Emergy & Environmental Accounting

OSU~EmEA-1

Integrating Biophysical & Economic Values:

The Emerging Discipline of Emergy Analysis

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Organization...

1. Systems of Value
2. Brief Overview of Emergy Accounting

Economic Value...

An economic value is the worth of a good or service as determined by the market

In neoclassical economics, the value of an object or service is often seen as the price it would bring in an open and competitive market....

....a utility theory of value

What we might call....

"Receiver" Value System

Natural Price...

Adam Smith introduced the concept of "natural price",

...The real price of every thing, what every thing really costs to the man who wants to acquire it, is the toil and trouble of acquiring it

An Inquiry into the Nature and Causes of the Wealth of Nations

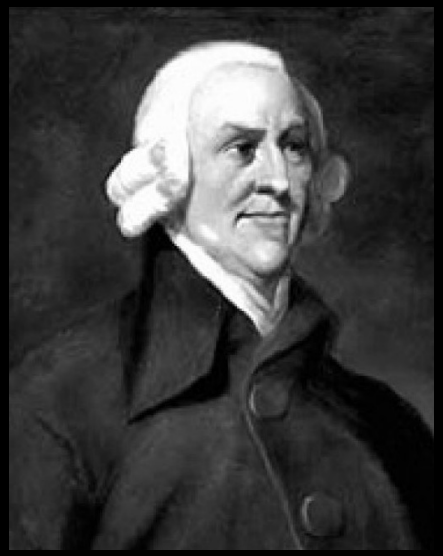
Cost-of-Production...

Cost-of-production - theory of value

Adam Smith's natural prices of commodities are the sum of the natural rates of the factors of production (wages, profits, and rent) that must be paid for inputs into production.

In economics, the cost-of-production theory of value is the theory that the price of an object is determined by the sum of the cost of the resources that went into making it.

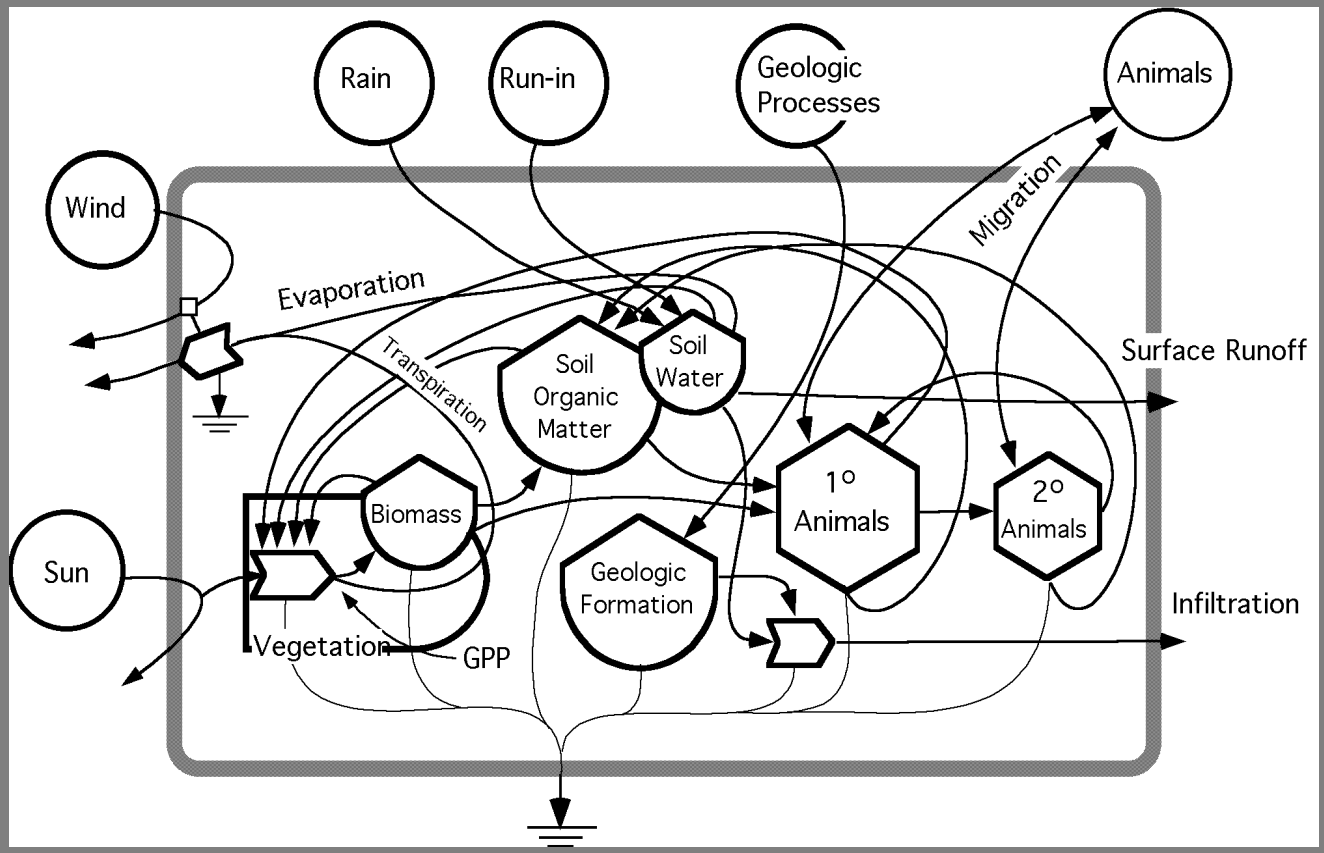
"Donor" Value System



Ecosystem Values...

