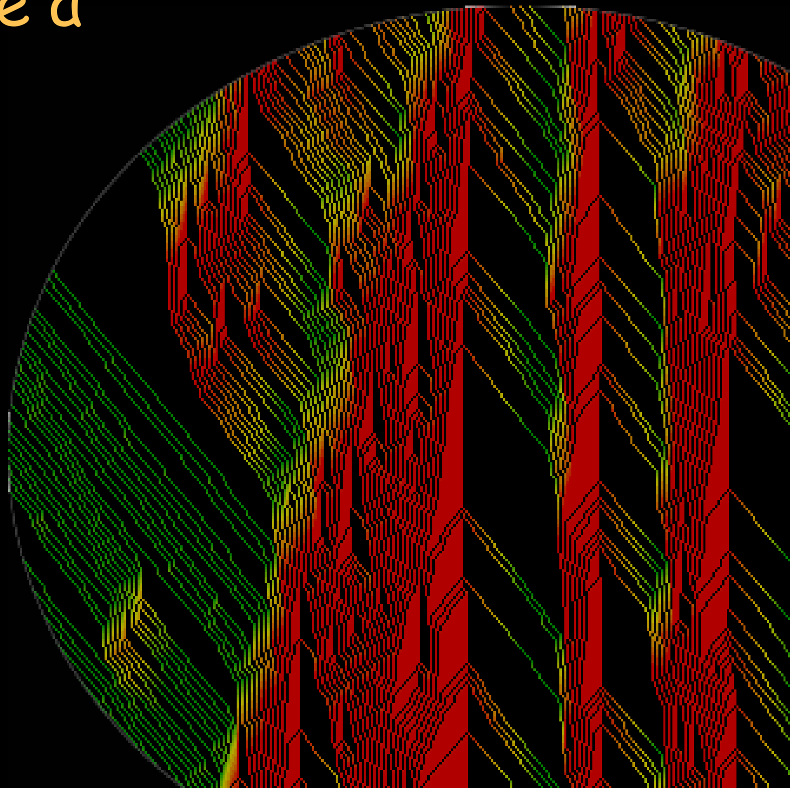
Net Emergy of Biomass

Mark T. Brown
21 February, 2006

Connect threads...

INTELLECTUAL TAPESTRY - something that is felt to resemble a tapestry in its complexity;



M.King Hubbert's Blip

"Reality is merely an illusion, albeit a very persistent one." ***Albert Einstein***

Peak Oil…

"My analyses are based upon the simple fundamental geologic fact that initially there was only a fixed and finite amount of oil in the ground, and that, as exploitation proceeds, the amount of oil remaining diminishes monotonically."

M.King Hubbert

Peak Oil…

The End of Oil and the Inevitable Road to Sustainability
by Bob Banner

Peaking World Oil Production Could Cause Severe Disruptions

IEA to call for an emergency oil plan
by Javier Blas and Kevin Morrison

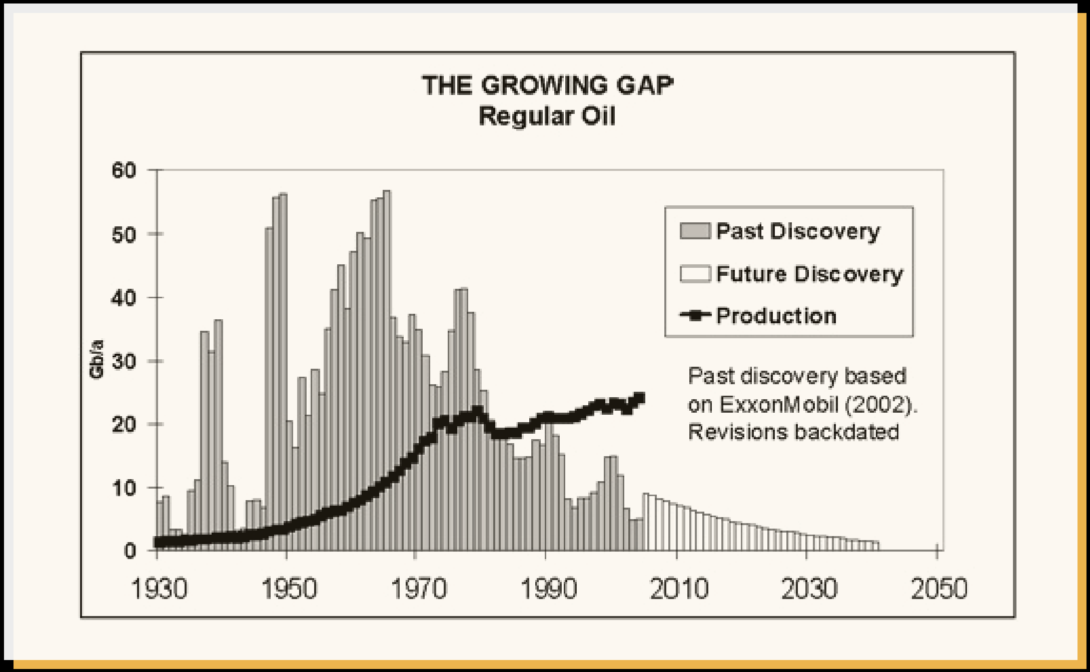
ASPO Association for the Study of Peak Oil&Gas
www.peakoil.net

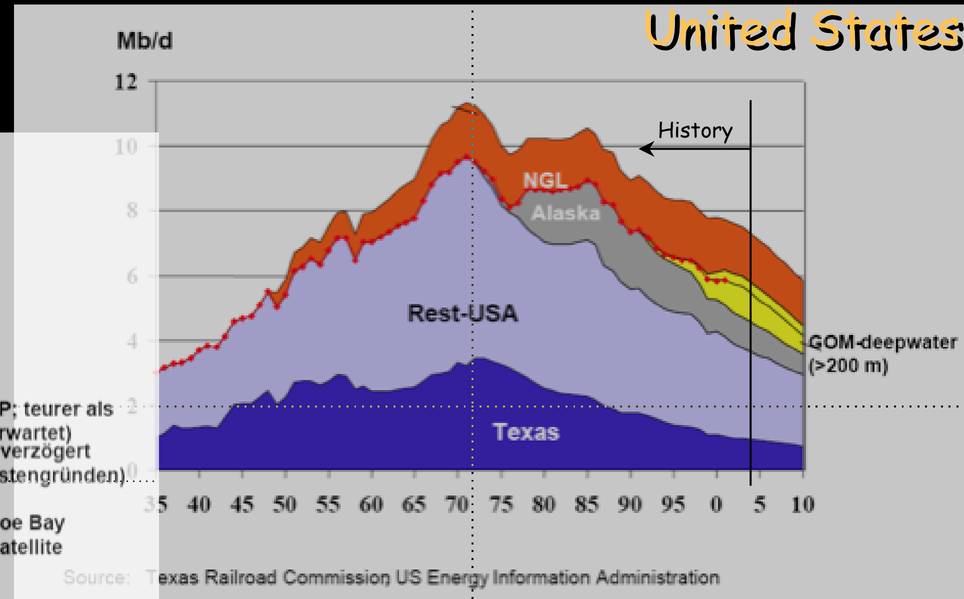
Running on empty
by Christopher Kremmer

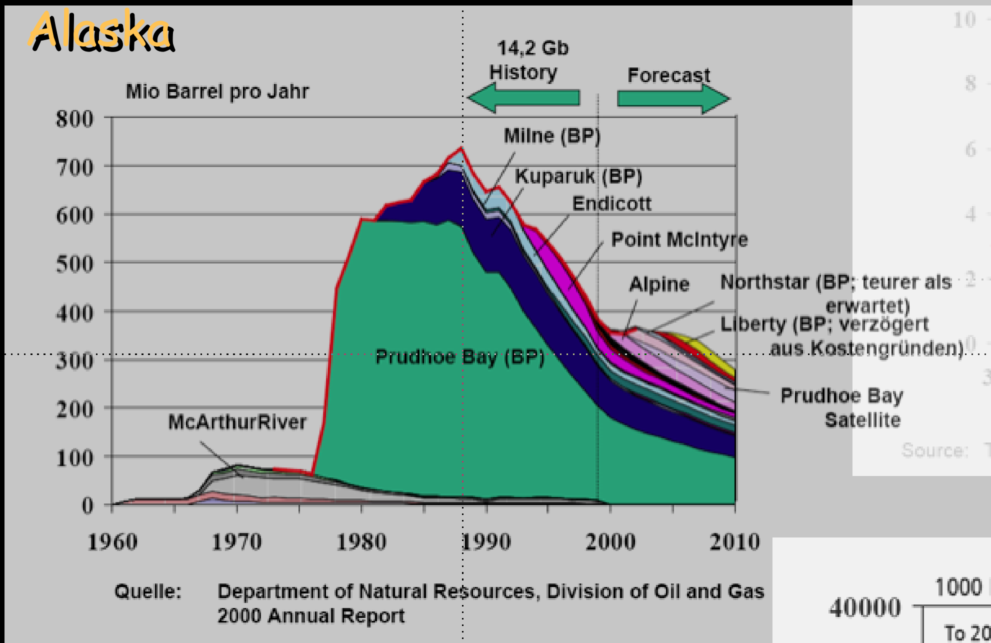
Back to the post-oil future
by Richard Heinberg

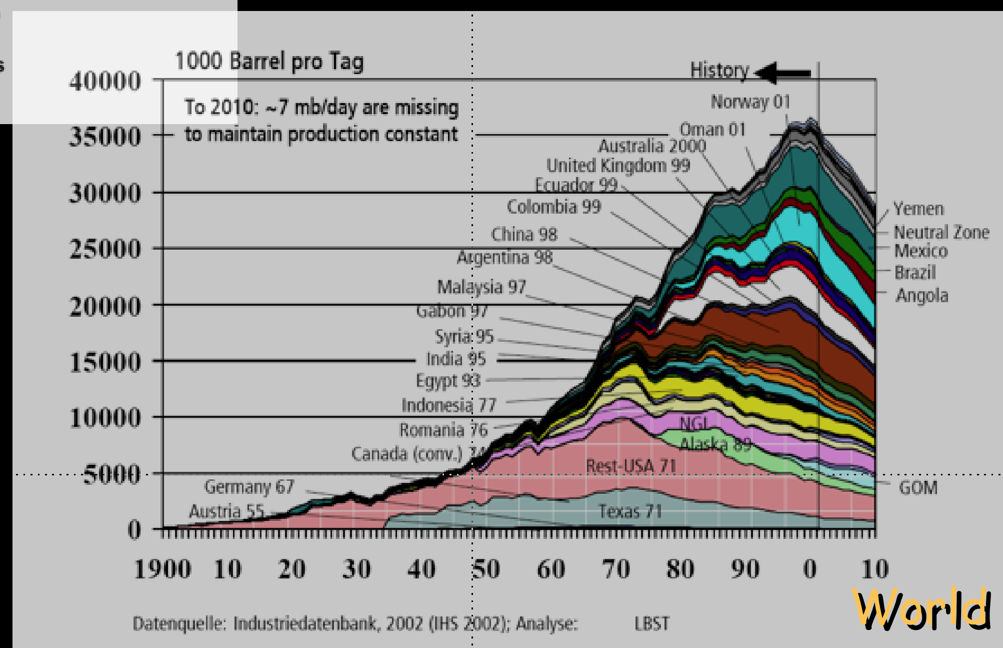
Peak Oil…

New discoveries are not keeping pace with demand







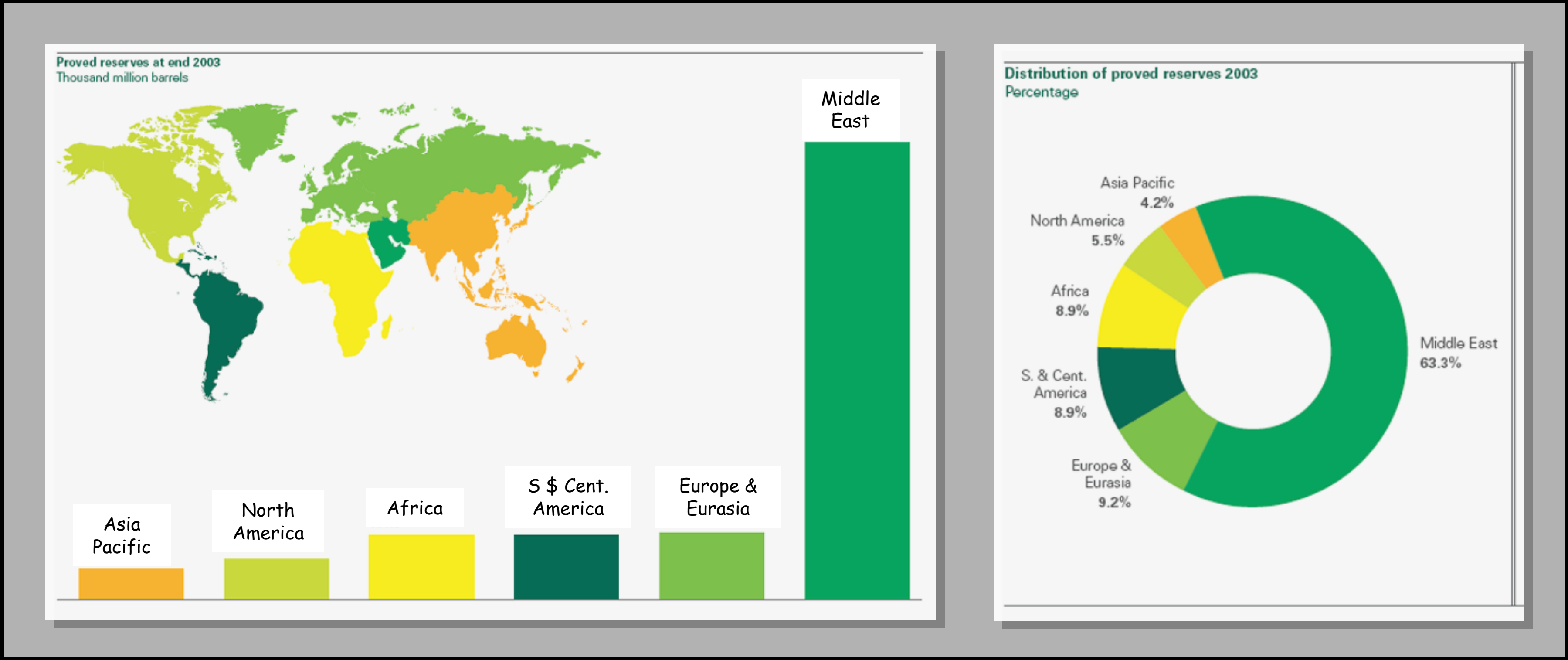


No matter how you cut it…

the hydrocarbon age is about over.

