Emergy in 60 Minutes

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"Everything you didn't know you wanted to know about emergy and didn't know to ask."

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Information Transfer Goals

(aka presentation outline)

- Basic Definitions and Semantics
- Emergy Applications
- Top 10 Things You Need to Know, with more applications

E M ERGY

What is EMERGY?

- EMergy is NOT energy misspelled!

What is EMERGY?

- Emergy is a tool, an assessor
- Some metaphors (transfer functions):
  - pH is the negative log of the number of H^+ ions
  - Dow Jones average is a measure of market activity
  - GNP is a measure of economic activity
  - Trophic state indices measure productivity

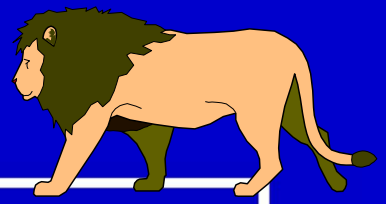
What is EMERGY?

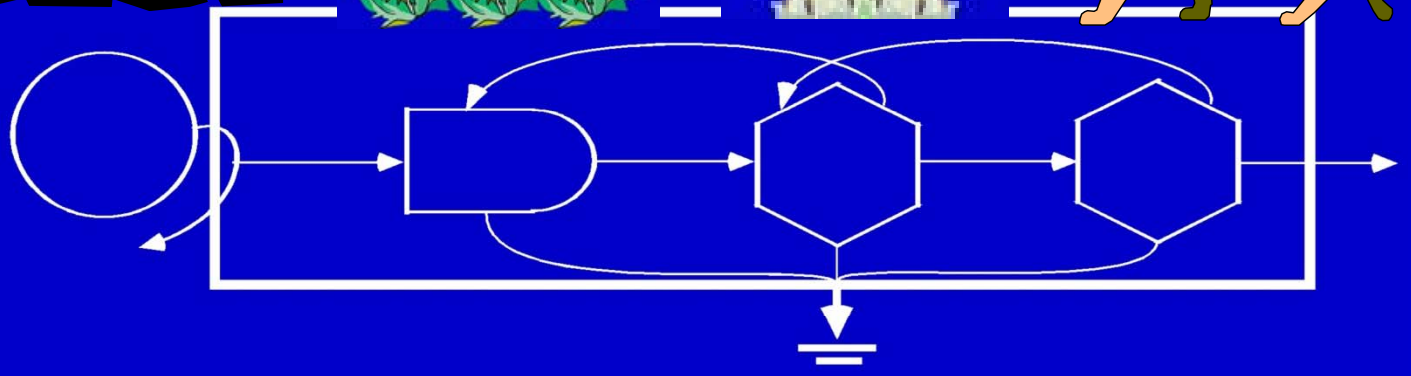
- Based on the laws of physics and thermodynamics
- Derived from energy systems principles
- All goods, services and information (either environmental, economic or cultural) are put into a common unit of measure

What is EMERGY?

- **Emergy** is the available energy of one kind previously used both directly and indirectly to make another form of energy, product or service.
- Emergy might be thought of as energy memory.

What is EMERGY?