Ecosystem – Factors of Production

Sunlight, wind, rain, nutrients, CO_2, etc...



Ecosystem Services – Natural Prices

So...if the natural price of ecosystem services is the sum of the natural rates of the factors of production ...

all we need to do is determine the costs of producing the factors of production.

ie... Sunlight, wind, rain, nutrients, etc...

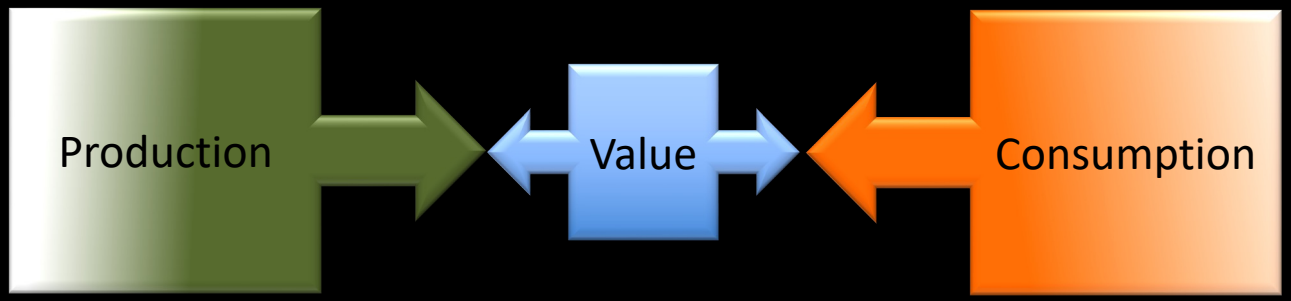
Biophysical VS Economic...

Two Views of Value...