Peak Oil…

Global politics for the next two decades…

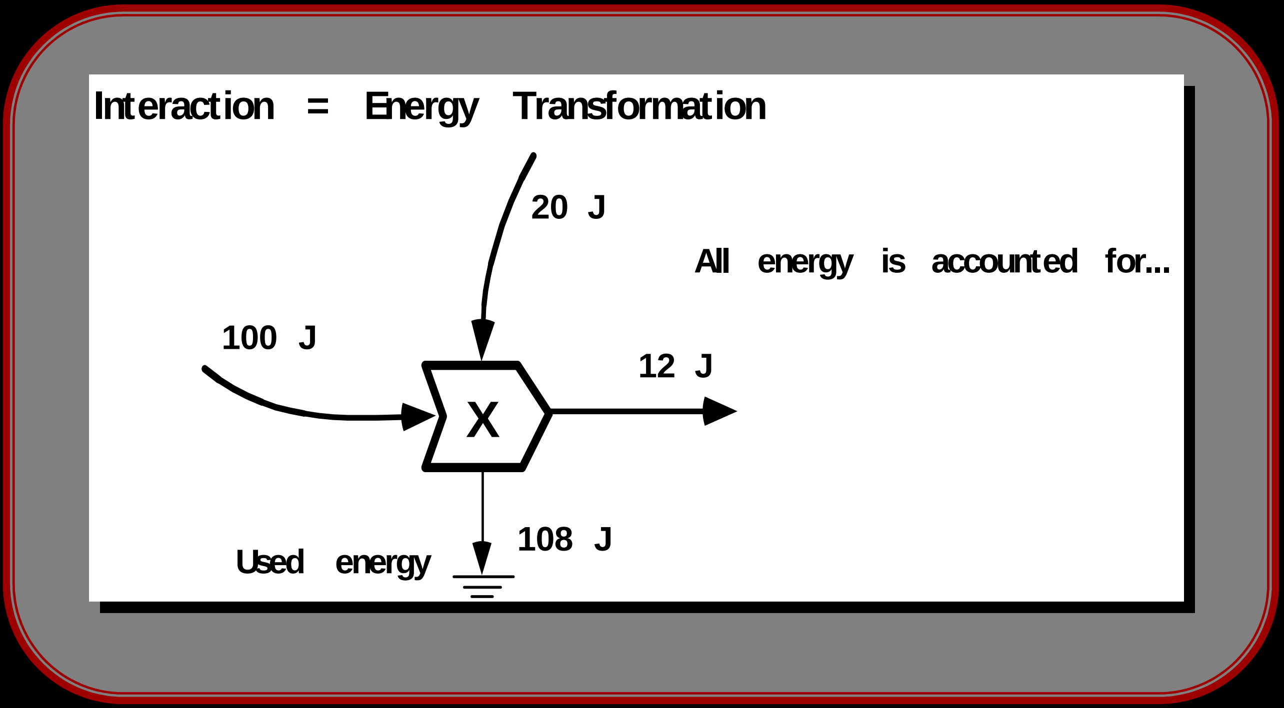


Energy Laws….

- 1st Law of Thermodynamics
- 2nd law of Thermodynamics
- 3rd law of Thermodynamics
- Maximum Power Principle (4th law)
- Hierarchically organized systems (5th law)
- Hierarchical material distribution (6th law)

1st Law of Thermodynamics

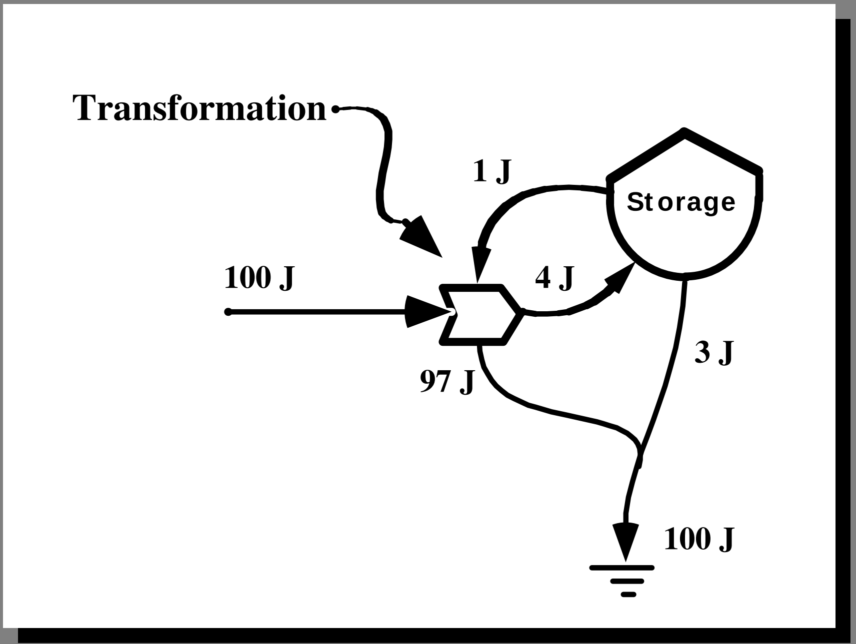
Energy cannot be created or destroyed



2nd Law of Thermodynamics

In all real process (transformations), some energy loses its ability to do work

We sometimes speak loosely of energy being "used up" whereas what is really meant is that the potential for driving work is consumed, while the calories of energy inflows and outflowing are the same.



3rd Law…
Absolute Zero Exists

Entropy at absolute zero is zero….

As heat content approaches absolute zero molecules are in crystalline states, and the entropy of the state is defined as zero

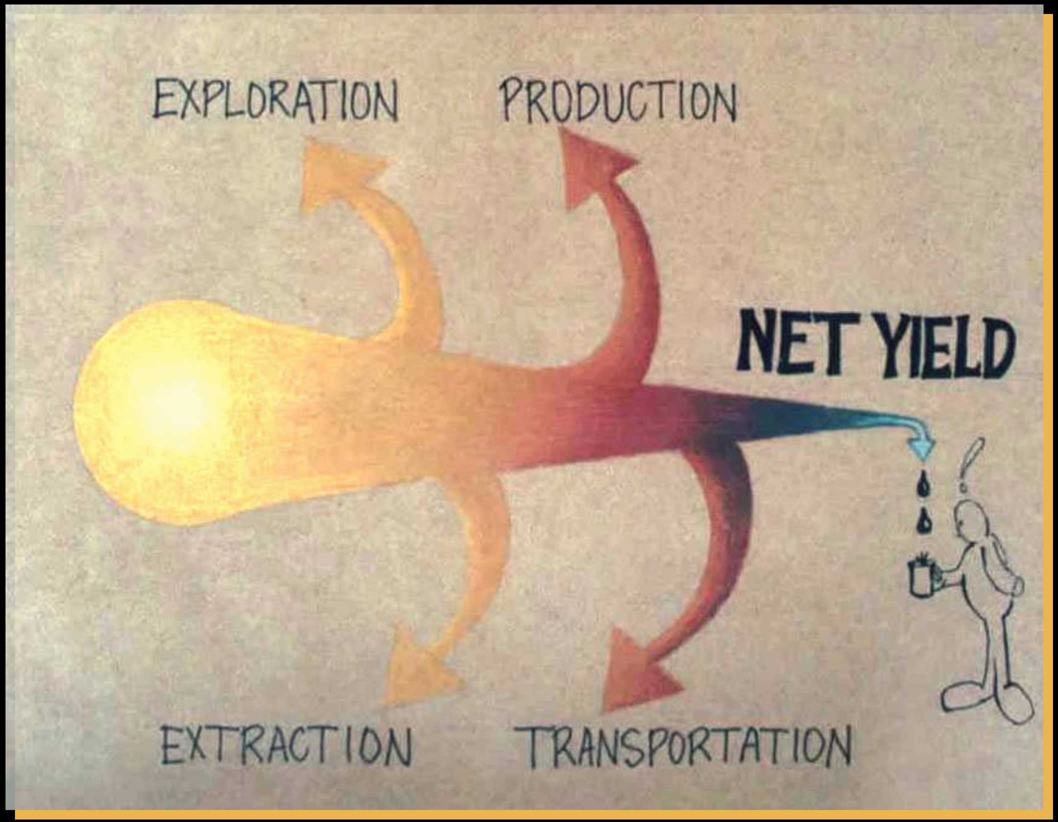
Net Energy

"Like ice in a fire, something for nothing you'll never acquire." ***Mr. Ryan (bulldog)***

Net Energy…energy costs of obtaining energy

When the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil, production will cease, no matter what the monetary price may be.

Net Energy…



We believe that to maintain society's current level of infrastructure and information processing, a net energy of about 4/1 is required.

