Energy and Globalization
A Fairy Tale – no Happy Ending

2nd Biophysical Economics Conference

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October 16, 2009

A fundamental change in economic dynamics requires a new approach to macroeconomics

The paradigm of traditional macroeconomics is “Growth”

- Shrinking economies are a result of “temporary market failures”
- Recessions are “adjustment mechanisms” for imbalances
- Natural resources (particularly energy) are of limited or of no relevance (i.e. they are just another production factor purchased with money)
- The role of money supply and credit in relation to economic output (GDP) is not recognized

Our research has lead to a much wider system definition

- Given the recent failure, we need new models explaining economic activity
- **New Paradigm**: Decline is as much part of a human ecosystem as is growth
- Macroeconomic systems need to be looked at involving multiple contributors
  - → Financial systems (money supply, credit, prices, etc.)
  - → Resource systems (energy, human labor, other natural resources)
  - → Global flows of goods, energy and funds (exports, imports, balances)
  - → Population development

Energy and GDP

- Global Energy – an advanced model
- Transfers of energy in products and services
- A chicken and egg question
- The price of energy

At IIER, we have taken another good look at energy inputs and output (GDP) generation

Total Global GDP (in US$ PPP)

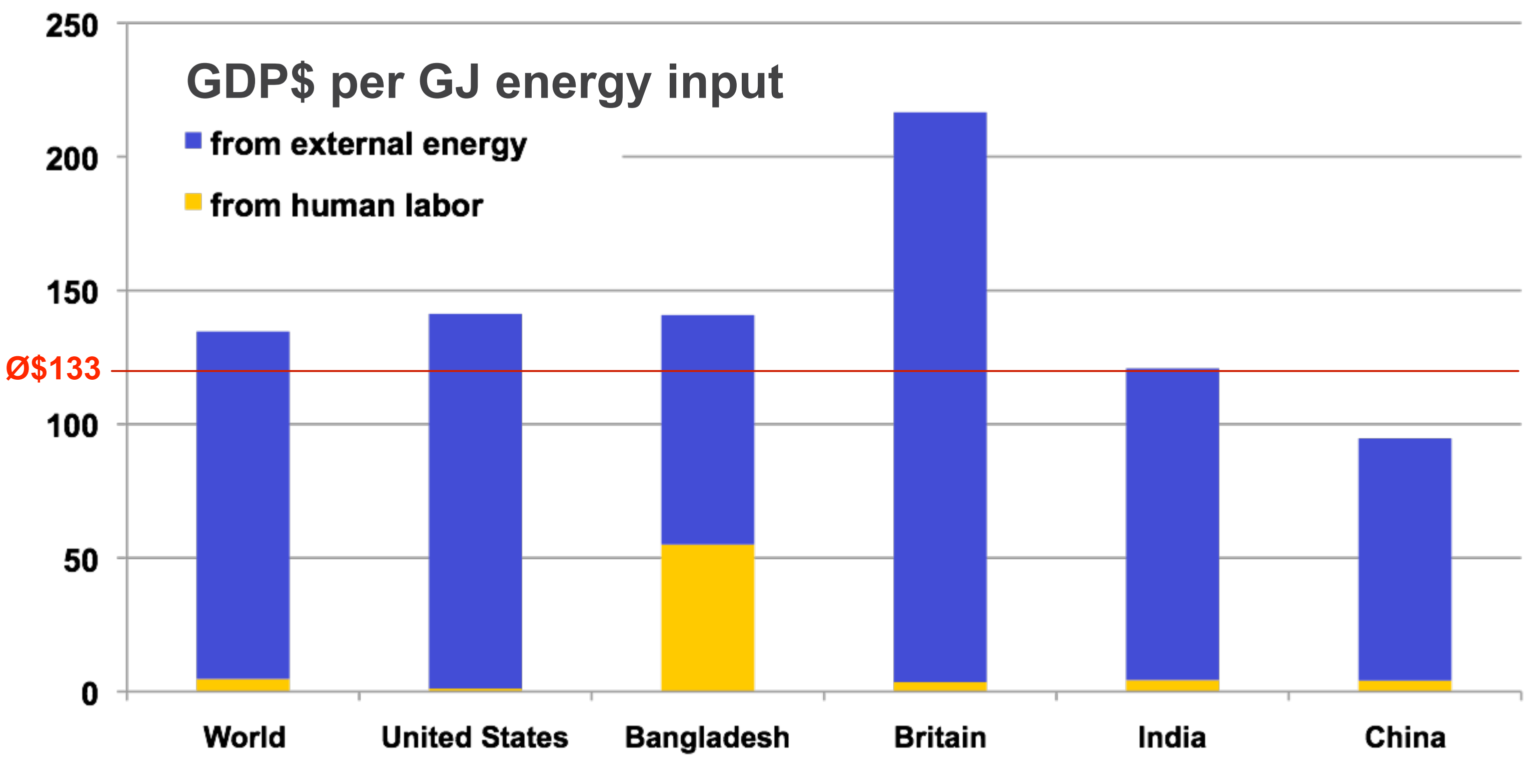
divided by

Human Labor (Joule)	**+ External Primary Energy Inputs (Joule)**
Calculated as average calorific food intake of 7.2 MJ/day per human (all ages)	All global primary energy inputs (including fossil fuels, hydropower, nuclear power, wood and renewables)

=

GDP$ per Energy Unit Consumed (GJ)

Results are surprisingly consistent, even before eliminating distortions from globalization



Sources: GDP 2007 (purchasing power parity): OECD, Energy 2006: IEA

Standard "energy efficiency" metrics are significantly distorted by imports and exports

