Emjoules and EcoFootprints

How Solar Energy Can Form a Common Basis for Measuring Environmental Stress Across Air, Water and Soil Media

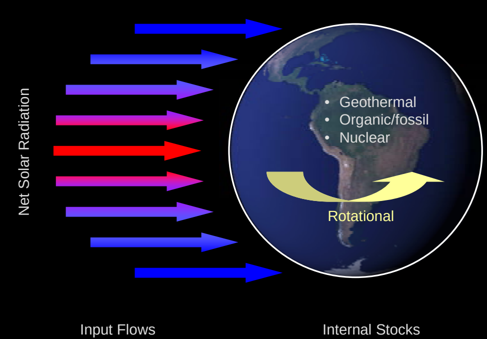
The Objective

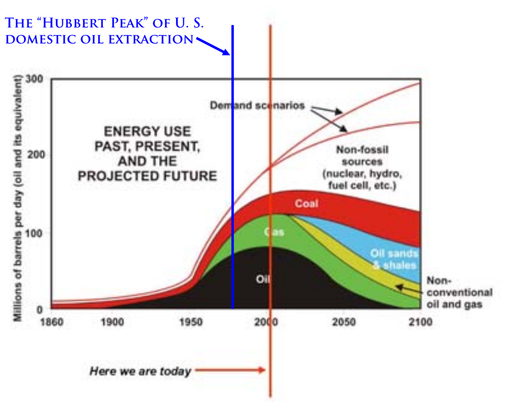
Help build a Texan dairy industry that is compatible with long-term, global, sustainability principles grounded in credible science, freedom and security

The Need

A way of measuring environmental sustainability that gives dairy producers a performance-based, marketable currency to trade on par with other industries

Sources of Primary Energy in the Ecosphere





Adapted from Rees (2003)

About the Hubbert Peak

- Not everybody agrees as to its significance
- Adherents are often thought to be "crying wolf" because some bold predictions using his methodology have been wrong
- Inaccurate predictions center mainly on wrong timing (i. e., "when the peak will occur")
- Every year sees another oil-reservoir discovery

A Few Truisms

- Domestic extraction of [X] will cease when one barrel of it is required to extract one barrel of it from its most accessible reservoir
- Extraction of fossil fuels – among other things it accomplishes, and whatever the ecological implications might be – moves energy and carbon from the *lithosphere* to the *ecosphere*
- Recent discoveries of oil reserves in the Gulf of Mexico and beneath the Rocky Mountains help in the short to medium term, but *they do not change the fundamental picture: long-term sustainability is an energy-limited scenario*

As we approach the limits of our easy access to energy, the defining economic currency will be dominated by availability of energy units rather than by an artificial currency, be that gold or dollars.

Paul Weisz
2004

A Sustainability Conjecture

No ecosystem can be considered sustainable if it must be subsidized indefinitely by non-renewable energy

Why Energy, and Not Matter?

- ✓ Both matter and energy are conserved, but…
  - × *…there is no mass sink equivalent to the 2nd Law's "energy abyss"*
- ✓ We could recycle matter (water, N, P) forever…
  - × *…if we were given an inexhaustible source of available energy to do so!*
- ✓ Nearly all pollution-prevention practices cost not only extra $$, but extra energy as well

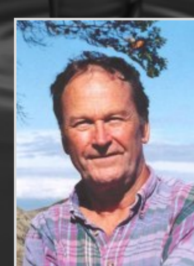
Energy-Based Sustainability Measures

Two Different Approaches

Ecological Footprint
(W. Rees et al.)

The *per capita* area of ecologically productive land and/or ocean needed to sustain an ecosystem indefinitely by:

- Providing all of the material and energy resources that it requires; *and*
- Safely using all of the wastes that it generates
- Key sustainability question: Does it exceed the EP area available?



Emergy: Embedded Energy
(H. T. Odum et al.)

The available energy having an arbitrary reference quality (e. g., solar radiation) previously required – directly and indirectly – to make a product or service

- Normalizes available energy to common units ("Solar EmJoules")
- Accounts for transformations among energy types differing in their ability to do useful work

Example #1

- Recommendation: *Increase N&P use efficiency of cattle feedyards by increasing digestibility/ nutrient availability of feed rations*
- Application: *Steam-flake grain*
- Marginal Energy Costs:
  - *Thermal energy to fire the steam chests*
  - *Fluid energy to pump water, move grain through the feed mill*
  - *Mechanical energy to drive the flaker rollers*

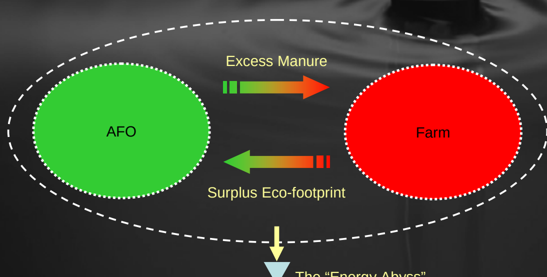
Example #2

- Recommendation: *Reduce organic-matter loading to lagoons to reduce odors*
- Application: *Solid-liquid separation via settling basins*
- Marginal Energy Costs:
  - *Mechanical energy to mine concrete aggregates, excavate basins*
  - *Thermal energy to manufacture Portland cement*
  - *Diesel fuel energy to transport materials, harvest and land-apply sediments*

