the system. To provide a more detailed assessment, two case studies of selected forests (Osceola, in south east region, and Deschutes in the northwest region) were also evaluated.

In a final comparative analysis, emergy of environmental services and natural capital of the USFS system, expressed as emdollars were compared to economic values derived using both market and non-market methodologies. Table 3 lists the work plan carried out over the year and 6 months of the project.

METHODS

General Methodology

The general methodology for emergy synthesis is a "top-down" systems approach (Odum, 1996). The first step is to construct systems diagrams that are a means of organizing thinking and relationships between components and pathways of exchange and resource flow. The second step is to construct emergy synthesis tables directly from the diagrams. The final step involves calculating emergy indices that summarize and relate emergy flows of the economy with those of the environment, and allow the prediction of economic and environmental viability. Given next is further elaboration on the methods used in this study.

Step 1: Overview System Diagrams

A system diagram in "overview" was drawn first to put the Forest Service System in perspective, to combine information about the system from various sources, and to organize data-gathering efforts. The process of diagramming the system of interest in overview ensured that all driving energies and interactions were included. Since the diagram included both the economy and environment of the system, it is like an impact diagram which shows all relevant interactions. The Forest Service System diagram was used as a guide to construct a table of data requirements for the emergy synthesis. Each pathway that crosses the system boundary was evaluated.

Step 2: Emergy Synthesis Tables of Flows

Emergy evaluations of systems are carried out by accounting for the flows of materials, energy, and information that support the system. An emergy synthesis table with the main headings and organization shown in the example of Table 4 is used to organize data and maintain consistency.

The evaluation of the USFS system accounted for all the flows of material, energy, information and money that support the USFS system on an annual basis at several scales of analysis. First, the flows of the larger system within which the Forest Service is embedded (the emergy economy of the USA) were evaluated. This was necessary in order to calculate needed multipliers and ratios that were used in the evaluation of the USFS system. Second, the flows of each of the FS regions were evaluated. This was necessary in order to take into account geographic differences in driving energies and storages throughout the USFS system. Then two National Forests (Osceola and Deschutes) were evaluated in detail to provide additional insight into variations between flows and storages that result from the dramatic differences in landscape setting.

Step 3: Emergy Synthesis Tables of Storages

The storages of natural and economic capital were evaluated for the USFS system and Deschutes and Osceola Forests. An Emergy synthesis table of storages like that shown in Table 4 for flows was constructed for each system. The column headings in the storage table are the same as those in the flows table. To calculate the emergy of stored quantities (storages) of environmental resources, for instance wood biomass or soils, it was necessary to sum the emergy of all of the inputs and then multiply by the time it takes to accumulate the storage. We estimated the time required from the literature. To calculate the emergy of economic storages, for instance buildings and roads, we summed all the inputs of energy, materials and labor required to produce them.

Step 4: Calculation of Emergy Indices

Several indices, which are calculated from the flows of emergy supporting processes and products are used to provide perspective when compared to other processes and products. Once the emergy synthesis tables were completed, emergy flows were summarized into total renewable flows, total nonrenewable, and total purchased. The indices are defined in Table 5 and include ratios that relate purchased emergy to renewable emergy, the intensity of emergy use, a ratio of yield to cost, and a ratio that provides an index of environmental stress.

Evaluations of the USFS System and Subsystems

Evaluations Based on Averaged Inputs

Generally emergy evaluations of systems are conducted using average annual flows. For renewable inputs to the USFS system, such as solar energy, tidal energy and rainfall, etc. annual averages were used. For economic inputs, we used the most recent annual data available from USFS sources. Thus, while averaged flows were used for the renewable inputs, the data for economic flows were not averaged, but consisted of annual flows for a recent fiscal year. The result is an emergy evaluation of the USFS system as if it was in a steady state during the most recent year for which data were available. We used data from several recent years, but the dominate annual flows were for the year 2005. Thus the time frame for this analysis of the USFS system is ca. 2005.

Emergy evaluation tables contain line items for each of the actual flows of renewable energy inputs, nonrenewable resources consumed from within the USFS system (eg soils eroded), and imported energies, materials, and labor supporting the system and the exports from the system.. Raw data on flows and storage reserves were converted into emergy units, and then summed for a total emergy flow to the system. Renewable inputs driving the system that come from the same source were not added, to avoid double counting. While each of the renewable driving energies were evaluated separately, only the larger input was utilized as the driving renewable input. Since each of the renewable inputs is derived from the geobiosphere's web of interactions and they are ultimately derived from the same global sources (ie sun, tidal momentum, deep heat) if the renewable inputs to the USFS were added together, the result would double count the global driving energies. In keeping with methods developed by Odum (1996) the largest of the renewable inputs was utilized as the driving renewable emergy input.

Emergy Intensities Based on Previous Studies

Emergy accompanying a flow or storage of something (energy, matter, information, etc.) is easily calculated if the Emergy Intensity (EI) is known. Instead of calculating EIs new with each evaluation, standard practice is to use EIs calculated in previous studies. Whenever an evaluation of a process or service is done, one of the outputs of the evaluation is the calculation of a EI.

These are complied in a database at the Center for Environmental Policy at the University of Florida (CEP, 2006), currently unpublished.

In this study, EIs for common goods services and information were compiled from previous evaluations. Flows and storages expressed in their usual units were multiplied by the emergy per unit of that flow or storage obtained from other studies. For example, the flow of fuels in joules per time was multiplied by the transformity of that fuel (emergy per unit energy in solar emjoules/joule). In like manner, the mass of a material input was multiplied by its specific emergy (emergy per unit mass in solar emjoules/gram). The emergy of a storage is readily calculated by multiplying the storage quantity in its usual units by its unit emergy value.

Calculation of EIs (Transformities and Specific Emergies)

Transformity and specific emergy are unit emergy values calculated as the total amount of emergy required to make a produce or service divided by the available energy of the product (resulting in a transformity) or divided by the mass of the product (resulting in a specific emergy). Figures 1 and 2 illustrate the method of calculating a transformity first in equation form (Figure 1) and then with example numbers (Figure 2). The transformity of the product is the emergy of the product divided by the energy of the product (units are sej/J). If the output flow is in mass then the specific emergy of the product is the emergy of the output divided by the mass (units are sej/g)

Several EIs were calculated as part of this study. They include transformities for: biodiversity, archeological artifacts, and endangered species. A transformity is calculated by first quantifying all the emergy used in making the product or service and dividing by the energy of the product or service. These EI evaluations are included as appendices to the report (Appendices B, C, D, and E.

Calculation of Emdollar Equivalents

Emdollars are a measure of the money that circulates in an economy as a result of a flow of emergy. The emdollar (^{em}\$) value of a flow of energy material or information is calculated by first determining the emergy of the flow and then converting to emdollars using a standard conversion factor. For average goods and services the conversion factor is obtained by dividing the total emergy driving an economy by the economy's Gross Domestic Product. Obviously this is an average value for an entire economy and can only be used to provide perspective suggesting that on the average for every dollar circulating in the economy there is so much emergy driving it. Total emergy driving the economy in the USA (ca. 2005) was 1.89 E25 sej and the GDP in that year was \$9.8 E 12 thus the ratio of emergy to dollars was

$$sej/\$ = \frac{1.89E25}{9.8E12} = 1.9E12 sej/\$$$

RESULTS

The results of this analysis of the Forest Service system include emergy synthesis of the storages (natural capital) and main ecological processes (environmental services) of Forest Service lands by region and for the entire USFS system. Emergy synthesis of the Osceola and Deschutes Forests are also included. Comparisons between regions, and between the two forests, are drawn and then compared to the USFS system as a whole. Finally a synthesis table is presented comparing economic and emdollar values of market and non-market environmental services and natural capital.

The US Forest Service System

Given in Figures 3 and 4 is a map and a systems diagram of the US Forest Service System respectively. In the systems diagram, driving energies are arranged along the outside with flows that cross the system boundary. Components include: 1) the forest ecosystems with native and no-naïve vegetation, insects and pests, wildlife and fish and a storage representing biodiversity; 2) surface water; 3) geologic structure an minerals; 4) soil and soil water; 5) a component representing tourism containing a storage of "image" and tourists: 6) the capital assets of the US Forest Service system.

Emergy Flows Supporting the USFS System

Emergy evaluation tables for each of the 9 regions of the US Forest Service Systems are given in Appendix A. A summary table of the annual flows of emergy supporting the US Forest Systems as a whole (ca. 2005) is given in Table 6. The flows of energy, material and money that cross the USFS system boundary are listed as line items in the table. Each is multiplied by its Emergy Intensity (EI) to convert all flows into emergy. Finally, in the last column emergy flows are converted to emdollars, which represent dollar equivalents of the emergy flows. In this way comparisons can be made between monetary flows and the other flows of emergy and material that support the USFS system.

The table is divided into six major categories of flows: Renewable Resources (annual inflows that result from overall global processes); Indigenous Nonrenewable Resources (resources such as soils that are "used" n support of USFS processes); Imported Resources (purchased energy, material, and labor as well as the inflows of tourists); Economic Payments Received (the flows of money received form various sources); Exports (materials, energy, and information that is exported from the USFS system); and Economic Payments Made (monetary payments made by USFS system to outside parties).

The annual driving emergy flows (ca. 2005) of the USFS system in Table 6 are summarized in billions of Emdollars in the bar graphs in Figure 5. The renewable inputs (top graph) were dominated by the chemical potential emergy in rainfall totaling ^{em}\$42.7 billion/yr. Not all the rain is "used" within the lands of the forest service system as some is exported, Therefore transpiration is shown in the graph as the emergy in rainfall that was used in primary production (valued at about ^{em}\$19 billion/yr). Water also has a geopotential emergy that is used as it runs off the lands to lower elevations and is shown as the second largest input that was used within the forest service system (about $^{em}\$$26.6 billion/yr). The emergy in waves (about $^{em}\$$16.3 billion/yr) was a relatively significant input to the overall system, derived from Region 10. Earth cycle ($^{em}\$$13.3 billion/yr) is the geologic inputs that were responsible for uplift and geologic concentrations of minerals expressed on an annual basis. Other inputs shown are Sunlight ($^{em}\$$2.3 billion/yr), wind ($^{em}\$$4.4 billion/yr)), Hurricanes ($^{em}\$$1.2 billion/yr), and tidal energy ($^{em}\$$2.5 billion/yr)

The imported nonrenewable sources (bottom graph, in Figure 5 - note the difference in scale of the Y axis) are dominated by the influx of tourists. The emergy expended by tourists represented an input of very high quality energy to the USFS system and amounted to $^{em}\$$13.3 billion in 2005. The next largest inputs were expenditures for miscellaneous services ($^{em}\$$4.9 billion) and labor (about $^{em}\$$4 billion). Interestingly, nonrenewable inputs like petroleum products, purchased goods and electricity amounted to only about $^{em}\$$0.48 billion combined. The flows that dominate the USFS system are all inputs associated with human inputs either as labor, services in purchased goods (Misc. services) or tourist time.

Figure 6 summarizes the values of exports from the entire USFS System (ca. 2005) that are tabulated in Table 6. Exports include both resources that have market values (wood, fossil fuels, minerals etc) and those that do not normally have them (e.g. chemical potential and geopotential energy of water). All exports were evaluated in the table in emergy terms and then converted to emdollars. The top graph in Figure 6 shows the most important exports and their percentages of the total. Geopotential and chemical potential energy of water accounted for about 40% of total exported value from Forest Service lands. Minerals and fossil fuels accounted for about 37% of all exports. Image, which was estimated as the percent of the environmental and economic assets that tourists experience (0.1%) during visits to Forest Service lands, amounted to 1.8% of total exports. Harvested wood accounted for about 1% of exports, while wildlife and fish harvested from Forest Service lands was about 9%. Finally hydroelectric power generated on Forest Service lands accounted for about 11% of exported value.

Total emdollar value of exports and environmental services from Forest Service lands (ca. 2005) equaled about $^{em}\$$263 billion per year (Table 6 and Figure 6). Chemical and geopotential energy in water totaled about $^{em}\$$103 billion/yr, while the value of fossil fuels and minerals exported was about $^{em}\$$65.3 billion/yr. Harvested fish and wildlife were valued at $^{em}\$$23.5 billion/yr, while harvested wood and firewood was valued at $^{em}\$$2.9 billion.

Shown in Figure 7 are pie charts of the distribution of exports for each of the regions of the US Forest System (ca. 2005). In general, the chemical and geopotential energy in water are the largest exports from Forest Service lands in the regions, with the exception of Region 3 where minerals are the largest. The value of the chemical potential of water is in its support of life processes in downstream riverine and estuarine systems and to a lesser extent, support of terrestrial ecosystems. Geopotential energy of water leaving National Forest lands, on the other hand, is valuable for the physical work that it performs (including the important services of pulsing) which helps to transport and distribute sediments, nutrients and organic matter.

Emergy in Storages of the USFS System

Emergy evaluation of storages of assets within the US Forest Service System (ca. 2005) are summarized in Table 7 and Figures 8 and 9 Emergy evaluations of assets by regions are given in Appendix B. The storages of assets on Forest Service lands are grouped into four categories: environmental assets, economic assets, geologic assets, and cultural assets. Environmental assets totaled ^{em}\$5.7 trillion of which glaciers were the largest contributor (^{em}\$2.1 trillion). Tree biomass was next largest contributing about ^{em}\$1.5 trillion to total environmental assets. Soil organic matter was valued at about ^{em}\$983 billion Wildlife was contributed about ^{em}\$566 billion Ground and surface water together were valued at about ^{em}\$512 billion.

Economic assets were dominated by roads. Combined the roads on the USFS lands were valued at ^{em}\$79.6 billion ^{em}\$ of which gravel roads were by far the largest. Buildings, machinery and office equipment accounted for ^{em}\$4.6 billion.

Critical species was the singled largest asset on USFS lands and dominated the geologic and cultural assets category. The value of critical species was ^{em}\$32.7 trillion. Fossil fuels were valued at about ^{em}\$4.1 trillion ^{em}\$ while minerals totaled about ^{em}\$1.6 trillion. Finally, the value of Indian artifacts totaled about ^{em}\$2 trillion.

Figure 9 shows the assets of the USFS as percentages of totals. In the top chart, only environmental assets are given. In the middle chart both environmental assets and nonrenewable assets (fossil fuels and minerals) are shown together. In the bottom chart all assets are combined.

Emdollar values of assets by region are shown in Figure 10. Environmental assets are shown in the top graph. Region 10 had the highest emdollar value of environmental assets (^{em}\$2.58 trillion) as a result of the prevalence of glaciers. Emdollar values of economic assets were generally about one to two orders of magnitude lower than the environmental assets (middle graph)

The pie charts in Figure 11 for each of the USFS regions show the percent of total environment assets by category. In general, tree biomass and soil organic matter comprised the largest percentages of total value in all the regions except Region 10 which was dominated by emergy value of glaciers. Ground water comprised from 8% to more than 28% of the total value of assets on USFS lands. While surface water was relatively unimportant in most regions, it contributed about 19% of the total value of environmental assets in Region 9.

Comparative indicators and indices for the USFS as a whole and for each of the regions are given in Table 8. The first three rows summarize renewable, indigenous nonrenewable, and imported emergy flows which are the main flows used to calculate most of the indices that follow. In general the USFS system, is dominated by renewable inputs with 41% renewable for the USFS system as a whole, and ranging from 41% to 96% renewable for the regions. The emergy yield ratio, which is a measure of the total emergy use per unit of emergy invested from the economy was about 3/1 for the USFS as a whole and between 1.7/1 (Region 2) and 26/1 (Region 10). The ratio of imports to exports for the USFS as a whole is quite low (0.09/1) and varied between 0.04/1 (Region 10) and 0.32/1 (Region 8). Emergy return on investment, which is a ratio of the exported environmental services to the emergy value of the inputs from the economy averaged 11.4/1 for the USFS system as a whole and varied between 3/1 (Region 8) and 27.6/1 (Region 10).

Evaluations of Osceola and Deschutes National Forests

The Osceola and Deschutes National Forests represent rather stark contrasts. Osceola is in the southeastern coastal plan, dominated by slash pine flatwoods, while Deschutes is on the eastern side of the cascade Mountains, has relatively high topographic relief, and is dominated by Lodgepole and Ponderosa Pine. Brief descriptions of each Forest follow.

Osceola Forest

Osceola National Forest is in North Central Florida and consists of 160,000 acres of predominately Slash Pine forest but also features hardwood and Cypress swamps and stands of Longleaf Pine. There are 174 km^2 of hardwood/Cypress swamp, 97 km^2 of Longleaf, and 376 km^2 of Slash pine. The topography is very flat, with an elevation range of about 30 meters and an average of approximately 100 meters above sea level. Osceola is managed for multiple uses. It produces timber, harbors wildlife, and provides people with hiking, hunting, fishing opportunities. The Timucuan Indians inhabited northern Florida and southern Georgia for 12,000 years; Osceola NF contains over 300 sites with evidence of the Timucua people, many of which are unexcavated. Osceola is the site of the yearly Olustee Civil War reenactment, attracting thousands to the forest.

Deschutes National Forest

The Deschutes National Forest in Central Oregon is managed in conjunction with the Ochoco National Forest and the Crooked River National Grassland. Deschutes and comprises more than half of the combined area, or 1.85 million acres of the total 2.5 million within the three management regions. It is on the east side of the Cascade Mountain Range, which extends from Southern British Columbia, Canada to northern California. Deschutes NF was established in 1908 and split into the Ochoco and Paulina National Forests in 1915. Deschutes has an average elevation of 2180 meters, varying from 750 to over 3000 meters in the Cascades. Deschutes is one of the most heavily recreated National Forests, receiving over eight million tourists a year and is the site of recreation opportunities such as ski resorts, snowmobile tracks, developed campgrounds, as well as wilderness areas and the Newberry National Volcanic Monument. Extensive lava fields are evidence of eruptions as recently as 500 years ago. The forest is generally dominated by pines, primarily Lodgepole and Ponderosa but also includes Spruce-Fir forests, mall clusters of mixed hardwood stands, and Mountain Hemlock stands. Deschutes is home to 233 species of mammals, 62 species of reptiles and amphibians, hundreds of species of birds and thousands of species of insects. The area was historically inhabited seasonally by the Umpqua Native Americans for over 10,000 years.

Emergy Flows supporting Deschutes and Osceola National Forests

Emegy evaluation tables for Deschutes and Osceola National Forests are given in Tables 9 and 10. As in the emergy evaluation of the National Forest System, the evaluation tables are organized into renewable flows, nonrenewable flows, imports, and exports. Economic payments received and made are also included. Figure 12 shows the driving emergy of Deschutes and Osceola Forests as percent of total.

Deschutes Forest is about 12 times the size of Osceola Forest and has about 5 1/2 times the driving renewable environmental emergy as compared to Osceola (Tables 9 and 10). When driving emergy is expressed as emdollars the total value of the renewable emergy driving Deschutes and Osceola Forests was $^{em}\$$386.1 million and $^{em}\$$70.2 million respectively. Imported emergy in the form of energy, goods and services when expressed in emdollars totaled $^{em}\$$1.3 million in Osceola and about $^{em}\$$33 million in Deschutes Forest. By far the largest imported emergy in both forests in 2005 was the emergy in visiting tourists which totaled $^{em}\$$124 million in Deschutes and $^{em}\$$6.2 million in Osceola Forest. Exports from Deschutes Forest totaled nearly $^{em}\$$2.2 billion, of which the geopotential energy in water leaving the forest represented about 63% of the total. Harvested timber was $^{em}\$$38 million (see Figure 13). On the other hand Osceola Forest exports totaled $^{em}\$$14.7 million of which harvested wood accounted for about $^{em}\$$8.9 million (see Figure 13).

Emergy Storages of the Deschutes and Osceola National Forests

The assets of the two Forests were nearly equal despite the difference in their relative sizes (Tables 11 and 12 and Figure 14). Ecological assets in the Deschutes and Osceola Forests totaled $^{em}\$$19.9 billion and $^{em}\$$16.6 billion respectively. Soil organic matter and tree biomass were the two largest assets categories in Deschutes (59.3% and 30.6%) while the largest ecological assets in the Osceola Forest were the ground water aquifer (49.8%) and peat (28.0%). Roads dominated the economic assets of both Forests totaling $^{em}\$$3.1 billion and $^{em}\$$1.0 billion in Deschutes and Osceola respectively. We had data to estimate the quantity of phosphate in subsurface formations in the Osceola Forest which totaled $^{em}\$$216.6 billion. Cultural assets which included Native American artifacts and critical species totaled $^{em}\$$2.2 trillion and $^{em}\$$174 billion for the Osceloa and Deschutes forests respectively.

SUMMARY AND CONCLUSIONS

The assets of the USFS system can be divided into environmental assets, which are sometimes called natural capital, economic assets (roads buildings etc.); geologic assets, often referred to as nonrenewable resources; and what we have termed cultural assets, or storages that have very high value because of their rarity. By far, the very rare artifacts and critical species have the highest emdollar values, totaling $^{em}\$11.4$ trillion and $^{em}\$32.7$ trillion respectively. Estimates of the emdollar value of biodiversity suggest they are worth $^{em}\$209$ trillion and genetic resources on USFS lands are valued at $^{em}\$154.1$ quadrillions. Extreme values such as these are indicative of values outside the moneyed economy. Since emergy is a measure of "replacement value" it is not extraordinary that the genetic resources have such extreme values.

Table 13 summarizes the emdollar and market values for a number of services (flows) of the US Forest Service System grouped as those with market values and those having no market value. The emdollar value of services with market values totaled $^{em}\$1.45$ trillion, while the market dollar value totaled $177.0 billion. The emdollar value was about 2.5 times that of the dollar value. By far the largest service of the forest system when evaluated in emdollars is organized recreation that was estimated as the emergy value of tourists visiting the USFS system on an annual basis ($^{em}\$1.33$ trillion). The largest service in economic terms is the estimated market value of water flowing out of Forest Service lands ($127.1 billion).

Of the non-market services, the emergy value of clean water (estimated as the total rainfall of USFS lands) was $^{em}\$42.7$ billion and clean air was estimated to be valued at $^{em}\$6.9$ billion. Total emdollar value of ecosystem functions including gross and net production and respiration were $^{em}\$1.3$, $^{em}\$0.5$, and $^{em}\$0.8$ billion respectively. Finally the value of scientific information generated by USFS scientists was $^{em}\$0.14$ billion. As a result of a our inability of estimating emergy values, several non market services including: pollination, seed dispersal, and predator control were not evaluated.

Table 14 summarizes the emdollar and dollar values for USFS assets grouped as those with market values and those having no market value. The emdollar value of coal was the largest of the assets with market values (totaling $^{em}\$4.0$ trillion and dollar value of $73.4 billion). USFS timber values when values in dollars and emdollars show marked difference. The Emdollar value of timber was $^{em}\$1.47$ trillion while the dollar value was about $147 billion. Dollar value of real estate were about 22 times greater that the emdollar values ($960 billion versus $^{em}\$43$ billion). Overall ,the total emdollar value of USFS assets having market values was $^{em}\$9.4$ trillion while the dollar value totaled $2.67 trillion. Emdollar values were about 3.5 times the dollar values.

Of the non-market assets by far the emdollar value of geologic formations was the largest, totaling $^{em}\$2.67$ quintillion (10^{18}), followed by genetic resources totaling $^{em}\$154.1$ quadrillion (10^{15}) and biodiversity ($^{em}\$209.1$ trillion)

In all, the USFS annual budget allocation in 2005 was about $4.9 billion. When compared to environmental services obtained from USFS lands ($^{em}\$1.5$ trillion) the budget allocation is about 0.3% of the services and when compared to the values of natural capital the budget is miniscule. Total exports from Forest Service lands were estimated to be worth $^{em}\$299.6$ billion or more than

60 times the USFS annual budget in 2005. The value of endangered species found on USFS lands, were estimated at nearly 6600 times the annual USFS budget, and if the values of biodiversity and genetic resources are included the annual budget appears diminishingly small in comparison.

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Table 1. Definitions of terms

Available Energy - Potential energy capable of doing work and being degraded in the process (units: kilocalories, Joules, etc.)
Useful Energy - Available energy used to increase system production and efficiency
Power - Useful energy flow per unit time
Emergy - Available energy (exergy) of one kind previously required directly and indirectly to make a product or service (units: emjoules, emkilocalories, etc.)
Empower - emergy flow per unit time (units: emjoules per unit time)
Transformity - emergy per unit available energy (units: emjoule per joule)
Solar emergy - Solar energy required directly and indirectly to make a product or service (units: solar emjoules)
Solar Empower - Solar emergy flow per unit time (units: solar emjoules per unit time)
Emergy Intensity - Emergy of one kind required to produce a product or service per unit of output of the product or service. There are two types of EIs: transformity and specific emergy
Solar Transformity - Solar emergy per unit available energy (units: solar emjoules per Joule)
Specific Emergy (solar) – Solar emergy per mass of a product (units: solar emjoules per gram)
Emdollars, (^{Em}$) - Dollars of gross economic product due to an emergy contribution's proportion of the national empower

(after Odum, 1996).

Table 2. Previous research projects using emergy synthesis

2004-07	Agency: UNEP. M.T. Brown & Matt Cohen Co-PIs. Emergy Accounting and Systems Synthesis of Land Management Interventions at Multiple Scales in the Sahel Region of West Africa. Part of a larger research effort titled: An Ecosystem Approach to Restoring West African Drylands and Improving Rural Livelihoods through Agroforestry-based Land Management Interventions
1997-98	Agency: USDA Coweeta Hydrologic Laboratory. M.T. Brown, PI. Emergy Evaluation & Simulation Models for the Wine Spring Creek Watershed & Blue Ridge Mtns. of NC. Research project for emergy analysis of management options of national forests using forests in the Blue Ridge Mountains of North Carolina as a case study (Tilley, 1999).
1993-94	Agency: Florida Department of Community Affairs. M.T. Brown, PI: Options and Perspectives for Florida's Future Energy Policy. Emergy analysis of community redevelopment in south Florida following the Hurricane Andrew disaster and analysis of alternative energy sources and efficiency technologies (Brown et al., 1995).
1990-92	Agency: Office of the Governor, Nayarit, Mexico. M.T. Brown, PI: Policy Perspectives and Master Planning for the State of Nayarit, Mexico. Development of a master plan and the necessary governmental and regulatory initiatives for the protection of the natural resources of the coastal zone of the State of Nayarit, Mexico. Funded by the Government of Nayarit through the Cousteau Society (Brown et al., 1992).
1990-91	Agency: The Cousteau Society, M.T. Brown, PI: Energy Evaluation of the Impacts and Mitigation of the Exxon Valdez Oil Spill in Alaska. Environmental and social impact evaluation of the Exxon Valdez oil spill and the costs and benefits of various mitigation and prevention alternatives (Brown et al., 1993).
1994-90	Agency: National Science Foundation, M.T. Brown, co-principle investigator: Methods for Evaluating Ecological Engineering. Development of energy analysis techniques to evaluate and rank ecological systems and environmental technologies. The methods developed are used to evaluate environmental impacts and assess sustainable development.
1988	Agency: The Cousteau Society. H.T Odum and M.T. Brown, Co-PIs: Energy Analysis and Public Policy Perspectives for Papua New Guinea. Evaluation of pressing resource questions, and policy recommendation for effective resource management and sustainable development. Included evaluations of forestry development projects, shrimp fishery, tourism, and foreign trade (Doherty et al., 1992).
1986-87	Agency: The Cousteau Society. M.T.Brown, PI: Energy Analysis and Public Policy Perspectives for the Sea of Cortez, Mexico. Evaluation of pressing resource questions, and policy recommendations for effective resource management and sustainable development. Included evaluations of the effect of the Colorado River diversions, shrimp fishery, and foreign trade (Brown et al., 1988).
1983-87	Agency: The Cousteau Society, H.T Odum and M.T. Brown, Co-PIs: Energy Analysis and Public Policy Perspectives for the Amazon Basin. Evaluation of pressing resource questions, and policy recommendations for effective resource management and sustainable development. Included evaluations of tropical forestry (Jari Forestal), hydroelectric development, alternative energy sources, foreign trade and simulation models of impacts of development on the economy and ecology of the Amazon (Odum et al., 1986).
1974-77	Agency: U.S. Department of Interior, H.T Odum and M.T. Brown, Co-PIs. The South Florida Study: Carrying Capacity for Man and Nature in South Florida. Systems ecology study and energy analysis of the Kissimmee/Everglades Basin, its environment, water, and human economies, including management suggestions for maximizing long term values (Odum and Brown, 1976).

Table 3. Abbreviated work plan

I. Working with USDA Forest Service staff
   1. Identify system boundaries for regional evaluations,
   2. Draw system diagrams for regional systems,
   3. Assemble data for regional analyses,

II. Conduct regional analyses
   1. Evaluate quantities of energy, materials and services that are driving the regional systems,
   2. Evaluate storages within system boundaries,
   3. Calculate indices for comparison of storages and flows within Forest Service regions.

III. Working with USDA Forest Service staff
   1. Identify two forests for case study evaluations,
   2. Draw system diagrams of each system,
   3. Assemble data for regional analyses,

IV. Conduct evaluations of case studies
   1. Evaluate quantities of energy, materials and services that are driving each system,
   2. Evaluate storages within system boundaries,
   3. Calculate indices for comparison of storages and flows between each case study and for comparison with economic values.

V. Summarize values of natural capital and environmental services for the entire Forest Service System

Table 4. Example emergy synthesis table

1 Note	2 Item	3 Raw Units	4 Emergy Intensity	5 Solar Emergy	6 Emdollars
1	Name 1…	Data 1…	EI_1	Col 3 * Col 4	Col 5/sej/$
2	Name 2…	Data 2…	EI_2	"	
3…	Name 3…	Data 3…	EI_3	"	
n	Name n…	Data 4…	EI_n	"	

Each row in the table is an inflow or outflow pathway in the aggregated systems diagram; pathways are evaluated as fluxes in units per year. Six columns describe each pathway as follows:

Column 1: (Note) The line number for each pathway, and corresponding footnote number that contains sources and calculations for the item.

Column 2: (Item) The item name that corresponds to the name of the pathway in the aggregated systems diagram.

Column 3: (Raw Units) The actual units of the flow, usually evaluated as flux per year. Most often the units are energy (joules/year), but sometimes are given in grams/year or dollars/year.

Column 4: (Emergy Intensity) EI of the item is often derived from previous studies.

Column 5: (Solar emergy, sej) The product of the raw units in Column 3 and the EI in Column 4.

Column 6: (Emdollars) The result of dividing solar emergy in Column 5 by the emergy-to-money ratio (calculated independently) for the economy of the nation within which the system of interest is embedded.

Table 5. Emergy indices for comparative evaluation

Emergy Investment Ratio. The Investment Ratio is the ratio of purchased inputs to a process to free renewable emergies derived from local sources. The name is derived from the fact that it is a ratio of "invested" emergy to resident emergy. The Investment Ratio is a dimensionless number: the bigger the Investment Ratio the greater the intensity of development.

Empower Density. The ratio of total emergy use in a process to the total area. Renewable and nonrenewable empower density are also calculated separately by dividing the total renewable emergy by area and the total nonrenewable emergy by area, respectively.

Emergy Yield Ratio. The ratio of the emergy yield from a process to the emergy costs. This ratio is a measure of how much a process will contribute to the economy.

Environmental Loading Ratio. An index of potential environmental impact, the Environmental Loading Ratio is the ratio of nonrenewable emergy to renewable . Low ELRs reflect relatively small environmental loading, while high ELRs suggest greater loading.

(after Odum, 1996; Odum et al., 1998).

Table 6. Summary of the annual emergy flows supporting the US National Forest System*

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^6$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	4.37E+21	1.00E+00	4371.0	2300.5
2	Rain Chemical Potential	J	2.62E+18	3.10E+04	81096.1	42682.1
3	Transpiration	J	1.18E+18	3.06E+04	36087.1	18993.2
4	Rain Geopotential	J	1.08E+18	4.70E+04	50609.1	26636.4
5	Wind, Kinetic	J	3.40E+18	2.45E+03	8326.4	4382.3
6	Hurricanes	J	3.38E+17	6.49E+03	2193.6	1154.5
7	Waves	J	6.07E+17	5.10E+04	30978.9	16304.7
8	Tides	J	1.96E+17	2.43E+04	4756.0	2503.2
9	Earth Cycle	J	2.10E+18	1.20E+04	27257.2	13293.2
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	9.73E+10	1.68E+09	163.5	86.1
10a	Soil OM loss (harvesting)	J	8.04E+13	7.40E+04	5.9	3.1
11	Misc. Products (plants) [1.]	J	2.50E+13	5.04E+04	1.3	0.7
IMPORTS:						
12	Petroleum Products	J	4.04E+15	1.11E+05	450.1	236.9
13	Machinery, Equipment	g	4.95E+09	1.13E+10	55.8	29.4
14	Misc. Goods	g	7.22E+07	1E9 - 7 E9	1.8	0.9
15	Seedlings	$	5.16E+07	1.90E+12	98.1	51.6
16	Tourist Time	J	1.69E+15	1.50E+07	25328.8	13331.0
17	Labor (FS + Contract) [2.]	hours	1.22E+08	6.30E+13	7683.6	4044.0
18	Electricity	J	1.07E+15	2.92E+05	313.5	165.0
19	Misc. Expenditures [2.]	$	2.97E+09	1.90E+12	9264.4	4876.0
ECONOMIC PAYMENTS RECEIVED						
20	Extracted timber	$	2.24E+08	1.90E+12	425.9	224.1
21	Extracted minerals/fuels	$	2.84E+09	1.90E+12	5390.2	2837.0
22	Fee Payments [2.]	$	5.05E+07	1.90E+12	95.9	50.5
EXPORTS:						
23	Extracted Firewood	J	1.17E+16	3.06E+04	358.9	188.9
24	Harvested Wood	J	1.02E+17	5.04E+04	5158.3	2714.9
25	Water, Chemical Potential	J	1.26E+18	8.10E+04	101748.4	53551.8
26	Water, Geopotential	J	2.01E+18	4.70E+04	94618.6	49799.3
27	Minerals	g	4.16E+12	mixed	60553.4	31870.2
28	Fossil Fuels [1.]	J	1.52E+18	mixed	124081.7	65306.2
29	Harvested wildlife	J	5.14E+16	1E5-9.9E5	42846.3	22550.7
30	Harvested Fish	J	9.96E+13	1.68E+07	1673.6	880.8
31	Information (research) [2.]	hrs	1.11E+06	2.35E+14	260.6	137.2

(Continued next page)

Table 6. (continued)

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
32	Hydroelectric Power [1.]	J	5.05E+17	1.20E+05	60743.1	31970.1
33	Image Exported with Tourists	hrs	3.69E+09	1.98E+16	77137.6	40598.7
	ECONOMIC PAYMENTS MADE					
34	State and Local Gov't Payments	$	4.15E+08	1.90E+12	787.7	414.6
35	Payments for Labor [2.]	$	1.32E+09	1.90E+12	2515.1	1323.7

* Data are summarized from regional evaluations given in Appendix A

1. No regional data were available. Quantities in this table from national data (NFS, 2005).

2. Data for regions includes portioned fraction of Washington DC offices and other expenditures not accounted for in regional budgets.

See APPENDIX C for footnotes to Table 6.

Table 7. Summary of the emergy value of US National Forest System assets

Note	Item	Units	Quantity	Emergy Intensities (sej/unit)	Solar Emergy ($x10^{21}$sej)	EmDollars ($x10^9$ Em$)
	ENVIRONMENTAL ASSETS					
1	Tree Biomass	J	7.71E+19	3.62E+04	2791.6	1469.3
2	Herb./Shrub Biomass	J	6.91E+18	17976	124.2	65.4
3	Land Area	ha	7.80E+07	1.05E+15	81.9	43.1
4	Soil OM	J	1.50E+20	1.24E+04	1868.2	983.3
5	Peat	J	3.95E+16	3.09E+05	12.2	6.4
6	Glaciers	g	6.23E+17	6.46E+06	4022.3	2117.0
7	Ground Water	J	2.80E+18	3.02E+05	845.3	444.9
8	Surface Water	J	1.59E+18	8.10E+04	129.1	68.0
9	Fauna	g	3.03E+14	mixed	1075.2	565.9
	ECONOMIC ASSETS					
10	Roads (dirt)	$	1.70E+09	1.90E+12	3.2	1.9
11	Roads (gravel)	g	8.01E+13	1.68E+09	134.6	70.9
12	Roads (paved)	g	4.81E+12	2.77E+09	13.3	7.0
13	Machinery & tools	g	9.90E+10	1.13E+10	1.1	0.6
14	Office Equipment	g	3.84E+10	1.13E+10	0.4	0.2
15	Buildings	g	1.10E+12	mixed	7.2	3.8
	GEOLOGIC ASSETS					
16	Fossil Fuels	J	1.05E+18	mixed	7770.5	4089.8
17	Minerals (Au, Si, Cu, Pb)	g	4.41E+13	7.06E+10	3112.8	1638.3
	CULTURAL ASSETS					
18	Native American Artifacts	J	1.15E+18	1.89E+07	21728.1	11435.8
19	Value of Critical Species	# of spp.	4.96E+02	--	62224.6	32749.8
20	Biodiversity	# of spp	1.08E+04	1.22E+25	397371.7	209143.0
21	Genetic Resources	J	2.40E+17	1.22E+12	292795703.2	154103001.7

See Appendix D for footnotes to table.

Table 8. Summary indices for the USFS system and regions (ca. 2005)

Index*	Unit	USFS	R- 1	R- 2	R- 3	R- 4	R- 5	R- 6	R- 8	R- 9	R-10
R (renewable absorbed)	sej/yr	8.7E+22	4.0E+21	3.7E+21	6.3E+21	9.6E+21	5.6E+21	1.9E+22	7.4E+21	5.6E+21	2.6E+22
N (local nonrenewable)	sej/yr	1.7E+20	3.2E+19	2.0E+19	3.9E+18	2.4E+19	1.1E+19	5.0E+19	7.7E+18	1.9E+19	2.8E+18
Imports (F)	sej/yr	4.3E+22	3.2E+21	5.4E+21	3.8E+21	4.7E+21	6.3E+21	5.3E+21	5.7E+21	3.9E+21	1.0E+21
Exports (B)	sej/yr	4.9E+23	2.1E+22	2.2E+22	3.0E+22	3.5E+22	4.4E+22	5.4E+22	1.8E+22	1.9E+22	2.9E+22
Use (R+N+N0+F)	sej/yr	1.3E+23	7.2E+21	9.1E+21	1.0E+22	1.4E+22	1.2E+22	2.4E+22	1.3E+22	9.5E+21	2.7E+22
Empower Density	sej/m^2/yr	1.7E+11	7.0E+10	1.0E+11	1.2E+11	1.1E+11	1.5E+11	2.4E+11	2.4E+11	1.9E+11	3.1E+11
Renewable EmP. Density	sej/m^2/yr	1.1E+11	3.8E+10	4.2E+10	7.4E+10	7.4E+10	6.8E+10	1.8E+11	1.4E+11	1.1E+11	2.9E+11
Use per Visitor	sej/capita	6.4E+14	5.4E+14	2.8E+14	4.9E+14	6.1E+14	3.9E+14	8.4E+14	4.2E+14	4.2E+14	9.4E+15
Timber Harvest	sej/m^2/yr	6.6E+09	5.5E+09	4.0E+09	2.2E+09	5.5E+09	8.3E+09	1.1E+10	1.4E+10	1.4E+10	1.4E+09
Emergy Yield Ratio (Y/F)		3.01	2.23	1.70	2.65	3.04	1.88	4.50	2.28	2.41	26.06
% renew		0.67	0.55	0.41	0.62	0.67	0.47	0.78	0.56	0.58	0.96
EIR (F/R+N)		0.50	0.81	1.43	0.61	0.49	1.13	0.28	0.78	0.71	0.04
Ratio imports to exports		0.09	0.16	0.24	0.13	0.14	0.14	0.10	0.32	0.21	0.04
Emergy Return on Invest.		11.39	6.38	4.14	7.78	7.37	7.02	10.18	3.11	4.74	27.55
ELR (F+N)/R		0.50	0.82	1.44	0.61	0.49	1.13	0.29	0.78	0.71	0.04
ESI (EYR/ELR)		6.01	2.72	1.18	4.37	6.17	1.67	15.64	2.93	3.39	651.23
Visitors	peo/ha/yr	2.63	1.28	3.64	2.43	1.80	3.76	2.81	5.76	4.60	0.33

* letters refer to flows and indices given in Figures 1 and 2.

Table 9. Annual emergy flows supporting Deschutes National Forest

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{16}$sej)	EmDollars ($x10^6$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	9.28E+16	1.00E+00	9.3	0.0
2	Rain Chemical Potential	J	2.20E+16	3.10E+04	68338.6	359.7
3	Transpiration	J	9.74E+15	3.06E+04	29792.0	156.8
4	Rain Geopotential	J	9.29E+15	4.70E+04	43650.7	229.7
5	Wind, Kinetic	J	4.59E+16	2.45E+03	11240.4	59.2
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	2.33E+16	1.20E+04	27928.2	147.0
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss	g	2.52E+11	1.68E+09	42359.5	222.9
10a.	Top soil loss	J	2.28E+14	7.40E+04	1686.2	8.9
IMPORTS:						
11	Petroleum Products	J	5.83E+13	1.11E+05	649.6	3.4
12	Machinery, Equipment	g	1.36E+08	1.13E+10	154.1	0.8
13	Misc. Goods	g	1.19E+06	2.49E+10	3.0	0.0
14	Seedlings	g	2.05E+07	4.70E+09	9.6	0.1
15	Tourist Time	J	1.58E+13	1.50E+07	23693.7	124.7
16	Labor	hours	8.14E+05	6.30E+13	5128.2	27.0
17	Electricity	J	1.54E+13	2.92E+05	450.5	2.4
ECONOMIC PAYMENTS RECEIVED						
18	Payment for timber	$	4.86E+06	1.90E+12	924.2	4.9
19	Payments for minerals extracted	$	6.44E+04	1.90E+12	12.2	0.1
20	Fee Payments (hunting, grazing, etc)	$	3.15E+06	1.90E+12	597.8	3.1
EXPORTS:						
21	Extracted Firewood	J	1.68E+14	3.60E+04	606.5	3.2
22	Harvested Saw Timber	J	1.44E+15	5.04E+04	7277.9	38.3
23	Water Chemical Energy	J	1.36E+16	8.10E+04	109812.1	578.0
24	Water Geopotential Energy	J	3.36E+16	7.77E+04	261072.1	1374.1
25	Minerals	g	1.07E+10	1.96E+09	2106.6	11.1
26	Harvested wildlife	J	2.31E+13	6.7E5-3E10	3370.8	17.7
27	Harvested Fish	J	1.71E+13	1.68E+07	28695.4	151.0
28	Information (research)	$	1.20E+04	2.35E+14	282.0	1.5
33	Image Exported with Tourists	hrs	3.64E+07	5.59E+13	203454.9	1070.8
ECONOMIC PAYMENTS MADE						
29	Payments to State and Local Gov't	$	8.46E+06	1.90E+12	1607.3	8.5
30	Payments for Labor	$	1.28E+07	1.90E+12	2424.4	12.8

See Appendix E for footnotes to table

Table 10. Annual emergy flows supporting Osceola National Forest

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{16}$sej)	EmDollars ($x10^3$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	3.14E+18	1.00E+00	314.4	1654.9
2	Rain Chemical Potential	J	4.02E+15	3.10E+04	12471.8	65641.1
3	Transpiration	J	3.13E+15	3.06E+04	9584.7	50445.9
4	Rain Geopotential	J	7.98E+14	4.70E+04	3751.2	19742.9
5	Wind, Kinetic	J	1.32E+15	2.45E+03	322.4	1696.8
6	Hurricanes	J	1.13E+12	6.49E+03	0.7	3.9
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	6.83E+14	5.80E+04	3961.1	20848.0
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	0	1.68E+09	0.0	0.0
10a.	Soil OM loss (harvesting)	J	0	7.40E+04	0.0	0.0
IMPORTS:						
11	Petroleum Products	J	1.10E+12	1.11E+05	12.2	64.4
12	Machinery, Equipment	g	1.29E+07	1.13E+10	14.6	76.6
13	Misc. Goods	g	0	1E9 - 7 E9	0.0	0.0
14	Seedlings	$	8.93E+04	1.90E+12	17.0	89.3
15	Tourist Time	J	7.84E+11	1.50E+07	1171.7	6166.7
16	Labor	hours	2.28E+04	6.30E+13	143.8	756.7
17	Electricity	J	8.76E+11	2.92E+05	25.6	134.6
18	FS Budget Misc.	$	9.57E+04	1.90E+12	18.2	95.7
19	Services	$	4.20E+04	1.90E+12	8.0	42.0
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	9.65E+05	1.90E+12	183.3	964.6
21	Payments for minerals	$	0	1.90E+12	0.0	0.0
22	Fee Payments	$	3.47E+04	1.90E+12	6.6	34.7
EXPORTS:						
23	Misc. Products (plants)	J	2.66E+10	1.80E+04	0.0	0.3
24	Extracted Firewood	J	5.01E+10	3.60E+04	0.2	0.9
25	Harvested Wood	J	3.36E+14	5.04E+04	1695.1	8921.8
26	Water, Chemical Potential	J	2.79E+14	3.10E+04	864.3	4549.2
27	Water, Geopotential	J	6.08E+12	7.77E+04	47.3	248.7
28	Minerals	g	0	5E8 - 3E12	0.0	0.0
29	Harvested wildlife	J	5.30E+10	3.36E+06	17.8	93.7
30	Harvested Fish	J	9.59E+10	1.68E+07	161.2	848.3
31	Information (research)	$	1.10E+04	1.90E+12	2.1	11.0
32	Image Exported w/ Tourists	hrs	1.80E+06	6.37E+13	11462.0	60326.5
ECONOMIC PAYMENTS MADE						
33	State and Local Gov't	$	5.94E+05	1.90E+12	112.9	594.2
34	Labor Payments	$	4.50E+05	1.90E+12	85.5	450.3

See Appendix E for footnotes to table.