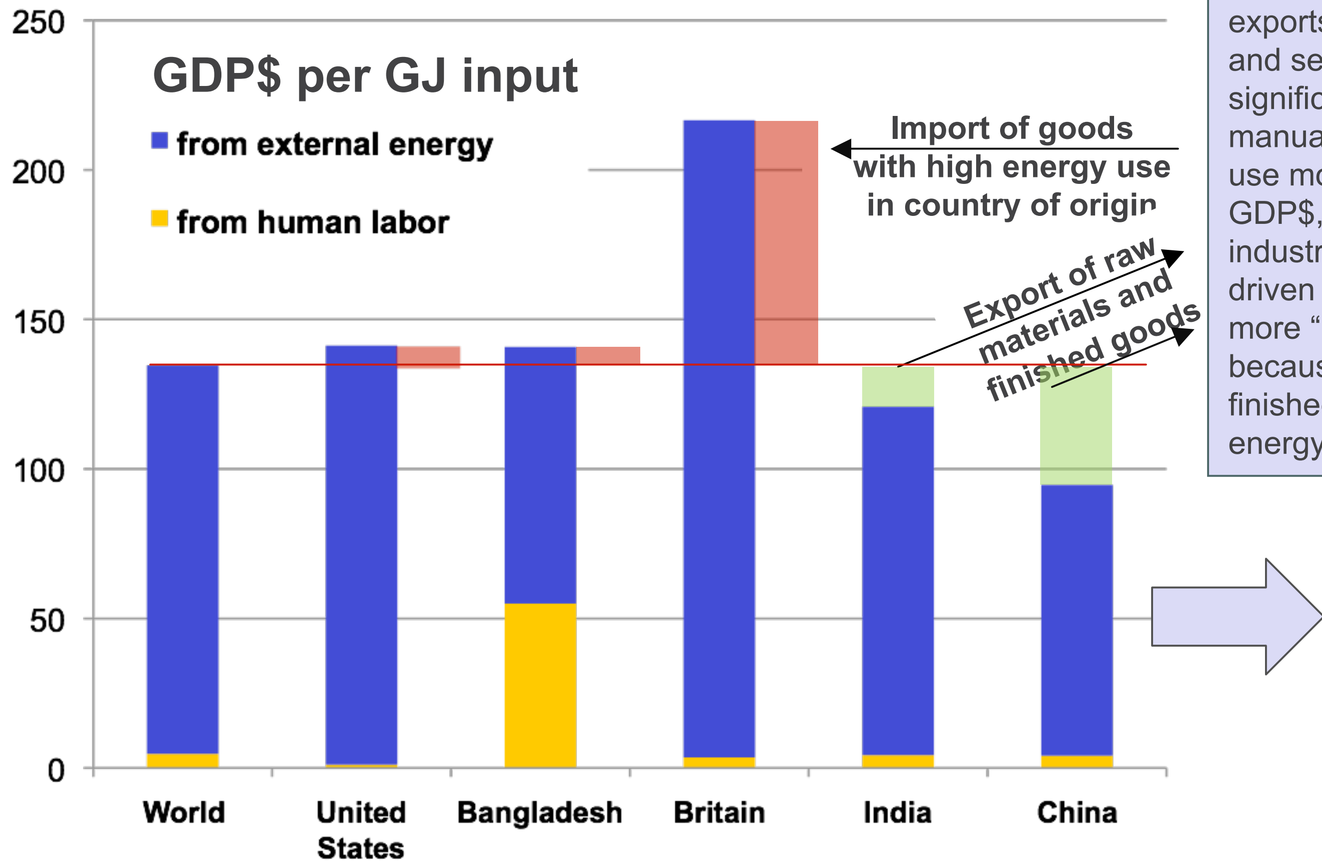
An economy's trade balance plays an important role in determining "true" energy productivity.

	Self Sufficiency		GDP$	Global Share of			
	Primary Energy	Food Calories	Per GJ	GDP	Iron + Steel Production	Aluminum Production	Fertilizer Production
United States	**71%**	**119%**	$141	21.1%	4%	7.6%	6.1%
China	**92%**	90-95%	**$95**	10.8%	**41%**	**37.5%**	**32.8%**
UK	80%	**74%**	**$217**	3.1%	**0.6%**	**1.1%**	**< 0.5%**

Mining, agricultural inputs, raw materials and manufacturing contain a significant amount of "energy accounted for elsewhere", which is not included in traditional energy efficiency reviews.

Sources: Energy: EIA, 2006 data, Food: multiple sources. Raw materials: WSA World Steel Association (2007 data), Fertilizer, aluminum: USGS, 2007/8 data.

Most differences can be explained from energy transfers from industrial processes



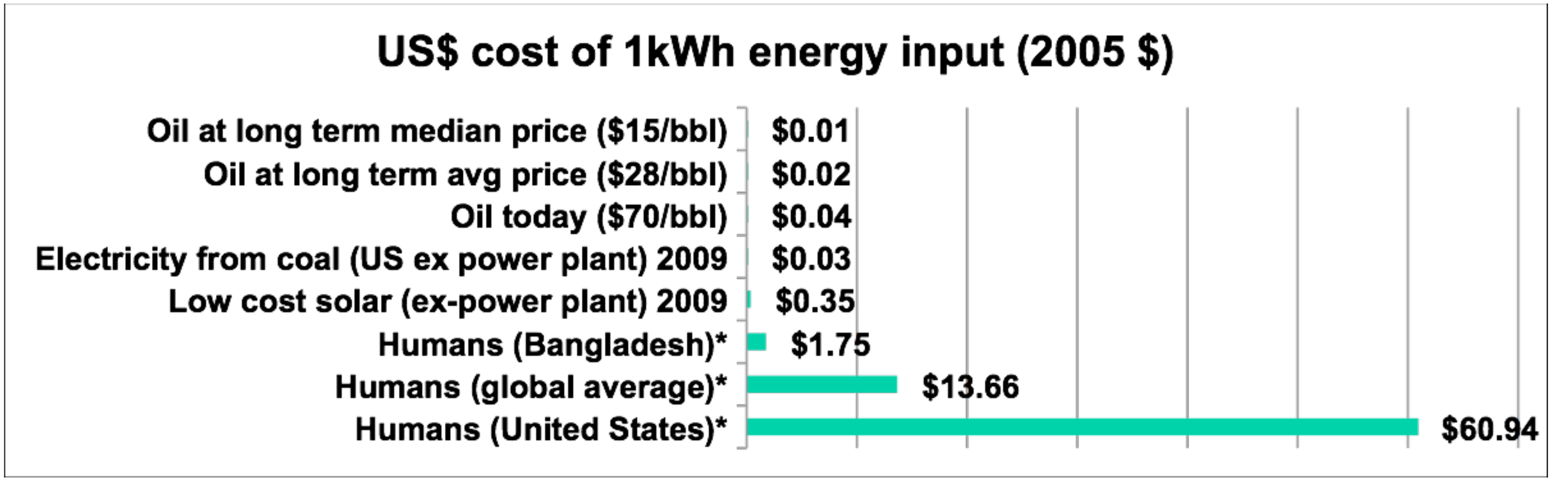
Economies with substantial exports of low-cost goods and services that include a significant amount of manual or industrial labor use more energy per GDP$, while de-facto de-industrialized service driven economies become more "energy efficient" because they import finished goods instead of energy and raw materials*

Primary Energy inputs and economic output are highly correlated

*Multiple sources and own calculations for key material transfers. Most sources state that approximately 40% of China's energy use is related to exports: e.g. http://www.carnegieendowment.org/publications/index.cfm?fa=view&id=23482

The price differences between human labor and fossil fuels are breathtaking

Fossil energy is significantly cheaper than energy from human labor (and renewables from solar inputs like photovoltaics, wind, etc.):



Fossil energy use provides wealth from past solar inputs

- Even very inefficient use of fossil fuels creates a surplus, as this energy provides abundant capacity unavailable (and unaffordable) from humans
- An increase in energy consumption leads to a higher standard of living due to increased outputs

* Human labor cost was derived from the energy-GDP model (pages 6-9), attributing GDP not used for energy purchases to human labor using the following approach: A full year of primary energy input (calorific food intake of a human) represents 365 x 2kWh x $60.94 per kWh = $44'486. Cross-check: U.S. median full time worker income for 2007 was reported as $43'460.

