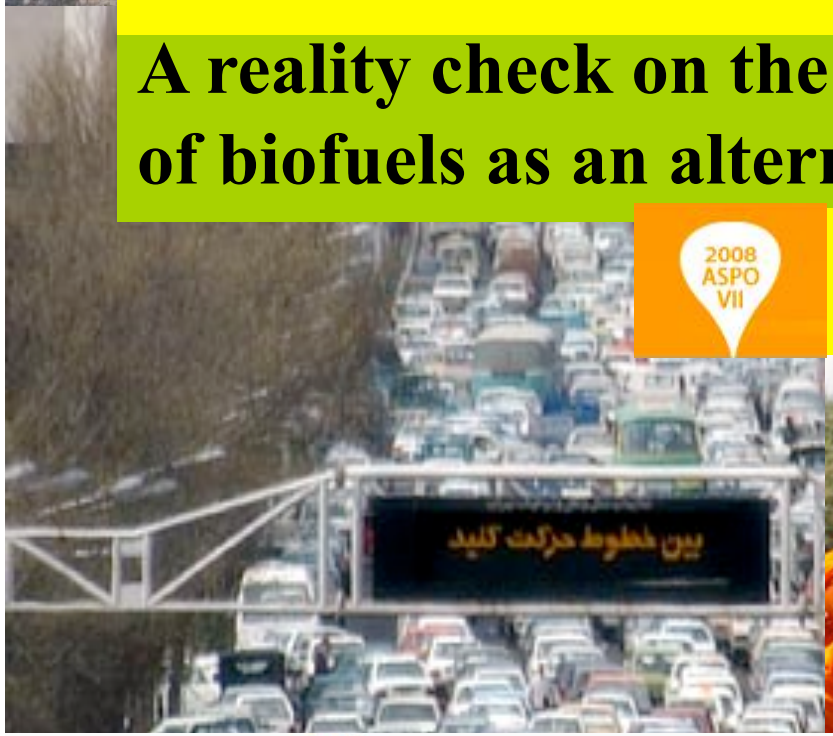
Mario Giampietro – ICREA Research Professor

A reality check on the feasibility and desirability of biofuels as an alternative to fossil energy fuels



2008 ASPO VII

Peak Oil: from below ground to above ground

VII ANNUAL INTERNATIONAL ASPO CONFERENCE

icta

Institute of Environmental Science and Technology • UAB

Research Group on Integrated Assessment

Structure of the talk

#1 **What happened to common sense?**

#2 **Some elements of Bioeconomics to assess the feasibility and desirability of biofuels**

#3 **Is it a large-scale biofuel production a viable and desirable alternative to fossil energy?**

#4 **How to explain the current blunder?**

PART 1

What happened to common sense?

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PM-10 emissions and power of a Diesel engine fueled with crude and refined Biodiesel from salmon oil

J.F. Reyes *, M.A. Sepúlveda

Department of Mechanization and Energy, Faculty of Agricultural Engineering, University of Concepción, Vicente Mendez 595 Chillan Chile

Received 18 October 2005; received in revised form 31 January 2006; accepted 5 February 2006

when looking for alternative fuels, does everything go?

What about refined biodiesel from human fat after liposuction?

+

=

after all this is a win-win solution . . .

"There's an interesting business model: link a biodiesel plant with the cosmetic surgeons," says Mr. Bethune. "In Auckland we produce about 330 pounds of fat per week from liposuction, which would make about 40 gallons of fuel. If it is going to be chucked out, why not?"

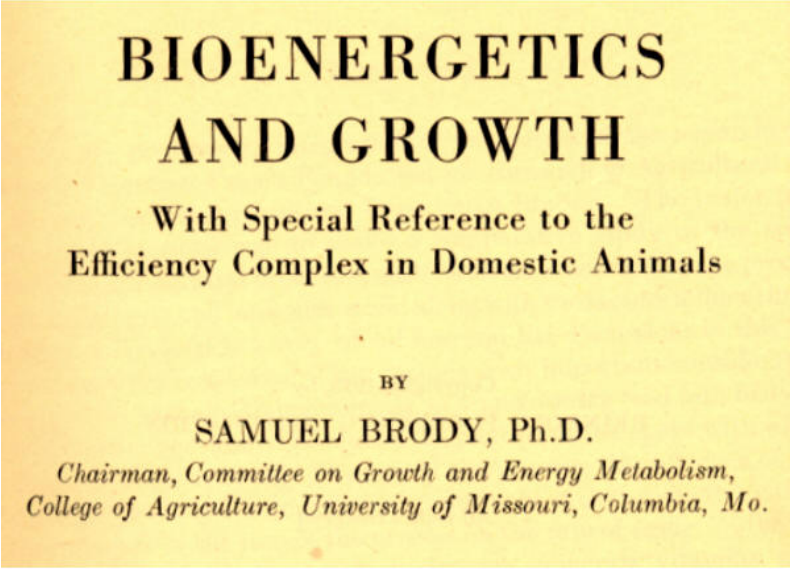
Peter Bethune

Peter Buthune is the founder of Earthrace, a project to promote the use of biofuel trying to break the round-the-world powerboat speed record in a boat powered by biodiesel fuel partly **manufactured from human fat**.

"A large liposuction operation involves removing 10 pounds of fat, which would drive a car about 50 miles once converted"

The lean Mr. Bethune had about three ounces of fat extracted from his body in a liposuction procedure, and he is seeking volunteers to donate more.

From: http://calorielab.com/news/2005/11/11/



BIOENERGETICS
AND GROWTH

With Special Reference to the
Efficiency Complex in Domestic Animals

BY

SAMUEL BRODY, Ph.D.

Chairman, Committee on Growth and Energy Metabolism,
College of Agriculture, University of Missouri, Columbia, Mo.

Samuel Brody - writing in 1945! – ends his masterpiece on energy and power analysis of US agriculture with a chapter about the future of power and energy sources for agriculture. In that chapter he stigmatizes those proposing biofuels* [based on corn] *for mechanizing US agriculture using a famous quote attributed to Marie Antoinette :

"if the people have no bread, let them eat the cake . . ."

PART 2

Some elements of Bioeconomics useful to assess the feasibility and desirability of biofuels

Let's imagine to evaluate an economic investment giving you **"a return of 10,000 €"**

Is this a good option for investing your money?

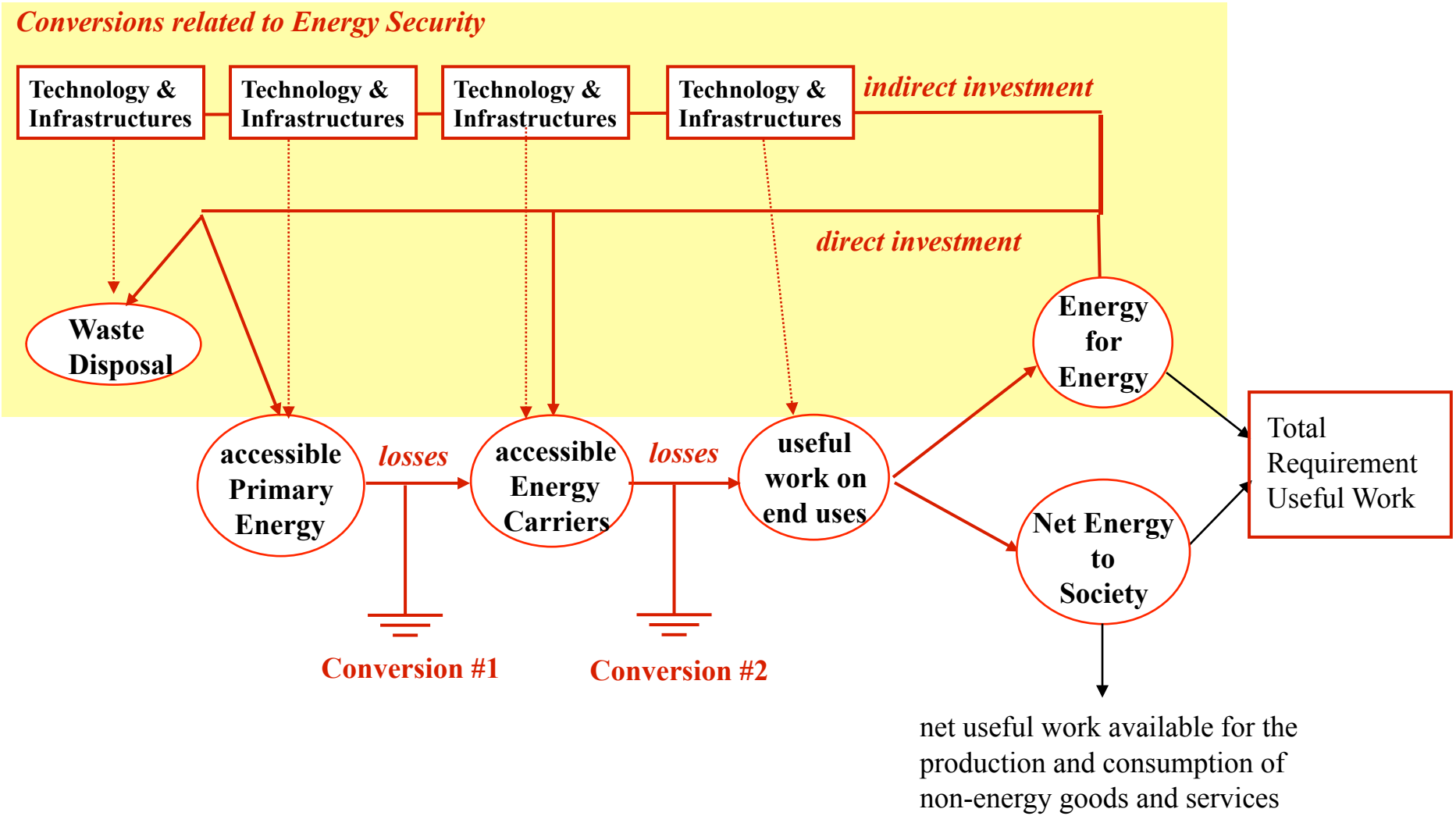
The answer depends on two questions:

A. How much do I have to invest to get the return of 10,000 €?

B. How long will it take to get the money back plus the interest?

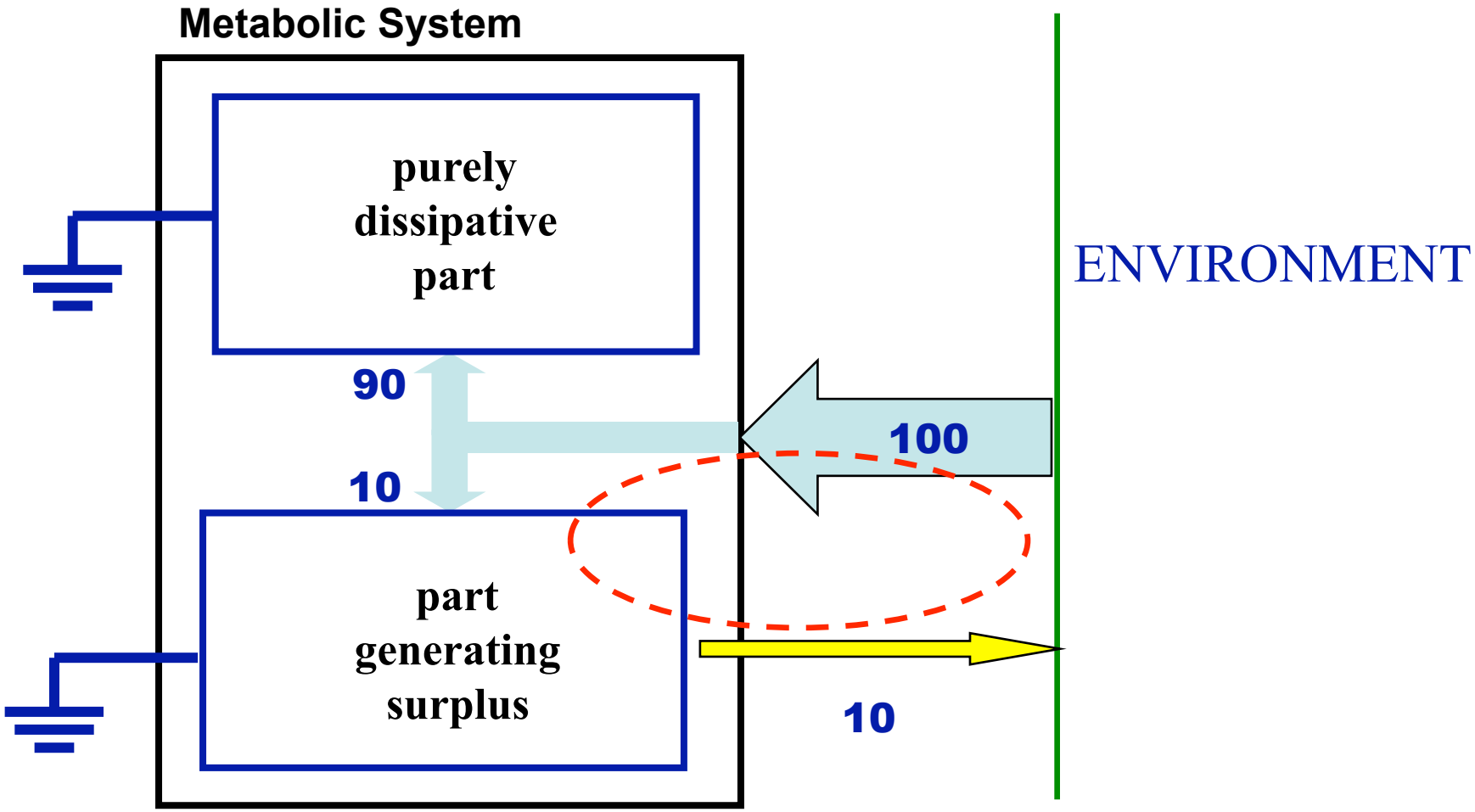
It is a VERY GOOD investment if: (A) it requires an amount of money invested of 10,000 €; and (B) if it pays back (with the interest) in only 1 year !

It is VERY BAD investment if: (A) it requires an amount of money invested of 1,000,000 €; and (B) if it pays back (with the interest) in more than 5 years!



EROI: the split between: (i) Energy for Energy; and (ii) Net Energy to Society

EXPECTED PATTERN FOR A STABLE METABOLISM: A DISSIPATIVE PART SUSTAINED BY A HYPERCYCLE



The time issue . . .

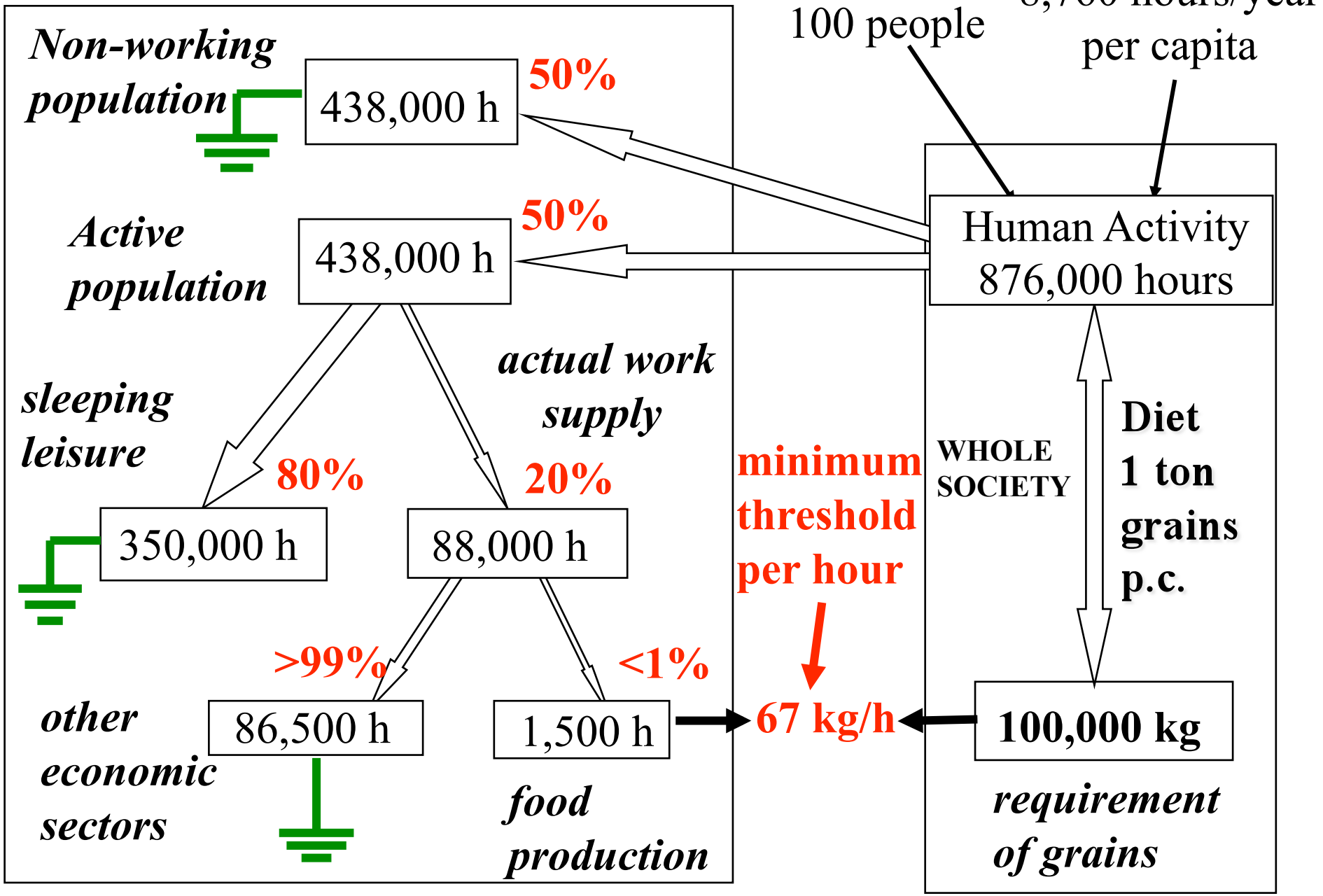
The BIOECONOMIC PRESSURE

Developed societies need to generate a huge supply of required flows of inputs per hour of labor in those compartments specialized in this task

Example #1

Bio-economic pressure in agriculture
→ ENDOSOMATIC ENERGY

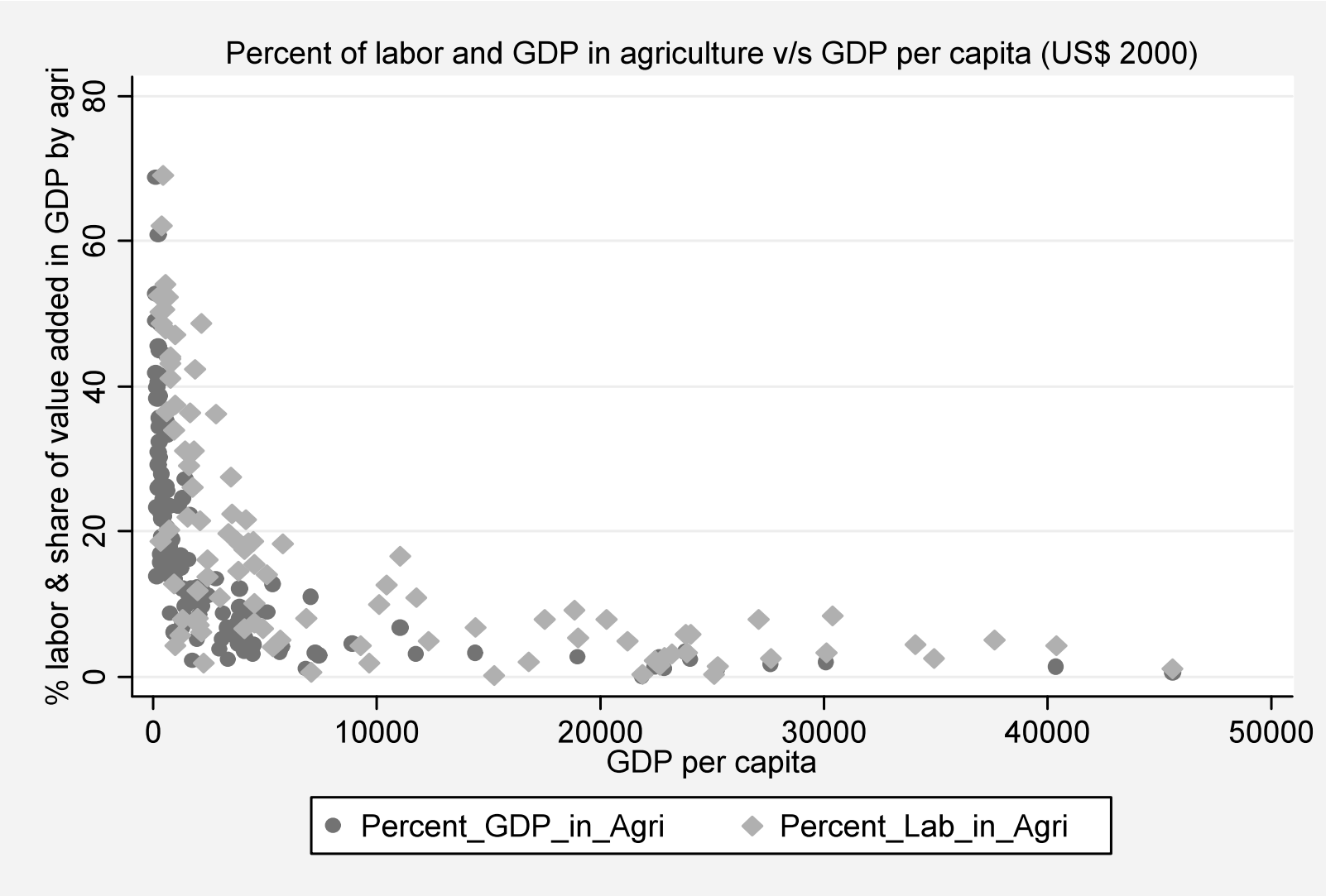
COMPARTMENTS OF SOCIETY



If the *work force* of a society is just producing its own food that society will never become rich . . .