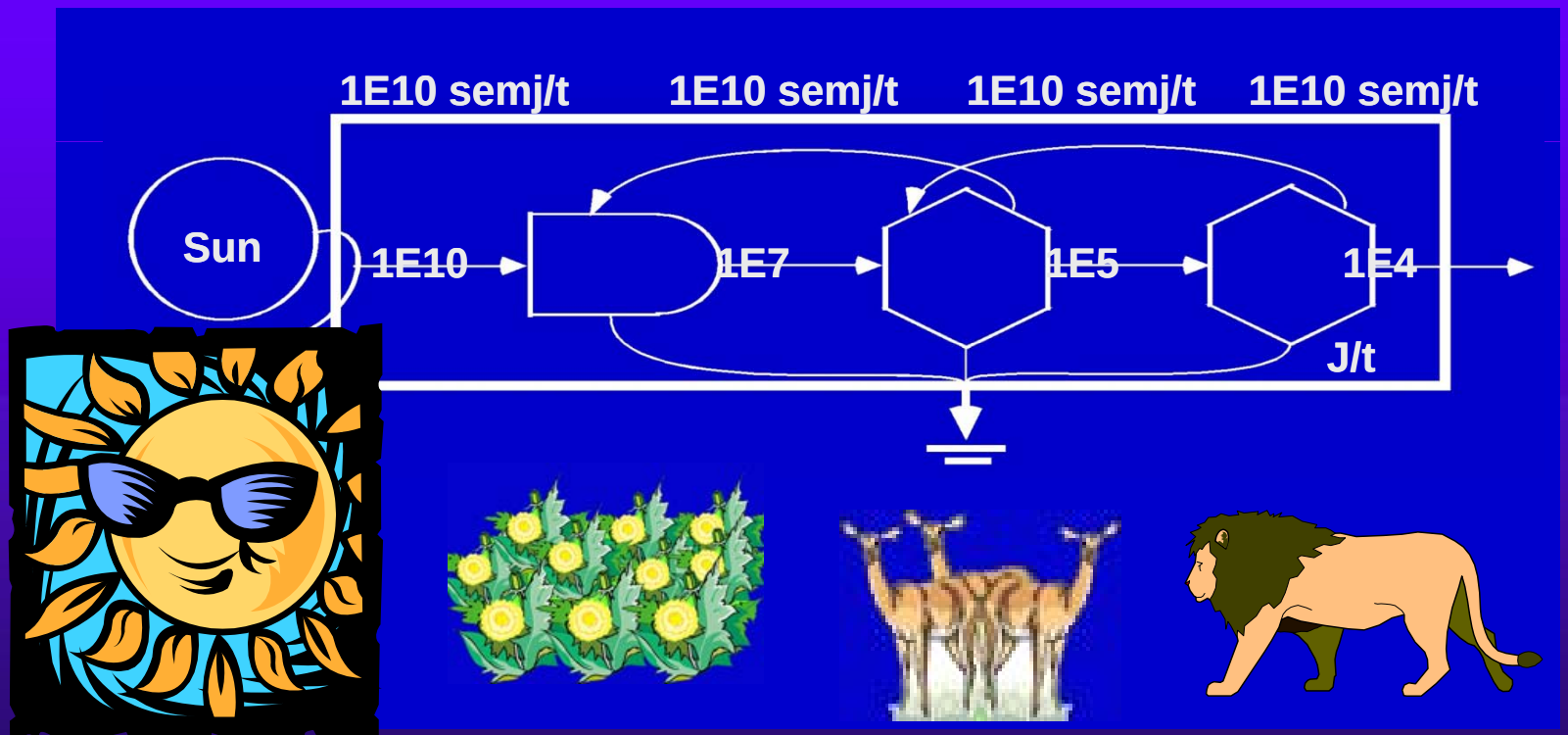




What is EMERGY?

- Its unit is the emjoule
- In this global system, use the solar emjoule (semj).

Transformations Concentrate Available Energy



Emergy Ratios

- Emergy per Unit Ratios
  - Transformities: The ratio of emergy inputs to energy output – semj/J (solar emjoules per joule)
  - Emergy per mass: the ratio of emergy inputs to mass output – semj/g (solar emjoules per gram)

Transformities

Solar emergy (semj/t) / Energy J/t)

1E10 / 1E10	1E10 / 1E7	1E10 / 1E5	1E10 / 1E4

Transformities

- The energy along any pathway can be quantified
- Energy is lost to the system in every transfer process
- The ratio of total emergy coming into the system to the energy leaving any component is a useful number known as the emergy per unit ratio.
- If the unit is energy, the ratio is called a transformity.