Most of our increased "productivity" comes from replacing human labor with fuel and machinery

Until early 1900s

- Manual milking
- Took approximately **30 minutes of physical work per cow and day**
- No equipment required (except for stool and bucket)
- No energy required beyond human labor

Today's standard

- Cows attached manually, but milking is automated
- Saves 50% of human labor (**15 minutes per cow and day**)
- Uses **300 kWh** electric energy per cow/year
- Equipment cost (de-preciation/maintenance): $**100 per cow and year**

Fully automated milking solutions

- Almost no manual work
- Human hours are 10% (**3 minutes per cow and day**)
- Uses **700 kWh** electric power per cow/year
- Equipment cost: $**200**

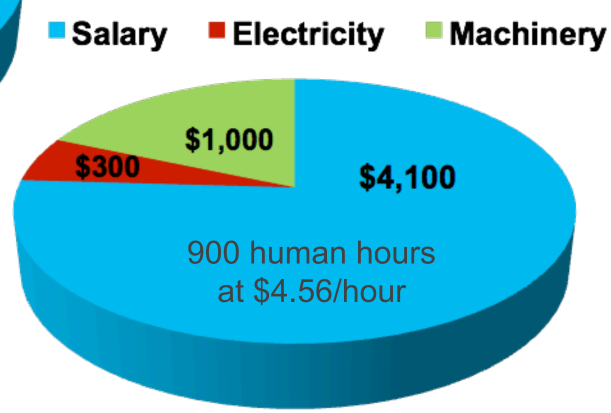
The "productivity increase" leads to immediate gains for an economy – and rising standards of living

Manual milking

10 cows manual	Input	Unit Price	Cost
Human hours	1800 hrs	**$3**	$5'400

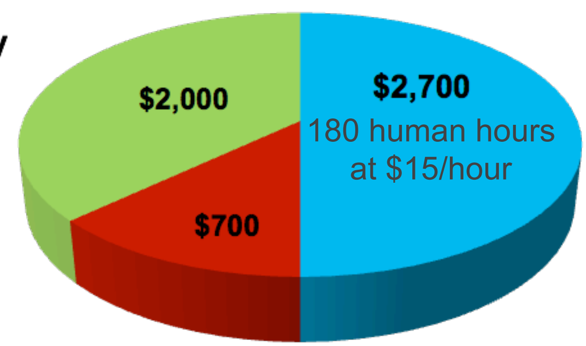
Semi-automated

semi-auto	Input	Unit Price	Cost
Human hours	900 hrs	**$4.56**	$4'100
Energy input	3000 kWh	**10 ct**	$300
Machine cost	10 cows	**$100**	$1'000
Total			$5'400



Fully automated

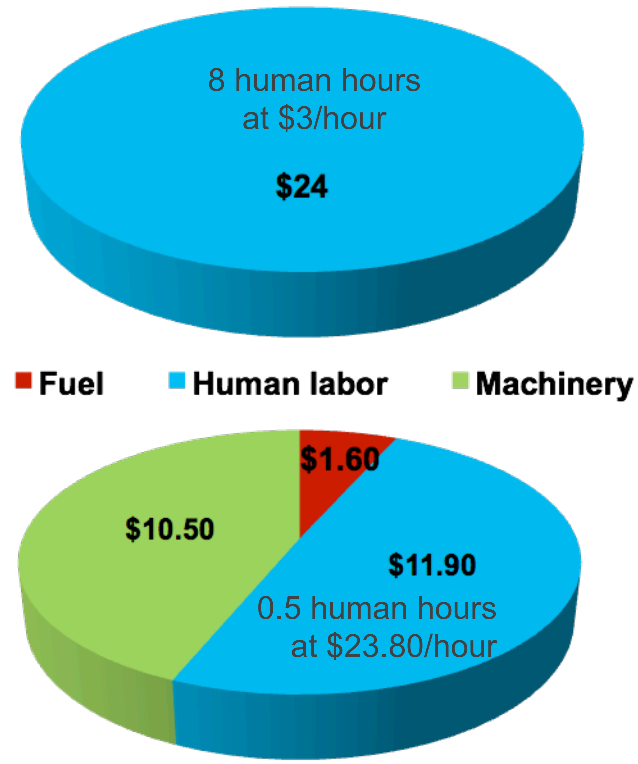
full auto	Input	Unit Price	Cost
Human hours	180 hrs	**$15**	$2'700
Energy input	7000 kWh	**10 ct**	$700
Machine cost	10 cows	**$200**	$2'000
Total			$5'400



Shifting from walking to using a passenger car increases a person’s “salary” by a factor of 8

Walking (8 hours)	Input	Price per unit	Cost	Substitution (labor with energy + tools)
Human hours	8 hours (~2 kWh)	**$3**	$24.00	20 kWh of gas per kWh saved, $1.50 of “machine cost” per hr saved

Driving (0.5 hrs)	Input	Price per unit	Cost	
Human hours	0.5 hours	**$23.80**	$11.90	using a car with a fuel efficiency of 22mpg at a speed of 50 miles/hour
Energy input	40 kWh	4 cents	$1.60	
Machine	7.5 hours	$1.50	$10.50	=42 cents/mile
Total Cost			$24.00	



All those highly energy-intensive shifts led to combinations of “wage increases” for humans and price reductions for goods or services

*Model assumptions: A person traveling a total of 25 miles (e.g. 5x2.5 miles in a week) by foot starts using a car for the commute, which reduces total commute time to ½ hour. An average car operating at 22mpg (and gas sold at $1.50/gallon) and cost for depreciation and maintenance of 42 cents/mile is used for the task. The saving results in a “salary increase” from 3$ to 24$/hour

Over the past decades, our fossil energy sources have become less efficient

Independent of the arrival of "Peak Oil", increasing amounts of upfront energy are required to explore the next new units of energy

The concept of EROI (Energy Return on (Energy) Investment) describes this as: Energy Units Gained from one Energy Unit Used

A change of EROIs from 80:1 to 20:1 (current estimate for global oil production) equals a "salary increase" of physical work from oil by a factor of almost 4, significantly reducing benefits to our economy

- With this change of contributions from energy, economic growth becomes increasingly difficult as more and more output is used for energy generation

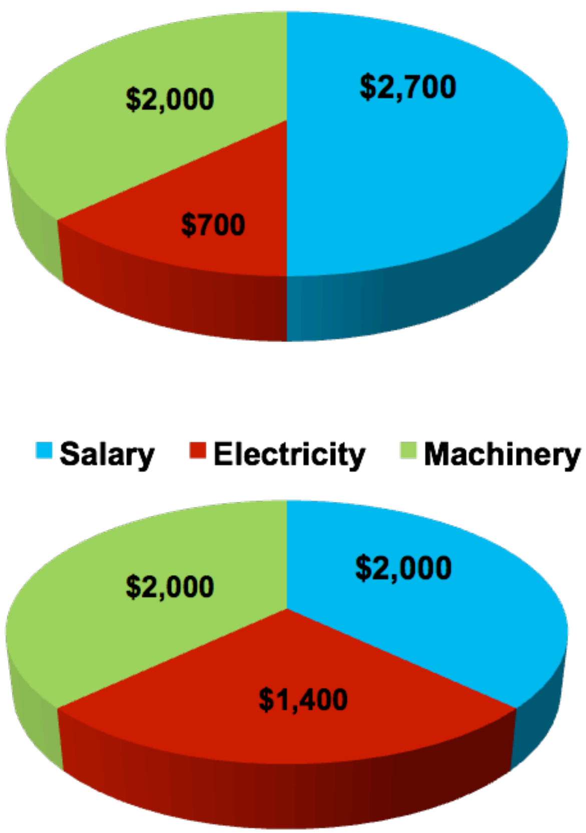
* Multiple sources, including Hall, Powers, Schoenberg, 2008 "Peak oil, EROI, investments and the economy in an uncertain future, Pp. 113-136 *in* Pimentel, David. (ed). Biofuels, Solar and Wind as Renewable Energy Systems", Elsevier, London