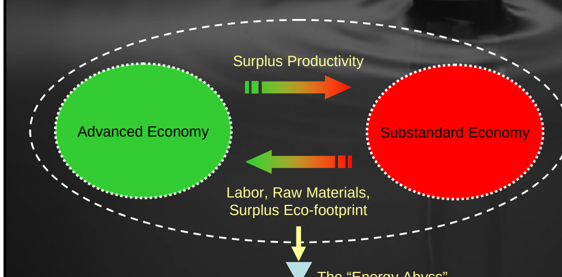
Example #3

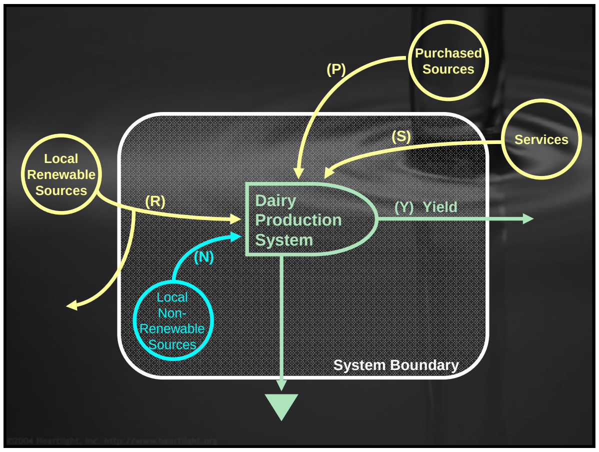
- Recommendation: *Increase break-even distance for hauling manure profitably as a phosphorus source, and reduce weeds and pathogens to reduce pesticide use*
- Application: *On-farm composting*
- Marginal Energy Costs:
  - *Mechanical energy to handle manure, turn compost*
  - *Biological energy to increase pile temperature; evaporate water; oxidize organic matter to CO_2, NH_3 and trace gases*

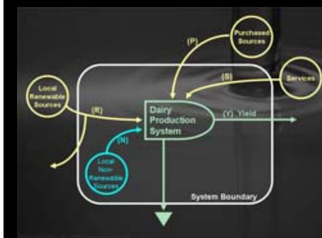
Local Manure Trading Couples Neighboring Ecosystems



Globalization Couples Distant Ecosystems



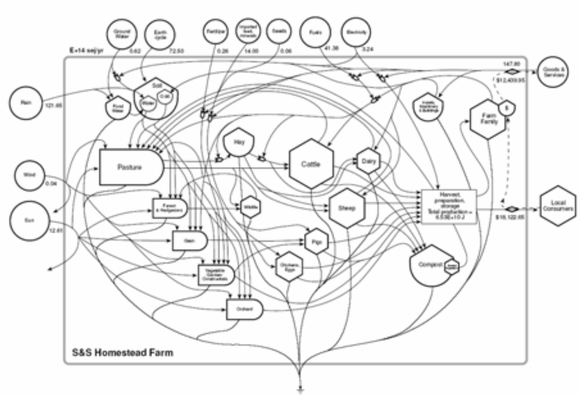




Emergy Yield Ratio
= Y/(P+S)

Environmental Loading Ratio
= (P+S+N)/R

Sustainability Index
= Y*(P+S+N)/{R*(P+S)}



Note	Item, unit	Data (units/yr)	Transformity* (sej/unit)	EMERGY (E14 sej/yr)	EmDollars (1993 USD)
RENEWABLE RESOURCES (R)					
1	Sun, J	1.26E+15	1[a]	12.61	$920.76
2	Wind, J	2.65E+09	1.50E+03[a]	0.04	$2.90
3	Rain, evapotranspiration, J	6.68E+11	1.82E+04[a]	121.65	$8,879.24
4	Rain, geopotential, J	9.34E+08	2.79E+04[a]	0.26	$19.00
5	Earth Cycle, J	2.50E+11	2.90E+04[a]	72.50	$5,291.97
6	Groundwater, J	2.73E+09	2.27E+04[a]	0.62	$45.18
	Largest renewable input			**121.65**	$8,879.24
NONRENEWABLE STORAGES (N)					
7	Net topsoil loss, J	2.73E+09	7.38E+04[a]	2.01	$146.89
	Sum of free inputs			**124.28**	**$9,071.31**
PURCHASED INPUTS (P)					
8	Fuels and lubricants, J	6.27E+10	6.60E+04[a]	41.38	$3,020.29
9	Electricity, J	2.02E+09	1.60E+05[a]	3.24	$236.39
10	Mechanical equipment, g	1.87E+05	4.10E+09[b]	7.66	$559.04
11	Buildings, fences, tools (wood), J	1.46E+10	3.49E+04[f]	5.09	$371.48
12	Tools, fencing, (steel), g	2.07E+05	3.20E+09[d]	6.61	$482.80
13	Ironwood posts (fencing), g	8.50E+03	3.90E+08[a]	0.03	$2.42
14	Insulators, ceramic (fencing), g	1.15E+03	1.00E+09[a]	0.01	$0.84
15	Plastic (greenhouse and fencing), g	8.85E+03	3.80E+08[d]	0.03	$2.46
16	Mineral salt, g	1.58E+05	1.00E+09[a]	1.58	$114.96
17	Potash, g K	7.13E+02	1.10E+09[a]	0.01	$0.57
18	Phosphate, g P	1.08E+03	1.78E+10[a]	0.19	$13.99
19	Nitrogen, g N	1.64E+03	3.80E+09[a]	0.06	$4.56
20	Seeds, J	1.81E+08	3.48E+04[d]	0.06	$4.60
21	Grocery store culls , g	1.18E+05	6.31E+09[b]	7.46	$544.43
22	Soy meal, J	1.70E+09	3.32E+05[b]	5.64	$411.50
SERVICES and LABOR (S)					
23	Labor, J	5.77E+09	2.56E+06[f]	147.80	$10,788.53
24	Infrastructure, service component, USD	6.88E+03	1.37E+12[c]	94.22	$6,877.30
25	Services, yearly expenditures, USD	5.56E+03	1.37E+12[c]	76.21	$5,562.65
	Sum of purchased inputs			**396.60**	**$28,948.86**
PRODUCTION, J					
26	Meat, J	3.01E+10			
27	Vegetables, fruit, grain, J	2.51E+10			
28	Eggs, dairy, J	1.02E+10			
28	Hay, J	3.55E+11			