Transformities of Some Common Items

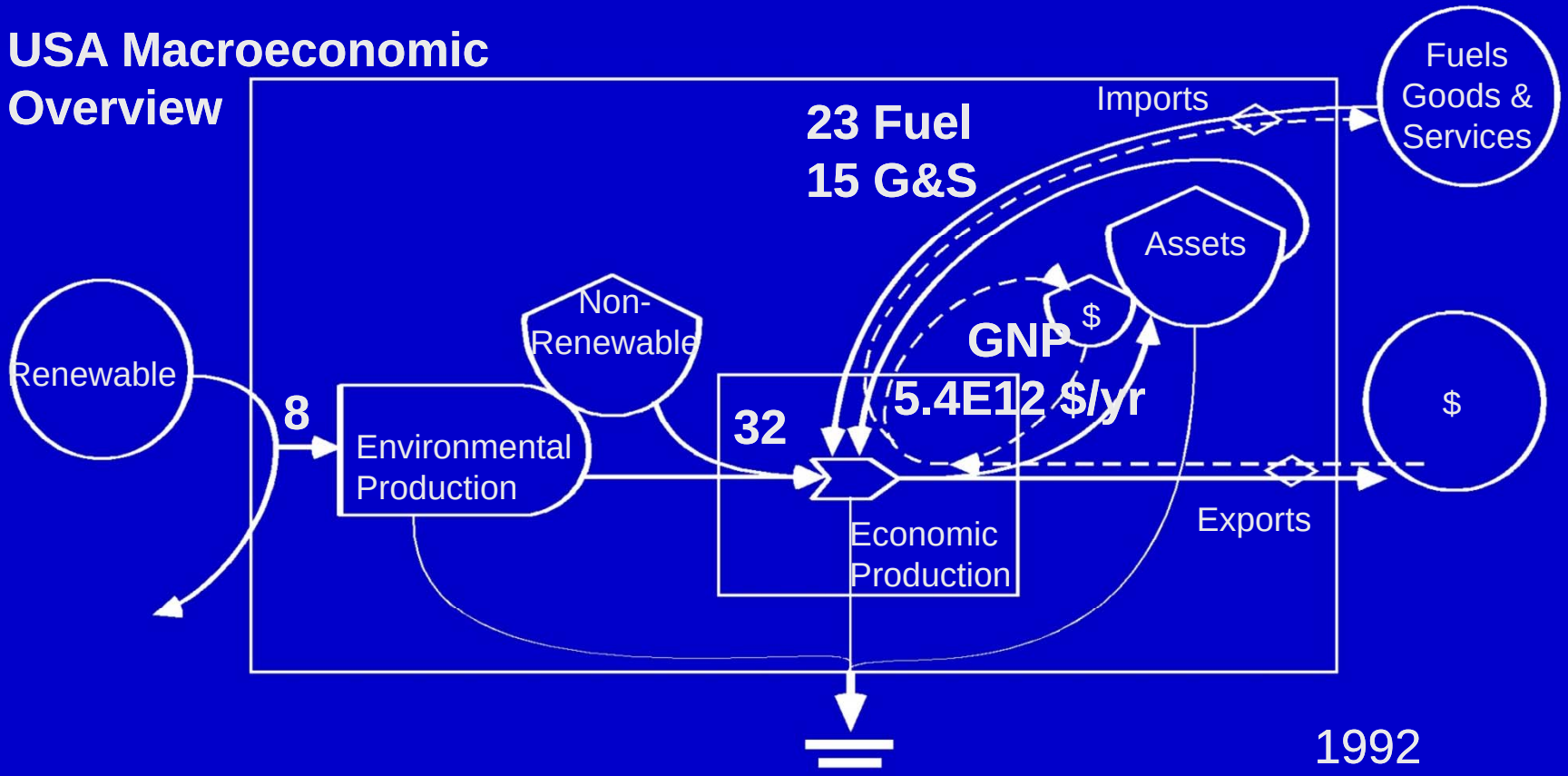
Item	Emergy/Unit	Units	Source
Incident solar radiation	1	semj/J	Odum (1996)
Wind	1470	semj/J	Odum (1996)
Rain, chemical potential	18100	semj/J	Campbell (2003)
Evapotranspiration	28100	semj/J	Campbell (2003)
Crude Oil	54200	semj/J	Bastianoni et al. (2005)
Corn, MN	65000	semj/J	Campbell and Ohrt (2009)
Ground water	159000	semj/J	Odum et al. (1998)
Electricity (average)	170400	semj/J	Odum (1996)
Soybeans	320000	semj/J	Brandt-Williams (2002)
Cattle	762000	semj/J	Brandt-Williams (2002)
Seals	10300000	semj/J	Campbell (2004)
College Graduate (labor)	336500000	semj/J	Odum (1996)