Higher energy cost quickly reverses previous gains from increased "productivity"

With rising cost of energy (in our milking case from 10 to 20 cents per kWh), the business model reverses abruptly – either massively affecting the price of goods or the "residual value" of human labor

	Input	Price per unit ($)	Total cost	New price/ unit ($)	New total cost
Human hours	180 hrs	**$15.00**	$2'700	**$11.11**	$2'000
Energy input	7'000 kWh	10 cents	$700	20 cents	$1'400
Machinery			$2'000		$2'000
Total Cost			**$5'400**		**$5'400**

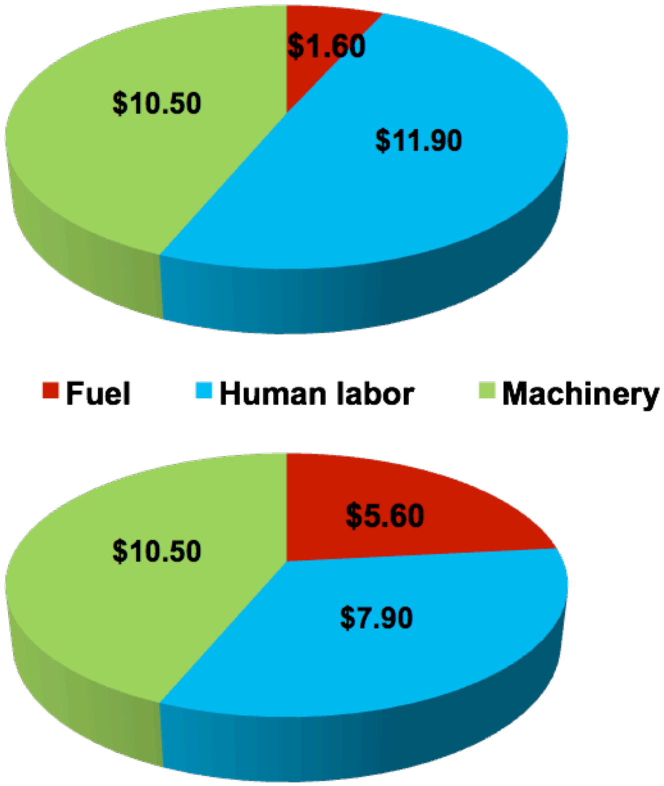
Significantly rising energy cost destroys the key economic driver of the past and immediately reduces money available for human labor



Higher energy cost quickly reverses previous gains from increased “productivity”

With energy cost more than tripling (equals a price rise from $1.50 to $5 per gallon of gasoline), the business model reverses abruptly

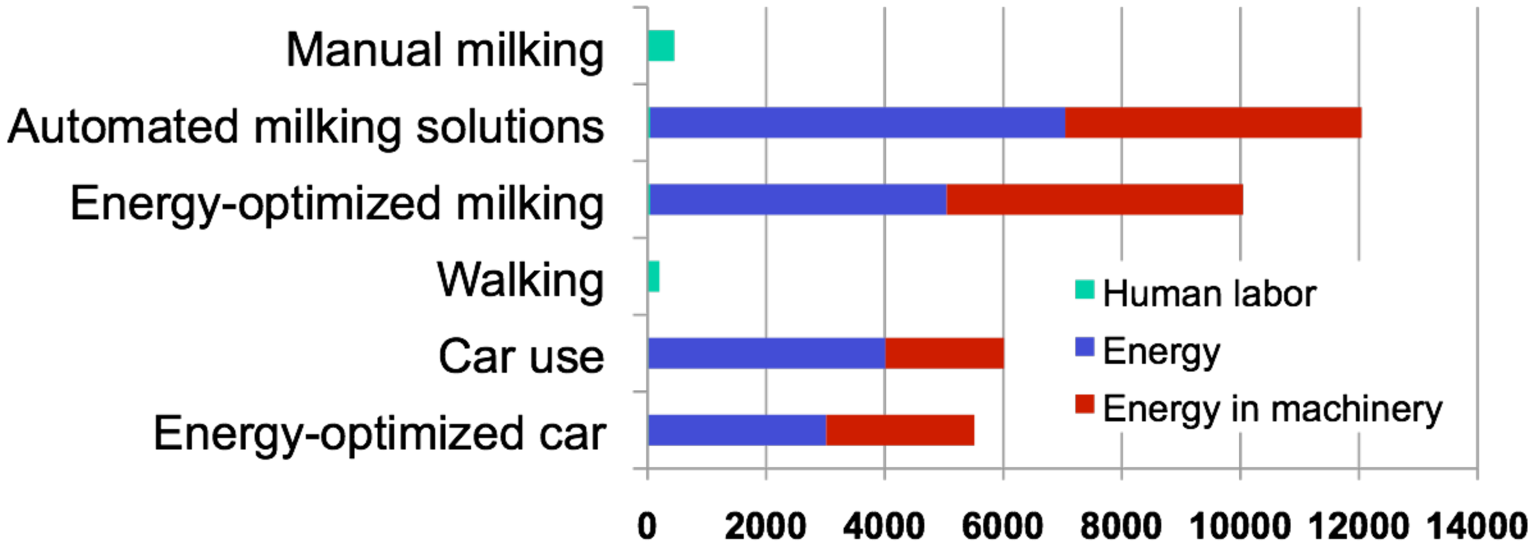
	Input	Price per unit ($)	Total cost	New price/ unit ($)	New total cost
Human hours	0.5 hrs	**$23.80**	$11.90	**$15.80**	$7.90
Energy input	40 kWh	4 ct ($1.5/gal)	$1.60	14 ct ($5/gal)	$5.60
Machinery			$10.50		$10.50
Total Cost			**$24.00**		**$24.00**



Significantly rising energy cost destroys the key economic driver of the past and immediately reduces money available for human labor

"Productivity gains" require increasing energy use by 2-3 orders of magnitude

Moving from animal and human labor to mechanical processing increased the required energy by a factor of 200 to 500 (2000-5000%) – energy efficiency measures typically reduce energy use by about 10-20%



Model assumptions: kWh used for milking 10 cows for one year, kWh used for getting a person transported 2500 miles

