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Brief CV

Ph.D.: U. of Maryland at College Park, (1996)

Over 60+ papers, 1500+ citations, $1.5M+ grant funding from DoD, NSF, DoE, State of Ohio

Directed 10+ Ph.D. thesis, 15+ M.S. thesis, research of 10 undergraduates

My own research

- Theory and computation
- Techniques: Quantum density functional theory, statistical mechanics, classical molecular dynamics, Monte Carlo
- Close connection with experimentalists
- Materials range from thin film to bulk materials, from metals to semiconductors, crystalline to disordered materials, and nano- to micro-length scales
- Details: See http://astro1.panet.utoledo.edu/~khare/

Pretest

- **Form groups of 3.**
- **What is the most important problem related to Power and Fuel Sustainability?**
- **What is its solution?**
- **Take 5 mins. to discuss these two questions.**
- **Give an answer to the whole class in 3 to 5 sentences.**

Power and Fuel Sustainability

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Acknowledgements

Many fellow students of Peak Resources issues, too numerous to acknowledge.
Some original material mixed with work of others.

Most Important Themes of this Discussion

1. Peak Energy Curve, EROEI
2. Wealth and Energy
3. Re-definition good life

Challenges lead to Opportunities

A Positive Perspective

- Every challenge can be used to create a transformative change
- This Challenge is no different
- We can pro-actively address it and create a far healthier, sustainable, egalitarian society

Outline

- What is the problem of peak energy or resource depletion?
- What is its imminence, scale and impact?
- What can we do about it?
- Reducing consumption of Energy and Material Goods is the First Step
- Using more Renewable Energy is the Second Step

Four Distinct Challenges

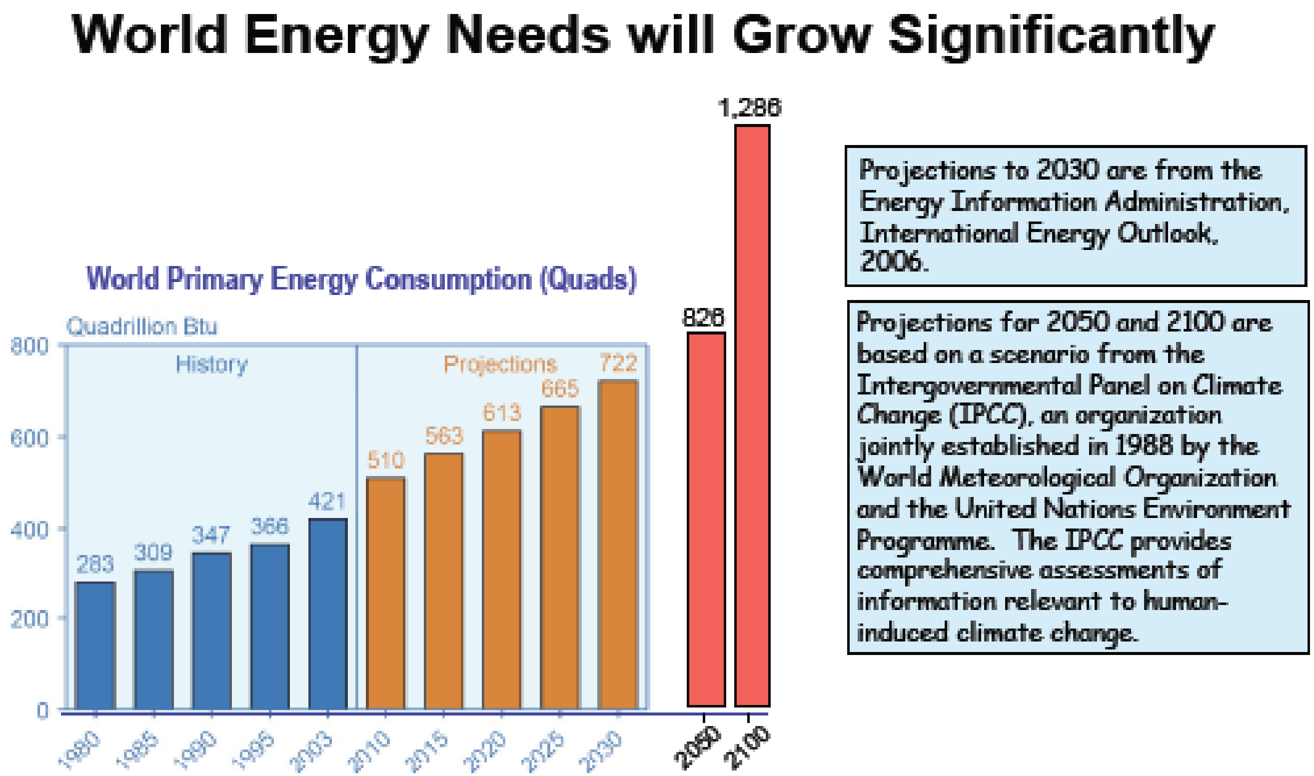
Problem	Imminence	Impact
I Global Warming	Approaching (5 to 10 years)	GRADUAL over 10 – 100+ years
II Peak Production Total Energy	Approaching (10 to 15 years)	CATASTROPIC
III Peak Production Portable Energy	Now (-3 to 5 years)	CATASTROPIC
IV Peak Other Materials (bees, grains, fish, top soil, fertile land, H_2O, Cu, P, U, Au)	Now (0 to 5 years)	CATASTROPIC Can be exacerbated by I - III

Least Important

↓

Most Important

Scale of consumption, 100 Q = 10^{20} J



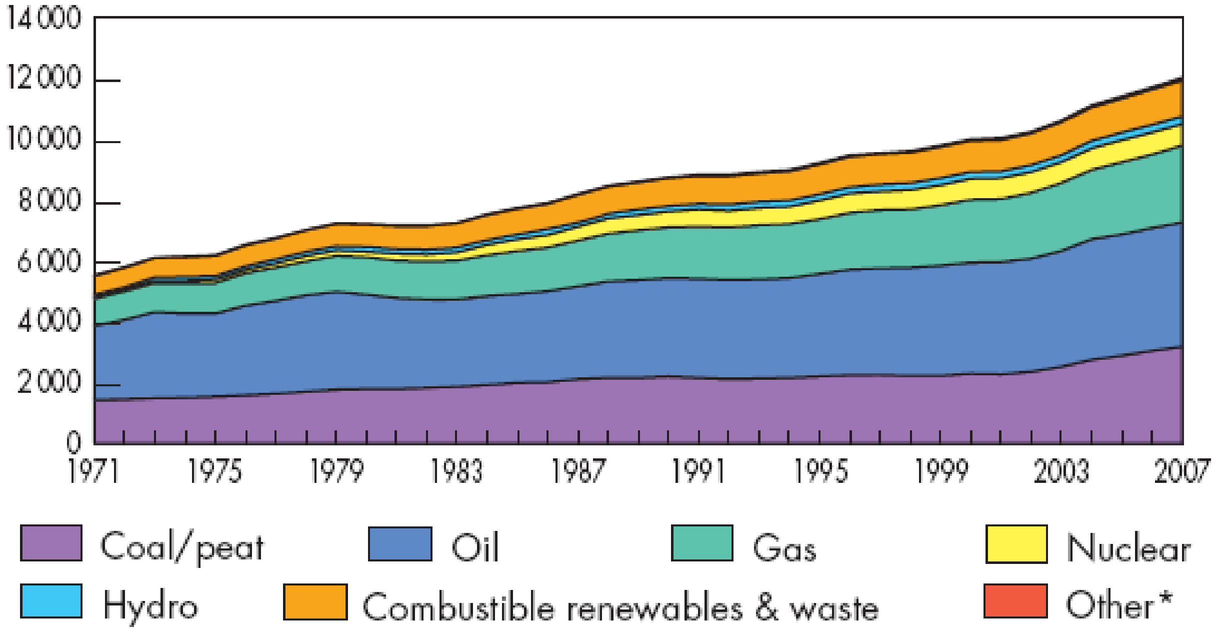
600 quads = 6.00×10^{17} BTU = 16.6×10^{25} kW-hour

= 19×10^{12} Watt-year = 19 TW-yr = 6×10^{20} J = 104 GBOE = 14.3 GTOE

1. Total Primary Energy Supply - TPES

World

Evolution from 1971 to 2007 of world total primary energy supply by fuel (Mtoe)



Key World Energy Statistics, International Energy agency , 2009

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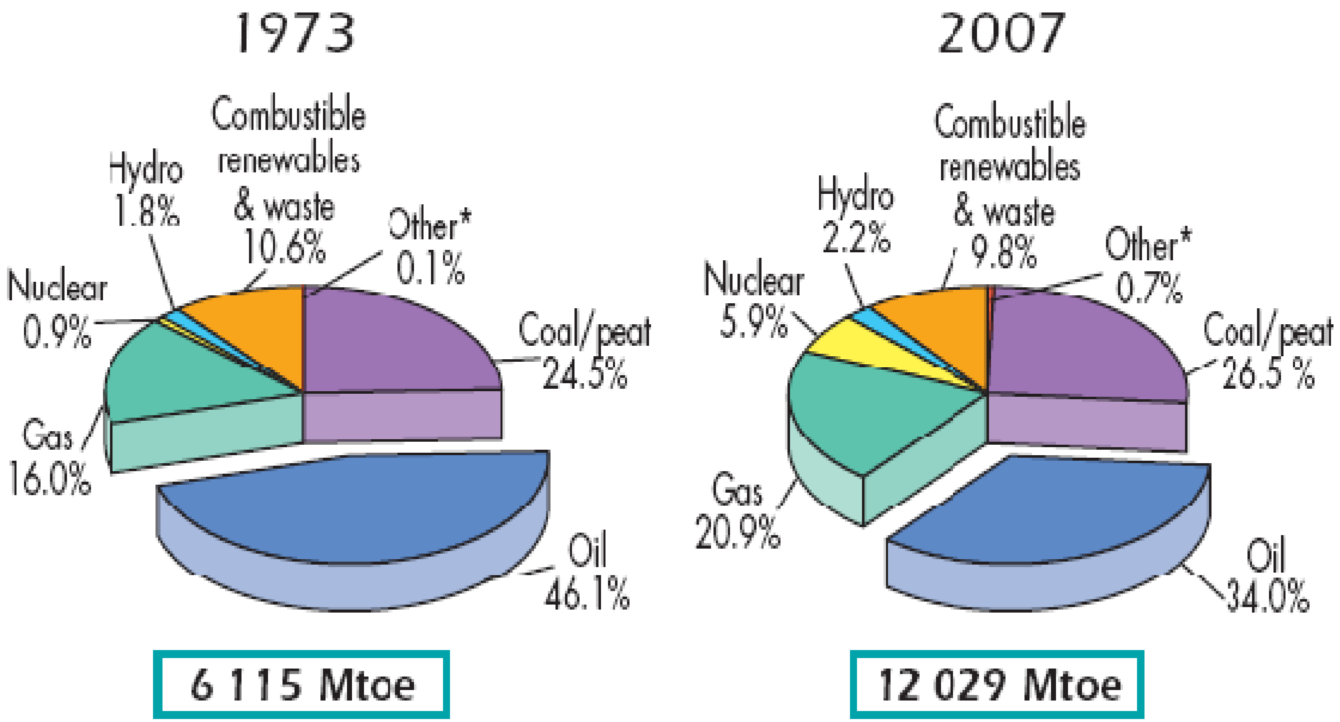
1973 and 2007 fuel shares of TPES



Key World Energy Statistics, International Energy agency, 2009

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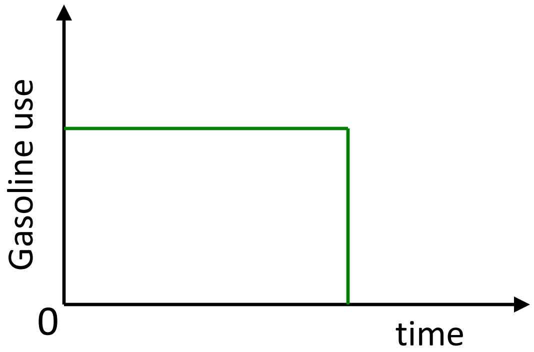
First crude oil found < 150 years ago

Before the first oil well was dug in Pennsylvania in 1859, Nature had made about two trillion barrels of oil and scattered it unevenly around the world.

