Ecological Economics

Valuing Real Wealth

Dr. Abel

Money as Value (以金錢為利)

- The amount of money that we pay for some product is an indication of how much we *value* (評價) that product, economists say
- If we buy an expensive car, then it must have great value to us

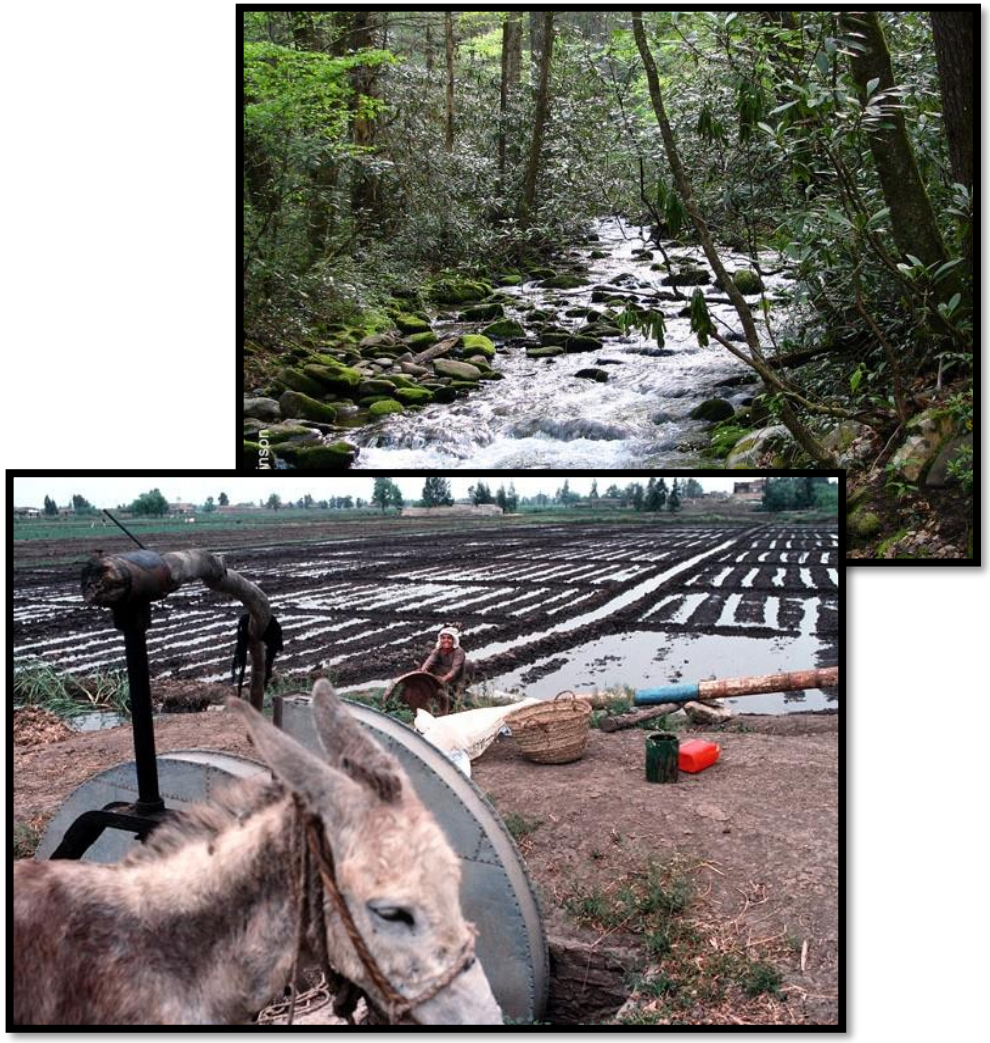
I love my car!

Money as Value

- But can we use money to value the many ecosystem services that nature provides?
- The wind that disperses the smoke from factories?
- The forest that builds soil to grow trees for timber?
- The wetland that cleans the rainwater runoff?

Money as Value

- The potential energy in streams?
- For a farmer, that energy is of great value
- The farmer uses that energy to spread water on his crops
- Nature provides products and services for “free”
- Money is NOT paid to nature for those services



Money as Value

- Instead, the money you pay for something (price) is determined by:
  - Scarcity (罕見)
  - Human labor costs (人力成本)
  - Perception (感覺)
- It does not reflect the work of the environment

I love my car!

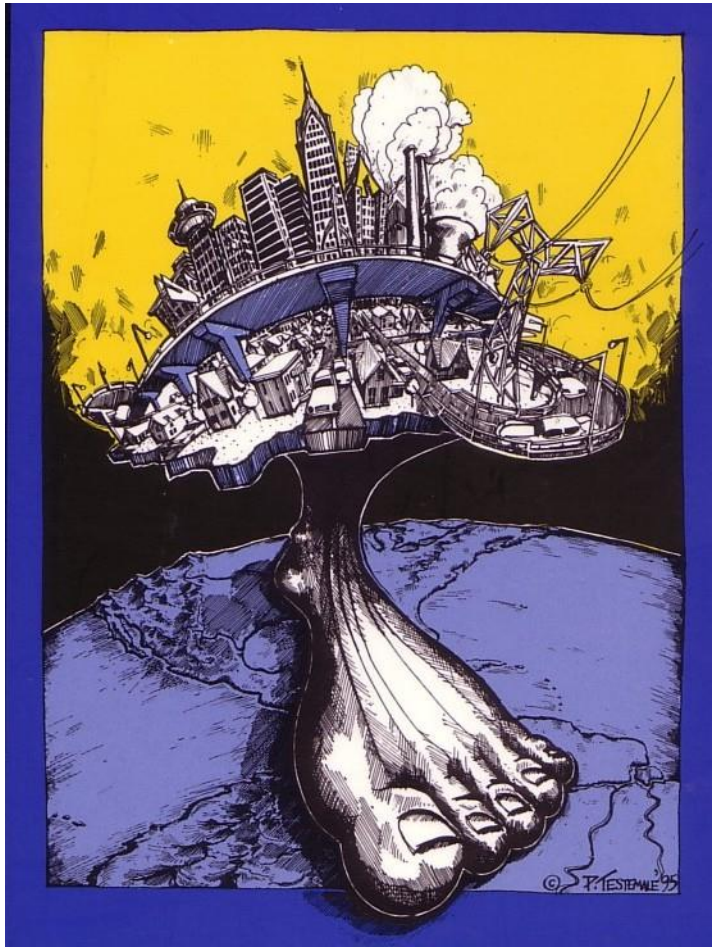
Ecological-Economics (生態經濟學)

- Ecological-Economics
- So can we find another way, besides money, to show how much we value something?
- There have been several attempts to create a new kind of currency, one that can value the work of nature
- Together these methods are called ecological-economics

Ecological Footprint
(生態足跡)

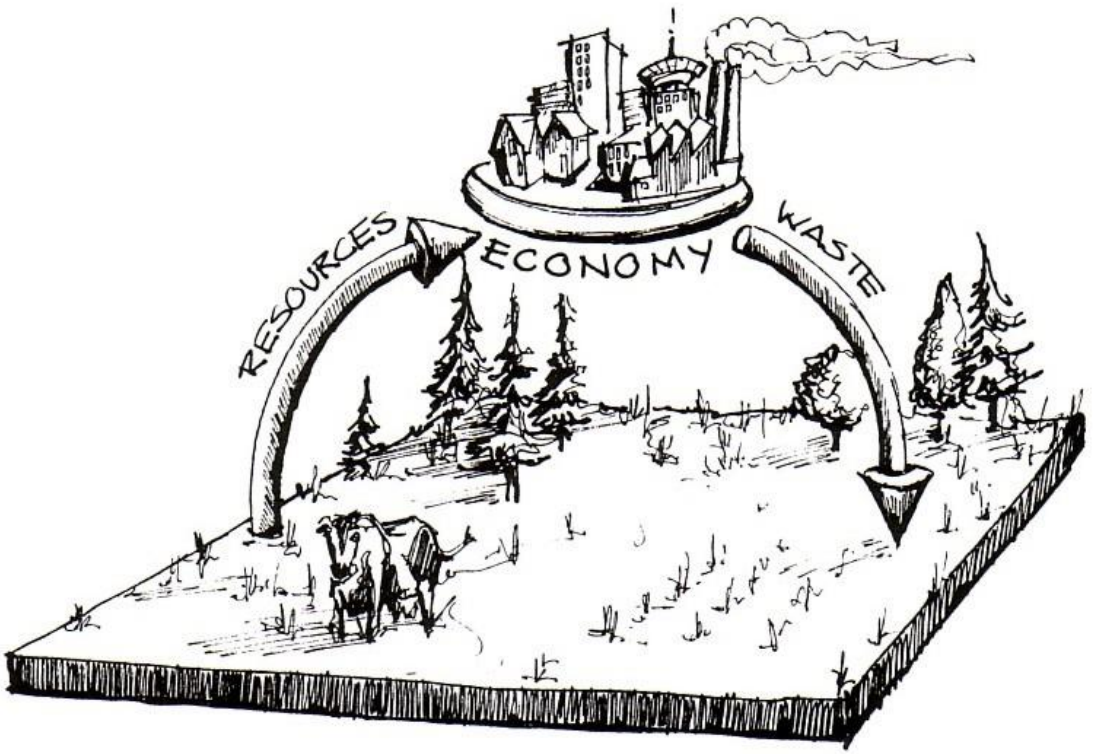
What is an Ecological Footprint?

- The Ecological Footprint is a measure of the "load" imposed by a given population on nature
- It accounts for the flows of energy and matter *to* and *from* any defined economy
- It represents the land/water *area* necessary to sustain current levels of resource consumption and waste discharge by that population



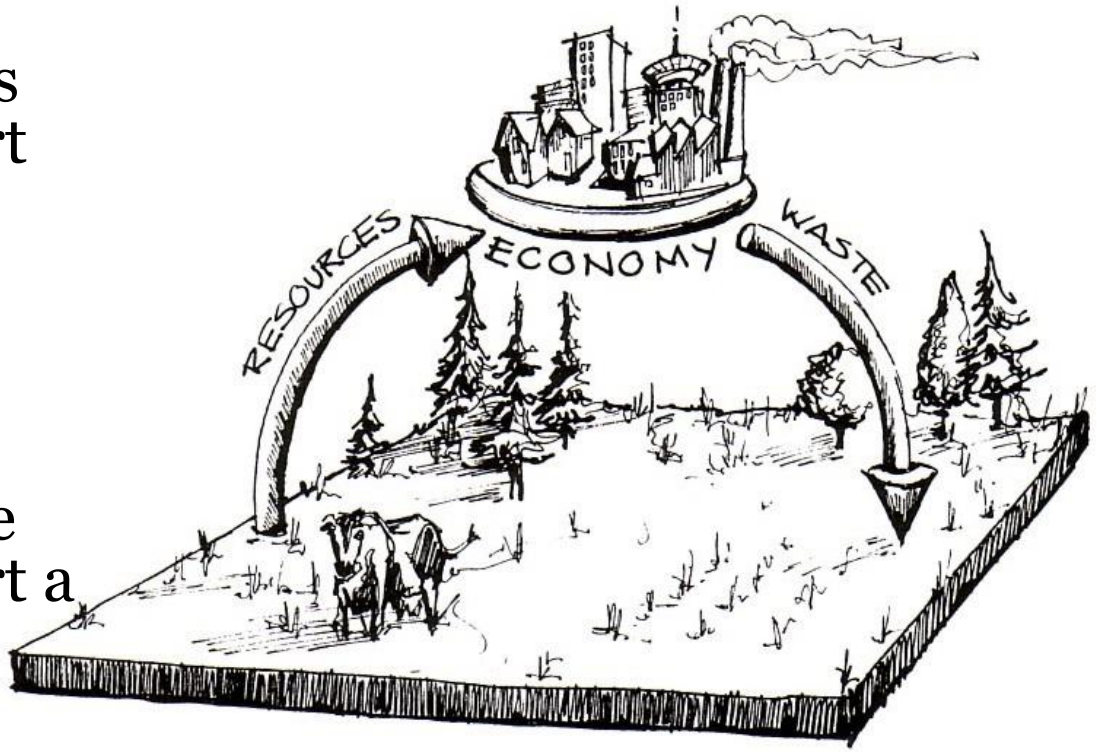
What is an Ecological Footprint?

