Crisis of Portable Energy: Imminence, Scale, Impact and Mitigation

Sanjay. V. Khare

Department of Physics and Astronomy,
The University of Toledo, Toledo, OH-43606
http://astro1.panet.utoledo.edu/~khare/

Acknowledgements

Some slides and contents in this presentation have been taken from other sources available online with or without proper citations. The author claims no credit for them nor attests to their veracity. This presentation is being used for raising general public awareness only.

Most Important Themes of this Discussion

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

Outline

- What is the problem of peak portable energy?
- What is its imminence, scale and impact?
- What can we do about it?

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

Four Distinct Crises

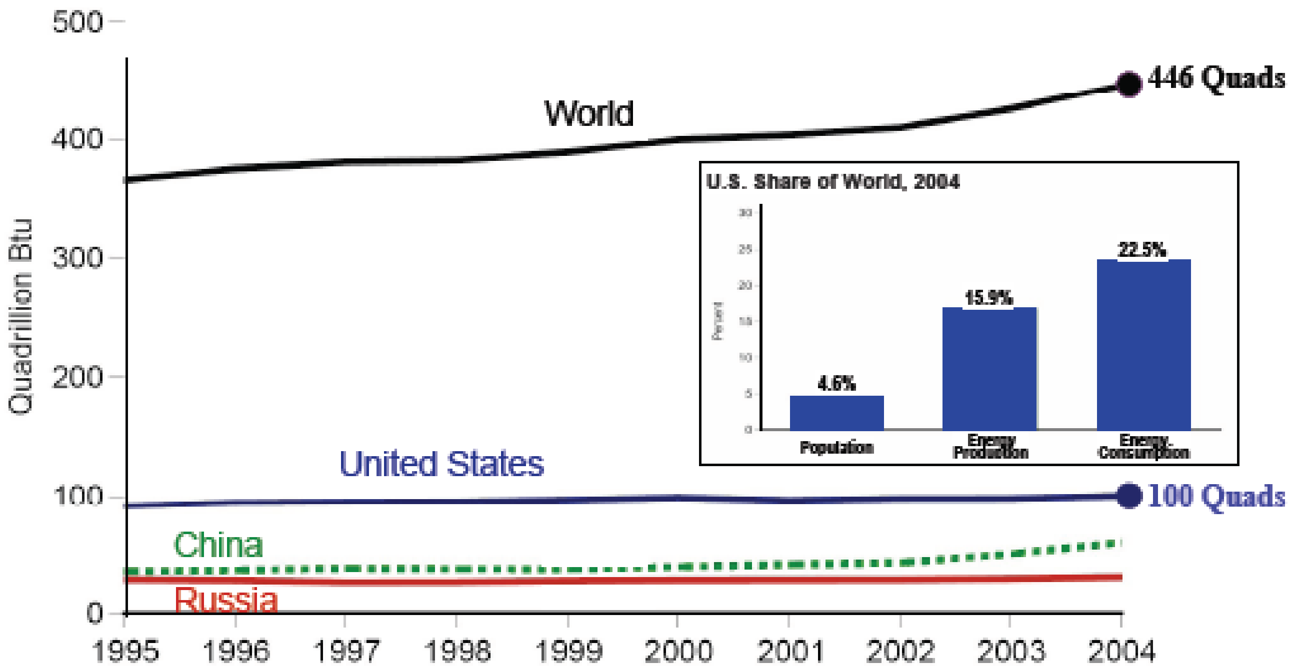
Problem	Imminence	Impact
I Global Warming	Approaching (5 to 10 years)	GRADUAL over 10 – 100+ years
II Peak Production Total Energy	Approaching (10 to 15 years)	CATASTROPIC
III Peak Production Portable Energy	Now (-3 to 5 years)	CATASTROPIC
IV Peak Other Materials (bees, grains, fish, top soil, fertile 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, 1 Q = 10^{18} J