By 2008 we've used up about one trillion. In other words we're near the half-way point.

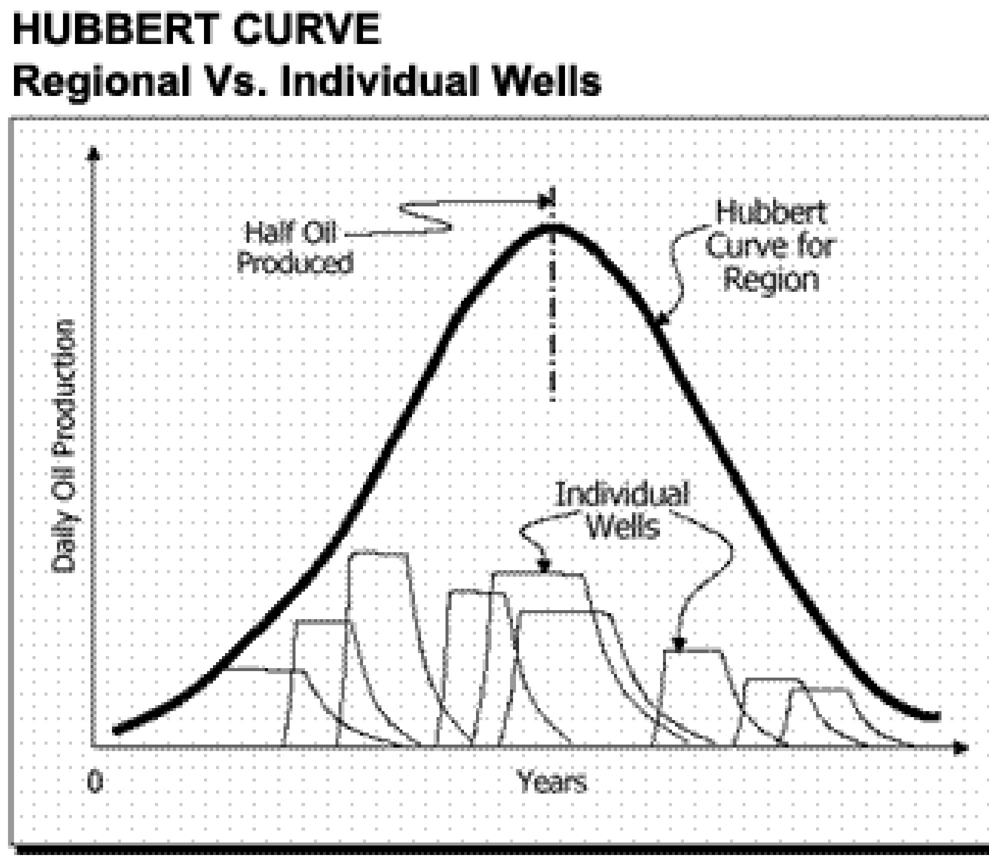
"Hubbert's Peak: The Impending World Oil Shortage", Kenneth S. Deffeyes

An oil well isn't like a car's fuel tank

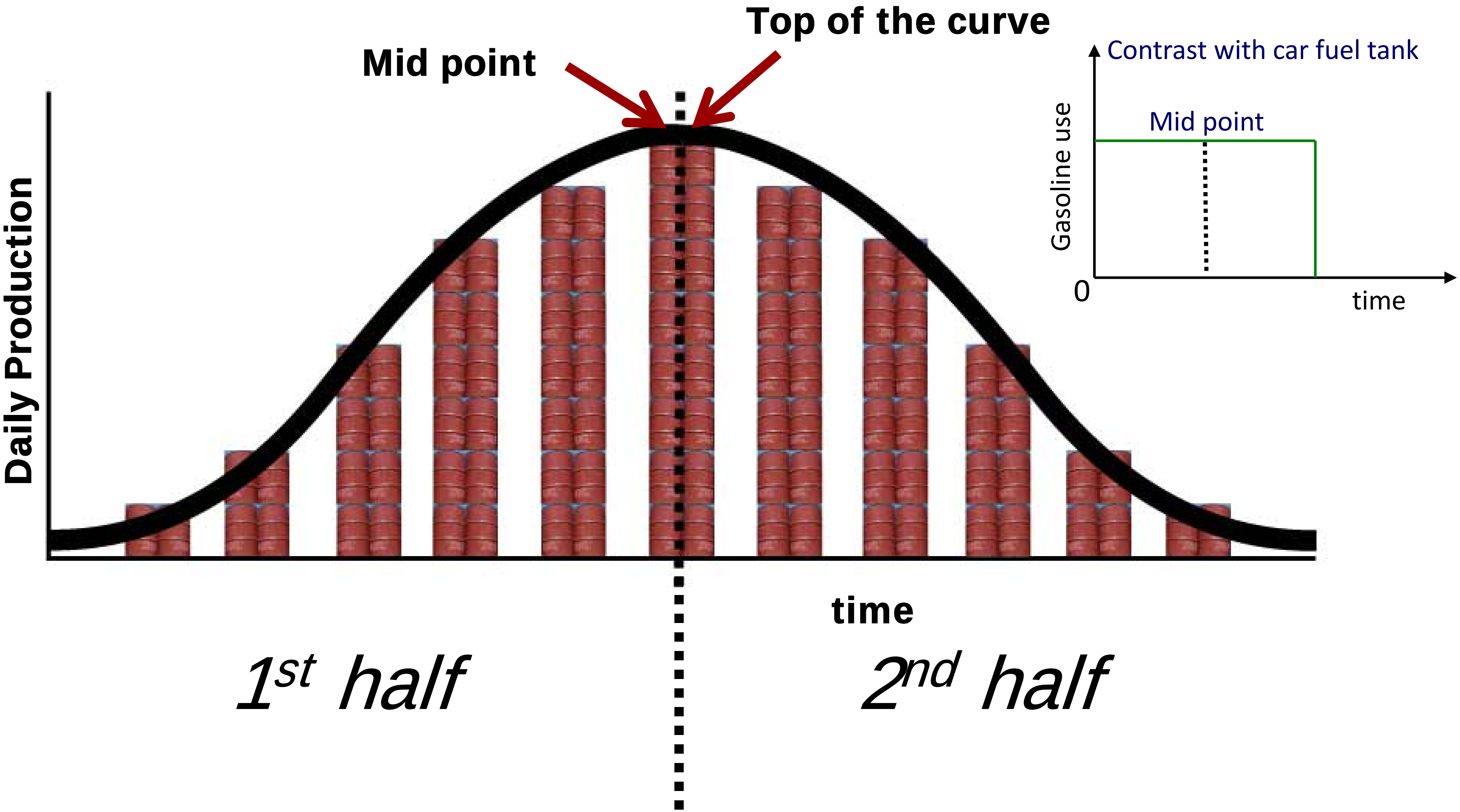


- With a car you can drive at full speed until the moment you run out of fuel.

Different Well Discovery and Production Times ==> Peak in Production Curve

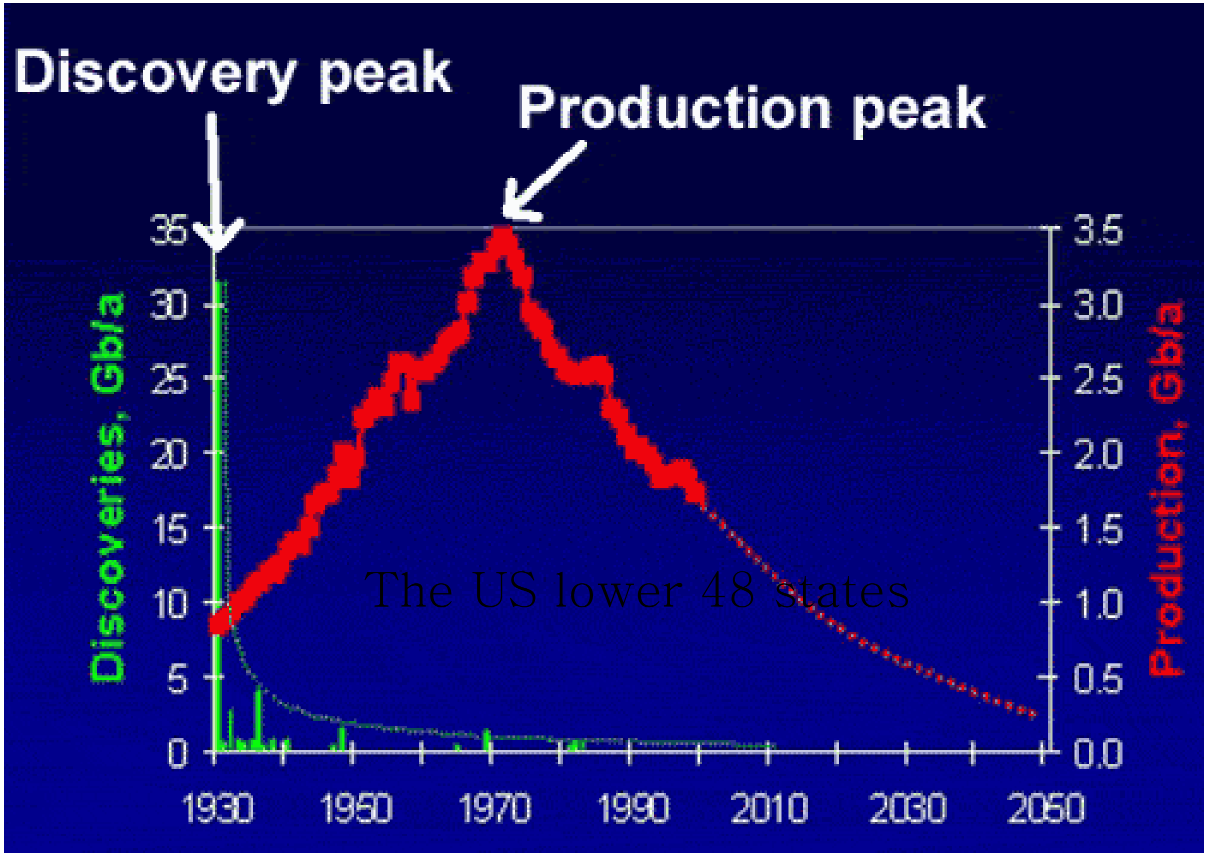


When you plot the production of <u>an aggregate</u> of oil fields, it approximates a <u>bell curve</u>