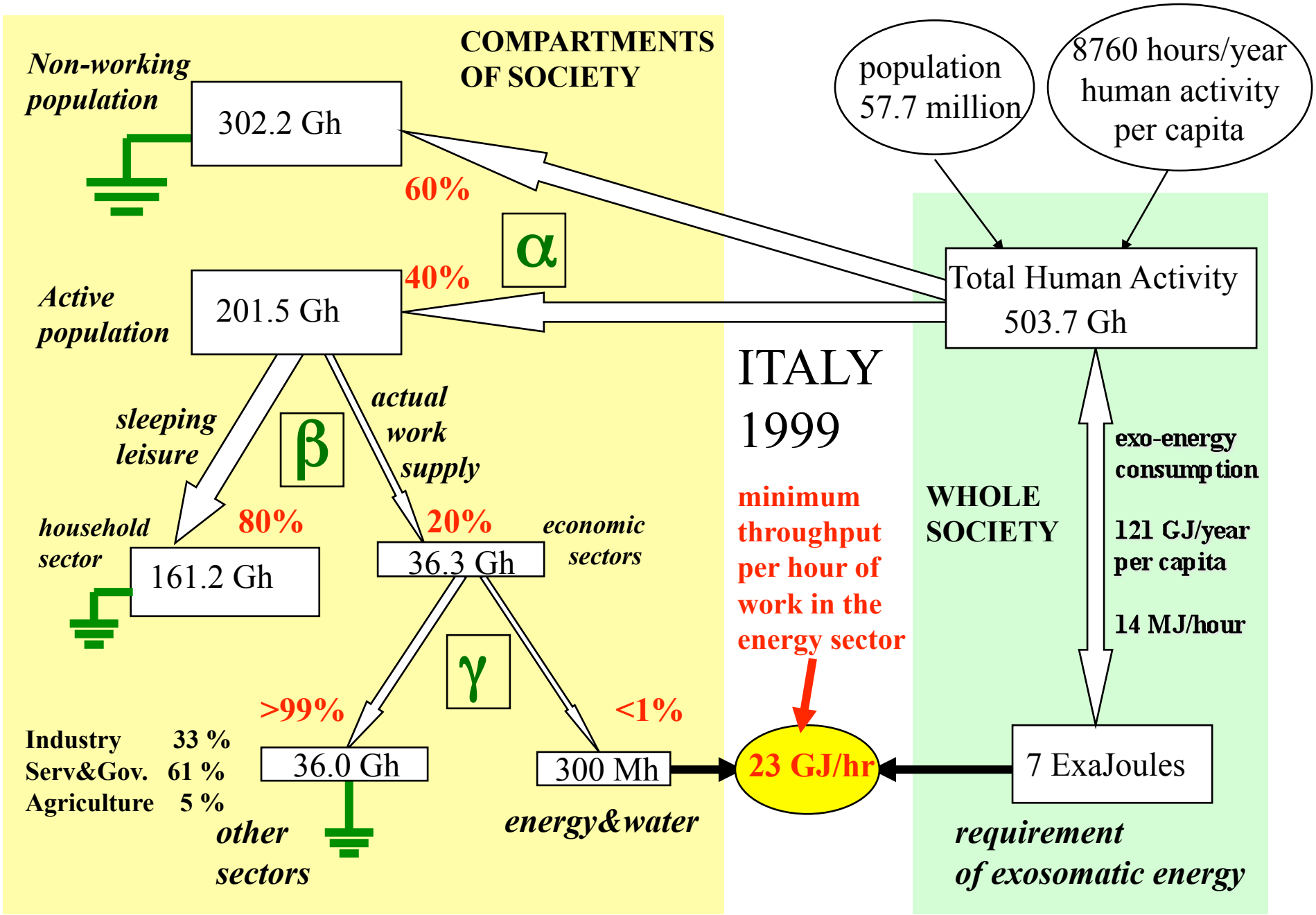
All developed countries have less than 5% of their work force in agriculture

Share of agricultural labor and agricultural GDP in total GDP *vs* per capita GDP, average 1999-2001 (USD 2000 prices)



Example #2

Bio-economic pressure in the energy sector
→ EXOSOMATIC ENERGY


COMPARTMENTS OF SOCIETY
Non-working population
302.2 Gh
60%
α
Active population
201.5 Gh
40%
sleeping leisure
β
actual work supply
household sector
80%
161.2 Gh
20%
36.3 Gh
economic sectors
γ
>99%
36.0 Gh
other sectors
<1%
300 Mh
energy&water
Industry 33 %
Serv&Gov. 61 %
Agriculture 5 %
population 57.7 million
8760 hours/year human activity per capita
Total Human Activity 503.7 Gh
ITALY 1999
minimum throughput per hour of work in the energy sector
23 GJ/hr
WHOLE SOCIETY
exo-energy consumption
121 GJ/year per capita
14 MJ/hour
7 ExaJoules
requirement of exosomatic energy

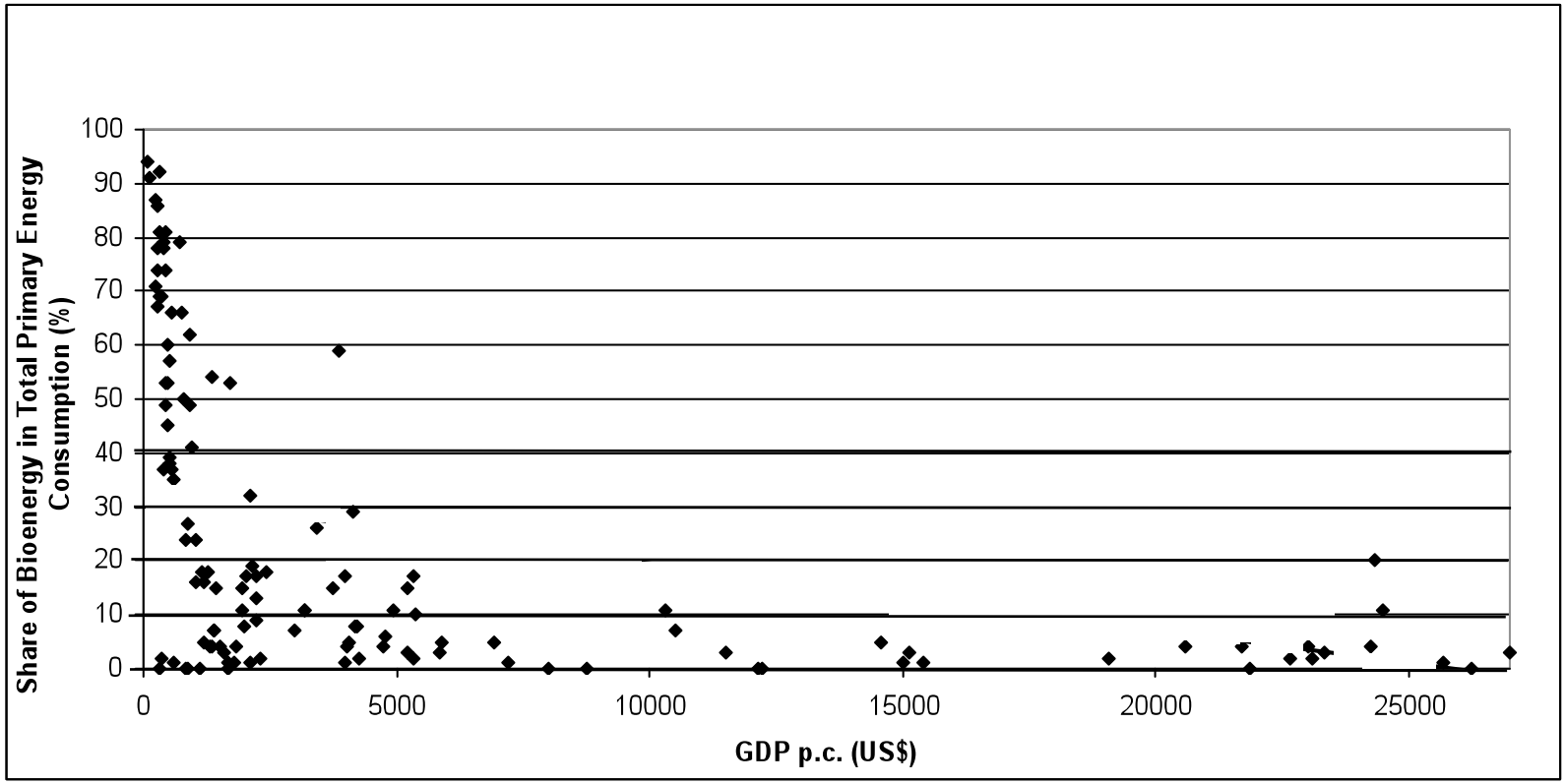
If the *work force* of a society is just producing its own energy input that society will never become rich . . .

does this implies that the fraction of the work force operating in the energy sector of a developed country must be very low (e.g. < 1%) ?

YES!