1. Value is derived from what goes into something
2. Value is in the eyes of the beholder

Donor value

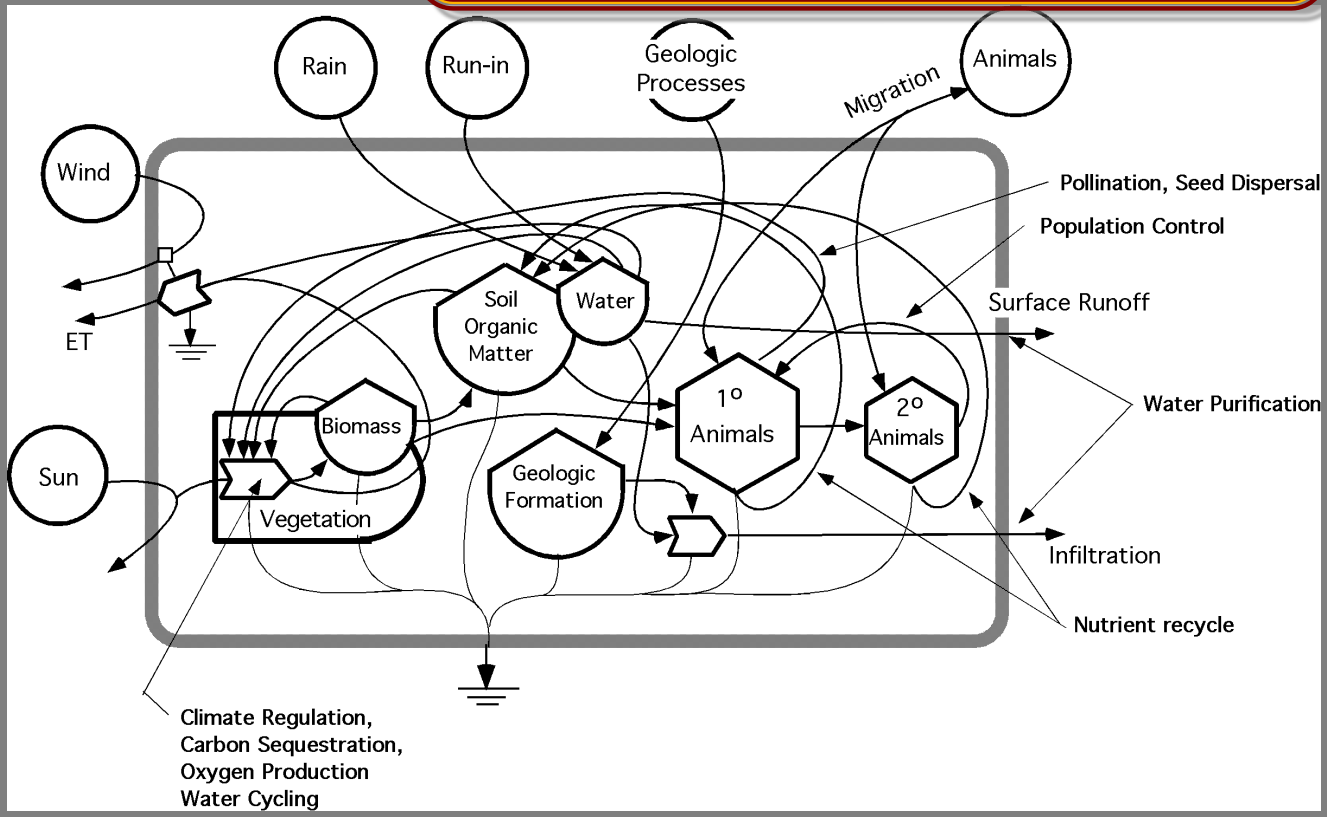
Receiver value



Ecosystem Values...

Ecosystem Services = Factors of Production

The value of Ecosystem Services... what is required to make them



Part 2: Emergy Accounting Methodology

Emergy Accounting...

Ecologists use Energy as the unit of measure for Factors of Production

ENERGY...

The ability to cause work.

Since all energy can be converted 100% to heat, it is convenient to express energy in heat units…btu's calories, joules.

Emergy Accounting...

There are many “forms” of energy….

Sunlight…

Wind…

Geopotential energy of elevated water…

Fuel…

Electricity…

Information...

Energy Accounting...

Not all forms of energy are equivalent...

sunlight ≠ wind ≠ fuels ≠ electricity

While they can all be converted to heat…one cannot say that calories of one form of energy are equal to calories of another form in their ability to cause work...

Energy Quality...

Heat energy in 1 litere crude oil = 3.7E7 J/l = 8.8 E3 Cal/l

Human heat output = 2600 Cal/da

Therefore it takes the output of 3.4 humans per day to equal the heat energy in one liter of crude oil

Emergy Accounting...

The realization that different forms of energy have differing abilities to cause work lead to the concept of Energy Quality

Energy Quality...

- related to concentration.
- flexibility
- ease of transportation
- convertibility

Energy Quality…

- The concept of quality required a new concept of energy.
- A concept of energy that recognized that not all forms of energy have the same qualities
- A quantitative means of measuring quality….

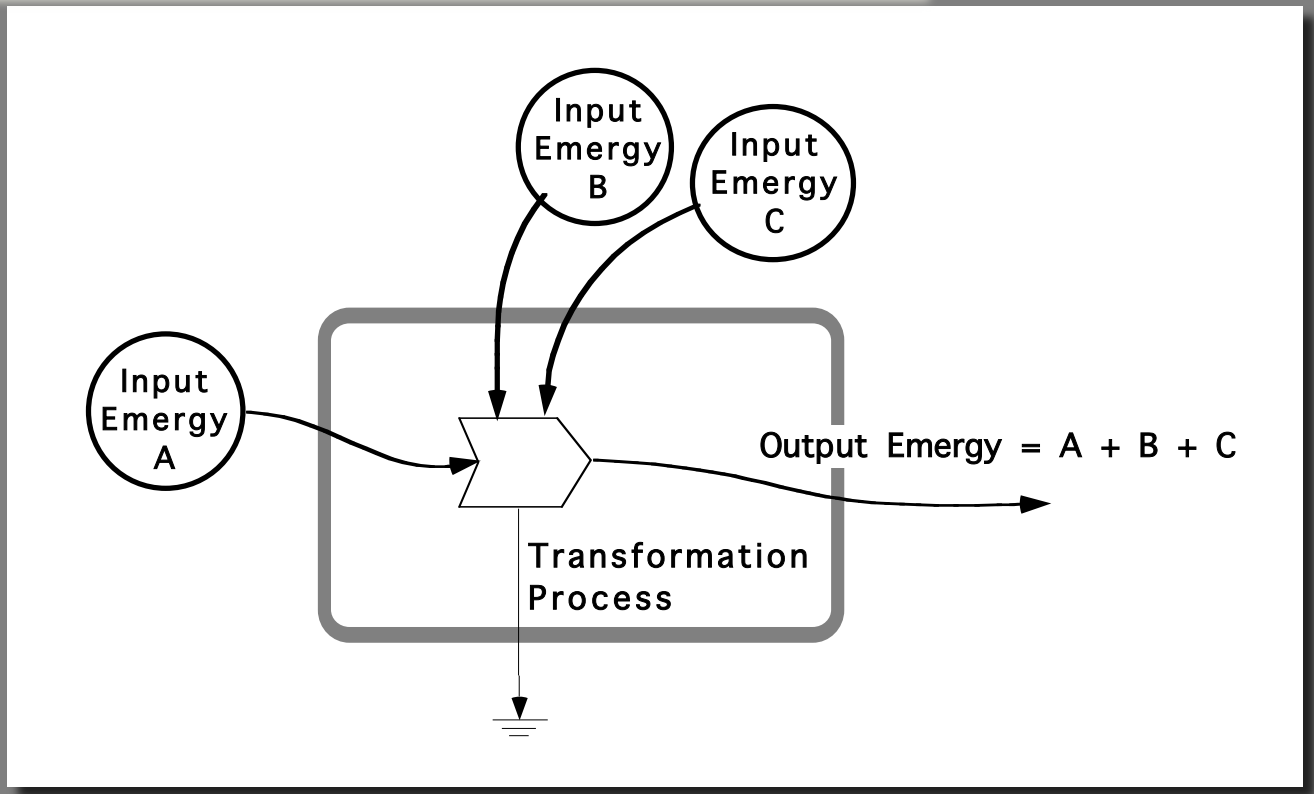
Emergy Accounting...