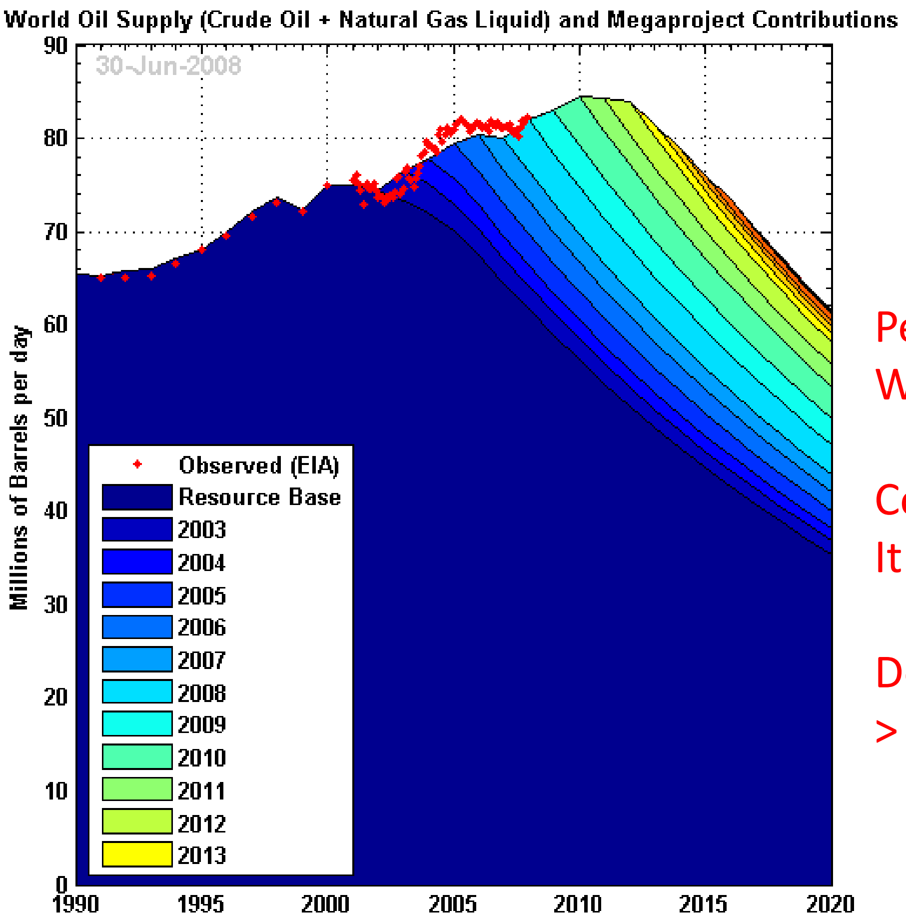
From geological peak – Production declines indefinitely forever

Oil *discoveries* in the US peaked
- then 40 years later *production* peaked



Adapted from Collin Campbell, University of Clausthal Conference, Dec 2000

Same Chart: Now a new projects analysis



From: Skrebowski at www.theoildrum.com, July 2008 posting and Wiki Oil Mega Projects database.

Peak oil is imminent.
Will happen in < 5 years!

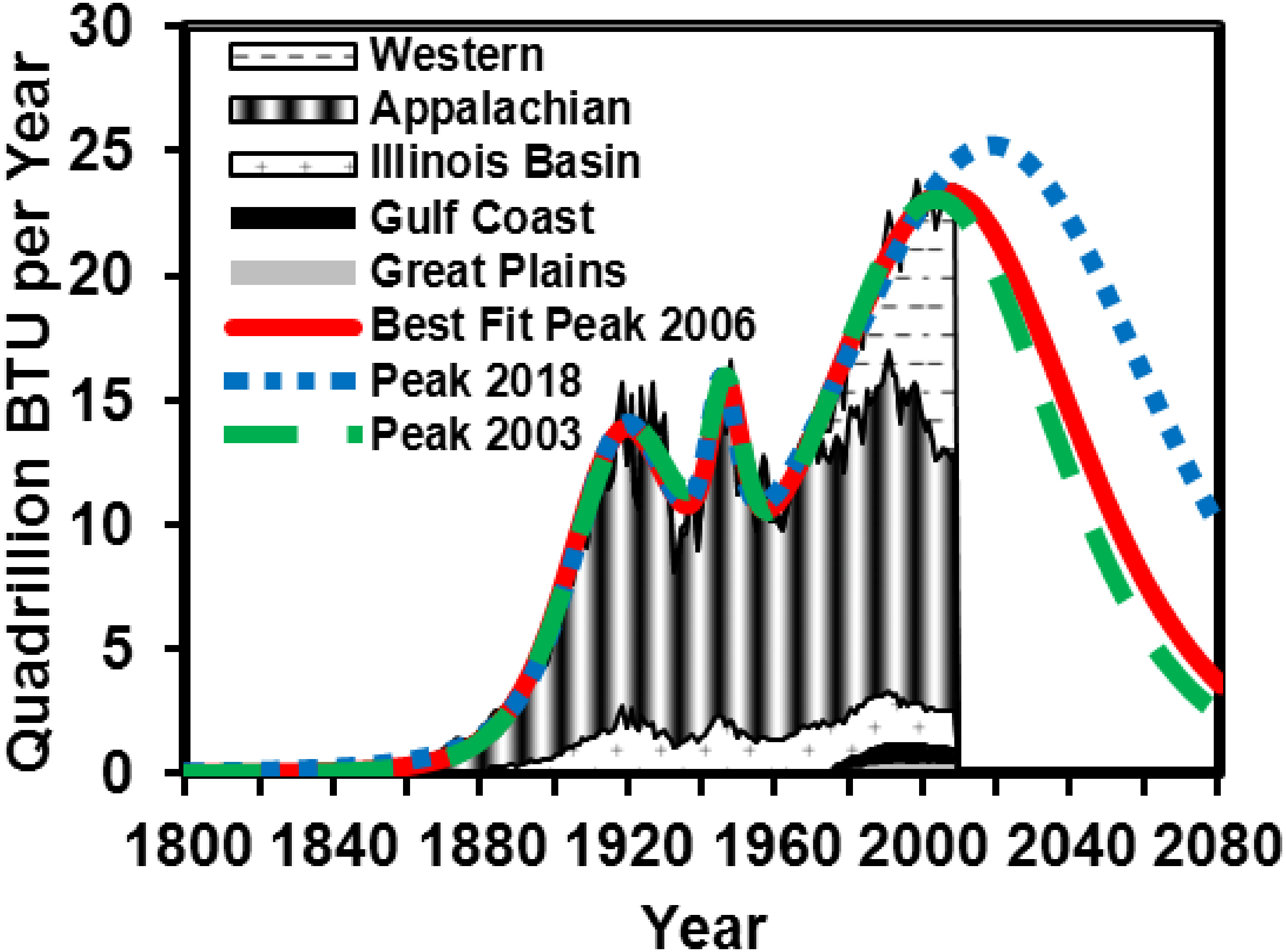
Conventional crude peaked in 2005.
It is already in the past tense!

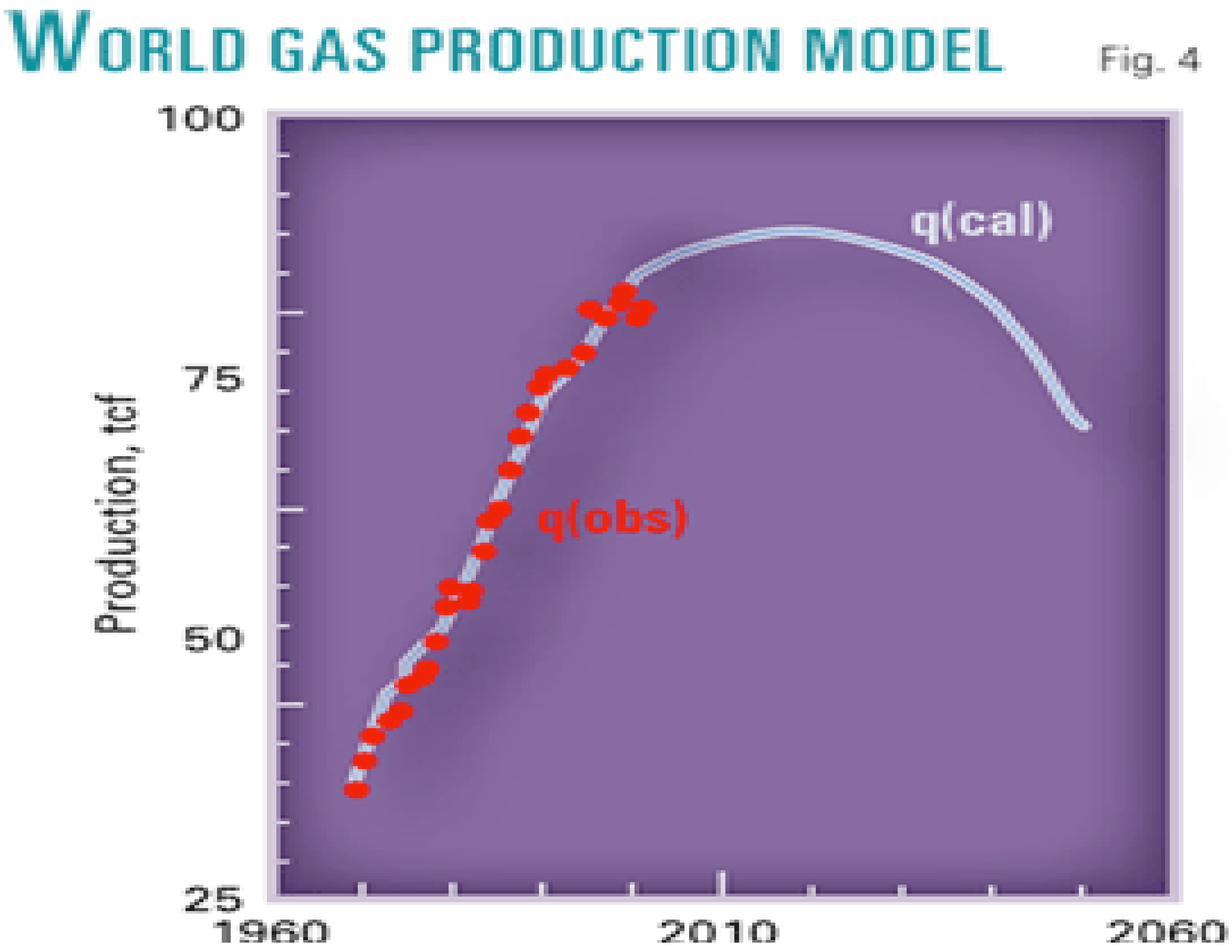
Decline after peak will be
> 5%/year!