Emergy to Dollar Ratio

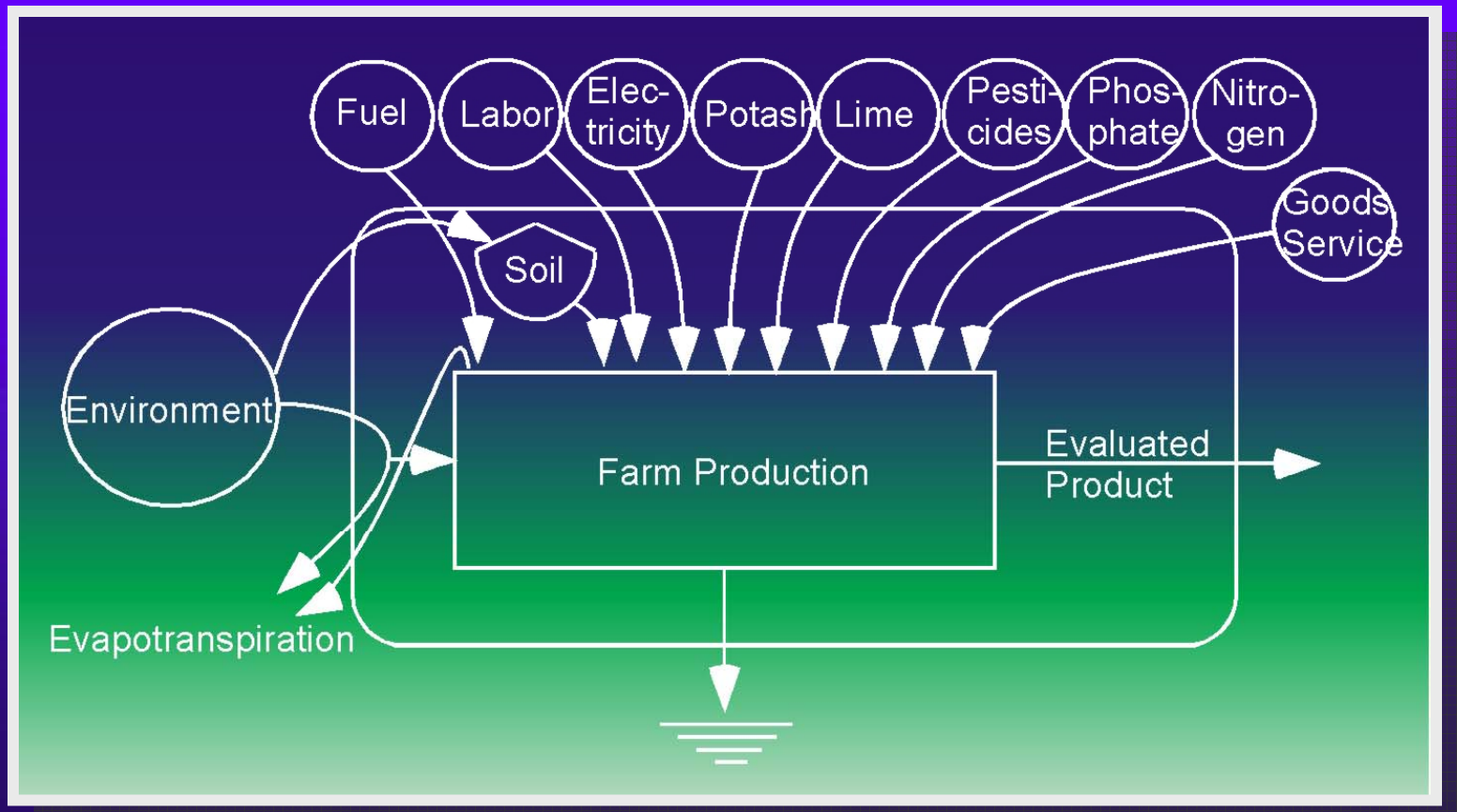
- Emergy to dollar ratio, em$
  - important interface with economics
  - economic activity is supported by the natural resource base
  - translate resources used in any year into emergy
  - divide by the currency in circulation for that year
  - direct link between environmental support and economic value

Emdollars

Calculation for US: (8 + 32 + 23 + 15) E23 semj/yr = 1.44 E12 semj/$
5.4 E12 $/yr