Table 11. Summary of the value of Deshutes National Forest assets (ca. 2005)

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{16}$sej)	EmDollars ($x10^{6}$ Em$)
ECOLOGICAL ASSETS (Natural Capital)						
1	Tree Biomass	J	3.19E+17	3.62E+04	1153988.8	6073.6
2	Herbaceous/Shrub Biomass	J	1.02E+16	17976	18273.8	96.2
3	Land Area	ha	7.50E+05	1.05E+15	78733.3	414.4
4	Soil OM	J	1.80E+18	1.24E+04	2241225.2	11795.9
5	Ground Water (drinking aquifer)	J	6.87E+15	3.02E+05	207788.6	1093.6
6	Surface Water	J	9.54E+15	8.10E+04	77289.5	406.8
ECONOMIC ASSETS						
7	Roads (dirt)	$	4.25E+07	1.90E+12	8067.0	42.5
8	Roads (gravel)	g	2.01E+12	1.68E+09	338237.1	1780.2
9	Roads (paved)	g	8.89E+11	2.77E+09	246322.2	1296.4
10	Machinery & tools	g	1.97E+09	1.13E+10	2219.1	11.7
11	Office Equipment	g	5.93E+09	1.13E+10	6678.4	35.1
12	Buildings	g	1.63E+11	mixed	102339.1	538.6
SOCIETAL ASSETS						
13	Info. in Archeological Artifacts	J	7.64E+15	1.22E+07	9308988.1	48994.7
14	Value of Critical Species	# of Spp	6.00E+00	mixed	2.4E+07	124973.7

See Appendix F for footnotes to table

Table 12. Summary of the value of Osceola National Forest assets (ca. 2005)

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{16}$ sej)	EmDollars ($x10^6$ Em$)
	ECOLOGICAL ASSETS (Natural Capital)					
1	Tree Biomass	J	4.46E+16	3.62E+04	161497.7	850.0
2	Herbaceous/Shrub Biomass	J	5.41E+16	17976	97193.5	511.5
3	Land Area	ha	6.54E+04	1.05E+15	6867.0	36.1
4	Soil OM	J	3.47E+17	1.24E+04	431156.4	2269.2
5	Peat	J	2.85E+16	3.09E+05	881020.6	4637.0
6	Ground Water (drinking aquifer)	J	5.19E+16	3.02E+05	1568743.4	8256.5
7	Surface Water	J	5.14E+14	8.10E+04	4161.5	21.9
	ECONOMIC ASSETS					
8	Roads (dirt)	$	3.19E+06	1.90E+12	606.5	3.2
9	Roads (gravel)	g	2.60E+11	1.68E+09	43677.0	229.9
10	Roads (paved)	g	5.32E+11	2.77E+09	147470.4	776.2
11	Machinery & tools	g	1.72E+08	1.13E+10	194.0	1.0
12	Office Equipment	g	2.58E+08	1.13E+10	290.0	1.5
13	Buildings	m^2	3.52E+03	mixed	253.8	1.3
	GEOLOGIC ASSETS					
14	Phosphorus	g	9.07E+13	4.54E+09	41149899.8	216578.4
14b	Phosphorus	$	2.27E+09	1.90E+12	430912.8	2268.0
	Cultural ASSETS					
15	Info. in Archeological Artifacts	J	1.01E+16	1.22E+07	12276512.9	64613.2
16	Value of Critical Species)	# of spps	3.00		29088118.1	153095.4

See Appendix F for footnotes to table

Table 13. Emergy , emdollar, and economic value of services of the National Forest System (ca. 2005)

Note	Parameter	Emergy Value (10^{21} sej)	Emdollars* (10^9 Em$)	Dollar Value (10^9 $)
Services with Market Value				
1	Research	0.2	0.1	0.02
2	Organized recreation	2535.4	1,334	9.2
3	Sales, Permits and Concessions	5.9	3.1	3.1
4	Hydroelectric energy	60.7	32.0	11.2
5	Water supply	101.7	53.6	127.1
6	Carbon sink	2.4	1.3	1.4
7	Watershed protection	3.8	2.0	19.9
8	Wildlife hunting	42.8	22.6	2.9
9	Fish Harvest	1.7	0.9	1.3
10	Wildlife watching	0.1	0.1	0.8
		TOTAL Market Services/yr.	**1449.9**	**177.0**
Non-Market Services				
11	Clean air	13.2	6.9	--
12	Clean water	81.1	42.7	--
13	Pollination	NA	--	--
14	Seed dispersal	NA	--	--
15	Predator control	NA	--	--
16	Gross primary productivity	2.4	1.3	--
17	Net primary productivity	1.0	0.5	--
18	Total respiration	1.4	0.8	--
19	Scientific information	0.26	0.14	--
		TOTAL NonMarket Services/yr.	**52.3**	**0.0**

* Emdollars are calculated by dividing emergy in column 3 by 1.9 E12 sej/$, the average ratio of emergy to money in the USA economy

Notes to Table 13.

1 **Research**

1. Emergy of FS personnel engaged in research activities.

Number of staff =	486	USFS, 2007
Emergy/ person =	4.704E+17	Odum, 1996
Emergy (sej) =	2.29E+20	

2. Economic costs of research (Salary)

Dollar costs = $20,416,365

2 **Organized recreation**

1. Emergy of tourists

Notes to Table 13.cont'd

Emergy of tourists (sej)	= 2.54E+24	Table 6, Note 16
2. Tourists economic expenditures for recreation		
Number of tourists	= 2.05E+08	Table 6, Note 16
Travel costs	= $45	Estimate
Dollar expenditures	= 9.2E+09	
3 Sales, Permits and Concessions		
1. Emergy equivalent of dollars = (dollars)* (1.9 E12 sej/$)		
Emergy (sej)	= 5.89E+21	
2. FS income from concessions and permits		
Dollar income	= $3,100,000,000	USFS, 2007
4 Hydroelectric energy		
1. Emergy value of hydroelectricity		
Emergy (sej)	= 6.07E+22	Table 6, Note 32
2. Dollar value hydroelectricity generated		
Avg price	= $ 0.08/kwh	Estimate
Total generated (kwh)	= 1.40E+11	USFS, 2007
Dollar value	= $11,200,000,000	
5 Water supply		
1. Emergy value of outflowing surface water		
Emergy (sej)	= 1.02E+23	Table 6, Note 25
2. Dollar value		
Price ($/$m^3$)	= 0.50	USEPA, 1999
Volume of water (m^3)	= 2.54E+11	Table 6, Note 25
Dollar value	= $127,141,046,382	
6 Carbon sink		
1. Emergy value of gross primary production (emergy driving GPP)		
Emergy (sej)	= 2.40E+21	Table 6, Note 3
2. Dollar value		
Price ($/tonn)	= $3	USFS, 2007
Quantity (tonn/ha)	= 6	USFS, 2007
Area (ha)	= 7.80E+07	
Dollar value	= $1,404,000,000	
7 Watershed protection		
1. Emergy value of Rainfall.		
Emergy (sej)	= 3.84E+21	Table 6, Note 2
2. Costs of watershed protection		
Cost ($/ha)	= $255	Estimate; NRCS (2005)
Area (ha)	= 7.80E+07	

Dollar value =	$19,890,000,000	

8 Wildlife hunting

Notes to Table 13.cont'd

1. Emergy of wildlife harvested

Emergy (sej) =	4.28E+22	Table 6, Note 29

2. Estimated dollar expenditures for hunting

Number of hunters =	1820000	USFS land = 35% of hunting on public lands
Expenditure/ hunter =	$1,585	USFWS (2002)
Total expenditures =	$2,884,000,000	

9 Fish Harvest

1. Emergy of fish harvested

Emergy (sej) =	1.67E+21	Table 6, Note 30

2. Estimated dollar expenditures for fishing

Number persons fishing =	1261700	estimate =3.7% of total fishers
Expenditure/fisher =	$1,044	USFWS (2002)
Total expenditures =	$1,317,200,000	

10 Wildlife watching

1. Emergy of tourists

Number of wildlife watchers =	806600	estimate =3.7% of total watchers
Emergy/person (sej/person)=	1.25E+14	Table 6, Note 16
Emergy (sej) =	1.01E+20	

11 Clean air

Emergy value airborne particulate deposition

Deposition (g/cm^2)=	1.00E-03	USFS, 2007

Total quantity (g/yr) = Area * deposition

Quantity (g/yr) =	7.80E+12	
Specific Emergy (sej/g) =	1.69E+09	Odum (2000)
Emergy (sej/yr) =	1.32E+22	

12 Clean water

Emergy value of rainfall

Emergy (sej/yr)=	8.11E+22	Table 7, Note 2

13 Pollination

No estimate available

14 Seed dispersal

No estimate available

15 Predator control

No estimate available

Notes to Table 13.cont'd

16 **Gross primary productivity**

Emergy value of gross primary production (emegy driving GPP)

Emergy (sej) = 2.40E+21 Table 6, Note 3

17 **Net primary productivity**

Emergy value of net primary production (40% GPP)

Emergy (sej) = 9.60E+20 Table 6, Note 3

18 **Total respiration**

Emergy value of respiration (60% GPP)

Emergy (sej) = 1.44E+21 Table 6, Note 3

19 **Scientific information**

Annual production of information

Emergy (sej/yr) = 2.61E+20 Table 7, Note 31

Table 14. Emergy , emdollar, and economic value of assets of the National Forest System (ca. 2005)

Note	Parameter	Emergy Value (10^{21} sej)	Emdollars (10^{9} Em$)	Dollar Value (10^{9} $)
Assets With Market Value				
1	People (employees)	5.3	2.8	1.3
2	Building Infrastructure	7.2	3.8	4.4
3	Machinery, Vehicles	1.1	0.6	0.5
4	Roads	151.2	79.6	15.0
5	Timber	2791.6	1469.3	147.7
6	Water (surface)	129.1	68.0	323.0
7	Water (ground)	845.3	444.9	102.0
8	Biomass fuel	2915.8	1534.7	189.0
9	Minerals	3112.8	1638.3	120.0
10	Real estate	81.9	43.1	960.0
11	Coal	7611.1	4005.8	73.4
12	Gas	27.8	14.6	8.9
13	Oil	159.0	83.7	721.5
14	Shale	NA	--	NA
15	Peat	12.2	6.4	0.004
16	Mushrooms	NA	--	0.0003
17	Exotic plants	NA	--	--
18	Food such as fruits	NA	--	small
19	Medicinal plants and animals	NA	--	--
20	Seeds	NA	--	small
21	Other forest products	NA	--	0.003
		TOTAL Market Assets	**9,396**	**2,667**
Non-Market Assets				
22	Soil	1,868	983	--
23	Old growth biomass	531	280	--
24	Wildlife	1,075	566	--
25	Endangered wildlife	62,225	32,750	--
26	Topography	1,490,580	784,516	--
27	Geologic formations	5,070,000,000	2,668,421,053	--
28	Priceless locations	2,573	1,354	--
29	Panorama	NA	--	--
30	Knowledge	370	195	--
31	Native American Artifacts	22	11	--
32	Biodiversity	397,372	209,143	--
33	Genetic resources	292,795,703	154,103,002	--
		TOTAL NonMarket Assets	**2,823,553,852**	**--**

* Emdollars are calculated by dividing emergy in column 3 by 1.9 E12 sej/$, the average ratio of emergy to money in the USA economy

Notes to Table 14.

1	**Employees**		
	1. Emergy value of employees	31, 511 people	
	Emergy per capita	1.68E+17	Odum, 1996
	Emergy =	Employees * Emergy percapita	
	Emergy =	5.3E+21	
	2. Total salary =	$1,323,745,000	USFS, 2006
2	**Building Infrastructure**		
	1. Emergy value of bldg =	7.18E+21	Table 7, Note 15
	2. Total dollar value =	$4,394,513,173	USFS, 2006 unpub.
3	**Machinery, Vehicles**		
	1. Emergy in machines, equip.=	1.11E+21	Table 7, Note 13
	2. Dollar value of machines =	$547,356,612	USFS, 2006 unpub.
4	**Roads**		
	1. Emergy in roads by class =	1.51E+23	Table 7, Notes 10, 11, 12
	2. Total dollar value =	$15,000,000,000	USFS, 2006 unpub.
5	**Timber**		
	1. Emergy in standing stock =	2.79E+24	Table 7, Note 1
	2. Total dollar value =	Wholesale - $250/1000 bd ft	USFS, 2007
	Dollar value =	$147,740,374,482	USFS, 2007
6	**Water (surface)**		
	1. Emergy of water volume =	1.29E+23	Table 7, Note 8
	2. Dollar price of water =	3.23 E11 m^3 * $1.00/$m^3$	Estimate
	Dollar value =	$323,000,000,000	
7	**Water (ground)**		
	1. Emergy value of groundwater =	8.45E+23	Table 7, Note 9
	2. Dollar price of water =	5.67E11 m3,	
	specific yield =	18%	
	price =	$2.00/1000 gal	Estimate
	Dollar value =	Volume * Sp.Yield*price	
	Dollar value =	$102,024,291,498	
8	**Biomass fuel**		
	1. Emergy value of total biomass =	2.92E+24	Table 7, Notes 1 & 2
	2. Dollar value of biomass =	5.4E12. Kg /1000 kg/tonn* $35/tonn	Estimate
	Dollar value =	$189,000,000,000	
9	**Minerals**		
	1. Emergy of minerals by type =	3.11E+24	Table 7, Note 17
	2. Dollar value =	$120,000,000,000	USGS, 2005

Notes to Table 14 cont'd

10	**Real estate**		
	1. Emergy value of lands =	8.19E+22	Table 7, Note 3
	2. real estate value =	192.7E6 acres* $500/acre	Estimate
	Dollar value =	$96,000,000,000	
11	**Coal**		
	1. Emergy value =	7.61E+24	Table 7, Note 16
	2.Dollar value =	4.59E9 mt @ $16 per metric ton	
	Dollar value =	$73,440,000,000	Citation
12	**Gas**		
	1. Emegy in natural gas reserves =	2.78E+22	Table 7, Note 16
	2. Dollar value of reserves =	2.26E17 J @ $1.5 per Mmbtu	
	Dollar value =	$8,940,147,610	
13	**Oil**		
	1. Emergy in petroleum reserves =	1.59E+23	Table 7, Note 16
	2. Dollar value of reserves =	1.11E10 barrels @ $65/barrel	Estimate
	Dollar value =	$721,500,000,000	
14	**Shale**		
	No data available		
15	**Peat**		
	1. Emergy in peat =	1.22E+22	Table 7, Note 5
	2. Dollar value of peat =	1.27E6 m^3 * $2.80/m3	Estimate
	Dollar value =	$3,559,927	
16	**Mushrooms**		
	1. emergy in mushrooms =	mass harvested not available	
	2. Dollar value =	$279,803	USFS, 2005
17	**Exotic plants**		
	No data available		
18	**Food (nuts, fruits)**		
	1. emergy in foods =	mass harvested not available	
	2. Dollar value =	$9,200	USFS, 2005
19	**Medicinal plants and animals**		
	No data available		
20	**Seeds**		
	1. Emergy in standing stock =	mass harvested not available	
	2. Dollar value =	$8,728	USFS, 2005
21	**Other forest products**		
	1. Emergy in standing stock =	mass harvested not available	
	2. Dollar value =	$3,084,232	USFS, 2005

Notes to Table 14 cont'd

22 **Soil**

Emergy in Soil Organic matter = 1.87E+24 — Table 7, Note 4

23 **Old growth biomass**

Emergy in standing stock= Assume 10% of tree biomass is old growth

Tree biomass = 7.71E19 J

Old growth = 7.71 E18 J

Transformity = 6.89E+04 — Odum, 1996

Emergy = 5.31E+23

24 **Wildlife**

Emergy in standing stock = 1.08E+24 — Table 7, Note 9

25 **Endangered wildlife**

Emergy in standing stock = 6.22E+25 — Table 7, Note 19

26 **Topography**

Emergy value of elevation = mass* gravitational potential

Avg. elevation = 1000m

Density = 2.6 E3 kg/m^2

Area = 7.8 E11 m^2

Energy = (Avg..elev.)(area)(9.8 m/sec2)(density)

Energy (J) = 1.98744E+21

Transformity = 7.5E5 sej/J — Odum, 2000

Emergy (sej) = 1.49058E+27

27 **Geologic Formations**

Emergy value of geologic form. = mountain mass * specific emergy

Avg. elevation = 1000 m

Area= 7.8 E11 m^2

Mass = (1000m)(2.6E3kg/m^3)(7.8E11m^2)

Specific Emergy (sej/g)= 2.50E+09 — Odum, 2000

Emergy (sej)= 5.07E+30

28 **Priceless locations**

Assume value of total content embodied in USFS lands

Continental area = 2.45 E7 km^2

Transformity = 1.05E15 sej/ha — Odum, 2000

Emergy = (area)(transformity)

Emergy (sej) = 2.5725E+24

29 **Panorama**

No data available

30 **Knowledge**

Emergy value of knowledge = emergy in experience

Notes to Table 14 cont'd

Employees =	31, 511 people	
Emergy per capita =	3.36E+17	Odum, 1996
Average age =	35 years	Estimate
Emergy =	(Employees) (Emergy per capita)(age)	
Emergy (sej) =	3.7E+23	

31 **Native American Artifacts**

Emergy in artifacts =	2.17E+22	Table 7, Note 18

32 **Biodiversity**

Emergy (sej) =	3.97E+26	Table 7, Note 20

33 **Genetic resources**

Emergy (sej) =	2.93E+29	Table 7, Note 21

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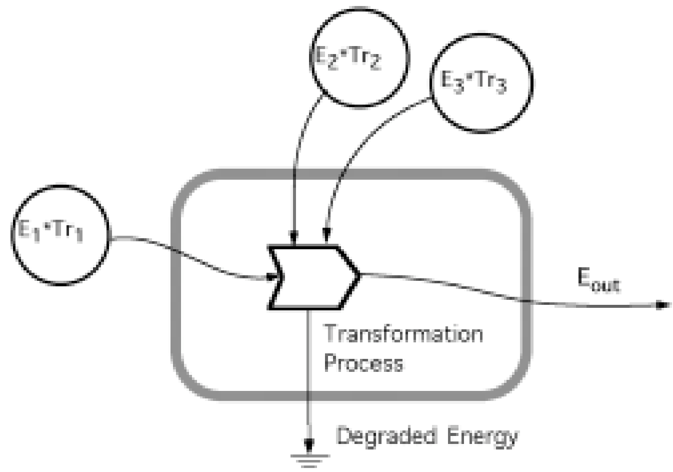


$$Em_{out} = \sum E_n * Tr_n$$

$$Tr = Em_{out} / E_{out}$$

Where;

$E_{1...n}$ = Available energy inputs
E_{out} = Available energy of output
Em = Emergy
Tr = Transformity

Figure 1. Diagram illustrating calculation of transformities.
In all processes, some energy is degraded and some is transformed into higher quality energy. The energy out is equal to the sum of the input energies minus the degraded energy. The emergy out is equal to the sum of the input emergies. The equations at the bottom of the figure show the general calculation of emergy of a product.

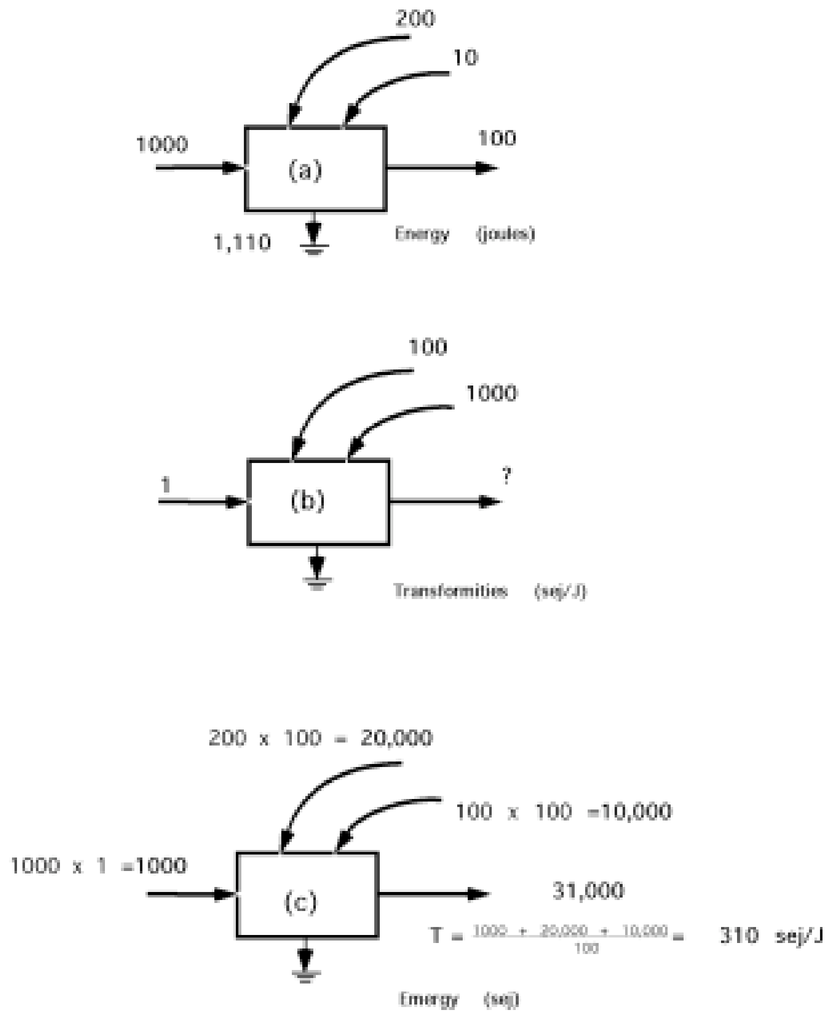


Figure 2. Diagram illustrating method of calculating transformity.
a) energy flows; b) transformity of the output is calculated by dividing the emergy of the output in (c) by the energy of the output in (a).

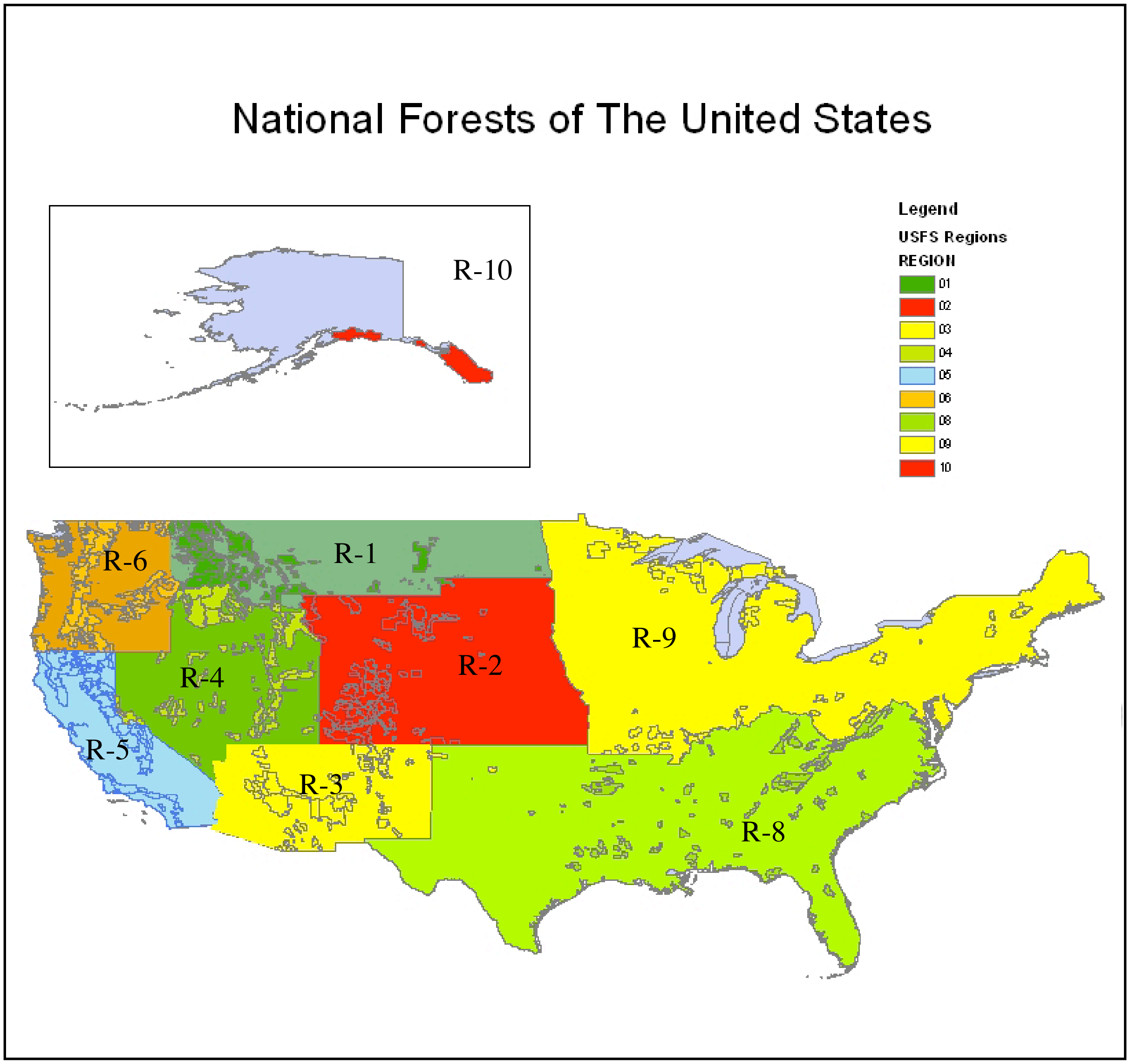


Figure 3. Map of the US Forest Regions.
Each region was evaluated separately and then summed for the total USFSS. (Note: there is no longer a Region 7 within the Forest Service system following a reorganization of regional boundaries).

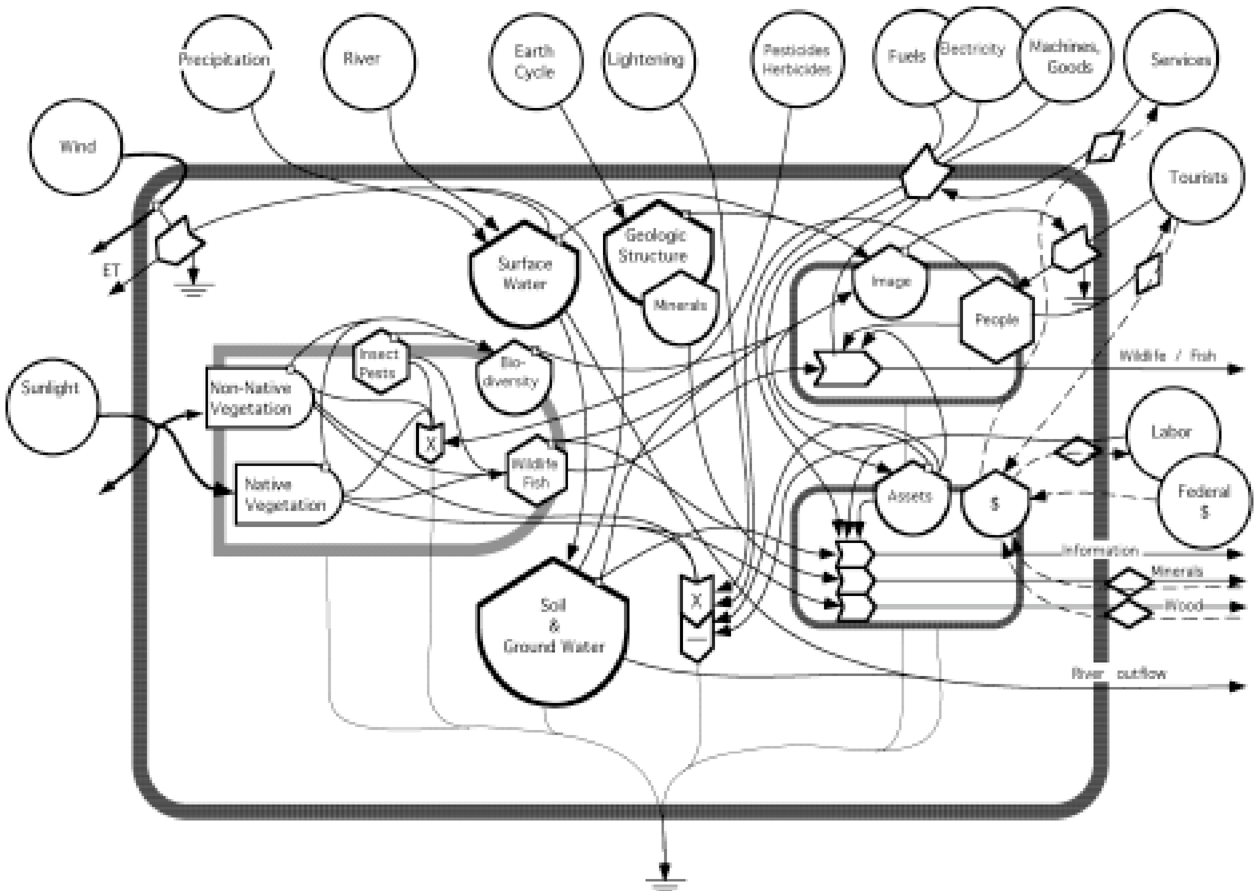
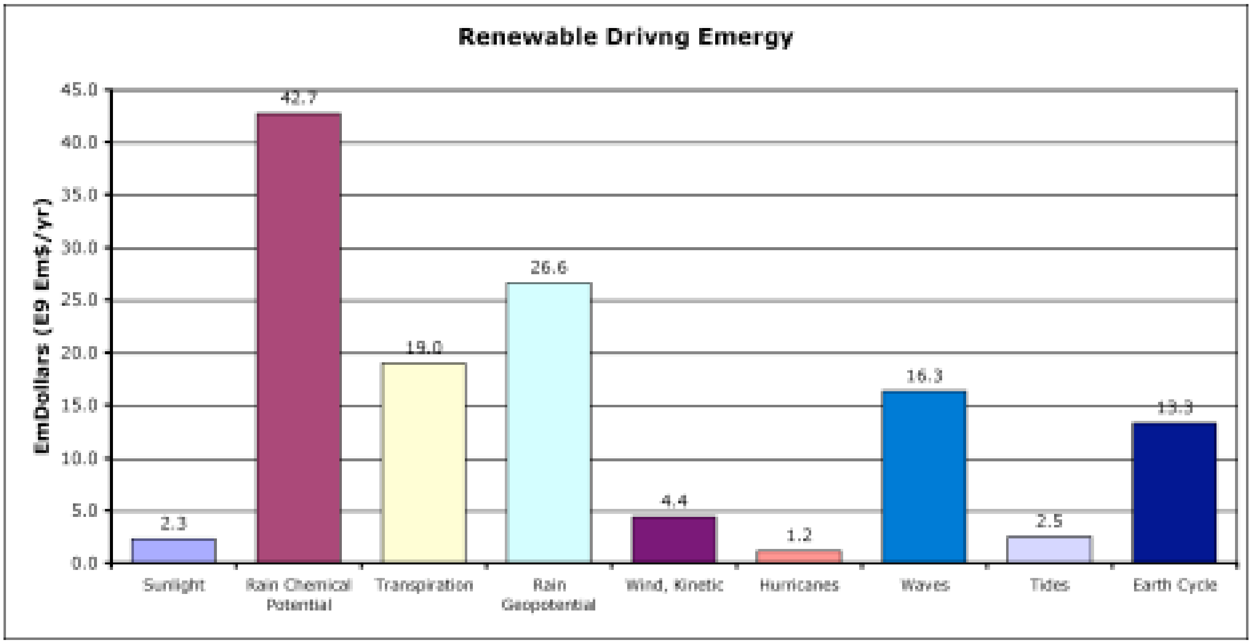


Figure 4. System diagram of the US National Forest System,
showing main driving energies, components, pathways of energy, material and information flows, and exports.



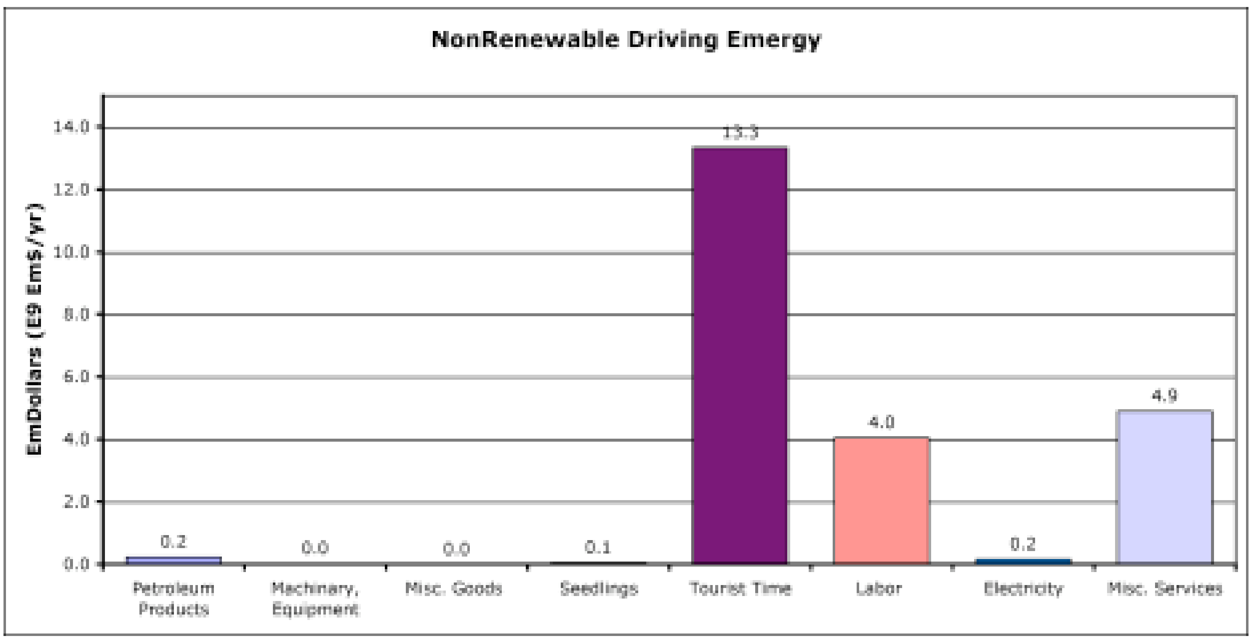
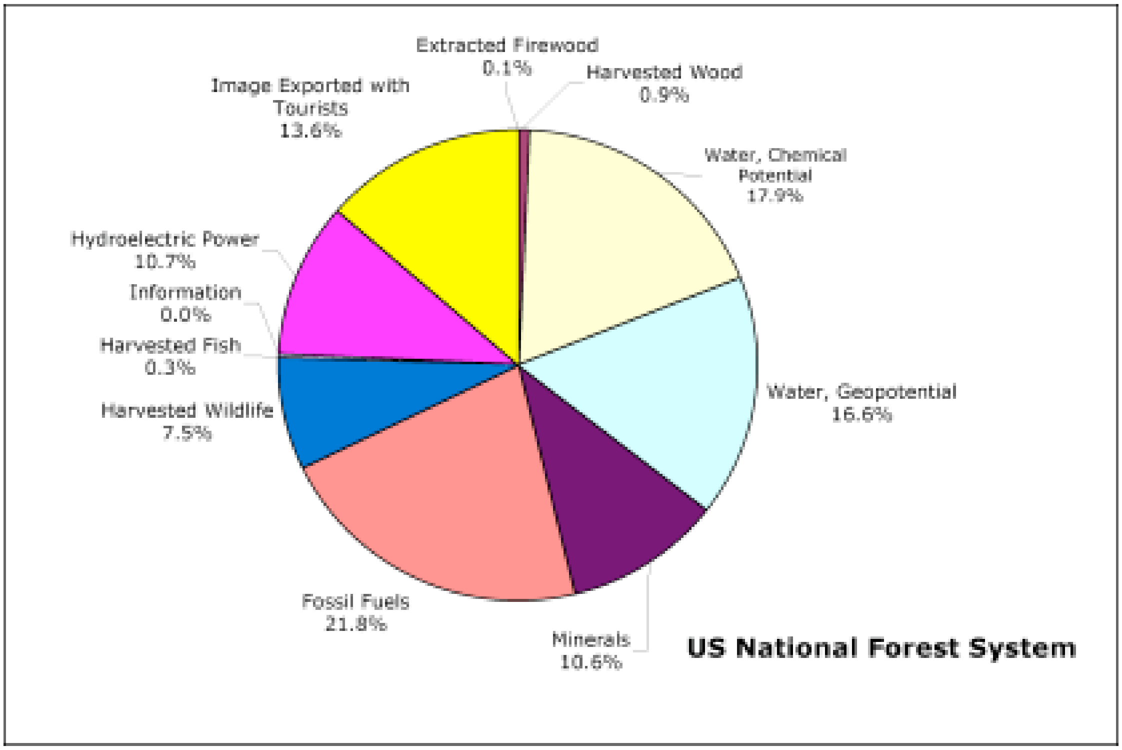


Figure 5. Emergy inflows driving the US Forest Service System.
Data are expressed as EmDollars. Renewable driving emergy flows (top) and nonrenewable emergy inflows including tourists (bottom).



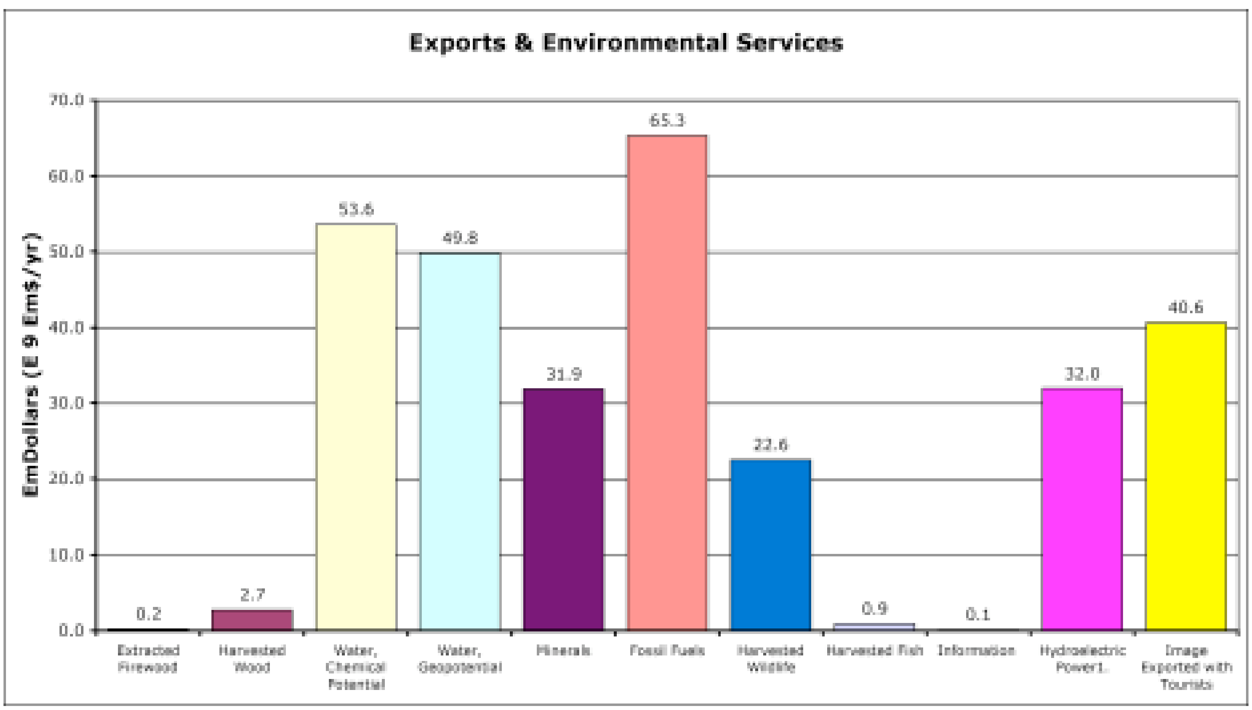


Figure 6. Emergy in exports and environmental services from US National Forest System.
Percent of the total (top), billions of emdollars (bottom).