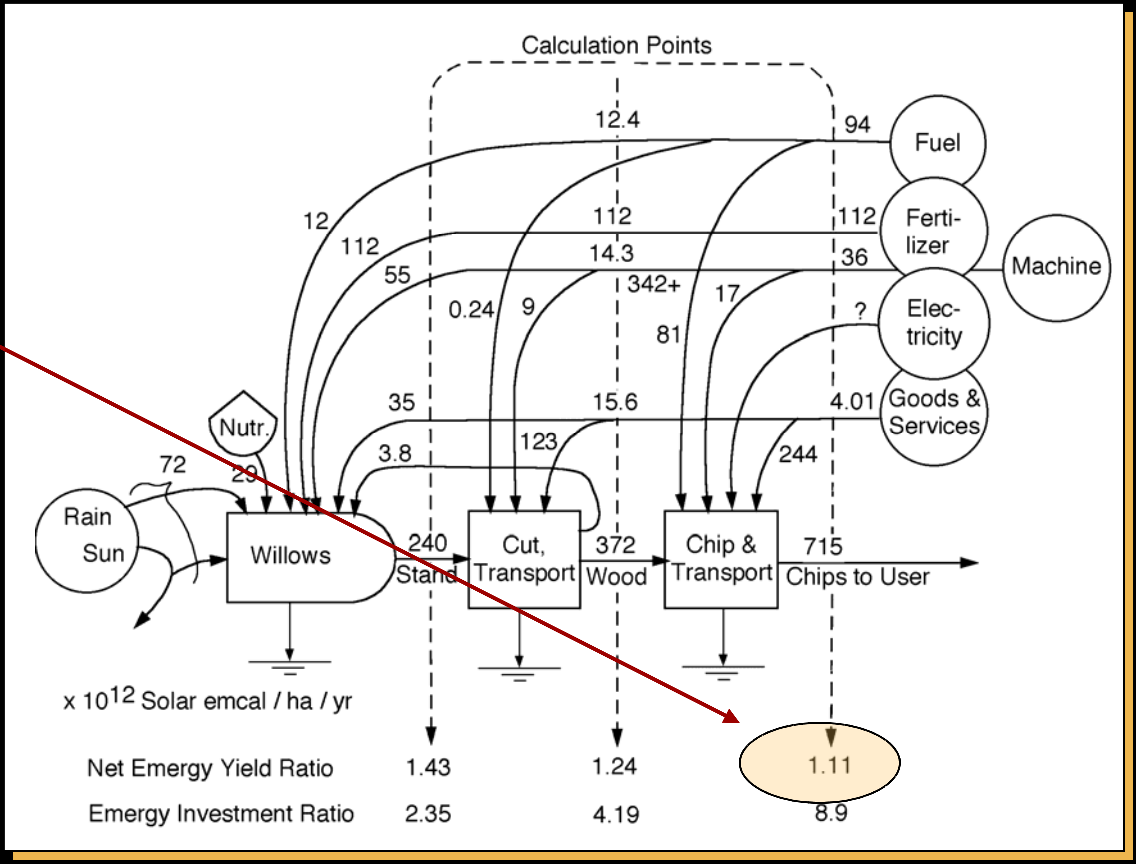
Net Energy…*conventional sources*

All declining…

Net Energy…*so called renewable sources*

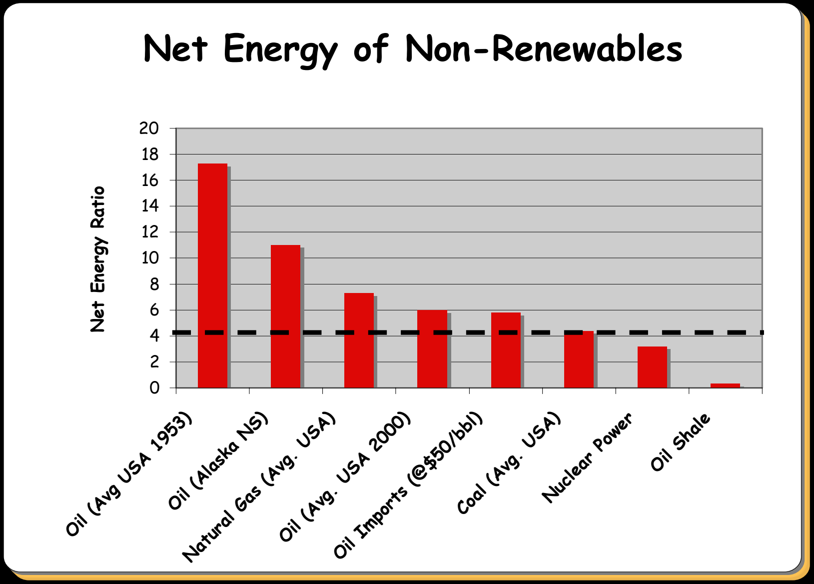
Net Energy…

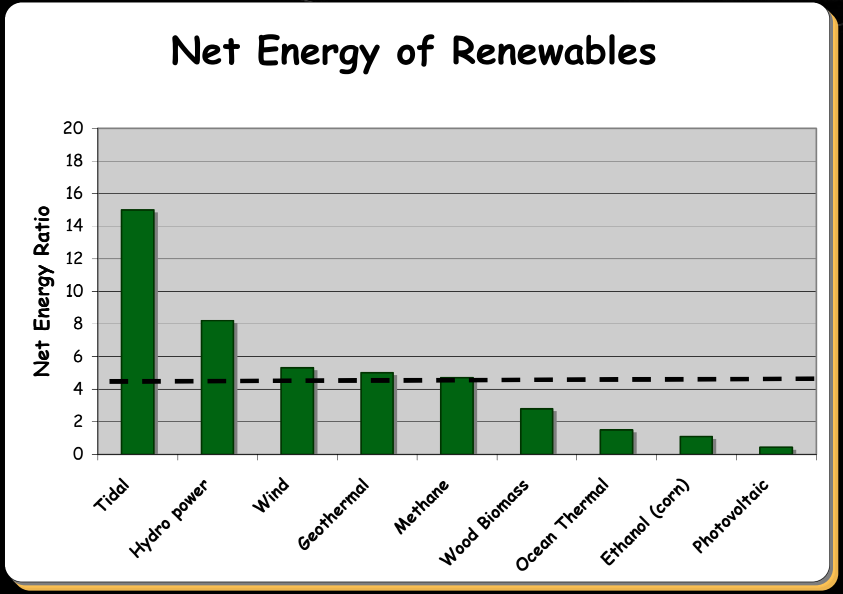
Net energy of biomass is barely 1/1



Net Energy…


Middelgrunden offshore wind farm, near Copenhagen, Denmark (55°40' N, 12°38' E).
http://www.yannarthusbertrand.org


Net Energy of Non-Renewables
Net Energy Ratio
0
2
4
6
8
10
12
14
16
18
20
Oil (Avg USA 1953)
Oil (Alaska NS)
Natural Gas (Avg. USA)
Oil (Avg. USA 2000)
Oil Imports (@$50/bbl)
Coal (Avg. USA)
Nuclear Power
Oil Shale


Net Energy of Renewables
Net Energy Ratio
0
2
4
6
8
10
12
14
16
18
20
Tidal
Hydro power
Wind
Geothermal
Methane
Wood Biomass
Ocean Thermal
Ethanol (corn)
Photovoltaic

Net Energy…

An important fact of life….

As the Net Energy declines, the amount of energy used to accomplish the same amount of end use (eg miles driven) increases…

At 10/1 compared to 5/1

You can drive twice as far for the same energy investment

MTB 02/21/06


OF COURSE IRAQ IS FREE! DIDN'T COST US A DIME. THE PUBLIC PAID FOR THE WHOLE OPERATION!
DANIK

Net Energy... of the IRAQ invasion...

IRAQ Oil reserves	113 E9 bbl =	3.76 E25 sej
USA Defense budget	$348 E9 / yr =	3.48 E23 sej
USA Fuel Use		2.23 E23 sej / yr
Cost of War	$100 E9 =	1 E23 sej
Reconstruction / Peacekeeping	$250 E9 =	2.5 E23 sej
Total cost		3.5 E23 sej
Benefit to Cost ratio	376 E23 / 3.5 E23	~ 100 / 1

Four Energy Studies…

1. Pimentel & Patzek,(2005)
2. Berndes et.al, (2003)
3. Patzek, (2003)
4. Giampietro, et.al 2003

Berndes et.al, 2003 …

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Biomass and Bioenergy 25 (2003) 1–28

BIOMASS & BIOENERGY

www.elsevier.com/locate/biombioe

The contribution of biomass in the future global energy supply: a review of 17 studies

Göran Berndes[a,*], Monique Hoogwijk[b], Richard van den Broek[c]

BioEnergy…

M. Hoogwijk et al. / Biomass and Bioenergy 25 (2003) 119–133

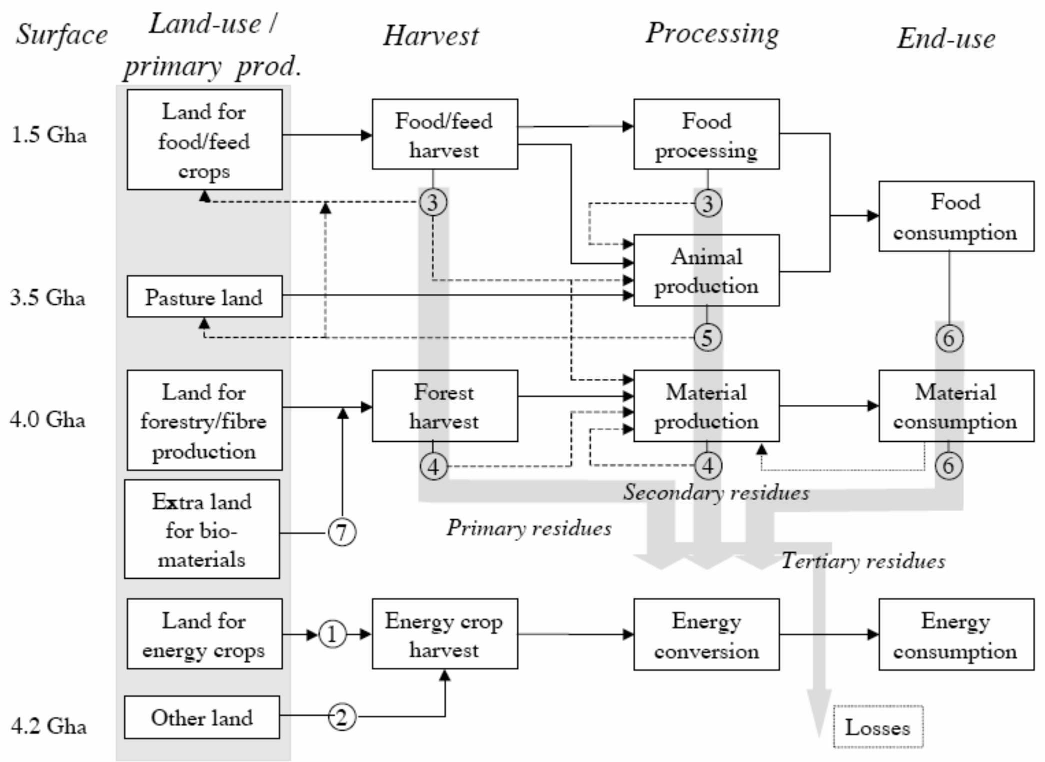

Fig. 1. Overview of various types of biomass flows and the global land surface (Based on: [1,22]). The black arrows indicate the main product flows, whereas the dotted lines show potential non-energy applications of various residue categories. The gray arrows represent the potential energetic use of the resources (1 = energy crops, 2 = energy crops at degraded land, 3 = agricultural residues, 4 = forest residues, 5 = animal manure, 6 = organic waste, 7 = bio-material).

Berndes et.al, 2003 …

BioEnergy Studies…

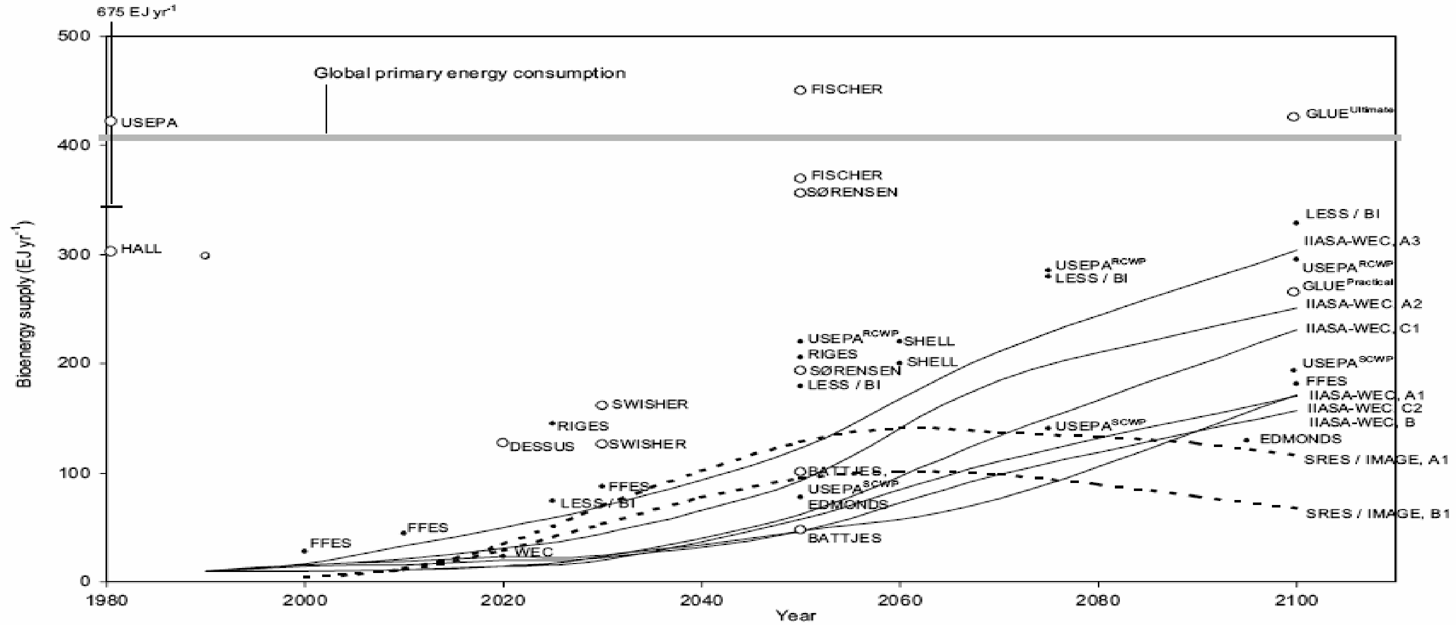

Fig. 2. Potential biomass supply for energy over time. Resource-focused studies are represented by hollow circles and demand-driven studies are represented by filled circles. USEPA and HALL, who do not refer to any specific time, are placed at the left side of the diagram. IIASA-WEC and SRES/IMAGE are represented by solid and dashed lines respectively, with scenario variant names given without brackets at the right end of each line. The present approximate global primary energy consumption is included for comparison. (The global consumption of oil, natural gas, coal, nuclear energy and hydro electricity 1999–2000 was about 365 EJ yr^{-1} [43]. Global biomass consumption for energy is estimated at 35–55 EJ yr^{-1} [44–46].)