- Think of an economy as having an “industrial metabolism” (工業代謝)
- It is thus similar to a cow in its pasture
- The economy needs to “eat” resources, and eventually, all this intake becomes waste and has to leave the organism – the economy - again



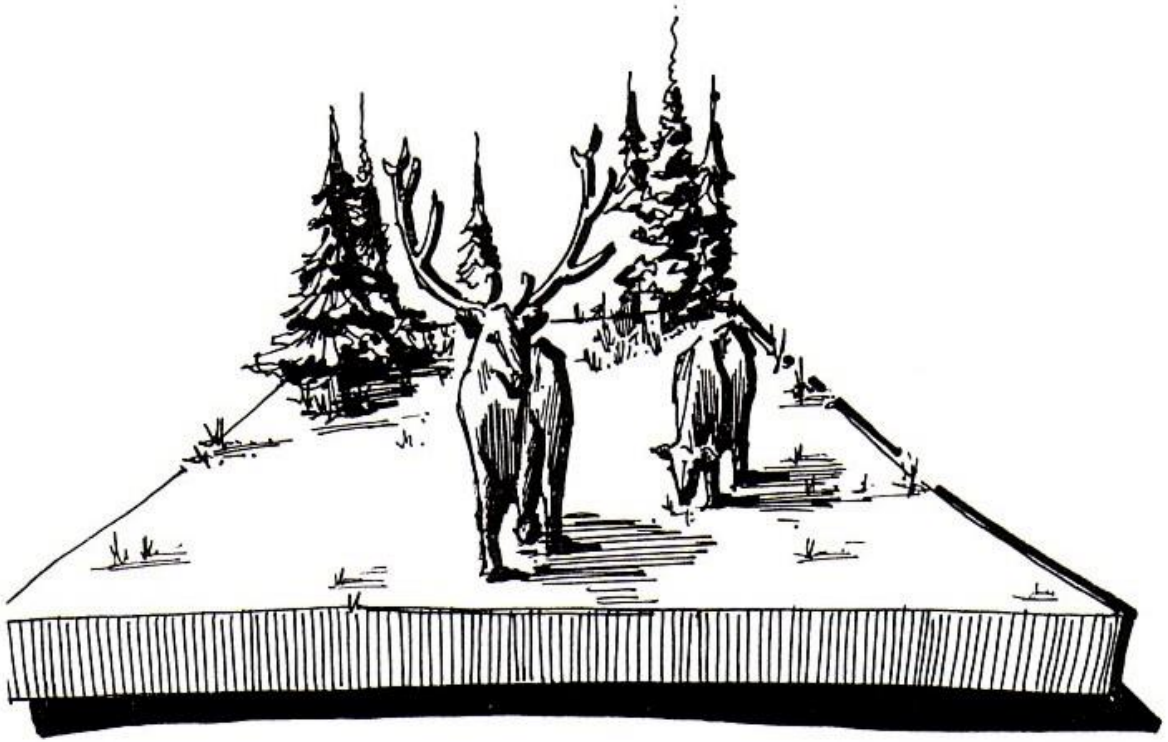
What is an Ecological Footprint?

- So the question becomes:
- How big a pasture is necessary to support that economy – to produce all its feed and absorb all its waste?
- Alternatively, how much land would be necessary to support a defined economy sustainably at its current material standard of living?



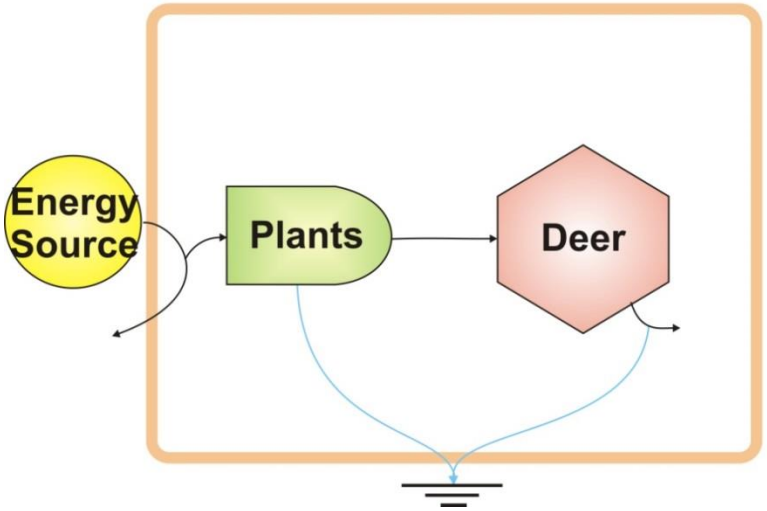
Carrying Capacity?

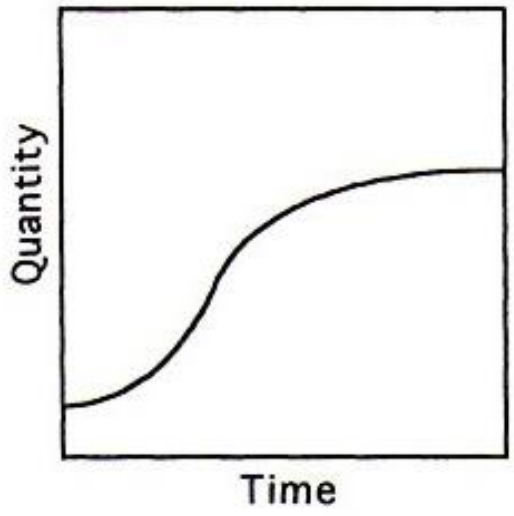
- An older concept than ecological footprint is carrying capacity (容納量)
- It is traditionally defined as the maximum population of a species that can be sustained indefinitely in a given habitat



Carrying Capacity?

- The concept of carrying capacity works fine for a deer population





Carrying Capacity?

- But human technology has made that measure useless
- Urban areas can be modified to support thousands or millions of people

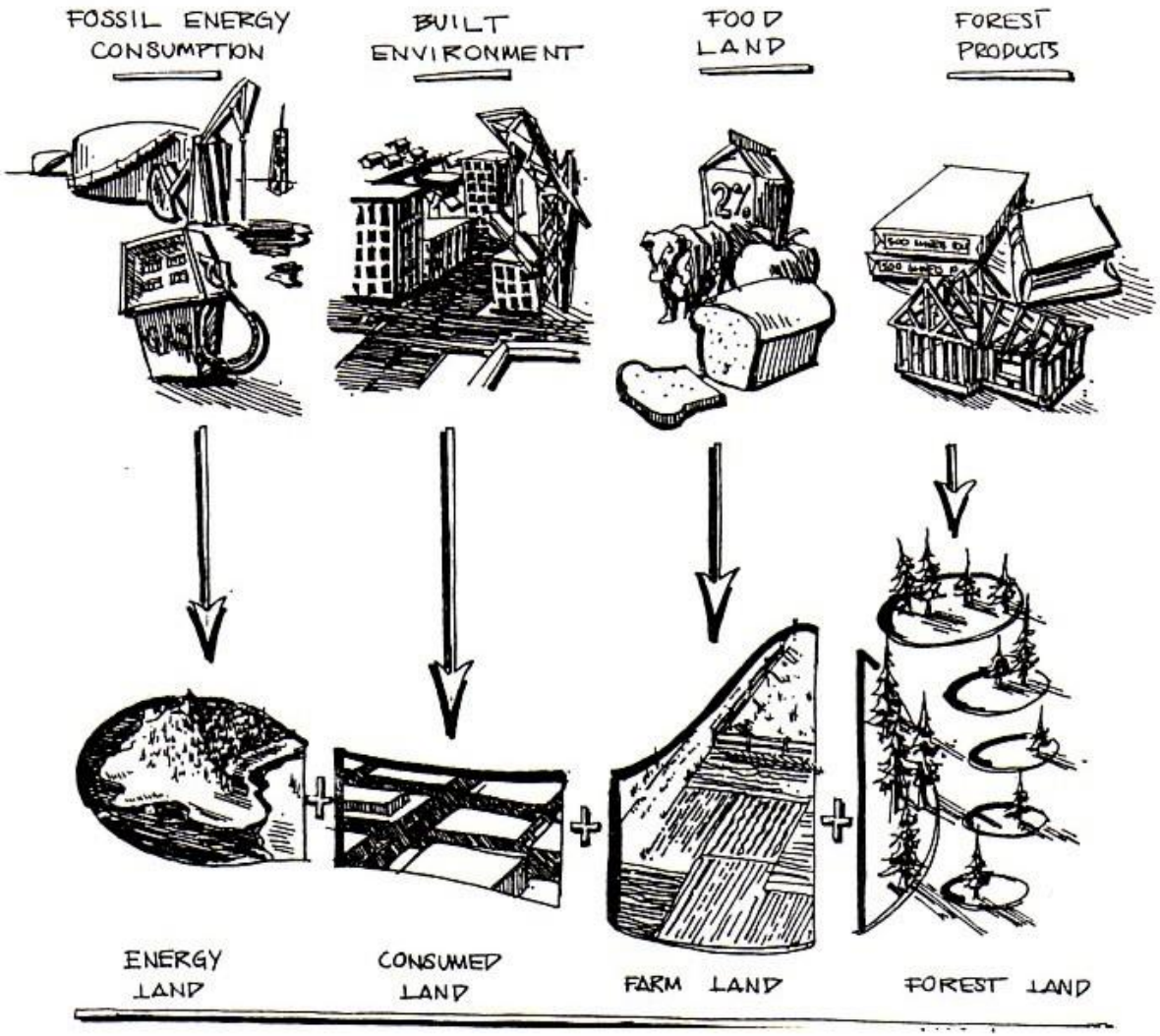
Carrying Capacity?

- The ecological locations of human settlements no longer coincide with their geographic locations
- This is the result of:
  - High population densities
  - The rapid rise in per capita energy and material consumption
  - The growing dependence on trade (貿易)
- Modern cities and industrial regions are dependent for survival and growth on a *vast and increasingly global hinterland* (腹地) of ecologically productive landscapes

A hinterland of agricultural production

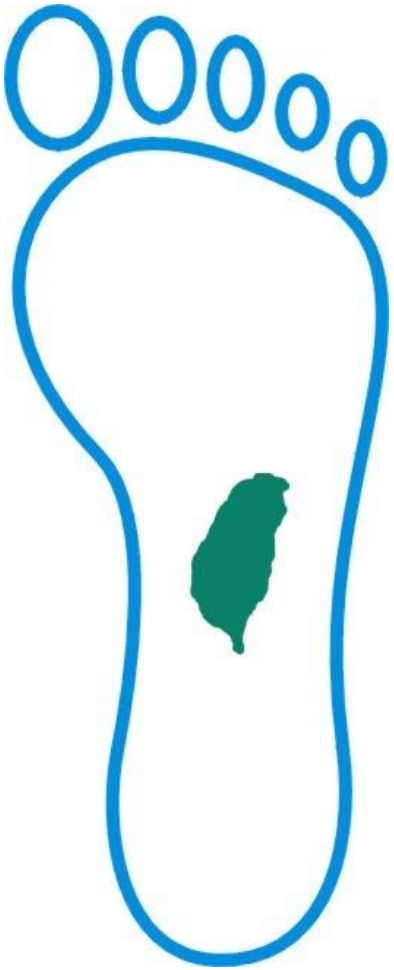
Carrying Capacity?