Sample Evaluation

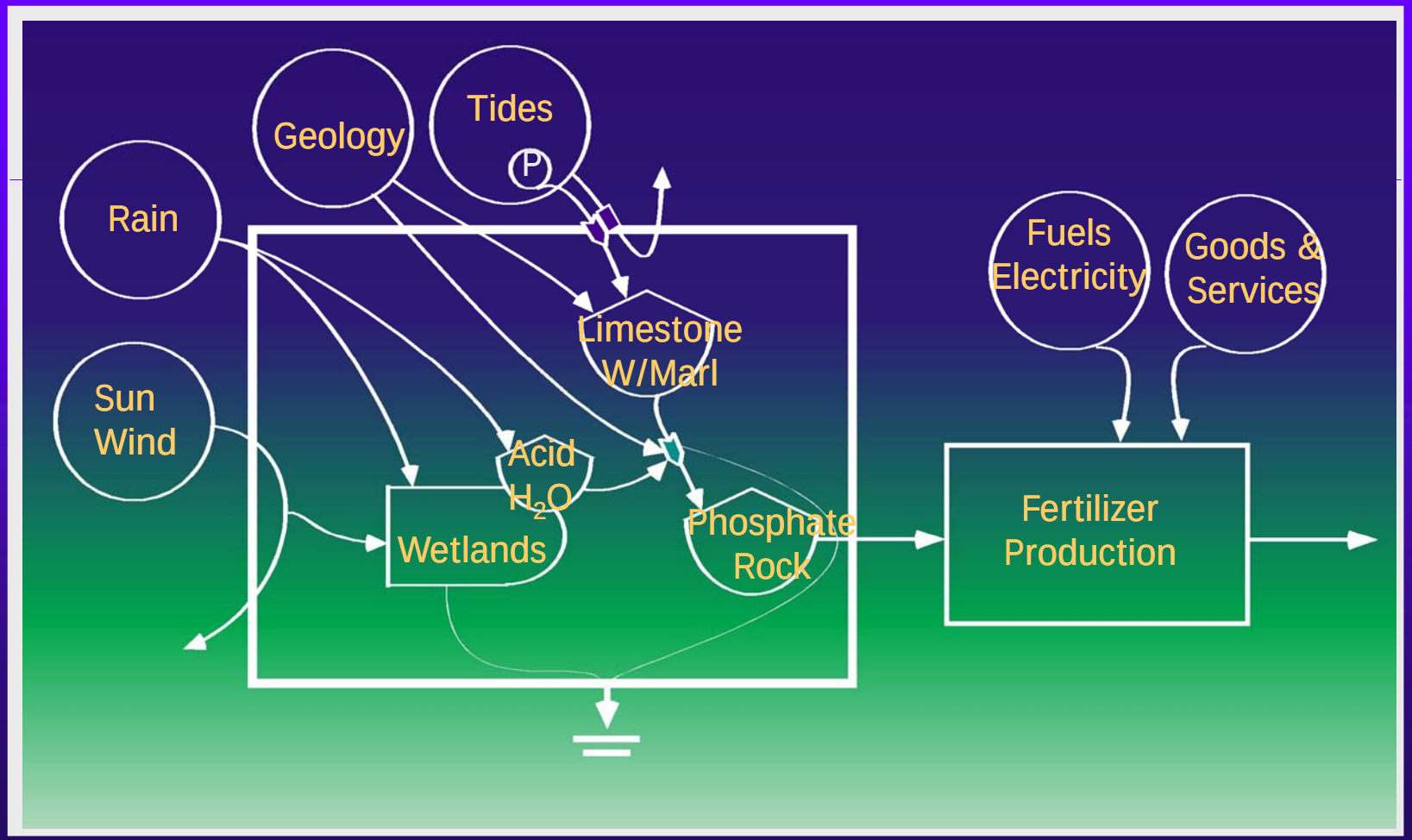


Environmental & Economic Inputs

Table 5: Emergy Evaluation of Oranges, per ha per year
(Modified from Folio #4, Brandt-Williams 2002, revised)

Note	Item	Unit	Data (units/yr)	Unit Solar EMERGY (sej/unit)	Solar EMERGY (Ξ13 sej/yr)
RENEWABLE RESOURCES					
1	Sun	J	6.35E+13	1.00E+00	6
3	Et	J	6.51E+10	2.59E+04	168
NONRENEWABLE STORAGES					
4	Net Topsoil Loss	J	6.33E+08	1.24E+05	8
	Sum of free inputs (sun, rain omitted)				176
PURCHASED INPUTS					
Operational inputs					
5	Fuel	J	1.99E+10	1.11E+05	221
6	Electricity	J	4.68E+08	2.69E+05	13
7	Potash	g K	2.36E+05	1.85E+09	44
8	Lime	g	2.40E+05	1.68E+09	40
9	Pesticides	g	1.79E+04	2.52E+10	45
10	Phosphate	g P	1.12E+04	3.70E+10	42
11	Nitrogen	g N	3.01E+04	4.05E+10	122
12	Labor	J	2.71E+08	4.45E+06	120
13	Services	$	3.01E+02	4.03E+12	121
	Sum of purchased inputs				768
	Total Emergy				944