All developed countries have a tiny fraction of their work force in the energy sector

Bioenergy use and GDP levels (2003)



Source: World Bank Development Data Group

The implications of EROI

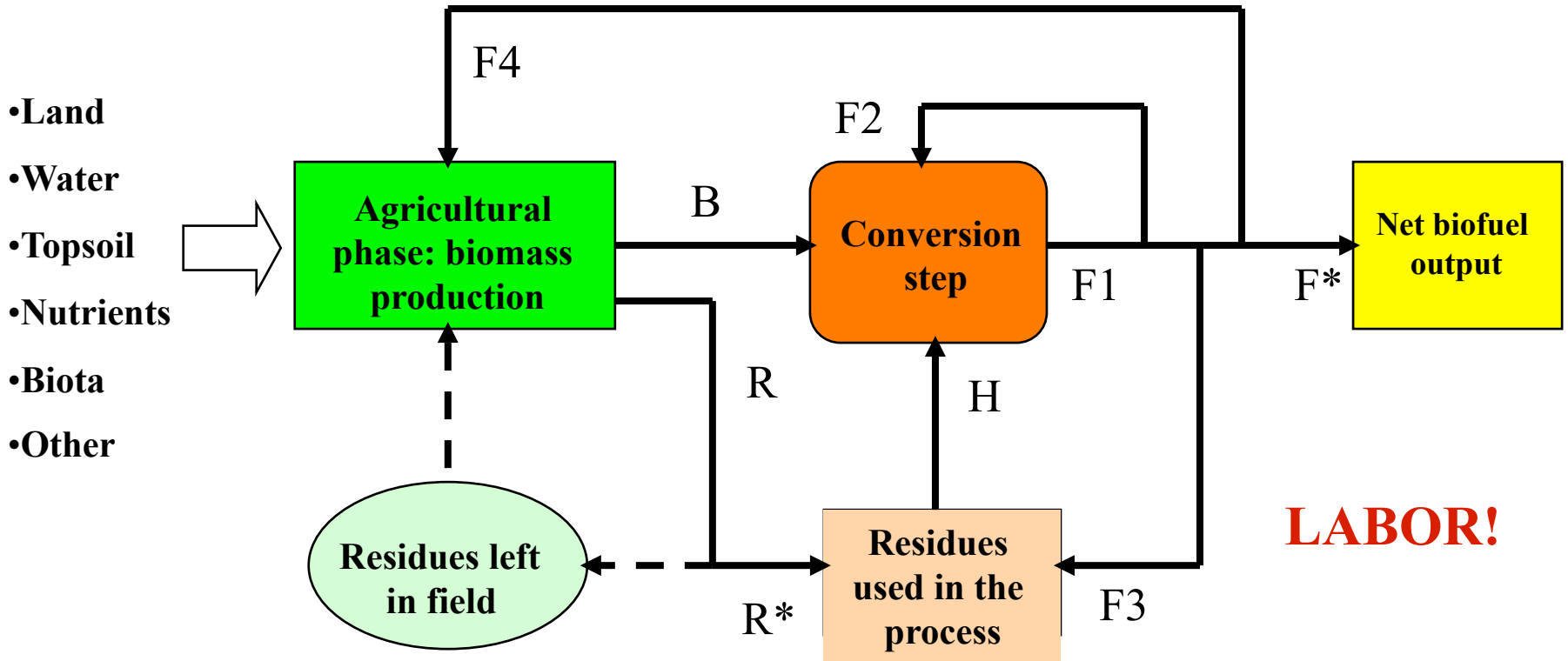
The crucial difference between:

- NET BIOFUEL ASSESSMENT; and
- GROSS BIOFUEL ASSESSMENT

EROI [Energy Return On the Investment]
the ratio between the quantity of energy delivered to society by an energy system and the quantity of energy used directly and indirectly in the delivery process.

Cleveland et al. 1984; Hall et al. 1986; Cleveland, 1992; Cleveland et al. 2000; Gever et al. 1991

Flow Diagram and Internal Loops in Biofuel Production



F1 = Gross biofuel production

F2 = Process energy demand met by biofuels

F3 = Biofuels invested in harvesting of residues

F4 = Biofuel demand for agricultural production

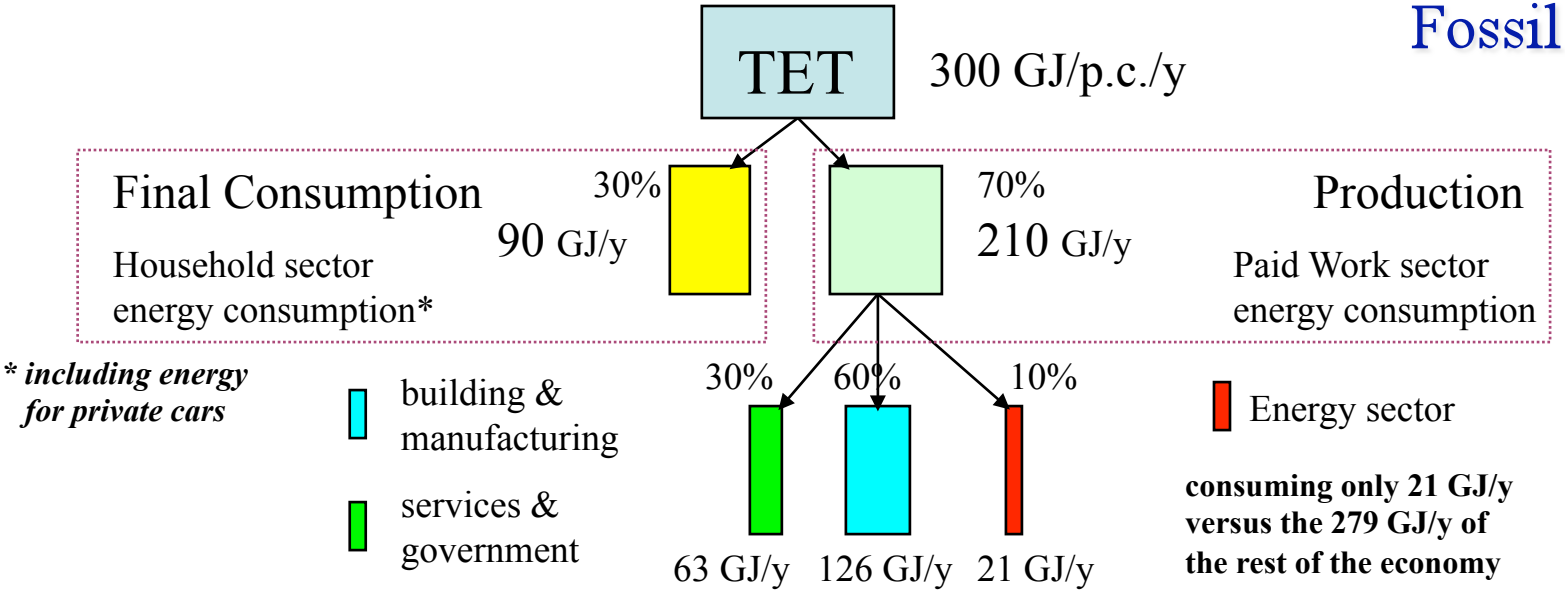
R = Potentially available residues (mass)

R* = Residues used in process (mass)

H = Process energy demand met by residues

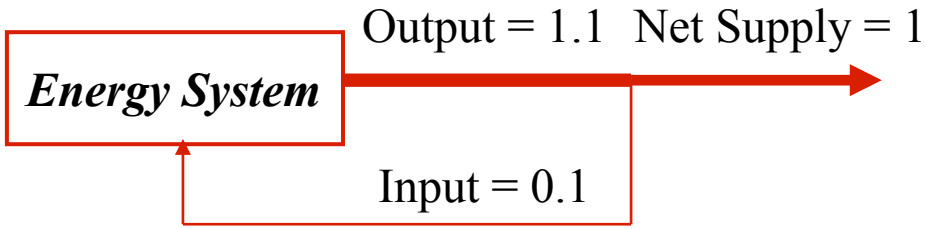
B = Total biomass produced (mass)

Fossil energy



High Quality Primary Energy Source

Output/Input = 11/1

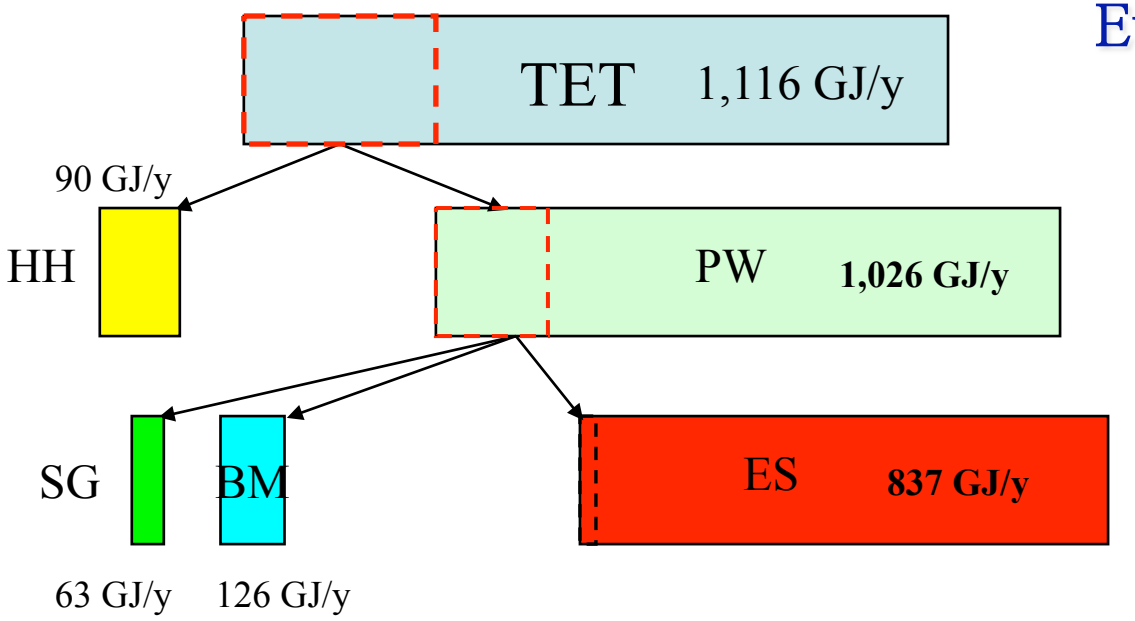


For each GJ of energy delivered to society the energy sector is consuming 0.1 GJ

energy for energy

same consumption of "the rest of society" → 279 GJ/y

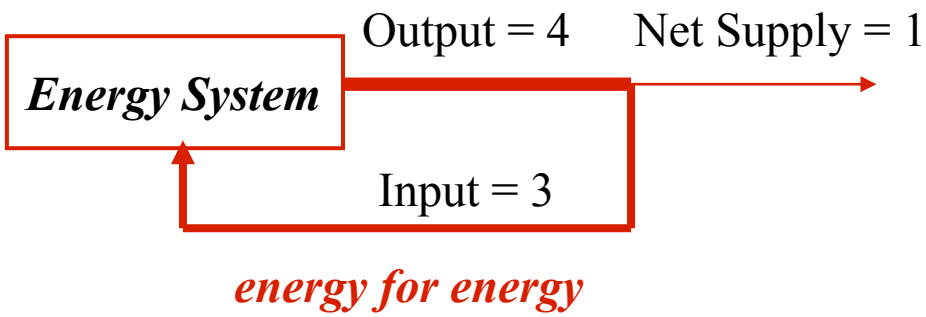
e.g. Biofuel in Europe



the "energy sector" will consume → 837 GJ/y !!!