- Ecological footprint accounts for *all* the many inputs that are required to support an urban "built environment"



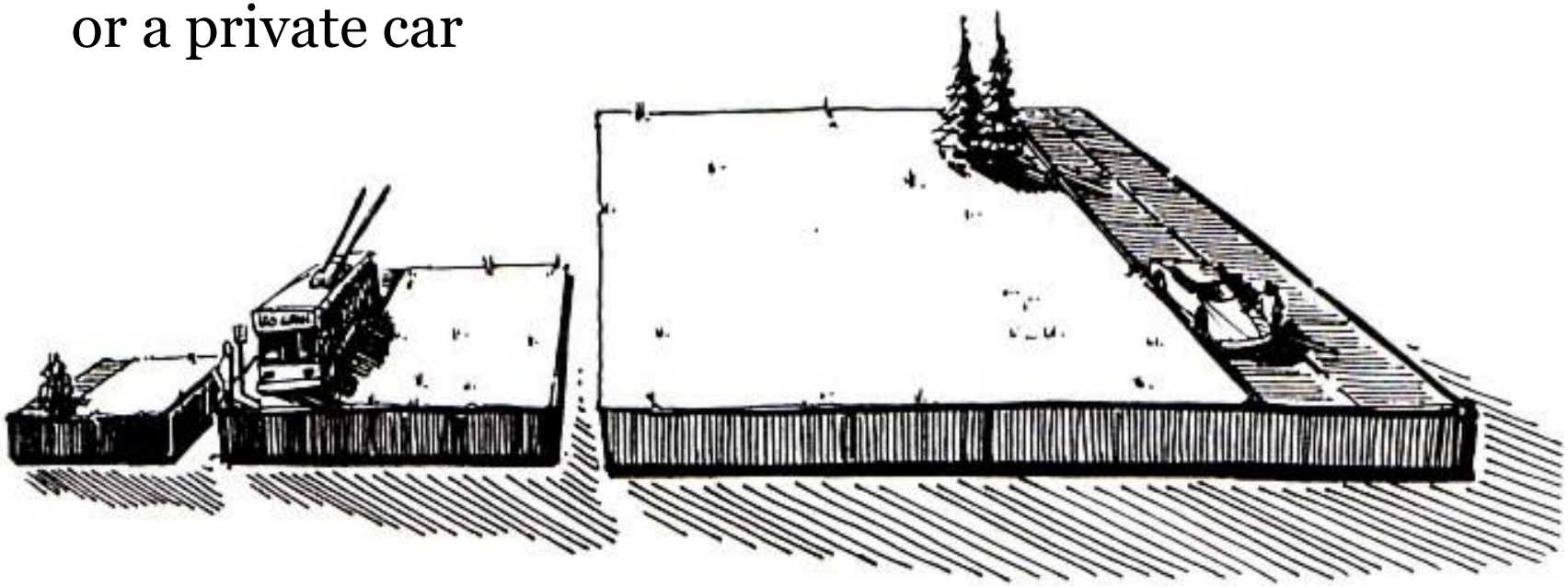
How big is your ecological footprint?

- How big is Taiwan's footprint?
- How big is Hualien's footprint?
- How big is your footprint?



How big is your ecological footprint?

- Ecological footprints are calculated with a table and then converted into spatial units (空間單元)
- They can be calculated for a nation, a person, or even a single activity, like getting to work
- The footprint of a person riding their bike to work is here compared with a person riding public transport or a private car



How big is your ecological footprint?

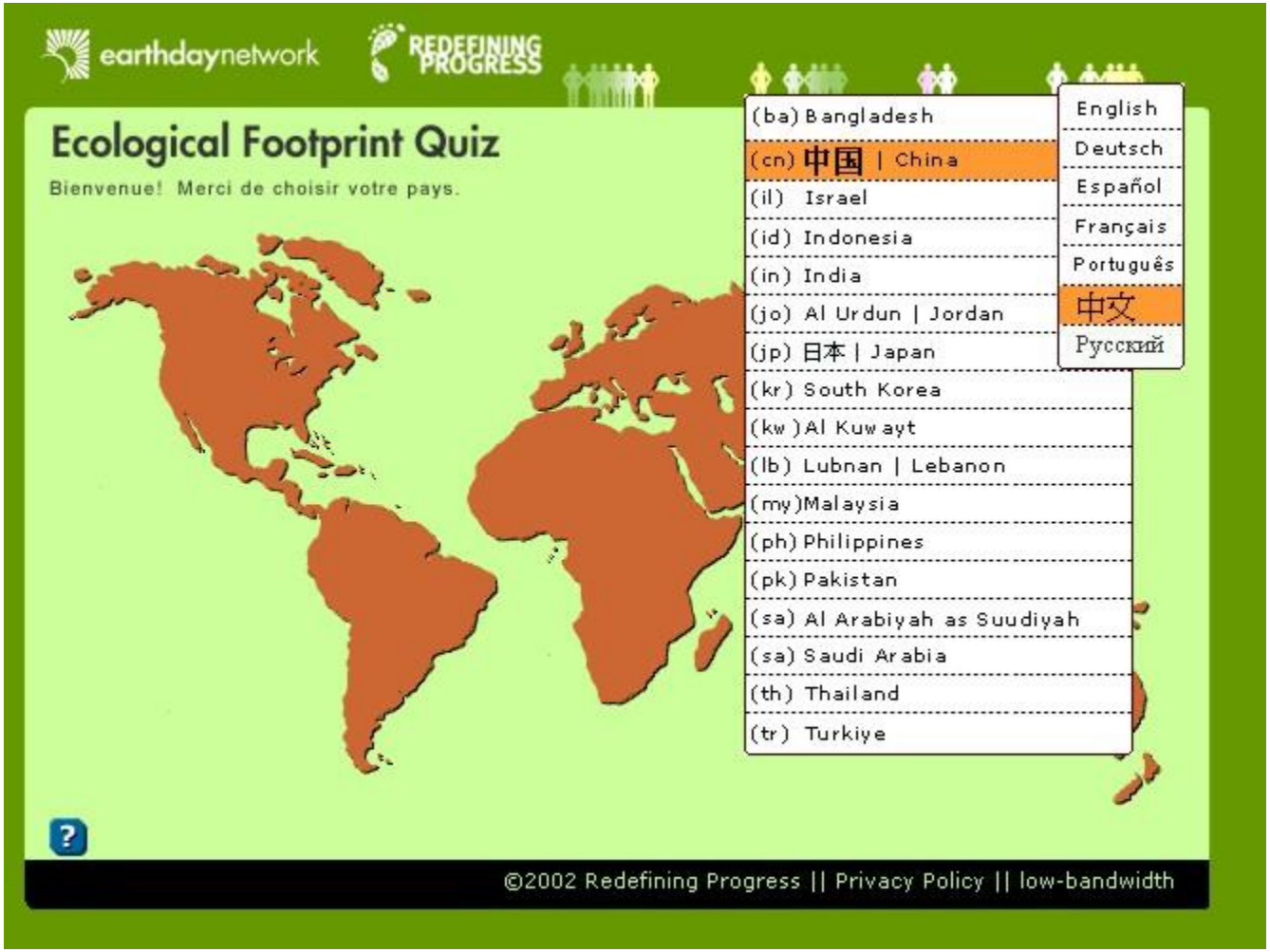
- Here are some calculated ecological footprints for comparison
- These are measured in hectares per person (公頃/人)

Table 3.4: Comparing people's average consumption in the US, Canada, India and the world[17]

Consumption per person in 1991	Canada	USA	India	World
CO_2 emission [in tonnes per yr]	15.2	19.5	0.81	4.2
Purchasing Power [in $ US]	19,320	22,130	1,150	3,800
Vehicles per 100 persons	46	57	0.2	10
Paper consumption [in kilograms/yr]	247	317	2	44
Fossil energy use [in Gigajoules/yr]	250 (234)	287	5	56
Fresh water withdrawal [in m^3 /yr]	1,688	1,868	612	644
Ecological Footprint [ha./person]	**4.3**	**5.1**	**0.4**	**1.8**

What is Your Ecological Footprint?

http://www.footprintnetwork.org/en/index.php/GFN/page/calculators/



What is Your Ecological Footprint?

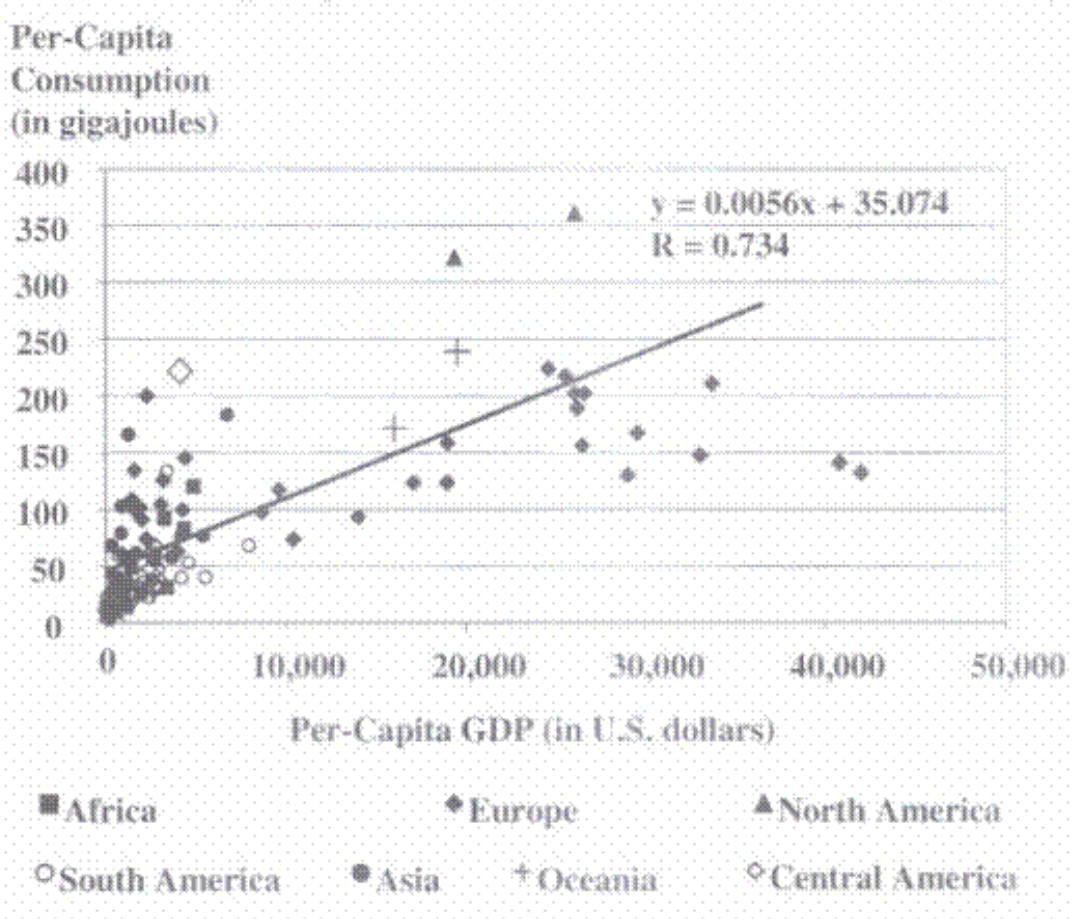
Energy and EROI

Energy and EROI

- If money cannot measure the contributions that are free from nature, perhaps ‘energy’ can
- When wind disperses the pollution of a factory, the wind can be measured with energy
- The moving water in a river can be measured with energy
- We will look at attempts to value the energy in natural resources shortly
- But first, energy has been used to construct some useful indicators (指標)