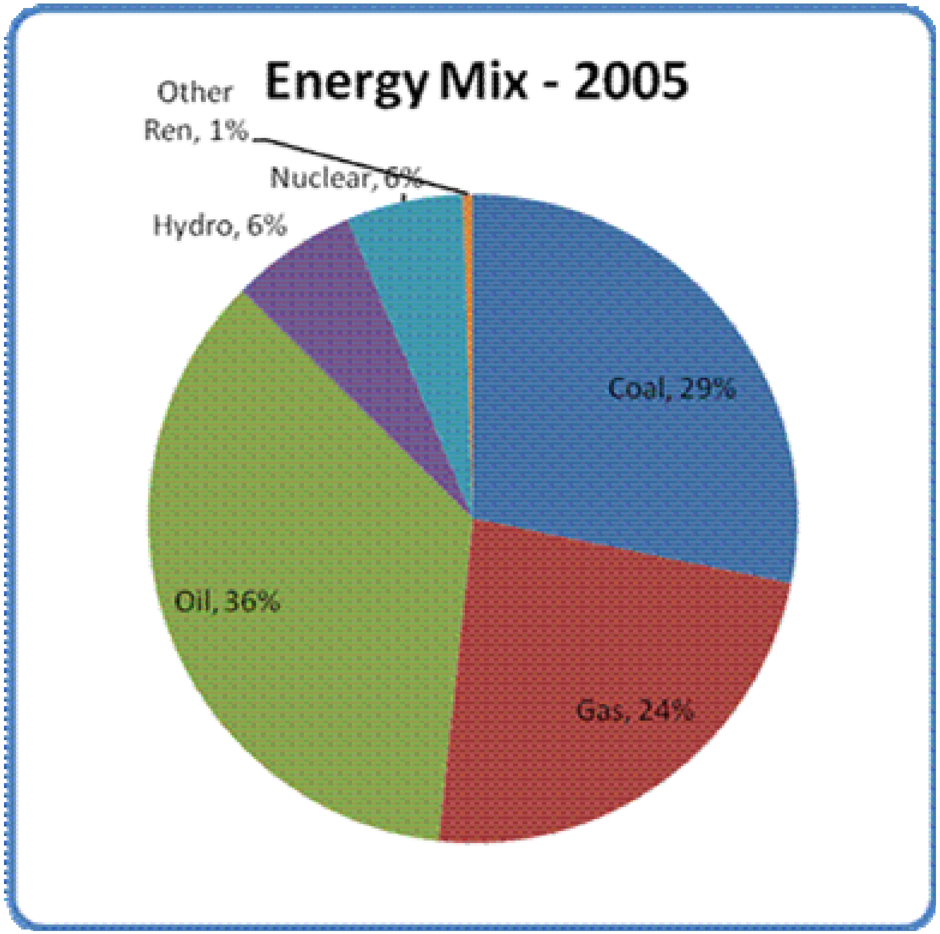
U.S. and World Energy Consumption Today



446 quads = 4.46×10^{17} BTU = 12.3×10^{25} kW-hour

= 14×10^{12} Watt-year = 14 TW-yr = 4.46×10^{20} J

Global energy allocation by source



The Global Energy Mix in 2005

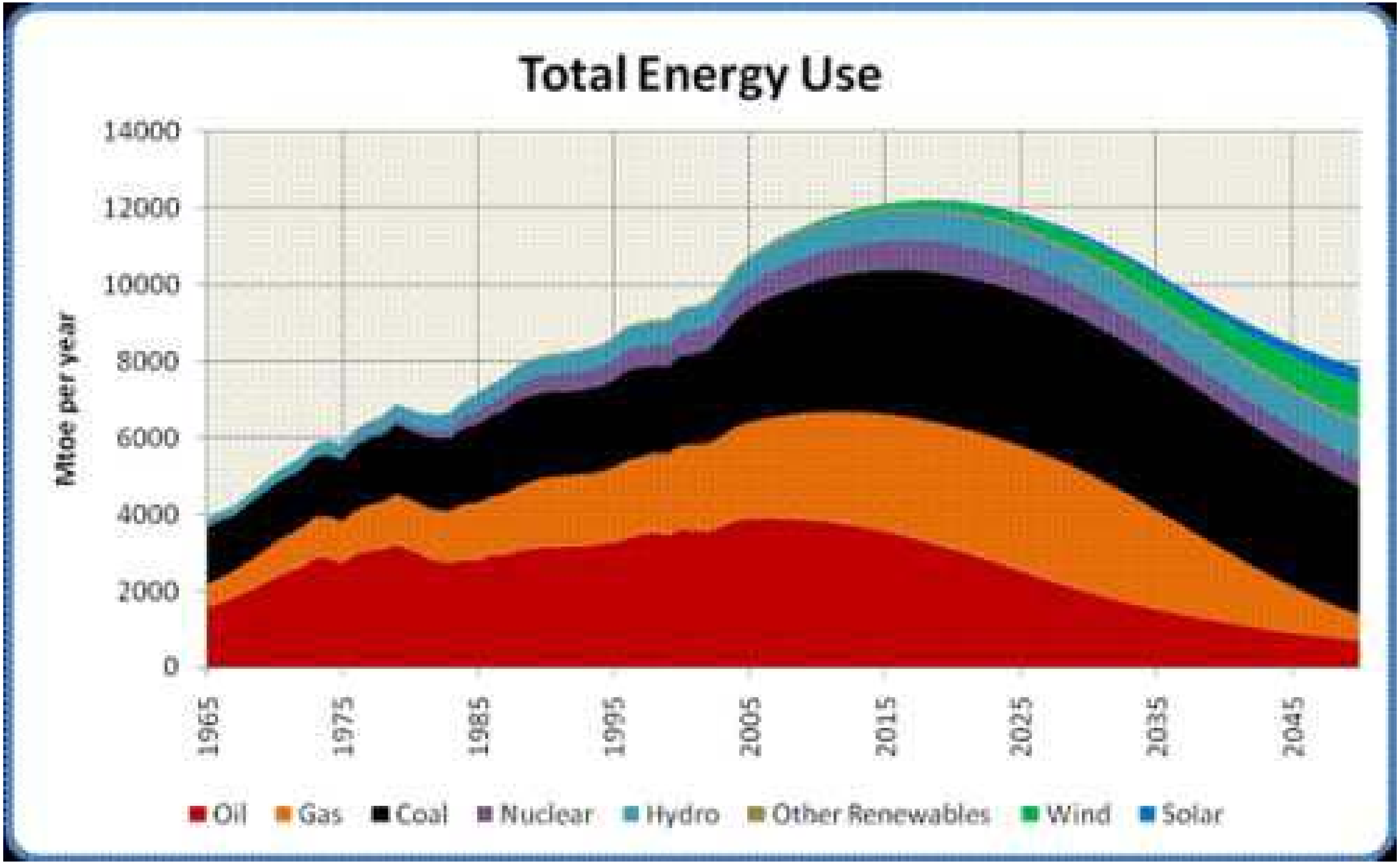
Peak means the maximum production of an energy source after which production declines indefinitely forever!

Oil will peak in -4 to +3 years

Gas will peak in 10 to 15 years

Coal will peak in 15 to 20 years

Peak Total Energy



Total Energy Use, 1965 to 2050, (Courtesy: Paul Chefurka)

PEAK OIL

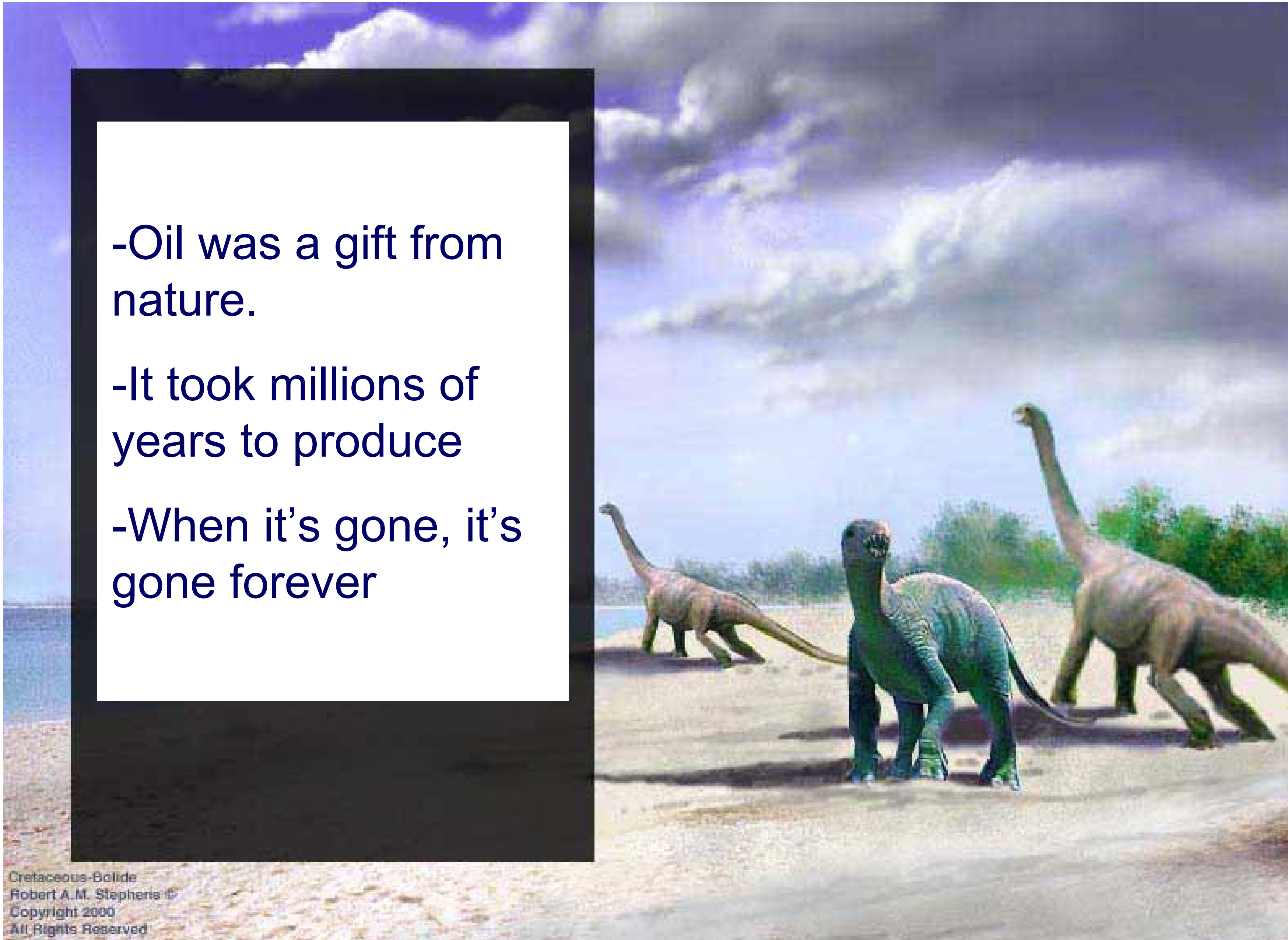
(and the unfolding energy crisis)

- What is Peak Oil?
- What are the consequences?
- What can we do about it?