Backtracking to the Sources



Top 10 Important Emergy Facts

What it can and can't do

How it works

#10

- Emergy accounting is an ecological economic methodology that quantifies relationships between economy, environment and culture using a common metric

#10 detailed description

- Fundamental principle: economy, all human activity, is dependent upon natural resource use
- Fundamental principle: all interactions are measurable using available energy measurement or calculation
- Fundamental principle: no high level interaction can occur without other lower level supporting interactions

#9

- Emergy analysis uses an energy systems approach:
  - boundaries are broader and analyses more comprehensive, can be used for all scales
  - allows pinpointing of inputs that might be altered to improve the picture presented by the results

#8

- Emergy provides an avenue for quantitatively investigating and understanding difficult problems in human perception such as the aesthetic and symbolic values held by people that influence their willingness to pay

#8 continued

- Emergy, as an established methodology, that was formulated in the mid 1980's
- Recently, studies have shown that human perception of value comes closer to donor-based valuation as knowledge of or exposure to a subject increases.

#7

- Emergy analysis can determine if a resource is capable of supporting long term economic growth (i.e., what is sustainable).

#7 Application of Principles

- Emergy analysis of shale oil presented in testimony before Congress in 1976.
- Findings:
  - No net emergy in shale oil
- Policy Recommendations:
  - Congress advised against appropriating funds for shale oil

Shale mine

Photo Patriot Energy

#6

- Evaluates development alternatives and ranks them by greatest benefit/impact.

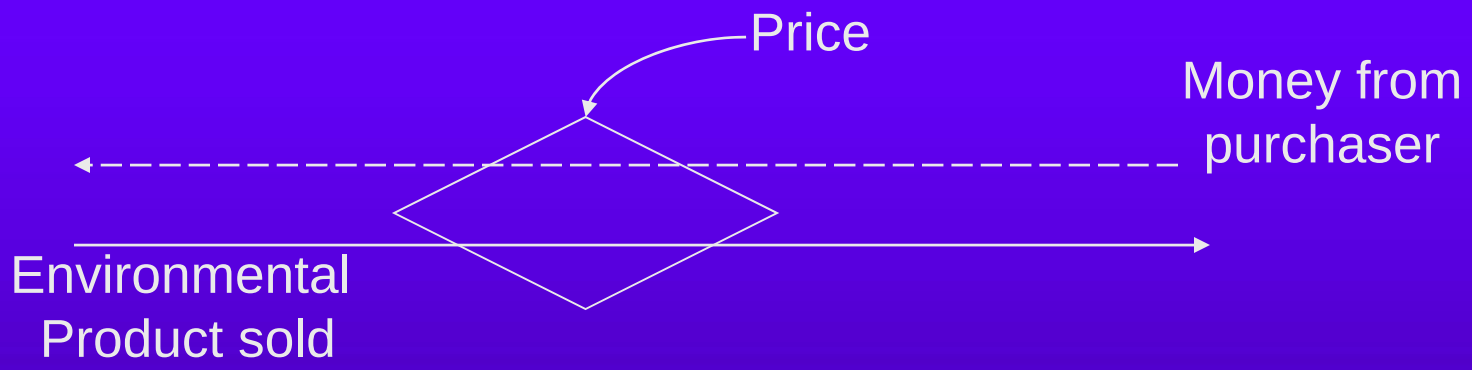
#6 continued

- Uses systems approach to identify all consequences, gains, losses associated with each alternative
- Emergy net benefits quantifies differences
- Relative ranks fall out

#5

- Emergy provides a standard for equitable exchanges in terms of real wealth

#5 Calculation of who benefits



$$\frac{\text{Emergy of product}}{\text{Emergy of money paid}} = \frac{\text{(flow)(unit emergy)}}{\text{(price)(emergy/currency)}} = \text{benefit ratio to purchaser}$$

#5 Source of inequity in trade

- Different emergy consumption leads to trading disparity
- Uses emergy to dollar ratio for each respective country