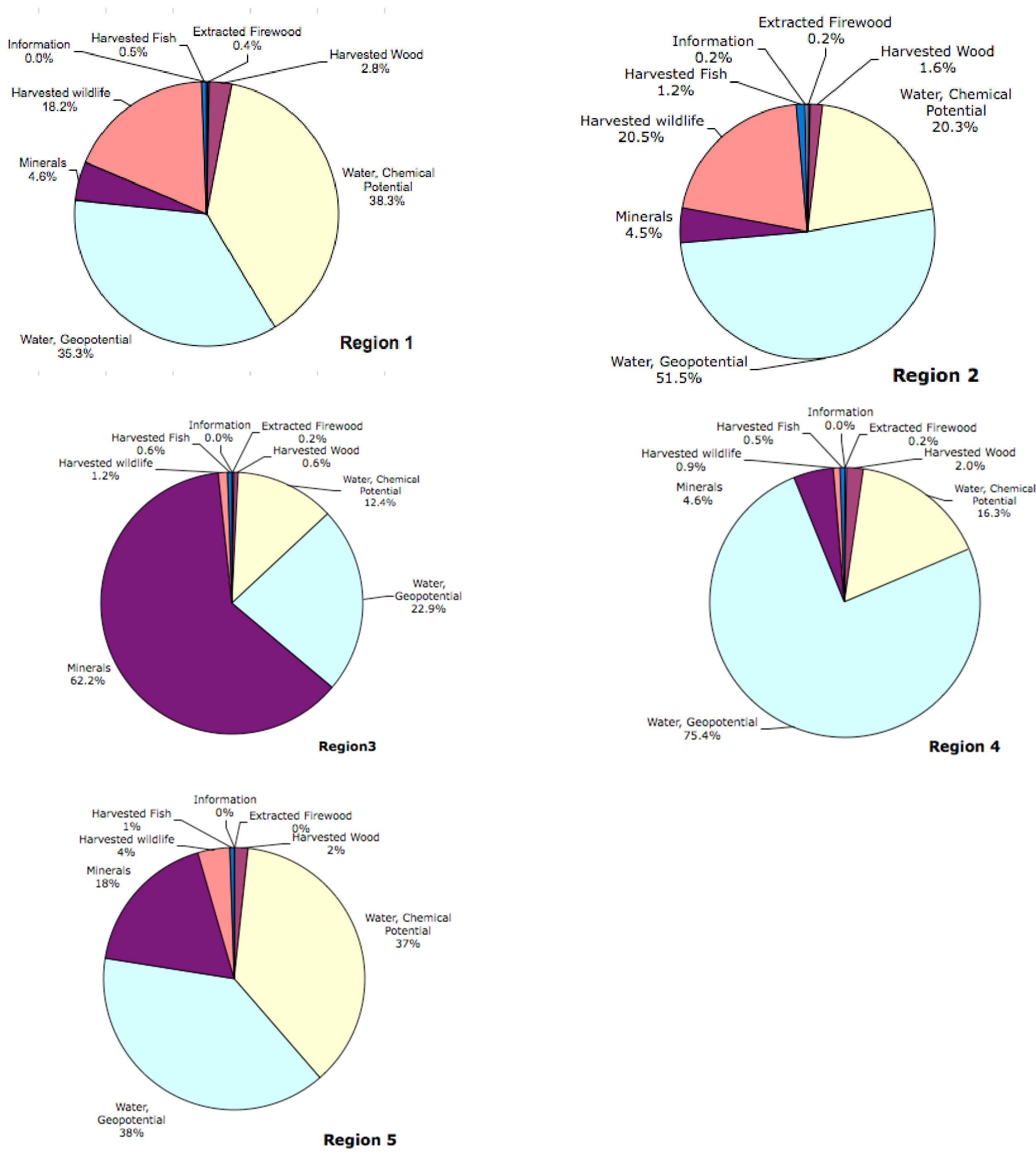


Figure 7. Emergy in exports and environmental services from US Forest lands (ca. 2005). Data are for regions 1 – 5.

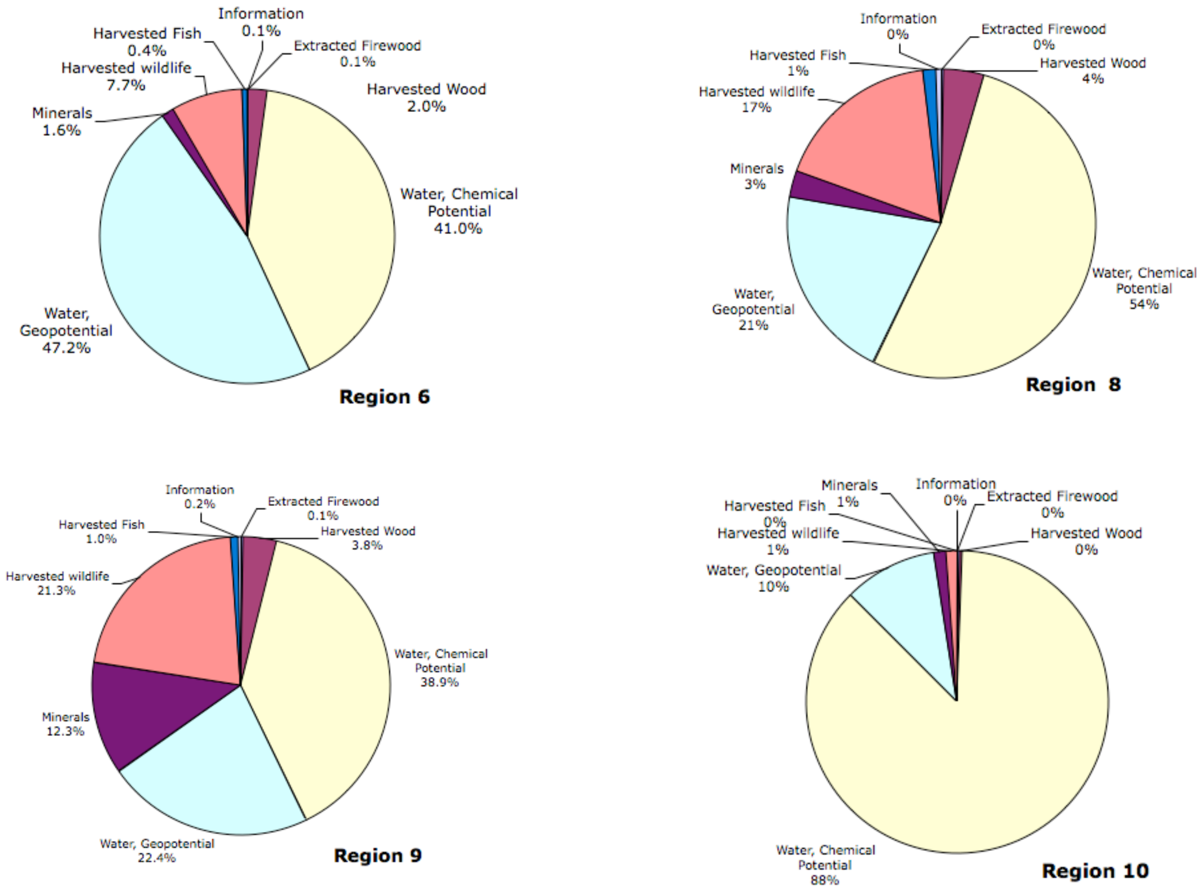


Figure 7 (continued). Emergy in exports and environmental services from US Forests (ca. 2005). Data are for regions 6 – 10.

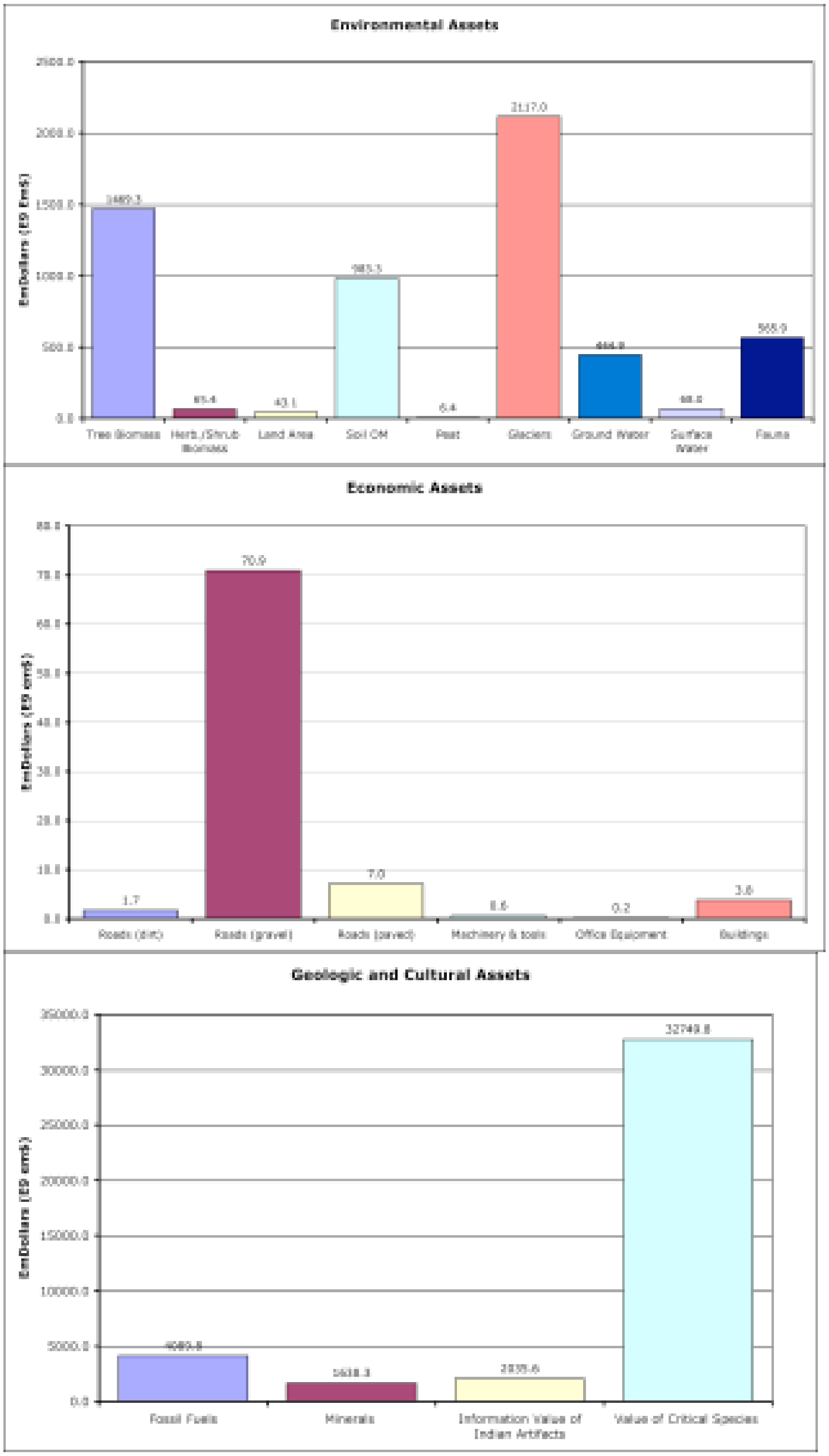


Figure 8. Emdollar value of assets on USFS lands (ca. 2005).
Environmental assets (top), economic assets (middle) and geologic and cultural assets (bottom)

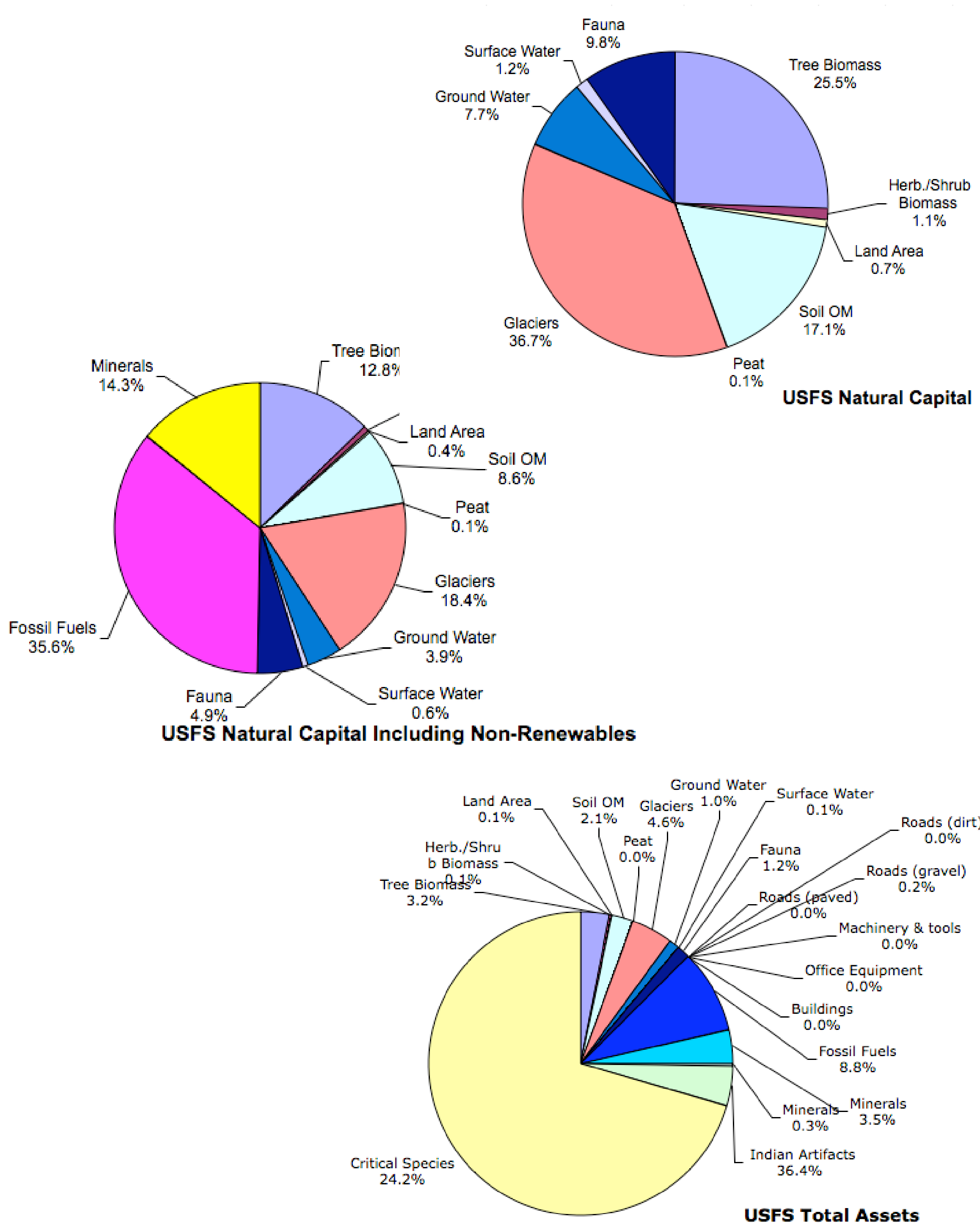


Figure 9. Emergy in assets of the US National Forest System expressed as percent of total.

a) emergy in environmental natural capital, b) emergy in natural capital including estimates of non-renewable reserves, and c) emergy in all assets including cultural assets

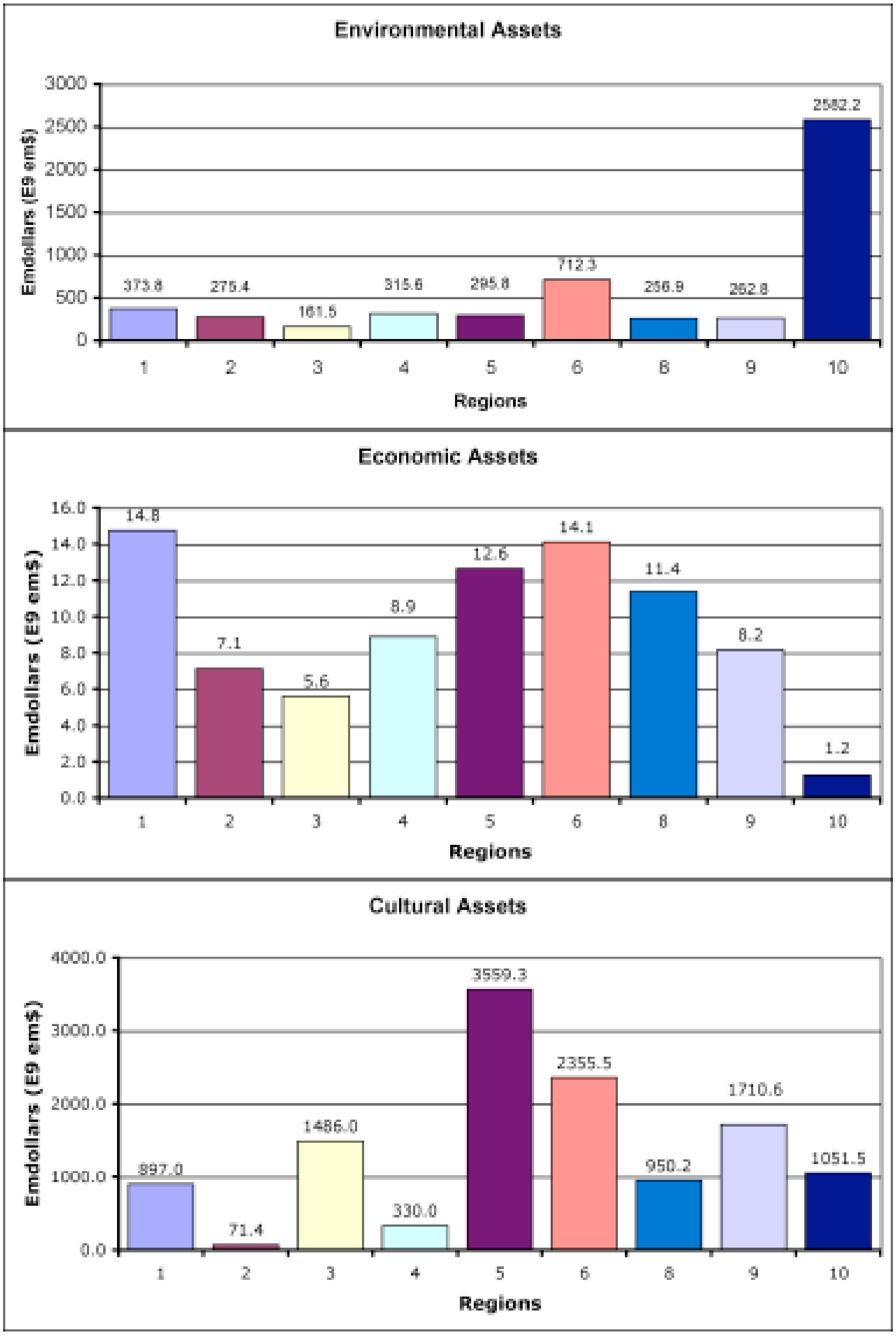


Figure 10. Emdollar value of assets of US Forest Service by region.
Environmental assets (top), economic assets (middle) and cultural assets (bottom).

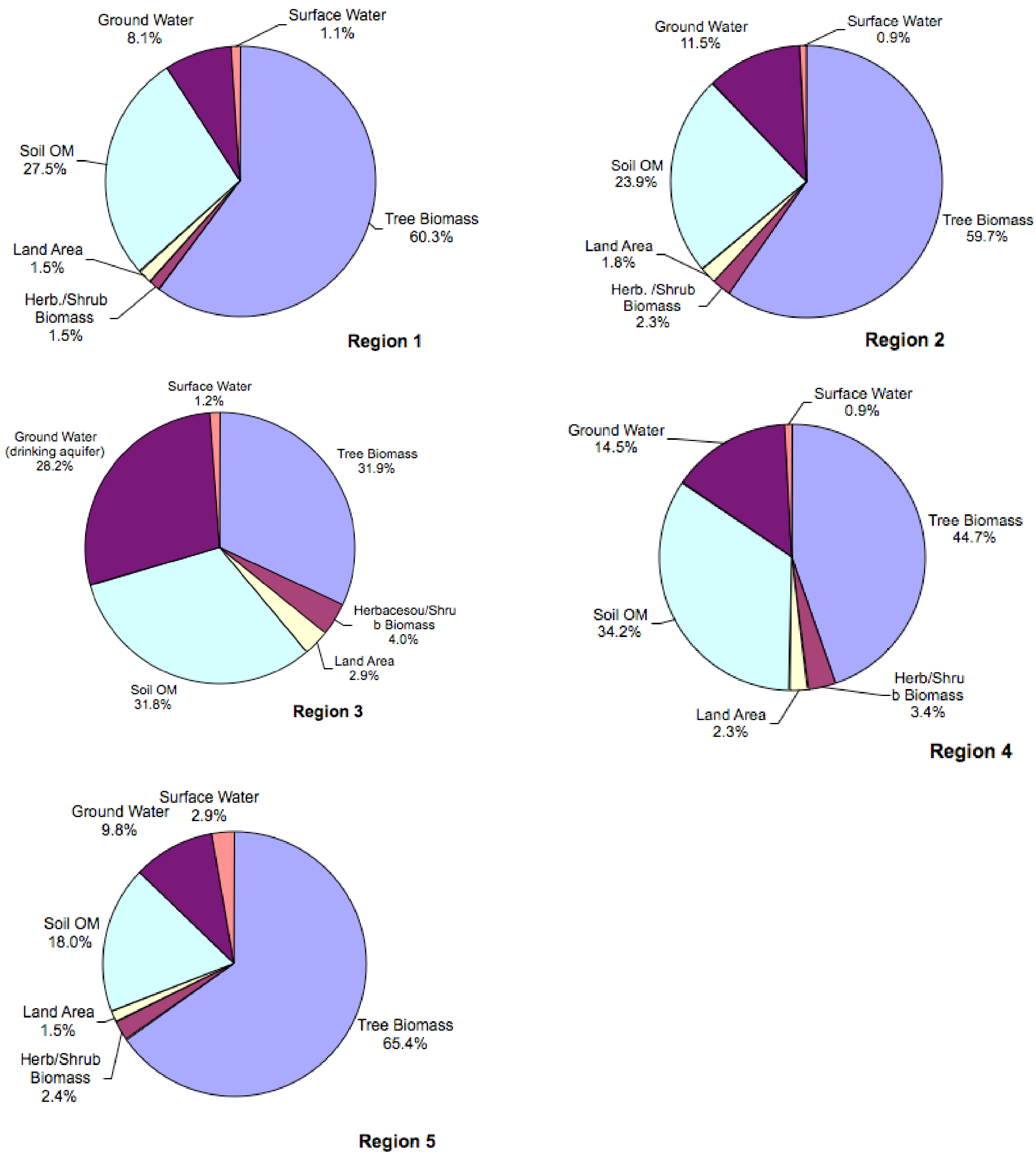


Figure 11. Emergy in environmental assets (natural capital) of US Forest System (ca. 2005) by region
Data shown as percent of total (Regions 1- 5).

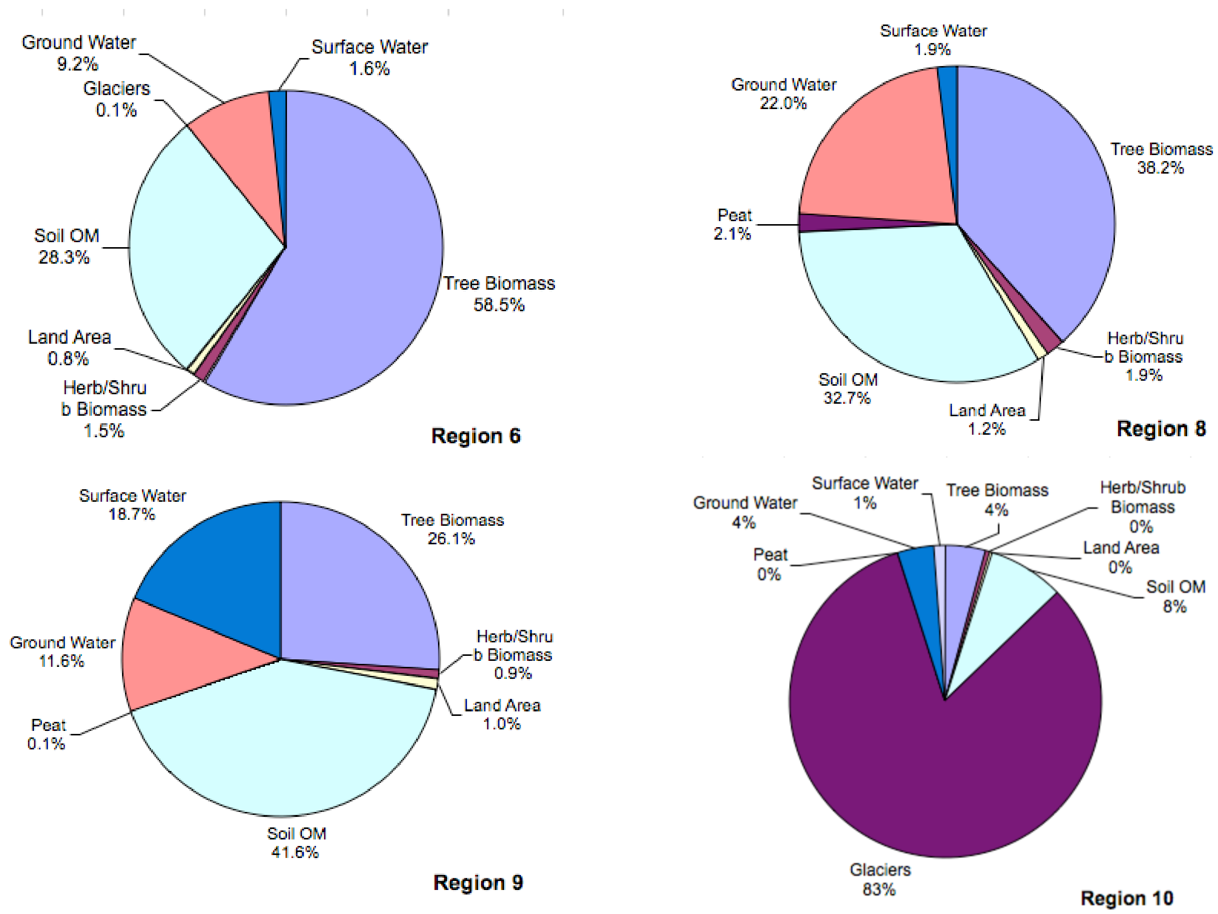
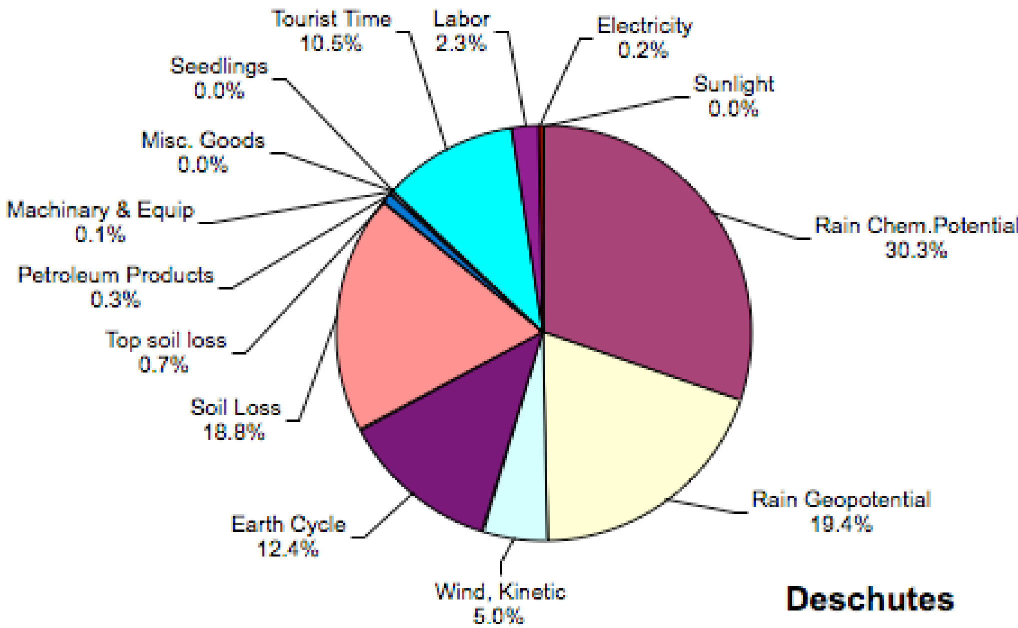


Figure 11 (continued). Emergy in environmental assets (natural capital) shown as percent of total for US Forests (ca. 2005) by region (Regions 6- 10).



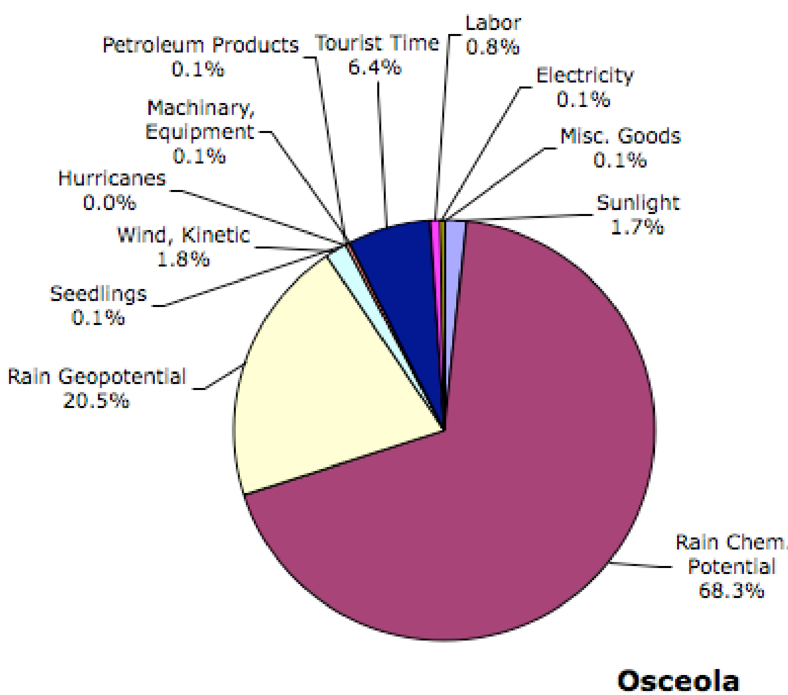
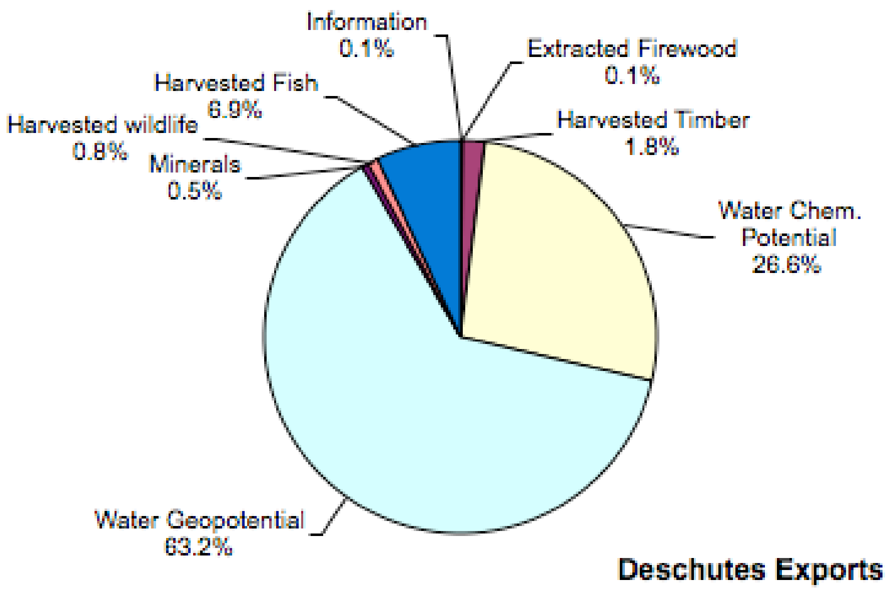


Figure 12. Driving emergy basis for Deschutes and Osceola Forests. Values are expressed as percent of total inflowing emergy.



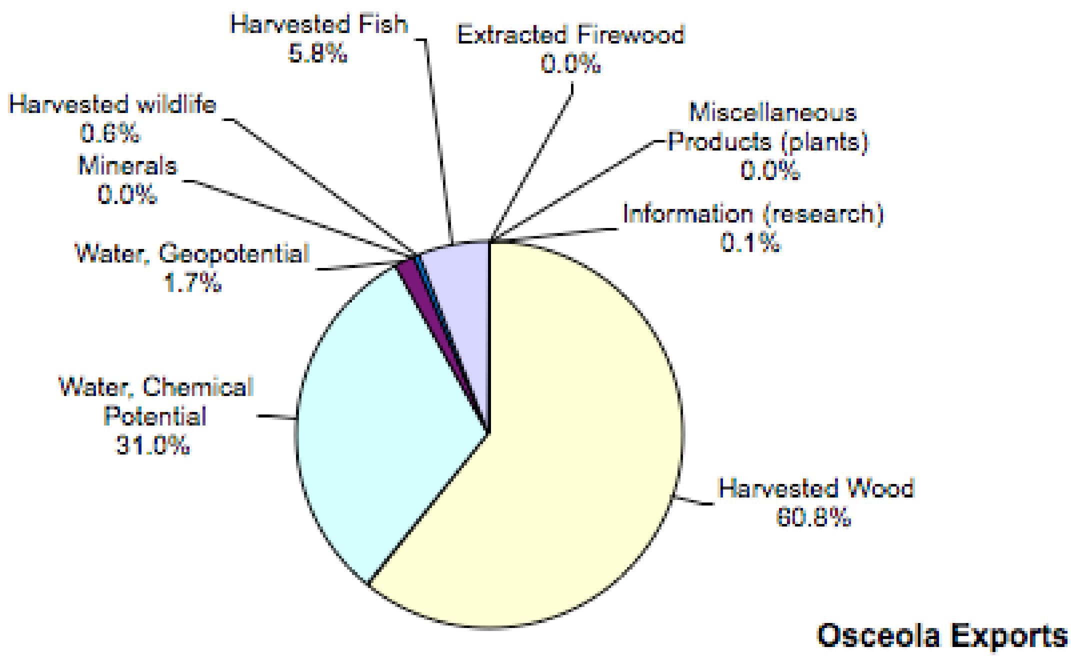
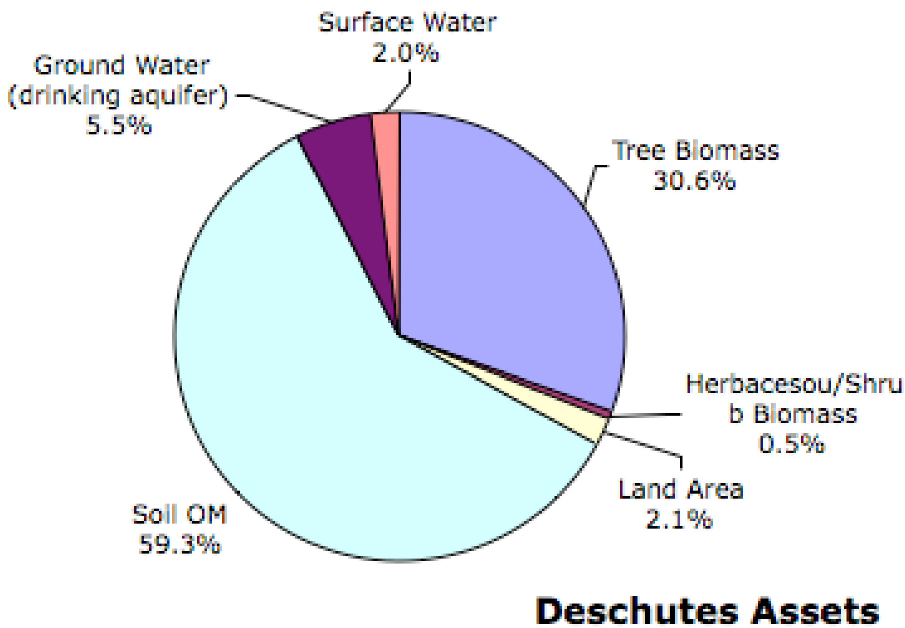


Figure 13. Emergy in exports form Deschutes and Osceola National Forests
Data shown as percent of total exports.



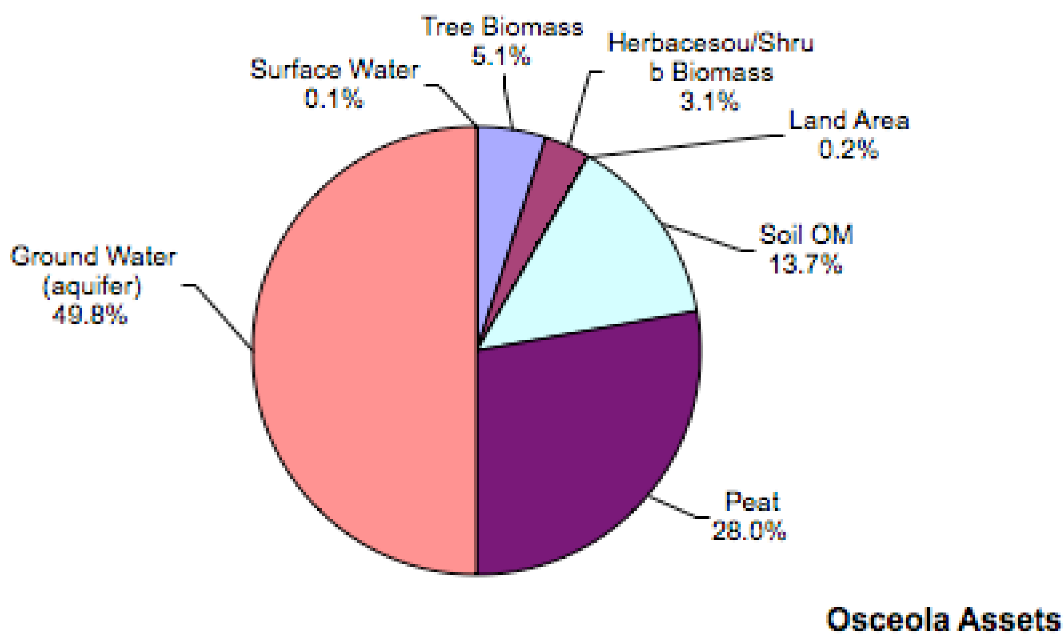


Figure 14. Assets (natural capital) of Deschutes and Osceola National Forests.
Assets are shown as percent of total.