BioEnergy Studies…

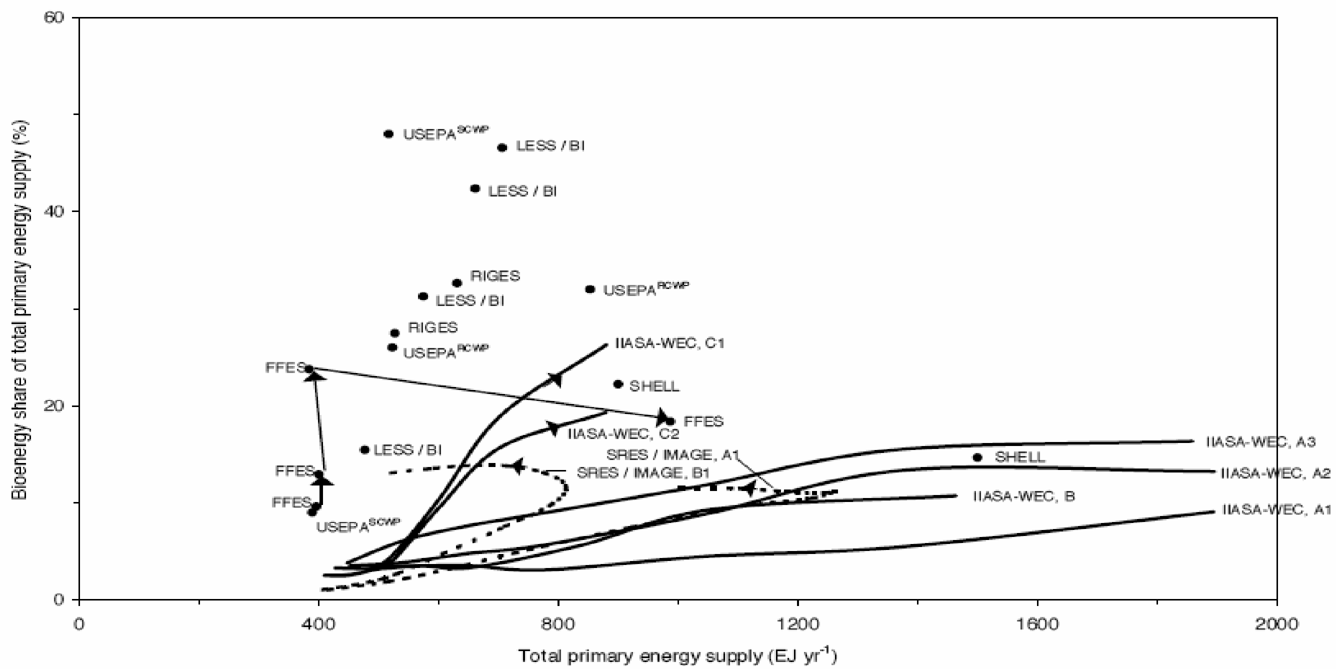

Fig. 3. Total primary energy supply, and share provided from biomass in demand-driven studies. Where no indication of development is made for a particular study, the changes over time are towards increasing total primary energy supply and bioenergy share. IIASA-WEC and SRES/IMAGE are represented by solid and dashed lines, respectively, with scenario variant names given without brackets at the right end of each line.

Berndes et.al, 2003 …

BioEnergy Studies…

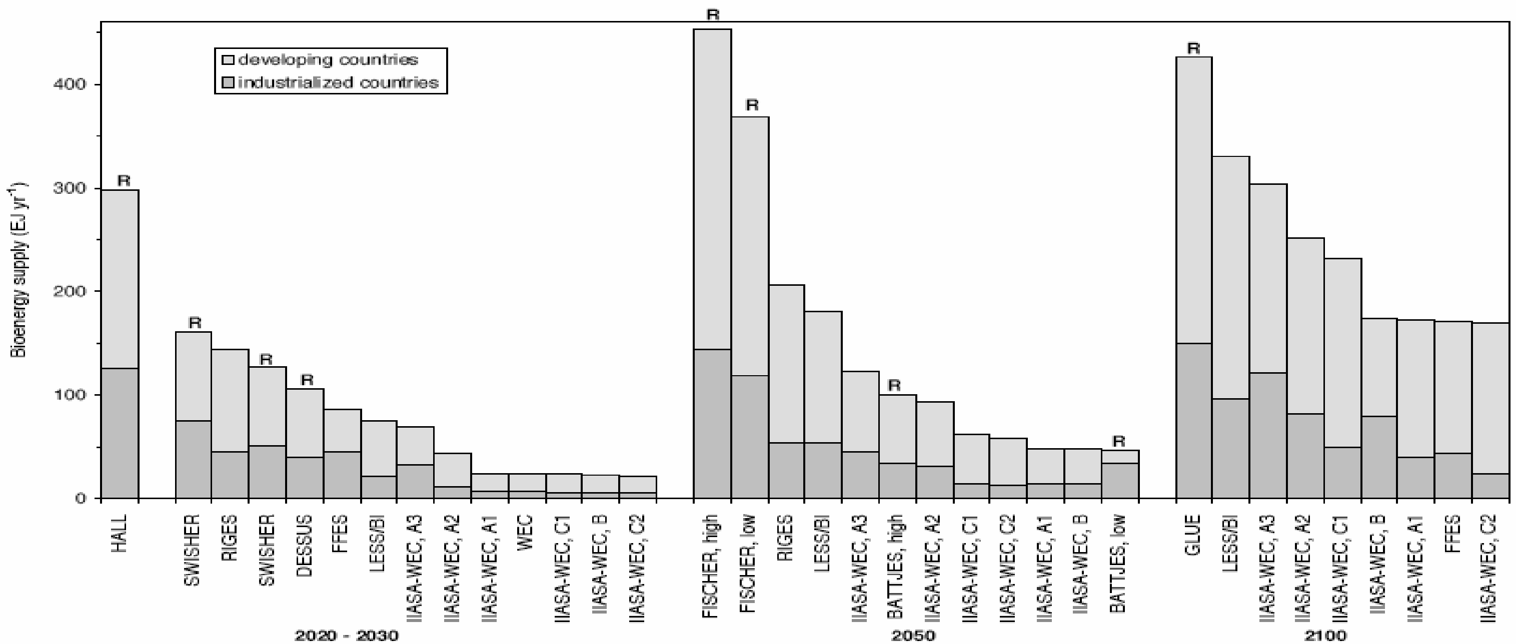

Fig. 4. Contribution of industrialized and developing regions to total bioenergy supply. Studies that are characterized as resource-focused are indicated with R. HALL does not refer to any specific time period. EDMONDS, USEPA and SHELL are not included since they only report results on the global level.

Berndes et.al, 2003 …

BioEnergy Studies…

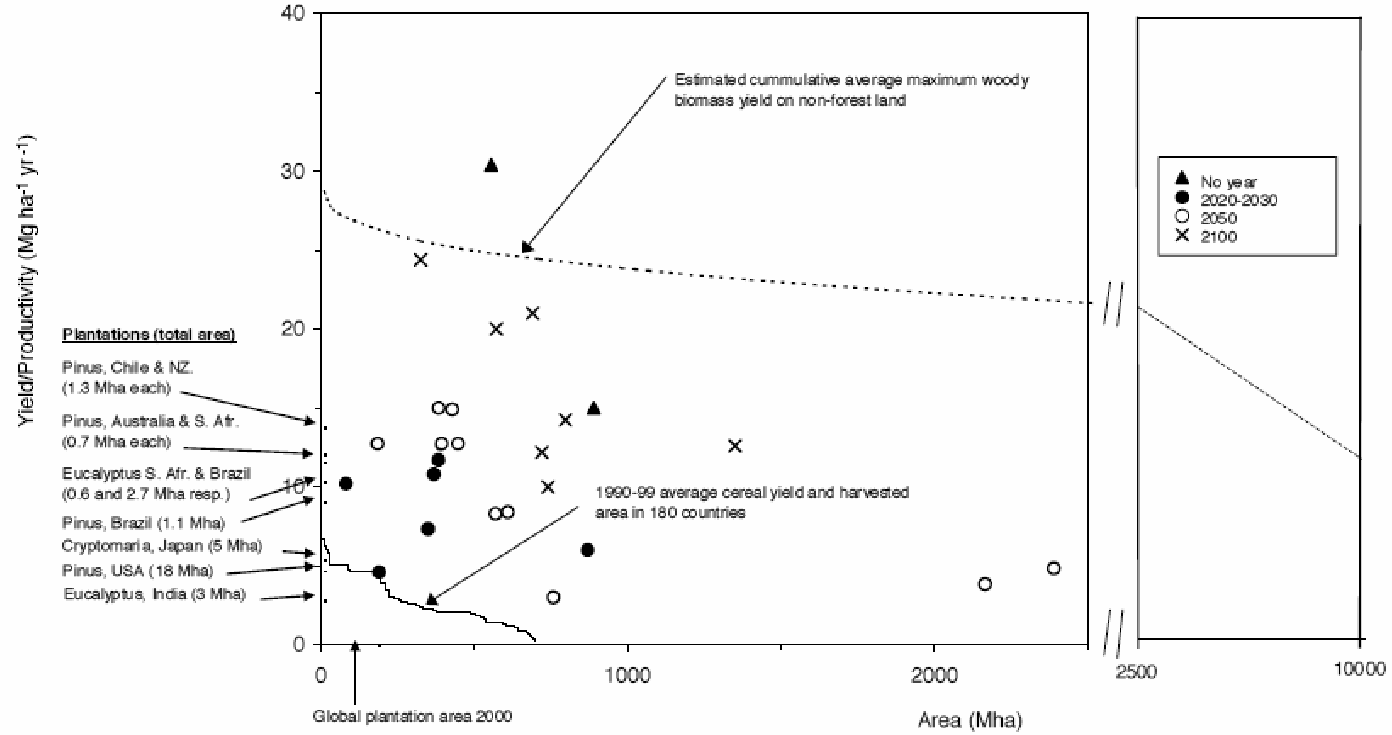

Fig. 6. Land use and yield levels in future energy crops production. Dots represent suggested plantation area and average yield levels in the studies. Lines represent suggested maximum woody biomass yield on non-forest land, and harvested area and yields in global cereal production. The global tree plantation area in 2000 is indicated on the X-axis. The average yield levels for Pinus and Eucalyptus plantations in selected countries are indicated along the Y-axis. The specific yields and plantation areas used are given for each study in Appendix A.

BioEnergy Studies…

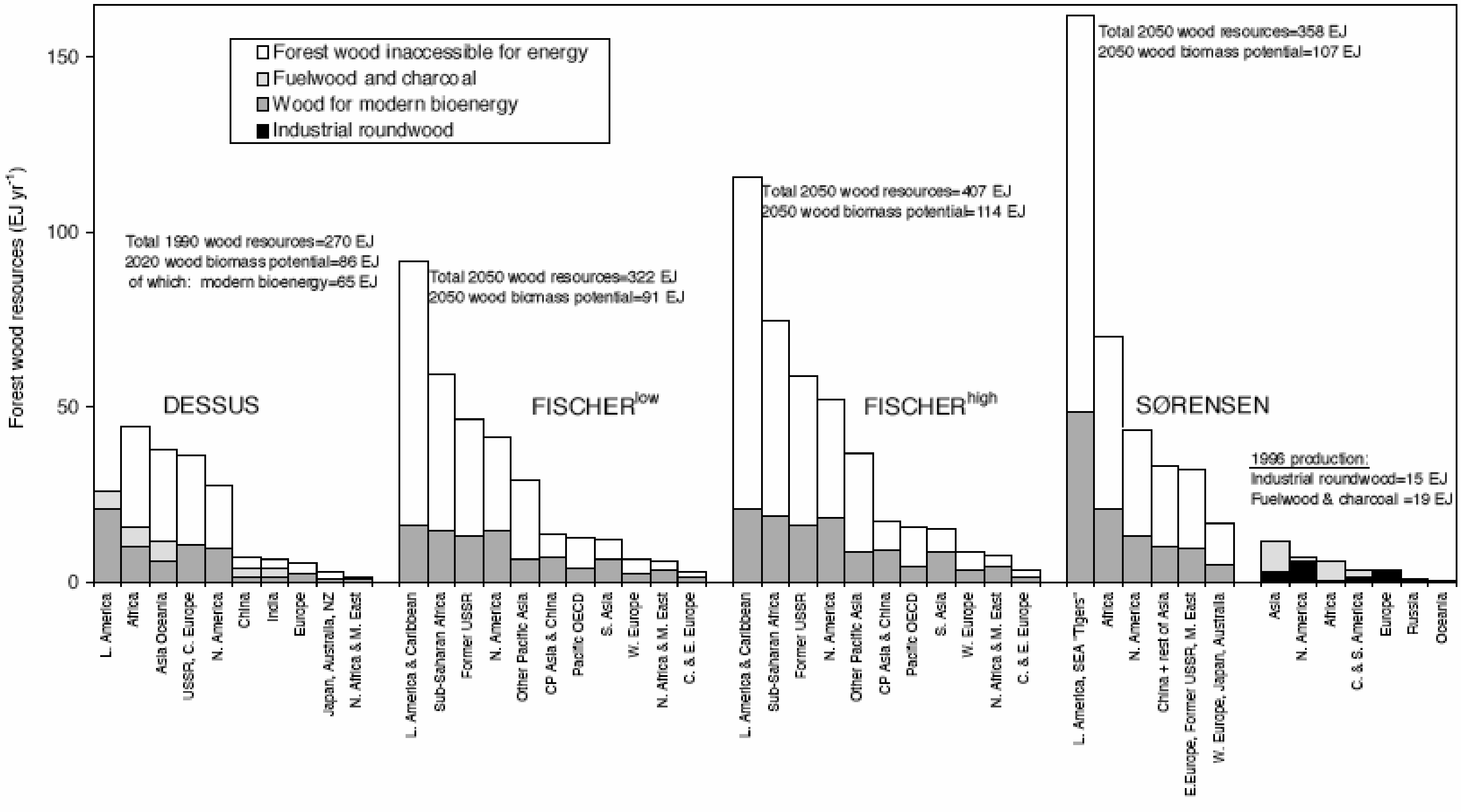

Fig. 8. The estimated bioenergy potential of forest wood. Note that the three studies use different geographic aggregation.