Energy and EROI

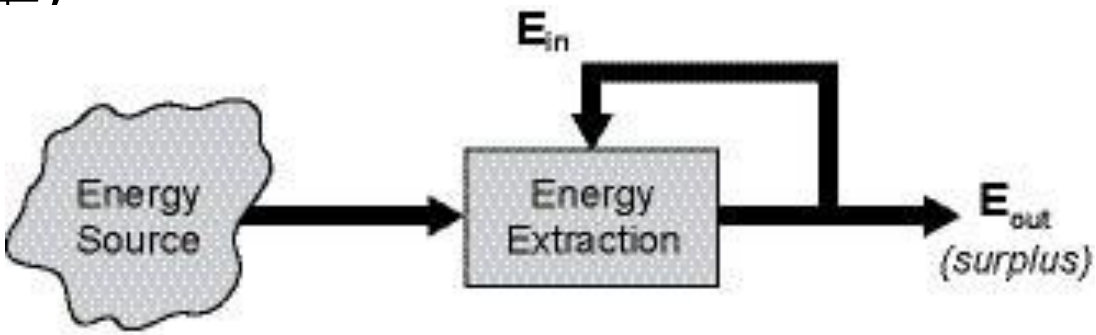
- Energy use per person (每人平均使用的能源) in a country is strongly correlated with GDP per person
- In other words, countries that use more energy are also richer



Energy and EROI

- But perhaps the index of most interest is EROI
- EROI = Energy return on investment (能源投資報酬率)

$$\text{EROI} = \frac{E_{returned}}{E_{invested}}$$



$$\text{Energy Return on Investment (EROI)} = \frac{E_{out}}{E_{in}}$$

www.eroei.com

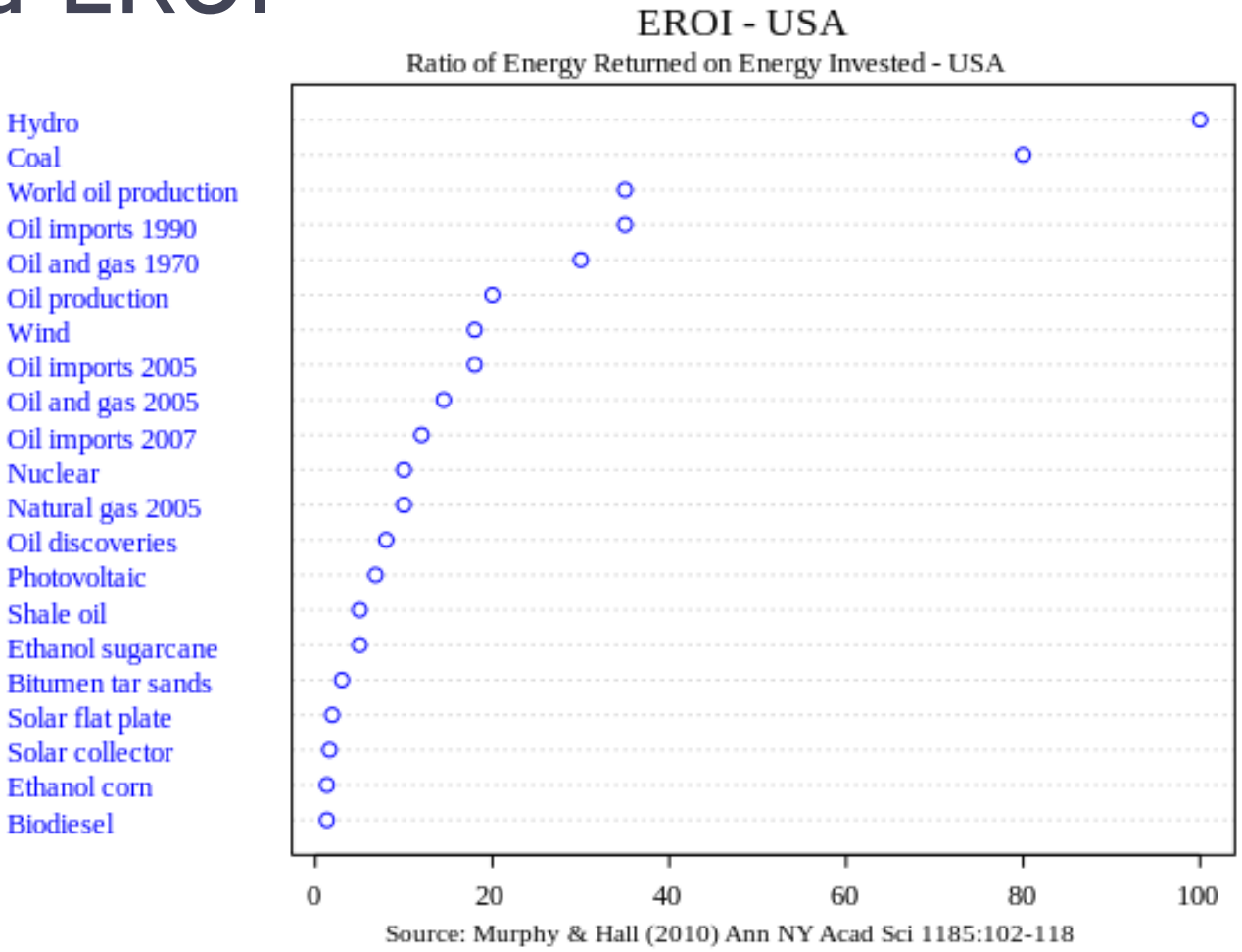
Energy and EROI

- The EROI is a measure of 'net' (淨值) production
- A 'net' value is the comparison between what goes 'in' to making something and what comes 'out'
- EROI is the *Energy*ROI, so units are energy, Joules or Calories
- For example, to get 500 Cal 'out' you must put 100 Cal 'in'
- 500/100 = 5/1 = 5
- The 'net energy' = EROI = 5

$$EROI = \frac{E_{returned}}{E_{invested}}$$

Energy and EROI

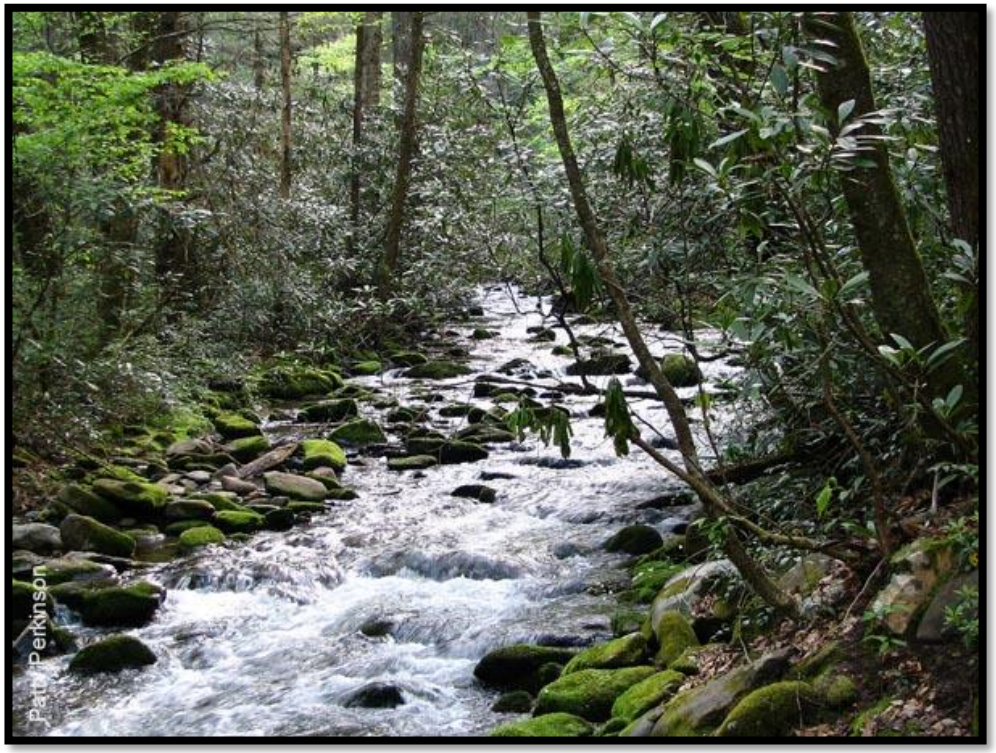
- 'Net' values are very useful for comparing energy sources
- Here is the EROI or 'net energy' for some renewable and non-renewable energy sources



E*m*ergy Accounting

Energy as Value

- We now return to the idea of using *energy* instead of money as a measure of value
- A stream could be valued by its potential energy



Energy as Value

- But is one joule (焦耳) or calorie (卡路里) of stream energy equal to one joule of nuclear energy?
- How about one joule of sunlight energy?

Energy as Value

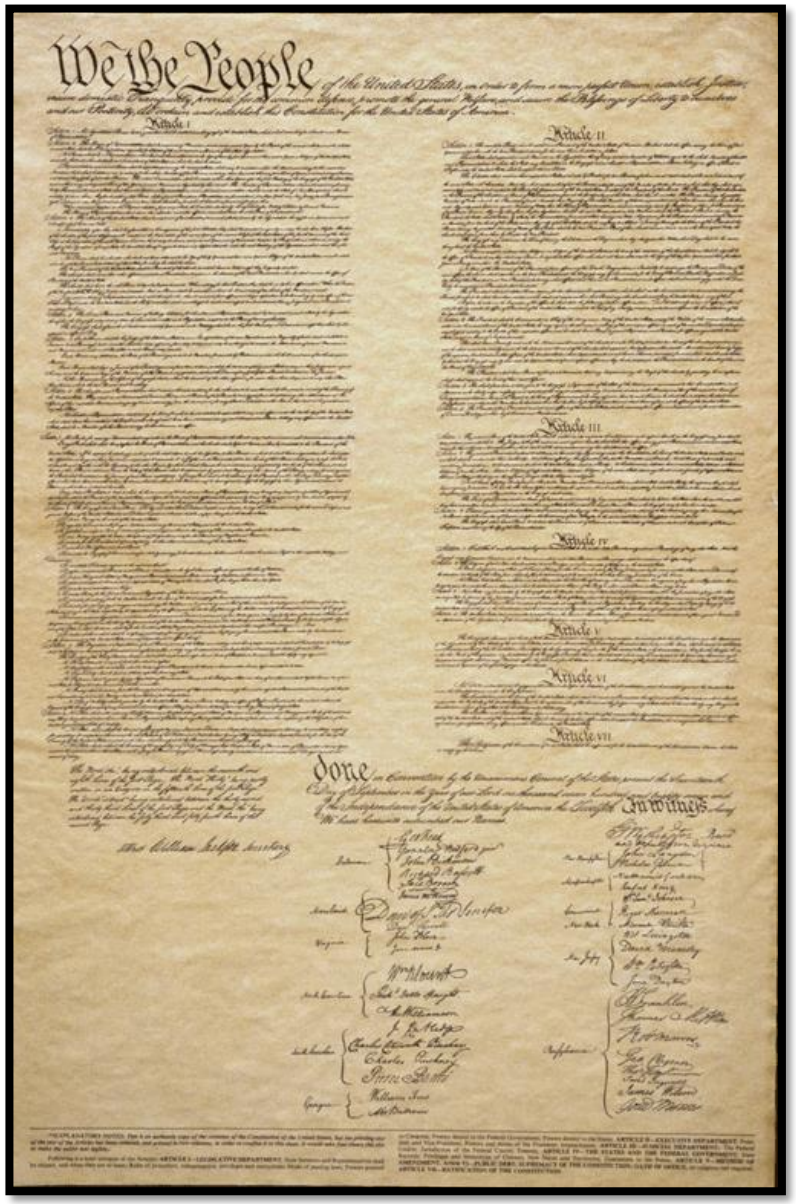
- How about one joule of energy in jet fuel?
- Or one joule of energy in the burning of a log?