APPENDICES

Appendix A: Emergy Evaluations of Regions 1-10 Flows
Appendix B: Emergy Evaluations of Regions 1 – 10 Assets
Appendix C: Notes to Table 6: National Flows
Appendix D: Notes to Table 7: National Assets
Appendix E: Notes to Tables 9 & 10: Deschutes & Osceola Flows
Appendix F: Notes to Tables 11 & 12: Deschutes & Osceola Assets
Appendix G: Emergy Evaluation of Fauna
Appendix H: Emergy Evaluation of Critical Species
Appendix I: Emergy Evaluation of Hunting
Appendix J: Emergy Evaluation of Critical Species

APPENDIX A - 1. Annual emergy flows supporting Region 1 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	5.017E+20	1.00E+00	501.7	264.0
2	Rain Chemical Potential	J	1.97E+17	3.10E+04	6101.8	3211.5
3	Transpiration	J	9.99E+16	3.06E+04	3053.3	1607.0
4	Rain Geopotential	J	1.92E+16	4.70E+04	904.1	475.9
5	Wind, Kinetic	J	6.35E+17	2.45E+03	1555.9	818.9
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	2.90E+17	1.20E+04	3482.5	1832.9
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	1.83E+10	1.68E+09	30.7	16.2
	Top soil loss (harvesting)	J	1.38E+13	7.40E+04	1.0	0.5
11	Misc. Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	2.07E+14	1.11E+05	23.0	12.1
13	Machinery, Equipment	g	4.08E+08	1.13E+10	4.6	2.4
14	Misc. Goods	g	9.53E+06	1E9 - 7 E9	0.2	0.1
15	Seedlings	$	6.57E+06	1.90E+12	12.5	6.6
16	Tourist Time	J	1.09E+14	1.50E+07	1632.5	859.2
17	Labor	hours	1.57E+07	6.30E+13	991.1	521.6
18	Electricity	J	1.15E+14	2.92E+05	33.5	17.6
19	Services	$	2.73E+08	1.90E+12	518.4	272.8
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	2.88E+07	1.90E+12	54.7	28.8
21	Payments for minerals extracted	$	7.92E+07	1.90E+12	150.4	79.2
22	Fee Payments (hunting, fishing, grazing, etc)	$	2.63E+06	1.90E+12	5.0	2.6
EXPORTS:						
23	Extracted Firewood	J	1.55E+15	5.04E+04	78.1	41.1
24	Harvested Wood	J	1.12E+16	5.04E+04	565.5	297.7
25	Water, Chemical Potential	J	9.70E+16	8.10E+04	7854.6	4134.0
26	Water, Geopotential	J	1.54E+17	4.70E+04	7233.1	3806.9
27	Minerals	g	1.14E+11	8.16E+09	933.0	491.1
28	Fossil Fuels	J				
29	Harvested wildlife	J	3.94E+15	1.10E+07	3722.8	1959.4
30	Harvested Fish	J	6.42E+12	1.68E+07	107.9	56.8
31	Information (research)	hrs	3.09E+04	1.90E+12	7.3	3.8
32	Hydroelectric Power	J				
33	Image Exported with Tourists	% area	0.10%	--	738.2	388.5
ECONOMIC PAYMENTS MADE						
34	Payments to St. & Local Gov't	$	2.92E+07	1.90E+12	55.5	29.2
35	Payments for Labor	$	1.60E+08	1.90E+12	304.9	160.5

Footnotes to Table A-1

RENEWABLE RESOURCES:			Sources
1 Solar Insolation			
	Land Area	1.03E+11m^2	
	Insolation	5.94E+09J/m^2/year	NREL, 2006
	Albedo	1.80E-01(% given as a decimal)	
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		5.02E+20J	
	Transformity	1.00E+00sej/J	
2 Rain			
Chemical Potential			
	Land Area	1.03E+11m^2	
	Rain	0.386868m/yr	NOAA, 2006
	Total Volume Rain	3.98E+10m^3	
	energy=	volume*1000kg/m^3*4940J/kg	
	=	1.97E+17	
	Transformity	3.10E+04sej/J	Odum, 2000
3 Transpiration		1.96E-01m/m^2/yr	
		2.02E+10m3	
		Energy=Vol*1000Kg/m^3*4940J/kg	
	Rain ET Energy	9.99E+16J/yr	
	Transformity	3.06E+04sej/J	Odum, 2000
4 Rain Geopotential			
	Rain	1.91E-01m/yr	NOAA 2006
	Mean Elevation Change	610m	
	Land Area	1.03E+11m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	1.92E+16J	
	Transformity	4.70E+04sej/J	Odum et.al, (2000)
5 Wind, Kinetic			
	Area	1.03E+11	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	4.39E+00mps	NOAA 2006
	Geostrophic wind	7.32E+00 observed winds are about	0.6 of geostrophic wind
	Drag Coeff.	2.00E-03	
		Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000	
	=	6.35E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6 Hurricanes			
None			
7 Waves			
None			
8 Tides			
None			
9 Earth Cycle			
	Heat Flow	8.94E+01miliwatts/m^2	IHFC, 2005
	area	1.03E+11m^2	

	energy=miliwatts/m^2*area*sec/yr		
		2.82E+06J/m^2	
	energy=	2.90E+17J/yr	
	Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:			
10 Soil Loss		1.83E+10g/yr	
	Top Soil Loss (3.5% of total SL)	6.40E+08g/yr	
	energy=g of C*5.4 kca'/g*4184 J/cal		
	=	1.38E+13J	
11 Misc. Products (Plants)		g/yr	NFS, 2005
	energy=g*3.5kcal/g*4186J/Kcal		
	=	2.66E+10joules	
	Transformity	1.80E+04sej/J	
IMPORTS:			
12 Petroleum Products			
	Forest Service Use	1.78E+05gal/yr	NFS, 2006
	energy=gal*13e7j/gal		
	energy=	2.32E+13J/yr	
	FS Building Use	2.94E+06sq feet	
		6.66E+04BTU/sq ft/yr	EIA, 1992
	energy use =BTU/sqft/yr*sq ft*1055 joules/BTU		
	=	2.07E+14J/yr	
	Total Fuel Use	2.30E+14J/yr	
	Transformity	1.11E+05sej/J	Odum, (1996)
	Est. Cost	3.10E+06$/yr	
13 Machinery, Equipment			
	FS	1880vehicles	
	avg. mass	4.34E+06g/vehicle	
	avg. vehicle lifespan	2.00E+01yrs	
	use per y = vehicles*g/vehicle*1/avg life of vehicle		
	=	4.08E+08g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Goods (Pesticides, herbicides, misc goods)		9.53E+06g/yr	R of FS, 2003
		2.49E+10sej/g	
	emergy=	2.37E+17sej/yr	
	Est. for cost	1.68E+06$/yr	
15 Replanting			
	Total Cost=	6.57E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism			
	Tourist Time	1.32E+07visits/yr	NFS, 2005
	average stay	1.90E+01hrs	
	Total Hours of Stay	2.51E+08hours/yr	
	avg. energy/hr	1.04E+02kcal/hr	
	total energy expenditure=kcal/hr*hrs*4186J/Kcal		
	=	1.09E+14J/y	
	Transformity	1.50E+07 sej/J	
17 Labor			

FS	6.12E+06hrs/yr	NFS, 2005
Contractors	6.10E+06hrs/yr	
Total Labor	1.57E+07hrs/yr	
Unit Emergy Value	6.30E+13sej/hr	USA emergy use (1.9E25 sej/yr);work force of 1.5 E8 workers
18 Electricity	2943770sq ft	USFS, 2005
	37000btu/ft^2/yr	EIA, 1992
	1.09E+11btu/yr	
energy=btu/yr*1055 j/btu		
=	1.15E+14J	
Transformity	2.92E+05	Odum, 1996
Est. Cost	2.87E+06$/yr	
Region Budget	2.89E+08$/yr	USFS, 2005
19 Services	2.73E+08$/yr	USFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20 Payment for timber	2.88E+07$/yr	USFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21 Payments for Extracted Minerals	7.92E+07$/y	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22 Fee Payments	2.63E+06$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:		
23 Extracted Firewood		
mass	1.03E+08kg	
energy=mass*1000g/kg15000j/g		
=	1.55E+15J/yr	
Transformity	3.60E+05sej/J	Brown and Bardi (2001)
24 Harvested Wood	1.39E+06m^3/yr	USFS, 2005
	5.40E+05g/m^3	
mass	7.48E+11g/yr	
energy=g*15000j/g		
=	1.12E+16J/yr	
Transformity (w/o services)	5.04E+04	
25 Water, Chemical Potential		
Total Export From Streams	1.96E+10m^3/yr	USFS, 2000
Chemical Potential= M^3/yr * 1000 kg/M^3 * 4940 J/kg		
joules =	9.70E+16	
Transformity =	8.10E+04	Odum, 2000
26 Water, Geopotential Energy		
Geopotential (J) =(volume)(elevation)(density)(gravity)		
avg. elevation	8.00E+02m	.
Geopotential (J) =(volume)(avg elevation)(density)(gravity)		
joules =	1.54E+17	
Transformity	4.70E+04sej/J	Odum, 2000

27 Minerals		1.14E+11g/yr	
	Sp. Emergy (avg)=	8.16E+09sej/g	
	emergy=	9.33E+20sej	
28 Fossil Fuels			
(National data only)			
29 Hunting			
	% Dry Weight for Wildlife	2.50E+01%	
	Big Game Extracted	99277.5Big Game/y	USFWS, 2002
	avg. mass	5.68E+04g/Game	
	energy content	2.65E+04J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	3.74E+15J/yr	
	Transformity=	9.90E+05sej/J	Brown,et al. 2005
	Emergy=	3.70E+21sej	
	Small Game Extracted	377254.5Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03g/animal	
	energy content	6.37E+03J/g	
	energy=#*avg mass*(percent dry weight)J/g		
	energy=	1.98E+14J/yr	
	Transformity=	1.20E+05sej/J	Brown,et al. 2005
	Emergy=	2.38E+19sej	
	Migratory Birds Extracted	297832.5#/yr	USFWS, 2002
	avg. mass	1.30E+03g/bird	
	energy content	8.83E+03J/g	
	energy=#*avg mass*(percent dry weight)J/g		
	energy=	8.55E+11J/yr	
	Transformity=	1.01E+05sej/J	Brown,et al. 2005
	Emergy=	8.63E+16sej	
	Other Species Extracted	33092.5#/yr	USFWS, 2002
	avg. mass	6.35E+03g	
	energy content	6.37E+03J/g	
	energy=#*avg mass*(percent dry weight)J/g		
		3.34E+11J/yr	
	Transformity=	1.50E+05sej/J	Brown,et al. 2005
	Emergy=	5.02E+16sej	
	Sum of Emergy from Game	3.72E+21sej	
	Weighted Trans. For Game	1.10E+07sej/J	
30 Fishing		3.76E+06fish caught	USFS, 2004
	avg. mass	4.54E+02g/fish	
	energy content	1.88E+04J/g	
	Energy Fish Caught	6.42E+12J	
	Transformity=	1.68E+07sej/J	
31 Research Information		# of papers	
	average time spent	8.05E+02hours/paper	
	research hours	30898.01hours/yr	
	Transformity	2.35E+14sej/hr	
	total sej of research	7.26E+18sej	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
32 Hydroelectric Power			

	(National Data Only)		
33	Image Exported with Tourists		
	Number of tourists	2.90E+06	USFS, 2006
	Percent forest experienced	0.10%	estimate
	Total Env. & Economic Assets	7.38E+23sej	From Table A3-1
	Emergy of image exported =	7.38E+20sej	
34	Payments to State	2.92E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.60E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)

APPENDIX A-2. Annual emergy flows supporting Region 2 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	5.253E+20	1.00E+00	525.3	276.5
2	Rain Chemical Potential	J	1.61E+17	3.10E+04	4980.1	2621.1
3	Transpiration	J	1.05E+17	3.06E+04	3208.1	1688.5
4	Rain Geopotential	J	1.11E+16	4.70E+04	519.6	273.4
5	Wind, Kinetic	J	4.87E+17	2.45E+03	1193.9	628.3
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	2.88E+17	1.20E+04	3450.4	1816.0
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	1.16E+10	1.68E+09	19.5	10.3
10a	Top soil loss (harvesting)	J	8.73E+12	7.40E+04	0.6	0.3
11	Miscellaneous Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	1.32E+14	1.11E+05	14.7	7.8
13	Machinery, Equipment	g	4.23E+08	1.13E+10	4.8	2.5
14	Misc. Goods	g	8.27E+06	1E9 - 7 E9	0.2	0.1
15	Seedlings	$	2.77E+06	1.90E+12	5.3	2.8
16	Tourist Time	J	2.69E+14	1.50E+07	4019.5	2115.5
17	Labor	hours	1.32E+07	6.30E+13	830.8	437.3
18	Electricity	J	7.35E+13	2.92E+05	21.4	11.3
19	Services	$	2.42E+08	1.90E+12	459.1	241.6
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	1.56E+07	1.90E+12	29.6	15.6
21	Payments for minerals extracted	$	8.42E+07	1.90E+12	160.0	84.2
22	Fee Payments (hunting, grazing,)	$	3.35E+06	1.90E+12	6.4	3.4
EXPORTS:						
23	Extracted Firewood	J	1.34E+15	3.60E+04	48.4	25.5
24	Harvested Wood	J	7.11E+15	5.04E+04	358.5	188.7
25	Water, Chemical Potential	J	5.57E+16	8.10E+04	4513.5	2375.6
26	Water, Geopotential	J	2.43E+17	4.70E+04	11430.2	6015.9
27	Minerals	g	1.21E+11	8.16E+09	990.6	521.4
28	Fossil Fuels	J				
29	Harvested wildlife	J	4.80E+15	1.10E+07	4543.8	2391.5
30	Harvested Fish	J	1.58E+13	1.68E+07	265.6	139.8
31	Information (research)	hrs	1.61E+05	2.35E+14	37.9	19.9
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%--		536.7	282.5
ECONOMIC PAYMENTS MADE						
34	Payments to St. & Local Gov't	$	1.19E+07	1.90E+12	22.5	11.9
35	Payments for Labor	$	1.67E+08	1.90E+12	31764.0	16717.9

Footnotes to Table A-2
RENEWABLE RESOURCES:

			Sources
1	Solar Insolation		
	Land Area	8.94E+10m^2	
	Insolation	7.17E+09J/m^2/year	NASA, 2006
	Albedo	1.80E-01(% given as a decimal)	Gholz and Clark, 2000
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		5.25E+20J	
	Transformity	1.00E+00sej/J	
2	Rain		
	Chemical Potential		
	Land Area	8.94E+10m^2	
	Rain	0.363811m/yr	NASA, 2006
	Total Volume Rain	3.25E+10m^3	
		energy=volume*1000kg/m^3*4940J/kg	
	=	1.61E+17	
	Transformity	3.10E+04sej/J	Odum et.al, (2000)
3	Transpiration	2.38E-01m/m^2/yr	
		2.12E+10m3	Sedell, 2000
		Energy=Vol*1000Kg/m^3*4940J/kg	
	Rain ET Energy	1.05E+17J/yr	
	Transformity	3.06E+04sej/J	Odum (2000)
4	Rain Geopotential		
	Runoff from Rain	0.126m/yr	NASA, 2006
	Mean Elevation Change	305m	
	Land Area	8.94E+10m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	1.11E+16J	
	Transformity	4.70E+04sej/J	Odum, (2000)
5	Wind, Kinetic		
	Area	8.94E+10	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	4.21E+00mps	
		observed winds are about 0.6 of geostrophic	
	Geostrophic wind	7.02E+00wind	
	Drag Coeff.	2.00E-03	
		Energy=area*density*dragcoef*(Geos-Grnd)^3*31500000	
	=	4.87E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6	Hurricanes		
	None		
7	Waves		
	None		
8	Tides		
	None		
9	Earth Cycle		
	Heat Flow	1.02E+02miliwatts/m^2	IHFC, 2005

area	8.94E+10m^2	
energy=miliwatts/m^2*area*sec/yr		
	3.22E+06J/m^2	
energy=	2.88E+17J/yr	
Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:		
10 Soil Loss	1.16E+10g/yr	USFS, 2005
Top Soil Loss (3.5% of total SL)	4.06E+08g/yr	
energy=g of C*5.4 kca'/g*4184 J/cal		
=	8.73E+12J	
Transformity=	7.40E+04 sej/j	
11 Misc. Products (Plants)	g/yr	USFS, 2005
energy=g*3.5kcal/g*4186J/Kcal		
=	joules	
Transformity	1.80E+04sej/J	
IMPORTS:		
12 Petroleum Products		
Forest Service Use	1.24E+06gal/yr	USFS, 2005
energy=gal*13e7j/gal		
energy=	1.61E+14J/yr	
FS Building Use	1.88E+06sq feet	
	6.66E+04BTU/sq ft/yr	EIA, 1992
energy use =BTU/sqft/yr*sq ft*1055 joules/BTU		
=	1.32E+14	
Total Fuel Use	2.93E+14J/yr	
Transformity	1.11E+05sej/J	Odum, (1996)
Est. Cost=gal*$2/gal+MMBTUs*$14/MMBTU		
	4.23E+06$/yr	
13 Machinery, Equipment		
mass	8.45E+09g	
avg. vehicle lifespan	2.00E+01yrs	
use per y =vehicles*g/vehicle*1/avg life of vehicle		
mass used per year	4.23E+08g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Misc. Goods (Pesticides, herbicides, etc)	8.27E+06g/yr	NFS, 2005
	2.49E+10sej/g	
emergy=	2.06E+17sej/yr	
Est. for cost	1.46E+06$/yr	
15 Replanting		
Total Cost=	2.77E+06$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism		
Tourist Time	3.25E+07visits/yr	USFS, 2005
average stay	1.90E+01hrs	
Total Hours of Stay	6.18E+08hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=Cal/hr*hrs*4186J/Cal		
=	2.69E+14J/y	

	Transformity	1.50E+07 sej/J	
17	Labor		
	FS	6.38E+06hrs/yr	USFS, 2005
	Contractors	3.86E+06hrs/yr	
	Total Labor	1.32E+07hrs/yr	
	Unit Emergy Value	6.30E+13sej/hr	Odum, 1996
18	Electricity	1882186sq ft	USFS, 2005
		37000btu/ft^2/yr	EIA, 1992
		6.96E+10btu/yr	
	energy=btu/yr*1055 j/btu		
	=	7.35E+13J	
	Transformity	2.92E+05	Odum, 1996
	Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
		1.84E+06$/yr	
	FS Regional budget	2.56E+08$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19	Services	2.42E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20	Payment for timber	1.56E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21	Payments for Extracted Minerals	8.42E+07$/y	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22	Fee Payments	3.35E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:			
23	Extracted Firewood		
	mass	8.96E+07kg	
	energy=mass*1000g/kg15000j/g		
	=	1.34E+15J/yr	
	Transformity	3.60E+04sej/J	Brown and Bardi (2001)
24	Harvested Wood	8.78E+05m^3/yr	USFS, 2005
		5.40E+05g/m^3	
	mass	4.74E+11g/yr	
	energy=g*15000j/g		
	=	7.11E+15J/yr	
	Transformity (w/o services)	5.04E+04	Brown, 2001
25	Water, Chemical potential		
	Total Export From Streams	1.13E+10m^3/yr	Sedell, 2000
	Chemical Potential=	M^3/yr * 1000 kg/M^3 * 4940 J/kg	
	joules =	5.57E+16J/yr	
	Transformity	8.10E+04sej/J	Odum, 2000
26	Water, Geopotential Energy		
	Geopotential (J) =	(volume)(elevation)(density)(gravity)	
	avg. elevation	2.20E+03m	USGS, 2006
	joules =	2.43E+17	
	Transformity	4.70E+04sej/J	Odum, 2000
27	Minerals	1.21E+11g/yr	estimate

	specific emergy=	8.16E+09sej/g	
28	Fossil Fuels		
	(National data only)		
29	Hunting		
	% Dry Weight for Wildlife	2.50E+01%	
	Big Game Extracted	1.21E+05Big Game/y	
	avg. mass	5.68E+04g/Game	
	energy content	2.65E+04J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	energy=	4.56E+15J/yr	USFWS, 2002
	Transformity=	9.90E+05sej/J	Brown et al, 2005
	Emergy=	4.51E+21sej	
	Small Game Extracted	4.60E+05Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03g/animal	
	energy content	6.37E+03J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	energy=	2.42E+14J/yr	
	Transformity=	1.20E+05sej/J	Brown et al, 2005
	Emergy=	2.90E+19sej	
	Migratory Birds Extracted	3.64E+05#/yr	USFWS, 2002
	avg. mass	1.30E+03g/bird	
	energy content	8.83E+03J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	energy=	1.04E+12J/yr	
	Transformity=	1.01E+05sej/J	Brown et al, 2005
	Emergy=	1.05E+17sej	
	Other Species Extracted	4.04E+04#/yr	USFWS, 2002
	avg. mass	6.35E+03g	
	energy content	6.37E+03J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
		4.08E+11J/yr	
	Transformity=	1.50E+05sej/J	Brown et al, 2005
	Emergy=	6.12E+16sej	
	Sum of Emergy from Game	4.54E+21sej	
	Weighted Trans. For Game	1.10E+07sej/J	
30	Fishing	9.26E+06fish caught	USFS, 2004
	avg. mass	4.54E+02g/fish	assume avg weight = 1 lb
	energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)
	Energy Fish Caught	1.58E+13J	assume 20% dry weight
	Transformity=	1.68E+07sej/J	
31	Research Information	1.62E+02# of papers	
	average time spent	8.05E+02hours/paper	
	research hours	161249hours/yr	
	Transformity	2.35E+14sej/hr	Odum, 1996

	total sej of researcl	3.79E+19sej	
32	Hydroelectric Power (National Data Only)		
33	Image Exported with Tourists		
	Number of toursits	2.90E+06	USFS, 2006
	Percent forest experiencec	0.10%	estimate
	Total Env. & Economic Assets	5.37E+23sej	From Table A3-2
	Emergy of image exportec =	5.37E+20sej	
34	Payments to State	1.19E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.67E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)

APPENDIX A-3. Annual emergy flows supporting Region 3 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity. (sej/unit)	Solar Emergy (x10^{18}sej)	EmDollars (x10^{6} Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	5.965E+20	1.00E+00	596.5	313.9
2	Rain Chemical Potential	J	1.24E+17	3.10E+04	3843.1	2022.7
3	Transpiration	J	7.87E+16	3.06E+04	2406.5	1266.6
4	Rain Geopotential	J	8.22E+16	4.70E+04	3861.5	2032.3
5	Wind, Kinetic	J	3.49E+17	2.45E+03	855.5	450.2
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	2.19E+17	1.20E+04	2628.0	1383.2
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	2.22E+09	1.68E+09	3.7	2.0
	Top soil loss (harvesting)	J	1.67E+12	7.40E+04	0.1	0.1
11	Misc. Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	1.62E+14	1.11E+05	18.1	9.5
13	Machinery, Equipment	g	4.74E+08	1.13E+10	5.3	2.8
14	Goods (Pesticides, herbicides, misc goods)	g	7.79E+06	1E9 - 7 E9	0.2	0.1
15	Seedlings	$	1.51E+06	1.90E+12	2.9	1.5
16	Tourist Time	J	1.70E+14	1.50E+07	2535.4	1334.4
17	Labor	hours	9.64E+06	6.30E+13	607.2	319.6
18	Electricity	J	9.01E+13	2.92E+05	26.3	13.8
19	Services	$	3.16E+08	1.90E+12	600.5	316.1
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	1.02E+06	1.90E+12	1.9	1.0
21	Payments for minerals extracted	$	1.56E+09	1.90E+12	2964.3	1560.2
22	Fee Payments (hunting, fishing,)	$	6.49E+06	1.90E+12	12.3	6.5
EXPORTS:						
23	Extracted Firewood	J	1.27E+15	3.60E+04	45.6	24.0
24	Harvested Wood	J	3.60E+15	5.04E+04	181.3	95.4
25	Water, Chemical Potential	J	4.53E+16	8.10E+04	3666.2	1929.6
26	Water, Geopotential	J	1.44E+17	4.70E+04	6752.3	3553.8
27	Minerals	g	2.25E+12	8.16E+09	18373.2	9670.1
28	Fossil Fuels	J				
29	Harvested wildlife	J	3.12E+15	1E5 - 9.9E5	345.3	181.7
30	Harvested Fish	J	9.96E+12	1.68E+07	167.4	88.1
31	Information (research)	hrs	3.09E+04	2.35E+14	7.3	3.8
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%	--	317.5	167.1
ECONOMIC PAYMENTS MADE						
34	Payments to St. & Local Gov't	$	1.01E+07	1.90E+12	19.2	10.1

35 Payments for Labor	$	1.32E+08	1.90E+12	251.2	132.2

Footnotes to Table A-3

RENEWABLE RESOURCES:

			Sources
1 Solar Insolation			
	Land Area	8.42E+10m^2	
	Insolation	8.64E+09J/m^2/year	NREL, 2006
	Albedo	1.80E-01(% given as a decimal)	
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		5.96E+20J	
	Transformity	1.00E+00sej/J	
2 Rain			
Chemical Potential			
	Land Area	8.42E+10m^2	
	Rain	0.297995m/yr	NOAA, 2006
	Total Volume Rain	2.51E+10m^3	
	energy=volume*1000kg/m^3*4940J/kg		
	=	1.24E+17	
	Transformity	3.10E+04sej/J	Odum (2000)
3 Transpiration		1.89E-01m/m^2/yr	
		1.59E+10m3 Et	
	Energy=Vol*1000Kg/m^3*4940J/kg		
	Rain ET Energy	7.87E+16J/yr	
	Transformity	3.06E+04sej/J	Odum, (2000)
4 Rain Geopotential			
	Rain	1.09E-01m/yr	NOAA, 2006
	Mean Elevation Change	915m	
	Land Area	8.42E+10m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	8.22E+16J	
	Transformity	4.70E+04sej/J	Odum, (2000)
5 Wind, Kinetic			
	Area	8.42E+10	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	3.85E+00mps	NOAA, 2006
	Geostrophic wind	6.41E+00	observed winds are about 0.6 of geostrophic wind
	Drag Coeff.	2.00E-03	
	Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000		
	energy	3.49E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6 Hurricanes			
None			
7 Waves			
None			
8 Tides			
None			
9 Earth Cycle			
	Heat Flow	82.40846miliwatts/m^2	IHFC, 2005
	area	8.42E+10m^2	

energy=miliwatts/m^2*area*sec/yr		
	2.60E+06J/m^2/yr	
energy=	2.19E+17J/yr	
Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:		
10 Soil Loss	2.22E+09g/yr	USFS, 2005
Top Soil Loss (3.5% of total SL)	7.77E+07g/yr	
energy=g of C*5.4 kca'/g*4184 J/cal		
=	1.67E+12J	
Transformity=	7.40E+04 sej/j	
11 Miscellaneous Products (Plants)	g/yr	USFS, 2005
energy=g*3.5kcal/g*4186J/Kcal		
=	2.66E+10joules	
Transformity	1.80E+04sej/J	
IMPORTS:		
12 Petroleum Products		
Forest Service Use	2.52E+06gal/yr	
energy=gal*13e7j/gal		
=	3.28E+14J/yr	
FS Building Use	2.31E+06sq feet	
	6.66E+04BTU/sq ft/yr	EIA, 1992
energy use =BTU/sqft/yr*sq ft*1055 joules/BTU		
	1.62E+14	
Total Fuel Use	4.90E+14J/yr	
Transformity	1.11E+05sej/J	Odum, (1996)
Est. Cost=gal*$2/gal+MMBTUs*$14/MMBTU		
	7.20E+06$/yr	
13 Machinery, Equipment		
mass	9.49E+09g	
avg. vehicle lifespan	2.00E+01yrs	
use per y =vehicles*g/vehicle*1/avg life of vehicle		
mass used per year	4.74E+08g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Goods (Pest, herbicides)	7.79E+06g/yr	USFS, 2005
	2.49E+10sej/g	
emergy=	1.94E+17sej/yr	
Est. for cost	1.37E+06$/yr	
15 Replanting		
Total Cost=	1.51E+06$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism		
Tourist Time	2.05E+07visits/yr	USFS, 2004
average stay	1.90E+01hrs/visit	
Total Hours of Stay	3.90E+08hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=kcal/hr*hrs*4186J/Kcal		
energy=	1.70E+14J/y	
Transformity	1.50E+07 sej/J	

17 Labor			
	FS	5.04E+06hrs/yr	USFS, 2005
	Contractors	2.44E+06hrs/yr	
	Total Labor	9.64E+06hrs/yr	
	Unit Emergy Value	6.30E+13sej/hr	Odum, (1996)
18 Electricity		2308712sq ft	USFS, 2005
		37000btu/ft^2/yr	EIA, 1992
		8.54E+10btu/yr	
	energy=btu/yr*1055 j/btu		
	=	9.01E+13J	
	Transformity	2.92E+05	Odum, 1996
	Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
		2.25E+06$/yr	
Regional FS budget		2.71E+08$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19 Services		3.16E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20 Payment for timber		1.02E+06$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21 Payments for Extracted Minerals		1.56E+09$/y	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22 Fee Payments		6.49E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:			
12 Extracted Firewood			
	mass	8.44E+07kg	
	energy=mass*1000g/kg15000j/g		
	=	1.27E+15J/yr	
	Transformity	3.60E+04sej/J	Brown & Bardi (2001)
24 Harvested Wood		4.44E+05m^3/yr	USFS, 2005
		5.40E+05g/m^3	
	mass	2.40E+11g/yr	
	energy=g	g*15000j/	
	=	3.60E+15J/yr	
	Transformity (w/o services)	5.04E+04	Brown, 2001
25 Water, Chemical potential			
Total Export From Streams		9.16E+09m^3/yr	Sedell, 2000
	Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
	joules =	4.53E+16J/yr	
	Transformity	8.10E+04sej/J	Odum, 2000
26 Water, Geopotential Energy			
	Geopotential (J) =(volume)(elevation)(density)(gravity)		
	avg. elevation=	1.60E+03m	USGS, 2006
	joules =	1.44E+17J/yr	
	Transformity	4.70E+04sej/J	Odum, 2000
27 Minerals		2.25E+12g/yr	USFS, 2003
	sp. Emergy (avg)=	8.16E+09sej/g	
28 Fossil Fuels			

(National data only)

29 Hunting		
% Dry Weight for Wildlife	2.50E+01%	
Big Game Extracted	7.88E+04Big Game/y	
avg. mass	5.68E+04g/Game	
energy content	2.65E+04J/g	
energy=#Game/yr*avg mass*(% dry weight)*J/g		
energy=	2.97E+15J/yr	USFWS, 2002
Transformity=	1.10E+05sej/J	Brown, et al 2005
Emergy=	3.26E+20sej	
Small Game Extracted	3.00E+05Small Game/yr	FWS
avg. mass	3.30E+03g/animal	
energy content	6.37E+03J/g	
energy=#Game/yr*avg mass*(% dry weight)*J/g		
energy=	1.57E+14J/yr	
Transformity=	1.20E+05sej/J	Brown, et al 2005
Emergy=	1.89E+19sej	
Migratory Birds Extracted	2.36E+05#/yr	USFWS, 2002
avg. mass	1.30E+03g/bird	
energy content	8.83E+03J/g	
energy=#Game/yr*avg mass*(% dry weight)*J/g		
energy=	6.79E+11J/yr	
Transformity=	1.01E+05sej/J	Brown, et al 2005
Emergy=	6.85E+16sej	
Other Species Extracted	2.63E+04#/yr	USFWS, 2002
avg. mass	6.35E+03g	
energy content	6.37E+03J/g	
energy=#Game/yr*avg mass*(% dry weight)*J/g		
	2.66E+11J/yr	
Transformity=	1.50E+05sej/J	Brown, et al 2005
Emergy=	3.98E+16sej	
Sum of Emergy from Game	3.45E+20sej	
Weighted Trans. For Game	sej/J	
30 Fishing	5.84E+06fish caught	
avg. mass	4.54E+02g/fish	assume avg weight = 1 lb
energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)
Energy Fish Caught	9.96E+12J	assume 20% dry weight
Transformity=	1.68E+07sej/J	
31 Research Information	# of papers	
average time spent	8.05E+02hours/paper	
research hours	30898.01hours/yr	
Transformity	2.35E+14sej/hr	
total sej of research	7.26E+18sej	
32 Hydroelectric Power		
(National Data Only)		
Image Exported with		
33 Tourists		
Number of toursits	2.90E+06	USFS, 2006
Percent forest experienced	0.10%	estimate

	Total Env. & Economic Assets	3.18E+23sej	From Table A3-10
	Emergy of image exported =	3.18E+20sej	
34	Payments to State	1.01E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.32E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	

APPENDIX A - 4. Annual emergy flows supporting Region 4 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity. (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	7.895E+20	1.00E+00	789.5	415.5
2	Rain Chemical Potential	J	1.99E+17	3.10E+04	6163.5	3243.9
3	Transpiration	J	1.29E+17	3.06E+04	3944.1	2075.8
4	Rain Geopotential	J	1.20E+17	4.70E+04	5654.1	2975.8
5	Wind, Kinetic	J	4.20E+17	2.45E+03	1028.0	541.1
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	3.88E+17	1.20E+04	4659.4	2452.3
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	1.39E+10	1.68E+09	23.3	12.3
10a	Top soil loss (harvesting)	J	1.04E+13	7.40E+04	0.8	0.4
11	Misc. Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	1.82E+14	1.11E+05	20.3	10.7
13	Machinery, Equipment	g	4.38E+08	1.13E+10	4.9	2.6
14	Misc. Goods (Pesticides, herb.)	g	1.20E+07	1E9 - 7 E9	0.3	0.2
15	Seedlings	$	2.99E+06	1.90E+12	5.7	3.0
16	Tourist Time	J	1.93E+14	1.50E+07	2881.7	1516.7
17	Labor	hours	1.87E+07	6.30E+13	1181.2	621.7
18	Electricity	J	1.01E+14	2.92E+05	29.6	15.6
19	Services	$	3.05E+08	1.90E+12	579.3	304.9
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	3.79E+06	1.90E+12	7.2	3.8
21	Payments for minerals extracted	$	1.35E+08	1.90E+12	255.7	134.6
22	Fee Payments (hunting, fishing,)	$	3.92E+06	1.90E+12	7.4	3.9
EXPORTS:						
23	Extracted Firewood	J	1.95E+15	3.60E+04	70.2	36.9
24	Harvested Wood	J	1.40E+16	5.04E+04	707.3	372.3
25	Water, Chemical Potential	J	6.98E+16	8.10E+04	5655.7	2976.7
26	Water, Geopotential	J	3.37E+17	7.77E+04	26139.2	13757.5
27	Minerals	g	1.94E+11	8.16E+09	1584.2	833.8
28	Fossil Fuels	J				
29	Harvested wildlife	J	3.45E+15	1e5 - 9.9e5	326.2	171.7
30	Harvested Fish	J	1.13E+13	1.68E+07	190.4	100.2
31	Information (research)	hrs	0.00E+00	1.90E+12	0.0	0.0
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%--		616.5	324.5
ECONOMIC PAYMENTS MADE						
34	Payments to St. & Local Gov't	$	2.48E+07	1.90E+12	47.1	24.8
35	Payments for Labor	$	1.82E+08	1.90E+12	345.5	181.9

Footnotes to Table A-4

RENEWABLE RESOURCES:

			Sources
1 Solar Insolation			
	Land Area	1.30E+11m^2	
	Insolation	7.43E+09J/m^2/year	NREL, 2006
	Albedo	1.80E-01(% given as a decimal)	
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		7.90E+20J	
	Transformity	1.00E+00sej/J	
2 Rain			
Chemical Potential			
	Land Area	1.30E+11m^2	
	Rain	0.31054394m/yr	NOAA, 2006
	Total Volume Rain	4.02E+10m^3	
		energy=volume*1000kg/m^3*4940J/kg	
	=	1.99E+17	
	Transformity	3.10E+04sej/J	Odum et.al, (2000)
3 Transpiration		2.01E-01m/m^2/yr	
		2.61E+10m3 et	
		Energy=Vol*1000Kg/m^3*4940J/kg	
	Rain ET Energy	1.29E+17J/yr	
	Transformity	3.06E+04sej/J	Odum et.al, (2000)
4 Rain Geopotential			
	Rain	1.09E-01m/yr	NOAA, 2006
	Mean Elevation Change	3.05E+02m	
	Land Area	1.30E+11m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	1.20E+17J	
	Transformity	4.70E+04sej/J	Odum et.al, (2000)
5 Wind, Kinetic			
	Area	1.30E+11	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	3.54E+00mps	
	Geostrophic wind	5.90E+00 observed winds are about 0.6 of geostrophic wind	
	Drag Coeff.	2.00E-03	
		Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000	
	=	4.20E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6 Hurricanes			
None			
7 Waves			
None			
8 Tides			
None			
9 Earth Cycle			
	Heat Flow	9.50E+01miliwatts/m^2	IHFC, 2005
	area	1.30E+11m^2	
		energy=miliwatts/m^2*area*sec/yr	

		3.00E+06J/m^2	
	energy=	3.88E+17J/yr	
	Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:			
10 Soil Loss		1.39E+10g/yr	
a.	Top Soil Loss (3.5% of total SL)	4.85E+08g/yr	
	energy=g of C*5.4 kca'/g*4184 J/cal		
		1.04E+13J	
	Transformity=	7.40E+04 sej/j	
11 Misc. Products (Plants)		g/yr	USFS, 2005
	energy=g*3.5kcal/g*4186J/Kcal		
	=	2.66E+10joules	
	Transformity	1.80E+04sej/J	
IMPORTS:			
12 Petroleum Products			
	Forest Service Use	1.30E+06gal/yr	estimate
	energy=gal*13e7j/gal		
	energy=	1.56E+14J/yr	
	FS Building Use	2.60E+06sq feet	
		6.66E+04BTU/sq ft/yr	EIA, 1992
	energy use =BTU/sqft/yr*sq ft*1055 joules/BTU		
	=	1.82E+14	
	Total Fuel Use	3.39E+14J/yr	
	Transformity	1.11E+05sej/J	Odum, (1996)
	Est. Cost=gal*$2/gal+MMBTUs*$14/MMBTU		
		5.02E+06$/yr	
13 Machinery, Equipment			
	mass	8.75E+09g	estimate
	avg. vehicle lifespan	2.00E+01yrs	
	use per y =vehicles*g/vehicle*1/avg life of vehicle		
	mass used per year	4.38E+08g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Goods (Pesticides, herbicides)		1.20E+07g/yr	USFS, 2005
		2.49E+10sej/g	
	emergy=	2.98E+17sej/yr	
	Est. for cost	2.11E+06$/yr	
15 Replanting			
Total Cost=		2.99E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism			
	Tourist Time	2.33E+07visits/yr	USFS, 2005
	average stay	1.90E+01hrs	
	Total Hours of Stay	4.43E+08hours/yr	
	avg. energy/hr	1.04E+02kcal/hr	
	total energy expenditure=kcal/hr*hrs*4186J/Kcal		
	energy=	1.93E+14J/y	
	Transformity	1.50E+07 sej/J	
17 Labor			

	FS	6.94E+06hrs/yr	USFS, 2005
	Contractors	7.62E+06hrs/yr	
	Total Labor	1.87E+07hrs/yr	
	Unit Emergy Value	6.30E+13sej/hr	based on USA emergy use (1.9E25 sej/yr) and work force of 1.5 E8 workers
18	Electricity	2596247sq ft	USFS, 2005
		37000btu/ft^2/yr	EIA, 1992
		9.61E+10btu/yr	
	energy=btu/yr*1055 j/btu		
	=	1.01E+14J	
	Transformity	2.92E+05	Odum, 1996
	Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
		2.53E+06$/yr	
	Regional FS budget	2.88E+08$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19	Services	3.05E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20	Payment for timber	3.79E+06$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21	Payments for Extracted Minerals	1.35E+08$/y	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22	Fee Payments	3.92E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
	EXPORTS:		
12	Extracted Firewood		
	mass	1.30E+08kg	NFS Web
	energy=mass*1000g/kg15000j/g		
	energy=	1.95E+15J/yr	
	Transformity	3.60E+04sej/J	Brown & Bardi (2001)
24	Harvested Wood	1.73E+06m^3/yr	USFS, 2005
		5.40E+05g/m^3	
	mass	9.36E+11g/yr	
	energy=g*15000j/g		
	=	1.40E+16J/yr	
	Transformity (w/o services)	5.04E+04	Brown, 2001
25	Water, Chemical potential		
	Total Export From Streams	1.41E+10m^3/yr	Sedell, 2000
	Chemical Potential= M^3/yr * 1000 kg/M^3 * 4940 J/kg		
	joules =	6.98E+16J/yr	
	Transformity	8.10E+04sej/J	Odum, 2000
26	Water, Geopotential Energy		
	Geopotential (J) =(volume)(elevation)(density)(gravity)		
	avg elevation	2.43E+03m^3/yr	USGS, 2006
	joules =	3.37E+17J/yr	

	Transformity	7.77E+04sej/J	Odum, 2000
27	Minerals	1.94E+11g/yr	estimate
	sp.emergy (avg)=	8.16E+09	CEP(2006)
28	Fossil Fuels		
	(National data only)		
29	Hunting		
	% Dry Weight for Wildlife	2.50E+01%	
	Big Game Extracted	8.70E+04Big Game/y	USFWS, 2002
	avg. mass	5.68E+04g/Game	
	energy content	2.65E+04J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	energy=	3.27E+15J/yr	
	Transformity=	9.90E+05sej/J	Brown et al, 2005
	Emergy=	3.24E+21sej	
	Small Game Extracted	3.31E+05Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03g/animal	
	energy content	6.37E+03J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	energy=	1.74E+14J/yr	
	Transformity=	1.20E+05sej/J	
	Emergy=	2.08E+19sej	
	Migratory Birds Extracted	2.61E+05#/yr	USFWS, 2002
	avg. mass	1.30E+03g/bird	
	energy content	8.83E+03J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	energy=	7.49E+11J/yr	
	Transformity=	1.01E+05sej/J	
	Emergy=	7.56E+16sej	
	Other Species Extracted	2.90E+04#/yr	USFWS, 2002
	avg. mass	6.35E+03g	
	energy content	6.37E+03J/g	
	energy=	#Game/yr*avg mass*(% dry weight)*J/g	
		2.93E+11J/yr	
	Transformity=	1.50E+05sej/J	
	Emergy=	4.39E+16sej	
	Sum of Emergy from Game	3.26E+21sej	
30	Fishing	6.64E+06fish caught	estimate
	avg. mass	4.54E+02g/fish	
	energy content	1.88E+04J/g	
	Energy Fish Caught	1.13E+13J	
	Transformity=	1.68E+07sej/J	
31	Information		
	$ spent for Research	0.00E+00$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
32	Hydroelectric Power		
	(National Data Only)		
33	Image Exported with Tourists		
	Number of toursits	2.90E+06	USFS, 2006
	Percent forest experienced	0.10%	estimate

	Total Env. & Economic Assets	6.1649E+23sej	From Table A3-10
	Emergy of image exported =	6.16E+20sej	
34	Payments to State	2.48E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.82E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)

APPENDIX A - 5. Annual emergy flows supporting Region 5 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity. (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^6$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	5.028E+20	1.00E+00	502.8	264.65
2	Rain Chemical Potential	J	1.86E+17	3.10E+04	5756.0	3029.46
3	Transpiration	J	1.42E+17	3.06E+04	4339.1	2283.73
4	Rain Geopotential	J	2.65E+16	4.70E+04	1244.3	654.92
5	Wind, Kinetic	J	1.80E+17	2.45E+03	440.9	232.08
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.00
7	Waves	J	1.61E+16	5.10E+04	819.7	431.44
8	Tides	J	1.30E+14	2.43E+04	3.2	1.66
9	Earth Cycle	J	2.09E+17	1.20E+04	2503.5	1317.65
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	6.08E+09	1.68E+09	10.2	5.38
	Top soil loss (harvesting)	J	4.58E+12	7.40E+04	0.3	0.18
11	Misc. Products (plants)	J		1.80E+04	0.0	0.00
IMPORTS:						
12	Petroleum Products	J	3.44E+14	1.11E+05	38.3	20.14
13	Machinery, Equipment	g	1.14E+09	1.13E+10	12.8	6.75
14	Misc. Goods	g	7.56E+06	1E9 - 7 E9	0.2	0.10
15	Seedlings	$	8.00E+06	1.90E+12	15.2	8.00
16	Tourist Time	J	2.54E+14	1.50E+07	3796.9	1998.34
17	Labor	hours	1.47E+07	6.30E+13	928.0	488.41
18	Electricity	J	1.91E+14	2.92E+05	55.7	29.31
19	Services	$	7.70E+08	1.90E+12	1463.1	770.05
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	1.92E+07	1.90E+12	36.5	19.21
21	Payments for minerals extracted	$	6.79E+08	1.90E+12	1289.5	678.70
22	Fee Payments (hunting, fishing, grazing, etc)	$	8.16E+06	1.90E+12	15.5	8.16
EXPORTS:						
23	Extracted Firewood	J	1.23E+15	3.60E+04	44.2	23.27
24	Harvested Wood	J	1.34E+16	5.04E+04	677.1	356.37
25	Water, Chemical Potential	J	2.02E+17	8.10E+04	16387.1	8624.78
26	Water, Geopotential	J	3.68E+17	4.70E+04	17278.6	9094.01
27	Minerals	g	9.79E+11	8.16E+09	7993.5	4207.11
28	Fossil Fuels	J				
29	Harvested wildlife	J	1.77E+15	1e5 - 9.9e5	1670.4	879.18
30	Harvested Fish	J	1.49E+13	1.68E+07	250.9	132.06
31	Information (research)	hrs	5.02E+04	2.35E+14	11.8	6.21
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%	--	586.0	308.4
ECONOMIC PAYMENTS MADE						
34	Payments to St. &Local Gov't	$	6.80E+07	1.90E+12	129.2	68.02
35	Payments for Labor	$	1.40E+08	1.90E+12	266.8	140.43

Footnotes to Table A-5

RENEWABLE RESOURCES:

1 Solar Insolation			Sources
	Land Area	8.17E+10m^2	
	Insolation	7.51E+09J/m^2/year	NREL, 2006
	Albedo	1.80E-01(% given as a decimal)	
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		5.03E+20J	
	Transformity	1.00E+00sej/J	
2 Rain			
Chemical Potential			
	Land Area	8.17E+10m^2	
	Rain	0.460202m/yr	NOAA, 2006
	Total Volume Rain	3.76E+10m^3	
	energy=volume*1000kg/m^3*4940J/kg		
	=	1.86E+17	
	Transformity	3.10E+04sej/J	Odum (2000)
3 Transpiration		3.52E-01m/m^2/yr	
	Energy=Vol*1000Kg/m^3*4940J/kg		
	Rain ET Energy	1.42E+17J/yr	
	Transformity	3.06E+04sej/J	Odum (2000)
4 Rain Geopotential			
	Rain	1.08E-01m/yr	NOAA, 2006
	Mean Elevation Change	3.05E+02 m	
	Land Area	8.17E+10m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	2.65E+16J	
	Transformity	4.70E+04sej/J	Odum (2000)
5 Wind, Kinetic			
	Area	8.17E+10	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	3.12E+00mps	NOAA, 2006
			observed winds are about 0.6 of geostrophic
	Geostrophic wind	5.19E+00wind	
	Drag Coeff.	2.00E-03	
	Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000		
	=	1.80E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6 Hurricanes			
None			
7 Waves			
	Shore length =	1.63E+05m	
	Wave height =	7.50E-01m	
	Energy(J) =	(shore length)(1/8)(density)(gravity)(wave height^2)(velocity)	
		(__m)(1/8)(1.025E3kg/m^3)(9.8 =m/sec^2)(__m)^2(__m/sec)(3.14E7s/yr)	
	Energy(J) =	1.61E+16J/yr	
	Transformity =	5.10E+04sej/J	2.98E+04

8 Tidal		
Cont Shelf Area =	1.63E+07m^2	
Avg Tide Range =	1.50E+00m	
Density =	1.03E+03kg/m^3	
Tides/year =	7.06E+02	(number of tides in 365 days)
Energy(J) =	(shelf)(0.5)(tides/y)(mean tidal range)^2 (density of seawater)(gravity)	
	=(____m^2)*(0.5)*(____/yr)*(____m)^2*(_____kg/m^3) *(9.8m/s^2)	
=	1.30E+14J/yr	
Transformity =	2.43E+04sej/J	
9 Earth Cycle		
Heat Flow	8.10E+01miliwatts/m^2	IHFC, 2005
area	8.17E+10m^2	
energy=	miliwatts/m^2*area*sec/yr	
	2.55E+06J/m^2	
energy=	2.09E+17J/yr	
Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:		
10 Soil Loss	6.08E+09g/yr	USFS, 2005
Top Soil Loss (3.5% of total SL)	2.13E+08g/yr	
energy=	g of C*5.4 kca'/g*4184 J/cal	
=	4.58E+12J	
Transformity=	7.40E+04 sej/j	
Miscellaneous Products 11(Plants)	g/yr	USFS, 2005
energy=	g*3.5kcal/g*4186J/Kcal	
=	2.66E+10joules	
Transformity	1.80E+04sej/J	
IMPORTS:		
12 Petroleum Products		
Forest Service Use	3.38E+06gal/yr	
energy=	gal*13e7j/gal	
=	4.39E+14J/yr	
FS Building Use	4.89E+06sq feet	
	6.66E+04BTU/sq ft/yr	EIA, 1992
energy use =	BTU/sqft/yr*sq ft*1055 joules/BTU	
=	3.44E+14	
Total Fuel Use	7.82E+14J/yr	
Transformity	1.11E+05sej/J	Odum, (1996)
Est. Cost=	gal*$2/gal+MMBTUs*$14/MMBTU	
	1.13E+07$/yr	
13 Machinery, Equipment		
FS Vechiles Mass	2.E+10g	
avg. vehicle lifespan	2.00E+01yrs	
use per y =	vehicles*g/vehicle*1/avg life of vehicle	
mass used per year	1.14E+09g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Goods (Pest/, herbicides)	7.56E+06g/yr	USFS, 2005