Patzek, 2003 …

Thermodynamics of the Corn-Ethanol Biofuel Cycle

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Email: patzek@patzek.berkeley.edu

Corn…

- Corn is the single largest U.S. crop (a record 300 million tons of moist corn grain in 2004).
- Corn is harvested from 30 million hectares, roughly the area of Poland or Arizona, and a bit less than 1/4 of all harvested cropland in the U.S.
- The recent average yield of moist corn grain has been 8600 kg/ha (and a record 10100kg/ha in 2004).

Corn…

Energy Inputs to Corn Production

Fossil energy is essential to industrial agriculture. The following are the major energy inputs to industrial corn farming:

- Nitrogen fertilizers (all fossil energy)
- Phosphate, potash, and lime (mostly fossil energy)
- Herbicides and insecticides (all fossil energy)
- Fossil fuels: diesel, gasoline, liquified petroleum gas (LPG), and natural gas (NG)
- Electricity (almost all fossil energy)
- Transportation (all fossil energy)
- Corn seeds and irrigation (mostly fossil energy)
- Infrastructure (mostly fossil energy)
- Labor (mostly fossil energy)

Energy…

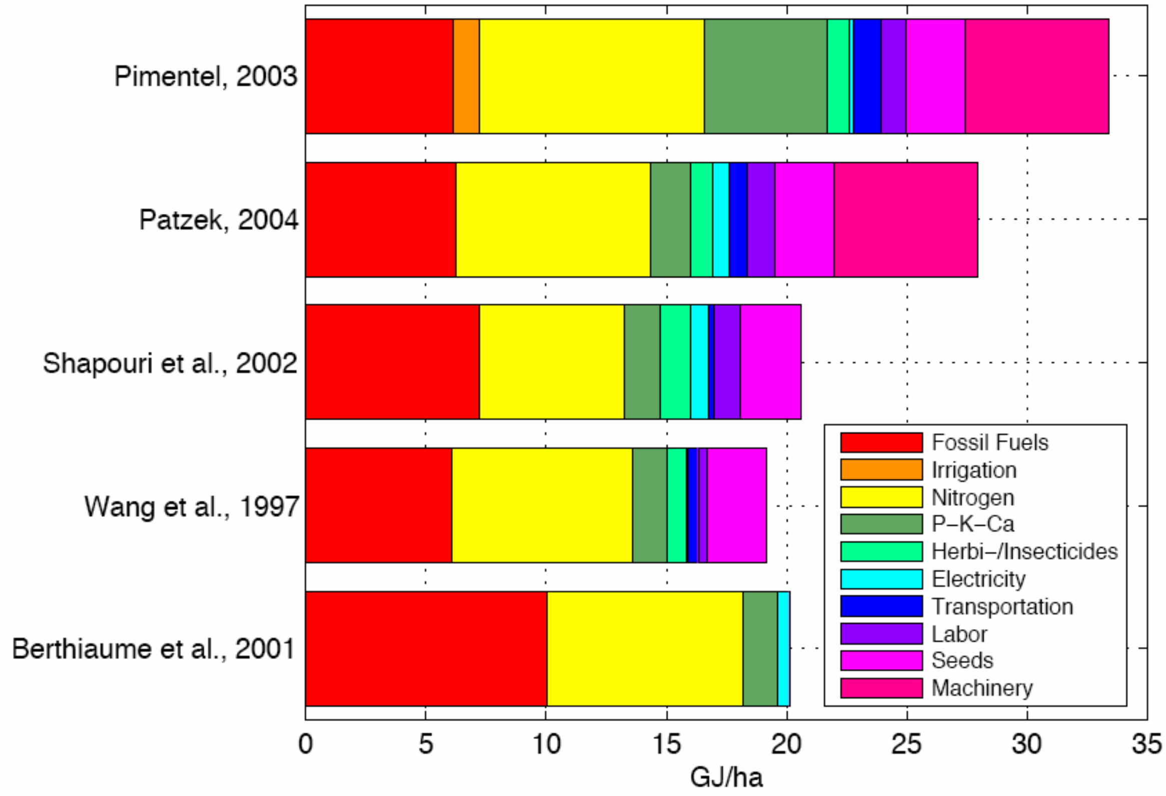

Figure 12: Major fossil energy inputs into corn farming.

Energy…

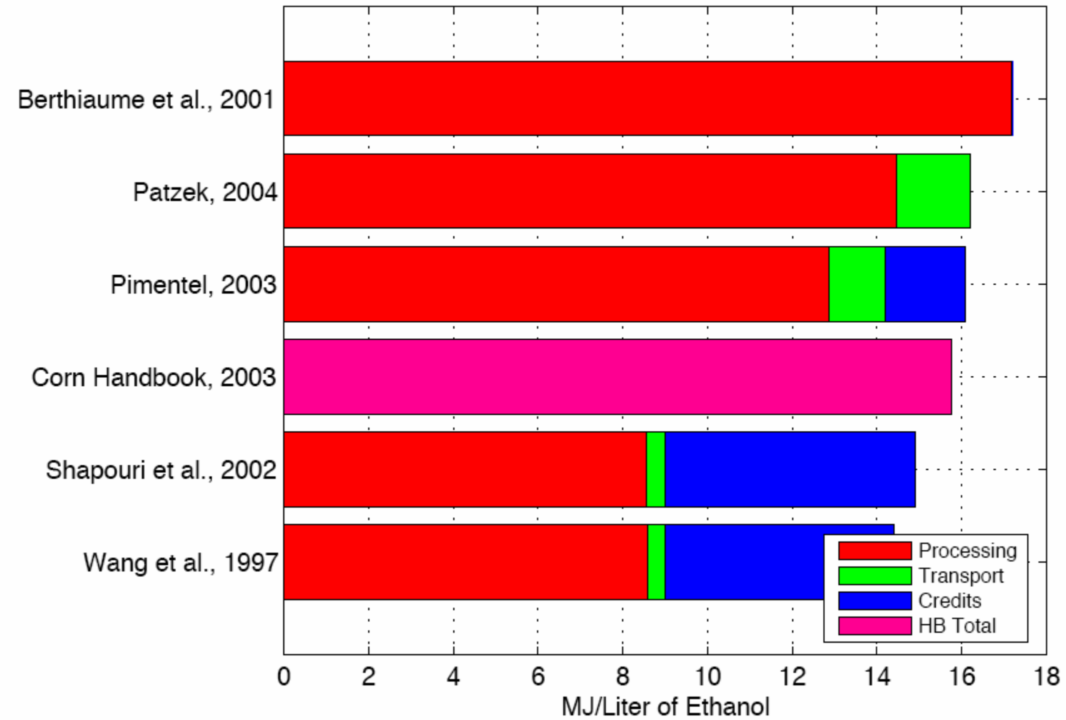

Figure 17: The average fossil energy inputs to ethanol production in a wet milling plant. The length of each bar is the total energy outlay to produce 1 liter of EtOH, and the blue parts denote the size of energy credits assumed by the different authors. The modern dry mill plants use 11.36 MJ/L as steam and 3.12 MJ/L as electricity, 14.5 MJ/L total, not counting transportation costs.

Energy…

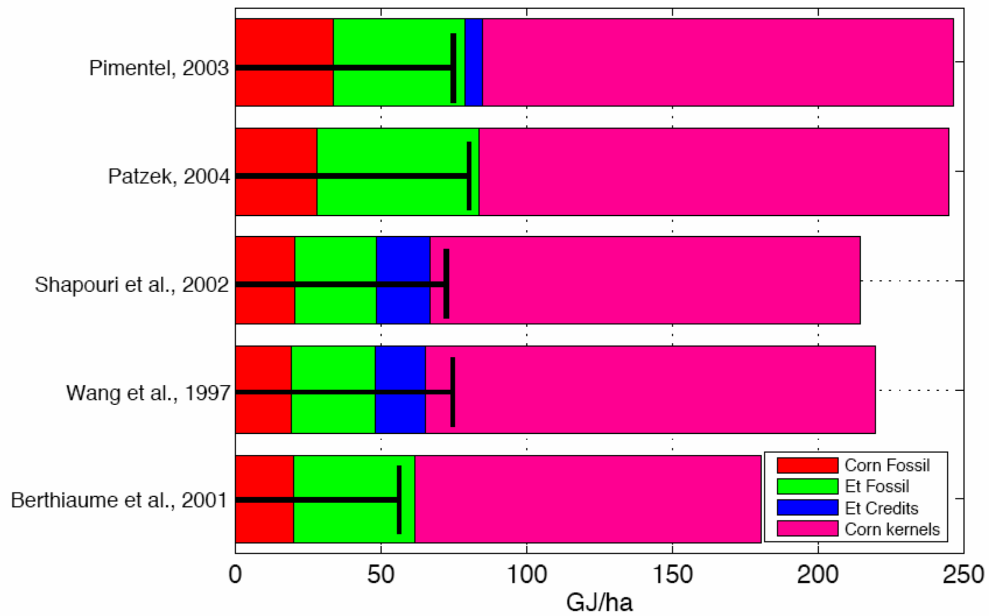

Figure 18: The overall energy balance of ethanol production. The two or three leftmost parts of each bar represent the specific fossil energy used in corn farming and ethanol production. The fossil energy inputs into ethanol production are the sum of the green part and the blue energy credit part for some authors. The rightmost part is the calorific value of corn grain harvested from 1 hectare. The total lengths of the horizontal bars represent all energy inputs into ethanol production. The horizontal lines with the vertical anchors represent the calorific value of ethanol obtained from one hectare of corn. Note that the total energy inputs into ethanol production are equivalent to ∼4–5 metric tonnes of gasoline per hectare. The ethanol's calorific value is equal to 1–1.3 metric tonnes of gasoline.

Energy…

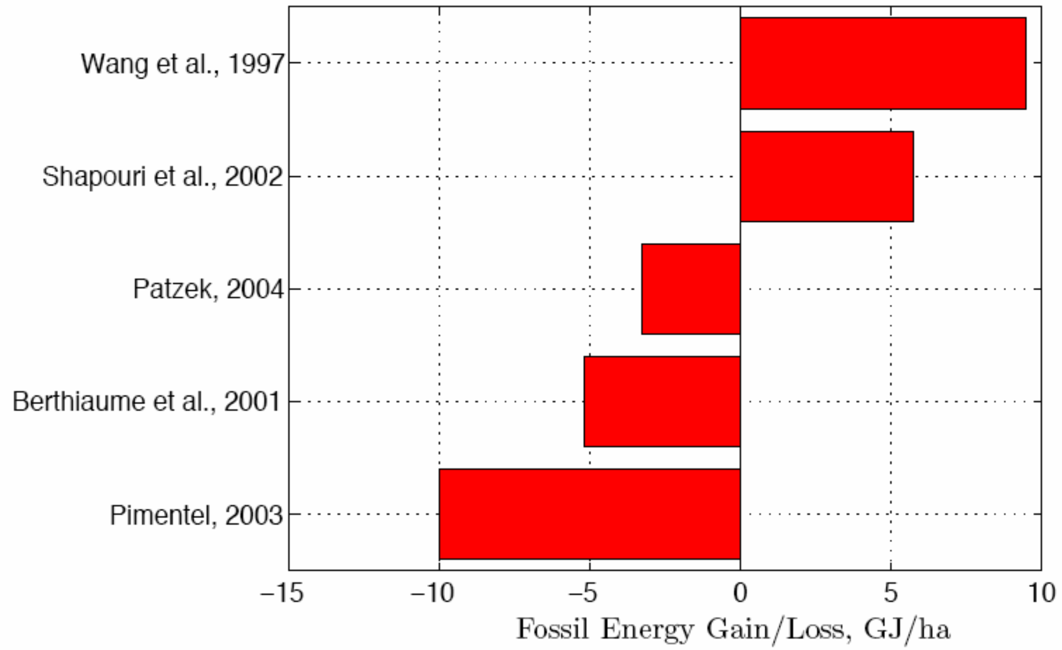

Figure 19: Fossil energy gain/loss in corn ethanol production. Note that the dubious energy credits described in Section 4.4 do not eliminate the use of fossil fuels in the first place, but present alternative useful outcomes of this use.

Energy...

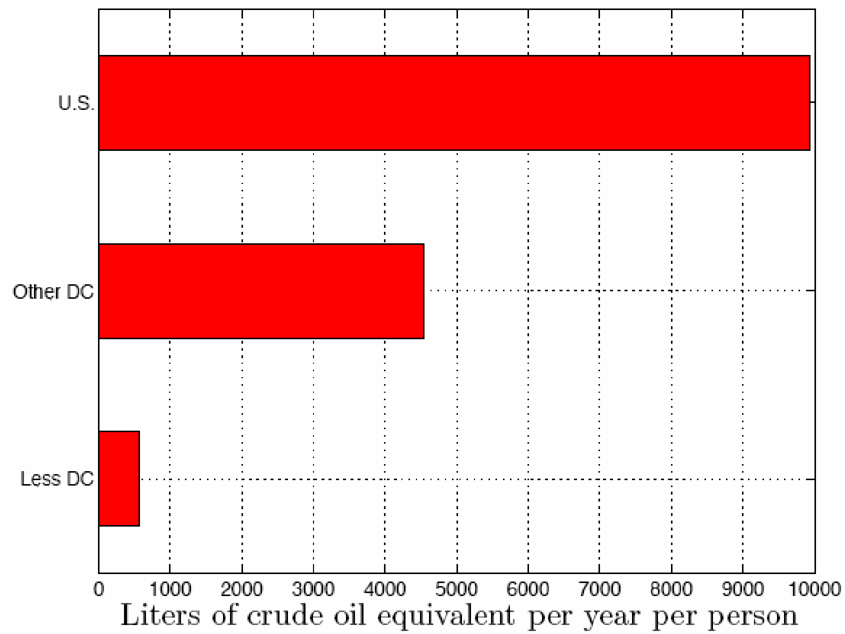

Figure 23: The 2001 per capita energy consumption in the U.S., other Developed Countries (DC), and the less Developed Countries. Source: The U.S. DOE Energy Information Agency.