…the world will peak between 2010-2015

Adapted from: Richard C. Duncan and Walter Youngquist

Peak Production of US coal
Similar trends for World coal (Reaver and Khare)

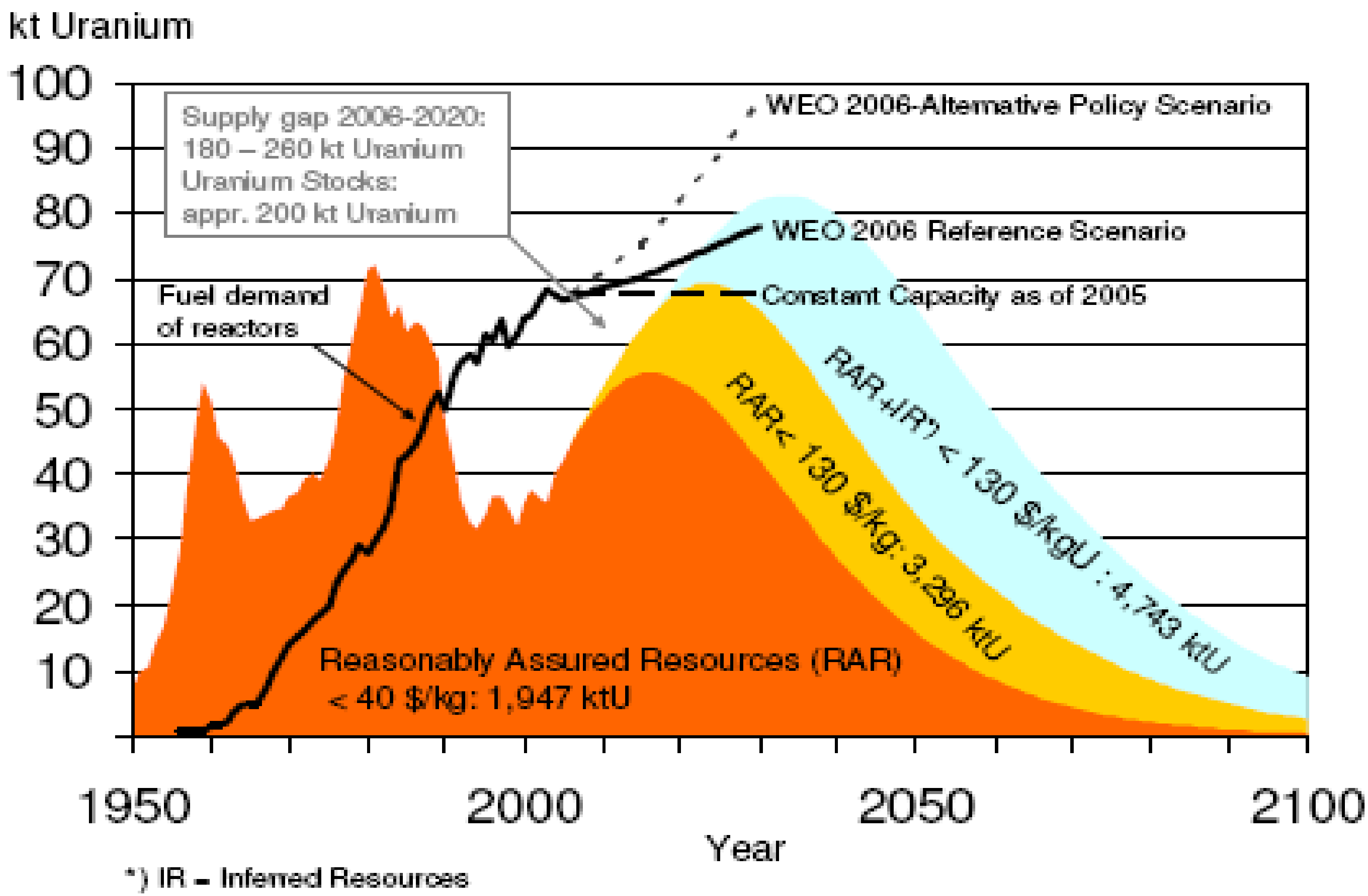




(Imam *et al.*, Oil and Gas Journal, August 2004)

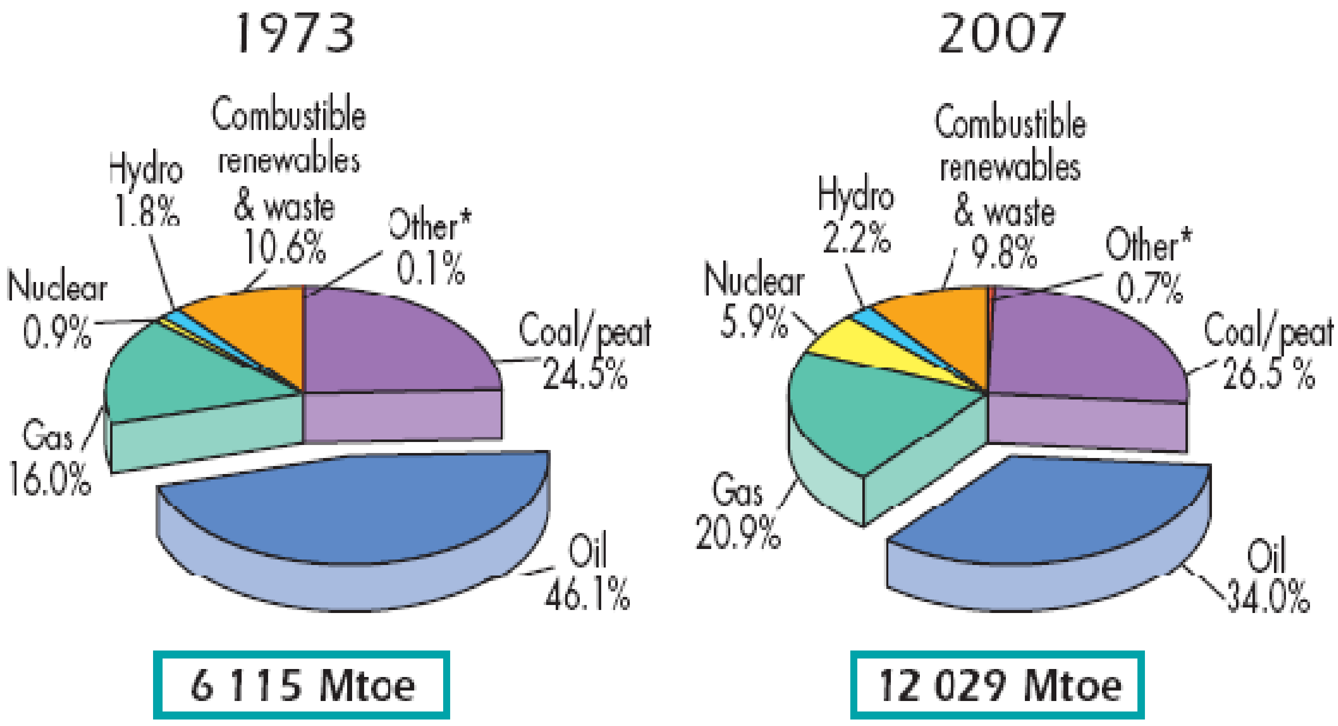
Uranium Supply

The figure summarizes the present supply situation



Uranium Resources and Nuclear Energy *by Energy Watch Group, December 2006*

1973 and 2007 fuel shares of TPES



Key World Energy Statistics, International Energy agency , 2009

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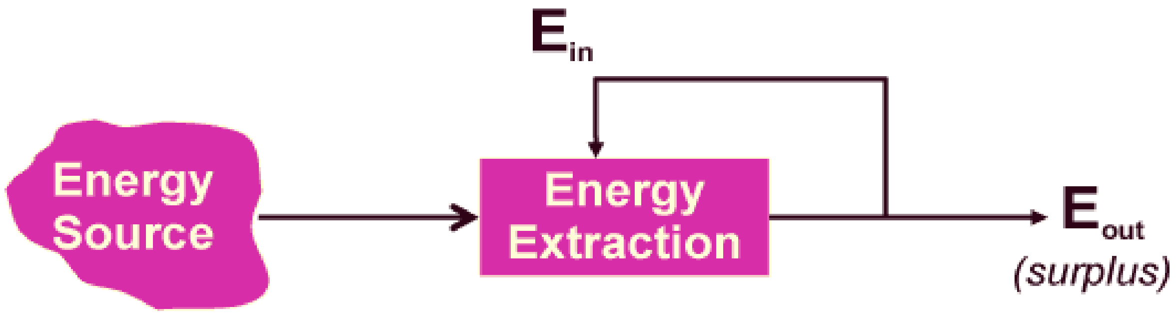
Energy returned on Energy invested

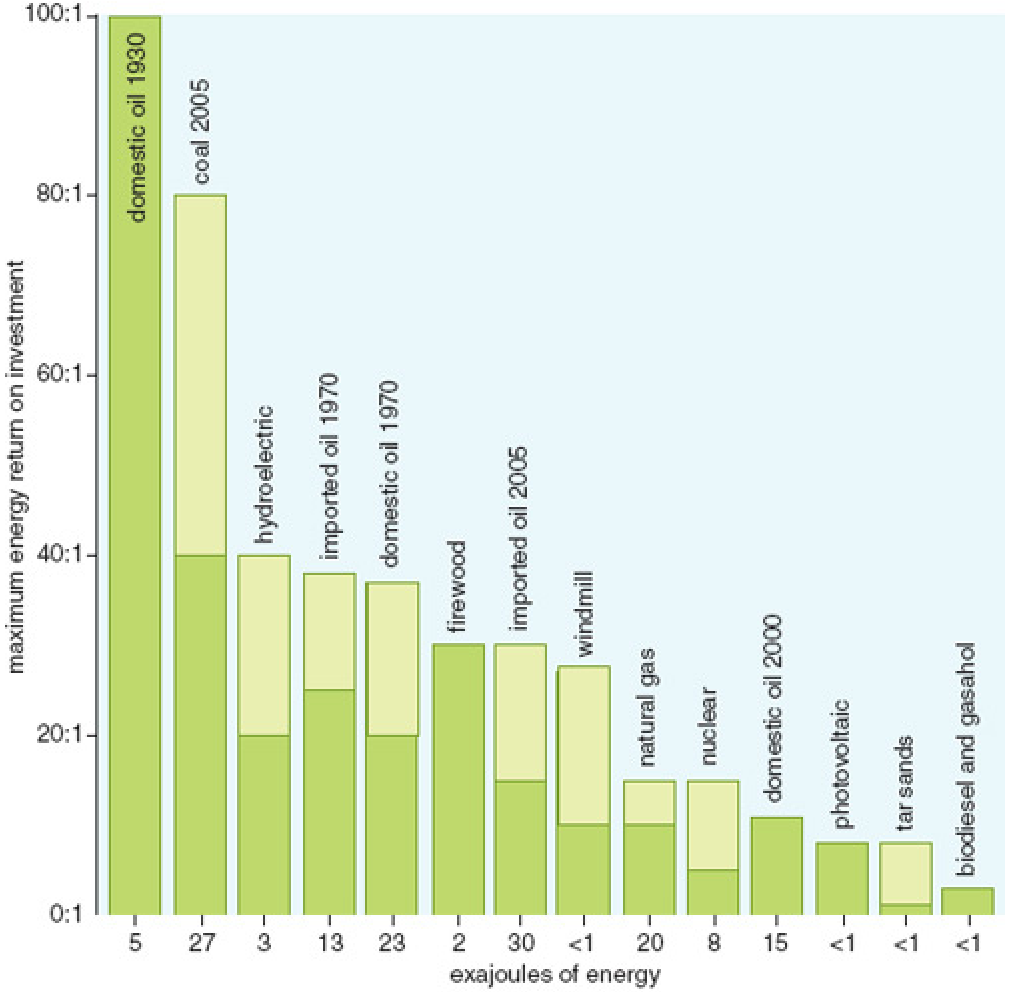


$$\text{Energy Return on Investment (EROI)} = \frac{E_{out}}{E_{in}}$$

Charles Hall, Pradeep Tharakan, John Hallock, Wei Wu and Jae-Young Ko, Advances in Energy Studies Conference, Porto Venere, Italy, September 2002