5.6:1 Japan wins

#5 A fairer way to trade

- More equitable trades

#4

- Emergy analyses use quantified magnitude of difference (#6) and equity of exchange (#5) at different scales and perspectives to demonstrate who benefits and who does not from development projects

#4 Application of the Principles

- Findings:
  - More emergy goes to developed nations in Ecuador's shrimp than is received in $ returned
  - Emergy benefit to shrimp farmers
  - Emergy deficit for local economies and Ecuador
- Policy recommendations:
  - Less intensive culture
  - Restore mangroves
  - Promote alternative development

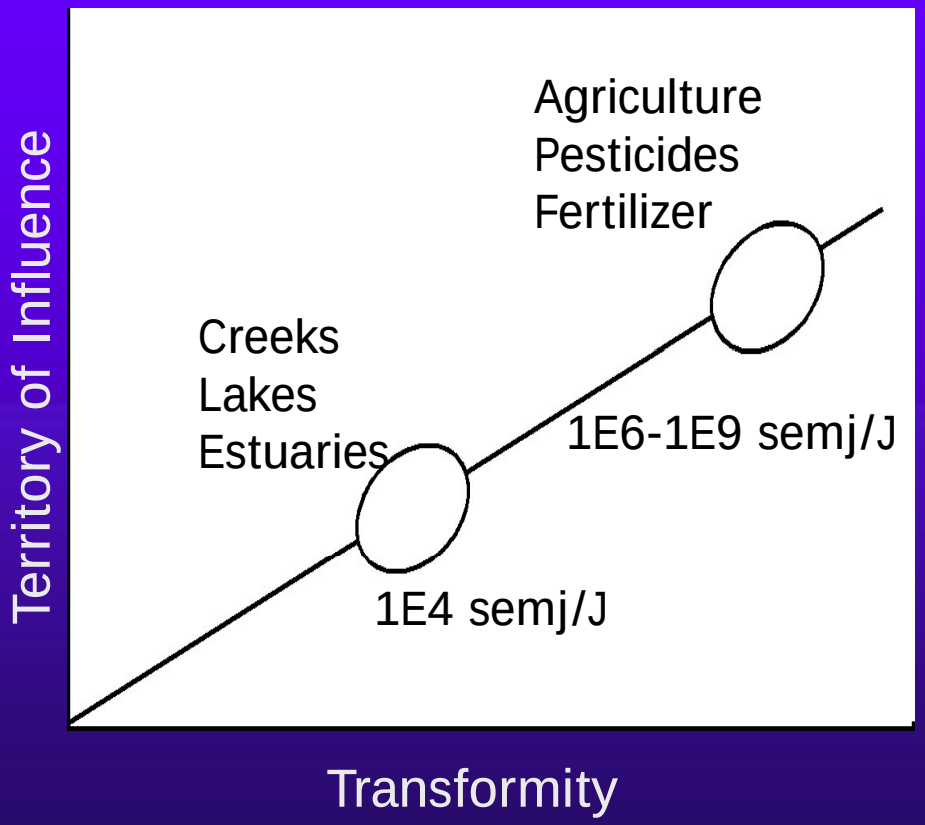
Ecuadorian shrimp farms where mangroves used to be

Photo Hosier at UNCW

#3

- Transformities and other unit emergy ratios tell you where things “belong”, and where they don’t

#3 Analyses Using Transformity



- works well in process at same point in hierarchy
- disrupts natural organization and process when out of place in hierarchy
- self-organizes to maximize output relative to higher emergy input

#2

- Emergy flows do not inform us about good or bad, but will tell us what systems will prevail under different resource availability scenarios

#2 Nature's Decision Criteria

- Maximum power principle
  - system that maximizes its ability to use emergy inputs will prevail
  - dependent upon the energy available
  - not necessarily maximum input (optimum loading for maximum empower, example 62%)
- Comparing the emergy required to maintain system structure and function to the emergy available for support gives an indication of sustainability

#1

- Measures *real wealth* embodied in an economic or environmental product
  - Real wealth is what an environmental product or service can do when used for its intended purpose within a system

#1 Example

- The same car traveling on a gallon of gas will only drive so far regardless of how much the gas costs
- This ability to do work is its real value

In Conclusion

- Emergy is a new tool, not a new science
- Allows direct comparison of typically disparate functions
- Emergy overcomes deficits in economic analysis by including externalities directly
- Often it does not reach same conclusions as economic evaluations
- Bridges the gap between environmental and social sciences