The human labor vs. energy trade breaks down even earlier for emerging economies

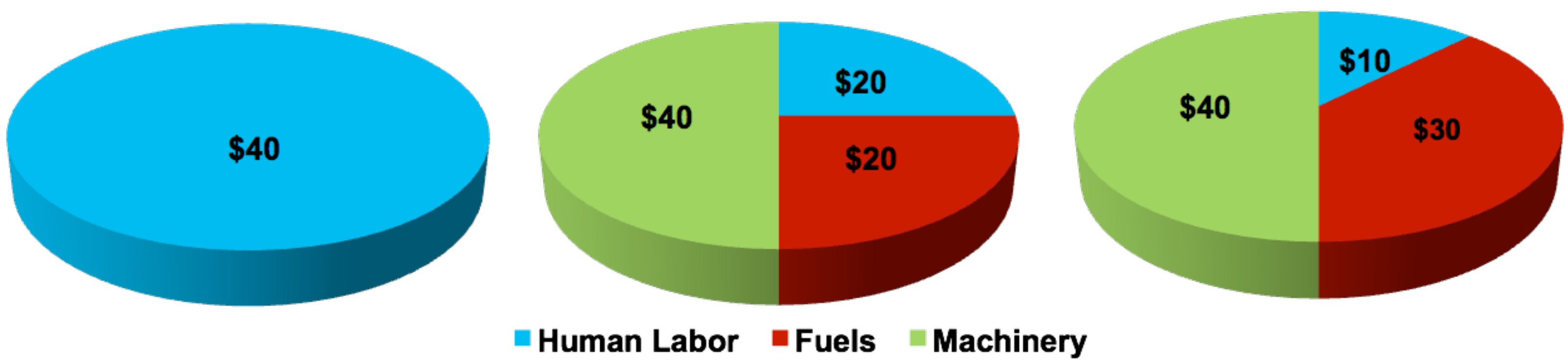
As all other countries, emerging economies need additional energy to fuel growth, particularly when adopting Western lifestyles

The “business model” is to replace cheap labor with even cheaper energy, with much lower margins when compared to the rest of the world:

40 hours at $2/hour

4 hours at $5/hour
1000 kWh at 2 cents
machinery at $40

4 hours at $2.5/hour
1000 kWh at 3 cents
machinery at $40



Emerging economies’ “productivity gains” disappear at relatively low energy prices (equivalent to 70$ oil per barrel)

Not all fuels are equal regarding their EROIs and their role in the economy

Oil

- Key transportation fuel (>90% of transportation is fueled by oil and derivatives)
- Low-cost base of most chemical products
- Peak probably has already arrived, rapidly decreasing EROIs

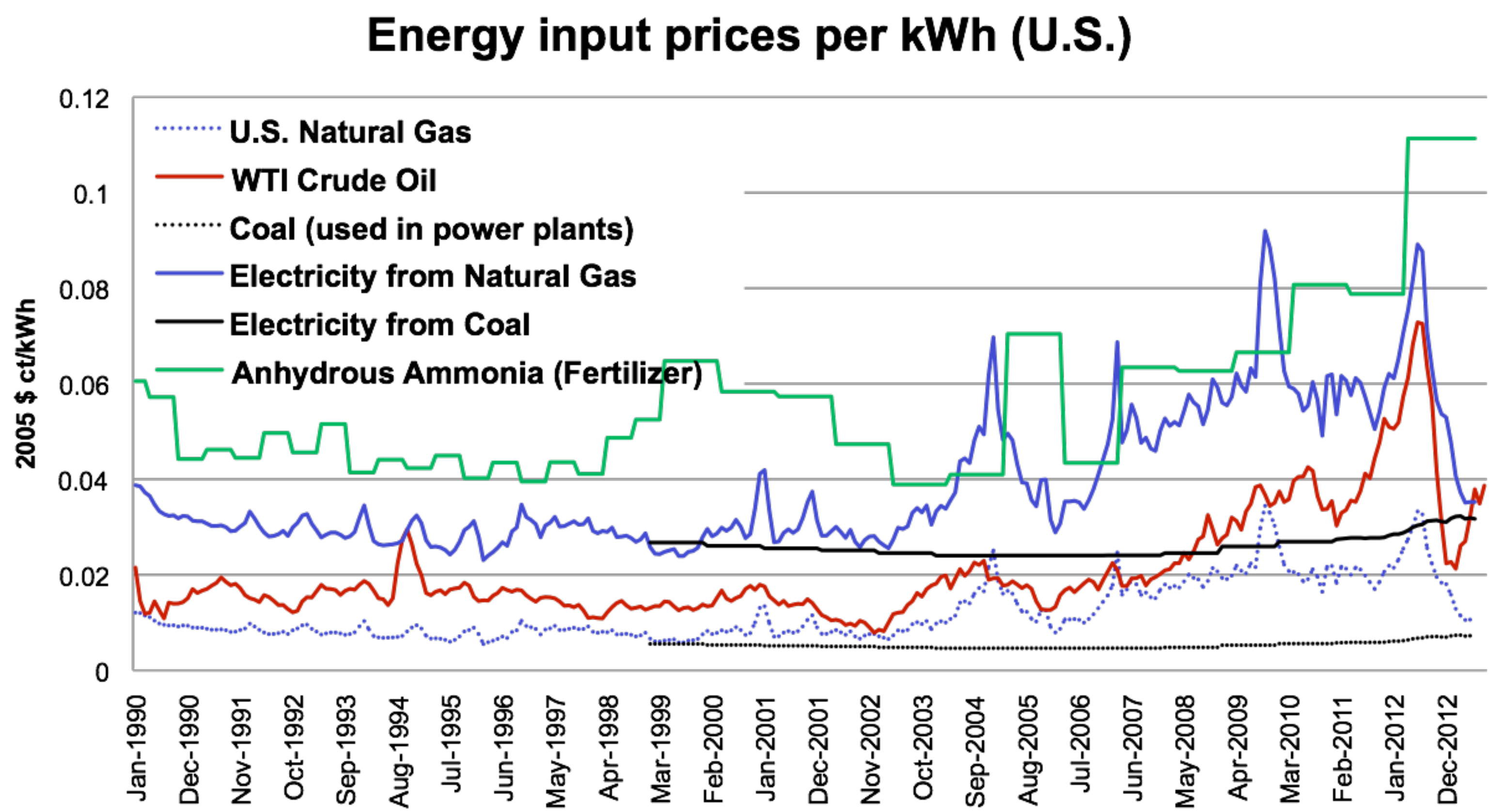
Natural Gas

- Key source for agricultural processes (fertilizer production, heating)
- One of the most valuable providers of electricity (peak production)
- Current oversupply, but peak arriving soon, slow EROI declines

Coal

- A key low cost process fuel
- Important in electricity generation
- Lower EROIs and lower quality, but global peak still a while away

It further helps to look at the cost per energy unit to see where problems might hit first



*Sources

Looking at EROIs and expected changes shows significant trouble ahead

	Process Energy	Heating/ Cooling	Electricity	Trans-portation	Agri-culture
EROI	30-80	20-30	15-30	15-25	1-5 (processed foods 0.1-
EROI Trend	→	↘	↘	↓	↓
EROI [2015]	25-80	15-25	15-25	5-15	0.5-3
Comments	Typically in locations with sufficient low cost energy	Many sub-stitutes available, including passive ones (reduced demand, insulation)	Slow decline expected, with more renewables and "clean coal" requirements	Substantial decline expected, no alternative has EROIs near today's fossil fuels	Particularly in oil and natural gas related areas (fertilizer, machinery), EROIs below 1 will soon be the norm

*Sources

Transportation will be highly affected by declining EROIs (and thus higher cost)