Low Quality Primary Energy Source

Output/Input = 1.33/1



For each GJ of energy delivered to society the energy sector is consuming **3 GJ !!!**

The internal loop of energy used to make energy

→the mother of all the troubles . . .

An additional problem with existing assessments of the performance of biofuel production: the energy credit for feed production

The devil is in the details . . . The issue of SCALE !!!!!!!!

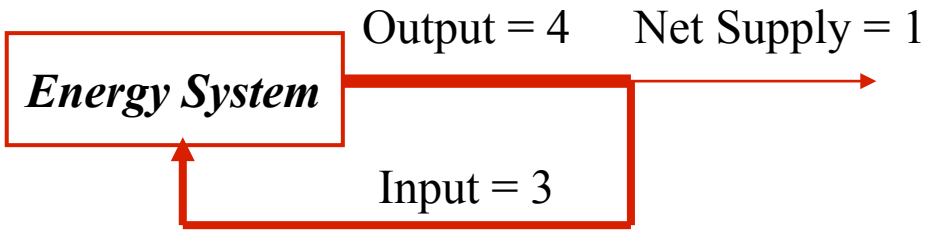
ETHANOL production from corn

Farrell et al. 2006 (Science)

Assuming an output/input = 1.3/1 - energy credit for by-products
(feed for animal production)

IF self-sufficient zero-emission !

= 4 liters of ethanol have to be produced to supply 1 NET liter of ethanol!



energy for energy

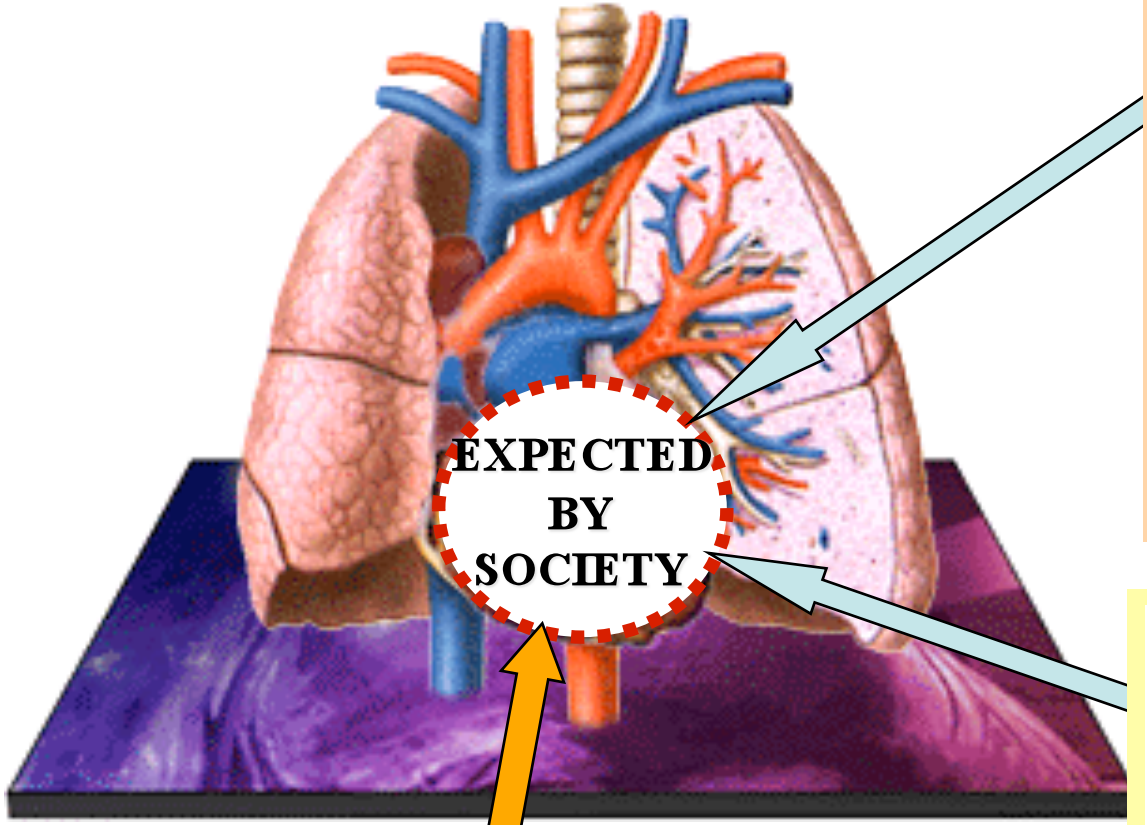
to cover 10% of the energy in the transport sector of the USA (30% of the total) in 2003 - this biofuel system would generate 500 million tons of DDG by-products

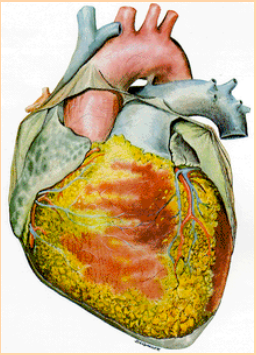
this amount is 10 TIMES the US consumption of high-protein feeds – in 2003

PART 3

Is it a large-scale biofuel production a viable and desirable alternative to fossil energy?

The heart metaphor





Energy Sector powered by fossil fuels

- Technical Coefficients
- Biophysical Constraints

Energy Sector powered by biofuels

- Technical Coefficients
- Biophysical Constraints

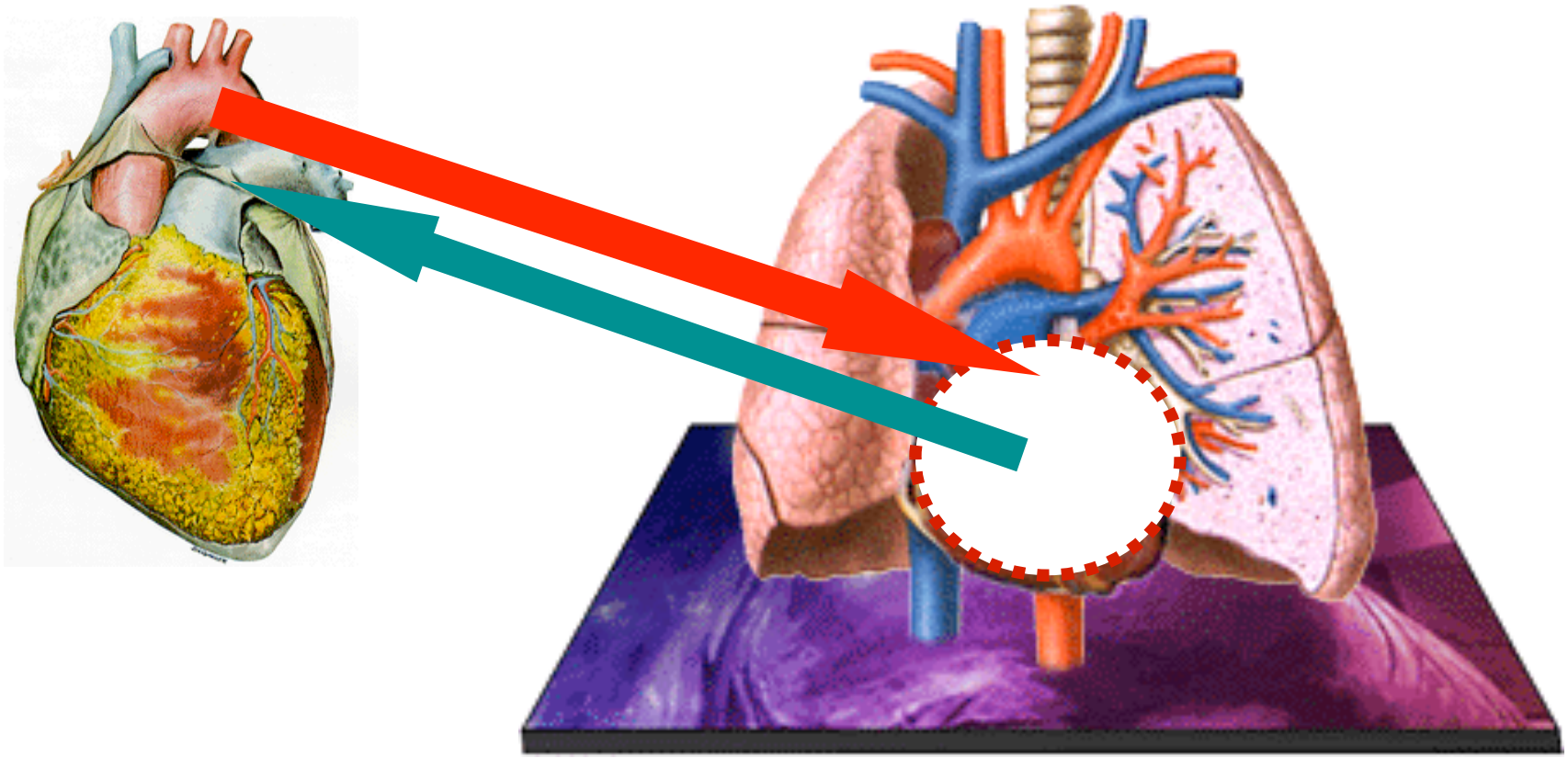
given the characteristics of its metabolism a society can only invest in its energy sector a limited amount of:

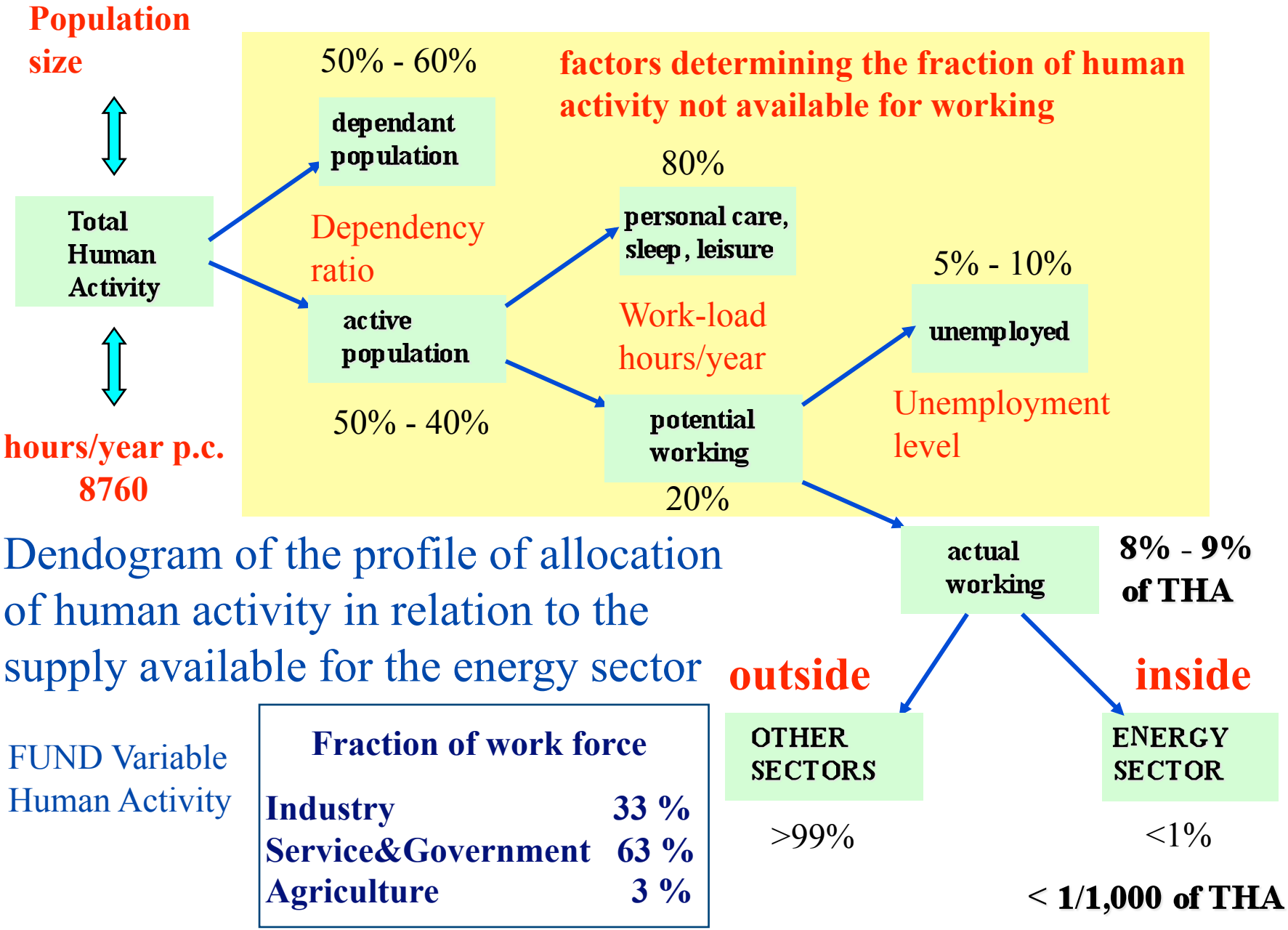
*** hours of work**

*** hectares of colonized land**

Checking the hearth metaphor in relation to the compatibility between:

(i) labor requirement; and (ii) **labor supply;**





Dendogram of the profile of allocation of human activity in relation to the supply available for the energy sector

FUND Variable Human Activity

Fraction of work force	
Industry	33 %
Service&Government	63 %
Agriculture	3 %

The hidden biophysical constraint affecting the feasibility of alternative fuels to be adopted in the energy sector of a developed economy