Energy as Value

- How about one joule of energy in the sound waves of a speech by U.S. President Obama?

Energy as Value

- How about the energy in a document, like the original U.S. Constitution?
- How about the energy in this ppt?



The Constitution of the United States

Energy as Value

- Obviously a joule of sunlight can do work
- But can it do as much work as a joule of electricity produced in a nuclear power plant and delivered to your house to run your computer to do your homework?

Energy as Value

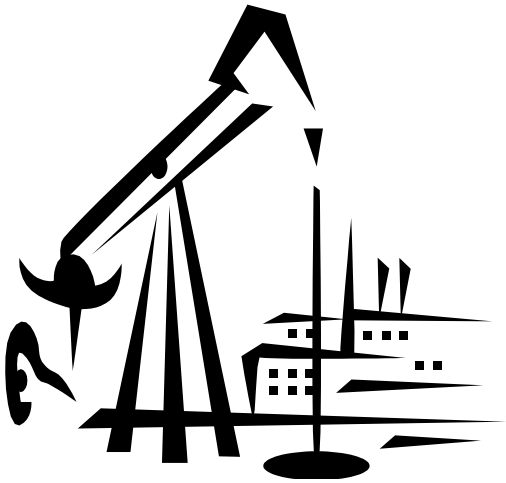
- With 1 million joules of electricity you get…
- One hour of computer use, or…
- One hour of sunlight on this small garden
- Are they equivalent?

Energy Quality (能量的質)

- Energy Quality
- Many researchers believe that they are not equivalent, for two reasons:
- They argue that energy forms differ in their ability to cause work
- Which is directly related to the work that went into making them

Energy Quality

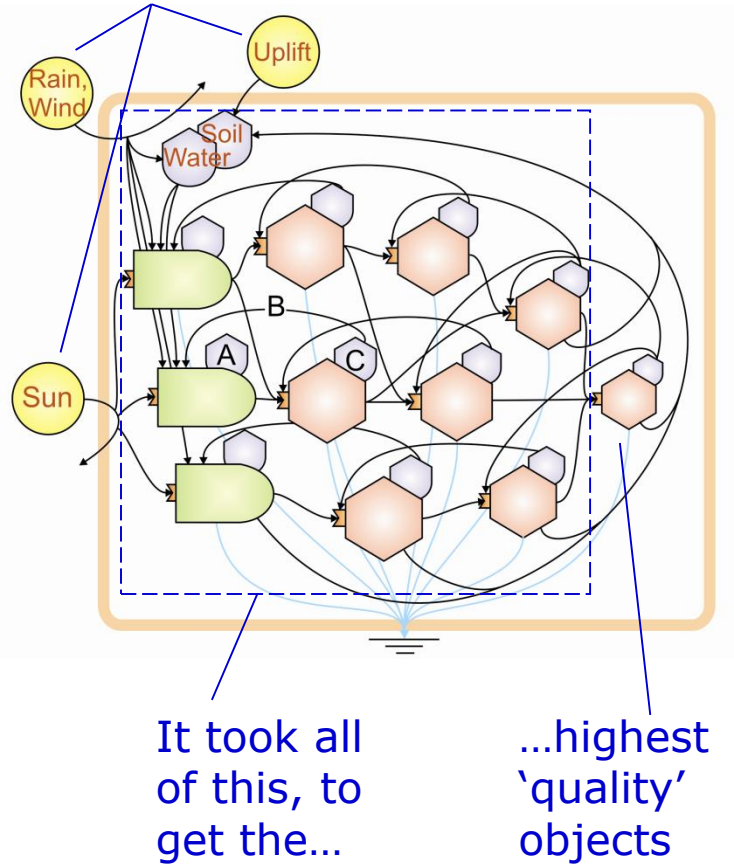
- Different energies are different in ‘Quality’
- Energy Quality is related to…
  - Concentration (濃度)
  - Flexibility (可撓性)
  - Ease of transportation (運送的方便性)
  - Convertibility (可轉換性)



Oil is highly concentrated in the ground, it is flexible in its many uses, it is easy to transport by pipeline or ship, and it can be converted into many forms of work

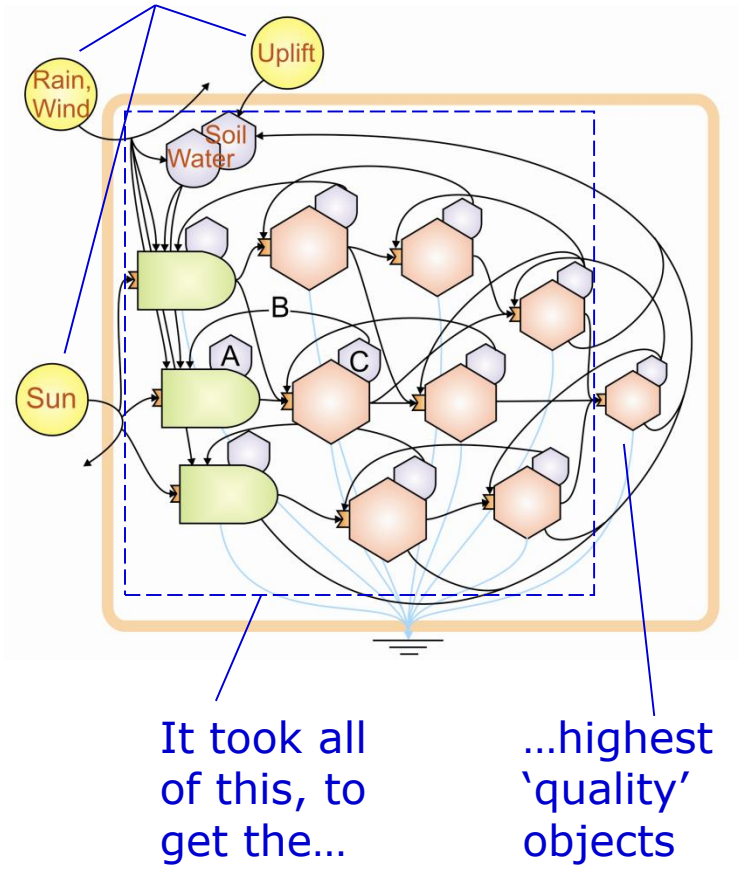
Energy Quality

- And these are related to the work that was needed to make the energy object
- As we know, objects to the right in a hierarchy required all the work to the left of it



Energy Quality

- That work concentrated the original ‘sources’ of sunlight, deep heat, and lunar gravity
- The product is something completely different: a lion, a human city, a first copy of a Shakespeare play



Energy Quality

- By this approach, ‘information’ (訊息) (like the Shakespeare play) is the highest quality energy in human society
- The concept of quality required a new concept of energy, it required ‘e*m*ergy’

Emergy

- Emergy: the total energy that it took to make any other form of energy, good, or service

- The name emergy comes from….
- ENERGY MEMORY

- Emergy values ‘remember’ all the energy work that went into making a new form of energy, good, or service

Measuring ‘Quality’

- In this brand of ecological-economics, energy values are converted to ‘emergy’ values
- Researchers have compiled tables of conversion factors (變換因素) for hundreds of important objects
- The conversion factors are called ‘transformities’

Energy (J) * Transformity (sej/J) = Emergy (sej)

Measuring ‘Quality’

Solar transformities

	Solar emjoules per Joule (sej/J)
Sunlight	1
Plant production	6,700
Wood	36,000
Coal	67,000
Oil	90,000
Electricity	300,000

Typical Solar Transformities

Measuring ‘Quality’

- With these conversion factors, any process can now be evaluated to achieve a new measure of the product’s *value*

Measuring ‘Quality’

- Emergy *inputs* to a process are simply added together to get the value of the product in the emergy currency (sej)
- Unlike energy measurements (joules, calories), with emergy (sej) any objects can be directly compared

Measuring 'Quality'

Household Emergy Inputs

	Item	Unit	Data (units/yr)	Unit Solar EMERGY* (sej/unit)	Solar EMERGY (E13 ej/yr)	Em$ Value ($/yr)
Household/Facility Operational Inputs						
11	Electricity	J	4.93E+09	269,000	133	524
12	Propane	J	1.83E+09	110,000	20	80
13	Water	J	2.71E+07	250,320	1	3
14	Food	J	1.15E+07	3.36E+06	4	15
15	Goods	$	1,370	1.10E+12	151	596
16	Healthcare	$	274	1.10E+12	30	119
	Sum of household operational inputs				**338**	**1,337**

Compare Electricity to Healthcare

Add emergy values together

Emergy

- Units of EMERGY…
  - Solar emergy joules…
  - or Solar emjoules…
  - or “sej”

Emergy Measure of Value

- Market values are poor measures of real wealth
- Market prices are effected by scarcity (罕見性)
- When environmental resources are abundant then prices are low
- But this is backwards
- When the contribution of real wealth to the economy is greatest, that is when living standards are highest
- I.e., things are good when there are many natural resources!