EMERGY - The available energy required directly and indirectly to make something

- Expressed in energy of the same FORM … usually solar energy
- Sometimes called Energy Memory = Emergy
- Similar to Embodied Energy
- Units = solar emjoules = sej

Emergy Accounting...

EMERGY - The available energy (of one form) required directly and indirectly to make something



Units of EMERGY...

Solar emergy Joules…

or Solar emjoules…

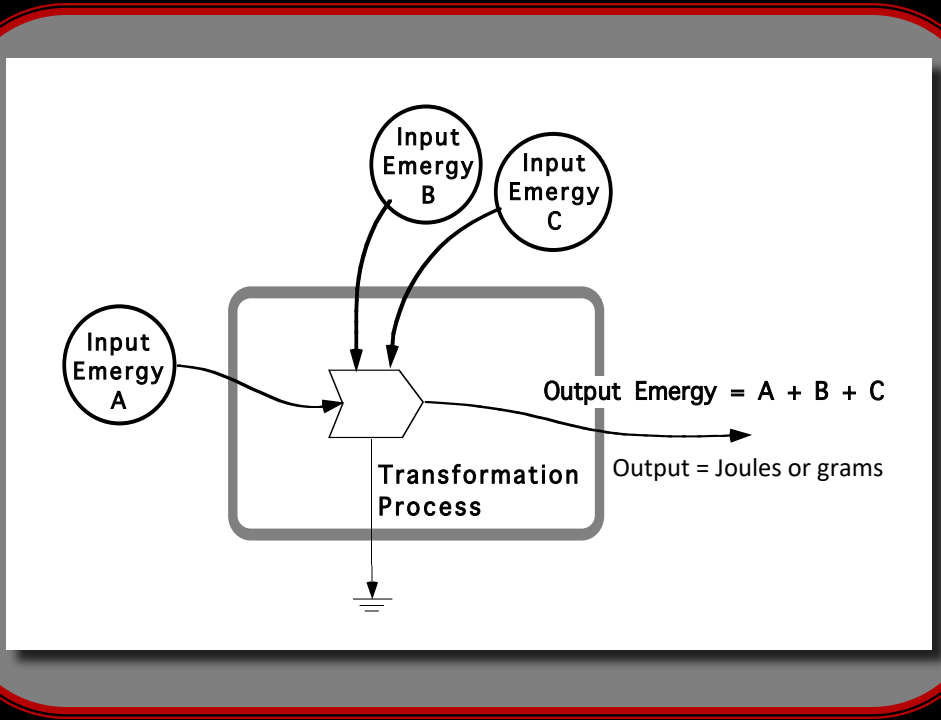
or “sej”

Emergy Accounting...

Unit Emergy Values (UEVs)…

The amount of emergy required to produce a given amount of mass or energy of a product

$$\text{UEV} = \frac{\text{Output in Emergy}}{\text{Output (Joules or grams)}}$$



Emergy Accounting...

Unit Emergy Values…

- If units are sej/J it is called Transformity
- If units are sej/g it is called Specific Emergy
- We also use sej/$

Emergy Accounting...

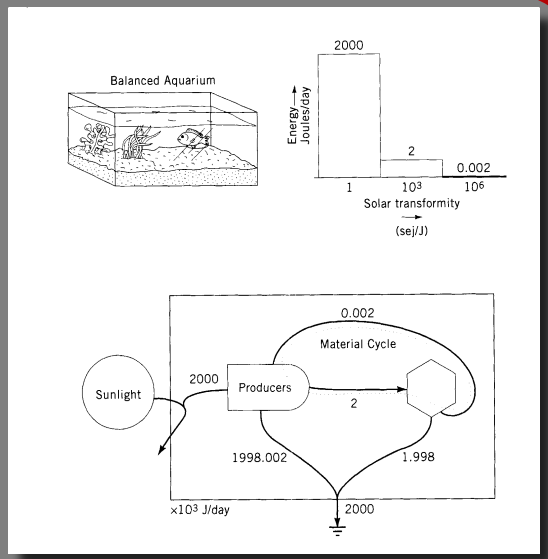
Unit Emergy Values…

Solar transformity of Production =
Solar Emergy / Exergy

Tr_p = 2.0E6sej / 2 J = 1E6 sej/J

Solar transformity of Material Cycle =
Solar Emergy / Exergy

Tr_{mc} = 2.0E6sej / 0.002 J = 1E9 sej/J



Emergy Accounting...