-Oil was a gift from nature.

-It took millions of years to produce

-When it’s gone, it’s gone forever



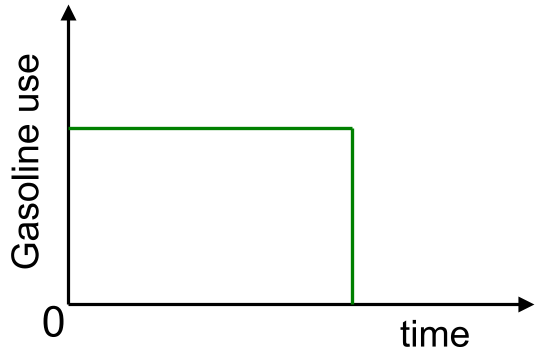
First crude oil found < 150 years ago

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.

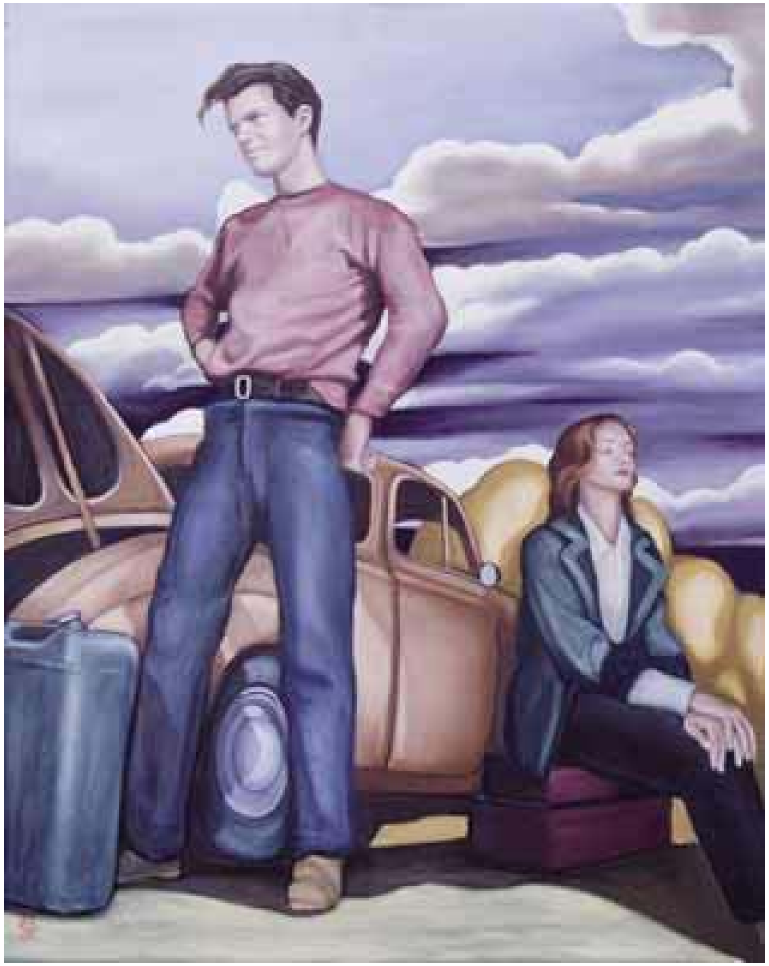
By 2008 we've used up about one trillion. In other words we're near the half-way point.

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

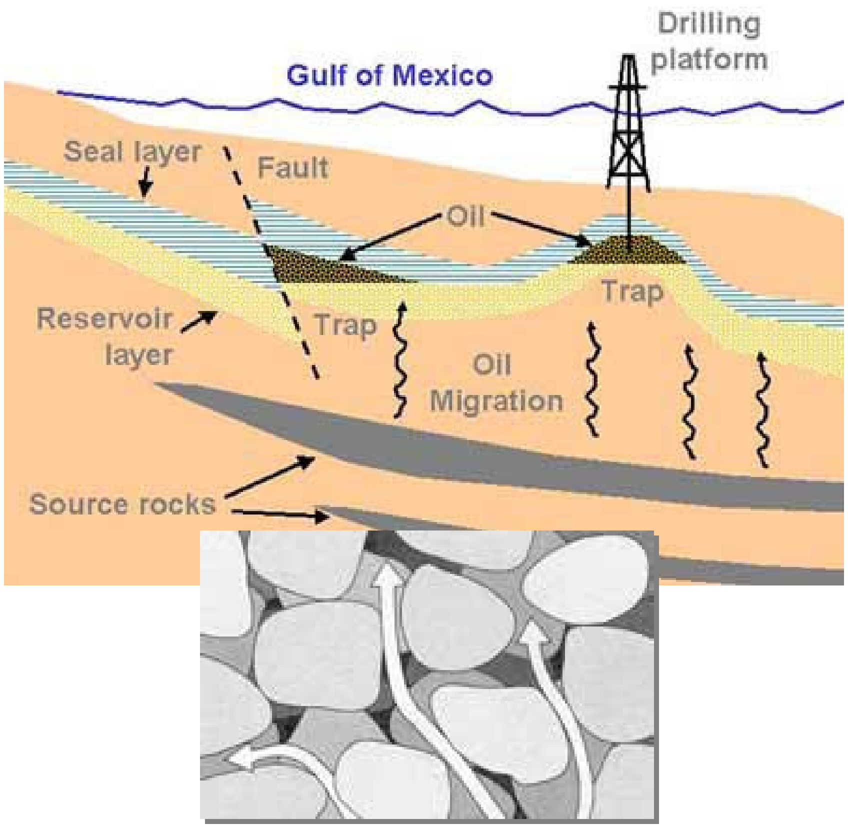
An oil well isn't like a car's fuel tank