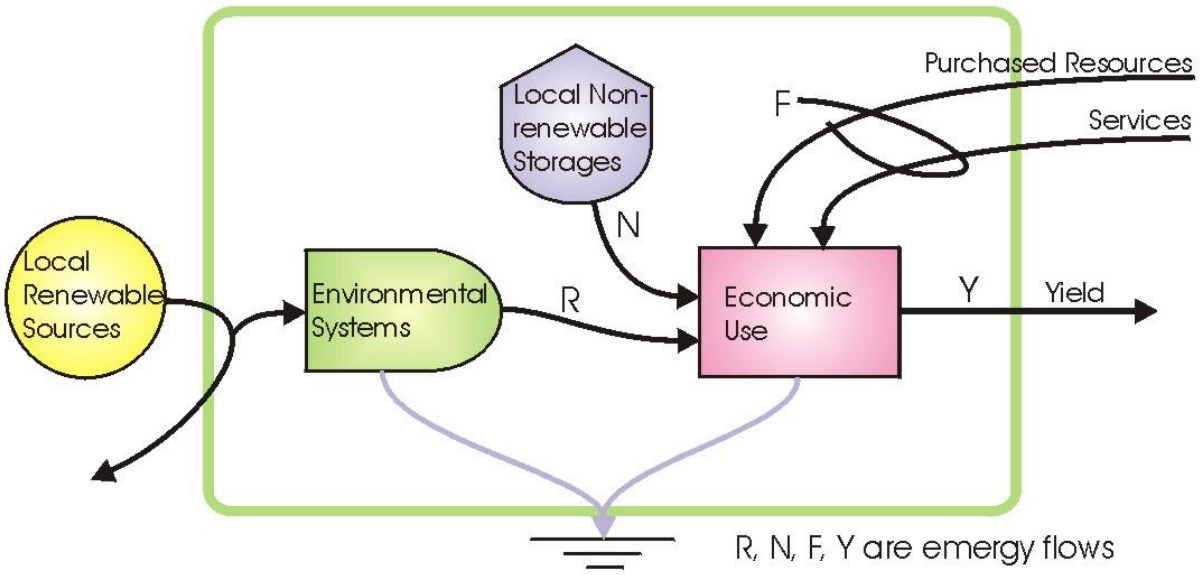
Living standards high
Optimism of 1950s

Emergy Measure of Value

- Market values are poor measures of real wealth
- When resources are scarce, the market puts a higher 'value' on a product (higher price)
- But with less natural resources there is less real wealth in the economy, fewer things are produced, and less work gets done
- Market values are inverse to real wealth contributions

Emergy Measure of Value

- There are better ways to judge the contribution of a flow or process to an economy
- Emergy 'indices' give valuable information



Yield (Y) = R+N+F
%Renew = R/(R+N+F)
Emergy Yield Ratio = Y/F
Environmental Loading Ratio = (F+N)/R

Emergy Indices

Emergy Indices

Index	How Calculate	What is it for?
EYR – Emergy Yield Ratio (Net Emergy)	Y/F	Can the product drive other processes or even the whole economy (use for fuel comparisons) – does it have a "net emergy"?
ELR – Environmental Loading Ratio	(F+N)/R	How much pull or pressure is there on matching renewable resources? (from the point of view of environmentalists)
Empower Density	U/Area	Another measure of development intensity (like ELR). This is total emergy flow, divided by area—therefore, the "density" of emergy flow
% Renew	R/(R+N+F)	How sustainable is a process? High percent means more sustainable in the long run, when non-renewables are depleted
EIR – Emergy Investment Ratio	F/(R+N)	How much had to be "invested" from the bigger scale to attract (capture) the environmental resources? (from the point of view of economic developers)
Emergy per Person	U/Person	This is a measure of personal wellbeing. Higher emergy per person means the person is receiving a greater flow of real wealth, or is able to do real work.

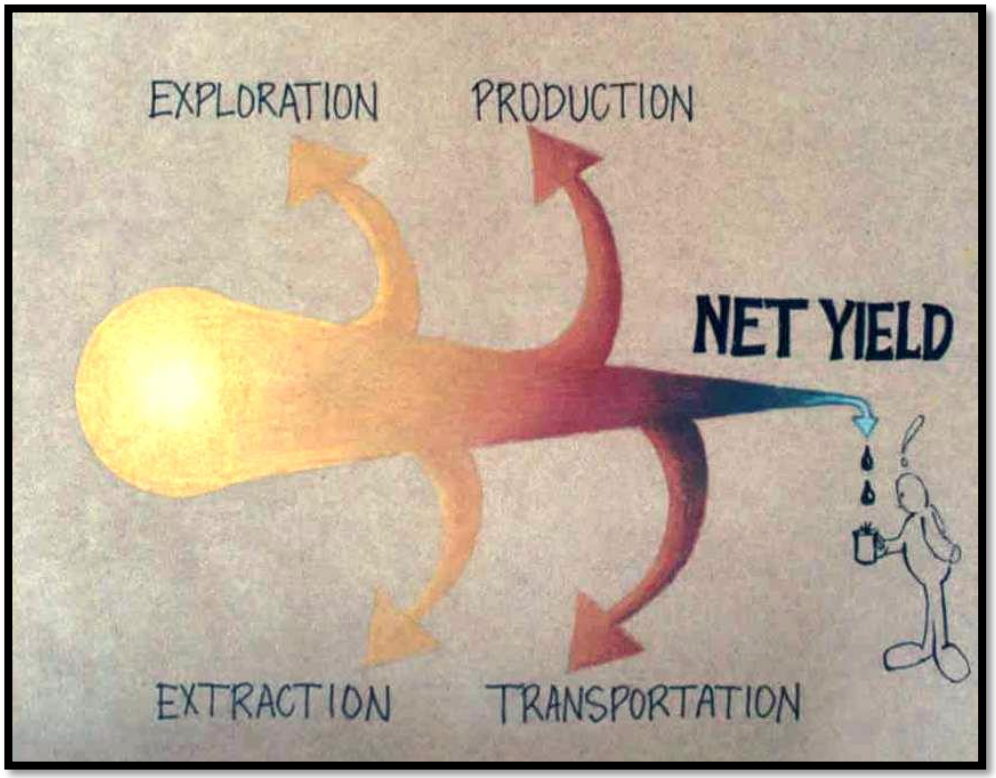
Emergy Yield Ratio (EYR)

- The emergy yield ratio (EYR) (能値產出率) is another measure of *net* (淨值) production
- The EYR compares the output against the input
- This is the same as EROI, but using e*m*ergy, not energy
- It is therefore sometimes also called 'net emergy' (淨能值)

$$EYR = \frac{Em_{returned}}{Em_{invested}}$$

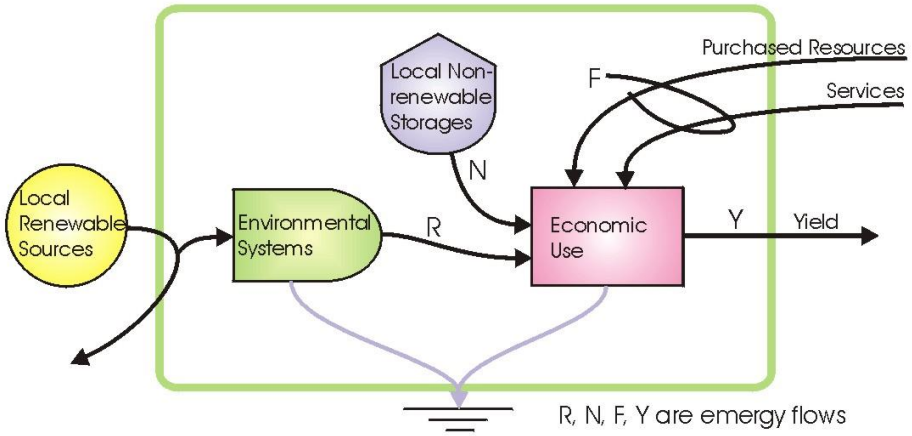
Emergy Yield Ratio (EYR)

- To get emergy output you must invest work – equipment, mining, pumping, transporting, storing, refining, research, new technologies, labor, educating technicians and researchers, etc.
- 'Net' measurements compare the output against the input



Emergy Yield Ratio (EYR)

- Just like EROI, the EYR is very valuable for evaluating and comparing fuels (oil, coal, solar, etc)
- Fuel sources must support the rest of the economy and so their *net* yields (淨產出) must be high (4-10)
- Fuels are a stimulus to the entire economy



Yield (Y) = R+N+F
%Renew = R/(R+N+F)
Emergy Yield Ratio = Y/F
Environmental Loading Ratio = (F+N)/R

Emergy Yield Ratio (EYR)

- Here are some EYR comparisons of energy sources

Item	*Emergy Yield Ratio*
Dependent Sources, No Net Emergy Yield:	
Farm windmill, 17 mph wind	0.03
Solar water heater	0.18
Solar voltaic cell electricity	0.41
Fuels, Yielding Net Emergy:	
Palm oil	1.06
Energy intensive corn	1.10
Sugarcane alcohol	1.14
Plantation wood	2.1
Lignite at mine	6.8
Natural gas, offshore	6.8
Oil, Mideast purchase	8.4
Natural gas, onshore	10.3
Coal, Wyoming	10.5
Oil, Alaska	11.1
Rainforest wood, 100 years growth	12.0

Coal

Emergy Yield Ratio (EYR)

- Here are some comparisons of EYR of electricity
- While geothermal and hydro electricity have high net yields, they are extremely limited in their locations on Earth

Hydro-electric power, Taiwan

Electricity Production

Item	*Emergy Yield Ratio*
Sources of Electric Power, Yielding Net Emergy:	
Ocean-thermal power plant	1.5
Wind electro-power, strong steady wind regime	2–?
Coal-fired power plant	2.5
Rainforest wood power plant	3.6
Nuclear electricity	4.5
Hydroelectricity, mountain watershed	10.0
Geothermal electric plant, volcanic area	13.0
Tidal electric, 25 ft tidal range	15.0

Coal-fired Power Plant

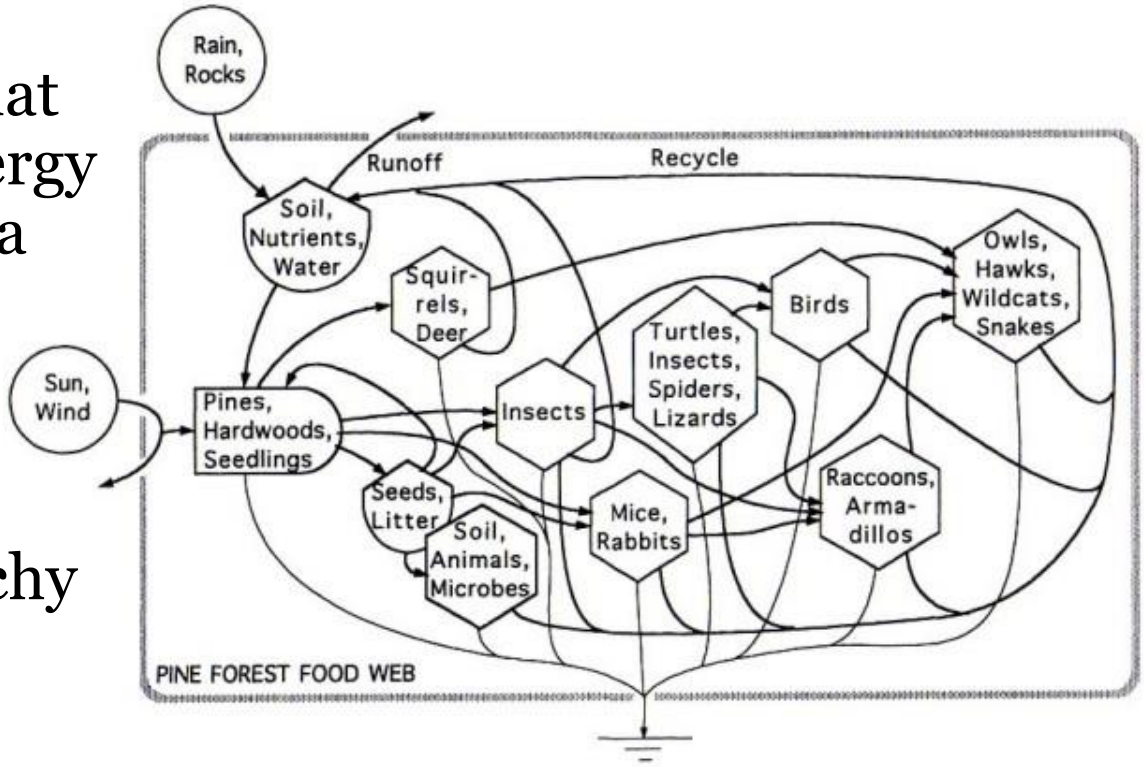
Emergy Accounting

- Unlike the footprint concept, emergy includes the “memory” of past and present resources
- This gives energy such as coal energy a much higher “weighted” value because of the great ecosystem work and geologic work that long ago contributed to its formation

Fossil fuels represent vast quantities of ancient solar energy

Emergy Accounting

- This also gives energy, such as that in beef, or the energy of human action, a higher 'weighted" value because it incorporates the position in the ecosystem hierarchy of cows or people and the greater energy that was required to support them



Making Noodles:
An Emergy Example

Making Noodles: An Emergy Example

- Imagine that you are making some noodles for dinner
- What did it take to make those noodles

Making Noodles: An Emergy Example

- It took the energy of sunlight shining on seedlings of wheat in some far away field

Wheat field

Making Noodles: An Emergy Example

- It took tractors and trucks to move that wheat, and factories to grind and process it

Processing wheat

Making Noodles: An Emergy Example

- But tractors, trucks and factories require fuels
- Fossil fuels required millions of years of ancient ecosystem production
- Followed by geologic work, and much later…

How many dinosaurs went into your bowl of noodles??