Unit Emergy Values…

Emergy = Exergy * UEV

So by definition the emergy of a flow can be calculated by multiplying the exergy (or mass) of the flow by its UEV

1E 6 grams oil * Sp_{oil} = Emergy in the oil

2E5 joules oil * Tr_{oil} = Emergy in the oil

Emergy Accounting...

Typical Solar Transformities

Solar transformities

	Solar emjoules per Joule (sej/J)
Sunlight	1
Plant production	6,700
Wood	36,000
Coal	97,000
Oil	148,000
Electricity	500,000

Emergy Accounting...

Typical Emergy Evaluation Table

Bioethanol

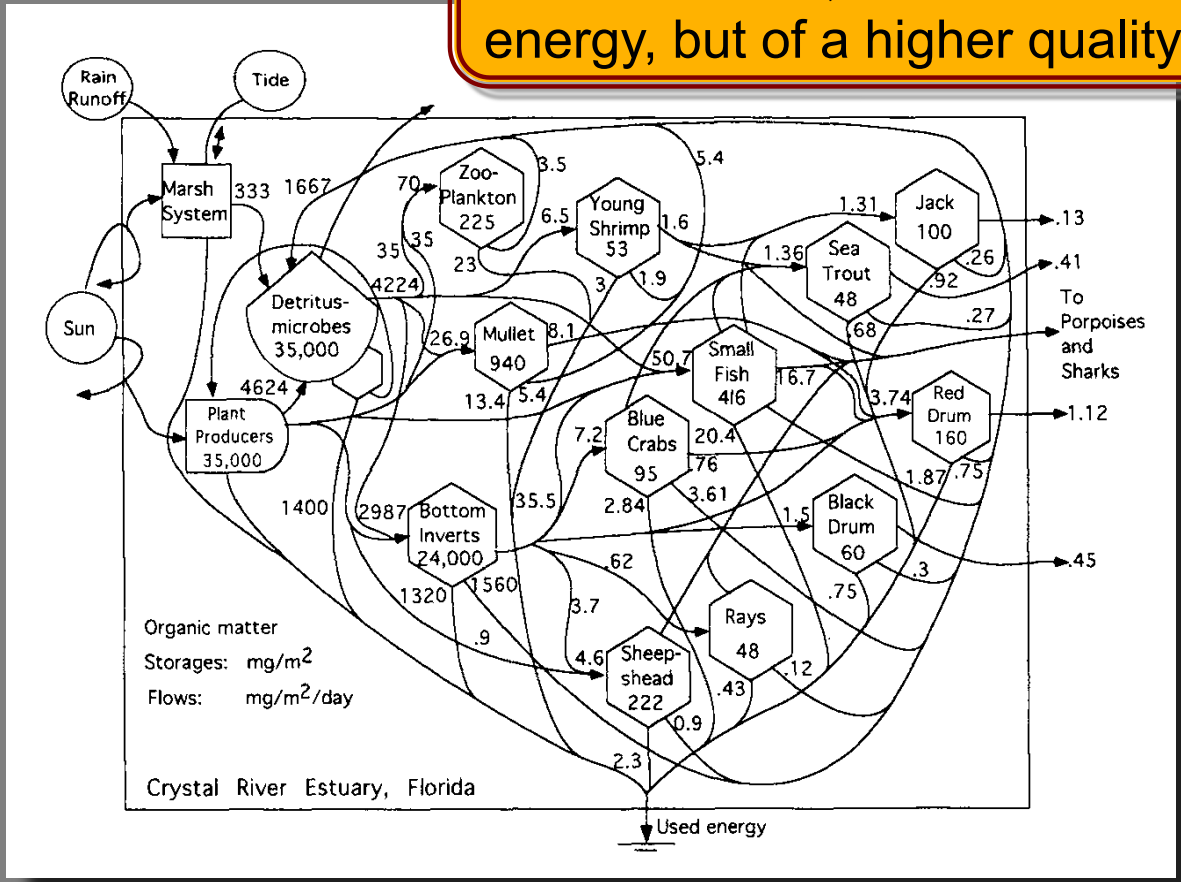
Table 5
Emergy analysis of ethanol production from sugarbeet in Italy (1984 nationwide average values per hectare per year).