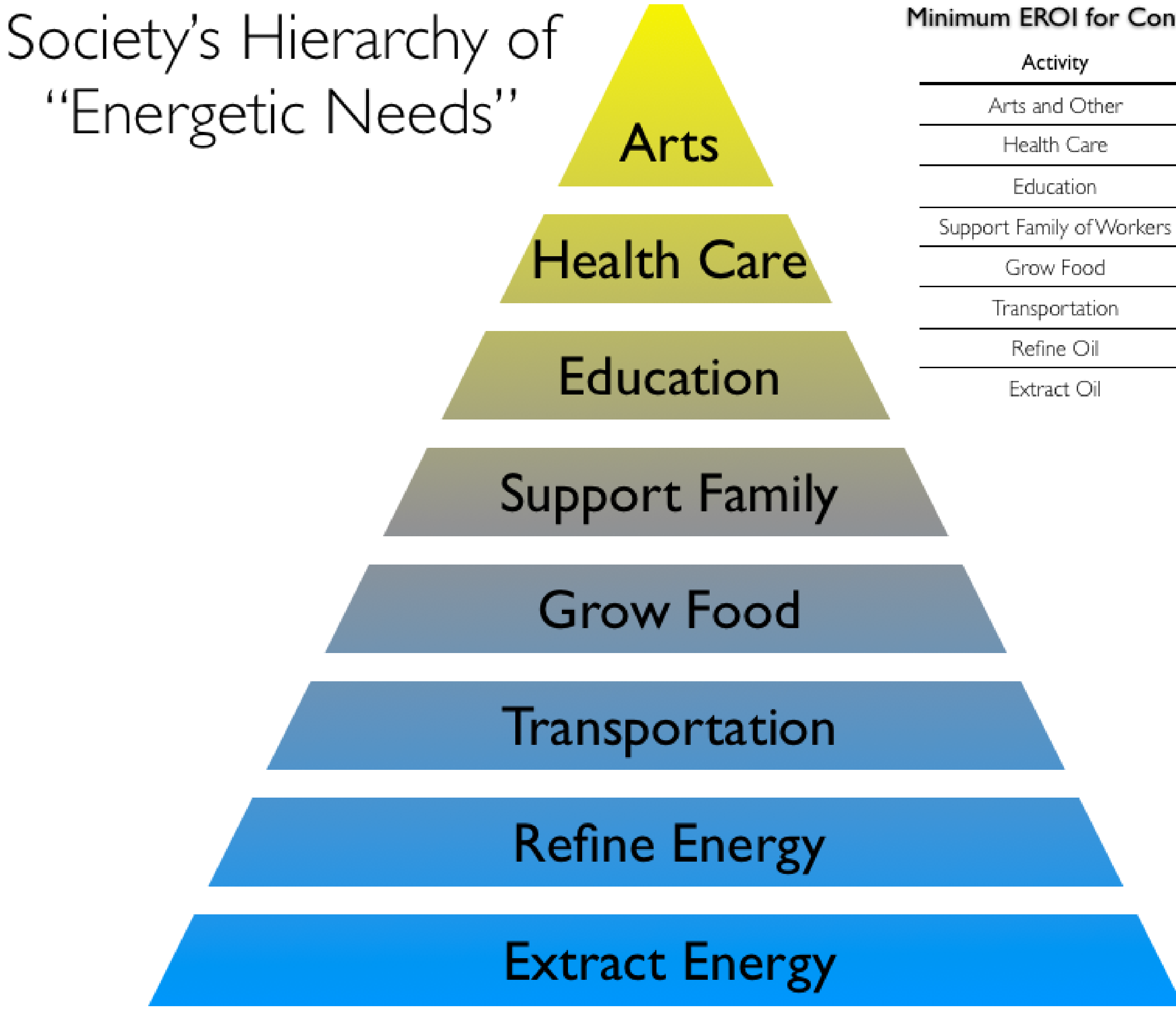
http://www.eroei.com/articles/the-chain/what-is-eroei/

EROEI for different fuels



Tom Konrad: http://www.greendump.net/the-oil-drum/managing-the-peak-fossil-fuel-transition-eroi-and-eirr

EROEI and culture



Minimum EROI for Conventional Sweet Crude Oi

Activity	Minimum EROI Required
Arts and Other	14 : 1
Health Care	12 : 1
Education	9 or 10 : 1
Support Family of Workers	7 or 8 : 1
Grow Food	5 : 1
Transportation	3 : 1
Refine Oil	1.2 : 1
Extract Oil	1.1 : 1

Lambert and C. Hall *et al*., 2012

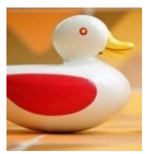
To Maintain Order We Need Energy

- $dF = dU - TdS$; natural systems want to minimize dF.
- If we want to oppose this trend we need constant input of energy $dQ = dU + dW$.
- Life and material richness is impossible without energy.
- Sustainable GDP growth with decreasing energy is an oxymoron or nonsense

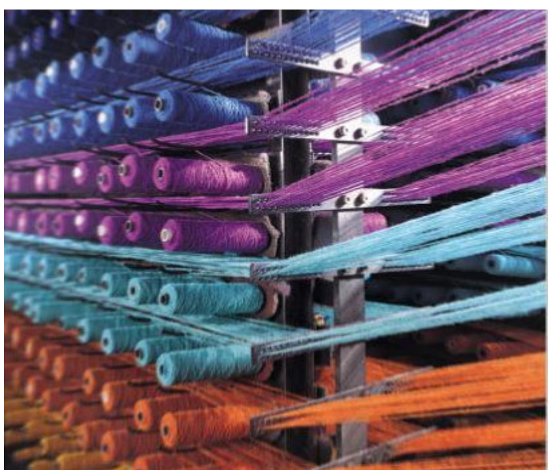
Materials from fossil fuels: Plastics, textiles, pharmaceuticals, paints, dyes, asphalt