		2.49E+10sej/g	
	emergy=	1.88E+17sej/yr	
	Est. for cost	1.33E+06$/yr	
15 Replanting			
	Total Cost=	8.00E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism			
	Tourist Time	3.07E+07visits/yr	USFS, 2004
	average stay	1.90E+01hrs	
	Total Hours of Stay	5.83E+08hours/yr	
	avg. energy/hr	1.04E+02kcal/hr	
	total energy expenditure=kcal/hr*hrs*4186J/Kcal		
	=	2.54E+14J/y	
	Transformity	1.50E+07 sej/J	
17 Labor			
	FS	5.36E+06hrs/yr	USFS, 2005
	Contractors	6.08E+06hrs/yr	
	Total Labor	1.47E+07hrs/yr	
	Unit Emergy Value	6.30E+13sej/hr	based on USA emergy use (1.9E25 sej/yr) and work force of 1.5 E8 workers
18 Electricity		4889205sq ft	USFS, 2005
		37000btu/ft^2/yr	EIA, 1992
		1.81E+11btu/yr	
	energy=btu/yr*1055 j/btu		
	=	1.91E+14J	
	Transformity	2.92E+05	Odum, 1996
	Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
		4.77E+06$/yr	
Regional FS budget		5.77E+08$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19 Services		7.70E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20 Payment for timber		1.92E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21 Payments for Extracted Minerals		6.79E+08$/y	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22 Fee Payments		8.16E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:			
23 Extracted Firewood			
	mass	8.19E+07kg	
	energy=mass*1000g/kg15000j/g		
	=	1.23E+15J/yr	
	Transformity	3.60E+04sej/J	Brown & Bardi (2001)
24 Harvested Wood		1.66E+06m^3/yr	USFS, 2005

		5.40E+05g/m^3	
	mass	8.96E+11g/yr	
	energy=g*15000j/g		
	=	1.34E+16J/yr	
	Transformity (w/o services)	5.04E+04	Brown, 2001
25	Water, Chemical potential		
	Total Export From Streams	4.10E+10m^3/yr	Sedell, 2000
	Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
	joules =	2.02E+17J/yr	
	Transformity	8.10E+04sej/J	Odum, 2000
26	Water, Geopotential Energy		
	Geopotential (J) =(volume)(elevation)(density)(gravity)		
	avg. elevation	9.16E+02m	USGS, 2006
	joules =	3.68E+17J/yr	
	Transformity	4.70E+04sej/J	Odum, 2000
27	Minerals	9.79E+11g/yr	estimate
	Sp. Emergy (avg)=	8.16E+09sej/g	
28	Fossil Fuels		
	(National data only)		
29	Hunting		
	% Dry Weight for Wildlife	2.50E+01%	
	Big Game Extracted	4.45E+04Big Game/y	USFWS, 2002
	avg. mass	5.68E+04g/Game	
	energy content	2.65E+04J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	1.68E+15J/yr	
	Transformity=	9.90E+05sej/J	Brown et al. 2005
	Emergy=	1.66E+21sej	
	Small Game Extracted	1.69E+05Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03g/animal	
	energy content	6.37E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	8.89E+13J/yr	
	Transformity=	1.20E+05sej/J	Brown et al. 2005
	Emergy=	1.07E+19sej	
	Migratory Birds Extracted	1.34E+05#/yr	USFWS, 2002
	avg. mass	1.30E+03g/bird	
	energy content	8.83E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	3.84E+11J/yr	
	Transformity=	1.01E+05sej/J	Brown et al. 2005
	Emergy=	3.87E+16sej	
	Other Species Extracted	1.48E+04#/yr	USFWS, 2002
	avg. mass	6.35E+03g	
	energy content	6.37E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
		1.50E+11J/yr	

	Transformity=	1.50E+05sej/J	Brown et al. 2005
	Emergy=	2.25E+16sej	
	Sum of Emergy from Game	1.67E+21sej	
30	Fishing	8.75E+06fish caught	
	avg. mass	4.54E+02g/fish	assume avg weight = 1 lb
	energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)
	Energy Fish Caught	1.49E+13J	assume 20% dry weight
	Transformity=	1.68E+07sej/J	
31	Research Information	2.40E+01# of papers	
	average time spent	8.05E+02hours/paper	
	research hours	50209.27hours/yr	
	Transformity	2.35E+14sej/hr	Odum, 1996
	total sej of research	1.18E+19sej	
32	Hydroelectric Power (National Data Only)		
33	Image Exported with Tourists		
	Number of tourists	2.90E+06	USFS, 2006
	Percent forest experienced	0.10%	estimate
	Total Env. & Economic Assets	5.86E+23sej	From Table A3-10
	Emergy of image exported =	5.86E+20sej	
34	Payments to State	6.80E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.40E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)

APPENDIX A - 6. Annual emergy flows supporting Region 6 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity. (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	4.628E+20	1.00E+00	462.8	243.6
2	Rain Chemical Potential	J	4.48E+17	3.10E+04	13880.6	7305.6
3	Transpiration	J	1.76E+17	3.06E+04	5370.1	2826.4
4	Rain Geopotential	J	2.80E+17	4.70E+04	13142.8	6917.3
5	Wind, Kinetic	J	3.06E+17	2.45E+03	748.7	394.0
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	3.30E+17	1.20E+04	3955.3	2081.7
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	2.88E+10	1.68E+09	48.4	25.5
	Top soil loss (harvesting)	J	2.17E+13	7.40E+04	1.6	0.8
11	Misc.Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	3.57E+14	1.11E+05	39.8	20.9
13	Machinary, Equipment	g	8.52E+08	1.13E+10	9.6	5.0
14	Misc.Goods (Pest/herbicides,)	g	9.29E+06	1E9 - 7 E9	0.2	0.1
15	Seedlings	$	1.44E+07	1.90E+12	27.4	14.4
16	Tourist Time	J	2.33E+14	1.50E+07	3487.7	1835.6
17	Labor	hours	2.06E+07	6.30E+13	1296.1	682.2
18	Electricity	J	1.98E+14	2.92E+05	57.9	30.5
19	Services	$	1.91E+08	1.90E+12	363.1	191.1
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	5.69E+07	1.90E+12	108.1	56.9
21	Payments for minerals extracted	$	7.19E+07	1.90E+12	136.5	71.9
22	Fee Payments (hunting, fishing, grazing, etc)	$	9.52E+06	1.90E+12	18.1	9.5
EXPORTS:						
23	Extracted Firewood	J	1.51E+15	3.60E+04	54.3	28.6
24	Harvested Wood	J	2.12E+16	5.04E+04	1068.8	562.5
25	Water, Chemical Potential	J	2.72E+17	8.10E+04	22041.8	11600.9
26	Water, Geopotential	J	5.40E+17	4.70E+04	25372.2	13353.8
27	Minerals	g	1.04E+11	8.16E+09	844.8	444.6
28	Fossil Fuels	J				
29	Harvested wildlife	J	4.39E+15	1e5 - 9.9e5	4152.0	2185.3
30	Harvested Fish	J	1.37E+13	1.68E+07	230.5	121.3
31	Information (research)	hrs	1.15E+05	2.35E+14	27.1	14.3
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%	--	588.6	309.8
ECONOMIC PAYMENTS MADE						
34	Payments to St. & Local Gov't	$	2.10E+08	1.90E+12	398.9	210.0
35	Payments for Labor	$	1.67E+08	1.90E+12	317.6	167.2

Footnotes to Table A-6
RENEWABLE RESOURCES:

1 Solar Insolation			Sources
	Land Area	1.00E+11m^2	
	Insolation	5.62E+09J/m^2/year	NREL, 2006
	Albedo	1.80E-01(% given as a decimal)	
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		4.63E+20J	
	Transformity	1.00E+00sej/J	
2 Rain			
Chemical Potential			
	Land Area	1.00E+11m^2	
	Rain	0.903022m/yr	NOAA 2006
	Total Volume Rain	9.06E+10m^3	
	energy=volume*1000kg/m^3*4940J/kg		
	=	4.48E+17	
	Transformity	3.10E+04sej/J	Odum (2000)
3 Transpiration		3.54E-01m/m^2/yr	
		3.56E+10m3	
	Energy=Vol*1000Kg/m^3*4940J/kg		
	Rain ET Energy	1.76E+17J/yr	
	Transformity	3.06E+04sej/J	Odum (2000)
4 Rain Geopotential			
	Rain	5.49E-01m/yr	NOAA 2006
	Mean Elevation Change	5.18E+02m	
	Land Area	1.00E+11m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	2.80E+17J	
	Transformity	4.70E+04sej/J	Odum (2000)
5 Wind, Kinetic			
	Area	1.00E+11	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	3.47E+00mps	NOAA 2006
	Geostrophic wind	5.79E+00 observed winds are about 0.6 of geostrophic wind	
	Drag Coeff.	2.00E-03	
	Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000		
	=	3.06E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6 Hurricanes			
None			
7 Waves			
None			
8 Tides			
None			
9 Earth Cycle			
	Heat Flow	1.04E+02miliwatts/m^2	IHFC, 2005
	area	1.00E+11m^2	
	energy=miliwatts/m^2*area*sec/yr		

	3.28E+06J/m^2	
energy=	3.30E+17J/yr	
Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:		
10 Soil Loss	2.88E+10g/yr	estimate
Top Soil Loss (3.5% of total SL)	1.01E+09g/yr	
energy=	g of C*5.4 kca'/g*4184 J/cal	
=	2.17E+13J	
Transformity=	7.40E+04 sej/j	
11 Miscellaneous Products (Plants)	g/yr	USFS, 2005
energy=	g*3.5kcal/g*4186J/Kcal	
=	2.66E+10joules	
Transformity	1.80E+04sej/J	
IMPORTS:		
12 Petroleum Products		
Forest Service Use	3.33E+06gal/yr	
energy=	gal*13e7j/gal	
=	4.33E+14J/yr	
FS Building Use	5.08E+06sq feet	
	6.66E+04BTU/sq ft/yr	EIA, 1992
energy use =	BTU/sqft/yr*sq ft*1055 joules/BTU	
=	3.57E+14	
Total Fuel Use	7.90E+14J/yr	
Transformity	1.11E+05sej/J	Odum, (1996)
Est. Cost=	gal*$2/gal+MMBTUs*$14/MMBTU	
	1.14E+07$/yr	
13 Machinery, Equipment		
FS Vehicle mass	1.7E+10g	
avg. vehicle lifespan	2.00E+01yrs	
use per y =	vehicles*g/vehicle*1/avg life of vehicle	
mass used per year	8.52E+08g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Goods (Pesticides, herbicides, misc goods)	9.29E+06g/yr	USFS, 2005
	2.49E+10sej/g	
emergy=	2.31E+17sej/yr	
Est. for cost	1.64E+06$/yr	
15 Replanting		
Total Cost=	1.44E+07$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism		
Tourist Time	2.82E+07visits/yr	USFS, 2004
average stay	1.90E+01hrs	
Total Hours of Stay	5.36E+08hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=	kcal/hr*hrs*4186J/Kcal	
=	2.33E+14J/y	
Transformity	1.50E+07 sej/J	

17	Labor		
	FS	6.38E+06hrs/yr	NFS, 2005
	Contractors	9.60E+06hrs/yr	
	Total Labor	2.06E+07hrs/yr	
	Unit Emergy Value	6.30E+13sej/hr	based on USA emergy use (1.9E25 sej/yr) and work force of 1.5 E8 workers
18	Electricity	5084087sq ft	USFS, 2005
		37000btu/ft^2/yr	EIA, 1992
		1.88E+11btu/yr	
	energy=btu/yr*1055 j/btu		
	=	1.98E+14J	
	Transformity	2.92E+05	Odum, 1996
	Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
		4.96E+06$/yr	
	Regional FS budget	4.51E+08$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19	Misc. Expenditures	1.91E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20	Payment for timber	5.69E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21	Payments for Extracted Minerals	7.19E+07$/y	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22	Fee Payments	9.52E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:			
23	Extracted Firewood		
	mass	1.01E+08kg	
	energy=mass*1000g/kg15000j/g		
	=	1.51E+15J/yr	
	Transformity	3.60E+04sej/J	Brown & Bardi (2001)
24	Harvested Wood	2.62E+06m^3/yr	USFS, 2005
		5.40E+05g/m^3	
	mass	1.41E+12g/yr	
	energy=g*15000j/g		
	=	2.12E+16J/yr	
	Transformity (w/o services)	5.04E+04	Brown, 2001
25	Water, Chemical potential		
	Total Export From Streams	5.51E+10m^3/yr	
	Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
	joules =	2.72E+17J/yr	
	Transformity	8.10E+04sej/J	Odum, 2000
26	Water, Geopotential Energy		
	Geopotential (J) =(volume)(elevation)(density)(gravity)		
	avg. elevation	1.00E+03m	USGS, 2006
	joules =	5.40E+17J/yr	

	Transformity	4.70E+04sej/J	Odum, 2000
27	Minerals	1.04E+11g/yr	
	Sp. Emergy (avg)=	8.16E+09sej/g	
28	Fossil Fuels (National data only)		
29	Hunting		
	% Dry Weight for Wildlife	2.50E+01%	
	Big Game Extracted	1.11E+05Big Game/y	USFWS, 2002
	avg. mass	5.68E+04g/Game	
	energy content	2.65E+04J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	4.17E+15J/yr	
	Transformity=	9.90E+05sej/J	Brown et al, 2005
	Emergy=	4.13E+21sej	
	Small Game Extracted	4.21E+05Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03g/animal	
	energy content	6.37E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	2.21E+14J/yr	
	Transformity=	1.20E+05sej/J	
	Emergy=	2.65E+19sej	
	Migratory Birds Extracted	3.32E+05#/yr	USFWS, 2002
	avg. mass	1.30E+03g/bird	
	energy content	8.83E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	9.53E+11J/yr	
	Transformity=	1.01E+05sej/J	
	Emergy=	9.63E+16sej	
	Other Species Extracted	3.69E+04#/yr	USFWS, 2002
	avg. mass	6.35E+03g	
	energy content	6.37E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
		3.73E+11J/yr	
	Transformity=	1.50E+05sej/J	
	Emergy=	5.59E+16sej	
	Sum of Emergy from Game	4.15E+21sej	
30	Fishing	8.04E+06fish caught	USFS, 2004
	avg. mass	4.54E+02g/fish	assume avg weight = 1 lb
	energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)
	Energy Fish Caught	1.37E+13J	assume 20% dry weight
	Transformity=	1.68E+07sej/J	
31	Research Information	1.05E+02# of papers	
	average time spent	8.05E+02hours/paper	
	research hours	115384.8hours/yr	
	Transformity	2.35E+14sej/hr	Odum, 1996
	total sej of research	2.71E+19sej	
32	Hydroelectric Power		

	(National Data Only) Image Exported w/		
33	Tourists		
	Number of tourists	2.90E+06	USFS, 2006
	Percent forest experienced	0.10%	estimate
	Total Env. & Economic Assets	5.89E+23sej	From Table A3-10
	Emergy of image exported =	5.89E+20sej	
	use/ha/hour	2.71E+11sej/ha	CEP (2006)
	emergy of image exported	3.61E+22sej/yr	
	Unit emergy value	6.73E+13sej/visitor hour	
34	Payments to State	2.10E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.67E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)

APPENDIX A - 7. Annual emergy flows supporting Region 8 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^6$ Em$)
	RENEWABLE RESOURCES:					
1	Sunlight	J	2.42E+20	1.00E+00	242.0	127.4
2	Rain Chemical Potential	J	3.21E+17	3.10E+04	9959.4	5241.8
3	Transpiration	J	2.05E+17	3.06E+04	6275.1	3302.7
4	Rain Geopotential	J	2.30E+16	4.70E+04	1081.8	569.4
5	Wind, Kinetic	J	2.43E+17	2.45E+03	595.1	313.2
6	Hurricanes	J	3.38E+17	6.49E+03	2193.6	1154.5
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	1.04E+17	1.20E+04	1253.6	659.8
	INDIGENOUS NONRENEWABLE RESOURCES:					
10	Soil Loss (harvesting)	g	4.45E+09	1.68E+09	7.5	3.9
	Top soil loss (harvesting)	J	3.35E+12	7.40E+04	0.2	0.1
11	Misc. Products (plants)	J		1.80E+04	0.0	0.0
	IMPORTS:					
12	Petroleum Products	J	5.93E+14	1.11E+05	66.1	34.8
13	Machinery, Equipment	g	7.48E+08	1.13E+10	8.4	4.4
14	Misc. Goods (Pesticides, herb)	g	4.98E+06	1E9 - 7 E9	0.1	0.1
15	Seedlings	$	8.10E+06	1.90E+12	15.4	8.1
16	Tourist Time	J	2.56E+14	1.50E+07	3834.0	2017.9
17	Labor	hours	1.49E+07	6.30E+13	940.6	495.0
18	Electricity	J	1.35E+14	2.92E+05	39.3	20.7
19	Services	$	4.35E+08	1.90E+12	825.8	434.6
	ECONOMIC PAYMENTS RECEIVED					
20	Payment for timber	$	4.02E+07	1.90E+12	76.4	40.2
21	Payments for minerals extracted	$	4.38E+04	1.90E+12	0.1	0.0
22	Fee Payments (hunting, grazing,)	$	9.01E+06	1.90E+12	17.1	9.0
	EXPORTS:					
23	Extracted Firewood	J	8.10E+14	3.60E+04	29.1	15.3
24	Harvested Wood	J	1.53E+16	5.04E+04	771.2	405.9
25	Water, Chemical Potential	J	1.16E+17	8.10E+04	9398.4	4946.5
26	Water, Geopotential	J	7.83E+16	4.70E+04	3678.3	1935.9
27	Minerals	g	6.32E+10	8.16E+09	515.7	271.4
28	Fossil Fuels	J				
29	Harvested wildlife	J	1.59E+16	1E5 - 9.9E5	3118.5	1641.3
30	Harvested Fish	J	1.51E+13	1.68E+07	253.4	133.4
31	Information (research)	hrs	3.25E+05	2.35E+14	76.3	40.1
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%	--	323.1	170.1
	ECONOMIC PAYMENTS MADE					
34	Payments to St. &Local Gov't	$	3.76E+07	1.90E+12	71.4	37.6
35	Payments for Labor	$	1.87E+08	1.90E+12	355.7	187.2

Footnotes to Table A - 7
RENEWABLE RESOURCES:

1 Solar Insolation			Sources
	Land Area	5.38E+10m^2	
	Insolation	5.48E+09J/m^2/year	NREL, 2006
	Albedo	1.80E-01(% given as a decimal)	
	Energy(J)	=(area)*(avg insolation)*(1-albedo)	
		2.42E+20J	
	Transformity	1.00E+00sej/J	
2 Rain			
Chemical Potential			
	Land Area	5.38E+10m^2	
	Rain	1.207792m/yr	NOAA, 2006
	Total Volume Rain	6.50E+10m^3	
	energy=volume*1000kg/m^3*4940J/kg		
	=	3.21E+17	
	Transformity	3.10E+04sej/J	Odum, (2000)
3 Transpiration		7.72E-01m/m^2/yr	
		4.15E+10m3	
	Energy=Vol*1000Kg/m^3*4940J/kg		
	Rain ET Energy	2.05E+17J/yr	
	Transformity	3.06E+04sej/J	Odum, (2000)
4 Rain Geopotential			
	Rain	4.36E-01m/yr	NOAA 2006
	Mean Elevation Change	1.00E+02 m	
	Land Area	5.38E+10m^2	
	Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
	=	2.30E+16J	
	Transformity	4.70E+04sej/J	Odum, (2000)
5 Wind, Kinetic			
	Area	5.38E+10	
	air density	1.30E+00kg/m^3	
	avg annual wind velocity	3.96E+00mps	NOAA
	Geostrophic wind	6.60E+00 observed winds are about 0.6 of geostrophic wind	
	Drag Coeff.	2.00E-03	
	Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000		
	=	2.43E+17	
	Transformity	2.45E+03sej/J	Odum (2000)
6 Hurricanes			
	Avg energy/storm	5.00E+05KCAL/m^2/day	Odum et al, 1983
	avg hurricane freq.	1.00E-01/yr	
	percent energy that is kinetic	3.00E+00%	
	percent of energy dispersed to land	1.00E+01%	
	avg. residence time	1.00E+00day/year	
	area	5.38E+10m^2	
	energy=0.1/yr*1yr/365 days*5e5Kcal/m^2/day*.003*area m^2*4186J/kcal		
	=	9.26E+13j/yr	
	Transformity	6.49E+03sej/J	Odum (2000)
7 Waves			

None			
8 Tides			
None			
9 Earth Cycle			
	Heat Flow	6.15E+01miliwatts/m^2	IHFC, 2005
	area	5.38E+10m^2	
	energy=miliwatts/m^2*area*sec/yr		
		1.94E+06J/m^2	
	energy=	1.04E+17J/yr	
	Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:			
10 Soil Loss		4.45E+09g/yr	estimate
Top Soil Loss (3.5% of total SL)		1.56E+08g/yr	
	energy=g of C*5.4 kca'/g*4184 J/cal		
	=	3.35E+12J	
	Transformity=	7.40E+04 sej/j	
11 Miscellaneous Products (Plants)		g/yr	
	energy=g*3.5kcal/g*4186J/Kcal		
	=	joules	
	Transformity	1.80E+04sej/J	
IMPORTS:			
12 Petroleum Products			
	Forest Service Vechicle Use	2.70E+06gal/yr	
	energy=gal*13e7j/gal		
	=	3.51E+14J/yr	
	FS Building Use	3.45E+06sq feet	
		6.66E+04BTU/sq ft/yr	EIA, 1992
	energy use =BTU/sqft/yr*sq ft*1055 joules/BTU		
	=	2.42E+14	
	Total Fuel Use	5.93E+14J/yr	
	Transformity	1.11E+05sej/J	Odum, (1996)
	Est. Cost=gal*$2/gal+MMBTUs*$14/MMBTU		
		8.61E+06$/yr	
13 Machinery, Equipment			
	FS Vechile mass	1.50E+10g	
	avg. vehicle lifespan	2.00E+01yrs	
	use per y =vehicles*g/vehicle*1/avg life of vehicle		
	mass used per year	7.48E+08g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
14 Goods (Pesticides, herbicides)		4.98E+06g/yr	estimate
		2.49E+10sej/g	
	emergy=	1.24E+17sej/yr	
	Est. for cost	8.78E+05$/yr	
15 Replanting			
	Total Cost=	8.10E+06$/yr	USFS, 2006 (unpub)
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism			
	Tourist Time	3.10E+07visits/yr	USFS, 2004
	average stay	1.90E+01hrs	

Total Hours of Stay	5.89E+08hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=kcal/hr*hrs*4186J/Kcal		
=	2.56E+14J/y	
Transformity	1.50E+07 sej/J	
17 Labor		
FS	7.14E+06hrs/yr	estimate
Contractors	4.45E+06hrs/yr	
Total Labor	1.49E+07hrs/yr	
Unit Emergy Value	6.30E+13sej/hr	Odum, 1996
18 Electricity	3448386sq ft	USFS, 2006 unpub.
	37000btu/ft^2/yr	EIA, 1992
	1.28E+11btu/yr	
energy=btu/yr*1055 j/btu		
=	1.35E+14J	
Transformity	2.92E+05	Odum, 1996
Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
	3.37E+06$/yr	
Regional FS budget	4.03E+08$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19 Misc. Expenditures	4.35E+08$/yr	USFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20 Payment for timber	4.02E+07$/yr	USFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21 Payments for Extracted Minerals	4.38E+07$/y	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22 Fee Payments	9.01E+06$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:		
23 Extracted Firewood		
mass	5.40E+07kg	USFS, 2007
energy=mass*1000g/kg*15000j/g		
=	8.10E+14J/yr	
Transformity	3.60E+04sej/J	Brown & Bardi (2001)
24 Harvested Wood	1.89E+06m^3/yr	USFS, 2007
	5.40E+05g/m^3	
mass	1.02E+12g/yr	
energy=g*15000j/g		
=	1.53E+16J/yr	
Transformity (w/o services)	5.04E+04	Brown, 2001
25 Water, Chemical potential		
Total Export From Streams	2.35E+10m^3/yr	Sedell, 2000
Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
joules =	1.16E+17J/yr	
Transformity	8.10E+04sej/J	Odum, 2000
26 Water, Geopotential Energy		
Geopotential (J) =(volume)(elevation)(density)(gravity)		
avg. elevation	3.40E+02m	USGS, 2006
joules =	7.83E+16J	

Transformity	4.70E+04sej/J	Odum, 2000
27 Minerals	6.32E+10g/yr	estimate
Sp. Emergy (avg)=	8.16E+09sej/g	
28 Fossil Fuels		
(National data only)		
29 Hunting		
% Dry Weight for Wildlife	2.50E+01%	
Big Game Extracted	4.01E+05Big Game/y	USFWS, 2002
avg. mass	5.68E+04g/Game	
energy content	2.65E+04J/g	
energy=	#Game/yr*avg mass*(% dry weight)*J/g	
=	1.51E+16J/yr	
Transformity=	2.00E+05sej/J	Brown, et al, 2005
Emergy=	3.02E+21sej	
Small Game Extracted	1.53E+06Small Game/yr	USFWS, 2002
avg. mass	3.30E+03g/animal	
energy content	6.37E+03J/g	
energy=	#Game/yr*avg mass*(% dry weight)*J/g	
energy=	8.01E+14J/yr	
Transformity=	1.20E+05sej/J	Brown, et al, 2005
Emergy=	9.61E+19sej	
Migratory Birds Extracted	1.20E+06#/yr	USFWS, 2002
avg. mass	1.30E+03g/bird	
energy content	8.83E+03J/g	
energy=	#Game/yr*avg mass*(% dry weight)*J/g	
energy=	3.46E+12J/yr	
Transformity=	1.01E+05sej/J	Brown, et al, 2005
Emergy=	3.49E+17sej	
Other Species Extracted	1.34E+05#/yr	USFWS, 2002
avg. mass	6.35E+03g	
energy content	6.37E+03J/g	
energy=	#Game/yr*avg mass*(% dry weight)*J/g	
	1.35E+12J/yr	
Transformity=	1.50E+05sej/J	Brown, et al, 2005
Emergy=	2.03E+17sej	
Sum of Emergy from Game	3.12E+21sej	
30 Fishing	8.84E+06fish caught	
avg. mass	4.54E+02g/fish	assume avg weight = 1 lb
energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)
Energy Fish Caught	1.51E+13J	assume 20% dry weight
Transformity=	1.68E+07sej/J	
31 Research Information	3.65E+02# of papers	USFS, 2007
average time spent	8.05E+02hours/paper	
research hours	324590.1hours/yr	
Transformity	2.35E+14sej/hr	Odum, 1996
total sej of research	7.63E+19sej	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
32 Hydroelectric Power		
(National Data Only)		

33	Image Exported with Tourists		
	Number of tourists	2.90E+06	USFS, 2006
	Percent forest experienced	0.10%	estimate
	Total Env. & Economic Assets	3.23E+23sej	From Table A3-10
	Emergy of image exported =	3.23E+20sej	
34	Payments to State and Local	3.76E+07$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
35	Payments for FS Labor	1.87E+08$/yr	USFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)

APPENDIX A-8. Annual emergy flows supporting Region 9 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity . (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^6$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	1.947E+20	1.00E+00	194.7	102.5
2	Rain Chemical Potential	J	2.04E+17	3.10E+04	6308.5	3320.3
3	Transpiration	J	1.14E+17	3.06E+04	3480.6	1831.9
4	Rain Geopotential	J	4.45E+16	4.70E+04	2089.9	1100.0
5	Wind, Kinetic	J	2.94E+17	2.45E+03	720.7	379.3
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	0	5.10E+04	0.0	0.0
8	Tides	J	0	7.39E+04	0.0	0.0
9	Earth Cycle	J	8.82E+16	1.20E+04	1058.0	556.9
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	1.07E+10	1.68E+09	18.1	9.5
	Top soil loss (harvesting)	J	8.09E+12	7.40E+04	0.6	0.3
11	Miscellaneous Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	2.61E+14	1.11E+05	29.1	15.3
13	Machinery, Equipment	g	3.62E+08	1.13E+10	4.1	2.1
14	Misc. Goods (Pesticides, herb)	g	4.53E+06	1E9 - 7 E9	0.1	0.1
15	Seedlings	$	7.08E+06	1.90E+12	13.5	7.1
16	Tourist Time	J	1.86E+14	1.50E+07	2782.7	1464.6
17	Labor	hours	8.80E+06	6.30E+13	554.1	291.7
18	Electricity	J	1.45E+14	2.92E+05	42.3	22.3
19	Services	$	2.72E+08	1.90E+12	516.0	271.6
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	5.80E+07	1.90E+12	110.3	58.0
21	Payments for minerals extracted	$	1.95E+08	1.90E+12	369.8	194.7
22	Fee Payments (hunting, fishing,	$	4.69E+06	1.90E+12	8.9	4.7
EXPORTS:						
23	Extracted Firewood	J	7.36E+14	3.60E+04	26.5	13.9
24	Harvested Wood	J	1.40E+16	5.04E+04	707.3	372.3
25	Water, Chemical Potential	J	8.97E+16	8.10E+04	7262.4	3822.3
26	Water, Geopotential	J	8.89E+16	4.70E+04	4179.9	2199.9
27	Minerals	g	2.81E+11	8.16E+09	2293.6	1207.1
28	Fossil Fuels	J				
29	Harvested wildlife	J	1.37E+16	1E5 - 3E5	3977.7	2093.5
30	Harvested Fish	J	1.09E+13	1.68E+07	183.7	96.7
31	Information (research)	hrs	1.66E+05	2.35E+14	39.0	20.5
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%	--	384.5	202.4
ECONOMIC PAYMENTS MADE						
34	Payments to St. and Local Gov't	$	1.48E+07	1.90E+12	28.1	14.8
35	Payments for Labor	$	1.07E+08	1.90E+12	203.3	107.0

Footnotes to Table A -8
RENEWABLE
RESOURCES:

1	Solar Insolation				Sources
		Land Area	4.89E+10	m^2	
		Insolation	4.85E+09	J/m^2/year	NREL, 2006
		Albedo	1.80E-01	(% given as a decimal)	
		Energy(J)	=(area)*(avg insolation)*(1-albedo)		
			1.95E+20	J	
		Transformity	1.00E+00	sej/J	
2	Rain				
	Chemical Potential				
		Land Area	4.89E+10	m^2	
		Rain	0.841641	m/yr	NOAA, 2006
		Total Volume Rain	4.12E+10	m^3	
		energy=volume*1000kg/m^3*4940J/kg			
		=	2.04E+17		
		Transformity	3.10E+04	sej/J	Odum, (2000)
3	Transpiration		4.71E-01	m/m^2/yr	
			2.30E+10	m3	
		Energy=Vol*1000Kg/m^3*4940J/kg			
		Rain ET Energy	1.14E+17	J/yr	
		Transformity	3.06E+04	sej/J	Odum, (2000)
4	Rain Geopotential				
		Rain	3.71E-01	m/yr	NOAA 2006
		Mean Elevation Change	2.50E+02	m	
		Land Area	4.89E+10	m^2	
		Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)		
		energy=	4.45E+16	J	
		Transformity	4.70E+04	sej/J	Odum, (2000)
5	Wind, Kinetic				
		Area	4.89E+10		
		air density	1.30E+00	kg/m^3	
		avg annual wind velocity	4.35E+00	mps	NOAA 2006
		Geostrophic wind	7.26E+00	observed winds are about 0.6 of geostrophic wind	
		Drag Coeff.	2.00E-03		
		Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000			
		=	2.94E+17		
		Transformity	2.45E+03	sej/J	Odum (2000)
6	Hurricanes				
	None				
7	Waves				
	None				
8	Tides				
	None				
9	Earth Cycle				
		Heat Flow	5.71E+01	miliwatts/m^2	IHFC, 2005
		area	4.89E+10	m^2	
		energy=miliwatts/m^2*area*sec/yr			
			1.80E+06	J/m^2	

energy=	8.82E+16	J/yr	
Transformity	1.32E+04	sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:			
10 Soil Loss	1.07E+10	g/yr	estimate
Top Soil Loss (3.5% of total SL)	3.76E+08	g/yr	
energy=	g of C*5.4 kca'/g*4184 J/cal		
=	8.09E+12	J	
Transformity=	7.40E+04	sej/j	
Miscellaneous Products			
11(Plants)		g/yr	
energy=	g*3.5kcal/g*4186J/Kcal		
=		joules	
Transformity	1.80E+04	sej/J	
IMPORTS:			
12 Petroleum Products			
Forest Service Use	1.50E+06	gal/yr	estimate
energy=	gal*13e7j/gal		
=	1.95E+14	J/yr	
FS Building Use	3.71E+06	sq feet	USFS, 2006 (unpub)
	6.66E+04	BTU/sq ft/yr	EIA, 1992
energy use =	BTU/sqft/yr*sq ft*1055 joules/BTU		
=	2.61E+14		
Total Fuel Use	4.56E+14	J/yr	
Transformity	1.11E+05	sej/J	Odum, (1996)
Est. Cost=	gal*$2/gal+MMBTUs*$14/MMBTU		
=	6.46E+06	$/yr	
13 Machinery, Equipment			
FS Vechile Mass	7.25E+09	g	
avg. vehicle lifespan	2.00E+01	yrs	
use per y =	vehicles*g/vehicle*1/avg life of vehicle		
mass used per year	3.62E+08	g	
Specific Emergy	1.13E+10	sej/g	CEP (2006)
Est. Cost of Vech. Depreciation	1.61E+06	$/yr	
14 Goods (Pesti, herbicides)	4.53E+06	g/yr	estimate
	2.49E+10	sej/g	
emergy=	1.13E+17	sej/yr	
Est. for cost	7.98E+05	$/yr	
15 Replanting			
Total Cost=	7.08E+06	$/yr	
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
16 Tourism			
Tourist Time	2.25E+07	visits/yr	USFS, 2004
average stay	1.90E+01	hrs	
Total Hours of Stay	4.28E+08	hours/yr	
avg. energy/hr	1.04E+02	kcal/hr	
total energy expenditure=	kcal/hr*hrs*4186J/Kcal		
=	1.86E+14	J/y	
Transformity	1.50E+07	sej/J	

17 Labor			
FS	4.08E+06	hrs/yr	estimate
Contractors	2.75E+06	hrs/yr	estimate
Total Labor	8.80E+06	hrs/yr	
Unit Emergy Value	6.30E+13	sej/hr	Odum, 1996
18 Electricity	3713620	sq ft	EIA, 1992
	37000	btu/ft^2/yr	
	1.37E+11	btu/yr	
energy=btu/yr*1055 j/btu			
=	1.45E+14	J	
Transformity	2.92E+05		Odum, 1996
Est. Cost=	3.62E+06	$/yr	
Regional FS budget	2.41E+08	$/yr	
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
19 Services	2.72E+08	$/yr	estimate
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
20 Payment for timber	5.80E+07	$/yr	USFS, 2007
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
21 Payments for Extracted Minerals	1.95E+08	$/y	USFS, 2006 (unpub)
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
22 Fee Payments	4.69E+06	$/yr	USFS, 2006 (unpub)
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
EXPORTS:			
23 ExtractedFirewood			
mass	4.91E+07	kg	USFS, 2005
energy=mass*1000g/kg15000j/g			
=	7.36E+14	J/yr	
Transformity	3.60E+04	sej/J	Brown & Bardi (2001)
24 Harvested Wood	1.73E+06	m^3/yr	USFS, 2005
	5.40E+05	g/m^3	
mass	9.36E+11	g/yr	
energy=g*15000j/g			
=	1.40E+16	J/yr	
Transformity (w/o services)	5.04E+04		
25 Water, Chemical potential			
Total Export From Streams	1.81E+10	m^3/yr	Sedell, 2000
Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg			
joules =	8.97E+16	J/yr	
Transformity	8.10E+04	sej/J	Odum, 2000
26 Water, Geopotential Energy			
Geopotential (J) =(volume)(elevation)(density)(gravity)			
avg. elevation	5.00E+02	m	USGS, 2006
joules =	8.89E+16	J	
Transformity	4.70E+04	sej/J	Odum, 2000
27 Minerals	2.81E+11	g/yr	estimate
Sp. Emergy (avg)=	8.16E+09	sej/g	

28	Fossil Fuels			
	(National data only)			
29	Hunting			
	% Dry Weight for Wildlife	2.50E+01	%	
	Big Game Extracted	3.45E+05	Big Game/y	USFWS, 2002
	avg. mass	5.68E+04	g/Game	
	energy content	2.65E+04	J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g			
	=	1.30E+16	J/yr	
	Transformity=	3.00E+05	sej/J	Brown et al, 2005
	Emergy=	3.89E+21	sej	
	Small Game Extracted	1.31E+06	Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03	g/animal	
	energy content	6.37E+03	J/g	
	energy=#*avg mass*(percent dry weight)J/g			
	energy=	6.88E+14	J/yr	
	Transformity=	1.20E+05	sej/J	
	Emergy=	8.26E+19	sej	
	Migratory Birds Extracted	1.03E+06	#/yr	USFWS, 2002
	avg. mass	1.30E+03	g/bird	
	energy content	8.83E+03	J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g			
	energy=	2.97E+12	J/yr	
	Transformity=	1.01E+05	sej/J	
	Emergy=	3.00E+17	sej	
	Other Species Extracted	1.15E+05	#/yr	USFWS, 2002
	avg. mass	6.35E+03	g	
	energy content	6.37E+03	J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g			
		1.16E+12	J/yr	
	Transformity=	1.50E+05	sej/J	
	Emergy=	1.74E+17	sej	
	Sum of Emergy from Game	3.98E+21	sej	
30	Fishing	6.41E+06	fish caught	
	avg. mass	4.54E+02	g/fish	assume avg weight = 1 lb
	energy content	1.88E+04	J/g	(4.5Cal/G*4187 J/cal)
	Energy Fish Caught	1.09E+13	J	assume 20% dry weight
	Transformity=	1.68E+07	sej/J	
31	Research Information	1.68E+02	# of papers	USFS, 2007
	average time spent	8.05E+02	hours/paper	
	research hours	166076.8	hours/yr	
	Transformity	2.35E+14	sej/hr	Odum, 1996
	total sej of research	3.90E+19	sej	
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
32	Hydroelectric Power			
	(National Data Only)			
	Image Exported w/			
33	Tourists			

	Number of toursits	0.00E+00	USFS, 2006
	Percent forest experienced	0.10%	estimate
	Total Env. & Economic Assets	3.85E+23 sej	From Table A3-10
	Emergy of image exported =	3.85E+20 sej	
34	Payments to State and Local Gov't	1.48E+07 $/yr	USFS, 2006 (unpub)
	Unit Emergy Value	1.90E+12 sej/$	CEP (2006)
35	Payments for FS Labor	1.07E+08 $/yr	USFS, 2006 (unpub)
	Unit Emergy Value	1.90E+12 sej/$	CEP (2006)

APPENDIX A-9. Annual emergy flows supporting Region 10 of the US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
RENEWABLE RESOURCES:						
1	Sunlight	J	5.56E+20	1.00E+00	555.7	292.5
2	Rain Chemical Potential	J	7.78E+17	3.10E+04	24103.0	12685.8
3	Transpiration	J	1.31E+17	3.06E+04	4010.4	2110.7
4	Rain Geopotential	J	4.70E+17	4.70E+04	22110.9	11637.3
5	Wind, Kinetic	J	4.85E+17	2.45E+03	1187.6	625.1
6	Hurricanes	J	0.00E+00	6.49E+03	0.0	0.0
7	Waves	J	5.91E+17	5.10E+04	30159.2	15873.2
8	Tides	J	1.96E+17	2.43E+04	4752.9	2501.5
9	Earth Cycle	J	1.89E+17	1.20E+04	2266.4	1192.8
INDIGENOUS NONRENEWABLE RESOURCES:						
10	Soil Loss (harvesting)	g	1.31E+09	1.68E+09	2.2	0.0
	Top soil loss (harvesting)	J	8.09E+12	7.40E+04	0.6	0.0
11	Miscellaneous Products (plants)	J		1.80E+04	0.0	0.0
IMPORTS:						
12	Petroleum Products	J	4.62E+13	1.11E+05	5.2	2.7
13	Machinary, Equipment	g	1.10E+08	1.13E+10	1.2	0.7
14	Misc Goods (Pesticides, herb.s)	g	8.23E+06	1E9 - 7 E9	0.2	0.1
15	Seedlings	$	1.76E+05	1.90E+12	0.3	0.2
16	Tourist Time	J	2.40E+13	1.50E+07	358.7	188.8
17	Labor	hours	5.62E+06	6.30E+13	354.4	186.5
18	Electricity	J	2.57E+13	2.92E+05	7.5	3.9
19	Services	$	1.66E+08	1.90E+12	315.0	165.8
ECONOMIC PAYMENTS RECEIVED						
20	Payment for timber	$	5.79E+05	1.90E+12	1.1	0.6
21	Payments for minereals extracted	$	3.35E+07	1.90E+12	63.7	33.5
22	Fee Payments (hunting, fishing, etc)	$	2.71E+06	1.90E+12	5.2	2.7
EXPORTS:						
23	Extracted Firewood	J	1.34E+15	3.60E+04	48.1	0.3
24	Harvested Wood	J	2.41E+15	5.04E+04	121.3	63.8
25	Water, Chemical Potential	J	3.08E+17	8.10E+04	24968.7	13141.4
26	Water, Geopotential	J	6.12E+16	4.70E+04	2874.1	1512.7
27	Minerals	g	4.82E+10	8.16E+09	393.6	207.1
28	Fossil Fuels	J				
29	Harvested wildlife	J	2.96E+14	1E5 - 9.9E5	280.1	147.4
30	Harvested Fish	J	1.41E+12	1.68E+07	23.7	12.5
31	Information (research)	hrs	3.09E+04	2.35E+14	7.3	3.8
32	Hydroelectric power	J				
33	Image Exported with Tourists	% area	0.10%	--	4908.5	2583.4
ECONOMIC PAYMENTS MADE						
34	Payments to St. and Local Gov't	$	8.24E+06	1.90E+12	15.7	8.2
35	Payments for Labor	$	8.02E+07	1.90E+12	152.4	80.2

Footnotes to Table A -9

RENEWABLE RESOURCES:

1 Solar Insolation — Sources

Land Area 8.89E+10m^2

Insolation 7.62E+09J/m^2/year — NREL, 2006

Albedo 1.80E-01(% given as a decimal)

Energy(J) =(area)*(avg insolation)*(1-albedo)