#	Item	Unit	Units/ha/yr	Solar transformity (sej/unit)	Ref. for Transf.	Solar emergy (E14 sej/ha/yr)
(numbers of each item refer to footnotes in the Appendix)						
ENVIRONMENTAL INPUTS						
1	Sunlight	J	4.41E+13	1.00E+00	[2]	0.44
2	Rain chemical potential	J	4.45E+10	1.82E+04	[2]	8.09
3	Wind	J	8.82E+10	1.50E+03	[2]	1.32
4	Earth cycle	J	3.00E+10	3.44E+04	[2]	10.32
AGRICULTURAL PRODUCTION PHASE						
5a	Loss topsoil, resid. in field	J	1.36E+10	7.38E+04	[1]	10.01
5b	Loss topsoil, resid.harvested	J	2.71E+10	7.38E+04	[1]	20.02
Inputs assuming that residues are left in field						
6	Nitrogen fertilizer (N)	g	1.36E+05	3.80E+09	[2]	5.17
7	Phosphate fertilizer (P2O5)	g	1.87E+05	3.90E+09	[2]	7.29
8	Potash (K2O)	g	7.28E+04	1.10E+09	[2]	0.80
9	Insecticides & pesticides	g	4.07E+04	1.48E+10	[1]	6.02
10	Herbicides	g	1.52E+04	1.48E+10	[1]	2.25
11	Diesel	J	1.33E+10	6.60E+04	[1]	8.75
12	Lubricants	J	2.53E+08	6.60E+04	[1]	0.17
13	Gasoline	J	4.42E+08	6.60E+04	[1]	0.29
14	Human labor	J	1.26E+08	7.38E+06	[3]	9.27
15	Agric. machinery	g	8.37E+04	6.70E+09	[1]	5.61
16	Electricity	J	5.86E+08	2.00E+05	[1]	1.17
17	Seeds	J	5.58E+07	8.94E+04	[3]	0.05
18a	Surface water for irrigation	J	6.17E+09	4.10E+04	[1]	2.53
18b	Fuel for irrigation (#)	J		6.60E+04	[1]	
Additional inputs if 70% residues are harvested						
19	Nitrogen loss with erosion	g	4.50E+04	3.80E+09	[2]	1.71
20	Phosph. loss with erosion	g	2.25E+04	3.90E+09	[2]	0.88
21	Potash loss with erosion	g	1.50E+05	1.10E+09	[2]	1.65
22a	Additional water demand	J	2.47E+09	4.10E+04	[1]	1.01
22b	Fuel for additional water demand	J	2.39E+09	6.60E+04	[1]	1.57
23	Nitrogen harv. in residues	g	3.50E+04	3.80E+09	[2]	1.33
24	Phosphorus harv. in resid.	g	2.10E+04	3.90E+09	[2]	0.82
25	Potash harv. in residues.	g	1.40E+05	1.10E+09	[2]	1.54
26	Diesel for residues	J	2.23E+09	6.60E+04	[1]	1.47
27	Labor for residues	J	4.38E+06	7.38E+06	[3]	0.32
28	Machinery for residues	g	2.46E+03	6.70E+09	[1]	0.16
Products of the agricultural phase						
29	Sugarbeet produced	J	1.14E+11	6.14E+04		69.70
30	Sugar available in sugarbeet	J	1.05E+11	6.66E+04		69.70
31	Residues in field as such (°)	J	4.67E+10	1.49E+05		69.70
32	70% harvested agric. resid. (°)	J	n.a.	n.a.		92.19
INDUSTRIAL PRODUCTION PHASE						
33	Plant machinery	g	7.24E+03	6.70E+09	[1]	0.48
34	Diesel for transport	J	1.77E+09	6.60E+04	[1]	1.17
35	Diesel for process heat	J	3.72E+10	6.60E+04	[1]	24.58
36	Electricity	J	1.87E+10	2.00E+05	[1]	37.49
Product of industrial phase						
37a	Ethanol, without residues	J	9.42E+10	1.42E+05		133.42
37b	Ethanol, with residues use	J	9.42E+10	1.65E+05		155.91

Biophysical Values...

Food web

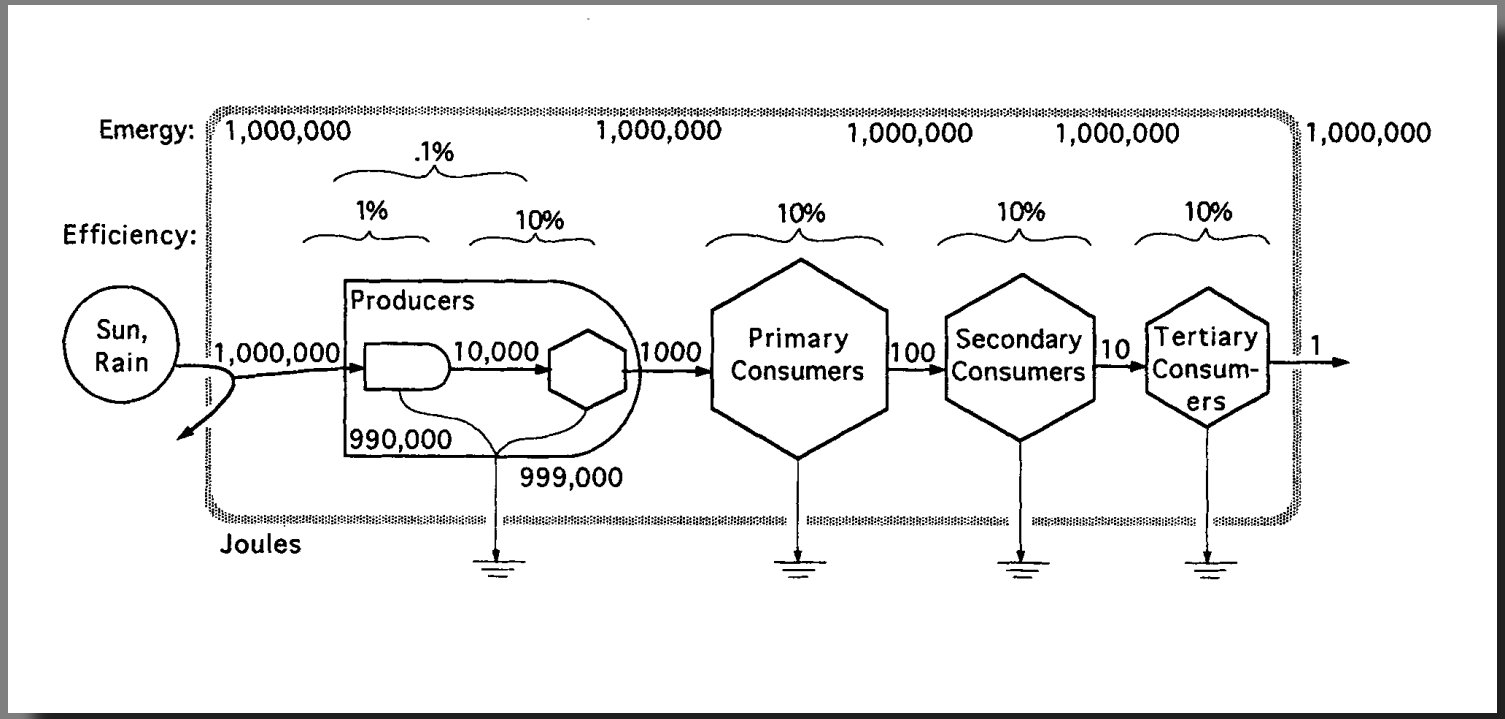
…with each successive energy transformation, there is less energy, but of a higher quality