FLOW Variable

Total Exosomatic Throughput

175 - 350 GJ/person/year
20 - 40 MJ/hour over THA

FUND Variable

Human Activity in the energy sector

0.001 of THA

pace of supply of fuel (energy carriers) per hour of work in the energy sector

40 MJ/h x 1,000 = 40,000 MJ/hour
20 MJ/h x 1,000 = 20,000 MJ/hour

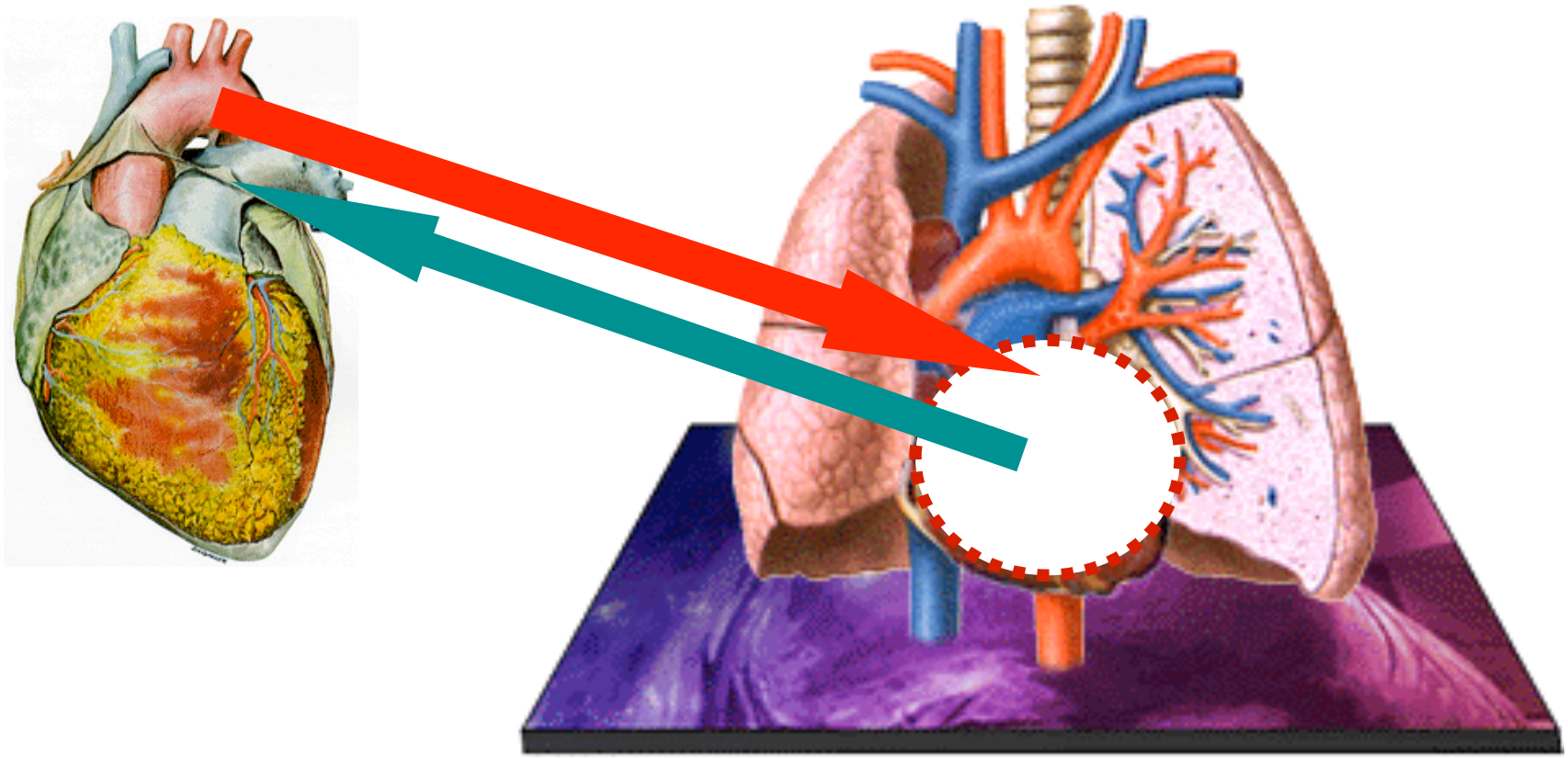
supply/hour benchmarks

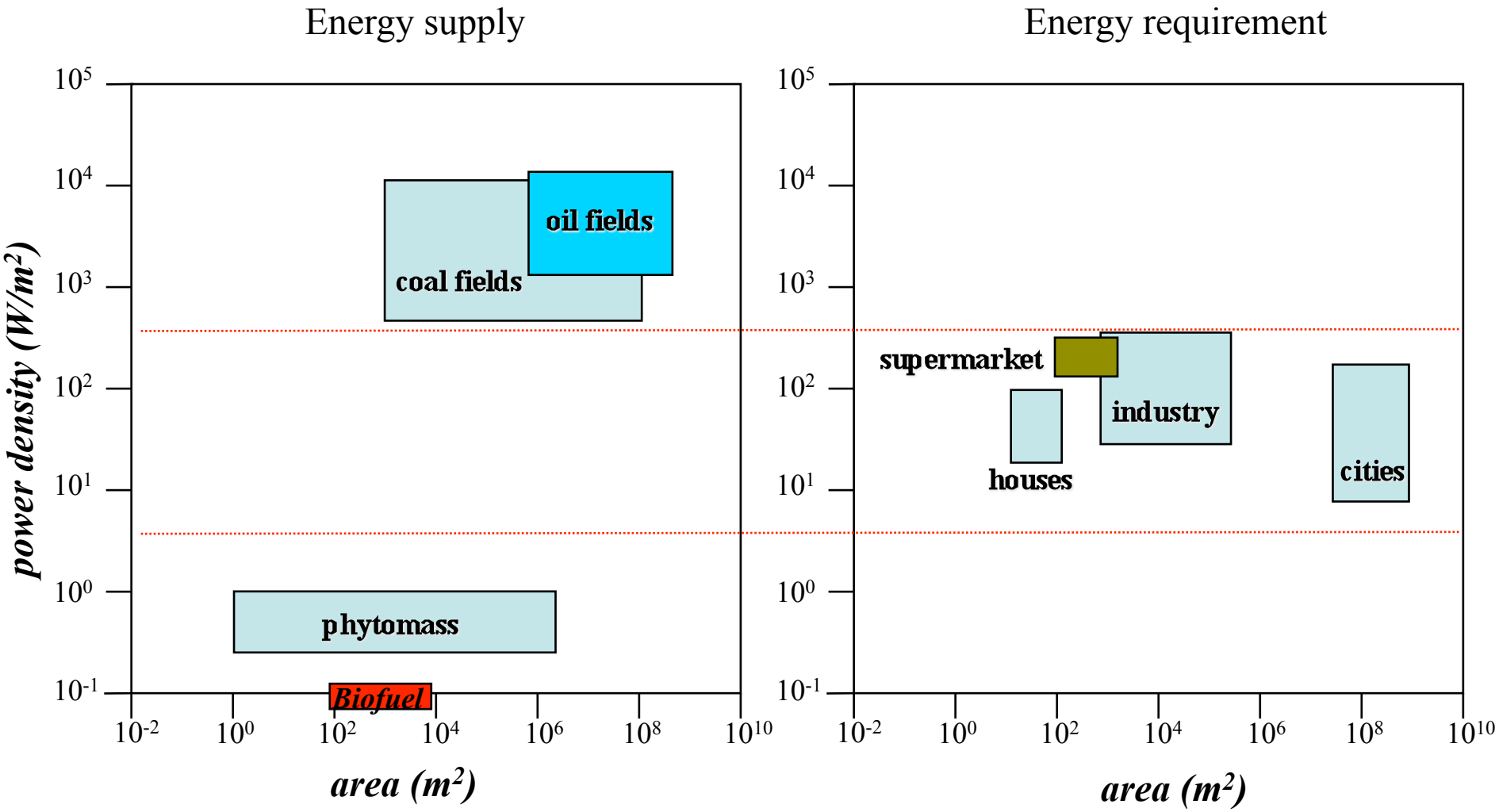

KRUPP


generating a supply of 10,000 trucks of coal/day
operated by 7 workers

The equivalent of less than a gallon of gasoline requiring the human activity of two persons to be transported . . .

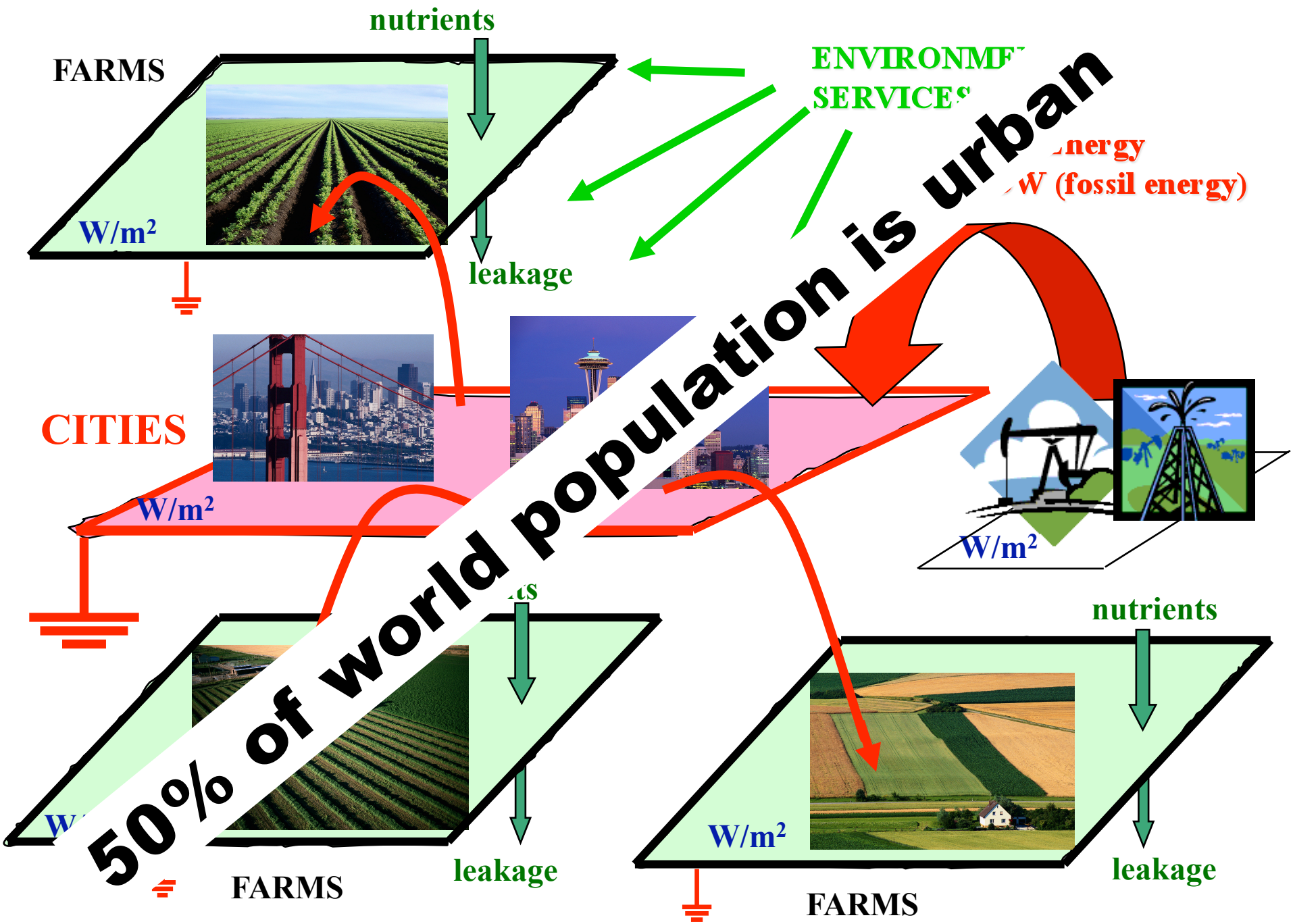
Checking the hearth metaphor in relation to the compatibility between:
(i) **land requirement;** and (ii) **land availability;**

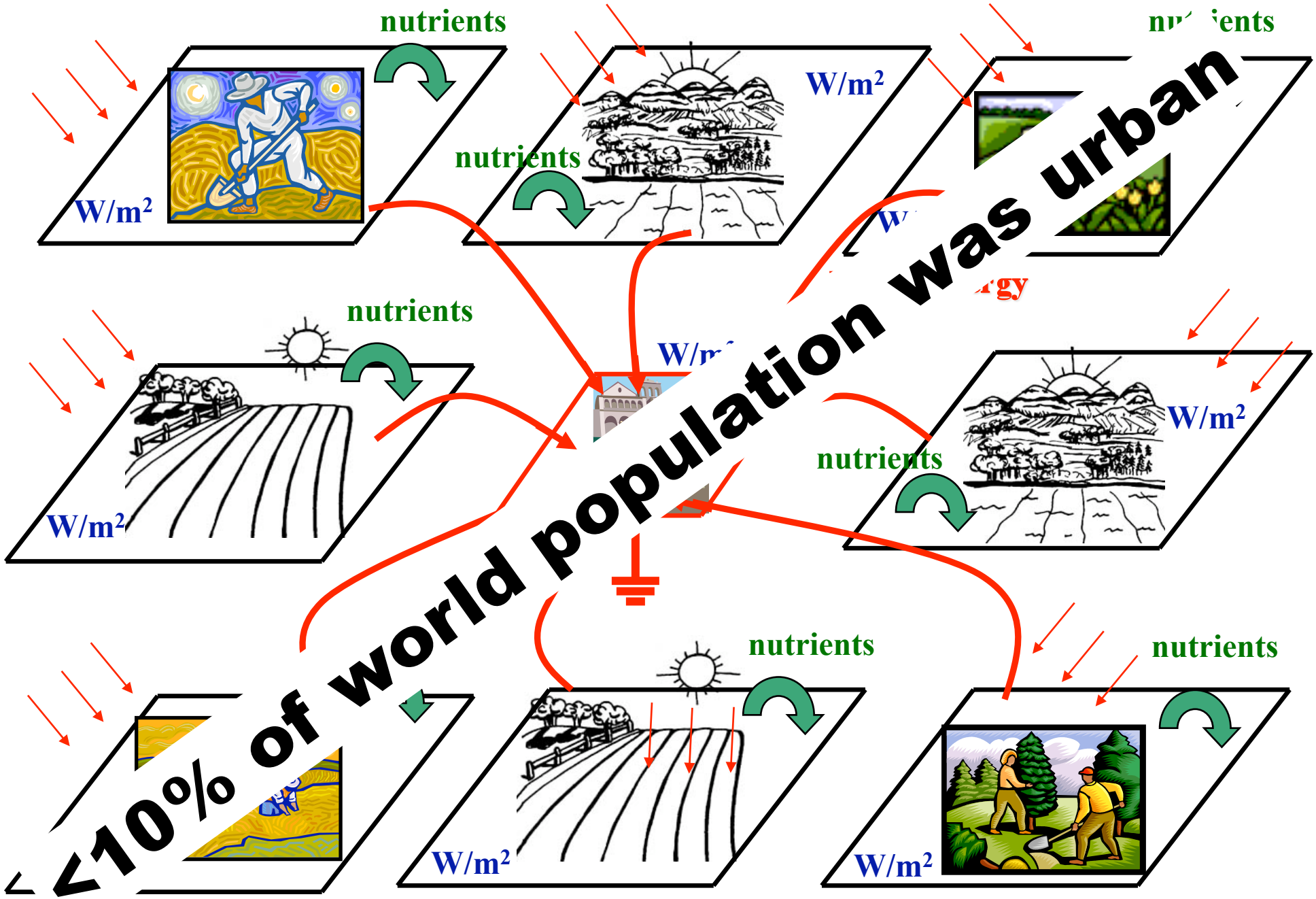




power density gaps

after Vaclav Smil 2003 Energy at the Crossroads, The MIT press
(Fig. 5.2 and Fig. 5.3)


nutrients
FARMS
W/m²
leakage
ENVIRONMF
SERVICES
nergy
W (fossil energy)
50% of world population is urban
CITIES
W/m²
W/m²
nutrients
W/m²
FARMS
leakage
W/m²
FARMS
leakage


nutrients
W/m2
nutrients
W/m2
nutrients
W/m2
nutrients
W/m2
nutrients
W/m2
nutrients
W/m2
nutrients
W/m2
<10% of world population was urban

EXPECTED BY SOCIETY	SUPPLIED BY BIOFUELS	**NET SUPPLY (no credit for by-products/feed)**
Supply of energy carriers in the Energy Sector	Supply of energy carriers in the Energy Sector	
USA – 47,000 MJ/hours	USA – 224 MJ/hours	(ethanol/corn)
Italy – 23,000 MJ/hours	Brazil – 140 MJ/hours	(ethanol/sugarcane)
Supply of energy carriers in the Energy Sector	Supply of energy carriers in the Energy Sector	
USA – 10-100 W/m^2	USA – 0.1 W/m^2	(ethanol/corn)
Italy – 10-100 W/m^2	Brazil – 0.02 W/m^2	(ethanol/sugarcane)

After removing the energy credit for by-products . . .

the output/input over the whole process of production = 1.1/1

ASSUMPTION

Covering 10% of energy consumption of ITALY in 1999 – 0.7EJ of biofuel

35 Ghours of work → **94%** of all the working hours of the work force in 1999

117 million ha → **7 times** the 158 million ha of arable land in 1999

ASSUMPTION

Covering 10% of energy in the transport sector of USA in 2003 – 3EJ of biofuel

148 Ghours of work → **48%** of all the working hours of the work force in 2003

5,500 million ha → **31 times** the 175 million ha of corn land in 2003

The crucial difference between fossil fuels and biofuels

Fossil energy has a tremendous advantage over all alternative energy sources. When assessing the biophysical cost of production of energy carriers, **oil has not to be produced, it is already there!**

Because of this fact, the EROI of fossil energy is much higher than alternative energy sources

Fossil fuels are energy carriers with a very low biophysical cost of production *(e.g. extraction → oil → gasoline)*

Biofuels are energy carriers with a very high biophysical cost of production *(e.g. soil + sun → biomass → beer → ethanol)*

The land issue . . .