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

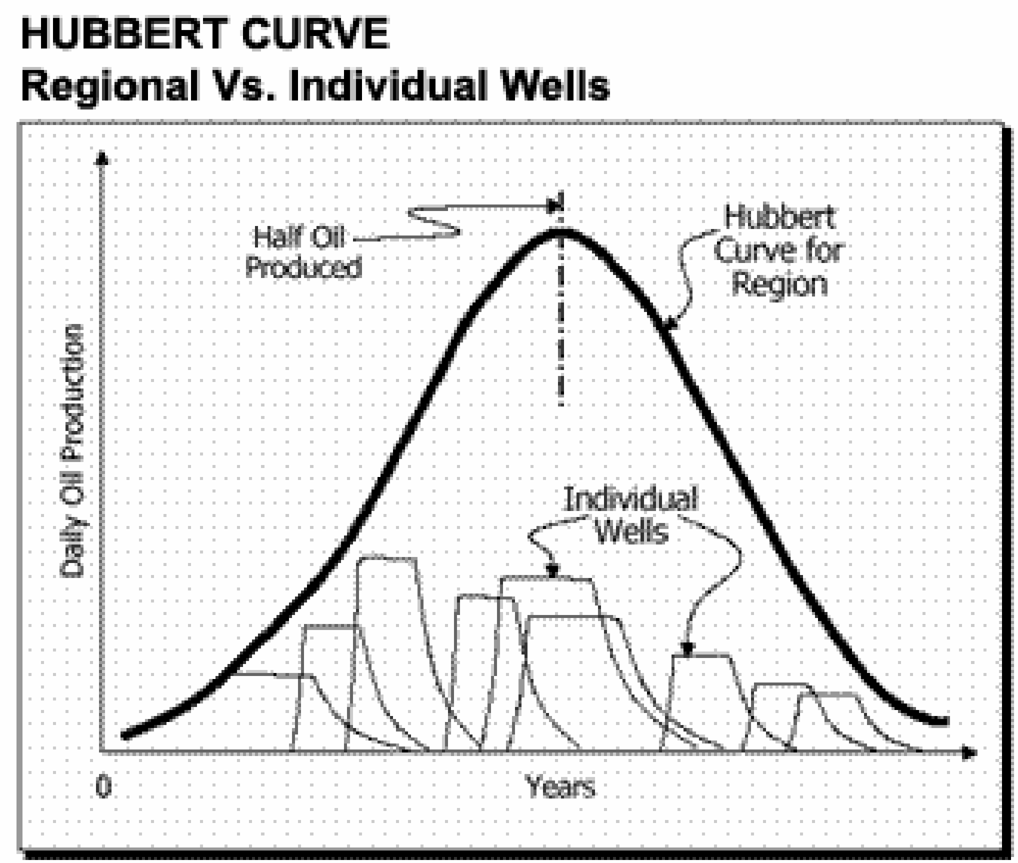


But an oil well isn't a hollow cavity

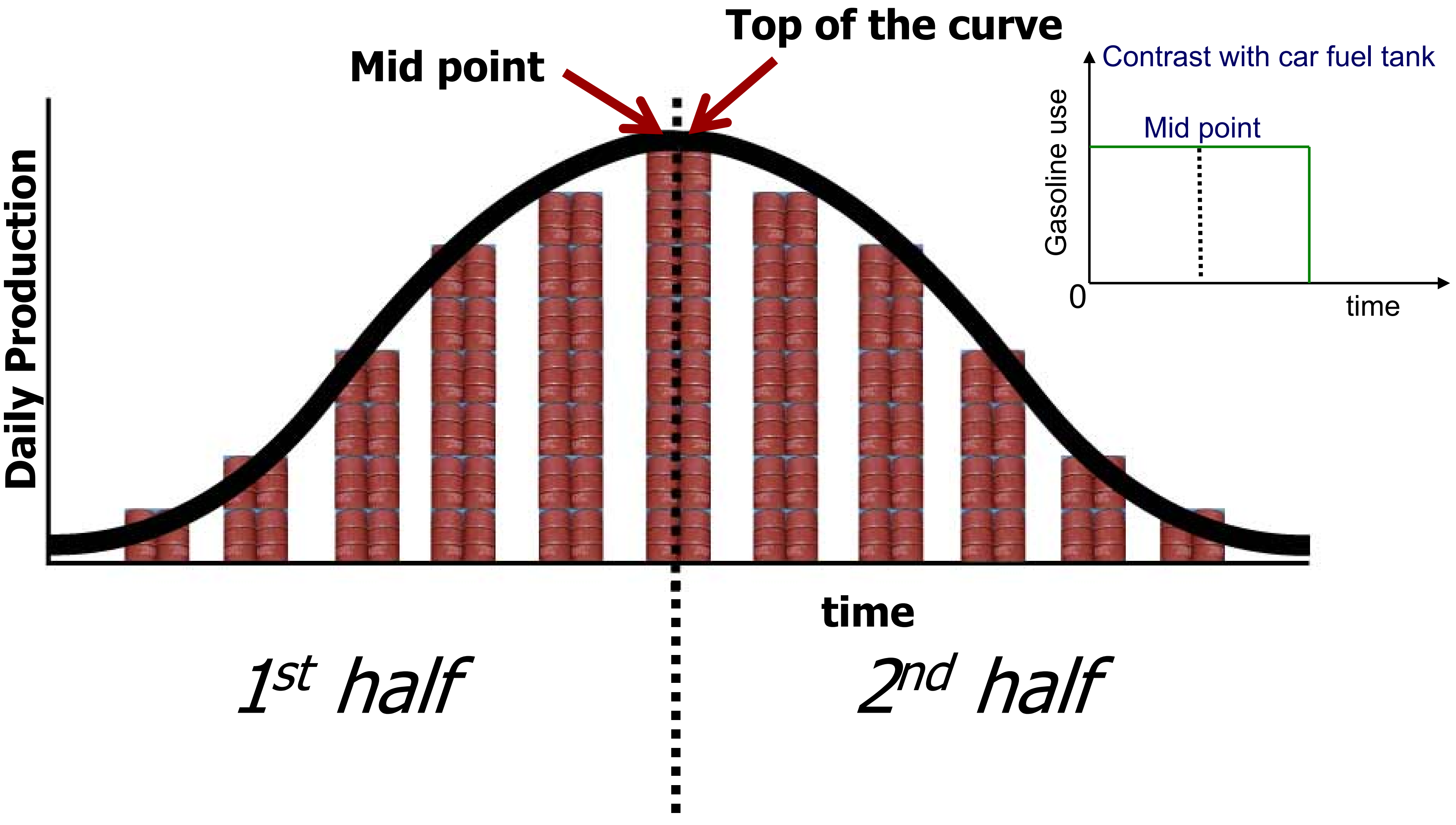


It takes time for oil to ooze from zones of high concentration to the zone of low concentration near the pipe.

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



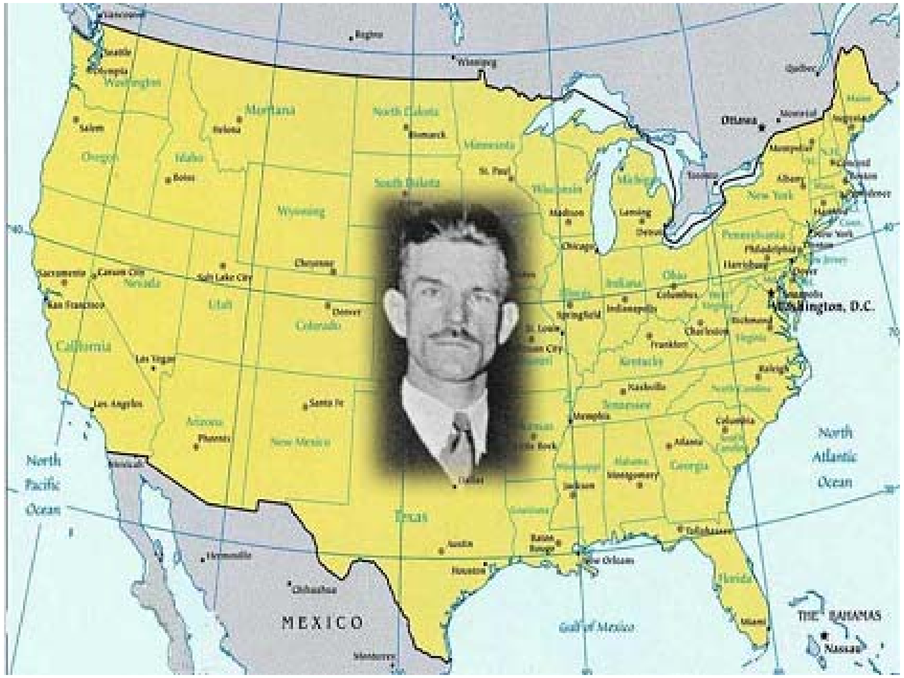
When you plot the production of an aggregate of oil fields, it approximates a bell curve