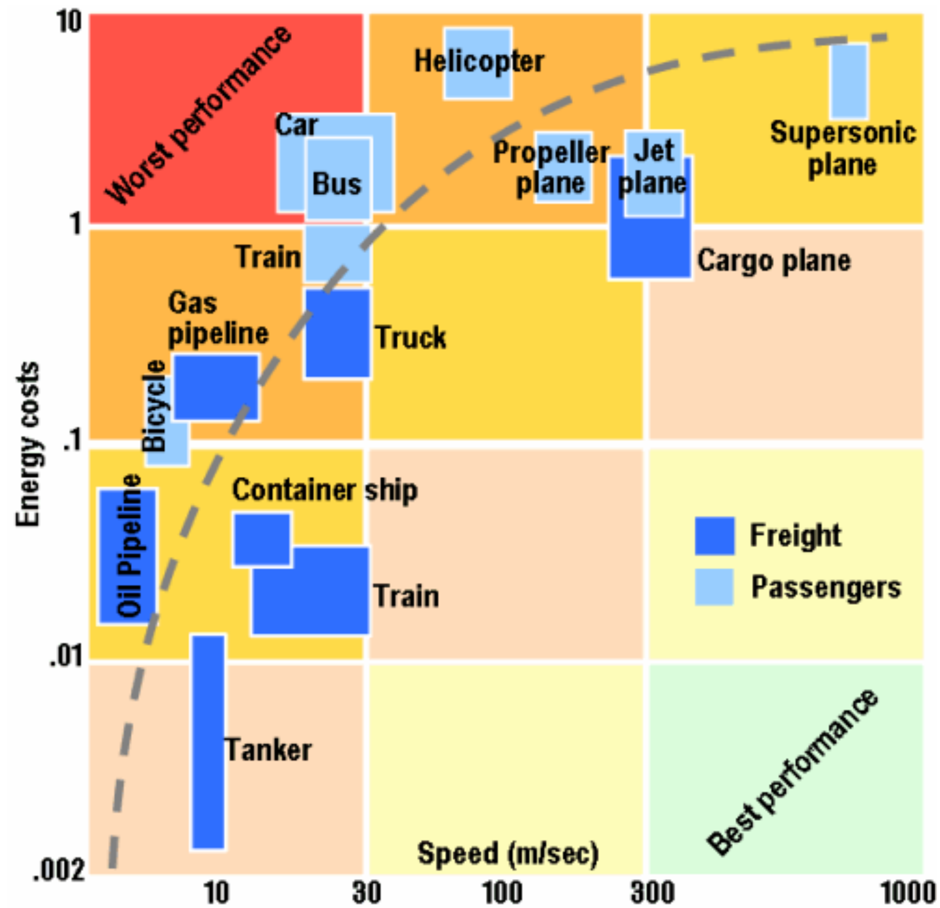
Examples

- Fuel is 30-40% of total operating expense of airlines*
- Direct fuel cost is 20-40% of total cost of trucking
- Fuel costs amount to 20-30% of cost in sea freight

No oil replacement is in sight for commercial transportation

Oil replacements for passenger car travel are not market-ready or significantly less attractive (cost/usability)

Energy Efficiency by Transportation Mode**

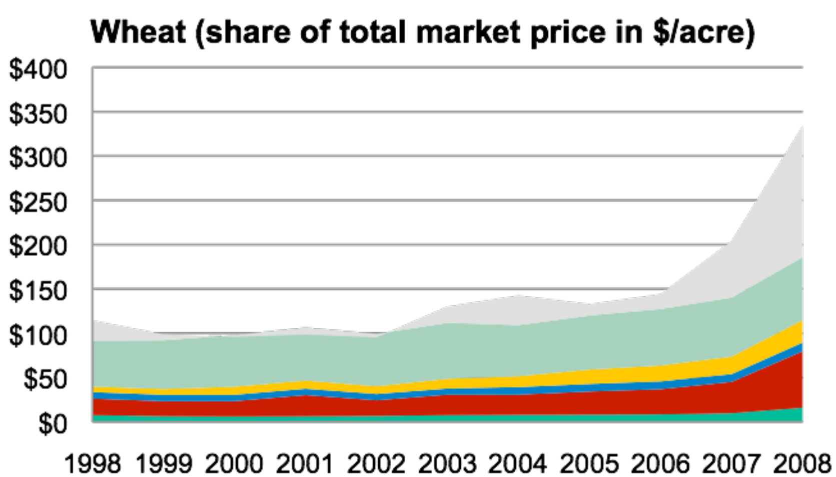


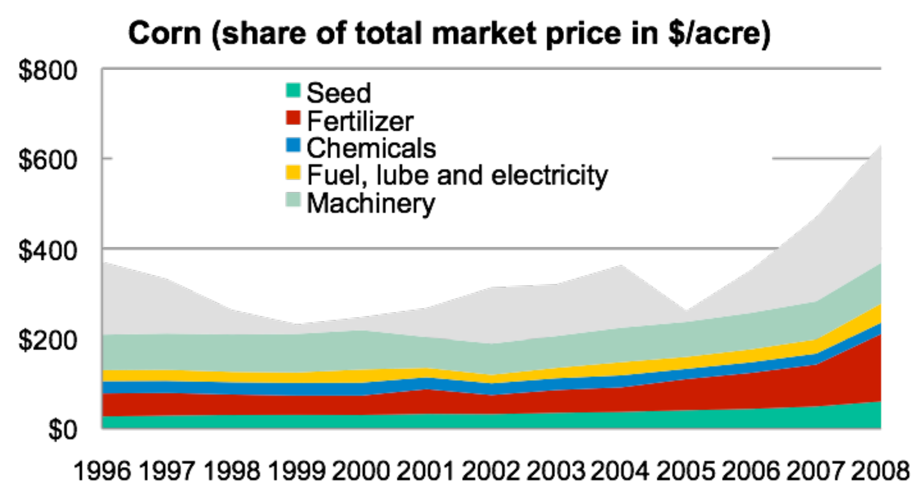
*Source: Fuel: Continental Airlines: 40.1% Jan 1- Jun 30, 2009) **graph: source and copyright © 1999-2009, Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University, Hempstead, NY, 11549 USA

The highest impact however will be seen in agricultural production

High contribution of energy to food production (4-5% of global non-renewable energy consumption goes into food); in OECD countries, another 10-15% is used for processing and transporting food