System Component	Unit	Quantity (units)	Fuel or Energy Type	Energy Req/Unit (J/unit-yr)	Direct Power Requirement (J/yr)	Transformity (sej/J)	Solar Empower (sej/yr)
Feedyard							
Labor	man-hr/yr	1.46E+05	Labor	2.40E+06	3.50E+11	9.76E+04	3.41E+16
Feed Milling	bu/yr		Natural Gas				
Manure Harvesting	wk/corral	4.00E+00	Diesel	3.65E+11	1.46E+12	6.60E+04	9.63E+16
Sprinkler Dust Control - Pumping Energy	in/yr	1.88E+01	Electricity	1.42E+10	2.66E+11	2.00E+05	5.31E+16
Sprinkler Dust Control - Water	in/yr	1.88E+01	Solar	5.95E+10	1.12E+12	1.00E+00	1.12E+12
Feed Truck Loading by Tractor	h/yr		Diesel				
Water Trough Heating	kWh/yr		Electricity				
Grain Handling/Conveying	bu/yr		Electricity				
Feed Truck Mileage	mi/yr		Diesel				
Light Truck Mileage	mi/yr		Gasoline				
Headquarters	kWh/yr		Electricity				
Lighting	kWh/yr		Electricity				
Drinking Water Distribution	ac-in/yr		Electricity				
Cattle Shipping to Slaughter	lb/yr		Diesel				
Cattle Shipping to Feedyard	lb/yr		Diesel				
% of Labor for Manure Harvesting	%	5.00	--	2.40E+06	1.75E+10	9.76E+04	1.71E+15
Corn Production							
Planting	ac/yr	4.36E+04	Diesel				
N Fertilization	lb/yr N		Diesel				
P Fertilization	lb/yr P2O5		Diesel				
Other Fertilization	TBD		Diesel				
Tillage	ac/yr	4.36E+04	Diesel				
Irrigation Pumping Power	ac-in/yr	5.23E+05	Electric	8.23E+07	4.30E+13	2.00E+05	8.60E+18
Pesticide Application	ac/yr	4.36E+04	Diesel				
Harvesting	ac/yr	4.36E+04	Diesel				
Irrigation Water	ac-in/yr	5.23E+05	Solar	3.46E+08	1.81E+14	1.00E+00	1.81E+14
Train Shipment of Corn from NE	wet tons/yr	1.83E+05	Railroad Diesel				
Waste Handling and Disposal							
Runoff Holding Pond Storage	ac-ft						
Runoff Holding Pond Evaporation	ac-in/yr		Solar				
Runoff Holding Pond Irrigation	ac-in/yr		Electricity				

The Paradox of Efficiency Gains

- Decline of the Ogallala Aquifer has accelerated despite astounding increases in irrigation efficiency (>95%)
- American farms have doubled their energy efficiency since 1978…still, due to more advanced processing, U.S. agriculture uses at least ten calories of fossil energy for every calorie of food energy produced (Miranowski, 2004; [acb] Lovins, 2005)
- My new 3GHz Dell PC still takes 4 minutes to boot up
- We plow efficiency savings back into the our businesses to maximize profit or leisure, not reduce net inputs (the “rebound effect”)
- As long as energy prices reflect *demand* instead of *scarcity*, the rebound effect will be with us

Thank God for $3.50 gasoline…We are criminally unserious about energy independence, and we will pay the price.

Charles Krauthammer
2005

A Thought to Chew On

No global ecosystem can be considered sustainable if its ecological footprint exceeds the ecologically productive area of the earth

…we are part of that ecosystem!

In the long run, we're all dead.

John Maynard Keynes
1923