Biophysical Values...

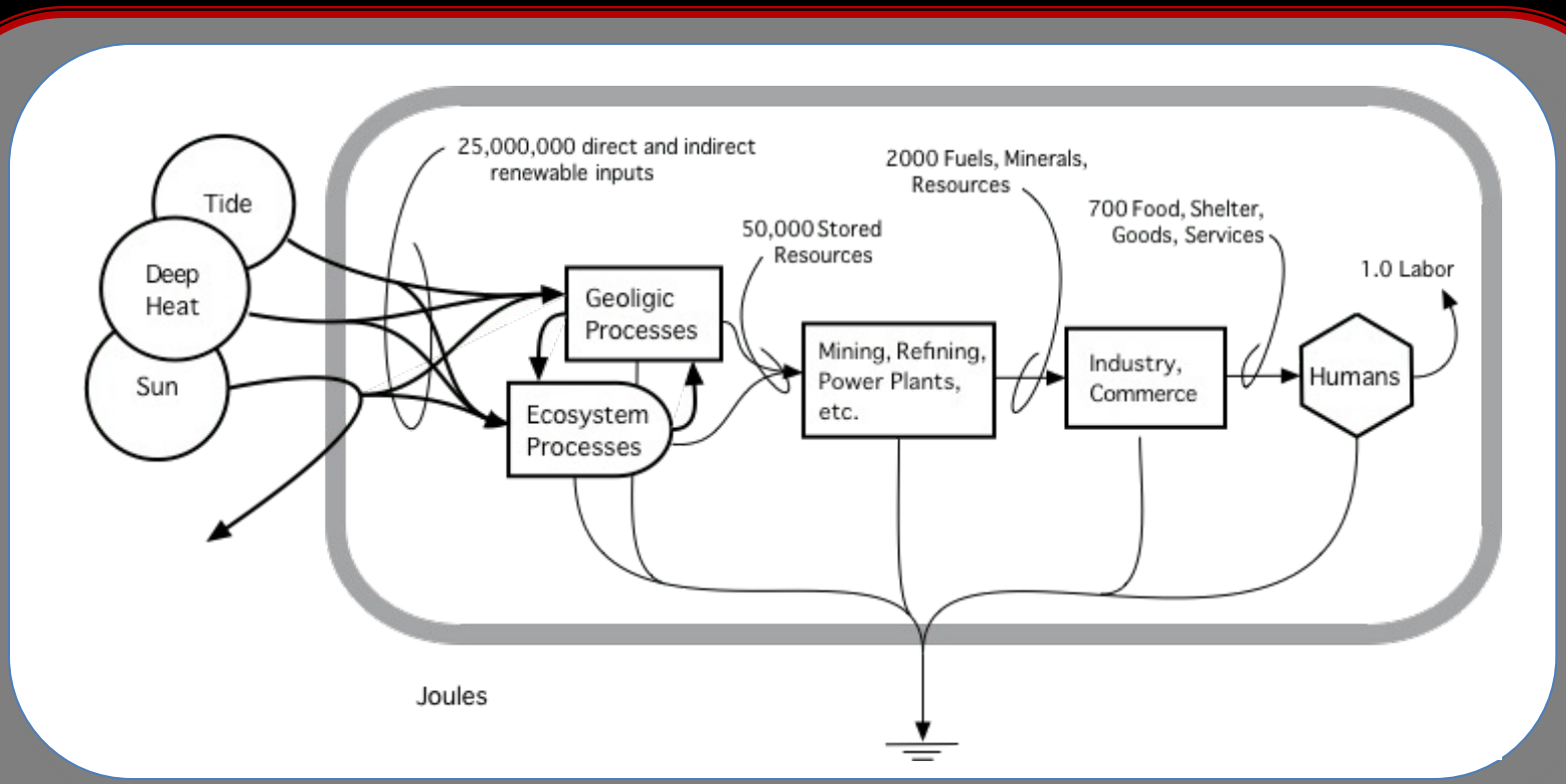
Energy Chain

The food chain can be thought of as an energy transformation chain. At each transformation step some energy is degraded and some is passed to the next step in the chain.