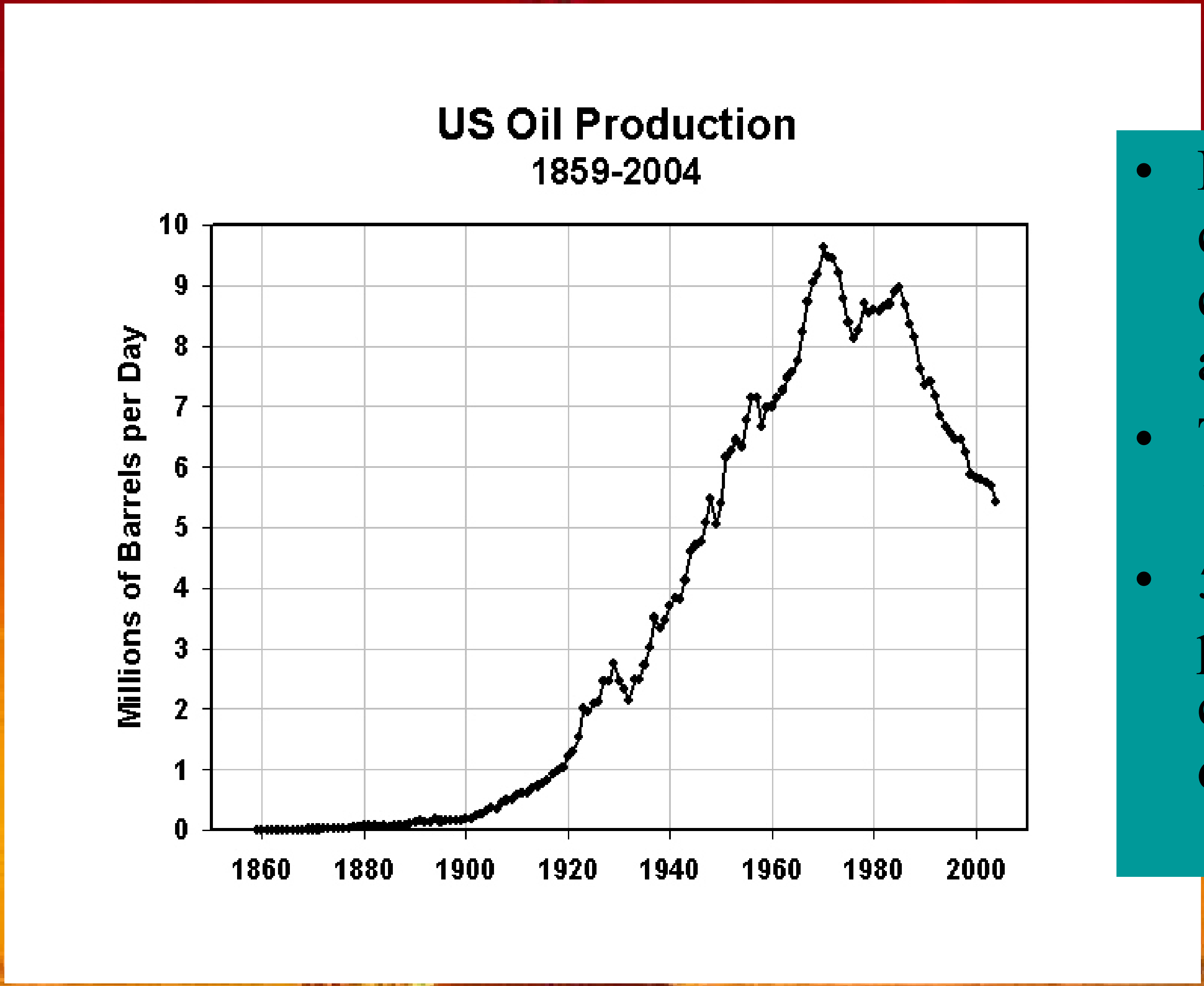
From geological peak – Production declines indefinitely forever

The Hubbert Peak

In 1956 Hubbert, using mathematical models, predicted that the oil extraction for the US lower 48 states would peak in 1970