5.56E+20J

Transformity 1.00E+00sej/J

2 Rain

Chemical Potential

Land Area 8.89E+10m^2

Rain 1.77m/yr — NOAA, 2006

Total Volume Rain 1.57E+11m^3

energy=volume*1000kg/m^3*4940J/kg

energy 7.78E+17

Transformity 3.10E+04sej/J — Odum, (2000)

3 Evapotranspiration 2.99E-01m/m^2/yr

volume= 2.66E+10m^3

Energy=Vol*1000Kg/m^3*4940J/kg

Rain ET Energy 1.31E+17J/yr

Transformity 3.06E+04sej/J — Odum, (2000)

4 Rain Geopotential

Rain 1.47E+00m/yr — NOAA, 2006

Mean Elevation Change 3.05E+02m

Land Area 8.89E+10m^2

Energy(J) =(area)(rainfall)(avg change in elevation)(density)(gravity)

energy= 4.70E+17J

Transformity 4.70E+04sej/J — Odum, (2000)

5 Wind, Kinetic

Area 8.89E+10

air density 1.30E+00kg/m^3

avg annual wind velocity 4.21E+00mps — NOAA, 2006

observed winds are about 0.6 of geostrophic

Geostrophic wind 7.02E+00wind

Drag Coeff. 2.00E-03

Energy=area*density*dragcoef*(Geos-grndVel)^3*31500000

energy 4.85E+17

Transformity 2.45E+03sej/J — Odum (2000)

6 Hurricanes

None

7 Waves

Shore length = 9.75E+05m

Wave height = 1.86E+00m

Energy(J) = (shore length)(1/8)(density)(gravity)(wave height$^{\wedge 2}$)(velocity)

(__m)(1/8)(1.025E3kg/m^3)(9.8

=m/sec^2)(__m)$^{\wedge 2}$(__m/sec)(3.14E7s/yr)

Energy(J) = 5.91E+17J/yr

Transformity = 5.10E+04sej/J

8 Tides

Cont Shelf Area = 5.14E+09m^2
Avg Tide Range = 3.28E+00m
Density = 1.03E+03kg/m^3
Tides/year = 7.06E+02 (number of tides in 365 days)
Energy(J) =(shelf)(0.5)(tides/y)(mean tidal range)^2
(density of seawater)(gravity)
=(____m^2)*(0.5)*(____/yr)*(____m)^2*(_____kg/m^3)
*(9.8m/s^2)
= 1.96E+17J/yr
Transformity = 2.43E+04sej/J

9 Earth Cycle
Heat Flow 6.74E+01miliwatts/m^2 IHFC, 2005
area 8.89E+10m^2
energy=miliwatts/m^2*area*sec/yr
2.12E+06J/m^2
energy= 1.89E+17J/yr
Transformity 1.20E+04sej/J Odum (2000)

INDIGENOUS NONRENEWABLE RESOURCES:

10 Soil Loss 1.31E+09g/yr estimate
Top Soil Loss (3.5% of
total SL) 3.76E+08g/yr
energy=g of C*5.4 kca'/g*4184 J/cal
8.09E+12J
Transformity= 7.40E+04sej/j

11 Misc Products (plants) g/yr
energy=g*3.5kcal/g*4186J/Cal
energy= joules
Transformity 1.80E+04sej/J CEP (2006)

IMPORTS:

12 Petroleum Products
Forest Service Use 1.65E+05gal/yr
energy=gal*13e7j/gal
energy= 2.15E+13J/yr
FS Building Use 6.58E+05sq feet
BTU/sq
6.66E+04ft/yr EIA, 1992
energy use =BTU/sqft/yr*sq ft*1055 joules/BTU
4.62E+13J/yr
Total Fuel Use 6.77E+13J/yr
Transformity 1.11E+05sej/J Odum, (1996)
Est. Cost=gal*$2/gal+MMBTUs*$14/MMBTU
9.44E+05$/yr

13 Machinery, Equipment
FS Vechile mass 2.2E+09g
avg. vehicle lifespan 2.00E+01yrs
use per y = vehicles*g/vehicle*1/avg life of vehicle
mass used per year 1.10E+08g
Specific Emergy CEP (2006) sej/g CEP (2006)

14 Goods (Pest/, herbicides) 8.23E+06g/yr NFS, 2005
2.49E+10sej/g

emergy=	2.05E+17sej/yr	
Est. for cost	1.45E+06$/yr	
15 Replanting		
Total Cost=	1.76E+05$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
16 Tourism		
Tourist Time	2.90E+06visits/yr	NVUM. 2005
average stay	1.90E+01hrs	
Total Hours of Stay	5.51E+07hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=Cal/hr*hrs*4186J/Kcal		
energy=	2.40E+13J/y	
Transformity	1.50E+07 sej/J	Odum, 1996
17 Labor		
FS	3.06E+06hrs/yr	NFS, 2005
Contractors	1.31E+06hrs/yr	
Total Labor	5.62E+06hrs/yr	
Unit Emergy Value	6.30E+13sej/hr	based on USA emergy use (1.9E25 sej/yr) and work force of 1.5 E8 workers
18 Electricity	658067sq ft	NFS, 2005
	37000btu/ft^2/yr	EIA, 1992
	2.43E+10btu/yr	
energy=btu/yr*1055 j/btu		
energy=	2.57E+13J	
Transformity	2.92E+05	Odum, 1996
Est. Cost=BTU/yr/3412btu/kwh*$0.09/kwh		
	6.42E+05$/yr	
Regional FS budget	1.47E+08$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19 Services	1.66E+08$/yr	NFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20 Payment for timber	5.79E+05$/yr	NFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
21 Payments for Extracted Minerals	3.35E+07$/y	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22 Fee Payments	2.71E+06$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:		
23 Extracted Firewood		
mass	8.91E+07kg	USFS, 2005
energy=mass*1000g/kg15000j/g		
energy=	1.34E+15J/yr	
Transformity	3.60E+04sej/J	Brown & Bardi (2001)
24 Harvested Wood	2.97E+05m^3/yr	USFS, 2005
	5.40E+05g/m^3	

	mass	1.60E+11g/yr	
	energy=g*15000j/g		
	energy=	2.41E+15J/yr	
	Transformity (w/o services)	5.04E+04	
25	Water, Chemical potential		
	Geopotential (J) =(volume)(elevation)(density)(gravity)		
	Total Export From Streams	6.24E+10m^3/yr	Sedell, 2000
	Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
	=	3.08E+17	
	Transformity	8.10E+04sej/J	Odum, 2000
26	Water, Geopotential Energy	(volume)(elevation)(density)(gravity)	
	avg. elevation	1.00E+02m	USGS, 2006
		6.12E+16J/yr	
	Transformity	4.70E+04sej/J	Odum, 2000
27	Minerals	4.82E+10g/yr	estimate
	Sp. Emergy (avg)=	8.16E+09sej/g	
28	Fossil Fuels		
	(National data only)		
29	Hunting		
	% Dry Weight for Wildlife	2.50E+01%	
	Big Game Extracted	7.47E+03Big Game/y	USFWS, 2002
	avg. mass	5.68E+04g/Game	
	energy content	2.65E+04J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	2.81E+14J/yr	
	Transformity=	9.90E+05sej/J	Brown et al, 2006
	Emergy=	2.78E+20sej	
	Small Game Extracted	2.84E+04Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03g/animal	
	energy content	6.37E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	1.49E+13J/yr	
	Transformity=	1.20E+05sej/J	Brown et al, 2006
	Emergy=	1.79E+18sej	
	Migratory Birds Extracted	2.24E+04#/yr	USFWS, 2002
	avg. mass	1.30E+03g/bird	
	energy content	8.83E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
	energy=	6.43E+10J/yr	
	Transformity=	1.01E+05sej/J	Brown et al, 2006
	Emergy=	6.50E+15sej	
	Other Species Extracted	2.49E+03#/yr	USFWS, 2002
	avg. mass	6.35E+03g	
	energy content	6.37E+03J/g	
	energy=#Game/yr*avg mass*(% dry weight)*J/g		
		2.52E+10J/yr	
	Transformity=	1.50E+05sej/J	Brown et al, 2006

Emergy=	3.77E+15sej		
Sum of Emergy from Game	2.80E+20sej		
30 Fishing	8.27E+05fish caught		USFS, 2004
avg. mass	4.54E+02g/fish	assume avg weight = 1 lb	
energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)	
Energy Fish Caught	1.41E+12J	assume 20% dry weight	
Transformity=	1.68E+07sej/J		
31 Research Information			
research hours	30898.01hours/yr		
Transformity	2.35E+14sej/hr		
total sej of research	7.26E+18sej		
Unit Emergy Value	1.90E+12sej/$		CEP (2006)
32 Hydroelectric Power (National Data Only)			
33 Image Exported with Tourists			
Number of tourists	2.90E+06		USFS, 2006
Percent forest experienced	0.10%		estimate
Total Env. & Economic Assets	4.91E+24sej		From Table A3-10
Emergy of image exported =	4.91E+21sej		
34 Payments to State	8.24E+06$/yr		USFS, 2006 (unpub)
Unit Emergy Value	1.90E+12sej/$		CEP (2006)
35 Payments for FS Labor	8.02E+07$/yr		USFS, 2006 (unpub)
Unit Emergy Value	1.90E+12sej/$		CEP (2006)

APPENDIX B-1. Emergy in stored assets of Region 1 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy (x10^18 sej)	EmDollars (x10^6 Em$)
ENVIRONMENTAL ASSETS						
1	Tree Biomass	J	1.18E+19	3.62E+04	428144.8	225339.4
2	Herb./Shrub Biomass	J	5.83E+17	17976	10475.4	5513.4
3	Land Area	ha	1.03E+07	1.05E+15	10812.1	5690.6
4	Soil OM	J	1.57E+19	1.24E+04	195211.6	102742.9
5	Ground Water	J	1.91E+17	3.02E+05	57684.5	30360.3
6	Surface Water	J	9.70E+16	8.10E+04	7854.6	4134.0
ECONOMIC ASSETS						
7	Roads (dirt)	$	2.30E+08	1.90E+12	437.7	230.4
8	Roads (gravel)	g	1.50E+13	1.68E+09	25219.9	13273.6
9	Roads (paved)	g	5.52E+11	2.77E+09	1529.2	804.8
10	Machinery & tools	g	8.16E+09	1.13E+10	91.8	48.3
11	Office Equipment	g	4.10E+09	1.13E+10	46.2	24.3
12	Buildings	g	1.09E+11	6.50E+09	707.5	372.4
13	Minerals (g)	g	NA	4.54E+09	NA	NA
13a	Minerals ($)	$	NA	1.90E+12	NA	NA
CULTURAL ASSETS						
14	Info.Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
15	Value of Critical Species	# of ind.	1.50E+01	2.26E+22	338366.3	178087.5

Notes to Table B-1

ENVIRONMENTAL ASSETS

1 Tree Biomass 1.50E+09 m^3 USFS, 2005
5.40E+02 kg/m^3
mass=m^3*kg/m^3*1000g/kg
= 8.07E+14 g
3.50E+00 Kcal/g of Tree Biomass
energy=g*4.5kcal/g*4186J/kcal
= 1.18E+19 J
Transformity 3.62E+04 sej/J

2 Total Understory 3.98E+07 mt USFS, 2005
1.00E+06 g/mt
mass=tons*g/ton
= 3.98E+13 g
energy=g*3.5kcal/g*4186J/kcal
= 5.83E+17 J
Transformity 9.79E+03 sej/J

3 Land Area 1.03E+07 ha
(emergy of land structure) 1.05E+15 sej/ha

4 Soil OM 6.95E+08 mt COLE, 2006
mass OM= 6.95E+14 g
Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal

		1.57E+19	J	
	Transformity	1.24E+04	sej/J	
5	Ground Water			
	Density of water	1000	kg/m3	
	Gibbs Free energy of water	4940	J/kg	
	Volume	3.86E+10	m3	USGS, 2005
	energy=	volume*1000kg/m^3*4940J/kg		
	=	1.91E+17	J	
	transformity	2.79E+05	sej/J	Buenfil (2001)
6	Surface Water			
	volume	1.96E+10	m^3	Sedell, 2000
	Density of water	1000	kg/m3	
	Gibbs Free energy of water	4940	J/kg	
	energy=	volume*1000kg/m^3*4940J/kg		
	=	9.70E+16	J	
	Transformity	8.10E+04	sej/J	
ECONOMIC ASSETS				
7	Roads, Dirt	3.84E+04	miles	USFS, 2006 (unpub)
		6.00E+03	$/mile	
		2.30E+08	$	
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
8	Roads, Gravel	2.12E+07	m length	USFS, 2006 (unpub)
		5.00E+00	m width	
	depth=	1.02E-01	m of gravel	
	volume=	1.08E+07	m^3 of limerock	
	density=	1.39E+03	kg/m^3 gravel	
	mass gravel=	m^3*kg/m^3*1000g/kg		
	=	1.50E+13	g	
	Specific Emergy	1.68E+09	sej/g	Odum (1996)
9	Paved Roads	7.23E+05	m	USFS, 2006 (unpub)
	area=	6.70E+00	m^2	
	depth=	5.08E-02	m depth	
	volume=	2.46E+05	m^3 of asphalt	
	density=	2.24E+03	kg/m^3 asphalt	
	mass asphalt=	m^3*kg/m^3*1000g/kg		
	=	5.52E+11	g	
	Specific Emergy	2.77E+09	sej/g	Odum (1996)
10	Machinery	1.80E+07	lbs	USFS, 2006 (unpub)
		4.54E+02	g/lb	
	mass machinery=	lbs*g/lb		
	=	8.16E+09	g	
	Specific Emergy	1.13E+10	sej/g	CEP (2006)
11	Office Equipment	1.50E+01	kg/m2 area	estimate
	mass office equipment=	SA*kg/m2*1000g/kg		
	=	4.10E+09	g	

	Specific Emergy	1.13E+10	sej/g	CEP (2006)
12	Buildings	2.73E+05	m^2	USFS, 2006 (unpub)
	Building Mass=	1.09E+11	g	
	Specific Emergy	6.50E+09	sej/g	Buranakarn, 1998
13	Minerals			
	Data NA for Regions			
SOCIETAL ASSETS				
14	Emergy of Cultural Information			
	Native Americans on FS lands (peak)	7.56E+04	people	estimate
	energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)		
	=	3.82E+09	J/yr	
	Yrs to develop information	2.50E+02		
	Energy of Population=	(population)*(J/yr/Indian)*(year)		
	Energy =	6.98E+15	J	
	Transformity	1.89E+07	sej/J	
15	Value of Critical Species			
	Endangered/Threatened Species	15		USFWS, 2006
	Percent of pop	27.80%	%	
	average emergy per species	3.96E+24	sej/species	
	Em. In critical species=	# of species*%of total Pop in FS land.*Em. Required to dev. species		
	Emergy in Critical Species (sum of above)	1.65E+25	sej	

APPENDIX B-2. Emergy in stored assets of Region 2 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
ENVIRONMENTAL ASSETS						
1	Tree Biomass	J	8.63E+18	3.62E+04	312275.2	164355.4
2	Herb. /Shrub Biomass	J	6.63E+17	17976	11926.7	6277.2
3	Land Area	ha	8.94E+06	1.05E+15	9383.7	4938.8
4	Soil OM	J	1.01E+19	1.24E+04	125035.8	65808.3
5	Ground Water	J	1.99E+17	3.02E+05	60076.8	31619.4
6	Surface Water	J	5.57E+16	8.10E+04	4513.5	2375.6
ECONOMIC ASSETS						
7	Roads (dirt)	$	1.52E+08	1.90E+12	289.7	152.5
8	Roads (gravel)	g	7.31E+12	1.68E+09	12281.2	6463.8
9	Roads (paved)	g	1.33E+11	2.77E+09	368.2	193.8
10	Machinery & tools	g	8.45E+09	1.13E+10	95.1	50.1
11	Office Equipment	g	2.62E+09	1.13E+10	29.5	15.5
12	Buildings	g	6.96E+10	6.50E+09	452.4	238.1
13	Minerals (g)	g	NA	4.54E+09	NA	NA
13a	Minerals ($)	$	NA	1.90E+12	NA	NA
CULTURAL ASSETS						
14	Info. Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
15	Value of Critical Species	# of ind.	1.60E+01	2.26E+22	360924.0	1899.6

Notes to Table B- 2

ENVIRONMENTAL ASSETS

1 Tree Biomass 8.48E+08 m^3 NFS, 2005
5.40E+02 kg/m^3
mass=m^3*kg/m^3*1000g/kg
= 4.58E+14 g
4.50E+00 Cal/g of Tree Biomass
energy=g*4.5kcal/g*4186J/kcal
= 8.63E+18 J
Transformity 3.62E+04 sej/J

2 Total Understory 4.53E+07 mt NFS, 2005
1.00E+06 g/mt
mass=tons*g/ton
= 4.53E+13 g
energy=g*3.5kcal/g*4186J/kcal
= 6.63E+17 J
Transformity 9.79E+03 sej/J

3 Land Area
(emergy of land structure) 1.05E+15 sej/ha

4 Soil OM 4.45E+08 mt
mass OM= 4.45E+14 g

Energy=massOM* 5.4 Cal/g of OM * 4186 j/Cal			
	1.01E+19	J	
Transformity	1.24E+04	sej/J	
5 Ground Water			
Density of water	1000	kg/m3	
Gibbs Free energy of water	4940	J/kg	
Volume	4.02E+10	m3	
energy=volume*1000kg/m^3*4940J/kg			
=	1.99E+17	J	
transformity	2.79E+05	sej/J	Buenfil (2001)
6 Surface Water			
volume	1.13E+10	m^3	Sedell, 2000
Density of water	1000	kg/m3	
Gibbs Free energy of water	4940	J/kg	
energy=volume*1000kg/m^3*4940J/kg			
=	5.57E+16	J	
Transformity	8.10E+04	sej/J	
ECONOMIC ASSETS			
7 Roads, Dirt	2.54E+04	miles	USFS, 2006 (unpub)
	6.00E+03	$/mile	
	1.52E+08	$	
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
8 Roads, Gravel	1.03E+07	m length	USFS, 2006 (unpub)
	5.00E+00	m width	
depth=	1.02E-01	m of gravel	
volume=	5.24E+06	m^3 of limerock	
density=	1.39E+03	kg/m^3 gravel	
mass gravel=m^3*kg/m^3*1000g/kg			
=	7.31E+12	g	
Specific Emergy	1.68E+09	sej/g	Odum (1996)
9 Paved Roads	1.74E+05	m	USFS, 2006 (unpub)
area=	6.70E+00	m^2	
depth=	5.08E-02	m depth	
volume=	5.92E+04	m^3 of asphalt	
density=	2.24E+03	kg/m^3 asphalt	
mass asphalt=m^3*kg/m^3*1000g/kg			
=	1.33E+11	g	
Specific Emergy	2.77E+09	sej/g	Odum (1996)
10 Machinery	1.86E+07	lbs	USFS, 2006 (unpub)
	4.54E+02	g/lb	
mass machinery=lbs*g/lb			
=	8.45E+09	g	
Specific Emergy	1.13E+10	sej/g	CEP (2006)
11 Office Equipment	1.50E+01	kg/m2	
mass office equipment=SA*kg/m2*1000g/kg			
=	2.62E+09	g	
Specific Emergy	1.13E+10	sej/g	CEP (2006)
12 Buildings	1.75E+05	m^2	USFS, 2006 (unpub)
Building Mass=	6.96E+10	g	

	Specific Emergy	6.50E+09	sej/g (avg)	Buranakarn, 1998
13	Minerals			
	Data NA for Regions			
CULTURAL ASSETS				
14	Emergy of Cultural Information			
	Native Americans on FS lands (peak)	7.31E+03	people	estimate
	energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)		
	=	3.82E+09	J/yr	
	Yrs to develop information	2.50E+02		estimate
	Energy of Population=	(population)*(J/yr/Indian)*(year)		
	Energy =	6.98E+15	J	
	Transformity	1.89E+07	sej/J	
15	Value of Critical Species			
	Endangered/Threatened Species	16		USFWS, 2006
	Percent of pop	27.80%	%	
	average emergy per species	3.96E+24	sej/species	
	Em. In critical species=	# of species*%of total Pop in FS land.*Em. Required to develop species		
	Emergy in Critical Species (sum of above)	1.76E+25	sej	

APPENDIX B - 3. Emergy in stored assets of Region 3 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
ENVIRONMENTAL ASSETS						
1	Tree Biomass	J	2.71E+18	3.62E+04	97990.0	51573.7
2	Herbacesou/Shrub Biomass	J	6.86E+17	17976	12331.9	6490.5
3	Land Area	ha	8.42E+06	1.05E+15	8840.6	4653.0
4	Soil OM	J	7.84E+18	1.24E+04	97495.8	51313.6
5	Ground Water (drinking aquifer)	J	2.86E+17	3.02E+05	86589.8	45573.6
6	Surface Water	J	4.50E+16	8.10E+04	3647.9	1920.0
ECONOMIC ASSETS						
7	Roads (dirt)	$	2.80E+08	1.90E+12	532.0	280.0
8	Roads (gravel)	g	5.32E+12	1.68E+09	8935.2	4702.7
9	Roads (paved)	g	1.64E+11	2.77E+09	455.1	239.5
10	Machinery & tools	g	9.48E+09	1.13E+10	106.7	56.1
11	Office Equipment	g	3.22E+09	1.13E+10	36.2	19.1
12	Buildings	g	8.54E+10	6.50E+09	554.9	292.0
13	Minerals (g)	g	NA	4.54E+09	NA	NA
13a	Minerals ($)	$	NA	1.90E+12	NA	NA
CULTURAL ASSETS						
14	Info.Value of Indian Artifacts	J	1.49E+17	1.89E+07	2810976.6	1479461.3
15	Value of Critical Species	# of ind.	5.50E+01	2.26E+22	1240676.3	6529.9

Notes to Table B-3

ENVIRONMENTAL ASSETS

1 Tree Biomass		3.42E+08m^3	USFS, 2005
		5.40E+02kg/m^3	
	mass=m^3*kg/m^3*1000g/kg		
	=	1.85E+14g	
		3.50E+00Kcal/g of Tree Biomass	
	energy=g*4.5kcal/g*4186J/kcal		
	=	2.71E+18J	
	Transformity	3.62E+04 sej/J	
2 Total Understory		4.68E+07mt	COLE, 2005
		1.00E+06g/mt	
	mass=tons*g/ton		
	=	4.68E+13g	
	energy=g*3.5kcal/g*4186J/kcal		
	=	6.86E+17J	
	Transformity	9.79E+03sej/J	
3 Land Area		8.42E+06ha	USFS, 2007
	(emergy of land structure)	1.05E+15 sej/ha	
4 Soil OM		3.47E+08mt	COLE, 2005
	mass OM=	3.47E+14g	
	Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal		

	7.84E+18J	
Transformity	1.24E+04 sej/J	
5 Ground Water		
Density of water	1000kg/m3	
Gibbs Free energy of water	4940J/kg	
Volume	5.80E+10m3	USGS, 2005
energy=volume*1000kg/m^3*4940J/kg		
=	2.86E+17J	
transformity	2.79E+05sej/J	Buenfil (2001)
6 Surface Water		
volume	9.12E+09m^3	Sedell, 2000
Density of water	1000kg/m3	
Gibbs Free energy of water	4940J/kg	
energy=volume*1000kg/m^3*4940J/kg		
=	4.50E+16J	
Transformity	1.04E+06sej/J	
ECONOMIC ASSETS		
7 Roads, Dirt	4.67E+04miles	USFS, 2006 (unpub)
	6.00E+03$/mile	
	2.80E+08$	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
8 Roads, Gravel	7.51E+06m length	USFS, 2006 (unpub)
	5.00E+00m width	
depth=	0.1016m of gravel	
volume=	3.82E+06m^3 of limerock	
density=	1.39E+03kg/m^3 gravel	
mass gravel=m^3*kg/m^3*1000g/kg		
mass gravel=	5.32E+12g	
Specific Emergy	1.68E+09sej/g	Odum (1996)
9 Paved Roads	215055.56m	
width=	6.7m^2	USFS, 2006 (unpub)
depth=	5.08E-02m depth	
volume=	7.32E+04m^3 of asphalt	
density=	2.24E+03kg/m^3 asphalt	
mass asphalt=m^3*kg/m^3*1000g/kg		
asphalt	1.64E+11g	
Specific Emergy	2.77E+09 sej/g	Odum (1996)
10 Machinery	2.09E+07lbs	USFS, 2006 (unpub)
	4.54E+02g/lb	
mass machinery=	9.48E+09g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
11 Office Equipment	1.50E+01kg/m2	
mass office equipment=buildingSA*kg/m2*1000g/kg		
=	3.22E+09g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
12 Buildings	2.14E+05m^2	USFS, 2006 (unpub)
Building Mass=	8.54E+10g	
Specific Emergy	6.50E+09 sej/g avg	Buranakarn, 1998

13 Minerals

Data NA for Regions

CULTURAL ASSETS

14 Emergy of Cultural Information

Native Americans on FS lands (peak)	1.56E+05people		estimate
energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)		
=	3.82E+09J/yr		
Yrs to develop information	2.50E+02		estimate
Energy of Population=	(population)*(J/yr/Indian)*(year)		
Energy =	1.49E+17J		
Transformity	1.89E+07	sej/J	

15 Value of Critical Species

Endangered/Threatened Species	55		USFWS, 2006
Percent of pop	27.80%%		
average emergy per species	3.96E+24sej/species		
Em. In critical species=	# of species*%of total Pop in FS land.*Em. Required to develop species		
Emergy in Critical Species (sum of above)	6.05E+25sej		

APPENDIX B - 4. Emergy in stored assets of Region 4 - US National Forest System

Note Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
ENVIRONMENTAL ASSETS					
1 Tree Biomass	J	7.40E+18	3.62E+04	267834.5	140965.5
2 Herb/Shrub Biomass	J	1.12E+18	17976	20150.5	10605.5
3 Land Area	ha	1.30E+07	1.05E+15	13605.4	7160.8
4 Soil OM	J	1.65E+19	1.24E+04	205249.9	108026.3
5 Ground Water	J	2.88E+17	3.02E+05	87105.3	45844.9
6 Surface Water	J	6.98E+16	8.10E+04	5655.7	2976.7
ECONOMIC ASSETS					
7 Roads (dirt)	$	5.21E+07	1.90E+12	99.1	52.1
8 Roads (gravel)	g	8.69E+12	1.68E+09	14594.5	7681.3
9 Roads (paved)	g	5.16E+11	2.77E+09	1429.9	752.6
10 Machinery & tools	g	8.74E+09	1.13E+10	98.4	51.8
11 Office Equipment	g	3.62E+09	1.13E+10	40.7	21.4
12 Buildings	g	9.60E+10	6.50E+09	624.0	328.4
13 Minerals (g)	g	NA	4.54E+09	NA	NA
13b Minerals ($)	$	NA	1.90E+12	NA	NA
CULTURAL ASSETS					
14 Info. Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
15 Value of Critical Species	# of ind.	2.70E+01	2.26E+22	609059.3	3205.6

Notes to Table B-4

ENVIRONMENTAL ASSETS

1 Tree Biomass 9.35E+08m^3 USFS, 2004
5.40E+02kg/m^3
mass=m^3*kg/m^3*1000g/kg
= 5.05E+14g
3.50E+00Kcal/g of Tree Biomass
energy=g*3.5kcal/g*4186J/kcal
= 7.40E+18J
Transformity 3.62E+04 sej/J

2 Total Understory 7.65E+07mt COLE, 2006
1.00E+06g/mt
mass=tons*g/ton
= 7.65E+13g
energy=g*3.5kcal/g*4186J/kcal
= 1.12E+18J
Transformity 9.79E+03sej/J

3 Land Area 1.30E+07ha USFS, 2007
(emergy of land structure) 1.05E+15 sej/ha

4 Soil OM 7.30E+08mt COLE, 2006
mass OM= 7.30E+14g
Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal
1.65E+19J

Transformity	1.24E+04 sej/J	
5 Ground Water		
Density of water	1000kg/m3	
Gibbs Free energy of water	4940J/kg	USGS, 2005
Volume	5.83E+10m3	
energy=volume*1000kg/m^3*4940J/kg		
energy=	2.88E+17J	
transformity	2.79E+05sej/J	Buenfil (2001)
6 Surface Water		
volume	1.41E+10m^3	Sedell, 2000
Density of water	1000kg/m3	
Gibbs Free energy of water	4940J/kg	
energy=volume*1000kg/m^3*4940J/kg		
=	6.98E+16J	
Transformity	8.10E+04sej/J	Odum, 2000
ECONOMIC ASSETS		
7 Roads, Dirt	5.21E+07miles	USFS, 2006 (unpub)
	6.00E+03$/mile	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
8 Roads, Gravel	1.23E+07m length	USFS, 2006 (unpub)
	5.00E+00m width	
depth=	0.1016m of gravel	
volume=	6.23E+06m^3 of limerock	
density=	1.39E+03kg/m^3 gravel	
mass gravel=m^3*kg/m^3*1000g/kg		
=	8.69E+12g	
Specific Emergy	1.68E+09sej/g	Odum (1996)
9 Paved Roads	675669.62m	USFS, 2006 (unpub)
width=	6.7m^2	
depth=	5.08E-02m depth	
volume=	2.30E+05m^3 of asphalt	
density=	2.24E+03kg/m^3 asphalt	
mass asphalt=m^3*kg/m^3*1000g/kg		
=	5.16E+11g	
Specific Emergy	2.77E+09 sej/g	Odum (1996)
10 Machinery	1.93E+07lbs	USFS, 2006 (unpub)
	4.54E+02g/lb	
mass machinery=	8.74E+09g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
11 Office Equipment	1.50E+01kg/m2	
mass office equipment=building(m^2)*kg/m2*1000g/kg		
=	3.62E+09g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
12 Buildings	2.41E+05m^2	USFS, 2006 (unpub)
Building Mass=	9.60E+10g	

Specific Emergy	6.50E+09	sej/g	Buranakarn, 1998
13 Minerals			
Data NA for Regions			
CULTURAL ASSETS			
14 Emergy of Cultural Information			
Native Americans on FS lands (peak)	3.44E+04	people	estimate
energy per capita=(2500Cal/day)*(365 d/y)*(4186J/Cal)			
=	3.82E+09	J/yr	
Yrs to develop information	2.50E+02		estimate
Energy of Population=(population)*(J/yr/Indian)*(year)			
Energy =	6.98E+15	J	
Transformity	1.89E+07	sej/J	
15 Value of Critical Species			
Endangered/Threatened Species	27		USFWS, 2006
Percent of pop	2.78E-01	%	
average emergy per species	3.96E+24	sej/species	
Em. In critical species=	# of Species*%of total Pop in FS land.*Em. Required to develop species		
Emergy in Critical Species (sum of above)	6.05E+25	sej	

APPENDIX B - 5. Emergy in stored assets of Region 5 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
ENVIRONMENTAL ASSETS						
1	Tree Biomass	J	1.01E+19	3.62E+04	367249.9	193289.4
2	Herb/Shrub Biomass	J	7.55E+17	17976	13565.2	7139.6
3	Land Area	ha	8.17E+06	1.05E+15	8573.9	4512.6
4	Soil OM	J	8.15E+18	1.24E+04	101294.4	53312.8
5	Ground Water	J	1.82E+17	3.02E+05	54892.3	28890.7
6	Surface Water	J	2.02E+17	8.10E+04	16387.1	8624.8
ECONOMIC ASSETS						
7	Roads (dirt)	$	2.01E+08	1.90E+12	381.9	201.0
8	Roads (gravel)	g	1.13E+13	1.68E+09	18994.5	9997.1
9	Roads (paved)	g	1.14E+12	2.77E+09	3148.8	1657.3
10	Machinery & tools	g	2.28E+10	1.13E+10	256.3	134.9
11	Office Equipment	g	6.81E+09	1.13E+10	76.7	40.4
12	Buildings	g	1.81E+11	6.50E+09	1175.0	618.4
13	Minerals (g)	g	NA	4.54E+09	NA	NA
13a	Minerals ($)	$	NA	1.90E+12	NA	NA
CULTURAL ASSETS						
14	Info. Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
15	Value of Critical Species	# of ind.	1.02E+02	2.26E+22	2300890.5	12110.0

Notes to Table B- 5

ENVIRONMENTAL ASSETS

1 Tree Biomass 1.28E+09 m^3 USFS, 2004
5.40E+02 kg/m^3
mass=m^3*kg/m^3*1000g/kg
= 6.93E+14 g
3.50E+00 Kcal/g of Tree Biomass
energy=g*4.5kcal/g*4186J/kcal
= 1.01E+19 J
Transformity 3.62E+04 sej/J

2 Total Understory 5.15E+07 mt COLE, 2005
1.00E+06 g/mt
mass= 5.15E+13 g
energy=g*3.5kcal/g*4186J/kcal
= 7.55E+17 J
Transformity 9.79E+03 sej/J

3 Land Area 8.17E+06 ha USFS, 2007
(emergy of land structure) 1.05E+15 sej/ha

Soil OM 3.60E+08 mt COLE, 2006
mass OM= 3.60E+14 g
Energy=mass OM* 5.4 kcal/g of OM * 4186 j/kcal
8.15E+18 J
Transformity 1.24E+04 sej/J

5 Ground Water			
Density of water	1000	kg/m3	
Gibbs Free energy of water	4940	J/kg	
Volume	3.67E+10	m3	USGS, 2005
energy=volume*1000kg/m^3*4940J/kg			
=	1.82E+17	J	
transformity	2.79E+05	sej/J	Buenfil (2001)
6 Surface Water			
volume	4.10E+10	m^3	Sedell, 2000
Density of water	1000	kg/m3	
Gibbs Free energy of water	4940	J/kg	
energy=volume*1000kg/m^3*4940J/kg			
=	2.02E+17	J	
Transformity	1.04E+06	sej/J	Odum, 2000
ECONOMIC ASSETS			
7 Roads, Dirt	3.35E+04	miles	USFS, (unpub.)
	6.00E+03	$/mile	
	2.01E+08	$	
Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
8 Roads, Gravel	1.60E+07	m length	NFS, 2005
	5.00E+00	m width	
depth=	0.1016	m of gravel	
volume=	8.11E+06	m^3 of limerock	
density=	1.39E+03	kg/m^3 gravel	
mass gravel=m^3*kg/m^3*1000g/kg			
=	1.13E+13	g	
Specific Emergy	1.68E+09	sej/g	Odum (1996)
9 Paved Roads	1487943.7	m	USFS, (unpub.)
width=	6.7	m^2	
depth=	5.08E-02	m depth	
volume=	5.06E+05	m^3 of asphalt	
density=	2.24E+03	kg/m^3 asphalt	
mass asphalt=m^3*kg/m^3*1000g/kg			
=	1.14E+12	g	
Specific Emergy	2.77E+09	sej/g	Odum (1996)
10 Machinery	5.02E+07	lbs	USFS, (unpub.)
	4.54E+02	g/lb	
mass machinery=	2.28E+10	g	
Specific Emergy	1.13E+10	sej/g	CEP (2006)
11 Office Equipment	1.50E+01	kg/m2	estimate
mass office equipment=Building SA*kg/m2*1000g/kg			
=	6.81E+09	g	
Specific Emergy	1.13E+10	sej/g	CEP (2006)
Value		$	NFS, 2005
12 Buildings	4.54E+05	m^2	USFS, (unpub.)
Building Mass=	1.81E+11	g	
Specific Emergy	6.50E+09	sej/g	Buranakarn, 1998
13 Minerals			
Data NA for Regions			

CULTURAL ASSETS

14 Emergy of Cultural Information			
Native Americans on FS lands (peak)	3.73E+05	people	estimate
energy per capita=(2500Cal/day)*(365 d/y)*(4186J/Cal)			
=	3.82E+09	J/yr	
Yrs to develop information	2.50E+02		estimate
Energy of Population=(population)*(J/yr/Indian)*(year)			
Energy =	6.98E+15	J	
Transformity	1.89E+07	sej/J	
15 Value of Critical Species			
Endangered/Threatened Species	1.02E+02		USFWS, 2006
Percent of pop	2.78E-01	%	
average emergy per species	3.96E+24	sej/species	
Em. In critical species=species	# of species*%of total Pop in FS land.*Em. Required to develop species		
Emergy in Critical Species (sum of above)	1.12E+26	sej	

APPENDIX B - 6. Emergy in stored assets of Region 6 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
ENVIRONMENTAL ASSETS						
1	Tree Biomass	J	2.19E+19	3.62E+04	791605.8	416634.6
2	Herb/Shrub Biomass	J	1.14E+18	17976	20458.1	10767.4
3	Land Area	ha	1.00E+07	1.05E+15	10537.1	5545.8
4	Soil OM	J	3.08E+19	1.24E+04	383022.5	201590.8
5	Glaciers	g	1.96E+14	6.46E+06	1266.8	666.7
6	Ground Water	J	4.46E+17	2.79E+05	124427.7	65488.2
7	Surface Water	J	2.72E+17	8.10E+04	22041.8	11600.9
ECONOMIC ASSETS						
8	Roads (dirt)	$	4.82E+08	1.90E+12	915.7	481.9
9	Roads (gravel)	g	1.27E+13	1.68E+09	21356.6	11240.3
10	Roads (paved)	g	1.10E+12	2.77E+09	3035.6	1597.7
11	Machinery & tools	g	1.70E+10	1.13E+10	191.7	100.9
12	Office Equipment	g	7.08E+09	1.13E+10	79.7	42.0
13	Buildings	g	1.88E+11	6.50E+09	1221.9	643.1
14	Minerals (g)	g	NA	4.54E+09	NA	NA
14b	Minerals ($)	$	NA	1.90E+12	NA	NA
CULTURAL ASSETS						
15	Info.Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
16	Value of Critical Species	# of ind.	2.20E+01	2.26E+22	496270.5	2612.0

Notes to Table B-6

ENVIRONMENTAL ASSETS

1 Tree Biomass 2.76E+09 m^3 USFS, 2004

5.40E+02 kg/m^3

mass=m^3*kg/m^3*1000g/kg

= 1.49E+15 g

3.50E+00 Kcal/g of Tree Biomass

energy=g*4.5kcal/g*4186J/kcal

= 2.19E+19 J

Transformity 3.62E+04 sej/J

2 Total Understory 7.77E+07 mt COLE, 2005

1.00E+06 g/mt

mass=tons*g/ton

= 7.77E+13 g

energy=g*3.5kcal/g*4186J/kcal

= 1.14E+18 J

Transformity 9.79E+03 sej/J

3 Land Area 1.00E+07 ha USFS, 2007

(emergy of land structure) 1.05E+15 sej/ha

4 Soil OM 1.36E+09 mt COLE, 2005

mass OM= 1.36E+15 g

Energy=massOM* 5.4 kcal/g of OM * 4186

		j/kcal	
		3.08E+19 J	
	Transformity	1.24E+04 sej/J	
5 Glaciers		2.13E+08 m^3	USGS, 2005
	density=	9.20E+05 g/m^3	
	mass=	1.96E+14 g	
	specific emergy=	6.46E+06 sej/g	
6 Ground Water			
	Density of water	1000 kg/m3	
	Gibbs Free energy of water	4940 J/kg	
	Volume	9.03E+10 m3	USGS, 2005
	energy=volume*1000kg/m^3*4940J/kg		
	=	4.46E+17 J	
	transformity	2.79E+05 sej/J	Buenfil (2001)
7 Surface Water			
	volume	5.51E+10 m^3	Sedell, 2000
	Density of water	1000 kg/m3	
	Gibbs Free energy of water	4940 J/kg	
	energy=volume*1000kg/m^3*4940J/kg		
	=	2.72E+17 J	
	Transformity	1.04E+06 sej/J	
ECONOMIC ASSETS			
8 Roads, Dirt		8.03E+04 miles	USFS, (unpub)
		6.00E+03 $/mile	
		4.82E+08 $	
	Unit Emergy Value	1.90E+12 sej/$	CEP (2006)
9 Roads, Gravel		1.80E+07 m length	USFS, (unpub)
		5.00E+00 m width	
	depth=	0.1016 m of gravel	
	volume=	9.12E+06 m^3 of limerock	
	density=	1.39E+03 kg/m^3 gravel	
	mass gravel=m^3*kg/m^3*1000g/kg		
	=	1.27E+13 g	
	Specific Emergy	1.68E+09 sej/g	Odum (1996)
10 Paved Roads		1434452.5 m length	USFS, (unpub)
	width=	6.7 m^2	
	depth=	5.08E-02 m depth	
	volume=	4.88E+05 m^3 of asphalt	
	density=	2.24E+03 kg/m^3 asphalt	
	mass asphalt=m^3*kg/m^3*1000g/kg		
	=	1.10E+12 g	
	Specific Emergy	2.77E+09 sej/g	Odum (1996)
11 Machinery		3.75E+07 lbs	USFS, (unpub)
		4.54E+02 g/lb	
	mass machinery=lbs*g/lb		
	=	1.70E+10 g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
12 Office Equipment		1.50E+01 kg/m2	
	mass office equipment=buildingSA*kg/m2*1000g/kg		

	=	7.08E+09g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
13 Buildings		4.72E+05m^2	USFS, (unpub)
	Building Mass=	1.88E+11g	
	Specific Emergy	6.50E+09 sej/g (avg)	Buranakarn, 1998
14Minerals			
	Data NA for Regions		
CULTURAL ASSETS			
15 Emergy of Cultural Information			
	Native Americans on FS lands (peak)	2.48E+05people	estimate
	energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)	
	=	3.82E+09J/yr	
	Yrs to develop information	2.50E+02	estimate
	Energy of Population=	(population)*(J/yr/Indian)*(year)	
	Energy =	6.98E+15J	
	Transformity	1.89E+07 sej/J	
16 Value of Critical Species			
	Endangered/Threatened Species	2.20E+01	USFWS, 2006
	Percent of pop	2.78E-01%	
	average emergy per species	3.96E+24sej/species	
	Em. In critical species=	# of species*%of total Pop in FS land.*Em. Required to develop species	
	Emergy in Critical Species (sum of above)	2.42E+25sej	

APPENDIX B - 7. Emergy in stored assets of Region 8 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
ENVIRONMENTAL ASSETS						
1	Tree Biomass	J	5.16E+18	3.62E+04	186598.2	98209.6
2	Herb/Shrub Biomass	J	5.26E+17	17976	9449.5	4973.4
3	Land Area	ha	5.38E+06	1.05E+15	5652.6	2975.1
4	Soil OM	J	1.29E+19	1.24E+04	159755.5	84081.8
5	Peat	J	3.25E+16	3.09E+05	10043.0	5285.8
6	Ground Water	J	3.55E+17	3.02E+05	107227.5	56435.5
7	Surface Water	J	1.16E+17	8.10E+04	9398.4	4946.5
ECONOMIC ASSETS						
8	Roads (dirt)	$	1.65E+08	1.90E+12	312.6	164.5
9	Roads (gravel)	g	1.11E+13	1.68E+09	18594.4	9786.5
10	Roads (paved)	g	5.92E+11	2.77E+09	1639.8	863.1
11	Machinery & tools	g	1.50E+10	1.13E+10	168.3	88.6
12	Office Equipment	g	4.81E+09	1.13E+10	54.1	28.5
13	Buildings	g	1.28E+11	6.50E+09	828.8	436.2
14	Minerals (g)	g	NA	4.54E+09	NA	NA
14a	Minerals ($)		NA	1.90E+12	NA	NA
CULTURAL ASSETS						
15	Info. Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
16	Value of Critical Species	# of ind.	1.96E+02	2.26E+22	4421319.0	23270.1