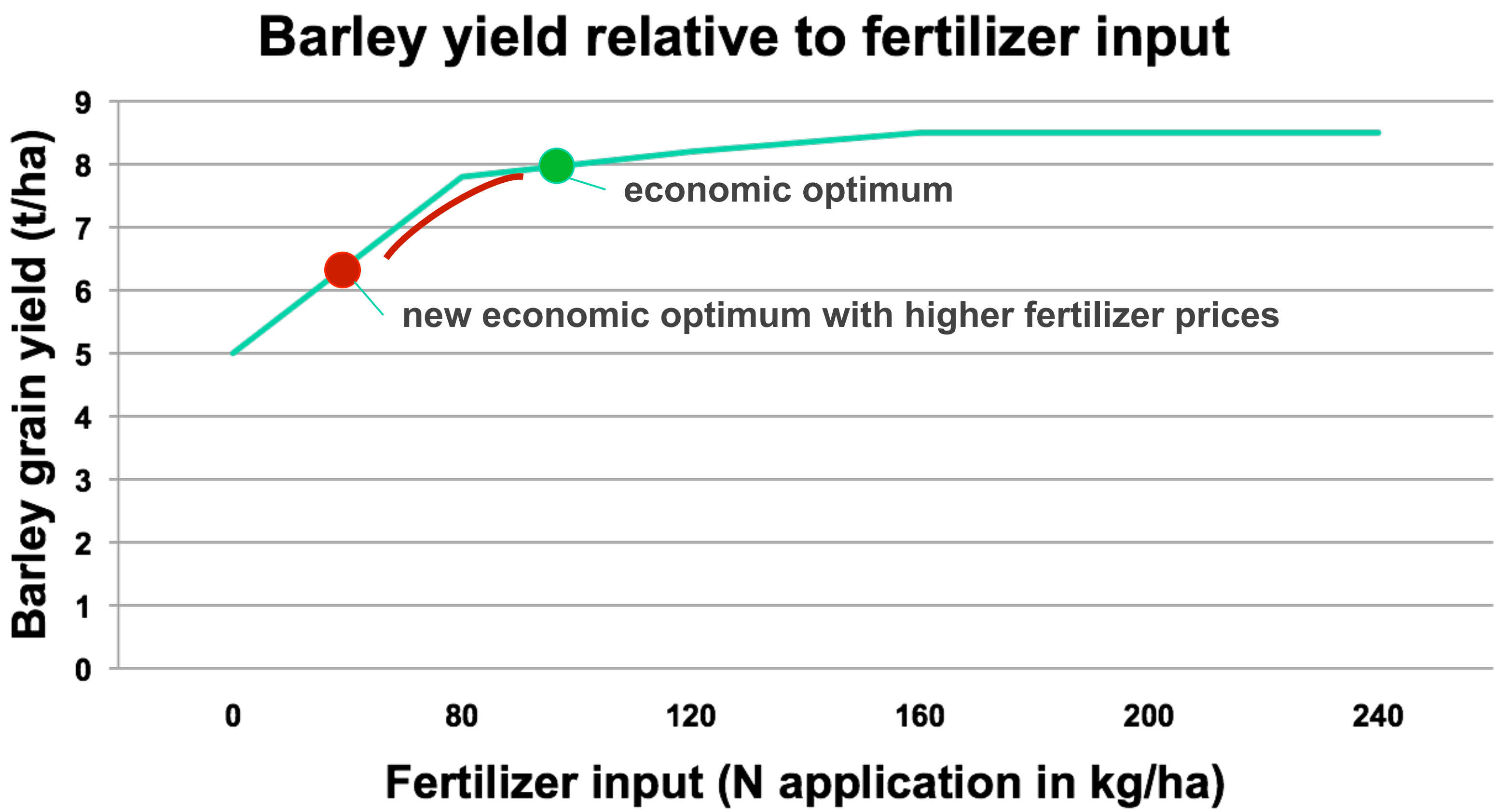
- With rising energy prices, farming and food processing will have to reduce input and thus output (less fertilizer equals less crop)
- Food prices will still rise both due to shortages and higher production cost and squeeze out poorer countries





*Source: U.S. Department of Agriculture (Economic Research Service)

With rising fertilizer prices, producing less is a sound economic decision

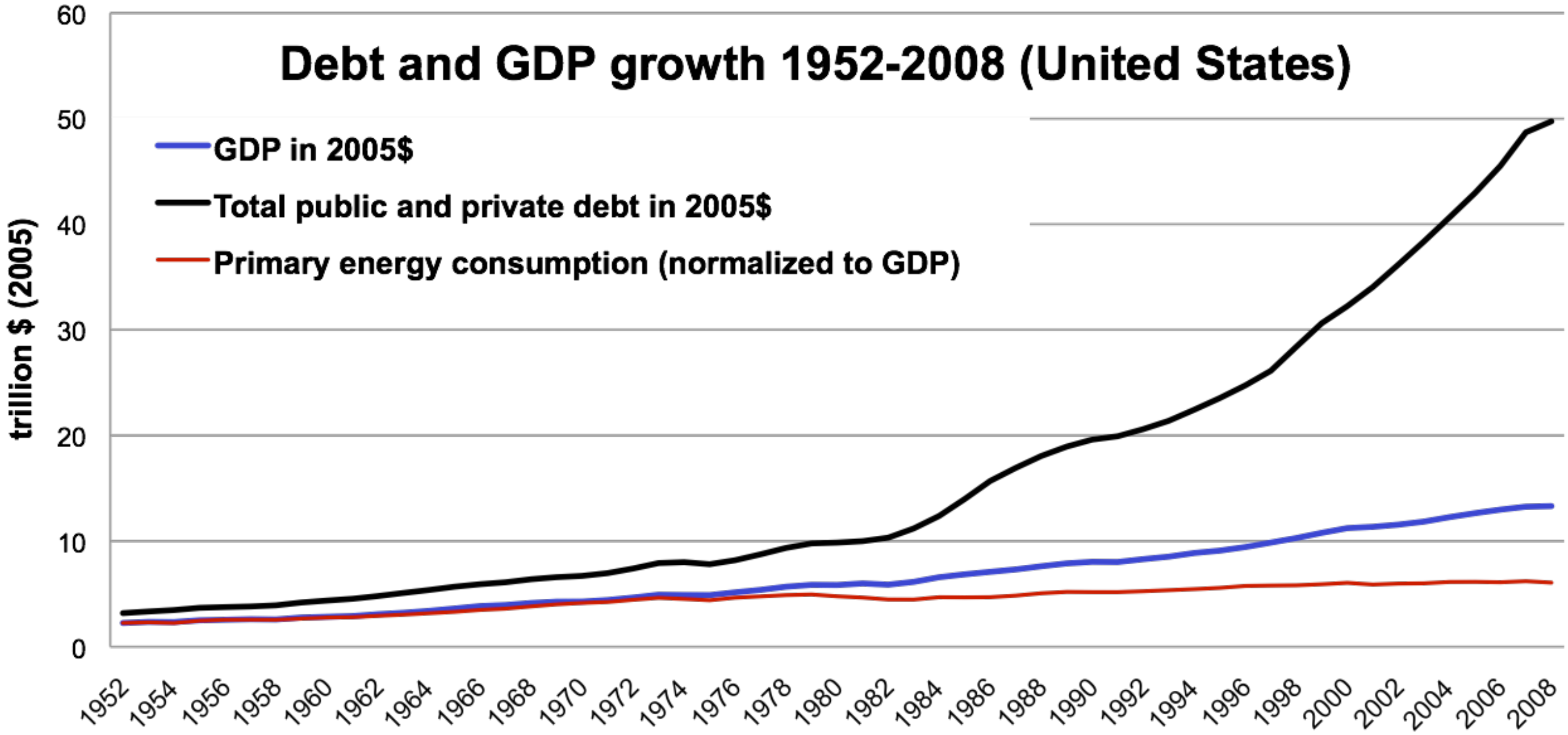


*Source: http://www.teagasc.ie/publications/2002/nattillageconf/paper04.asp

Outlook

- A slow squeeze-out of energy applications…
- …hitting an overleveraged world means
- …breaking supply chains…
- …and cheaper fuel, at times.
- Can China save us?