Making Noodles: An Emergy Example

- …by the drilling, extraction and refining of oil into gasoline and other fuels

…and more work…

Making Noodles: An Emergy Example

- Finally, the cooking of your noodles required still more fossil fuels…and so more ancient ecosystem production, mining, refining, etc.

Yum, let's eat!

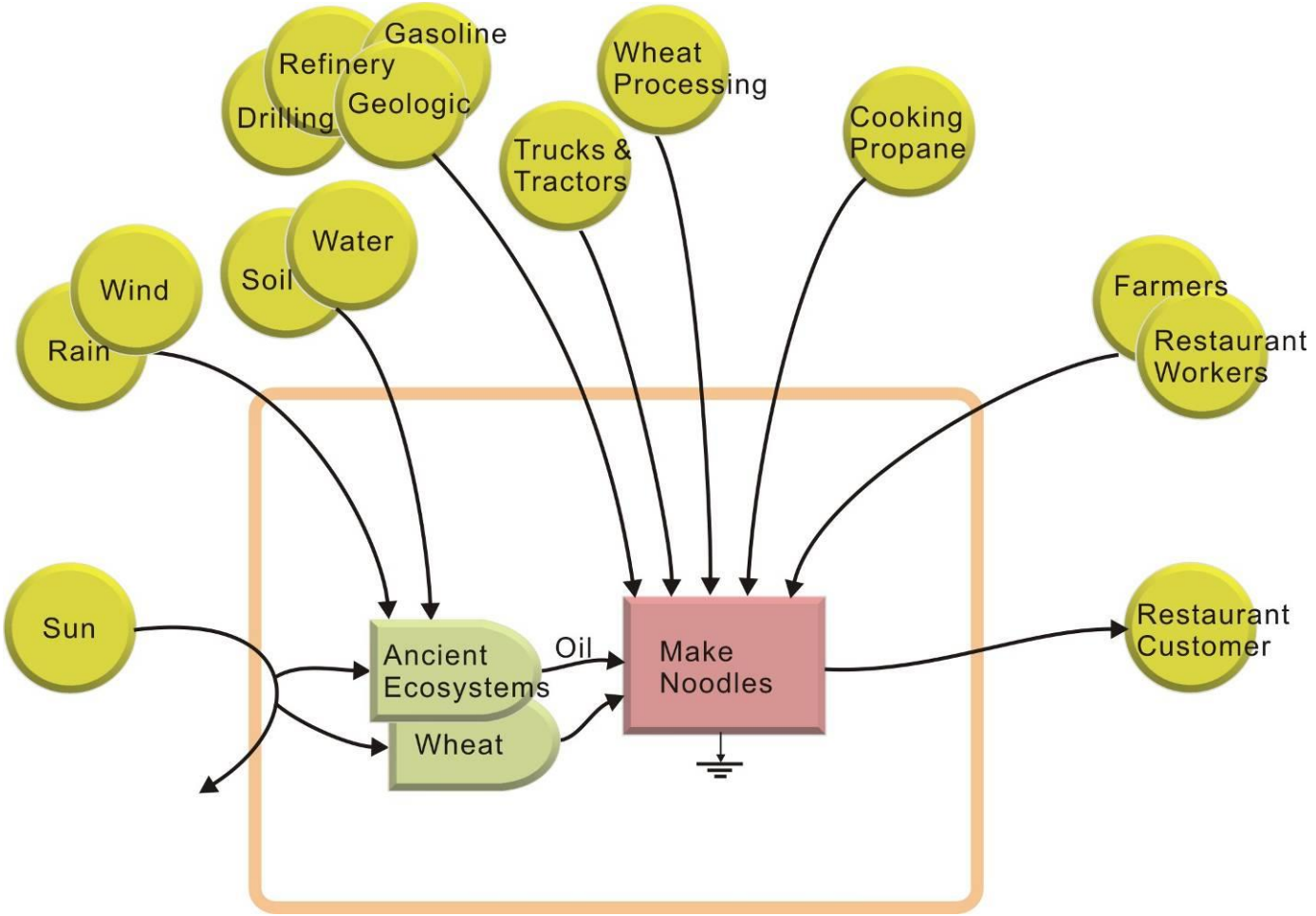
Making Noodles: An Emergy Example

- This process is repeated countless times daily across Taiwan, and elsewhere

Making Noodles: An Emergy Example

- Today, in this place and time, these are the necessary inputs to the creation of your bowl of noodles
- These inputs may only be properly accounted and compared with ‘emergy’ (or some other currency of ecological economics)

Making Noodles: An Emergy Example



Ecological Economics

- We now, hopefully, have a better way to judge the vital energy sources that power our modern world
- Energy is not simply about Dollars or Yen or Euros
- Energy supplies must be rich enough to support all the work done in society
- We will next look at the many energy options
- Next week!

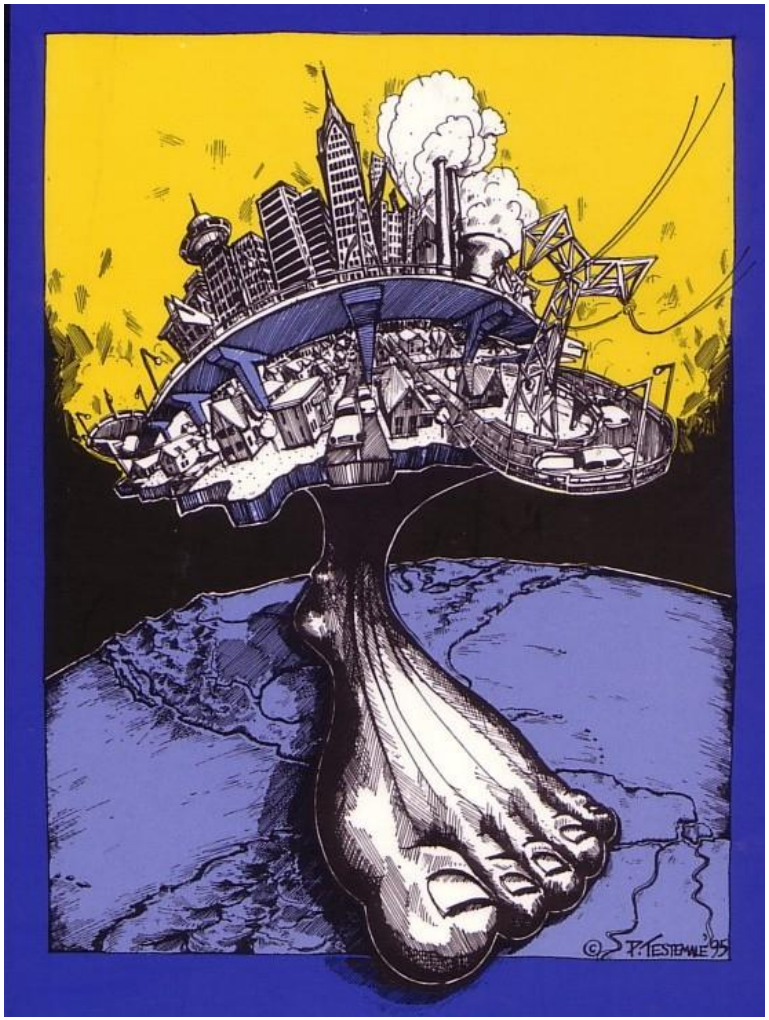
Appendices
(not required)

Ecological Economics

Comparisons and Evaluations

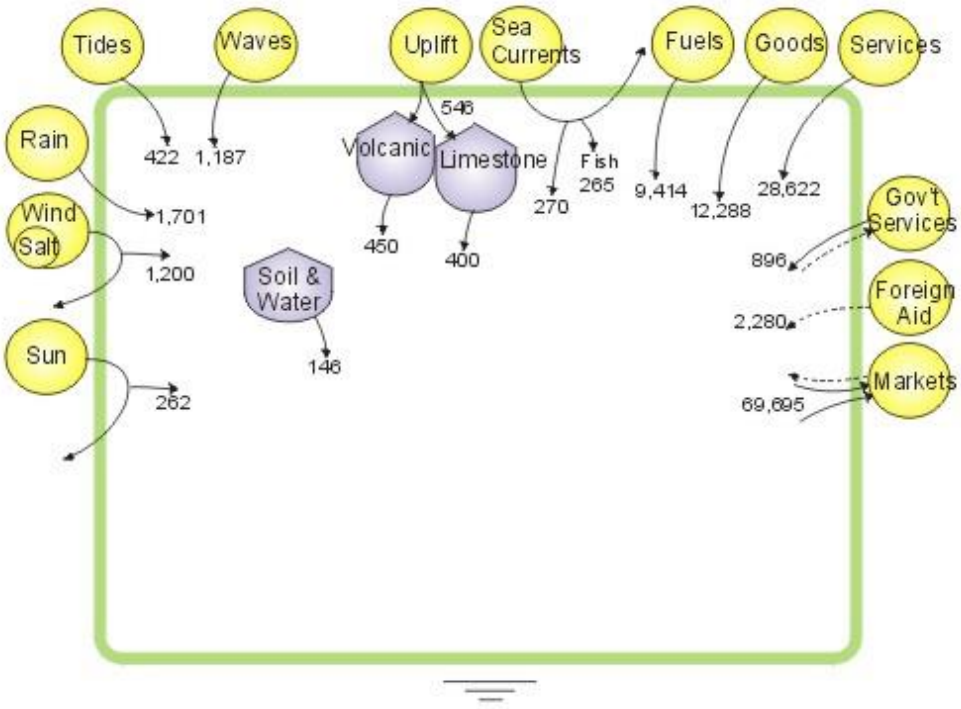
Ecological Footprint – W&R

- Land-area-based calculation of resource use
- A heuristic device – good for teaching about resource use by modern economies



Emergy Accounting - Odum

- Emergy is "energy memory"
- Emergy is the available energy of one kind previously used up directly or indirectly to make a service or product
- It puts all input energies and materials into the single emergy currency – measured in solar emjoules (sej)
- This makes all flows comparable



Sources and storages that support an economy

Exergy Economics

- Exergy is “available energy” – potential energy capable of doing work and being degraded in the process
- It is used to distinguish energy that is available to do work from the total inflows of energy (such as from the sun)
- It does not include transformity and thus the idea of energy ‘quality’ and hierarchy
- Goran Wall, Italians, Swedish?

Wood has exergy in its chemical bonds

Socio-Economic Metabolism

- Human Appropriation of Net Primary Production (HANPP)
- They are most concerned with reducing human impacts on ecosystems
- These questions are asked:
  - On a given territory, how much energy is diverted by humans as compared with the energy potential available?
  - How strongly does human use of a defined area affect its primary productivity?
  - How much of the NPP is harvested by humans and therefore not available for non-human processes?