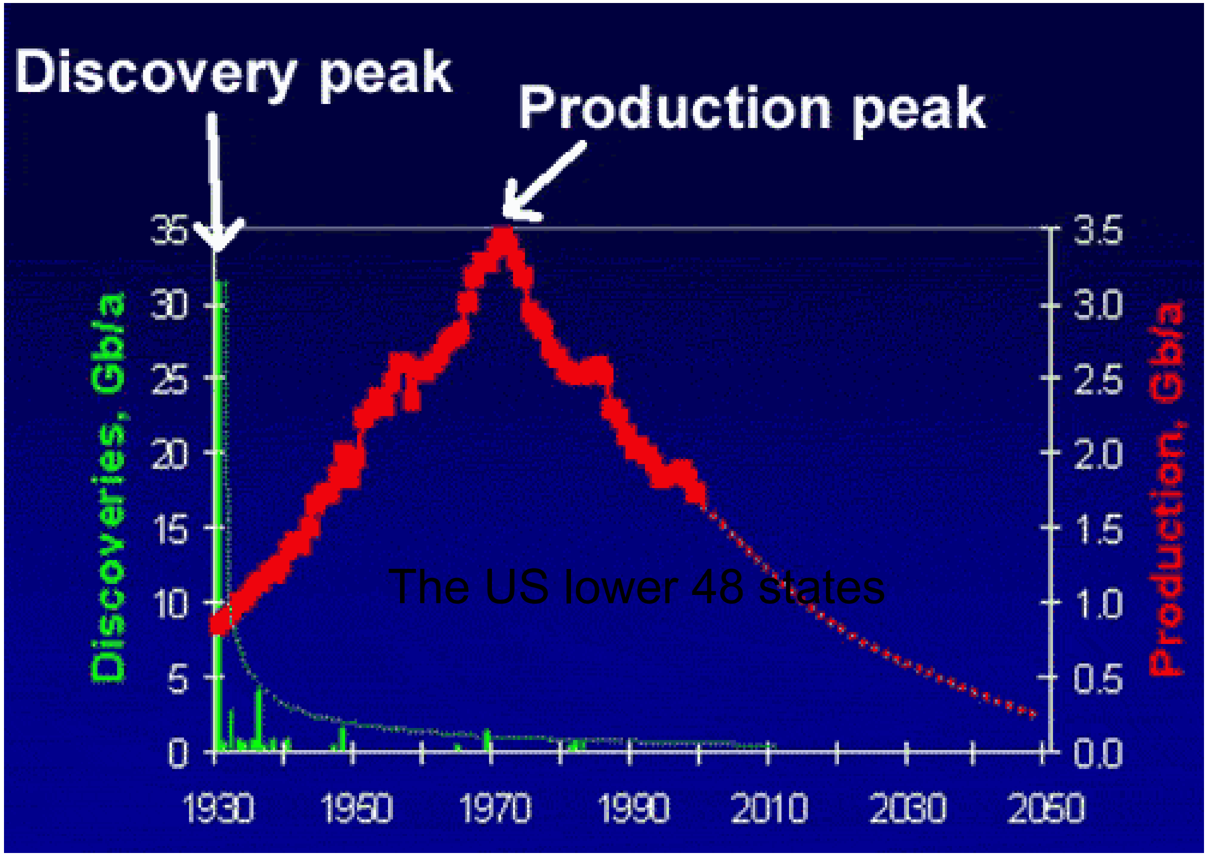


http://www.hubbertpeak.com/hubbert/



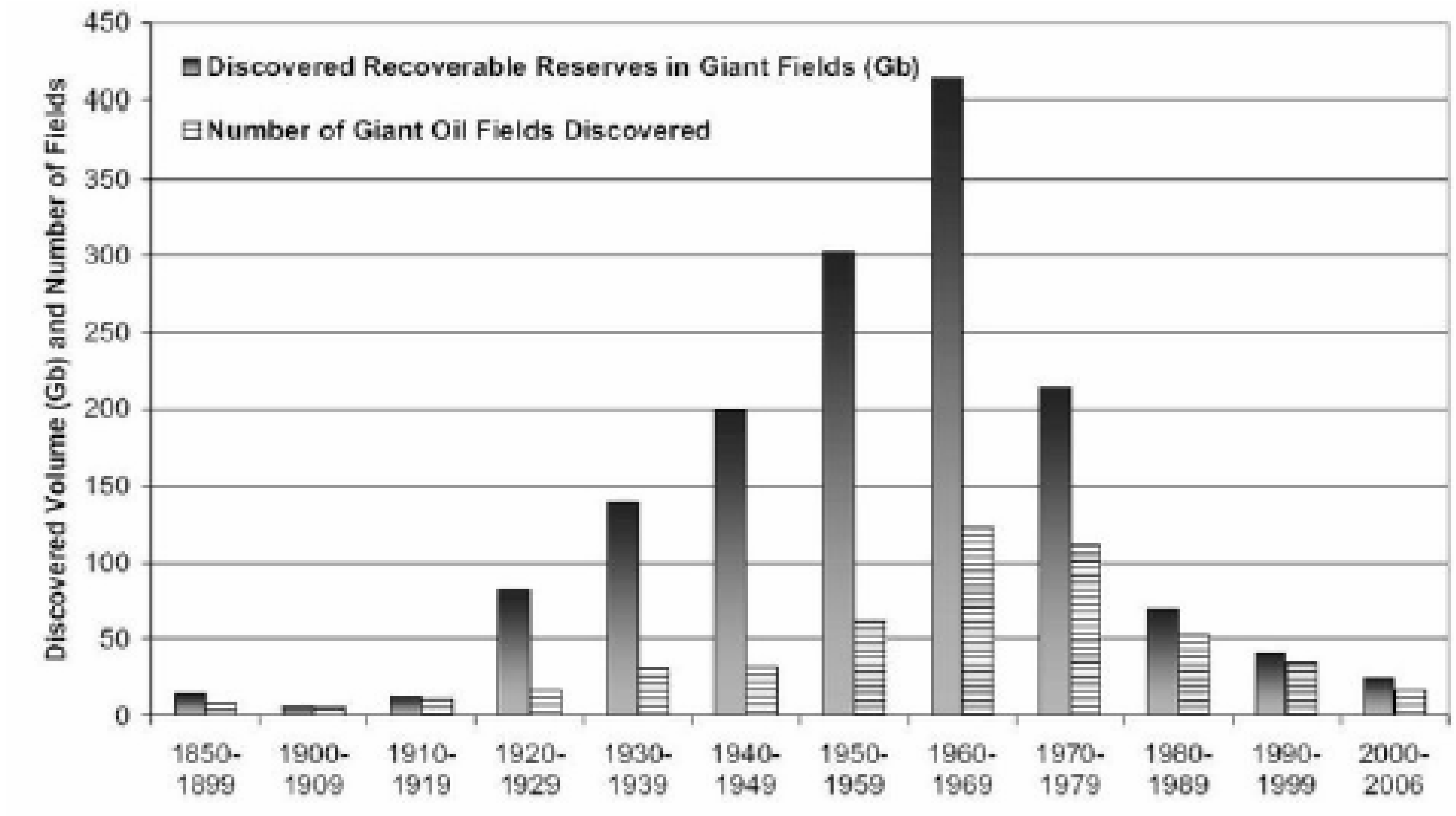
- Many oil fields, countries, and oil companies have already peaked.
- The US peaked in 1970.
- 53 of 68 oil producing countries are in decline.

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



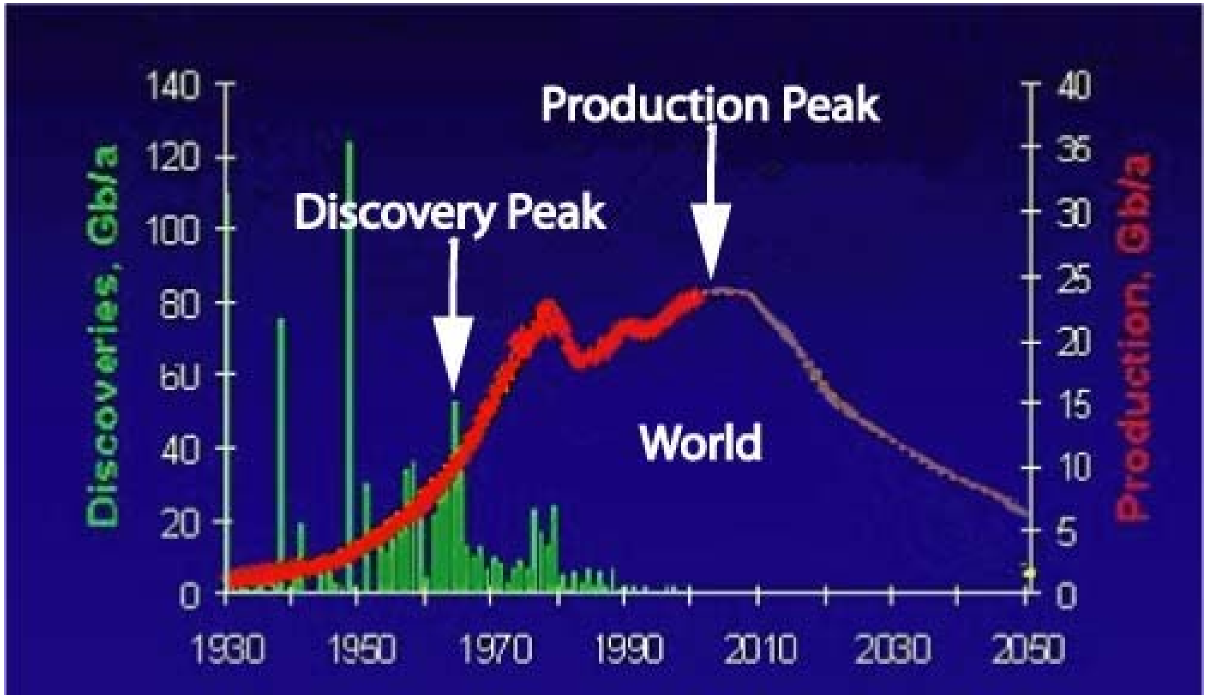
Adapted from Collin Campbell, University of Clausthal Conference, Dec 2000