Over the past 50+ years, two components have supported growth: energy and increasing debt



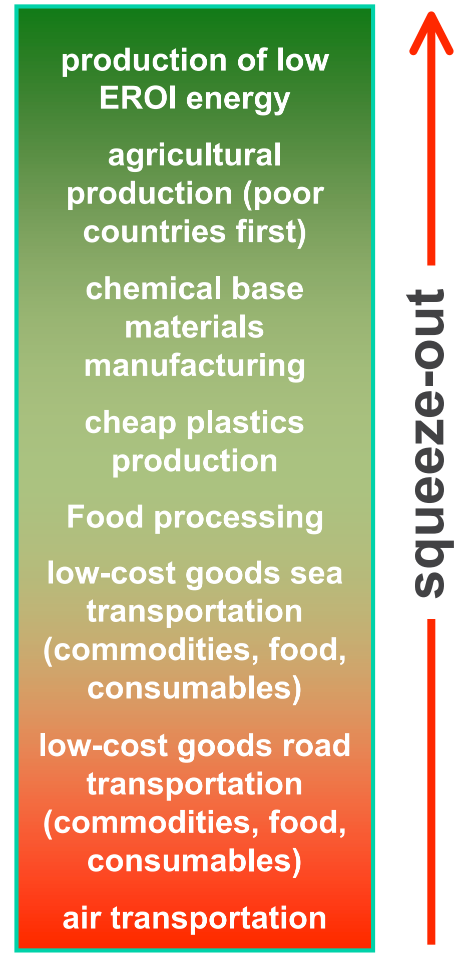
- Before 1973: Energy was cheap and growth directly possible from increased use; during this period, energy consumption grew along with GDP
- After 1973: Growing debt has been contributing to economic expansion – particularly at times of high energy prices

Lower EROIs will start squeezing out low-efficiency applications of energy…

A significant number of industrial transportation and production chains will become unmanageable

- Cost of commodity transportation becomes significant
- Global arbitrage of labor cost for low-cost/high-volume goods will become unattractive over long distances
- A substantial portion of global trade (the lower cost bracket) will be unattractive,
  - → Significant reversal of wealth gains in OECD countries
  - → Reduced wealth for today's manufacturing powerhouses
  - → Overall reduced output (and reduced energy consumption)

Food production and processing will no longer work on today's levels, with more local food and less processing



Results might be very different compared to most people's expectations

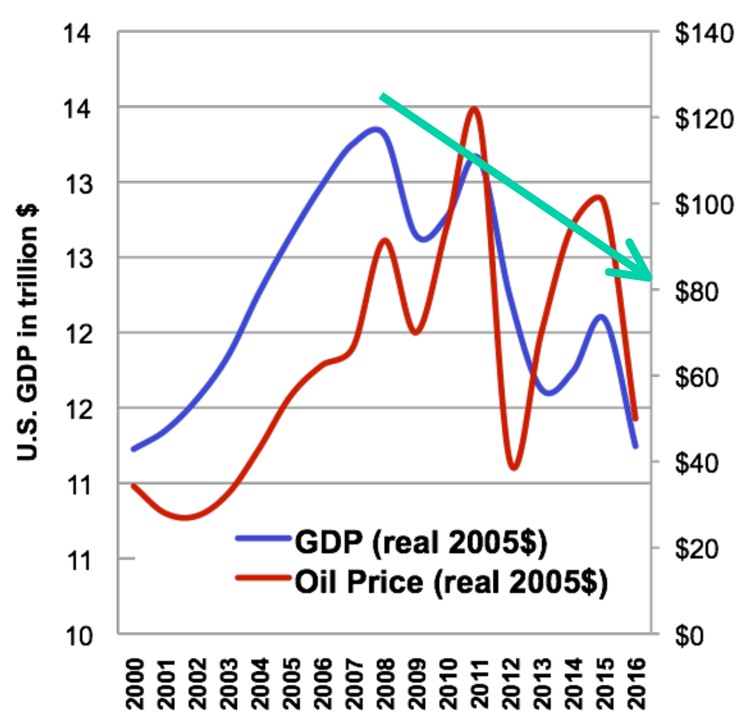
Every time we see refueled growth

- this will be curtailed by growing energy prices
- leading to a shrinking economy
- and another commodity (and energy) price crash

Key effects

- A downward trajectory
- Reduced readiness to invest (including investments into energy technology and exploration)
- Even fewer available resources

Potential future scenario



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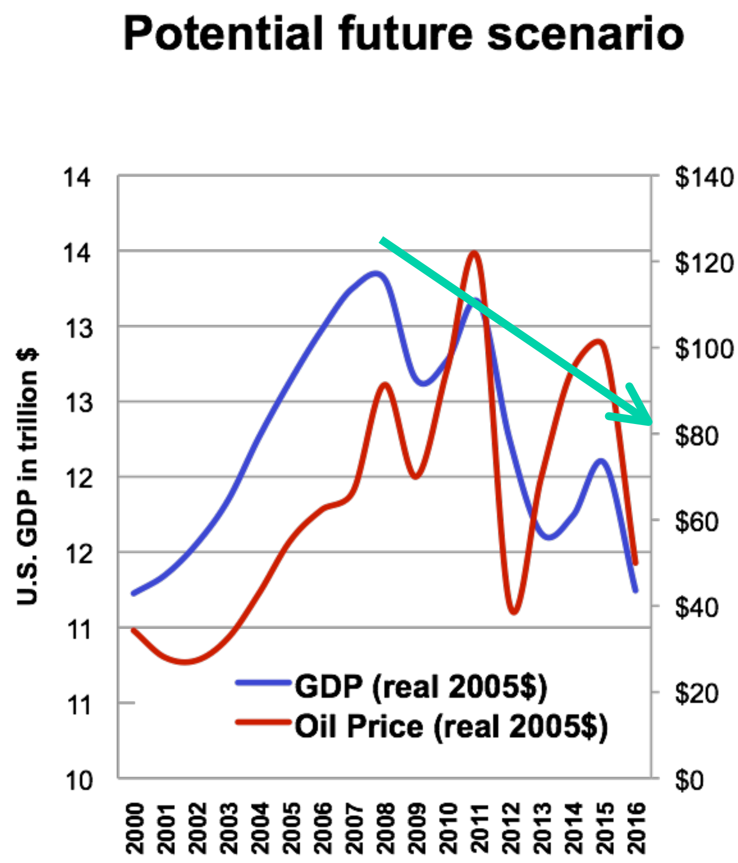

Potential future scenario
U.S. GDP in trillion $
14
14
13
13
12
12
11
11
10
$140
$120
$100
$80
$60
$40
$20
$0
GDP (real 2005$)
Oil Price (real 2005$)
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Why is China's Gross Domestic Product growing at 8-9% in 2009?

China has decided to take the "Western Medicine", using credit as a means to fuel short term growth:

- In 2008, total private sector credit grew by 17% of GDP
- In 2009, total private sector debt will likely grow by 35% of GDP to more than 150% of GDP (for comparison: United States private non-financial sector debt in 2008: 169% of GDP)

Once China reaches the limit to further deficit spending, GDP will contract