Water…

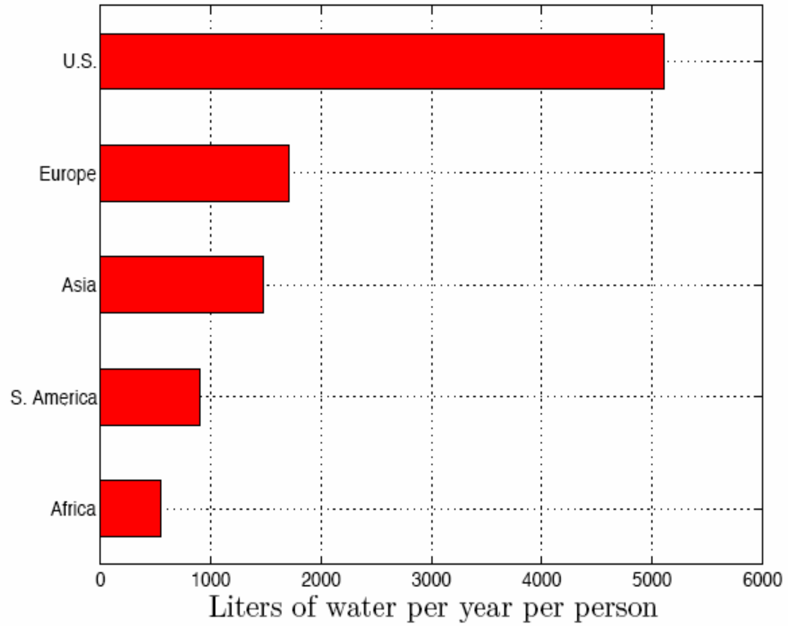

Figure 24: The 1990 per capita total (personal + industrial) water consumption in the U.S., and elsewhere. Source: Water Quality Association, 151 Naperville Road Lisle, IL 60532-1088, USA.

CO_2…

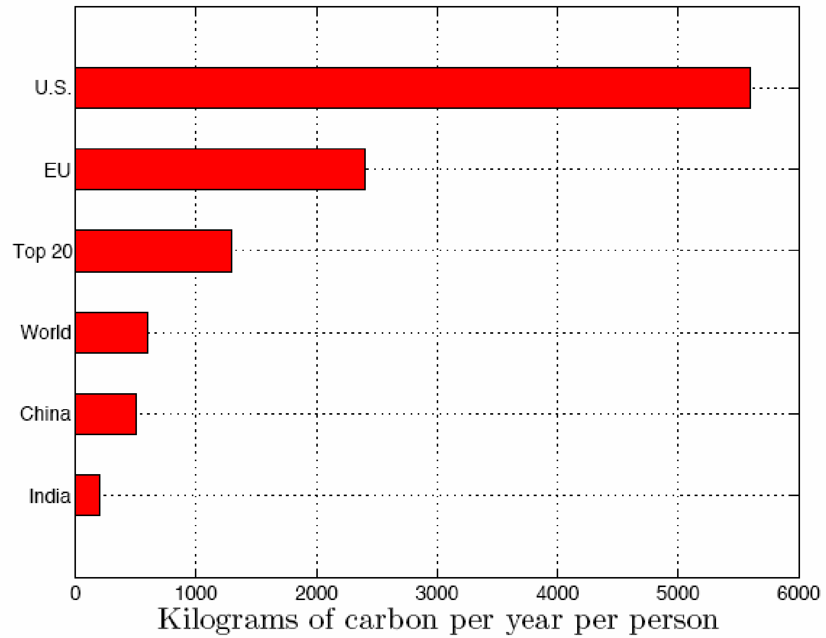

Figure 25: The 1999 per capita carbon emission estimates in the U.S., and elsewhere. Source: World Resources Institute, U.S. EIA.

CO_2…

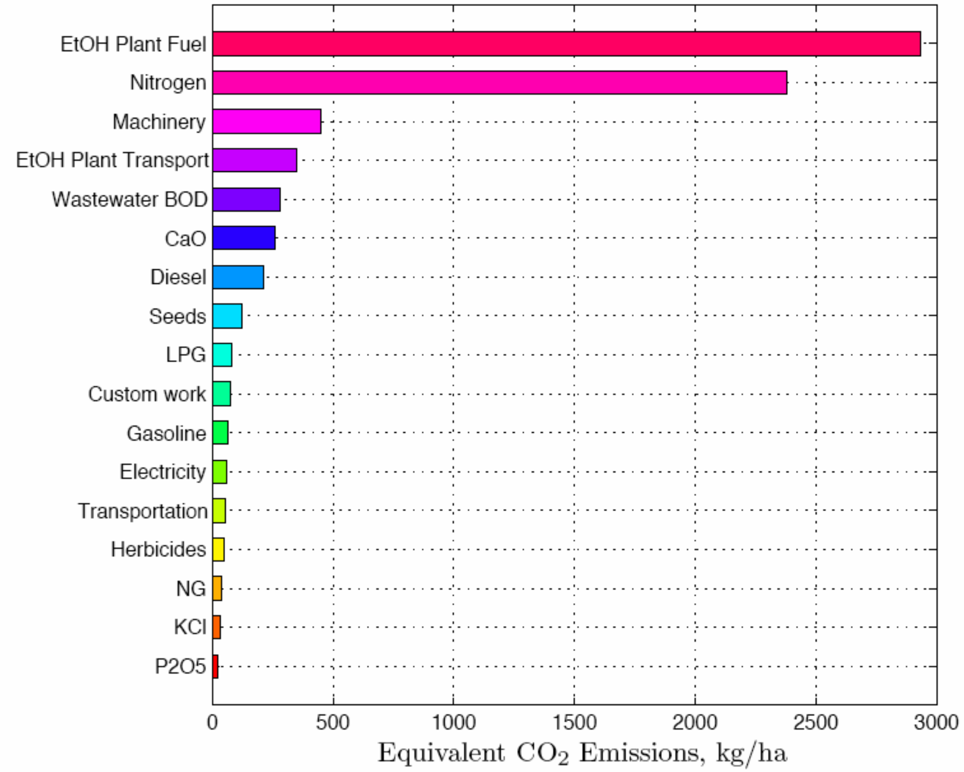

Figure 37: Equivalent CO_2 emissions from each major non-renewable resource consumed by the industrial Corn-EtOH cycle.

CO_2…

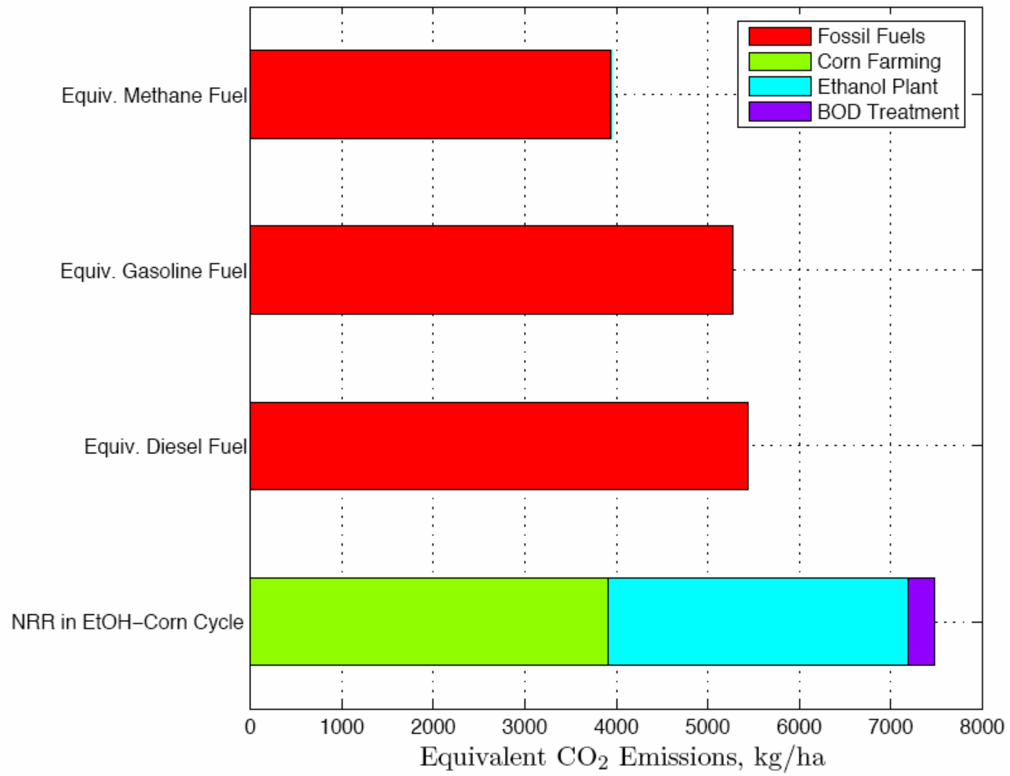

Figure 38: The total equivalent CO_2 emissions from the consumption of nonrenewable resources by the industrial corn-ethanol cycle. The CO_2 emissions from the energy-equivalent amounts of methane, gasoline and diesel fuel were increased by 15% to account for their recovery, transport, and refinement.

(Pimentel & Patzek, 2005)

Natural Resources Research, Vol. 14, No. 1, March 2005 (© 2005)
DOI: 10.1007/s11053-005-4679-8

Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower

David Pimentel[1,3] and Tad W. Patzek[2]

Received and accepted 30 January 2005

(Pimentel & Patzek, 2005)

Corn to Ethanol...

Table 1. Energy Inputs and Costs of Corn Production Per Hectare in the United States

Inputs	Quantity	kcal × 1000	Costs $
Labor	11.4 hrs[a]	462[b]	148.20[c]
Machinery	55 kg[d]	1,018[e]	103.21[f]
Diesel	88 L[g]	1,003[h]	34.76
Gasoline	40 L[i]	405[j]	20.80
Nitrogen	153 kg[k]	2,448[l]	94.86[m]
Phosphorus	65 kg[n]	270[o]	40.30[p]
Potassium	77 kg[q]	251[r]	23.87[s]
Lime	1,120 kg[t]	315[u]	11.00
Seeds	21 kg[v]	520[w]	74.81[x]
Irrigation	8.1 cm[y]	320[z]	123.00[aa]
Herbicides	6.2 kg[bb]	620[ee]	124.00
Insecticides	2.8 kg[cc]	280[ee]	56.00
Electricity	13.2 kWh[dd]	34[ff]	0.92
Transport	204 kg[gg]	169[hh]	61.20
Total		8,115	$916.93
Corn yield 8,655 kg/ha[ii]		31,158	kcal input: output 1:3.84

Table 2. Inputs Per 1000 l of 99.5% Ethanol Produced From Corn[a]

Inputs	Quantity	kcal × 1000	Dollars $
Corn grain	2,690 kg[b]	2,522[b]	284.25[b]
Corn transport	2,690 kg[b]	322[c]	21.40[d]
Water	40,000 L[e]	90[f]	21.16[g]
Stainless steel	3 kg[i]	12[i]	10.60[d]
Steel	4 kg[i]	12[i]	10.60[d]
Cement	8 kg[i]	8[i]	10.60[d]
Steam	2,546,000 kcal[j]	2,546[j]	21.16[k]
Electricity	392 kWh[j]	1,011[j]	27.44[l]
95% ethanol to 99.5%	9 kcal/L[m]	9[m]	40.00
Sewage effluent	20 kg BOD[n]	69[h]	6.0
Total		6,597	$453.21

5.1 E6/6.6 E6= net yield
0.77/1

(Pimentel & Patzek, 2005)

Switchgrass to Ethanol...