No easy scalable substitute for oil

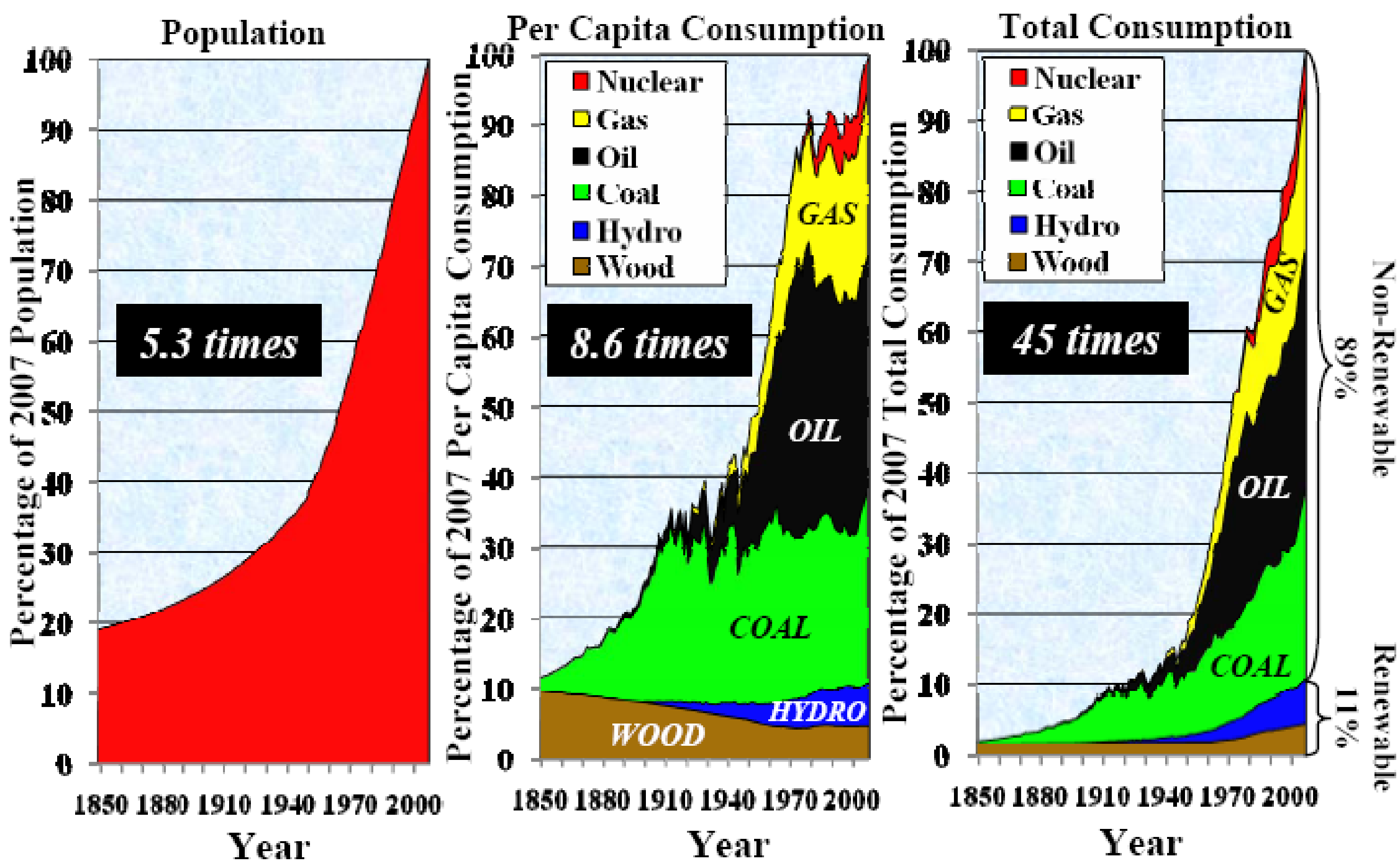
Easy means low EROEI



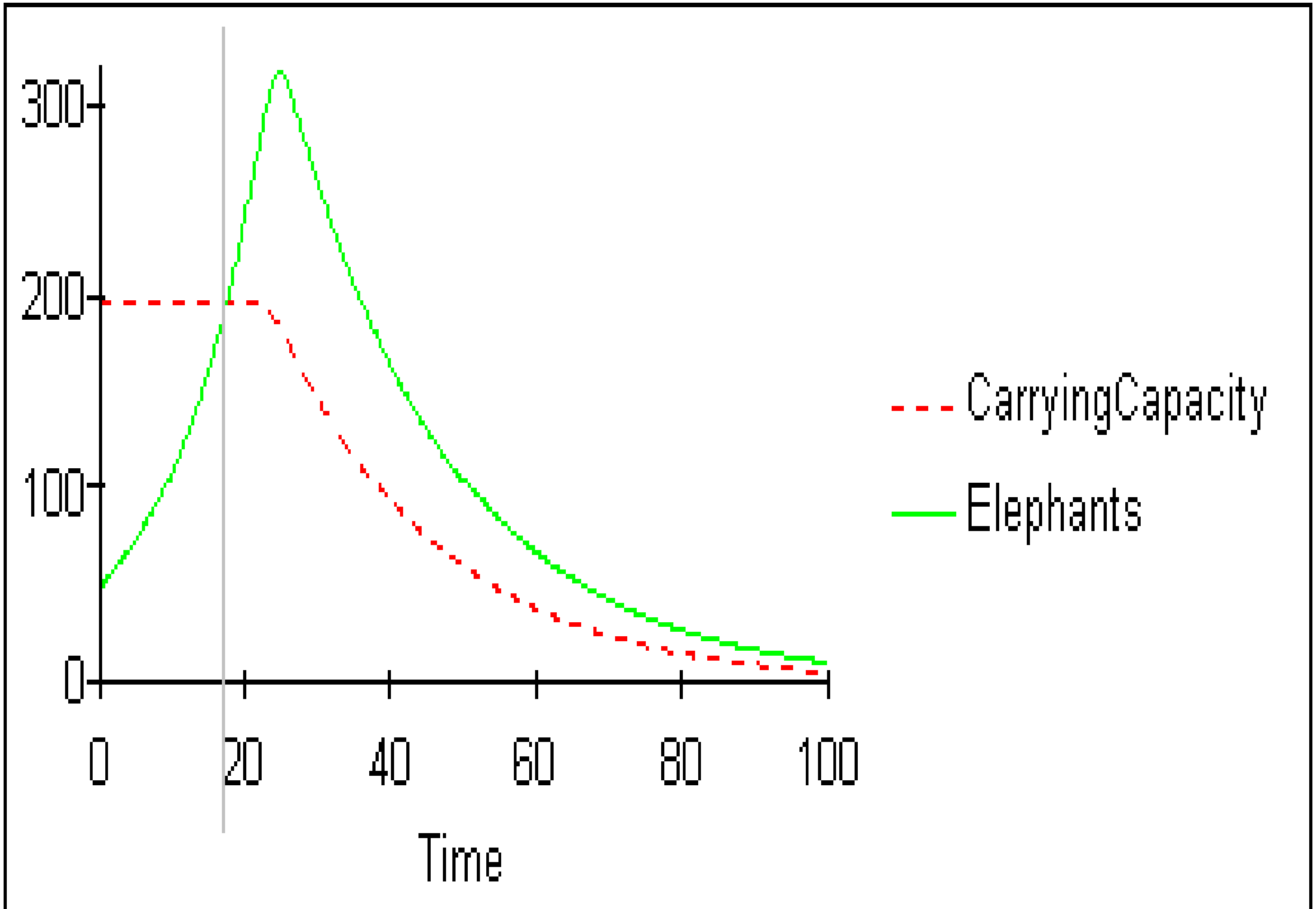

World Population, Per Capita and Primary Energy consumption



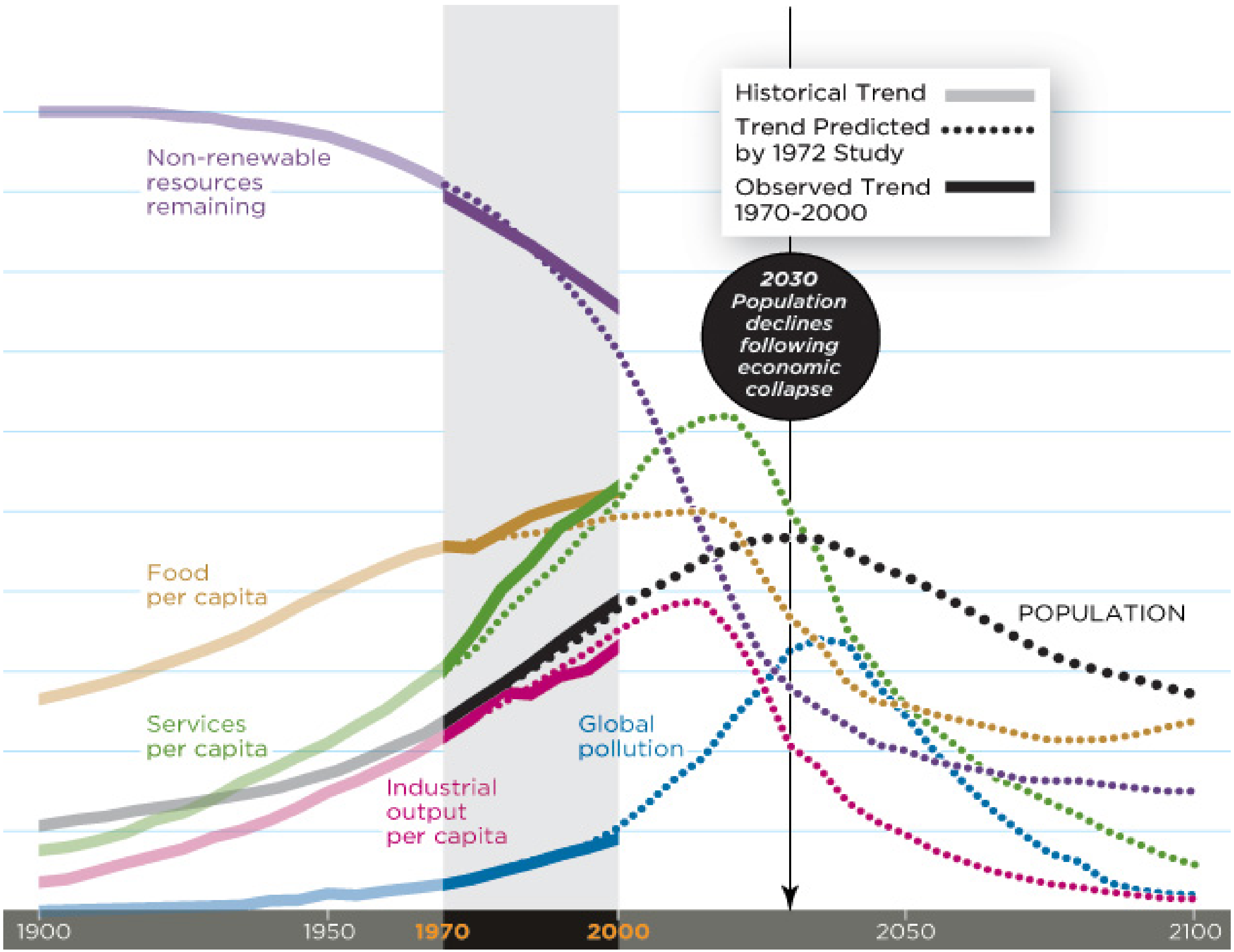
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2008; U.S. Bureau of Census, 2008)

http://www.aspo-usa.org/aspousa4/proceedings/Hughes_David_Coal_ASPOUSA2008.pdf

Systems Analysis Model for Human Population Future

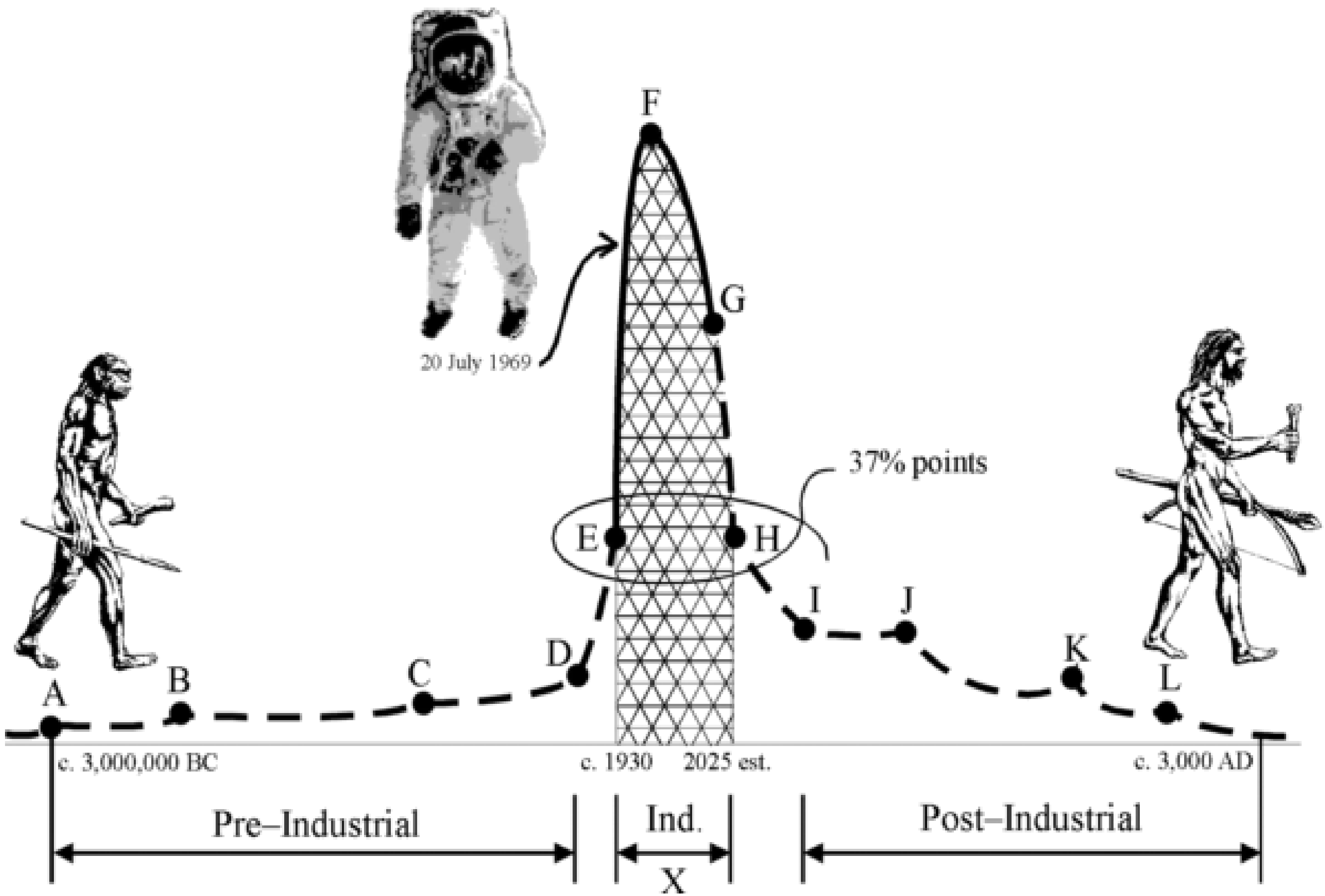


Summation of all this data: Growth and Decline



From Alan Turner in Australia

Industrial Civilization Lifetime about 200 years



From Olduvai Gorge

All Roads Lead to ~~Rome~~ Voluntary Reduced Consumption & Efficiency!