Socio-Economic Metabolism

- NPP is the amount of energy yearly available as an energy input to all food chains.
- HANPP is a way to asses the effect of human land use on the availability of biomass energy in ecosystems. It measures:
  - Changes in productivity induced by human land use; e.g. impacts on NPP of the conversion of natural ecosystems to agro-ecosystems or other kinds of land cover
  - The reduction of energy availability in ecosystems caused by human harvest of biomass

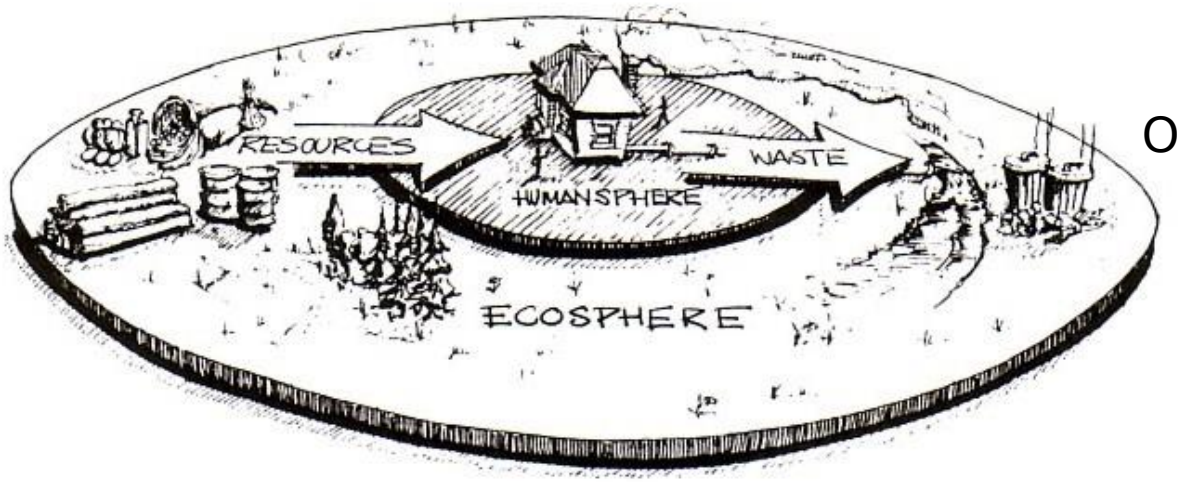
Socio-Economic Metabolism

- Socioeconomic metabolism is an analogy of biological metabolism
- It describes physical exchange processes (material and energy flows) between human societies and their natural environment, and also internal material and energy flows of human societies
- Socioeconomic systems are conceived as systems dependent upon a *continuous throughput* of material and energy
- Socioeconomic systems extract raw materials from their natural environment and transform them as part of the economic process

Socio-Economic Metabolism

- Materials are accumulated for certain periods of time (forming material stocks) or they are more or less quickly released into ecosystems as wastes and emissions
- It addresses two sustainability problems:
  - Problems occurring on the input side of the socioeconomic system – for example, scarcity of resources
  - Problems occurring on the output side – for example, problems related to pollution or emissions.

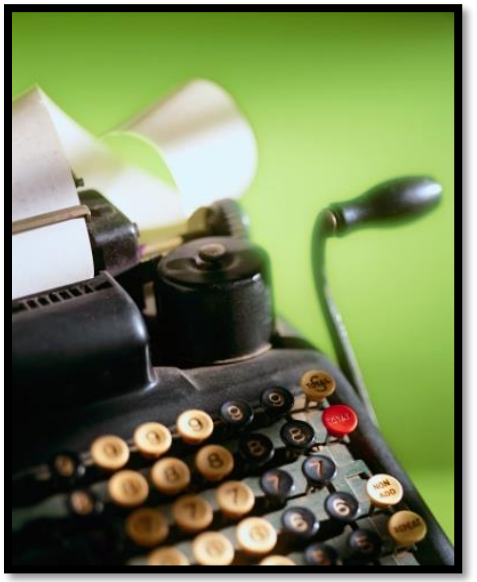
Input



Output

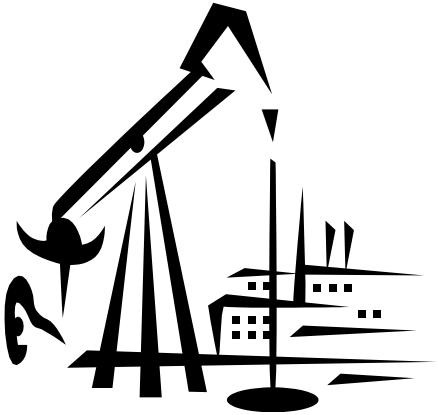
Socio-Economic Metabolism

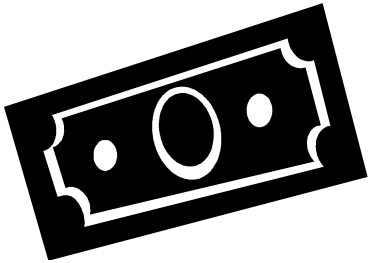
- Material and Energy Flow Accounting (MEFA)
- The "MEFA framework" is an accounting framework of material flow accounting (MFA), energy flow accounting (EFA), and HANPP
- These concepts also do not include transformity and thus the idea of energy hierarchy
- These concepts do not account for the ecosystem energy required for fossil fuel production (like the ecological footprint)
- Fischer-Kowalski, Haberl



Natural Capital and Nature's Services

- Maintaining natural capital stocks by using a natural capital depletion tax
- Valuation of ecosystem services
- Value in economics is an expression of individualistic human preferences
- A biophysical basis for value – in the long run, humans come to value things according to how costly they are to produce
- This cost is ultimately a function of how organized they are relative to their environment (concentrating the resources and assembling the parts)





Natural Capital and Nature's Services

- Discounting is a numerical way to operationalize the value judgment that:
  - The near future is worth more than the distant future to the present generation of humans
- Beyond some point the worth of the future to the present generation of humans is negligible
- Costanza, Daly

Growth rate is 5%, cut 5% each year, or… Cut it, invest the money, make 10%?

Labels

- Here is a list of commonly used labels:
  - Environmental Economics
  - Ecological Economics
  - Energy Economics
  - Green Economics
  - Natural Capital, Nature's Services and Valuation

Environmental Economics

- A subfield of economics
- Concerned with environmental issues
- Uses standard methods of economics – like externalities
- Natural capital?, discounting? – Daly, Costanza

Ecological Economics

- Economics is a subfield of ecology
- Natural capital is undervalued and treated as a factor of production that is interchangeable with labor and technology
- Natural capital? – Daly, Costanza

Energy Economics

- Ecological Footprint
- Emergy accounting
- Socioeconomic metabolism

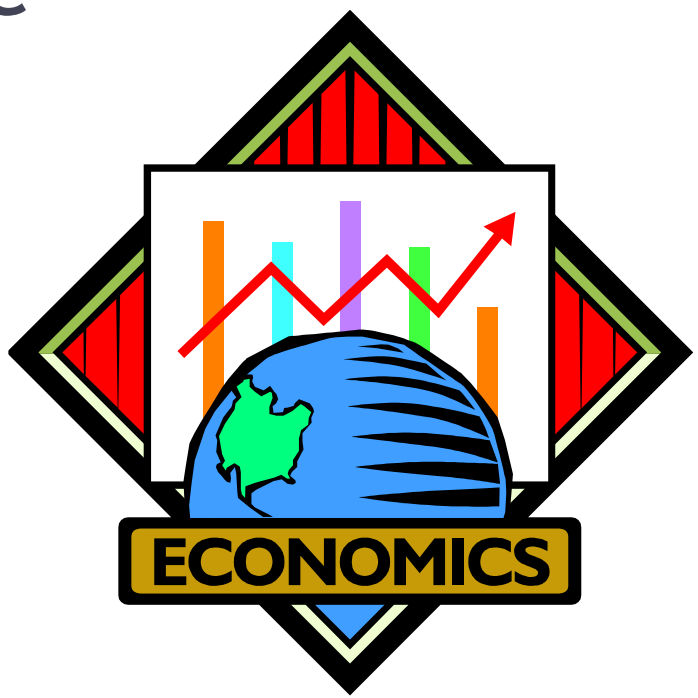
Green Economics

- Like ecological economics, economy is a component of ecosystems
- Holistic and concerned with broader ecological and social concerns, including a distrust of capitalism itself
- Anti-Fordism anti-productivism, anti-growth
- Small is beautiful
- Anti-globalization
- Biodiversity conservation

The Economists’ Game

The Economists' Game

- By using the language, and addressing the issue of "sustainable development", a person is accepting the narrative of economics.
- Economic growth, value, valuation, GNP, commodities, and trade. These are tools that economists use to construct the world in terms of commodities and their exchange in the market.

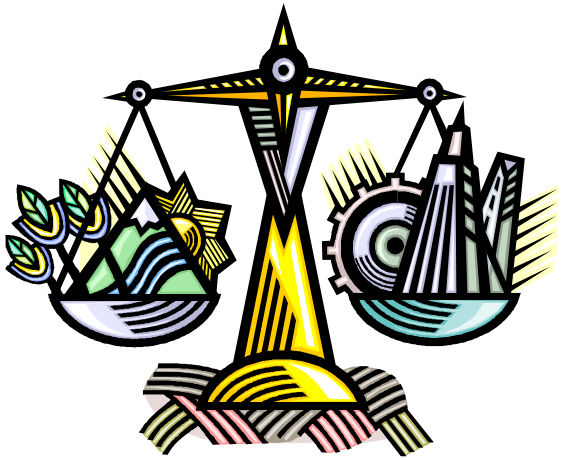


The Economists' Game

- Economic growth is an issue especially of interest to the financiers and money managers who bet on the future "growth" of the economy
  - For them a no-growth world is disaster
- Economic growth is also an issue of dire concern for politicians, who have borrowed a trillion dollars against the future to purchase public infrastructure (construction projects for roads, dams, etc.) and therefore votes
  - For them a no-growth world is also a disaster

The Economists' Game

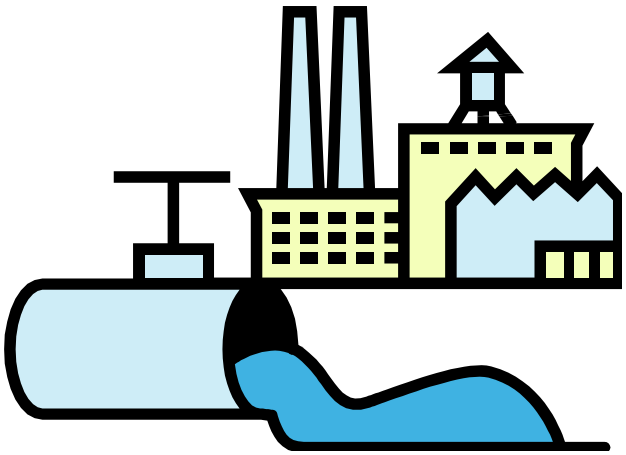
- Many ecologists have chosen to join the economists' game by talking about sustainable development.
- They were stung by the backlash against the Club of Rome, and they are choosing to fight on with the politically correct approach of sustainable development
- But at what cost?
- They must now live in the economists' world where they are novices



Costs and benefits,
Receiver value,
Donor value,
Etc.

The Economists' Game

- They are trapped in the politically conservative discourse formation that gives no role to power and resource control inequality
- They are trapped within the discourse of "exchange" in which all things (including natural resources) are commodities and are substitutable



The Economists' Game

- The result can be less than satisfactory
- We will consider these issues further when we look at NGOs and the Environmental Movements in the world in a couple weeks