Notes to Table B-7

ENVIRONMENTAL ASSETS

1 Tree Biomass 6.52E+08 m^3 USFS, 2004
5.40E+02 kg/m^3
mass=m^3*kg/m^3*1000g/kg
= 3.52E+14 g
3.50E+00 Kcal/g of Tree Biomass
energy=g*4.5kcal/g*4186J/kcal
= 5.16E+18 J
Transformity 3.62E+04 sej/J

2 Total Understory 3.59E+07 mt COLE, 2005
1.00E+06 g/mt
mass=tons*g/ton
= 3.59E+13 g
energy=g*3.5kcal/g*4186J/kcal
= 5.26E+17 J
Transformity 9.79E+03 sej/J

3 Land Area 5.38E+06 ha USFS, 2007
(emergy of land structure) 1.05E+15 sej/ha

4 Soil OM 5.68E+08 mt COLE, 2006
mass OM= 5.68E+14 g
Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal

	=	1.29E+19 J	
	Transformity	1.24E+04 sej/J	
5 Peat		1.75E+05 mt	estimate
	mass Peat OM=mt*1e6g/mt		
	=	1.44E+12 g	
	Energy=g* 5.4 kcal/g of OM* 4186 J/kcal		
	=	3.25E+16 J	
	Transformity	3.09E+05 sej/J	
6 Ground Water			
	Density of water	1000 kg/m3	
	Gibbs Free energy of water	4940 J/kg	
	Volume	7.18E+10 m3	USGS, 2005
	energy=volume*1000kg/m^3*4940J/kg		
	=	3.55E+17 J	
	transformity	2.79E+05 sej/J	Buenfil (2001)
7 Surface Water			
	volume	2.349E+10 m^3	Sedell, 2000
	Density of water	1000 kg/m3	
	Gibbs Free energy of water	4940 J/kg	
	energy=volume*1000kg/m^3*4940J/kg		
	=	1.16E+17 J	
	Transformity	8.10E+04 sej/J	Odum, 2000
ECONOMIC ASSETS			
8 Roads, Dirt		2.74E+04 miles	USFS, (unpub)
		6.00E+03 $/mile	
		1.65E+08 $	
	Unit Emergy Value	1.90E+12 sej/$	CEP (2006)
9 Roads, Gravel		1.56E+07 m length	USFS, (unpub)
		5.00E+00 m width	
	depth=	0.1016 m of gravel	
	volume=	7.94E+06 m^3 of limerock	
	density=	1.39E+03 kg/m^3 gravel	
	mass gravel=m^3*kg/m^3*1000g/kg		
	=	1.11E+13 g	
	Specific Emergy	1.68E+09 sej/g	Odum (1996)
10 Paved Roads		774876.7 m length	USFS, (unpub)
	width=	6.7 m^2	
	depth=	5.08E-02 m depth	
	volume=	2.64E+05 m^3 of asphalt	
	density=	2.24E+03 kg/m^3 asphalt	
	mass asphalt=m^3*kg/m^3*1000g/kg		
	=	5.92E+11 g	
	Specific Emergy	2.77E+09 sej/g	Odum (1996)
11 Machinery		3.30E+07 lbs	USFS, (unpub)
		4.54E+02 g/lb	
	mass machinery=	1.50E+10 g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
12 Office Equipment		1.50E+01 kg/m2	estimate

	mass office equipment=buildingSA*kg/m2*1000g/kg			
	=	4.81E+09	g	
	Specific Emergy	1.13E+10	sej/g	CEP (2006)
13	Buildings	3.20E+05	m^2	USFS, (unpub)
	Building Mass=	1.28E+11	g	
	Specific Emergy	6.50E+09	sej/g	Buranakarn, 1998
14	Minerals			
	Data NA for Regions			
CULTURAL ASSETS				
15	Emergy of Cultural Information			
	Native Americans on FS lands (peak)	9.75E+04	people	estimate
	energy per capita=(2500Cal/day)*(365 d/y)*(4186J/Cal)			
	=	3.82E+09	J/yr	
	Yrs to develop information	2.50E+02		estimate
	Energy of Population=(population)*(J/yr/Indian)*(year)			
	Energy =	6.98E+15	J	
	Transformity	1.89E+07	sej/J	
16	Value of Critical Species			
	Endangered/Threatened Species	1.96E+02		USFWS, 2006
	Percent of pop	2.78E-01	%	
	average emergy per species	3.96E+24	sej/species	
	Em. In critical species=species	# of species*%of total Pop in FS land.*Em. Required to develop species		
	Emergy in Critical Species (sum of above)	2.16E+26	sej	

APPENDIX B - 8. Emergy in stored assets of Region 9 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
	ENVIRONMENTAL ASSETS					
1	Tree Biomass	J	3.60E+18	3.62E+04	130401.2	68632.2
2	Herb/Shrub Biomass	J	2.43E+17	17976	4361.8	2295.7
3	Land Area	ha	4.89E+06	1.05E+15	5138.2	2704.3
4	Soil OM	J	1.67E+19	1.24E+04	207861.1	109400.6
5	Peat	J	1.19E+15	3.09E+05	366.8	193.0
6	Ground Water	J	1.91E+17	3.02E+05	57881.4	30463.9
7	Surface Water	J	8.97E+16	1.04E+06	93389.5	49152.4
	ECONOMIC ASSETS					
8	Roads (dirt)	$	1.21E+08	1.90E+12	230.51	121.3
9	Roads (gravel)	g	7.47E+12	1.68E+09	12545.1	6602.7
10	Roads (paved)	g	6.20E+11	2.77E+09	1719.8	905.2
11	Machinery & tools	g	7.24E+09	1.13E+10	81.5	42.9
12	Office Equipment	g	5.17E+09	1.13E+10	58.2	30.7
13	Buildings	g	1.37E+11	6.50E+09	892.5	469.7
14	Minerals (g)	g	NA	4.54E+09	NA	NA
14a	Minerals ($)	$	NA	1.90E+12	NA	NA
	CULTURAL ASSETS					
15	Info. Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
16	Value of Critical Species	# of ind.	5.20E+01	2.26E+22	1173003.0	617370.0

Notes to Table B- 8

ENVIRONMENTAL ASSETS

1 Tree Biomass		4.55E+08m^3	NFS, 2005
		5.40E+02kg/m^3	
	mass=m^3*kg/m^3*1000g/kg		
	=	2.46E+14g	
		3.50E+00Kcal/g of Tree Biomass	
	energy=g*3.5kcal/g*4186J/kcal		
	=	3.60E+18J	
	Transformity	3.62E+04 sej/J	
2 Total Understory		1.66E+07mt	NFS, 2005
		1.00E+06g/mt	COLE, 2005
	mass=tons*g/ton		
	=	1.66E+13g	
	energy=g*3.5kcal/g*4186J/kcal		
	=	2.43E+17J	
	Transformity	9.79E+03sej/J	
3 Land Area		4.89E+06ha	NFS, 2006
	(emergy of land structure)	1.05E+15 sej/ha	
4 Soil OM		7.40E+08mt	COLE, 2006
	mass OM=	7.40E+14g	

	Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal		
		1.67E+19J	
	Transformity	1.24E+04 sej/J	
5 Peat		7.50E+04mt	estimate
	mass Peat OM=mt*1e6g/mt*70% OM		
	=	5.25E+10g	
	Energy=massPeat* 5.4 kcal/g of OM*1000g/kg* 4186 J/kcal		
	=	1.19E+15J	
	Transformity	2.52E+04sej/J	
6 Ground Water			
	Density of water	1000kg/m3	
	Gibbs Free energy of water	4940J/kg	
	Volume	3.87E+10m3	USGS, 2005
	energy=volume*1000kg/m^3*4940J/kg		
	=	1.91E+17J	
	transformity	2.79E+05sej/J	Buenfil (2001)
7 Surface Water			
	volume	1.81E+10m^3	Sedell, 2000
	Density of water	1000kg/m3	
	Gibbs Free energy of water	4940J/kg	
	energy=volume*1000kg/m^3*4940J/kg		
	=	8.97E+16J	
	Transformity	1.04E+06sej/J	
ECONOMIC ASSETS			
8 Roads, Dirt		2.02E+04miles	USFS, 2006 (unpub)
		6.00E+03$/mile	
		1.21E+08$	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
9 Roads, Gravel		1.05E+07m length	USFS, 2006 (unpub)
		5.00E+00m width	
	depth=	0.1016m of gravel	
	volume=	5.36E+06m^3 of limerock	
	density=	1.39E+03kg/m^3 gravel	
	mass gravel=m^3*kg/m^3*1000g/kg		
	=	7.47E+12g	
	Specific Emergy	1.68E+09sej/g	Odum (1996)
10 Paved Roads		812691.42m length	USFS, 2006 (unpub)
	width=	6.7m^2	
	depth=	5.08E-02m depth	
	volume=	2.77E+05m^3 of asphalt	
	density=	2.24E+03kg/m^3 asphalt	
	mass asphalt=m^3*kg/m^3*1000g/kg		
	=	6.20E+11g	
	Specific Emergy	2.77E+09 sej/g	Odum (1996)
11 Machinery		1.60E+07lbs	USFS, 2006 (unpub)
		4.54E+02g/lb	
	mass machinery=	7.24E+09g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
12 Office Equipment		1.50E+01kg/m2	

mass office equipment=buildingSA*kg/m2*1000g/kg			
=	5.17E+09g		
Specific Emergy	1.13E+10	sej/g	CEP (2006)
13 Buildings	3.45E+05m^2		USFS, 2006 (unpub)
Building Mass=	1.37E+11g		
Specific Emergy	6.50E+09	sej/g (avg)	Buranakarn, 1998
14 Minerals			
Data NA for Regions			
CULTURAL ASSETS			
15 Emergy of Cultural Information			
Native Americans on FS lands (peak)	1.15E+05people		estimate
energy per capita=(2500Cal/day)*(365 d/y)*(4186J/Cal)			
=	3.82E+09J/yr		
Yrs to develop information	2.50E+02		estimate
Energy of Population=(population)*(J/yr/Indian)*(year)			
Energy =	6.98E+15J		
Transformity	1.89E+07	sej/J	
16 Value of Critical Species			
Endangered/Threatened Species	5.20E+01		USFWS, 2006
Percent of pop	2.78E-01%		
average emergy per species	3.96E+24sej/species		
Em. In critical species=	# of species*%of total Pop in FS land.*Em. Required to develop species		
Emergy in Critical Species (sum of above)	5.72E+25sej		

APPENDIX B - 9. Emergy in stored assets of Region 10 - US National Forest System

Note	Item	Units	Quantity	Emergy Intensity (sej/unit)	Solar Emergy ($x10^{18}$sej)	EmDollars ($x10^{6}$ Em$)
	ENVIRONMENTAL ASSETS					
1	Tree Biomass	J	5.79E+18	3.62E+04	209524.1	110275.8
2	Herb/Shrub Biomass	J	1.20E+18	17976	21498.6	11315.1
3	Land Area	ha	8.88E+06	1.05E+15	9321.0	4905.8
4	Soil OM	J	3.16E+19	1.24E+04	393301.9	207001.0
5	Glaciers	g	6.22E+17	6.46E+06	4021050.3	2116342.2
6	Peat	J	5.84E+15	2.52E+04	147.3	77.5
7	Ground Water	J	6.58E+17	3.02E+05	198917.7	104693.5
8	Surface Water	J	6.46E+17	8.10E+04	52354.2	27554.9
	ECONOMIC ASSETS					
9	Roads (dirt)	$	1.57E+07	1.90E+12	29.9	15.7
10	Roads (gravel)	g	1.26E+12	1.68E+09	2122.4	1117.1
11	Roads (paved)	g	2.11E+09	2.77E+09	5.9	3.1
12	Machinery & tools	g	2.19E+09	1.13E+10	24.7	13.0
13	Office Equipment	g	9.17E+08	1.13E+10	10.3	5.4
14	Buildings	g	2.43E+10	6.50E+09	158.2	83.2
15	Minerals (g)	g	NA	4.54E+09	NA	NA
15a	Minerals ($)	$	NA	1.90E+12	NA	NA
	CULTURAL ASSETS					
16	Info. Value of Indian Artifacts	J	6.98E+15	1.89E+07	132082.0	69516.9
17	Value of Critical Species	# of ind.	1.10E+01	2.26E+22	248135.3	130597.5

Notes to Table B-9

ENVIRONMENTAL ASSETS

1 Tree Biomass		7.32E+08m^3	USFS, 2004
		5.40E+02kg/m^3	
	mass=m^3*kg/m^3*1000g/kg		
	mass=	3.95E+14g	
		3.50E+00Cal/g of Tree Biomass	
	energy=g*3.5kcal/g*4186J/kcal		
	energy=	5.79E+18J	
	Transformity	3.62E+04 sej/J	
2 Total Understory		8.16E+07mt	USFS, 2004
		1.00E+06g/mt	COLE, 2005
	mass=tons*g/ton		
	=	8.16E+13g	
	energy=g*3.5 Cal/g*4186J/kcal		
	=	1.20E+18J	
	Transformity	9.79E+03sej/J	
3 Land Area		8.88E+06ha	USFS, 2007
	(emergy of land structure)	1.05E+15 sej/ha	
4 Soil OM		1.40E+09mt	COLE, 2006
	mass OM=	1.40E+15g	

	Energy=massOM* 5.4 Cal/g of OM * 4186 j/kcal		
		3.16E+19J	
	Transformity	1.24E+04 sej/J	
5 Peat		2.58E+05mt	estimate
	mass Peat OM=mt*1e6g/mt		
	=	2.58E+11g	
	Energy=mass Peat* 5.4 kcal/g of OM*1000g/kg* 4184 J/Cal		
	=	5.84E+15J	
	Transformity	2.52E+04sej/J	
6 Glaciers		6.77E+11m^3	USGS, 2005
	density=	9.20E+05g/m^3	
	mass=	6.22E+17g	
	specific emergy=	6.46E+06sej/g	
7 Ground Water			
	Density of water	1000kg/m3	
	Gibbs Free energy of water	4940J/kg	
	Volume	1.33E+11m3	USGS, 2005
	energy=volume*1000kg/m^3*4940J/kg		
	energy=	6.58E+17J	
	transformity	2.79E+05sej/J	Buenfil (2001)
8 Surface Water			
	volume	1.31E+11m^3	Sedell, 2000
	Density of water	1000kg/m3	
	Gibbs Free energy of water	4940J/kg	
	energy=volume*1000kg/m^3*4940J/kg		
	=	6.46E+17J	
	Transformity	8.10E+04sej/J	Odum, 2000
ECONOMIC ASSETS			
9 Roads, Dirt		2.62E+03miles	USFS, 2006 (unpub)
		6.00E+03$/mile	
		1.57E+07$	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
10 Roads, Gravel		1.78E+06m length	USFS, 2006 (unpub)
		5.00E+00m width	
	depth=	0.1016m of gravel	
	volume=	9.06E+05m^3 of limerock	
	density=	1.39E+03kg/m^3 gravel	
	mass gravel=m^3*kg/m^3*1000g/kg		
	=	1.26E+12g	
	Specific Emergy	1.68E+09sej/g	Odum (1996)
11 Paved Roads		2.77E+03m length	USFS, 2006 (unpub)
	width=	6.7m^2	
	depth=	5.08E-02m depth	
	volume=	9.41E+02m^3 of asphalt	
	density=	2.24E+03kg/m^3 asphalt	
	mass asphalt=m^3*kg/m^3*1000g/kg		
	=	2.11E+09g	
	Specific Emergy	2.77E+09 sej/g	Odum (1996)
12 Machinery		4835710.2lbs	USFS, 2006 (unpub)

	4.54E+02g/lb		
mass machinery=lbs*g/lb			
=	2.19E+09g		
Specific Emergy	1.13E+10	sej/g	CEP (2006)
13 Office Equipment	1.50E+01kg/m2		estimate
mass office equipment=buildingSA*kg/m2*1000g/kg			
=	9.17E+08g		
Specific Emergy	1.13E+10	sej/g	CEP (2006)
14 Buildings	6.11E+04m^2		USFS, 2006 (unpub)
Building Mass=	2.43E+10g		
Specific Emergy	6.50E+09		Buranakarn, 1998
15 Minerals			
Data NA for Regions			
CULTURAL ASSETS			
Emergy of Cultural			
16Information			
Native Americans on FS lands (peak)	9.69E+04people		estimate
energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)		
=	3.82E+09J/yr		
Yrs to develop information	2.50E+02		estimate
Energy of Population=	(population)*(J/yr/Indian)*(year)		
Energy =	6.98E+15J		
Transformity	1.89E+07	sej/J	
17 Value of Critical Species			
Endangered/Threatened Species	1.10E+01		USFWS, 2006
Percent of pop	2.78E-01%		
average emergy per species	3.96E+24sej/species		
Em. In critical species=	#species*%of total Pop in FS land.*Em. Required to develop species		
Emergy in Critical Species (sum of above)	1.21E+25sej		

APPENDIX C. Notes to Table 6. Summary of annual emergy flows supporting the US National Forest System

RENEWABLE RESOURCES:			
1 Solar Insolation			Source
	Land Area	7.80E+11 m^2	
	Insolation	6.83E+09 J/m^2/year	NREL, 2006
	Albedo	1.80E-01 (% given as a decimal)	
	Energy =	(area)*(avg insolation)*(1-albedo)	
	=	4.37E+21 J	
	Transformity	1.00E+00 sej/J	Odum et.al, (2000)
2 Rain			
Chemical Potential			
	sum of the regions	2.62E+18 J/yr	
	Transformity	3.10E+04 sej/J	Odum et.al, (2000)
3 Transpiration			
	Energy (sum of the regions)=	1.18E+18 J/yr	
	Transformity	3.06E+04 sej/J	Odum et.al, (2000)
4 Rain Geopotential			
	Energy (sum of regions)	1.08E+18 J	
	Transformity	4.70E+04 sej/J	Odum et.al, (2000)
5 Wind, Kinetic			
	sum of the regions	3.40E+18	
	Transformity	2.45E+03 sej/J	Odum (2000)
6 Hurricanes			
	Energy (sum of regions)	3.38E+17 j/yr	
	Transformity	6.49E+03 sej/J	Odum (2000)
7 Wave			
	sum of the regions	6.07E+17 J/yr	
	Transformity=	5.10E+04 sej/J	CEP, 2000
8 Tidal			
	sum of the regions	1.96E+17 J/yr	
	Transformity=	2.43E+04 sej/J	CEP, 2000
9 Earth Cycle			
	sum of the regions	2.10E+18 J/yr	
	Transformity	1.13E+04 sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:			
10 Soil Loss			(this study)
	sum of the regions	9.73E+10 g/yr	
	Transformity	1.68E+9 sej/g	Odum (2000)
10a Soil OM Loss			
	sum of the regions	8.04E+13 J/yr	
	Transformity	7.4E+04 sej/J	
11 Misc. Products (Plants)		1.40E+09 g/yr	NFS, 2005
	energy=	(g)*(3.5kcal/g)*(4186J/Cal)	
	=	2.05E+13 joules	
	Transformity	1.80E+04 sej/J	
IMPORTS:			
12 Petroleum Products			
	sum of the regions	4.04E+15 J/yr	
	Transformity	1.11E+05 sej/J	Odum, (1996)

13 Machinery, Equipment				
	sum of the regions	4.95E+09	g	
	Specific Emergy	1.13E+10	sej/g	CEP (2006)
14 Misc. Goods (Pesticides, herbicides, etc)				
	sum of the regions	7.22E+07	g/yr	
	emergy=	1.79E+18	sej/yr	
15 Seedlings				
	Total Cost=	5.16E+07	$/yr	NFS, (2005)
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
	Tourist Time	2.05E+08	people/yr	NFS NVUM 2004
	average stay	1.80E+01	hrs	NFS NVUM 2005
	Total Hours of Stay	3.69E+09	hours/yr	
	avg. energy/hr	1.04E+02	kcal/hr	
	total energy expenditure=(kcal/hr)*(hrs)*(4186J/Cal)			
	energy=	1.69E+15	J/y	
	Transformity	1.50E+07	sej/J	Odum, 1996
17 Labor				
	FS	7.77E+07	hrs/yr	USFS, 2005
	Contractors	4.42E+07	hrs/yr	estimate
	Total Labor	1.22E+08	hrs/yr	
	Unit Emergy Value	6.30E+13	sej/hr	
18 Electricity				
	Sum from regions	1.07E+15	J	
	Transformity	2.92E+05		Odum, 1996
19 Misc. Expenditures		2.97E+09	$/yr	
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
	emergy=	5.64E+21	sej/yr	
20 Payment Received for timber		2.24E+08	$/yr	UFSF, 2005
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
21 Payments for Ext. Minerals		2.84E+09	$/y	
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
22 Fee Payments Received		5.05E+07	$/yr	USFS PAR, 2006
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
EXPORTS:				
23 Extracted Firewood				
	Sum of regions	1.17E+16	J/yr	
	Transformity	3.06E+04	sej/J	Brown and Bardi (2001)
24 Harvested Wood				
	sum of the regions	6.82E+12	g/yr	
	Energy=	1.02E+17	J/yr	
	Transformity	5.04E+04		Brown, 2001
25 Water, Chemical potential				
	Total Export From Streams	2.54E+11	m^3/yr	USFS, 2000
	joules =	1.26E+18	J/yr	
	Transformity	8.10E+04	sej/J	Odum, 2000
26 Water, Geopotential Energy				
	sum of the regions	2.01E+18	J/yr	
	Transformity	4.70E+04	sej/J	Odum, 2000
27 Minerals		4.16E+12	g/yr	NFS, 2003
	average specific emergy	mixed	sej/g	see app. 3

	emergy=	6.06E+22sej/yr	see app. 3
28	Fossil Fuels		
	Oil	9.42E+17J/yr	FS, 2005
	Transformity	9.11E+04sej/J	
	Natural Gas	5.58E+16J/yr	FS, 2005
	Transformity	7.31E+04sej/J	
	Coal	5.20E+17J/yr	FS, 2005
	Transformity	6.59E+04sej/J	
	Total Fossil Fuel Emergy	1.24E+23	
29	Hunting		
	Sum of Emergy from Game	4.28E+22sej	see Appendix I
	Weighted Trans. For Game	1.10E+07sej/J	
30	Fishing		
	Sum of Regions =	9.97E+13J	assume 20% dry weight
	Transformity=	1.68E+07sej/J	
31	Information		
	Public information	3.60E+04hr/yr	Estimate
	Washington Office	1.00E+05hours	
	Research Information	1.21E+03# of papers	USFS, 2006
	Average time spent	8.05E+02hours/paper	Estimate
	Research hours	9.72E+05hours/yr	Estimate
	Total hours	1.11E+06	
	Transformity	2.35E+14sej/hr	Odum, 1996
32	Hydroelectric Power	15%of US total	estimate
	From FS lands	16000MW	USFS, 2005
	=	1.6E+10watts	
	energy=(watt)*(sec/yr)*(1J/sec)		
	=	5.05E+17Joules	
	Transformity =	120300.00sej/J	Odum, 1996
33	Image Exported with Tourists		
	Sum of Regions	3.69E+09hrs	USFS, 2006
33	Payments to States	4.15E+08$/yr	
	Unit Emergy Value	1.90E+12sej/$	
34	Payments for FS Labor	1.32E+09$/yr	
	Unit Emergy Value	1.90E+12sej/$	

APPENDIX D - Notes to Table 7. Assets of National Forest System

ENVIRONMENTAL ASSETS				
1 Tree Biomass				
	Sum of the regions	7.71E+19J		
	Transformity	3.62E+04	sej/J	CEP, 2001
2 Total Understory				
	Sum of the regions	6.91E+18		
	Transformity	9.79E+03	sej/J	CEP, 2001
3 Land Area				
	Sum of the regions	7.80E+07	ha	
	emergy of land structure=	1.05E+15	sej/ha	
4 Soil OM			mt	COLE, 2006
	Sum of the regions	1.50E+20J		
	Transformity	1.24E+04	sej/J	CEP, 2002
5 Peat				
	Sum of the regions	3.95E+16J		
	Transformity	3.09E+05	sej/J	CEP, 2002
6 Glaciers				
	Sum of the regions	6.23E+17g		
	Specific Emergy=	6.46E+06	sej/g	CEP, 2000
7 Ground Water				
	Sum of the regions	2.80E+18J		
	Transformity	2.79E+05	sej/J	Buenfil (2001)
8 Surface Water				
	Sum of the regions	1.59E+18J		
	Transformity	8.10E+04	sej/J	Odum, 2000
9 Biodiversity				
Primary Consumer		6.52E+13g		USFS, RPA 2004
	Specific emergy=	1.27E+09	sej/g	
Herbivores		1.30E+14g		Appendix I
	Specific emergy=	1.27E+09		
Omnivores		7.17E+13g		Appendix 1
	Specific emergy=	2.31E+09		
Carnivores		3.03E+13g		Appendix 1
	Specific emergy=	8.19E+09		
Top Carnivores		5.05E+12g		Appendix 1
	Specific emergy=	8.19E+10		
	total Biodiversity=	1.08E+24	sej	
ECONOMIC ASSETS				
10 Roads, Dirt				
	Sum of the regions	1.70E+09$		
	Unit Emergy Value	1.90E+12	sej/$	CEP (2006)
11 Roads, Gravel				
	Sum of the regions	8.01E+13g		
	Specific Emergy	1.68E+09	sej/g	Odum (1996)
12 Paved Roads				
	Sum of the regions	4.81E+12g		

	Specific Emergy	2.77E+09sej/g		Odum, 1996
13 Machinery				
	Sum of the regions	9.90E+10g		
	Specific Emergy	1.13E+10 sej/g		CEP, 2006
14 Office Equipment				
	Sum of the regions	3.84E+10g		
	Specific Emergy	1.13E+10 sej/g		CEP (2006)
15 Buildings				FS, 2005
	Sum of the regions	1.10E+12g		
	Wash. Office and Misc Buildings	8.72E+10g		
	total	1.19E+12		
	Specific Emergy	6.50E+09		
16 Fossil Fuels				
	Oil	1.0396E+18J		USGS, 2005
	Transformity	1.53E+05sej/J		Odum, 1996
	Natural Gas	3.7023E+15J		USGS, 2005
	Transformity	1.23E+05sej/J		Odum, 1997
	Coal	4.59E+15g		EIA, 1999
	energy=	(g coal)*(15000J/g)		
	=	6.88E+19J		
	Transformity	1.11E+05sej/J		Odum, 1996
	Total Fossil Fuel Storage=	7.77E+24sej		
17 Minerals				
	Gold=	1.17E+09g	est. 5% of total US Reserves	
	Lead=	1.51E+13g	est. 5% of total US Reserves	
	Silver=	9.33E+10g	est. 5% of total US Reserves	
	Copper=	6.81E+12g	est. 5% of total US Reserves	
	total=	4.41E+13g		
	value=	1.20E+11$		
	Specific Emergy	4.54E+09 sej/g	average	
CULTURAL ASSETS				
Emergy of Cultural				
18Information				
	Native Americans on FS lands (peak)	1.20E+06people		estimate
	energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)		
	=	3.82E+09J/yr		
	Yrs to develop information	2.50E+02		estimate
	Energy of Population=	(population)*(J/yr/Indian)*(year)		
	Energy =	1.15E+18J		
	Transformity	1.89E+07sej/J		
19 Value of Critical Species				
	Endangered Species	4.96E+02		USFWS, 2006
	Percent of pop	3.17%	(% of Continental Area)	
	average emergy per species	3.96E+24sej/species		
	Em. In critical species=	(# of Species)*(%of total Pop in FS land)*(Em. Required to develop species)		
	Emergy in Critical Species	6.22E+25sej		
20 Biodiversity				20
	Number of species =	1.09E+05		estimate

Unit emergy value =	1.22E+25	Odum 1996
USFS lands percent of NA lanc =	0.03%	
Emergy =	3.97E+26	
21 Genetic resources		
Grams DNA =	1.15E+13	Appendix I
Energy (J) =	2.40E+17	
Specific Emergy (sej/g) =	1.22E+12	Odum, 1996
Emegy (sej) =	2.93E+29	

APPENDIX E.1 - Notes to Table 9 - Annual Emergy Flows Supporting Deschutes National Forest

RENEWABLE RESOURCES:

1 Solar Insolation — Sources

Land Area 7.50E+09m^2

Insolation 1.49E+07J/m^2/year — NASA SSE

Albedo 1.70E-01(% given as a decimal)

Energy(J) =(area)*(avg insolation)*(1-albedo) — Gholz and Clark, 2000

9.28E+16J

Transformity 1.00E+00sej/J

2 Rain

Chemical Potential

Land Area 7.50E+09m^2

Rain 0.595m/yr — NASA SSE

Volume Rain 4.46E+09m^3

energy=volume*1000kg/m^3*4940J/kg

= 2.20E+16

Transformity 3.10E+04sej/J — Odum et.al, (2000)

3 Transpiration 0.263m/m^2/yr — GIS Coverage

Energy=Vol*1000Kg/m^3*4940J/kg

Rain ET Energy 9.74E+15J/yr

Transformity 3.06E+04sej/J — Odum et.al, (2000)

4 Rain Geopotential

Runoff 0.332m/m^2/yr — NASA SSE

Mean Elevation Change 380.60m

Land Area 7.50E+09m^2

Energy(J) =(area)(runoff)(avg change in elevation)(density)(gravity)

= 9.29E+15J

Transformity 4.70E+04sej/J — Odum et.al, (2000)

5 Wind, Kinetic

Area 7.50E+09m^2

air density 1.30kg/m^3

avg annual wind velocity 4.38mps

Geostrophic wind 7.30 observed winds are about 0.6 of geostrophic wind

Drag Coeff. 0.002

Energy=area*density*drag coef*(Geos-grndVel)^3*31500000

= 4.59E+16

Transformity 2.45E+03sej/J — Odum (2000)

7 Waves

None

8 Tides

None

9 Earth Cycle

Heat Flow 9.84E+01miliwatts/m^2 — IHFC, 2005

area 7.50E+09m^2

joules= 3.10E+06J/m^2

energy=miliwatts/m^2*area*sec/yr

=	2.33E+16J/yr	
Transformity	1.20E+04sej/J	Odum (2000)
INDIGENOUS NONRENEWABLE RESOURCES:		
10 Soil Loss	2.52E+11g/yr	
Percent Org. Matter	4%	
Top Soil Loss	1.01E+10g/yr	
energy=mass	OM*5.4kcal/g*4184J/kcal	
=	2.28E+14J	
Soil Gain	0.00E+00g/yr	NFS, 2005
IMPORTS:		
Petroleum 11Products		
Forest Service Use	2.35E+05gal/yr	
energy=gal*13e7j/gal		
energy=	3.05E+13J/yr	
FS Building Use	3.96E+05sq feet	
	6.66E+04BTU/sq ft/yr	
energy use =(BTU/sqft/yr) * (sq ft) * (1055 joules/BTU)		
	2.78E+13J/yr	
total=	5.83E+13	
Transformity	1.11E+05sej/J	Odum, (1996)
12 Machinery, Equipment		
FS	2.E+09g of vehicles	
avg. vehicle lifespan	2.00E+01yrs	
use per y =vehicles*g/vehicle*1/avg life of vehicle		
mass used per year	1.36E+08g	
Specific Emergy	CEP (2006) sej/g	CEP (2006)
13 Misc. Goods	1.19E+06g/yr	NFS, 2005
14 Seedlings		
Seedlings	5.85E+06seedlings	
avg. mass	3.50E+00g/seedling	
Total Mass=	2.05E+07g/yr	
15 Tourism		
Tourist Time	2.80E+06people/yr	NFS, 2005
average stay	1.30E+01hrs	
Total Hours of Stay	3.64E+07hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=kcal/hr*hrs*4186J/Kcal		
=	1.58E+13J/y	
Transformity	1.50E+07 sej/J	
16 Labor		
FS Employees	8.14E+05hrs/yr	NFS, 2005
Unit Emergy Value	6.30E+13sej/hr	USA emergy use (1.9E25 sej/yr)/ of 1.5 E8 workers
17 Electricity	3.96E+05sq ft	NFS, 2005
	37000btu/ft2/yr	EIA, 1992

		1.46E+10btu/yr	
	energy=(btu/yr)*(1055 j/btu)		
	=	1.54E+13J	
	Transformity	2.92E+05	Odum, 1996
	Est. Cost	3.86E+05$/yr	
18	Payment for timber	4.86E+06$/yr	NFS, 2005
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19	Payments for Extracted Minerals	6.44E+04$/y	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20	Fee Payments	3.15E+06$/yr	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:			
21	Extracted Firewood		
	mass	1.12E+10g	
	energy=mass*15000j/g		
	=	1.68E+14J/yr	
	Transformity	3.60E+04sej/J	Brown and Bardi (2001)
22	Harvested Timber	9.63E+10g/yr	
	energy=g*15000j/g		USFS, 2006
	=	1.44E+15J/yr	
	Transformity (w/o services)	5.04E+04 sej/j	
23	Water, Chemical Potential		
	Total Export From Streams	2.74E+09m^3/yr	
	Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
	joules =	1.36E+16	
	Transformity	sej/J	
24	Water, Geopotential		
	Geopotential=	(volume)(elevation)(density)(gravity)	
	elevation=	1250m	
	joules =	3.36E+16	
	Transformity	7.77E+04sej/J	
25	Minerals	1.07E+10g/yr	USFS, 2006
26	Hunting		
	% Dry Weight for Wildlife	2.50E+01%	
	Deer Extracted	6.12E+02#/yr	ODFW, 2006
	avg. mass	5.70E+04g	
	energy content	2.65E+04J/g	
	energy=#*avg mass*(% dry weight)*J/g		
	=	2.31E+13J	

Transformity=	6.74E+05sej/J	Transformities based on sej in diet/joules of animal
Emergy=	1.56E+19sej	
Elk Extracted	1.11E+02#	ODFW, 2006
avg. mass	2.70E+05g	
energy content	4.78E+03J/g	
energy=#*avg mass*(% dry weight)*J/g		
=	3.58E+12J	
Transformity=	4.29E+07sej/J	
Emergy=	1.56E+19sej	
Bear Extracted	4.00E+00#/yr	ODFW, 2006
avg. mass	1.02E+05g	
energy content	6873.714J/g	energy=#*avg massr*(% dry weight)*J/g
energy=#*avg mass*(% dry weight)*J/g		
=	7.02E+08J	
Transformity=	2.29E+09sej/J	
Emergy=	1.61E+18sej	
Upland Game Birds Extracted	8.00E+03#/yr	ODFW, 2006
avg. mass	2.52E+02g	
energy content	7.95E+03J/g	
energy=#*avg mass*(% dry weight)*J/g		
=	4.01E+09J	
Transformity=	3.30E+08sej/J	
Emergy=	1.32E+18sej	
Mid-Sized Game Extracted	7.55E+02#yr	ODFW, 2006
avg. mass	6.35E+03g	
energy content	4.78E+03J/g	
energy=#*avg mass*(% dry weight)*J/g		
=	5.73E+09J/yr	
Transformity=	5.23E+07sej/J	
Emergy=	3.00E+17sej	
Ducks Extracted	5.33E+03#/yr	ODFW, 2006
avg. mass	1.30E+03g	
energy content	8.83E+03J/g	
energy=#*avg mass*(% dry weight)*J/g		
=	1.53E+10J/yr	
Transformity=	5.92E+08sej/J	
Emergy=	9.06E+18sej	
Geese Extracted	1.30E+03#/yr	ODFW, 2006
avg. mass	4.00E+03g	
energy content	1.55E+04J/g	
energy=#*avg mass*(% dry weight)*J/g		
=	2.02E+10J	
Transformity=	3.50E+07sej/J	
Emergy=	7.06E+17sej	
Mountain Lion	4.00E+00#/yr	ODFW, 2006
avg. mass	7.48E+04g	
energy content	5.08E+03J/g	
energy=#*avg mass*(% dry weight)*J/g		

	=	3.80E+08J		
	Transformity=	1.34E+10sej/J		
	Emergy=	5.11E+18sej		
	Sum of Emergy from Game	3.37E+19sej		
27	Fishing			
	avg. mass	4.54E+09g of fish	assume avg weight = 6 lb	ODFW, 2006
	energy content	1.88E+04J/g	(4.5Cal/G*4187 J/cal)	
	Energy Fish Caught	1.71E+13J	assume 20% dry weight	
	Transformity=	1.68E+07sej/J		
28	Information	1.20E+04hours of research		
	Transformity	2.35E+14sej/hr		
	total sej of research	2.82E+18sej		
29	Payments to State	8.46E+06$/yr	NFS, 2005	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)	
30	Payments for Labor	1.28E+07$/yr	NFS, 2005	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)	

APPENDIX E.2 Notes to Table 10 - Annual Emergy Flows Supporting Osceola National Forest

RENEWABLE RESOURCES:

1.Solar Insolation		
Land Area	6.56E+08m^2	
Insolation	5.84E+09J/m^2/year	NASA SSE
Albedo	1.80E-01(% given as a decimal)	
Energy(J)	=(area)*(avg insolation)*(1-albedo)	Gholz and Clark, 2000
	3.14E+18J	
Transformity	1.00E+00sej/J	Odum et.al, (2000)
2.Rain		
Chemical Potential		
Land Area	6.56E+08m^2	
Rain	1.241m/yr	NASA SSE
Total Volume Rain	8.14E+08m^3	
	energy=volume*1000kg/m^3*4940J/kg	
=	4.02E+15	
Transformity	3.10E+04sej/J	Odum et.al, (2000)
3.Transpiration	9.67E-01m/m^2/yr	Ghjolz and Clark, 2000
	Energy=Vol*1000Kg/m^3*4940J/kg	
Rain ET Energy	3.13E+15J/yr	
Transformity	3.06E+04sej/J	Odum et.al, (2000)
4.Rain Geopotential		
Rain	1.241m/yr	NASA SSE
Mean Elevation Change	1.00E+02 m	
Land Area	6.56E+08m^2	
Energy(J)	=(area)(rainfall)(avg change in elevation)(density)(gravity)	
=	7.98E+14J	
Transformity	4.70E+04sej/J	Odum et.al, (2000)
5.Wind, Kinetic		
Area	6.56E+08	
air density	1.30E+00kg/m^3	
avg annual wind velocity	3.02E+00mps	
Geostrophic wind	5.03E+00 observed winds are about 0.6 of geostrophic wind	
Drag Coeff.	2.00E-03	
	Energy=area*density*dragcoef*Geos^3*31500000	
=	1.32E+15	
Transformity	2.45E+03sej/J	Odum (2000)
6.Hurricanes		
Avg energy/storm	5.00E+05KCAL/m^2/day	Odum et al, 1983
avg hurricane freq.	1.00E-01/yr	
percent energy that is kinetic	3.00E+00%	
percent of energy dispersed to land	1.00E+01%	
avg. residence time	1.00E+00day/year	
area	6.56E+08m^2	
	energy=0.1/yr*1yr/365 days*5e5Kcal/m^2/day*.003*area in m^2*4186J/kcal	
=	1.13E+12j/yr	
Transformity	6.49E+03sej/J	Odum (2000)
7.Waves		

None
8.Tides
None
9.Earth Cycle

Heat Flow	3.30E+01miliwatts/m^2	IHFC, 2005
area	6.56E+08m^2	
energy=miliwatts/m^2*area*sec/yr		
	1.04E+06J/m^2	
energy=	6.83E+14J/yr	
Transformity	5.80E+04sej/J	Odum (2000)

INDIGENOUS NONRENEWABLE RESOURCES:

10.Soil Loss	0.00E+00g/yr	
Top Soil Loss	0.00E+00g/yr	
Soil Gain	0.00E+00g/yr	NFS, 2005

IMPORTS:

11.Petroleum Products		
Forest Service Use	3.41E+03gal/yr	
energy=gal*13e7j/gal		
=	4.44E+11J/yr	
Contractor Use	5.04E+03gal/yr	
energy=	6.55E+11J/yr	NFS, 2005
Total Fuel Use	1.10E+12J/yr	
Transformity	1.11E+05sej/J	Odum, (1996)
12.Machinary, Equipment		
FS	6vehicles	
avg. mass	2.87E+07g/vehicle	
avg. vehicle lifespan	2.00E+01yrs	
use per y =mass*#vehicle/avg life *% of use on FS		
mass used per year	8.62E+06g	
Contractors	9vehicles	
percent of use on FS land	33%	
use per y =mass*#vehicle/avg life *% of use on FS		
g used per year	4.31E+06g	
Total (FS and Contractors)=	1.29E+07g	
Specific Emergy	1.13E+10 sej/g	CEP (2006)
13.Misc. Goods	0.00E+00g/yr	NFS, 2005
(See note 18 below)		
14.Replanting		
Seedlings	1.00E+05seedlings	
avg. mass	3.50E+00g/seedling	
Total Mass=	3.50E+05g/yr	
Total Cost=	8.93E+04$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
15.Tourism		
Tourist Time	1.50E+05people/yr	NFS, 2005
average stay	1.20E+01hrs	
Total Hours of Stay	1.80E+06hours/yr	
avg. energy/hr	1.04E+02kcal/hr	
total energy expenditure=kcal/hr*hrs*4186J/Kcal		
=	7.84E+11J/y	
Transformity	1.50E+07 sej/J	Brown and Bardi (2001)

16.Labor		
FS	2.08E+04hrs/yr	NFS, 2005
Contractors	2.02E+03hrs/yr	
Total Labor	2.28E+04hrs/yr	
Unit Emergy Value	6.30E+13sej/hr	
17.Electricity	18000$/yr	
	0.0735$/kwh	
	2.43E+05kwh	
energy=kwh*3.6e6 J/kwh		
=	8.76E+11J	
Transformity	2.92E+05	Odum (1996)
Unaccounted for FS		
18.budget	1.06E+06$/yr	
Total Budget for Osceola		
from FS	2.37E+06$/yr	S. Kett (2006)
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
19.Services	4.20E+04$/yr	NFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
20.Payment for timber	9.65E+05$/yr	NFS, 2005
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
Payments for Extracted		
21.Minerals	0.00E+00$/y	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
22.Fee Payments	3.47E+04$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
EXPORTS:		
23.Misc. Products (Plants)	1.81E+06g/yr	NFS, 2005
energy=g*3.5kcal/g*4186J/Kcal		
=	2.66E+10joules	
Transformity	1.80E+04sej/J	Brown and Bardi (2001)
24.Extracted Firewood		
mass	3.34E+03kg	
energy=mass*1000g/kg15000j/g		
=	5.01E+10J/yr	
Transformity	3.60E+04sej/J	Brown and Bardi (2001)
25.Harvested Wood	2.74E+10g/yr	NFS, 2005
energy=g*15000j/g		
=	3.36E+14J/yr	
Transformity (w/o services)	5.04E+04	Brown and Bardi (2001)
26.Water Chemical Potential		
Total Export From Streams	5.64E+07m^3/yr	
Chemical Potential=M^3/yr * 1000 kg/M^3 * 4940 J/kg		
joules =	2.79E+14	
transformity	3.06E+04	Odum, 1996
Water, Geopotential		
27.Energy		
Geopotential (J) = (volume)(elevation)(density)(gravity)		
=	6.08E+12	
Transformity	7.77E+04sej/J	Brown and Bardi (2001)
28.Minerals - (none)	0.00E+00g/yr	
29.Hunting		