Tables on US and World Total and Per Capita Energy Consumption

	World Energy Consumption per year	US energy Consumption per year
TW - yr	15.936	3.0346
100 Quad Btu	4.762	0.90696
10 GTon Oil Eq.	1.2002[a]	0.2286[c]
ExaJoules (EJ)	504.8	96.123
10 Giga Barrels of Oil	7.889	1.5708
1 Giga short ton of coal	19.051	3.6278
1 Giga metric tons of coal	17.416	3.265

	World energy consumption per capita per year	US energy consumption per capita per year
Kw-yr	2.312	9.92531
MBTU	69.09	296.639
TOE	1.741	7.47517
GJ	73.24	314.39
BOE	11.45	51.3761
Short ton of coal	2.764	11.8653
Metric ton of coal	2.488	10.6788

Renewable Energy and Materials: Wind

Total reserves of Neodymium = M_{Nd} $= 8 \times 10^9$ Kg

Mass of Nd required to produce 1 MW energy = m_{Nd} $= 275$ Kg

Total power produced = $\frac{M_{Nd}}{m_{Nd}} \times 10^6\, W = \frac{8\times10^9}{275} \times 10^6\, W$ $= 29$ TW

Total energy produced per year = 29 TW-yr × Capacity factor = 7.25 TW-yr

Renewable Energy and Materials: Cars

<u>TOYOTA PRIUS CALCULATION</u> :

Mass of Neodymium required for 1 car = m_{Nd} = 1 kg

Mass of Dysprosium required for 1 car = m_{Dy} = 0.1 kg

Total reserves of Neodymium = M_{Nd} = 8×10^9 kg

Present production of Dysprosium per year = M_{Dy} = 1×10^5 kg

Hence number of cars produced using Neodymium = $\frac{M_{Nd}}{m_{Nd}}$ = $\frac{8\times10^9}{1}$ = 8 billion

But mass of Dysprosium required for this is = $8 \times 10^9 \times 0.1$ $= 8 \times 10^8$ kg

Solutions: Four types of wealth

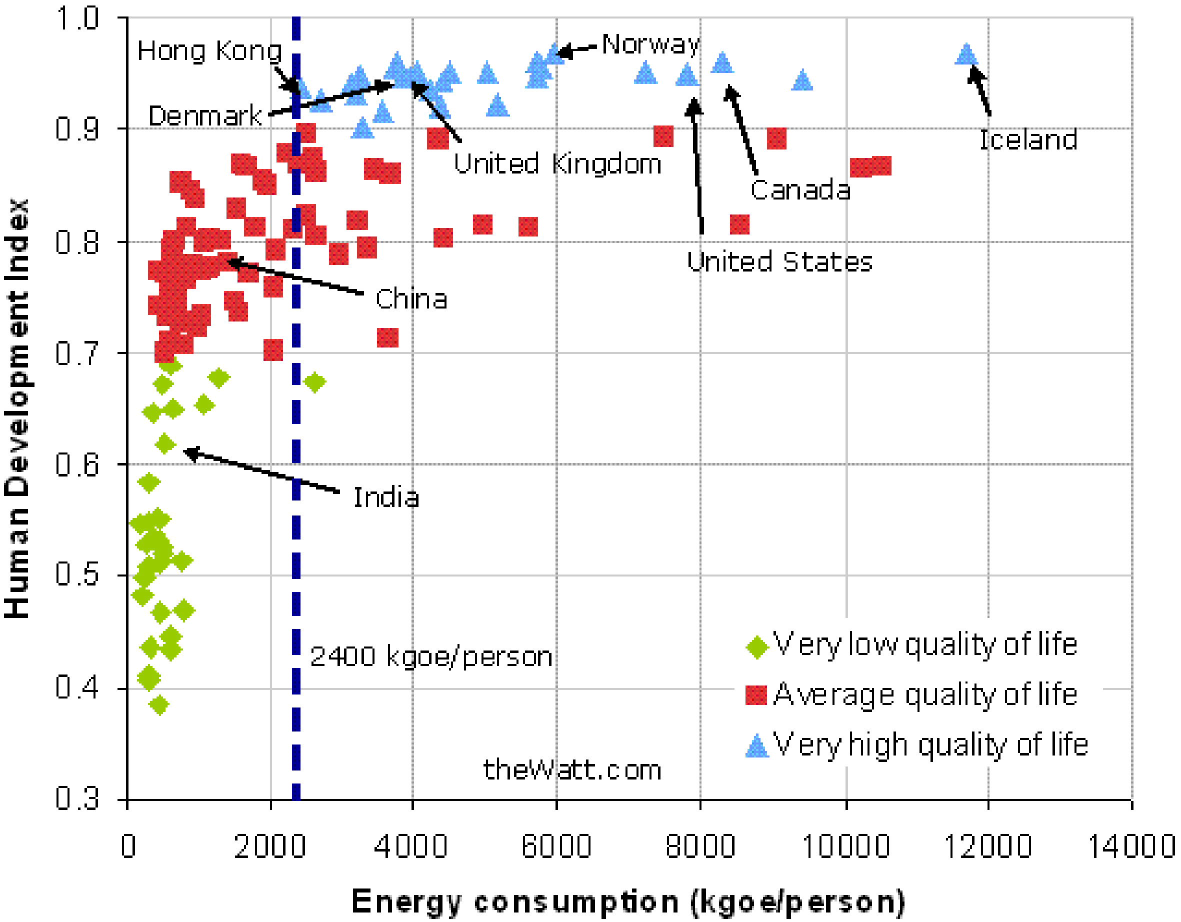
- Human or individual capital (self-actualization, Maslow)
- Social or inter-personal capital
- Natural or ecological capital
- Material capital

Focus our values on Human, Social and Natural capital.
Move away from Material capital pro-actively!

Solutions: Correct definition of a good life

Less material consumption

More meaningful relationships with humans, plants, animals and location.



(Source: UNDP, 2002, WRI, 2002)

HDI = Longevity + Education Level + GDP

Solutions: Mitigation First

Type of Effort	Urgency & Importance
Conservation and efficiency, personal and societal	High
Rapid deployment of existing technology, public transport, electric-transport, wind, solar-heat and photovoltaic, geothermal	High
Raising awareness by scientists and engineers of locals, media and policy makers	High
Applied engineering research	Medium term (5 – 10 years)
Fundamental research done today will have scaled impact after 20 years	Long Term (10 – 20 years)

Solutions: Priorities (USA)

-Massive public education for demand reduction (target 50 to 80% per capita in 10 years)

-Reactivate electric trains, trams, trolleys, buses; Upgra electric grid

-World War II type effort for car and truck batteries, solar, wind, geothermal, and wave energy

-World War II type effort for energy conservation in homes and buildings, lighting, CAFE standards

-Buying locally produced goods where possible, home gardens

-Greater use of arable land for growing crops such as oilseed willow for wood pellets, forest generation

-Stop corn ethanol immediately

-Tackle population growth

Solutions: What can I do immdediately?

- Worship, Prayer, Secular Meditation
  - Brings about a relaxation neural response, good decision making, avoids panic

- Work on:
  - Getting educated yourself first
  - Reducing your liquid fuels consumption by 50% to 80%
  - Educating family, friends, co-workers, policy-makers
  - Form community support networks
  - Contacting your local, state, and federal representatives
  - Trying to reduce consumption in your line of work
  - Changing careers from energy consuming to energy producing industries
  - Participating and influencing the media

- Teach children about these issues to continue dialogue into future generations

Positives

- Less pollution, less climate change
- Vegan life styles, less illness of affluence
- More physical activity, less obesity
- Three generations of family live together so less daycare and no isolated old age
- Slower lifestyle, less stress and aging
- Greater overall quality of life for all

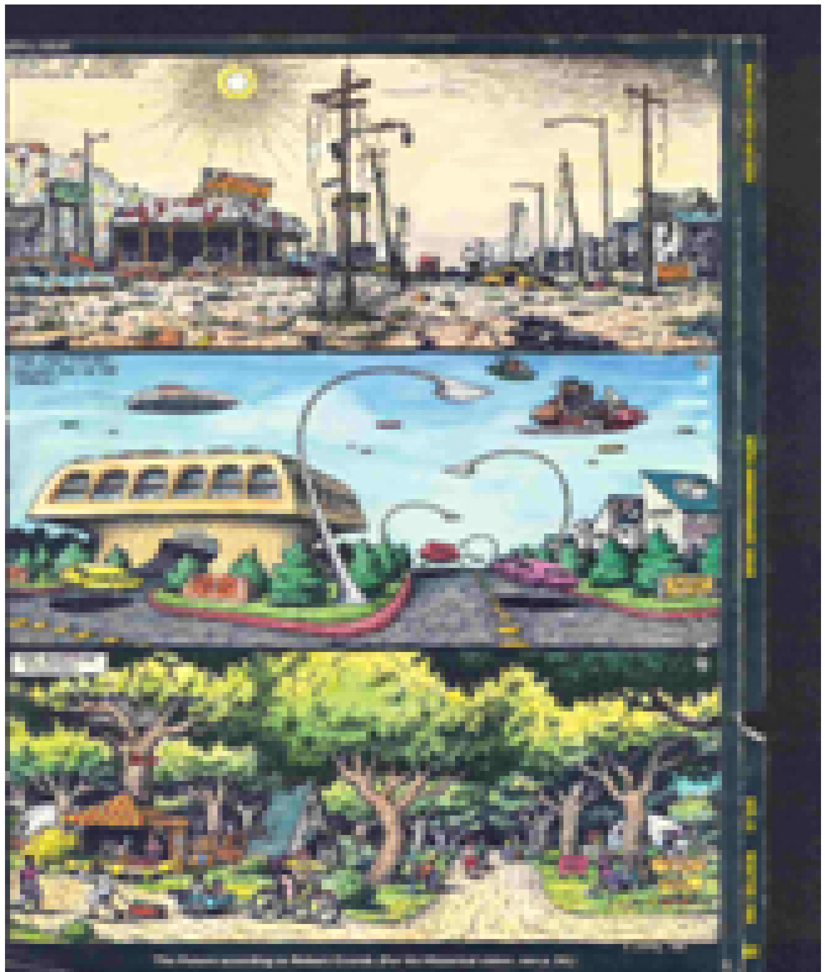
Our actions will make the future

Which Future?

Mad Max

Star Trek

The Beach



If we do nothing

Techno-fantasy led
techno-fixes
with no basis in reality

If we work very hard
for 50 years!

A 10 TW-yr energy production in 2116 C.E.

- Human population of 4 billion
- 20% from efficiency
- 30% from reduction in consumption
- 30% of energy from wind
- 20% of energy from solar power, including PV, solar thermal and solar thermal electric
- 10% from hydroelectric
- 5% from geothermal
- 5% from biomass including wood, human & animal waste
- Decrease in per capita energy use by 70% for Americans
- Per capita energy use goes up by 30% for rest of the world

Global long term promises

- **I will have a smaller family**
- **I will live in a small house or apartment or condo**
- **I will live, work and play all in a 5 mile radius**
- **I will eat a whole food plant based diet**
- **I will use only renewable energy**

Posttest

- **Form groups of 3.**
- **What is the most important problem related to Power and Fuel Sustainability?**
- **What is its solution?**
- **Take 5 mins. to discuss these two questions.**
- **Give an answer to the whole class in 3 to 5 sentences.**
- **Provide some evaluation of what you have learned.**
- **Ask questions.**

Promises to be completed by 16th July 2019

- **I will reduce my energy consumption from food by 30%.**
- I will reduce my gas usage by 10 to 20%.
- I will reduce my cosmetic usage by 30 to 40%.
- **I will reduce my textile and clothing usage by 30%.**
- I will reduce my electricity consumption by 5 to 10%.
- I will reduce my paper usage by 10%.
- I will reduce my gadgets usage by 10%.
- I will reduce my travel miles by 20%
- I will reduce my use of materials or energy in hobbies by 30%
- I will take shorter showers by 30%.
- **I will buy smaller cars on graduation.**
- **I will buy a smaller house or condo**

Thank You

References:

- www.theoildrum.com
- www.resilience.org
- www.aspo-usa.org
- astro1.panet.utoledo.edu/~khare/sustainability/index.html
- Beyond Oil: The View from Hubbert's Peak; By Kenneth S. Deffeyes
- Out of Gas: The End of the Age of Oil; By David Goodstein
- Twilight in the Dessert; by Matthew R. Simmons
- Peak Everything, Richard Heinberg

Table of embodied energy of consumables

Utility	$1 = 360 MJ[a]
Transportation	$1 = 37 MJ[b]
Other expenses	$1 = 252 MJ[c]
Red meat	1kg = 2131 MJ
White meat	1kg = 663 MJ
Dairy	1kg = 481 MJ
Rice	1kg = 220 MJ
Vegetables	1kg = 90 MJ
Miscellaneous food	1kg = 159 MJ

a – price of 1 kWh electric power is assumed to be $0.10.

b – price and energy content of a gallon gasoline is assumed to be $4 and 149 MJ respectively.

c – It is assumed that other expenses consume a fraction (1/3) of energy from gasoline and the remaining (2/3) from utility electric power at rates of $4 for gasoline and $0.10/kWh for electric power.