Discoveries: Total oil and Giant Fields



Source: Fredrick Robelius, Giant Oil Fields the Highway to Oil, 2007

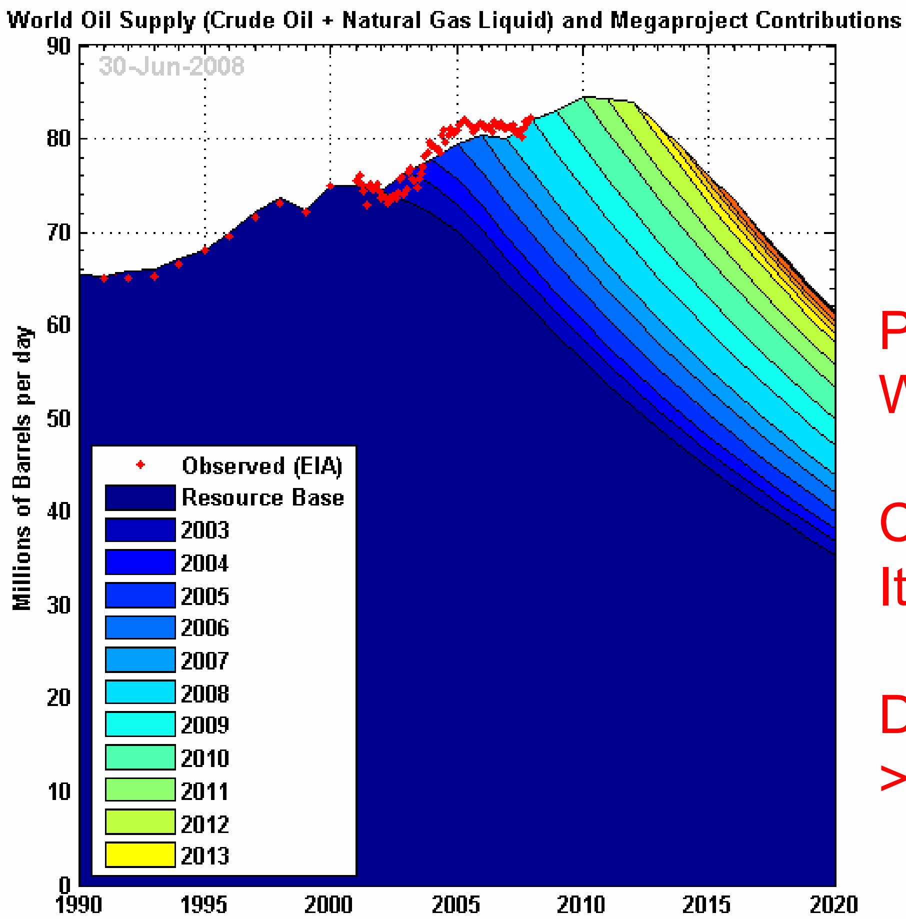
US oil production peaked in 1970.
It now produces < 60% of its peak!
If the world follows the US pattern:



…the world would peak soon

Adapted from: Richard C. Duncan and Walter Youngquist

Same Chart: Now a new projects analysis



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

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

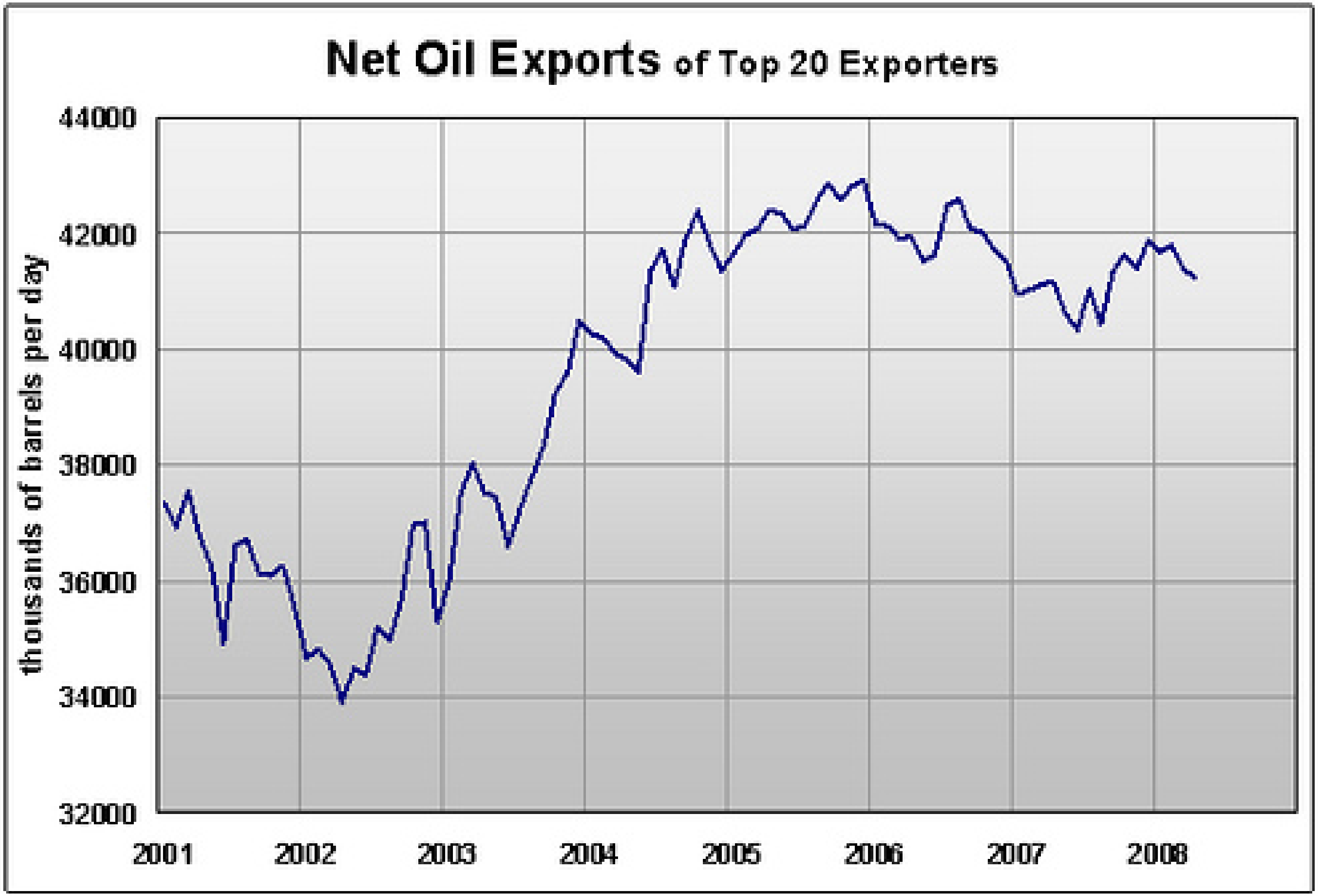
Conventional crude peaked in 2005.
It is already in the past tense!

Decline after peak will be
> 5%/year!