Land is a crucial for food security:

→ 99% of the world's food supply comes from land
→ arable land per capita, at the global level, is less than half a hectare per capita
→ additional arable land for feeding 8 billions will have to be obtained by reducing the amount of land not yet colonized
→ a switch to a diet with more animal products will boost such a demand

The role of fossil energy:

→ providing 'ghost land' for environmental services (nitrogen fertilizer, pumping water for irrigation, pesticides). The nitrogen fertilizer produced today is already equivalent to more than an additional planet, and it is keeping alive at least one third of current human population

→ eliminating the competing demand of land for exosomatic power (forest land for timber and charcoal, plus pasture and cropping land for animal power).

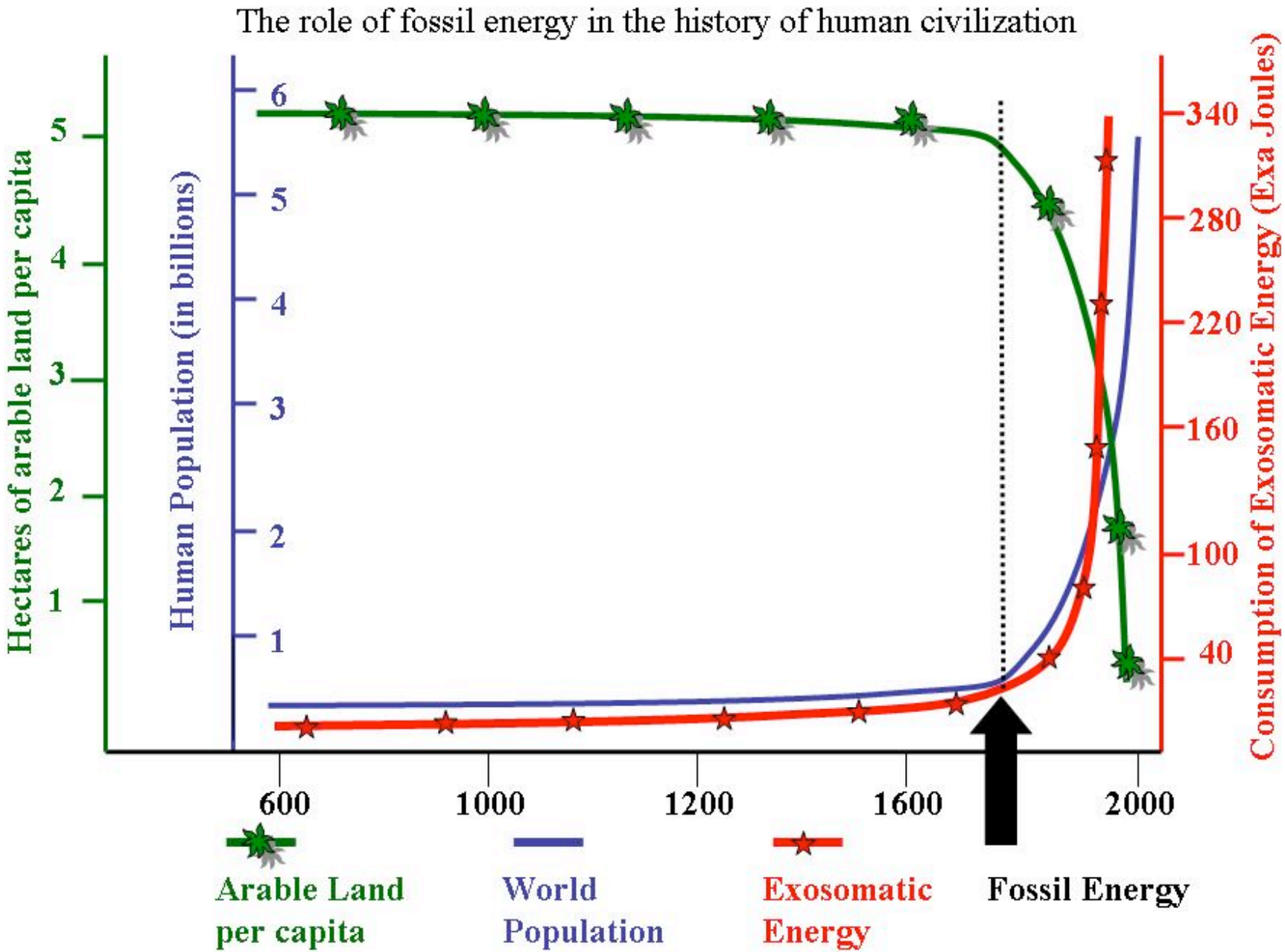
Human Appropriation of Net Primary Productivity (NPP) at the global level

year 1700	less than 5%	Haberl (2006)
year 1990	more than 40%	Vitousek et al. (1991)
year 2000	about 50%	Pimentel (2001)

The larger the amount of energy metabolized by human societies the larger is the requirement on terrestrial ecosystems for sink capacity and resilience. On the contrary, in the last decades non-colonized land has been shrinking at a frightening rate.

Fossil energy made it possible to supply more energy carriers per capita to more humans while requiring less land and less human labor

Land shortage is occurring on the sink side (not enough land to sequestrate the excess of carbon in the atmosphere), rather than on the supply side (not enough land to generate the required power supply)


The role of fossil energy in the history of human civilization
Hectares of arable land per capita
Human Population (in billions)
Consumption of Exosomatic Energy (Exa Joules)
1
2
3
4
5
6
40
100
160
220
280
340
600
1000
1200
1600
2000
Arable Land per capita
World Population
Exosomatic Energy
Fossil Energy

PART 4

How to explain the current blunder?

Since biofuel is not a feasible and desirable option when produced in a self-sufficent way to get “zero emissions” (!), the large investments in biofuel production are possible only because they rely on oil as input.

However, buying a barrel of oil at 70/100 US$, and then adding capital, labor and land (all factors of production which requires additional energy and cost in economic terms) to produce a net supply of 1.1 barrel equivalent of ethanol seems to be not a particular smart move.

The big question is then:
can we explain the agro-biofuel folly?

#1 – Humans look always for the easy solution

Two problems: “peak oil” and “climate change”
One solution: Agro-biofuels

→People want to believe that agro-biofuels are the needed silver bullet generating “renewable” and “zero emission” carriers

#2 – There are a lot of "energy experts" who do not know what they are talking about

Sentence included in the draft of a big report – October 2007!

"currently the average assessment of the oil price **in the next decades** is around **45 $** (2000)/bbl (DoE, 2006; IEA, 2006)".

Reply received when I asked to remove the sentence

Subject: Re: Chapter XXXX
To: Mario Giampietro <giampietro@liphe4.org>
From: XXXXXXXXXXXXXX
Date: Wed, 28 Nov 2007 13:25:34 +0100

Mario,

Thanks for noting the oil price sentence. I have written that particular sentence about a year ago.

Only 5 years ago – my expected oil price of 45$/bbl in 1995$ was ridiculed by economists in the Netherlands as being way too high. Now, I am off the chart in the other direction.

. . . **there is no physical reason in this world** why it should be higher than 45, maybe 60. Everything above that level is politics, economics, speculation and fear. But I know that you will disagree with me on that.

#3 – Biofuels from energy crops represent the last hope for the agonizing paradigm of industrial agriculture

WTO Trade Talks
Doha Round → Amber Box

Commodity support programs, such as:

- crop insurance
- export subsidies
- loan deficiency payments
- countercyclical payments

are considered to distort production and trade

They will be restricted by WTO Trade Agreements

US = 19 billions **EU = 80 billions**

For those willing to keep receiving subsidies for industrial agriculture the subsidized production of biofuels is very close to the invention of the machine of perpetual motion!

In fact, a self-sufficient biofuel system consumes almost entirely what it produces in its own operation, so that the supply of energy crops for biofuel will never experience a problem of surplus within developed countries.

THE WALL STREET JOURNAL. Digital Network

Grain Companies' Profits Soar As Global Food Crisis Mounts

By DAVID KESMODEL, LAUREN ETTER and AARON O. PATRICK

April 30, 2008; Page A1

At a time when parts of the world are facing food riots, Big Agriculture is dealing with a different sort of challenge: huge profits.
On Tuesday, grain-processing giant Archer-Daniels-Midland Co. said its fiscal third-quarter profits jumped 42%, including a sevenfold increase in net income in its unit that stores, transports and trades grains such as wheat and corn, as well as soybeans.

Monsanto Co., maker of seeds and herbicides, Deere & Co., which builds tractors, combines and sprayers, and fertilizer maker Mosaic Co. all reported similar windfalls in their latest quarters.

If the people is without bread, then let them eat cake . . .

BP Selects Strategic Partners For Energy Biosciences Institute

Press Release date: 01 February 2007

University of California Berkeley, the University of Illinois and the Lawrence Berkeley National Lab join research effort

BP today announced it has selected the University of California Berkeley and its partners the University of Illinois, Urbana-Champaign and the Lawrence Berkeley National Laboratory to join in a **$500 million research program** that will explore how bioscience can be used to increase energy production and reduce the impact of energy consumption on the environment.

The Energy Biosciences Institute will perform ground-breaking research aimed at the production of new and cleaner energy, initially focusing on renewable biofuels for road transport.

The problem is that this advice is given by those making cakes!