% Dry Weight for Wildlife	2.50E+01%	
Deer Extracted	2.74E+02deer/y	
avg. mass	4.72E+04g/deer	
energy content	2.65E+04J/g	
energy=#*avg mass*(% dry weight)*J/g		
=	4.26E+10J/yr	FFWCC
Transformity=	5.84E+05sej/J	This study
Emergy=	2.48E+16sej	
Hog Extracted	4.40E+01hog/yr	FFWCC
avg. mass	5.67E+04g/hog	
energy content	2.72E+04J/g of hog	
energy=#*avg mass*(% dry weight)*J/g		
=	8.48E+09J/yr	
Transformity=	1.70E+07sej/J	This study
Emergy=	1.44E+17sej	
Turkey Extracted	5.60E+01turkey/yr	FFWCC
avg. mass	8.16E+03g/turkey	
energy content	2.84E+04J/g turkey	
energy=#*avg mass*(% dry weight)*J/g		
energy=	1.62E+09J/yr	
Transformity=	6.11E+05sej/J	This study
Emergy=	9.93E+14sej	
Grey Squirrel Extracted	2.32E+02squirrel/yr	FFWCC
avg. mass	5.50E+02g	
energy content	2.32E+04J/g	
energy=#*avg mass*(% dry weight)*J/g		
	3.70E+08J/yr	
Transformity=	2.24E+07sej/J	This study
Emergy=	8.29E+15sej	
Sum of Emergy from Game	1.78E+17sej	
Weighted Trans. For Game	3.36E+06sej/J	
30.Fishing	5.63E+04fish caught	(estimate)
avg. mass	4.54E+02g/fish	
energy content	1.88E+04J/g	
Energy =#*avg mass*(% dry weight)*J/g		
Energy Fish Caught	9.59E+10J	
Transformity=	1.68E+07sej/J	Brown and Bardi (2001)
31.Information	3.00E+00research groups/year	
average time spent	2.00E+01days/group	
total days spent	6.00E+01days/yr	
$ Spent by outside researchers	6.00E+03$/yr	
$ Spent by NFS	5.00E+03$/yr	
$ spent for Research in Osceola	1.10E+04$/yr	
Unit Emergy Value	1.90E+12sej/$	CEP (2006)
32.Image Exported with Tourists		
Tourism Time in NF's	1.80E+06hrs	NFS, 2005
site area=	2.07E+02ha	CEP (2006)
	1.20E+00sites/visit	
ha/visit	2.48E+02ha	NFS, 2005

use/ha/hour	2.56E+11sej/ha/hr	
emergy of image exported	1.15E+20sej/yr	
Unit emergy value	6.37E+13sej/visitor hour	CEP (2006)
33.Payments to State	5.94E+05$/yr	
Unit Emergy Value	1.90E+12sej/$	
34.Payments for FS Labor	4.18E+05$/yr	USFS, 2005
Payments for Contractor Labor	3.23E+04$/yr	
Total Labor Payments	4.50E+05$/yr	
Unit Emergy Value	1.90E+12sej/$	

APPENDIX F.1 - Notes to Table 11. Emergy Value of Deshutes National Forest Assets

ECOLOGICAL ASSETS (Natural Capital)

1 Tree Biomass		3.92E+07	m^3	NFS, 2005
		5.40E+02	kg/m^3	
	mass=m^3*kg/m^3*1000g/kg			
	=	2.12E+13	g	
		4.50E+00	Kcal/g of Tree Biomass	
	energy=g*.8% dry weight*4.5kcal/g*4186J/kcal			
	=	3.19E+17	J	
	Transformity	3.62E+04	sej/J	
2 Shrubs and Herbaceous		2.31E+06	mt	NFS, 2005
	mass=tons*g/ton			
	=	2.31E+12	g	
	energy=g*0.3% dry weight*3.5kcal/g*4186J/kcal			
	=	1.02E+16	J	
	Transformity	9.79E+03	sej/J	
3 Land Area		7.50E+05	ha	
	emergy of land structure	1.05E+15	sej/ha	
4 Soil OM		7.25E+07	m^3 OM	
	massOM=m^3*1100kg/m^3(Bulk Density)*1000g/kg			
	=	7.98E+13	g	
	Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal			
	=	1.80E+18	J	
	Transformity	1.24E+04	sej/J	
5 Ground Water				
	Density of water	1000	kg/m3	US GWA, 2000
	Gibbs Free energy of water	4940	J/kg	
	Volume	1.39E+09	m3	
	energy=volume*1000kg/m^3*4940J/kg			
	=	6.87E+15	J	
	transformity	2.79E+05	sej/J	
6 Surface Water				
	volume	1.93E+09	m^3	
	Density of water	1000	kg/m3	Buenfil (2001)
	Gibbs Free energy of water	4940	J/kg	
	energy=volume*1000kg/m^3*4940J/kg			
	=	9.54E+15	J	
	Transformity	1.04E+06	sej/J	

ECONOMIC ASSETS

7 Roads, Dirt		6.00E+03	$/mi	
		7.08E+03		
		4.25E+07	value of dirt roads	
	Unit Emergy Value	1.90E+12	sej/$	
8 Roads, Gravel		2.59E+06	m length	
		5.49E+00	m width	
	depth=	1.02E-01	m of gravel	
	volume=	1.44E+06	m^3 of limerock	NFS, 2005

	density=	1.39E+03	kg/m^3 gravel	
	mass gravel=m^3*kg/m^3*1000g/kg			
	=	2.01E+12	g	
	value of gravel	5.00E+00	$/ton	
		0.0011023	kg/shrt ton	
	Specific Emergy	1.68E+09	sej/g	Odum, 1996
9	Paved Roads			
	volume=	3.96E+05	m^3 of asphalt	
	density=	2.24E+03	kg/m^3 asphalt	
	mass asphalt=m^3*kg/m^3*1000g/kg			
	=	8.89E+11	g	
	Specific Emergy	2.77E+09	sej/g	Odum (1996)
10	Machinary	4.35E+06	lbs	
		4.54E+02	g/lb	
	mass machinary=lbs*g/lb			NFS, 2005
	=	1.97E+09	g	
	Specific Emergy	1.13E+10	sej/g	
11	Office Equipment	1.50E+01	kg/m2	CEP (2006)
	mass off. equip =(bldg area)*(kg/m2)*(1000g/kg)			NFS, 2005
	=	5.93E+09	g	
	Specific Emergy	1.13E+10	sej/g	
12	Buildings	3.96E+05	m^2	CEP (2006)
	total mass of materials (see Appendix K)			
	Building Mass=	1.63E+11	g	
	Specific Emergy	mixed		
	Energy Inputs (see calcs)=	4.24E+14	J	
	Emergy (see calcs)=	1.02E+21	sej	
SOCIETAL ASSETS				
13	Info in Archeological Artifacts	1.03E+03	# of Arch. Sites	NFS, 2005
	Acres of Arch. Sites	1.61E+04	acres	
	density of Indian pop	1.45E+00	Indians/mi^2	
	Estimate of avg Indian Pop	2.00E+03	people	
	energy per capita=2500kcal/day*365 d/y*4186J/kcal			
	Energy per capita	3.82E+09	J/yr/Indian	
	Yrs of cultural development	1.00E+03	yrs	
	Indian Info=Indians on Des*energy/capita*yrs of cultural dev.			
	Energy in Pop. Info	7.64E+15		
	Transformity	1.24E+07	sej/J	
14	Value of Critical Species			
	Endangered/Threatened Species	6.00E+00		NFS, 2005
	Percent of pop	1.00%	%	
	average emergy per species	3.96E+24	sej/species	
	Em. In critical species=(# of Spp)*(%of total Pop in FS land)*(Emergy to develop species)			
	Emergy in Critical Species	2.37E+23	sej	

Appendix F.2 - Notes to Table 12. Emergy Value of Osceola National Forest Assets

ECOLOGICAL ASSETS (Natural Capital)

1 Tree Biomass		4.02E+06m^3	NFS, 2005
		5.90E+02kg/m^3	
	mass=m^3*kg/m^3*1000g/kg		
	=	2.37E+12g	
		4.50E+00Kcal/g of Tree Biomass	
	energy=g*4.5kcal/g*4186J/kcal		
	=	4.46E+16J	
	Transformity	3.62E+04 sej/J	Brown and Bardi (2001)
2 Shrubs		1.36E+06shrt tons	NFS, 2005
		9.07E+05g/shrt ton	
	mass=tons*g/ton		
	=	1.23E+12g	
Herbaceous Cover		2.71E+06shrt tons	
	mass=tons*g/ton		
	=	2.46E+12g	
Shrub/Herb Total		3.69E+12g	
	energy=g*3.5kcal/g*4186J/kcal		
	=	5.41E+16J	
	Transformity	9.79E+03sej/J	Brown and Bardi (2001)
3 Land Area		6.54E+04ha	
	Emergy of land =	1.05E+15 sej/ha	Odum,(1996)
4 Soil OM			

Soil Storages	Area (m^2)	Depth of Topsoil (m)	Volume (m^3)	Organic Matter (m^3)
B Class (6% org)	3.7 E+08	0.508	1.87 E+08	11.28 E+06
C&D Class (2.5% org)	1.8 E+08	0.508	9.38 E+08	23.45 E+06
H Class (40% org)	6.8 E+08	0.9144	622 E+08	24.89 E+06
TOTAL				38.51 E+06

	massOM=m^3*1100kg/m^3(Bulk Density)*1000g/kg		
	=	4.24E+13g	
	Energy=massOM* 5.4 kcal/g of OM * 4186 j/kcal		
	=	3.47E+17J	
	Transformity	1.24E+04 sej/J	Brown and Bardi (2001)
5 Peat		3.15E+06m^3	FFS, U of F
	mass Peat OM=m^3*400kg/m^3(Bulk Density)		
	=	1.26E+12g	
	Energy=massPeat* 5.4 kcal/g of OM*1000g/kg* 4186 J/kcal		
	=	2.85E+16J	
	Transformity	3.09E+05sej/J	Brown and Bardi (2001)
6 Ground Water			
	Density of water	1000kg/m3	
	Gibbs Free energy	4940J/kg	
	Volume	1.05E+10m3	
	energy=volume*1000kg/m^3*4940J/kg		
	=	5.19E+16J	
	transformity	2.79E+05sej/J	Buenfil (2001)

7 Surface Water			
	volume	1.04E+08m^3	
	Density of water	1000kg/m3	
	Gibbs Free energy of water	4940J/kg	
	energy=volume*1000kg/m^3*4940J/kg		
	energy=	5.14E+14J	
	Transformity	1.04E+06sej/J	Brown and Bardi (2001)
ECONOMIC ASSETS			
8 Roads, Dirt		3.19E+06$	
	Unit Emergy Value	1.90E+12sej/$	CEP (2006)
9 Roads, Gravel		3.40E+05m length	NFS, 2005
		3.66E+00m width	
	area=	1.24E+06m^2	
	depth=	1.50E-01m of gravel	
	volume=	1.87E+05m^3 of limerock	
	density=	1.39E+03kg/m^3 gravel	
	mass gravel=m^3*kg/m^3*1000g/kg		
	=	2.60E+11g	
	Specific Emergy	1.68E+09sej/g	Odum (1996)
10 Paved Roads		1.72E+05m	
	area=	1.12E+06m^2	
	depth=	5.08E-02m depth	
	volume=	2.84E+04m^3 of asphalt	
	density=	2.24E+03kg/m^3 asphalt	
	mass gravel calculated as above		
	gravel	4.68E+11g	
	mass asphalt=m^3*kg/m^3*1000g/kg		
	asphalt	6.38E+10g	
	total mass	5.32E+11g	
	Specific Emergy	2.77E+09 sej/g	Odum (1996)
11 Machinary		3.80E+05lbs	
		4.54E+02g/lb	
	mass machinary=lbs*g/lb		
	=	1.72E+08g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
12 Office Equipment		5.68E+05lbs	
		4.54E+02g/lb	
	mass office equipment=lbs*g/lb		
	=	2.58E+08g	
	Specific Emergy	1.13E+10 sej/g	CEP (2006)
13 Buildings			
	building area	3.52E+03m^2	Kett, 2005
	mass per m^2	see appendix	
	emergy=	2.54E+18sej	
14 Phosphorus		9.07E+13g	USGS (1978)
	value	2.27E+09$	
	Specific Emergy	4.54E+09 sej/g	Odum, (1996)

CULTURAL ASSETS

15	Info in Archeological Artifacts	3.21E+02	# of Arch. Sites	USFS, 2005
	Acres of Arch. Sites	3.90E+06	M^2	
	density of Timucuan pop	1.04E+01	Indians/mi^2	
	Estimat of Timucuan on Osc.	2.64E+03	people	
	energy per capita=2500kcal/day*365 d/y*4186J/kcal			
	=	3.82E+09	J/yr/Indian	
	Years of cultural development	1.00E+03	yrs	
	Timucuan Info=Indians on Osc*energy/capita*yrs of cultural dev.			
	Energy in Pop. Info	1.01E+16		
	Transformity	1.24E+07	sej/J	
16	Value of Critical Species			USFS, 2006
	Red Cockaded Woodpecker	1.68E+02	ind.	
	Percent of pop	1.79E+00	%	
	Florida Black Bear	8.00E+01	ind.	
	Percent of pop	5.33E+00	%	
	Wood Stork	2.50E+01	ind.	
	Percent of pop	2.27E-01	%	
	Avg. Emergy of a Species	3.96E+24	sej	
	Em. In critical species=%of total Pop. On Osc.*Em. Required to develop species			
	Emergy in Critical Spp	2.91E+23	sej	

APPENDIX G - Fauna on USFS Lands

In calculating fauna biomass the concepts of trophic efficiency and turnover time were utilized to obtain an estimate for storage within the USFS system. Estimates for the storage of primary producers on USFS lands were available from USFS documents (USFS, 2004) and these numbers were used as the basis for consumers in the system. The primary production system is assumed to have an average turnover time of 5 years and a trophic energy transfer efficiency of 3%. The energy then transfers through consumption into primary, secondary, and tertiary consumers (see Fig. G.1 and Table G.1). All consumer trophic levels have an energy transfer efficiency of 10%, but have varying turnover times and flow paths (see Figure G.1), resulting in different emergy storages in the system.

Table G.1. Storage of Biomass on USFS Lands

Note	Item	Units	Quantity[1a]	UEV	Emergy
1	Primary Producer	g	5.43E+15	7.61E+07	4.14E+23
2	Primary Consumer (Insects)	g	1.30E+13	6.34E+09	8.27E+22
3	Herbivore	g	2.61E+13	6.34E+09	1.65E+23
4	Omnivore	g	1.43E+13	1.15E+10	1.65E+23
5	Carnivore	g	4.24E+12	5.85E+10	2.48E+23
6	Top Carnivore	g	2.99E+12	1.11E+11	3.31E+23

Note				Source
1	Primary Producer Storage			
	Tree Biomass	5.13E+15	g	Pugh, 2004
	Shrub/Herb Biomass	2.98E+14	g	COLE, 2005
	total PP Storage in NF's=	5.43E+15	g	
	turnover time	5	yrs	estimate
2	Primary Consumer Storage			
	Trophic Efficiency	3	%	
	percentage of PP consumed by Primary consumers	40	%	estimate
	Turnover Time of PC	1	yr	estimate
	Primary Consumers in NF's=	3%*40%*5.43E15 g PP/ 5 yr TT * 1yr Storage		
	=	1.30E+13	g	

3	Herbivore Storage			
	Trophic Efficiency	3	%	
	Percentage of PP consumed by Herbivores	40	%	estimate
	Turnover Time of Herbivores	2	yrs	estimate
	Herbivore Storage in NF's=	3%*40%* 5.43E15 g PP/5 yr TT * 2 yrs Storage		
	=	2.61E+13	g	
4	Omnivore Storage			
	Trophic Efficiency from PP	3	%	
	Trophic Efficiency from PC	10	%	
	Percentage of PP consumed by Omnivores	20	%	estimate
	Percentage of PC consumed by Omnivores	100	%	estimate
	Turnover Time	2	yrs	estimate
	Omnivore Storage in NF's=	(3%*20%*5.43E15 g PP/5 yr TT + 10% * 6.52E13 g PC/2 yr TT)* 2yrs Storage		
	=	1.43E+13	g	
5	Carnivore Storage			
	Trophic Efficiency from Omnivores, Herbivores	10	%	
	Percentage of Omnivores and Herbivores consumed	70	%	estimate
	Turnover Time	3	yrs	estimate
	Carnivore Storage on NF's=	(10%*2.61E13 g Herb * 70%/2 yr TT + 10% * 1.43E13 g Omni * *70%/ 2 yr TT)*3 yrs storage		
	=	4.24E+12	g	
6	Top Carnivore			
	Trophic Efficiency	10	%	
	Percentage of Omnivores and Herbivores consumed	30	%	estimate
	Percentage of Carnivores Consumed	100	%	estimate
	Turnover Time	4	yrs	estimate
	Top Carnivore Storage on NF's=	(10%*2.61E13g Herb * 30%/ 2 yr TT + 10% * 1.43E13 g Omni * 30%/ 2 yr TT+ 4.23E12 g Carn./3 yr TT)*4 yr storage		
	=	2.99E+12	g	

Trophic Transfers Determining Fauna Storage

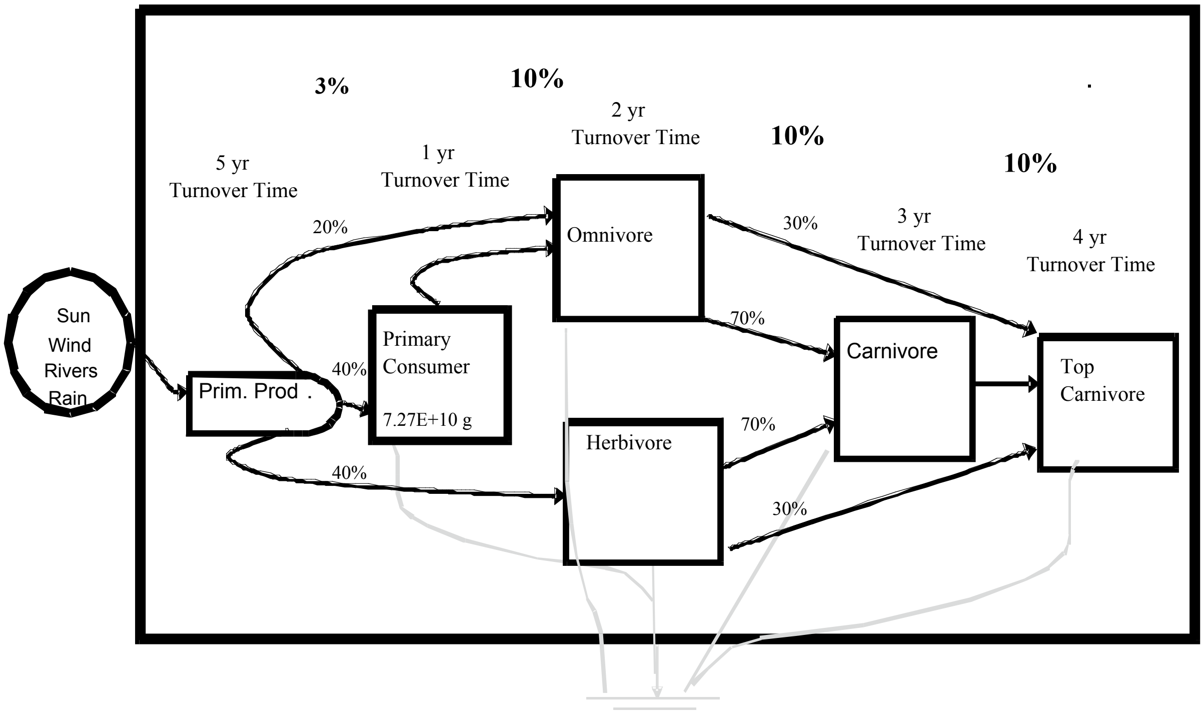


Figure G-1. Energy Transfer Across Trophic Level. Numbers that are **bolded** represent trophic efficiencies, numbers on pathways represent the percent of transfer from each trophic level to the next.

APPENDIX H - Emergy of Endangered Species

The emergy of a species is equal to the emergy that was required for the evolution of that species from its closest relative. The process of natural selection is captured in the genetic information of a species. Only the emergy of endangered species was quantified in this study because the emergy value represents the potential environmental work that will be lost if those species go extinct. An average value for emergy required to develop a species was estimated as follows: First, an average value for turnover time of species (Weir, 2007), 3 million years, and a median estimate for total number of species (10 million) was used. The renewable emergy budget of the globe was multiplied by three million and then divided by the 10 million species to obtain an estimate of emergy required per species (see Table H.1 note 1). There are approximately 496 endangered species supported by USFS lands and the USFS comprises 3.17% of the North American continent. The emergy per species was multiplied by these values to obtain an estimate for emergy embodied in the endangered species inhabiting USFS lands. A further improvement to the calculation could be made by looking at inhabitation on a per species basis to estimate how significant USFS lands are in provision of habitat. Ideally the evolutionary history and required habitat for development of each species would be analyzed in order to make a specific estimate for emergy required to develop the species.

Table H.1 Emergy of Endangered Species on USFS Lands

Note	Item	Units	Quantity	Emergy Intensities (sej/unit)	Solar Emergy ($x10^{21}$sej)	EmDollars ($x10^{9}$ Em$)
1	Endangered Species	# of species	4.96E+02	2.26E+22	62224.6	32749.8

Note				Source
1	Value of Critical Species			
	Endangered Species	4.96E+02		USFWS, 2006
	Percent of pop	3.17%	(% of Continental Area)	
	emergy per species=	(3E6 yrs of Dev.*15.83E24 sej/yr)/10E6 species		
	=	3.96E+24	sej/species	
	Emergy in Critical Species=	(# of Species)*(%of total Pop in FS land)*(Em. Required to develop species)		
	=	6.22E+25	sej	

APPENDIX I – Emergy Evaluation of Game Hunting on USFS Lands

Estimates for harvested wildlife were based on a USFS document from 2002 that provided estimates for hours of hunting spent on US public lands. From this an estimate was made for number of game taken per hour, based on literature values (USFW). These values were then multiplied by 28.7%, the percentage of US public lands that are National Forests, to obtain an estimate for game taken from USFS lands. These estimates could have been improved if data was available for individual states, and if harvest data was taken for individual species rather than categories. This data may be available on an individual state basis but does not appear to exist in a national database as public information.

Table I.1 Yearly Game Extracted From FS Lands

Note	Item	Units1	Quantity	UEV	Emergy
1	Big Game	J	4.21E+16	9.90E+05	4.17E+22
2	Small Game	J	9.92E+15	1.20E+05	1.19E+21
3	Migratory Birds	J	2.92E+13	1.01E+05	2.95E+18
4	Other	J	1.57E+13	1.50E+05	2.35E+18

Notes				Source
	% Dry Weight for Wildlife	2.50E+01	%	
1	Big Game Extracted	1.58E+06	Big Game/y	
	avg. mass	5.68E+04	g/Game	
	energy content	1.88E+04	J/g	estimate
	energy=	(#Game/yr)*(avg mass)*(% dry weight)*(J/g)		
	y=	4.21E+16	J/yr	USFWS, 2002
	Transformity=	9.90E+05	sej/J	Brown et al, 2005
	Emergy=	4.17E+22	sej	
2	Small Game Extracted	6.38E+06	Small Game/yr	USFWS, 2002
	avg. mass	3.30E+03	g/animal	
	energy content	1.88E+04	J/g	
	energy=	(#Game/yr)*(avg mass)*(% dry weight)*(J/g)		
	=	9.92E+15	J/yr	
	Transformity=	1.20E+05	sej/J	Brown et al, 2005
	Emergy=	1.19E+21	sej	
3	Migratory Birds Extracted	4.78E+06	#/yr	USFWS, 2002
	avg. mass	1.30E+03	g/bird	

	energy content	1.88E+04	J/g	
	energy=	(#Game/yr)*(avg mass)*(% dry weight)*(J/g)		
	=	2.92E+13	J/yr	
	Transformity=	1.01E+05	sej/J	Brown et al, 2005
	Emergy=	2.95E+18	sej	
4	Other Species Extracted	5.25E+05	#/yr	USFWS, 2002
	avg. mass	6.35E+03	g	
	energy content	1.88E+04	J/g	
	energy=	(#Game/yr)*(avg mass)*(% dry weight)*(J/g)		
	=	1.57E+13	J/yr	
	Transformity=	1.50E+05	sej/J	Brown et al, 2005
	Emergy=	2.35E+18	sej	

APPENDIX J -Emergy of Native American Cultural Information

The emergy embodied in Native American Artifacts is based on an assumed period of cultural innovation. It was assumed that the bulk of cultural innovation occurs over the first ten generations of a culture's development and then traditions are passed down over time. We estimated the average lifespan of Native Americans pre-colonization as 25 yrs, so ten generations equals 250 years. The estimate for the population of Native Americans on USFS lands was made using a population density map (Figure J.1). To obtain the emergy driving the system the time of cultural development were multiplied by the current renewable emergy driving the USFS (this assumes climatic conditions were similar during development). The emergy driving the civilization is then divided by the joules expended over that time period to obtain a transformity (see note 1). Further improvements on this calculation are possible with more extensive research into cultural development periods, which would likely require isolating populations and performing tailored calculations for each population. Accounting for cultural turnover and rate of cultural information innovation would improve the calculation. This is a fertile area for future research, merging emergy and anthropology.

Table J.1 Emergy of Native American Cultural Information

Note	Item	Units	Quantity	Emergy Intensities (sej/unit)	Solar Emergy ($x10^{21}$sej)	EmDollars ($x10^9$ Em$)
1	Information Value of Artifacts	J	1.15E+18	1.89E+07	21728.1	11435.8

Note				Source
1	Emergy of Cultural Information			
	Native Americans on FS lands (peak)	1.20E+06	people	estimate
	energy per capita=	(2500Cal/day)*(365 d/y)*(4186J/Cal)		
	=	3.82E+09	J/yr	
	Yrs to develop information	2.50E+02		estimate
	Energy of Population=	(population)*(J/yr/Indian)*(year)		
	=	1.15E+18	J	
	Renewable Emergy Budget	8.67E+22	sej/yr	
	Native American Info=	(Yrs. Of Development)*(Renewable Emergy per year)		
	Energy embodied in Pop. Info	2.17E+25	sej	
	Transformity =	Emergy of information / energy of population		
	=	1.89E+07	sej/J	

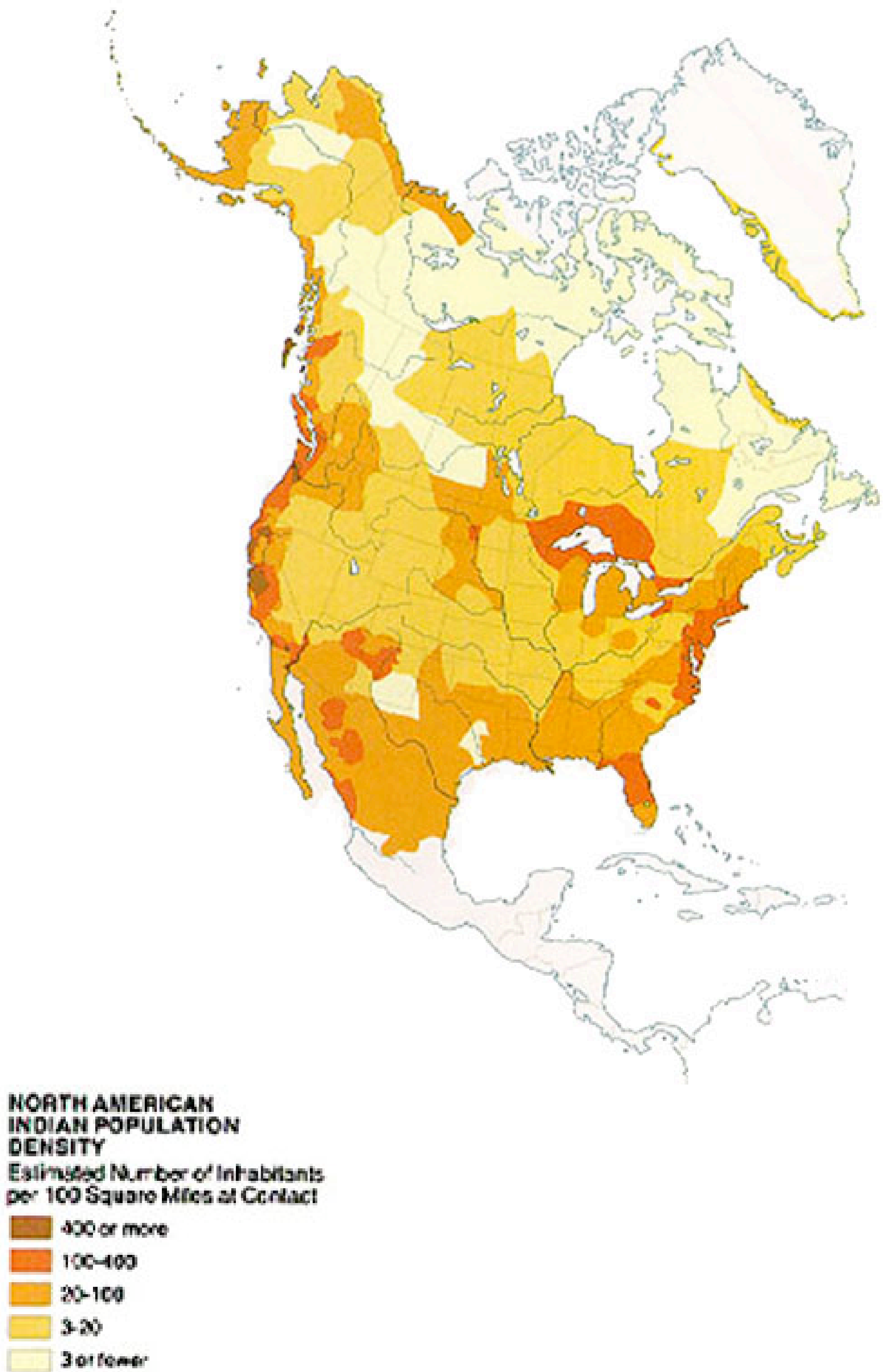


Figure J.1 Native American Population Density Estimate

APPENDIX K: Emergy in USFS Buildings

Some methods of emergy synthesis have been improved in the course of completion of this thesis. A previous evaluation of emergy content of buildings, Evaluation of Recycling and Reuse of Building Materials Using the Emergy Analysis Method, by V. Buranakarn completed in 1998, is the basis for the emergy in USFS buildings calculation. The material, energy and labor data in Buranakarn's study were updated using newer emergy intensities. In this way only the square meters of floor must be known for an estimate to be made for the emergy of the entire building. The square meters of floor are multiplied by the emergy value for each building component per m^2 for an estimate of the emergy embodied in the building. These estimates are based on the assumption of a two story office building. This calculation could be improved by obtaining standards for buildings of different heights and uses. Table A.1 shows the mass per m^2 values of building components, the Unit Emergy Values, and the Emergy per m^2 of the component. Table A.2 shows the calculation used to determine the emergy of USFS buildings.

Table K-1. Emergy of Building Components on USFS Lands

Note	Item	Units	units per m^2	Emergy Intensity	Emergy Density (per m^2)
1	Cement	g	3.72E+04	3.70E+09	1.38E+14
2	Concrete	g	2.81E+04	2.12E+09	5.96E+13
3	Masonry, 8" CMU	g	9.29E+04	2.27E+09	2.11E+14
4	Masonry, 4" tile brick	g	2.98E+04	3.90E+09	1.16E+14
5	Structural Steel	g	1.42E+04	2.99E+09	4.24E+13
6	other metals	g	3.41E+04	2.99E+09	1.02E+14
7	Glass	g	8.26E+02	3.19E+09	2.64E+12
8	Dry Wall	g	1.01E+05	3.44E+09	3.49E+14
9	Vinyl tile, carpet	g	1.26E+04	9.86E+09	1.25E+14
10	Paint	g	4.55E+03	2.55E+10	1.16E+14
11	Electrical System	g	1.51E+03	1.13E+10	1.70E+13
12	Elevators	g	5.74E+03	1.13E+10	6.46E+13
13	HVAC	g	1.39E+04	1.13E+10	1.56E+14
14	Fire System	g	4.50E+03	1.13E+10	5.06E+13
15	Plumbing System	g	3.32E+03	1.13E+10	3.74E+13
16	Furnishings	g	1.34E+04	7.88E+09	1.05E+14
17	Water	j	4.93E+05	8.06E+04	3.98E+10
18	Fuel	j	5.97E+08	1.11E+05	6.62E+13
19	Electricity	j	4.73E+08	2.92E+05	1.38E+14
20	Machinery	g	1.48E+04	1.13E+10	1.66E+14
21	Labor	$	5.25E+02	1.00E+12	5.25E+14

Notes to Table K-1				Sources
1 Cement				
	(4015 sq ft)(20 lb/sq ft)(454 g/lb)			
	= 36456200	g		
Specific Emergy	3.70E+09	sej/g	cement	Buranakarn, 1998

2	Concrete				
			(405 cu. Yd.)(150 lb/cu.yd.)(454 g/lb)		
		=	27590500		
	Specific Emergy		2.12E+09	sej/g	Buranakarn, 1998
3	Masonary, 8" CMU				
			(4015 sq. ft.)(50 lb/sq. ft.)(454 g/lb)		
		=	91140500	g	
	Specific Emergy		2.27E+09	sej/g	Buranakarn, 1998
4	Masonary, 4" tile brick				
			(4015 sq. ft.)(16 lb/sq. ft.)(454 g/lb)		
		=	2916490	g	
	Specific Emergy		3.90E+09	sej/g	Buranakarn, 1998
5	Structural Steel		(30560 lb)(454 g/lb)		
		=	13874240	g	
	Specific Emergy		2.99E+09	sej/g	Odum, 1996
6	Other Metals				
			(65664 lb stud)(454 g/lb)+(8153 lb metals)(454 g/lb)		
		=	33512918	g	
	Specific Emergy		2.99E+09	sej/g	Steel, Odum 1996
7	Glass				
			(1088 sq. ft.)(1.64 lb/sq. ft. 1/8")(454 g/lb)		
		=	810081.28	g	
	Specific Emergy		3.19E+09	sej/g	Buranakarn, 1998
8	Drywall				
			(2 sides)(10 lb/sq. ft.)(10944 sq. ft.)(454 g/lb)		
		=	99371520	g	
	Specific Emergy		3.44E+09	sej/g	Haukoos, 1995
9	Vinyl tile and carpet				
			(10900 sq. ft.)(2.5 lb/sq. ft.)(454 g/lb)		
		=	12371500	g	
	Specific Emergy		9.86E+09	sej/g	Buranakarn, 1998
10	Paint				
			(2 sides)(10944 sq. ft.)(1 gal/26 sq. ft.)(11.68 lb/gal)(454 g/lb)		
		=	4464074.4	g	
	Specific Emergy		2.55E+10	sej/g	Buranakarn, 1998
11	Electrical System				
			(3252 lb)(454 g/lb)		
		=	1476408	g	
	Specific Emergy		1.13E+10	sej/g	machinery, Odum 1996

12	Elevators				
			(12400 lb)(454 g/lb)		
		=	562900	g	
	Specific Emergy		1.13E+10	sej/g	machinery, Odum 1996
13	HVAC				
			(3660 lb)+(13380 lb)+(7*1869 lb)}(454 g/lb)		
		=	13647240	g	
	Specific Emergy		1.13E+10	sej/g	machinery, Odum 1996
14	Fire System				
			(9720 lb)(454 g/lb)		
		=	326880	g	
	Specific Emergy		1.13E+10	sej/g	machinery, Odum 1996
15	Plumbing				
			(7200 lb)(454 g/lb)		
		=	3268800	g	
	Specific Emergy		1.13E+10	sej/g	machinery, Odum 1996
16	Furnishings				
			(28750 lb)(454 g/lb)		
		=	13052500	g	
	Specific Emergy		7.88E+09	sej/g	Burnanakarn, 1998
17	Water				
			(1800 gal/mo)(15 mo)(8 lb/gal)(454 g/lb)(4.94 J/g)		
		=	484436160	J	
	Transformity		8.06E+04	sej/J	Odum, 1996
18	Fuel				
			(4447.4 gal)(125000 Btu/gal)(1054 J/Btu)		
		=	5.89E+11	J	
	Transformity		1.11E+05	sej/J	Odum, 1996
19	Electricity				
			{(15 mo)*419 kWh/mo trailer)+(14 mo)*7700 kwh/mo building+(14700 kWh last mo)}(3.6E6 J/kWh)		
		=	4.36E+11	J	
	Transformity		2.92E+05	sej/J	Odum, 1996
20	Machinery				
	Average age of machinery		4.3	yrs	
	Life expectancy		5	yrs	

			50000 lb/crane/12 mo, 3*15000 lb/backhoe/2 mo, 20000 lb/loader/mo 2*15000 lb/forklifts/12 mo, 3*20000 lb/truck/12 mo, 5*6000 lb/platform/12 mo 10000+1500+33+6000+8000+6000= 31833 lb		
			(31833 lb)(454 g/lb)		
		=	14452182	g	
	Specific Emergy		1.13E+10	sej/g	Odum, 1996
21	Labor				
			(515252 $/15 mo)		
		=	515252	$	
	Transformity		1.00E+12	sej/$	Odum, 1996
22	Yield of Commercial Building (g)				
			(390233922 g of 15 mo)		
		=	390233922	g	
			35801.277	g/sq. ft.	
			397791.969	g/sq m	
23	Yield of Commercial Building (sq ft)				
			(10900 sq. ft.)		
		=	10900	sq ft	
24	Yield of Commercial Building (sq. m)				
			(10900 sq. ft)(0.09 sq. m/sq. ft_		
		=	981	sq. m	

Table A.2 Emergy of USFS Buildings

Building Area=	2.79E+06	m^2

Table K-2. Emergy of USFS Buildings

Note	Item	Unit	Units Per m^2	Input Resource	Emergy Intensity	Emergy
1	Cement	g	3.72E+04	1.04E+11	3.70E+09	3.83E+20
2	Concrete	g	2.81E+04	7.84E+10	2.12E+09	1.66E+20
3	Masonry, 8" CMU	g	9.29E+04	2.59E+11	2.27E+09	5.87E+20
4	Masonry, 4" tile brick	g	2.98E+04	8.30E+10	3.90E+09	3.23E+20
5	Structural Steel	g	1.42E+04	3.95E+10	2.99E+09	1.18E+20
6	other metals	g	3.41E+04	9.52E+10	2.99E+09	2.85E+20
7	Glass	g	8.26E+02	2.30E+09	3.19E+09	7.35E+18
8	Dry Wall	g	1.01E+05	2.82E+11	3.44E+09	9.73E+20
9	Vinyl tile, carpet	g	1.26E+04	3.52E+10	9.86E+09	3.48E+20
10	Paint	g	4.55E+03	1.27E+10	2.55E+10	3.24E+20
11	Electrical System	g	1.51E+03	4.21E+09	1.13E+10	4.73E+19
12	Elevators	g	5.74E+03	1.60E+10	1.13E+10	1.80E+20
13	HVAC	g	1.39E+04	3.87E+10	1.13E+10	4.35E+20
14	Fire System	g	4.50E+03	1.25E+10	1.13E+10	1.41E+20
15	Plumbing System	g	3.32E+03	9.27E+09	1.13E+10	1.04E+20
16	Furnishings	g	1.34E+04	3.72E+10	7.88E+09	2.93E+20
17	Water	j	4.93E+05	1.38E+12	8.06E+04	1.11E+17
18	Fuel	j	5.97E+08	1.67E+15	1.11E+05	1.85E+20
19	Electricity	j	4.73E+08	1.32E+15	2.92E+05	3.85E+20
20	Machinery	g	1.48E+04	4.12E+10	1.13E+10	4.64E+20
21	Labor	$	5.25E+02	1.46E+09	1.90E+12	2.78E+21
					sum=	7.21E+21

Notes to Table K-2 — Source

1 Cement

			Source
	3.72E+04	g/m^2	Buranakarn, 1998
USFS Building Area	2.79E+06	m^2	
mass=	mass/m^2*m^2 USFS Buildings		
=	1.04E+11	g	
Specific Emergy	3.70E+09	sej/g	Buranakarn, 1998

2 Concrete

			Source
units per m^2	2.81E+04	g/m^2	Buranakarn, 1998
USFS Building Area	2.79E+06	m^2	
mass=	mass/m^2*m^2 USFS Buildings		
=	7.84E+10	g	
Specific Emergy	2.12E+09	sej/g	Buranakarn, 1998

3 Masonry, 8" CMU

			Source
units per m^2	9.29E+04	g/m^2	Buranakarn, 1998
USFS Building Area	2.79E+06	m^2	

	mass=	mass/m^2*m^2 USFS Buildings		
	=	2.59E+11	g	
	Specific Emergy	2.27E+09	sej/g	Buranakarn, 1998
4	Masonry, 4" tile brick			
	units per m^2	2.98E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	8.30E+10	g	
	Specific Emergy	3.90E+09	sej/g	Buranakarn, 1998
5	Structural Steel			
	units per m^2	1.42E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	3.95E+10	g	
	Specific Emergy	2.99E+09	sej/g	Odum, 1996
6	other metals			
	units per m^2	3.41E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	9.52E+10	g	
	Specific Emergy	2.99E+09	sej/g	Steel, Odum 1996
7	Glass			
	units per m^2	8.26E+02	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	2.30E+09	g	
	Specific Emergy	3.19E+09	sej/g	Buranakarn, 1998
8	Dry Wall			
	units per m^2	1.01E+05	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	2.82E+11	g	
	Specific Emergy	3.44E+09	sej/g	Buranakarn, 1998
9	Vinyl tile, carpet			
	units per m^2	1.26E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	3.52E+10	g	

	Specific Emergy	9.86E+09	sej/g	Buranakarn, 1998
10	Paint			
	units per m^2	4.55E+03	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.27E+10	g	
	Specific Emergy	2.55E+10	sej/g	Buranakarn, 1998
11	Electrical System			
	units per m^2	1.51E+03	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	4.21E+09	g	
	Specific Emergy	1.13E+10	sej/g	machinery, Odum 1996
12	Elevators			
	units per m^2	5.74E+03	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.60E+10	g	
	Specific Emergy	1.13E+10	sej/g	machinery, Odum 1996
13	HVAC			
	units per m^2	1.39E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	3.87E+10	g	
	Specific Emergy	1.13E+10	sej/g	machinery, Odum 1996
14	Fire System			
	units per m^2	4.50E+03	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.25E+10	g	
	Specific Emergy	1.13E+10	sej/g	machinery, Odum 1996
15	Plumbing System			
	units per m^2	3.32E+03	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	9.27E+09	g	
	Specific Emergy	1.13E+10	sej/g	machinery, Odum 1996

16	Furnishings			
	units per m^2	1.34E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	3.72E+10	g	
	Specific Emergy	7.88E+09	sej/g	Buranakarn, 1998
17	Water			
	units per m^2	4.93E+05	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.38E+12	g	
	Transformity	8.06E+04	sej/g	Odum, 1996
18	Fuel			
	units per m^2	5.97E+08	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.67E+15	g	
	Transformity	1.11E+05	sej/g	Odum, 1996
19	Electricity			
	units per m^2	4.73E+08	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.32E+15	g	
	Transformity	2.92E+05	sej/g	Odum, 1996
20	Machinery			
	units per m^2	1.48E+04	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	4.12E+10	g	
	Specific Emergy	1.13E+10	sej/g	Odum, 1996
21	Labor			
	units per m^2	5.25E+02	g/m^2	Buranakarn, 1998
	USFS Building Area	2.79E+06	m^2	
	mass=	mass/m^2*m^2 USFS Buildings		
	=	1.46E+09	g	
	Specific Emergy	1.90E+12	sej/g	Odum, 1996