Promises to be completed by 16th April 2016

- I will reduce my energy consumption from food by 10%.
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- I will buy smaller cars on graduation.
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Impact: Economic, Social and Cultural

- ~~Growth Economics~~ ==> Steady or Shrinking Economy
- Industries
  - Tourism ↓
  - Entertainment (movies in theaters, sports, theme parks, shopping) ↓
  - Restaurants ↓
  - Transportation (cars, trucks, oil-ships vs. electric (trains and cars), sail-ships) ↔
  - Banking & Finance ↓
  - Law & Health Services ↓
  - Housing (Suburban long commute vs. urban walking), Education ↓
  - Farming, Solar, Wind, Geothermal, Lumbering, Energy equipment ↑
- Family Structure
  - Grandparent-Parent-Child relationship
  - Husband-Wife relationship
  - Neighbor-Neighbor relationship (less house mobility)

Sequence of Emotional Reactions

Steps

- Surprise and Shock
- Denial of Problem
- Anger
- Bargaining "Give me some time"
- Depression
- Acceptance or Surrender
- Adaptation and Creative Action

Adapted from "On Death and Dying," Elisabeth Kubler-Ross

Fuel Prices

Yesterday

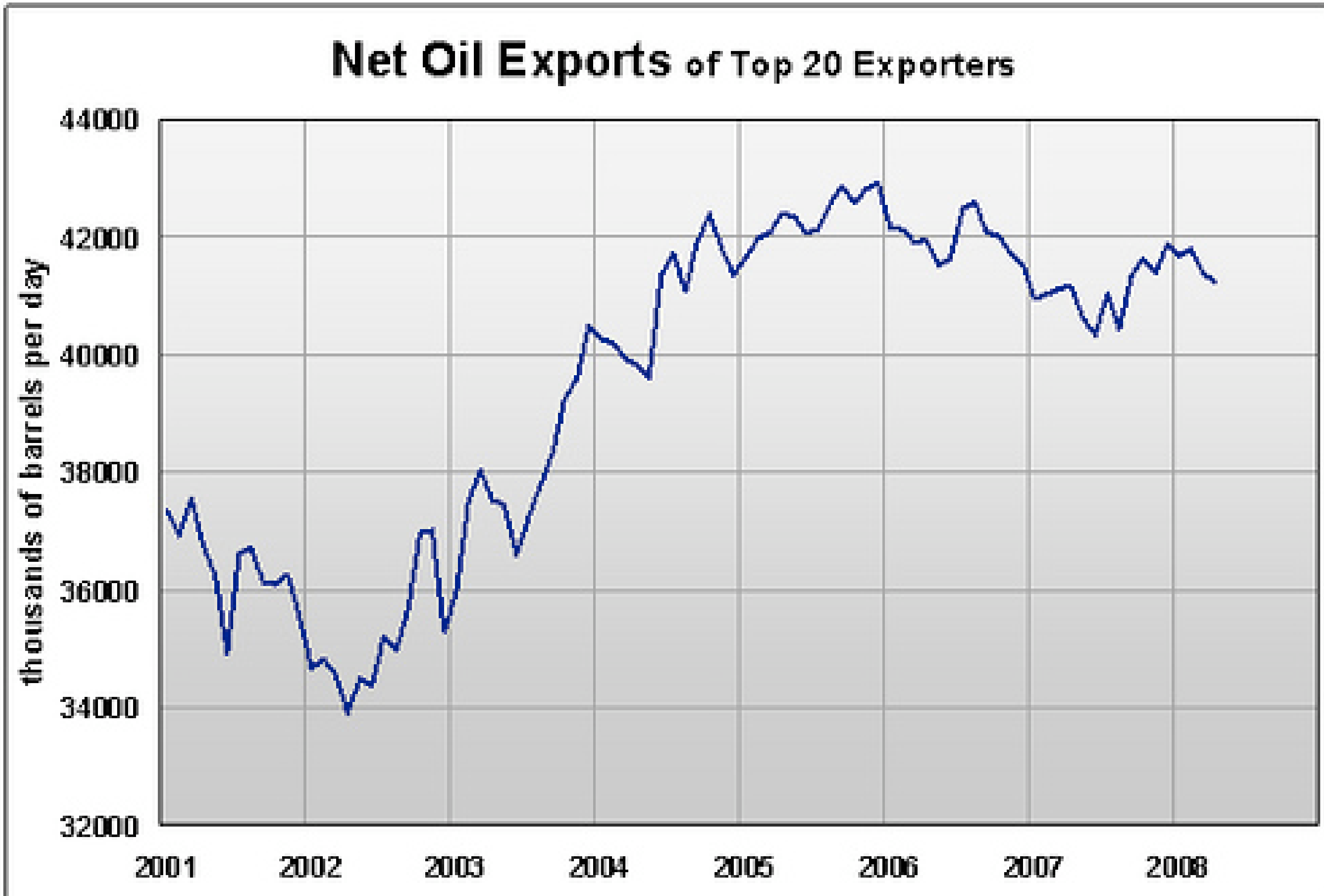
1955

Today

2012

… Tomorrow?

No spare capacity AND Net exports are decreasing!

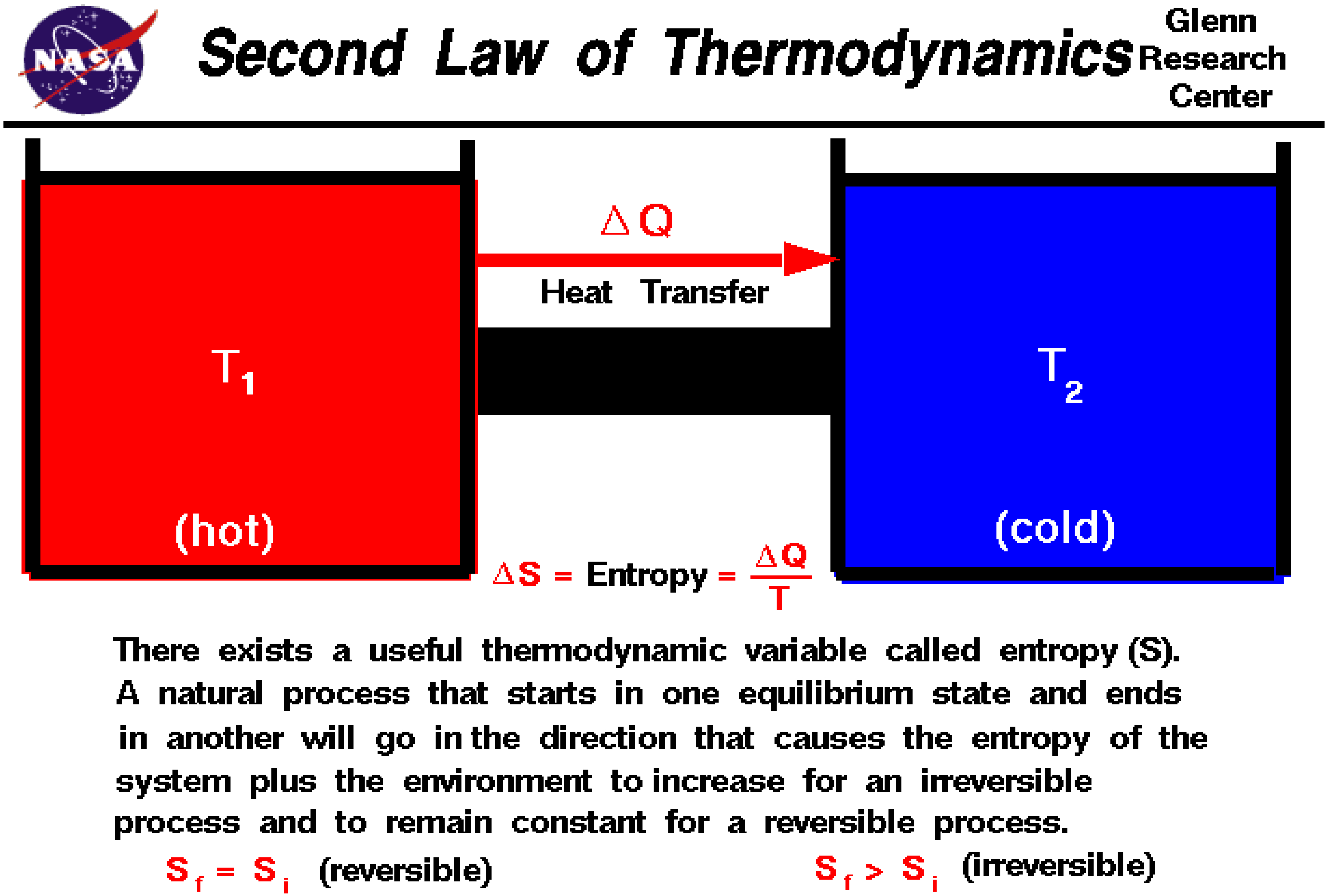


Sources: EIA, IEA, TOD

Spurious OPEC Reserve (GBOE) Revisions

Year	Abu Dhabi	Dubai	Iran	Iraq	Kuwait	Neutral Zone	Saudi Arabia	Venezuela
1980	28.0	1.4	58.0	31.0	65	6.1	163	18
1981	29.0	1.4	57.5	30.0	66	6.0	165	18
1982	30.6	1.3	57.0	29.7	65	5.9	165	20
1983	30.5	1.4	55.3	41.0	64	5.7	162	22
1984	30.4	1.4	51.0	43.0	64	5.6	166	25
1985	30.5	1.4	48.5	44.5	**90**	5.4	169	26
1986	30.0	1.4	47.9	44.1	90	5.4	169	26
1987	31.0	1.4	48.8	47.1	92	5.3	167	25
1988	**92.2**	**4.0**	**92.9**	**100**	92	5.2	167	**56**
1989	92.2	4.0	92.9	100	92	5.2	170	58
1990	92.2	4.0	92.9	100	92	5.0	**258**	59
1991	92.2	4.0	92.9	100	95	5.0	258	59
1992	92.2	4.0	92.9	100	94	5.0	258	63
1993	92.2	4.0	92.9	100	94	5.0	259	63
1994	92.2	4.3	89.3	100	94	5.0	259	65
1995	92.2	4.3	88.2	100	94	5.0	259	65
1996	92.2	4.0	93.0	112.0	94	5.0	259	65
1997	92.2	4.0	93.0	112.5	94	5.0	259	72
1998	92.2	4.0	89.7	112.5	94	5.0	259	73
1999	92.2	4.0	89.7	112.5	94	5.0	261	73
2000	92.2	4.0	89.7	112.5	94	5.0	261	77
2001	92.2	4.0	89.7	112.5	94	5.0	261	78
2002	92.2	4.0	89.7	112.5	94	5.0	261	78

Thermodynamics – Second Law



http://www.grc.nasa.gov/WWW/K-12/airplane/thermo.html