Table 3. Average Inputs and Energy Inputs Per Hectare Per Year for Switchgrass Production

Input	Quantity	10^3 kcal	Dollars
Labor	5 hr[a]	20[b]	$65[c]
Machinery	30 kg[d]	555	50[a]
Diesel	100 L[e]	1,000	50
Nitrogen	50 kg[e]	800	28[e]
Seeds	1.6 kg[f]	100[a]	3[f]
Herbicides	3 kg[g]	300[h]	30[a]
Total	10,000 kg yield[i] 40 million kcal yield	2,755 input/output ratio	$230[j] 1:14.4[k]

Table 4. Inputs Per 1000 l of 99.5% Ethanol Produced From U.S. Switchgrass

Inputs	Quantities	kcal × 1000[a]	Costs
Switchgrass	2,500 kg[b]	694[c]	$250[o]
Transport, switchgrass	2,500 kg[d]	300	15
Water	125,000 kg[e]	70[f]	20[m]
Stainless steel	3 kg[g]	45[g]	11[g]
Steel	4 kg[g]	46[g]	11[g]
Cement	8 kg[g]	15[g]	11[g]
Grind switchgrass	2,500 kg	100[h]	8[h]
Sulfuric acid	118 kg[i]	0	83[n]
Steam production	8.1 tons[i]	4,404	36
Electricity	660 kWh[i]	1,703	46
Ethanol conversion to 99.5%	9 kcal/L[j]	9	40
Sewage effluent	20 kg (BOD)[k]	69[l]	6
Total		7,455	$537

5.1 E6/7.5 E6= net yield
0.68/1

(Pimentel & Patzek, 2005)

Wood Cellulose to Ethanol…

Table 5. Inputs Per 1000 l of 99.5% Ethanol Produced From U.S. wood cellulose

Inputs	Quantities	kcal × 1000[a]	Costs
Wood, harvest (fuel)	2,500 kg[b]	400[c]	$ 250[n]
Machinery	5 kg[m]	100[m]	10[o]
Replace nitrogen	50 kg[c]	800	28[o]
Transport, wood	2,500 kg[d]	300	15
Water	125,000 kg[e]	70[f]	20[o]
Stainless steel	3 kg[g]	45[g]	11[g]
Steel	4 kg[g]	46[g]	11[g]
Cement	8 kg[g]	15[g]	11[g]
Grind wood	2,500 kg	100[h]	8[h]
Sulfuric acid	118 kg[b]	0	83[p]
Steam production	8.1 tons[b]	4,404	36
Electricity	666 kWh[bl]	1,703	46
Ethanol conversion to 99.5%	9 kcal/L[i]	9	40
Sewage effluent	20 kg (BOD)[j]	69[k]	6
Total		8,061	$575

5.1 E6/8.1E6= net yield
0.63/1

(Pimentel & Patzek, 2005)

Soybean to Biodiesel…

Table 6. Energy Inputs and Costs in Soybean Production Per Hectare in the U.S.

Inputs	Quantity	kcal × 1000	Costs $
Labor	7.1 h[a]	284[b]	92.30c
Machinery	20 kg[d]	360[e]	148.00[f]
Diesel	38.8 L[a]	442[g]	20.18
Gasoline	35.7 L[a]	270[h]	13.36
LP gas	3.3 L[a]	25[i]	1.20
Nitrogen	3.7 kg[j]	59[k]	2.29[l]
Phosphorus	37.8 kg[j]	156[m]	23.44[n]
Potassium	14.8 kg[j]	48[o]	4.59[p]
Lime	4800 kg[v]	1,349[d]	110.38[v]
Seeds	69.3 kg[a]	554[q]	48.58[r]
Herbicides	1.3 kg[j]	130[e]	26.00
Electricity	10 kWh[d]	29[s]	0.70
Transport	154 kg[t]	40[u]	46.20
Total		3,746	$537.22
Soybean yield 2,668 kg/ha[w]		9,605	kcal input: output 1:2.56

Table 7. Inputs Per 1,000 kg of Biodiesel Oil From Soybeans

Inputs	Quantity	kcal × 1000	Costs $
Soybeans	5,556 kg[a]	7,800[a]	$1,117.42[a]
Electricity	270 kWh[b]	697[c]	18.90[d]
Steam	1,350,000 kcal[b]	1,350[b]	11.06[e]
Cleanup water	160,000 kcal[b]	160[b]	1.31[e]
Space heat	152,000 kcal[b]	152[b]	1.24[e]
Direct heat	440,000 kcal[b]	440[b]	3.61[e]
Losses	300,000 kcal[b]	300[b]	2.46[e]
Stainless steel	11 kg[f]	158[f]	18.72[g]
Steel	21 kg[f]	246[f]	18.72[g]
Cement	56 kg[f]	106[f]	18.72[g]
Total		11,878	$1,212.16

9.0 E6/11.9E6= net yield
0.75/1

(Pimentel & Patzek, 2005)

Sunflower to Biodiesel…

Table 8. Energy Inputs and Costs in Sunflower Production Per Ha in the U.S.

Inputs	Quantity	kcal × 1000	Costs $
Labor	8.6 h[a]	344[b]	111.80[c]
Machinery	20 kg[d]	360[e]	148.00[f]
Diesel	180 L[a]	1,800[g]	93.62[h]
Nitrogen	110 kg[j]	1,760[k]	68.08[l]
Phosphorus	71 kg[j]	293[m]	44.03[n]
Potassium	100 kg[j]	324[o]	34.11[p]
Lime	1000 kg[j]	281[d]	23.00[v]
Seeds	70 kg[a]	560[q]	49.07[r]
Herbicides	3 kg[j]	300[v]	60.00[i]
Electricity	10 kWh[d]	29[s]	0.70
Transport	270 kg[t]	68[u]	81.00
Total		6,119	$601.61
Sunflower yield 1,500 kg/ha[w]		4,650	kcal input: output 1:0.76

Table 9. Inputs Per 1,000 kg of Biodiesel Oil From Sunflower

Inputs	Quantity	kcal × 1000	Costs $
Sunflower	3,920 kg[a]	15,990[a]	$1.570.20[a]
Electricity	270 kWh[b]	697[c]	18.90[d]
Steam	1,350,000 kcal[b]	1,350[b]	11.06[e]
Cleanup water	160,000 kcal[b]	160[b]	1.31[e]
Space heat	152,000 kcal[b]	152[b]	1.24[e]
Direct heat	440,000 kcal[b]	440[b]	3.61[e]
Losses	300,000 kcal[b]	300[b]	2.46[e]
Stainless steel	11 kg[f]	158[f]	18.72[g]
Steel	21 kg[f]	246[f]	18.72[g]
Cement	56 kg[f]	106[f]	18.72[g]
Total		19,599	$1,662.48

9.0 E6/19.6E6= net yield
0.46/1

Pimentel & Patzek, 2005 …

Energy outputs from ethanol produced using corn, switchgrass, and wood biomass were each less than the respective fossil energy inputs. The same was true for producing biodiesel using soybeans and sunflower, however, the energy cost for producing soybean biodiesel was only slightly negative compared with ethanol production. Findings in terms of energy outputs compared with the energy inputs were: • Ethanol production using corn grain required 29% more fossil energy than the ethanol fuel produced. • Ethanol production using switchgrass required 50% more fossil energy than the ethanol fuel produced. • Ethanol production using wood biomass required 57% more fossil energy than the ethanol fuel produced. • Biodiesel production using soybean required 27% more fossil energy than the biodiesel fuel produced (Note, the energy yield from soy oil per hectare is far lower than the ethanol yield from corn). • Biodiesel production using sunflower required 118% more fossil energy than the biodiesel fuel produced.

Feasibility of Large-Scale Biofuel Production

Does an enlargement of scale change the picture?

Mario Giampietro, Sergio Ulgiati, and David Pimentel

Biofuels are widely seen as a feasible alternative to oil. Indeed, in 1995 the Clinton Administration proposed amendments to the Clean Air Act that would require gasoline sold in the nine most polluted US cities to contain additives from renewable sources, such as grain alcohol. This move, even if blocked by a three-judge panel of the US Court of Appeals in Washington, DC (Southerland 1995), has helped to focus attention on the question of whether research and development in biofuel production from agricul-

Large-scale biofuel production is not an alternative to the current use of oil and is not even an advisable option to cover a significant fraction of it

for fossil fuels. Common examples are ethanol, methanol, and biodiesel. Ethanol alcohol can be obtained by yeast- or bacteria-mediated fermentation of sugar crops, such as sugarcane, sugarbeet, and sweet sorghum, or of starchy crops, such as corn and cassava. It can also be obtained, albeit at lower yields, from cellulose, a sugar polymer from woody crops, through acid or enzymatic hydrolysis followed by fermentation. Methanol can be obtained from wood or woody crops by means of a wood gasification process followed by com-

Table 1. Typical biofuel production systems from agricultural crops.

Indicators of performance	Biodiesel[a]	Ethanol in temperate areas	Ethanol in (sub)tropical areas
Gross energy yield ($GJ \cdot ha^{-1} \cdot yr^{-1}$)	20–40	40–80	80[b]–130[c]
Net energy yield ($GJ \cdot ha^{-1} \cdot yr^{-1}$)	<0–10	<0–30	50[b]–70[c]
Output–input energy ratio	0.6–1.3	0.5–1.7	3.0[b]–2.5[c]
Net to gross ratio (F*/F1)	<0–0.2	<0–0.4	0.66[b]–0.60[c]
Water requirement ($t \cdot ha^{-1} \cdot yr^{-1}$)	4000–7000	4000–8000	10,000[b]–15,000[c]
Energy throughput (net MJ/h)	<0–250	<0–1000	250[b]–1600[c]
Best-performing system	oilseed rape	corn–sorghum	sugarcane
Land requirement (ha/net GJ)	0.100	0.033	0.020[b]–0.014[c]
Water requirement (t/net GJ)	500	170	200[b]–200[c]
Labor requirement (h/net GJ)	4	1	4[b]–0.6[c]

[a]Trans-methylester from oil seeds (sunflower, rapeseed, or soybeans). Sunflower and soybean systems have net energies close to or less than zero.
[b]Low-input production, as in the Brazilian ProAlcohol Project (Giampietro et al. 1997a).
[c]High-input production, as reported in Pimentel et al. (1988).

Water…

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Water…

Using the numbers in the previous table…

- FL Transportation energy = 9.5 E17 J/yr
- FL water consumption = 11.3 E 12 l/yr
- Water required for ethanol from sugarcane = 200t/net GJ = 2 E5 l/1 E9 J

$$\frac{9.5\text{ E }17\text{ J/yr}}{1.0\text{ E9 J/ha}} * 2\text{E5 l} =$$ **1.9 E 14 liters of water**

This is almost 17 times current total water consumption in the State!!!

Global Land…

Table 2. Land and water demand in large-scale biofuel production compared to availability (expressed on a per capita basis).

Country	Commercial energy consumption (GJ/yr)[a]	Arable land available (ha)[b]	Fresh water withdrawal (t/yr)[b]	Land demand for biofuel (ha)	Water demand for biofuel (t/yr)	Total arable land demand[f]/ supply ratio	Biofuel water demand/current withdrawal ratio
Burundi	8	0.20	20	0.16[c]	1600[c]	1.8	80
Egypt	21	0.05	1028	0.42[c]	4200[c]	9.4	4
Ghana	6	0.08	35	0.12[c]	1200[c]	2.5	34
Uganda	8	0.28	20	0.16[c]	1600[c]	1.4	80
Zimbabwe	31	0.29	136	0.62[c]	6200[c]	2.9	46
Argentina	66	0.81	1042	1.32[c]	13,200[c]	2.1	13
Brazil	49	0.40	245	0.98[c]	9800[c]	3.0	40
Canada	437	1.75	1688	14.42[d]	74,300[d]	8.7	44
Costa Rica	35	0.10	780	0.70[c]	7000[c]	8.0	9
Mexico	54	0.27	921	1.78[d]	9200[d]	7.6	10
United States	325	0.76	1868	10.72[d]	55,200[d]	14.6	30
Bangladesh	3	0.08	212	0.06[c]	600[c]	1.8	3
China	25	0.08	462	0.50[c]	5000[c]	7.2	11
India	12	0.20	612	0.24[c]	2400[c]	2.2	4
Japan	134	0.03	732	4.42[d]	22,800[d]	148.3	31
France	163	0.32	778	5.38[d]	27,700[d]	17.6	36
Italy	113	0.16	996	3.73[d]	19,200[d]	24.3	19
Netherlands	202	0.06	994	6.66[d]	34,300[d]	112.0	34
Spain	87	0.52	1188	2.87[d]	14,800[d]	6.5	12
United Kingdom	155	0.12	253	5.11[d]	26,300[d]	43.6	104
Australia	216	2.90	1306	3.02[e]	43,200[e]	1.5	33

Giampietro, et.al 2003 …

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Land...

Methanol production from woody biomass

Characteristics of the process	Conventional wood production	Short-rotation woody crops
Fertilizer input (as N, P_2O_5, K_2O) ($kg \cdot ha^{-1} \cdot yr^{-1}$)	none	100, 20, 60[a]
Pesticide application ($kg \cdot ha^{-1} \cdot yr^{-1}$)	none	0.39[b]
Energy input in wood production (MJ/t gross methanol produced)	0	2054[c]
Energy input in wood production (MJ/ha)	0	9143[c]
Energy inputs for wood harvesting and handling (MJ/t gross methanol produced)	data not available	1712[d]
Energy inputs at the plant (F2) (MJ/t gross methanol produced)	8726[e]	8726[e]
Wood yield ($kg \cdot ha^{-1} \cdot yr^{-1}$)	2500	10,000
Heat equivalent of wood (MJ/kg)	16.73	16.73
Energy density of wood biomass production for fuel (Q) ($MJ \cdot ha^{-1} \cdot yr^{-1}$)	41,820	167,300
Conversion efficiency of wood biomass into methanol (F1/Q)	0.53[e]	0.53[e]
Net/gross methanol supply (F*/F1)	0.55[f]	0.37[g]
Net methanol supply (F*)[h] (GJ/ha)	12.2	32.8

Land…

Using the numbers in the previous table…

FL gasoline consumption = 9.49 E 17 J/yr

$$\frac{9.49\text{ E }17\text{ J/yr}}{12.2\text{ E9 J/ha}} = 7.8\text{ E }7\text{ ha of land}$$

Florida LAND Area = 1.4 E7 ha

We would need 5.6 Florida's (7.8/1.4 =5.6) just to produce our current gasoline consumption

With short rotation woody crops (switch grass, etc) we would need about 2 Florida's

The Tapestry...