A. Review of concepts and definitions ...

The 20th century energy food chain of techno-humans…



Biophysical Values...

EmDollars…
the money equivalent of emergy.

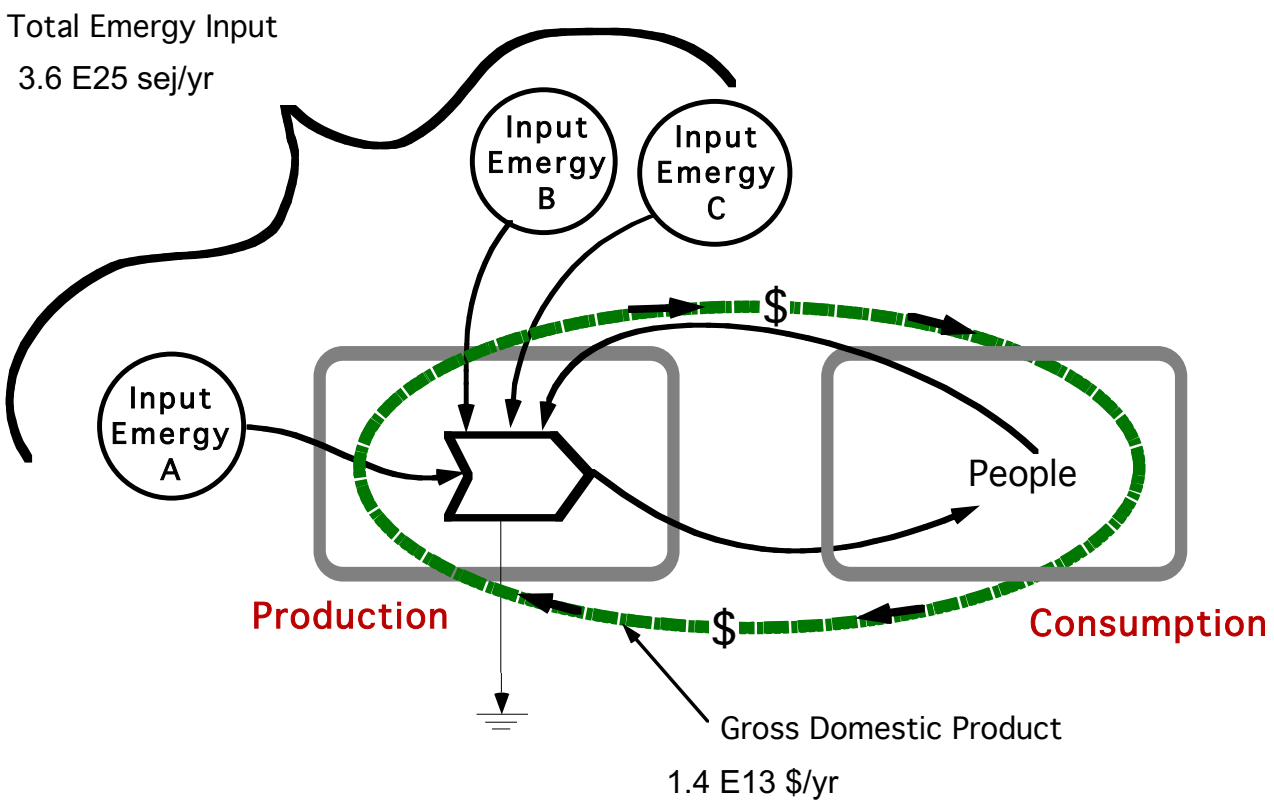
By using a standard conversion factor, we can express emergy in dollar equivalents…

In the same way as we can express dollars in energy equivalents..ie gallons of gas

for instance $1 today = 0.25 gallons... or
$1 = 3.3 E7 joules of fossil fuel energy

Biophysical Values...

Emergy/Money Ratio… USA ~ 2008



Total Emergy Use / GDP = 3.6 E25 sej/yr / 1.4 E13 $/yr = 2.5 E12 sej/$

Biophysical Values...

Emdollars of the US Economy

$$\frac{\text{Total Emergy Use}}{\text{Gross Domestic Product}} = 2.5\ \text{E12 sej/dollar}$$

So...

Every dollar spent in US economy has "embodied" in it, 2.5 E 12 sej of emergy

Biophysical Values...

Express emergy as ^{Em}dollars for ease of recognition...

An emergy input of 5.0 E18 sej/yr…
becomes...
2.0 E6 ^{em}$

$$\frac{5.0\ E18\ sej/yr}{2.5\ E12\ sej/\$} = 2.0\ E6\ ^{em}\$$$

Thank You...

Questions?