OK, so lets put it all together...the bottom line is BIOMASS is not the answer....

So what then?

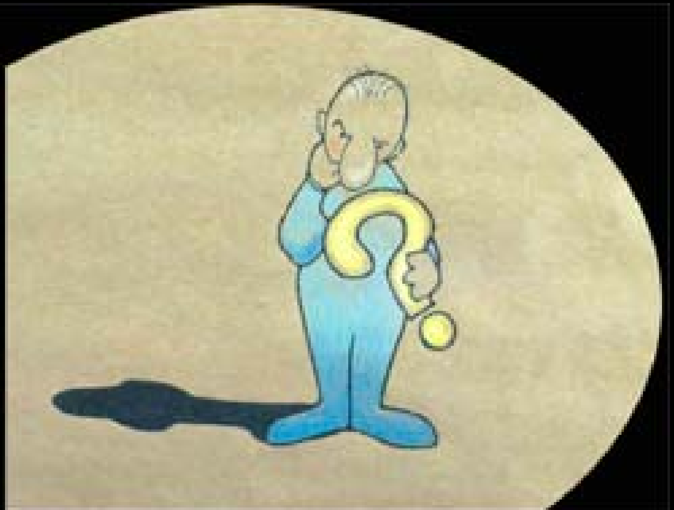
Leslie White's Law *"Other factors remaining constant, culture evolves as the amount of energy harnessed per capita per year is increased..."*

The Tapestry…

…So, then do we de-evolve with less energy?

There's a good chance that the energy with which we power our technological civilization is peaking, and there does not appear to be alternatives.

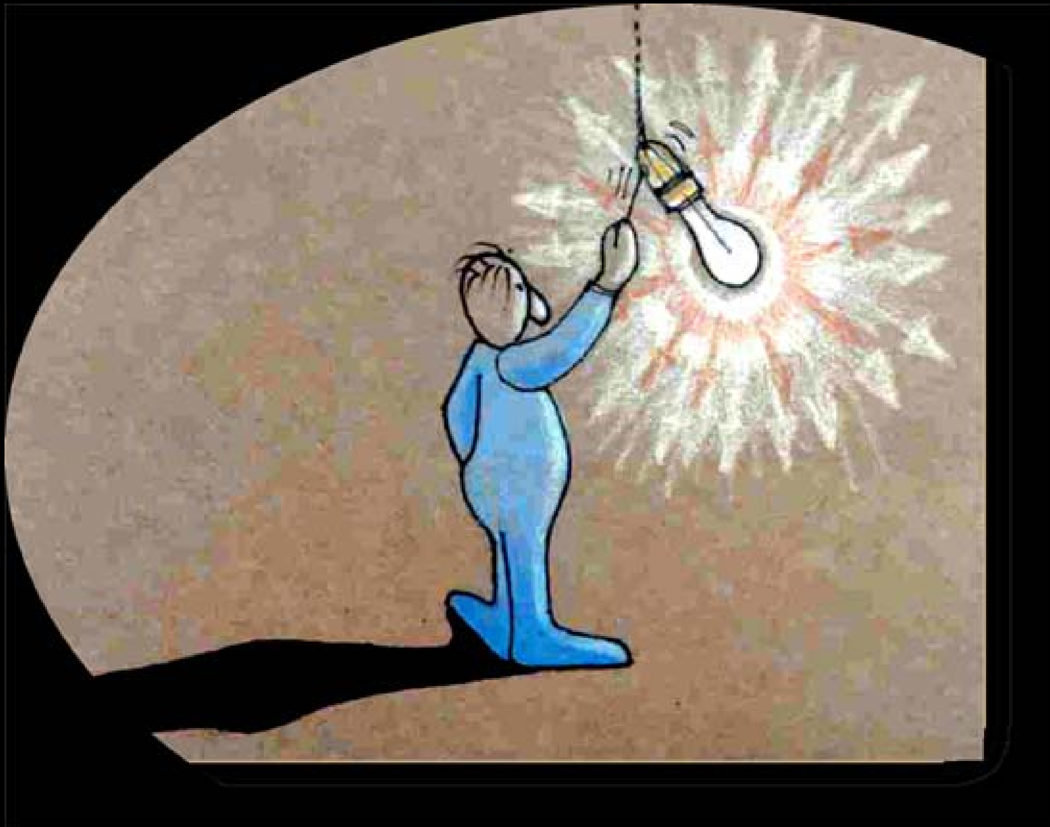
(prudence would suggest that even if you believe in a technological fix, we should have a backup plan …just in case)



The Tapestry…

After the peak…

Thoughts for transition and descent…



The Tapestry… Environment

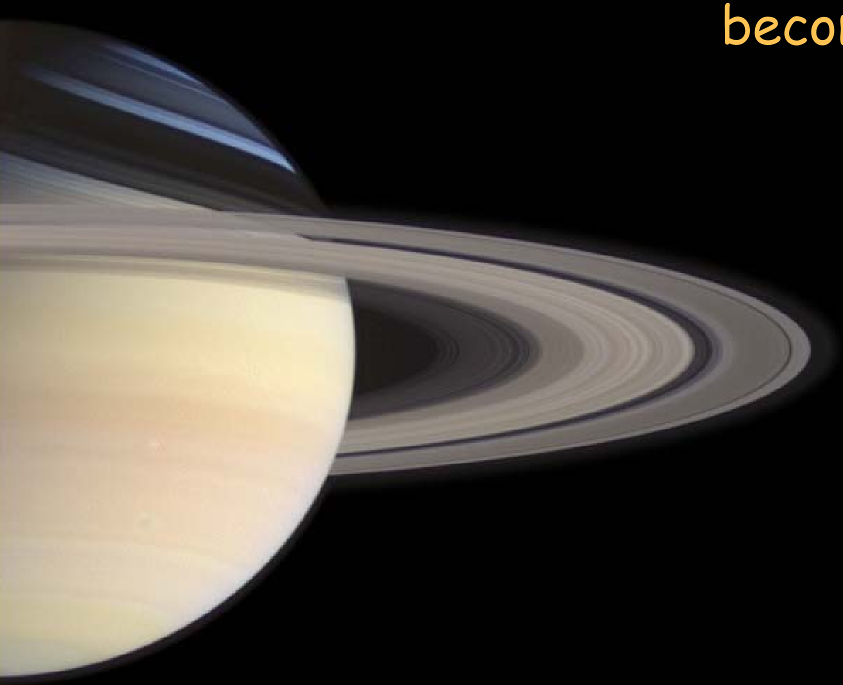
1. Recycle should become the main strategy for dealing with "wastes"
2. We will need to rebuild natural capital (forests, soils, wetlands and water)
3. Discontinue ecological bigotry that calls some species exotic, and undesirable.. Use all of the earth's biodiversity in rebuilding global natural capital.

The Tapestry…Work

1. Everyone needs to feel part of the society with sufficient useful work contributing to productivity.
2. Cut wages across the board before laying off workers
3. Institute minimum and maximum wage reform
4. Achieve full employment of the young and old through sliding pay scales
5. Tele-commuting where possible

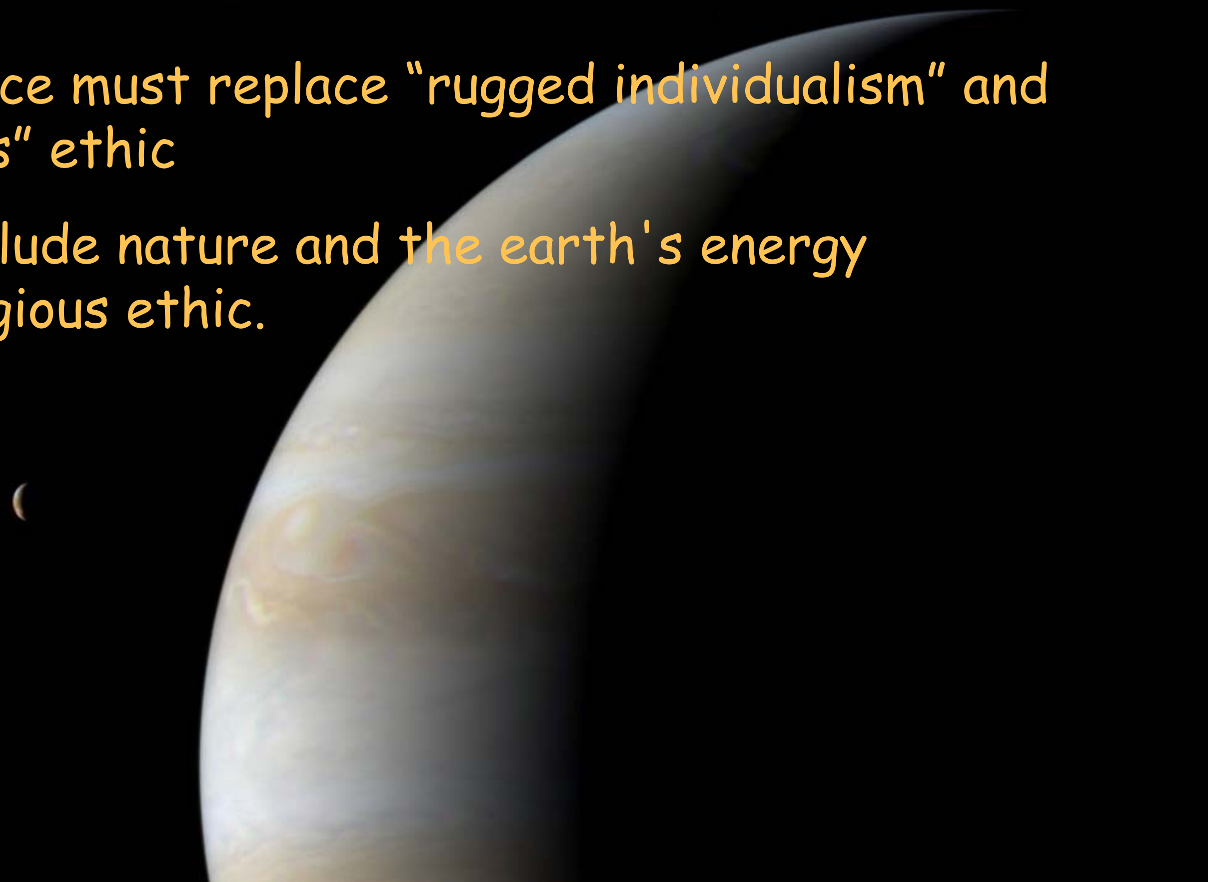
The Tapestry…Information

1. TV needs moderation and focus on broader issues with some optimal entertainment
2. TV is the global "campfire" and as such needs to focus on shared ideas, purposes, and ethics.
3. Universities will need to once again become society's storehouse of information, and its generation, testing, and selecting.
4. How much information is appropriate?



The Tapestry…Religion

1. Religion must stress the larger scale issues such as environment, capitalism, globalization, community, population growth, war
2. Service and sacrifice must replace “rugged individualism” and “growth is progress” ethic
3. We will need to include nature and the earth's energy systems in our religious ethic.



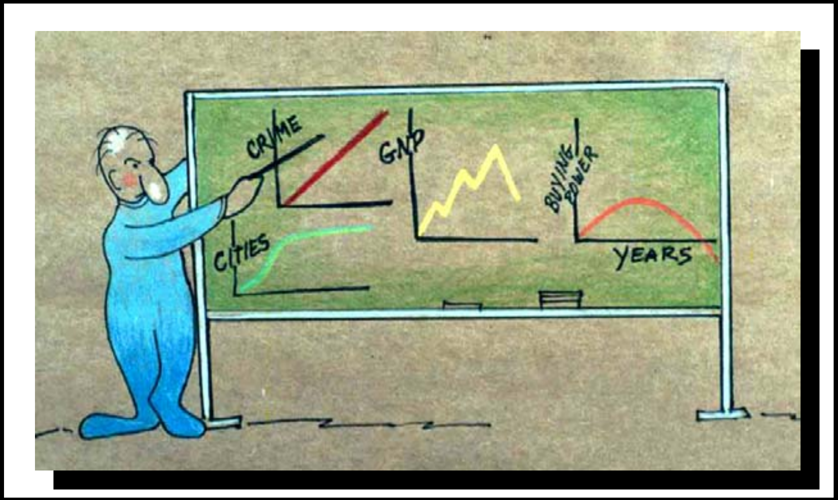
The Tapestry… Education

1. All education is environmental education, systems education is a must.

2. A common core of knowledge in science, arts, civics, and culture with flexibility built in for the rest.

3. Orient schools to stress different life themes, not everyone needs to go to college

4. With reduced energy comes a welcomed reduction in the technology and "big sports" of education… smaller schools can result.



"As sometimes attributed to past cultures, people may find glory in being an agent of the Earth. It remains to be seen whether the social mechanisms will be conscious, logical, emotional, ritualistic, regimented, or by some means we can't imagine."

H.T. Odum, 2001