…the world will peak between 2010-2013

Adapted from: Richard C. Duncan and Walter Youngquist

No spare capacity AND Net exports are decreasing!

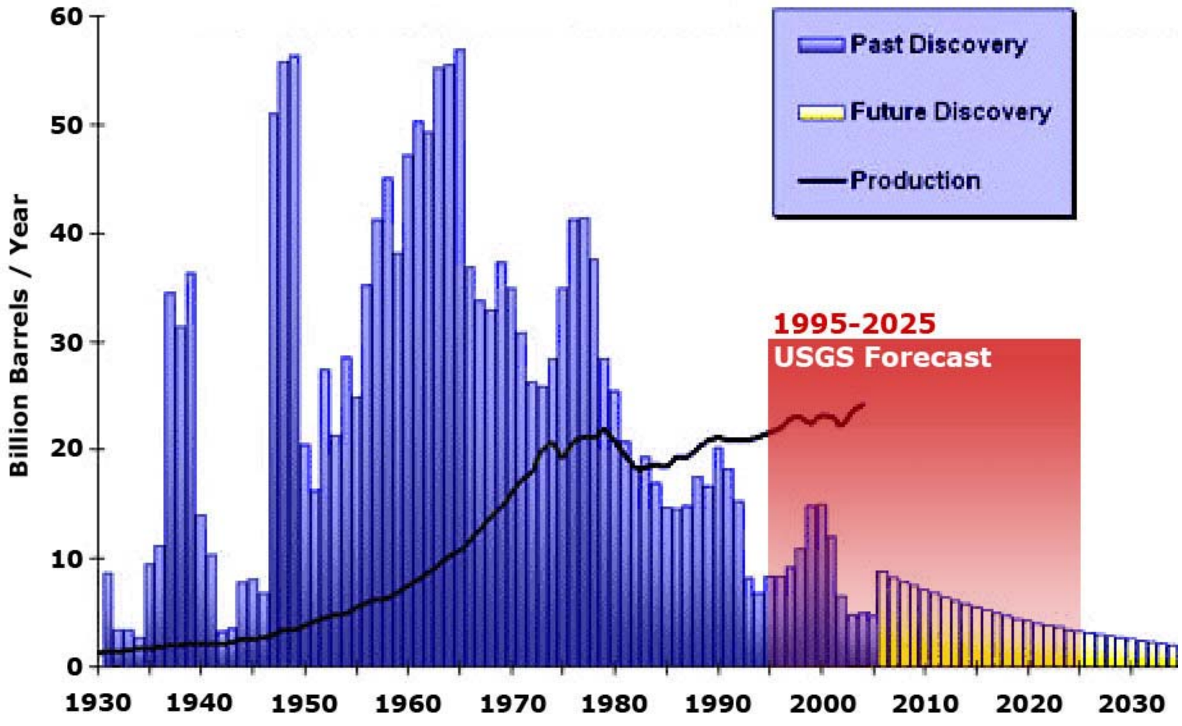


Sources: EIA, IEA, TOD

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

Spurious OPEC Reserve Revisions

Optimistic USGS forecasts



•Discovery Source Data: Longwell (ExxonMobil), World Energy, Vol 5 No3 2002

Same optimism infects EIA and IEA forecasts!
IEA slightly improved in November 2008.

Energy Return On Energy Invested (EROEI)

It refers to the ratio of:

The amount of energy in the fuel:
Either gasoline, diesel, kerosene, etc.

AND

The amount of energy spent on getting the fuel: exploration, drilling, pumping, transportation and refining

"The Party's Over", Richard Heinberg

Energy Return On Energy Invested

is diminishing as we resort to going after the hard-to-get oil:

- Before 1950 it was about 100 to 1
- In the 1970s it was down to 30 to 1
- Now (2005) it's about 10 to 1
- The Tar Sands have an EROEI of about 4 to 1

"The Party's Over", Richard Heinberg

Net Surplus Energy (NSE)

TM = Total mass of energy providing material
e.g., oil, coal, gas, wind turbine, PV modules

EPM = Energy produced per unit mass

NSE ~~= TM x EPM~~ (Naive Calculation)

Correct Calculation

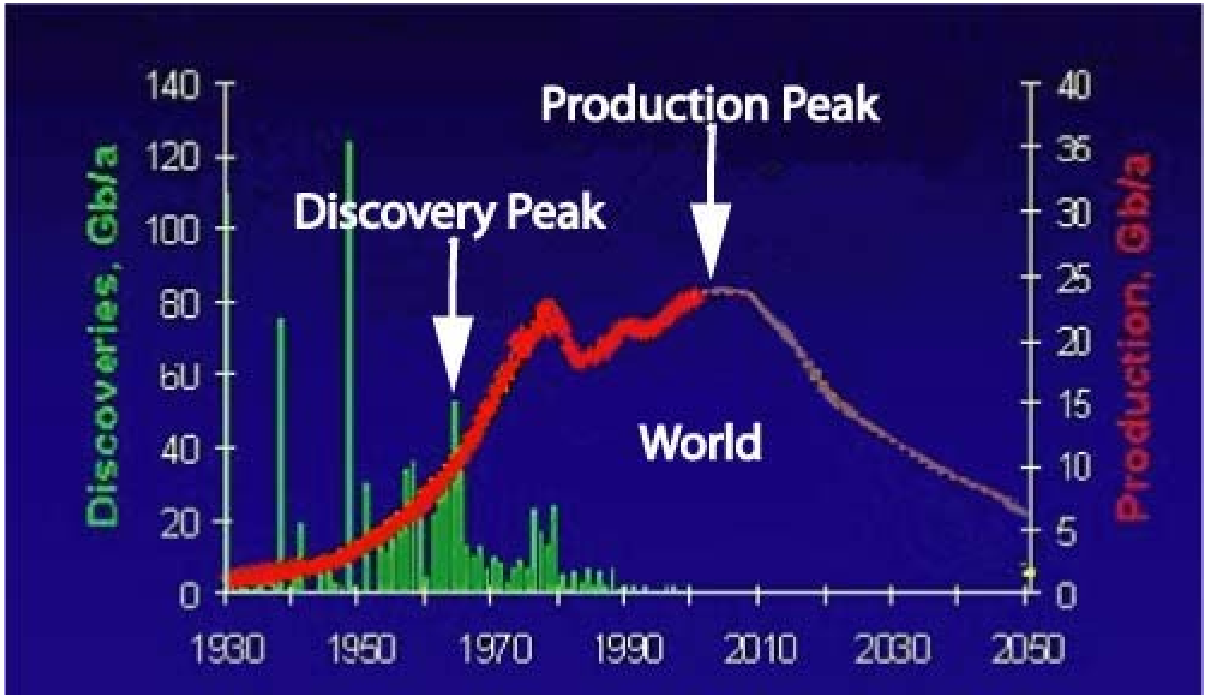
EROEI= Energy Returned on Energy Invested = $\frac{E_{out}}{E_{in}}$

E_{out} = TM x EPM

NSE = $E_{out} - E_{in} = E_{in}\left[\frac{E_{out}}{E_{in}} - 1\right]$

We are running out of *both* TM *and* EROEI

If the world follows the US pattern:



…the world would peak soon

Adapted from: Richard C. Duncan and Walter Youngquist

Myths about Saviours

- #1 Canadian sands will save us
- #2 More drilling and exploration will save us
- #3 Biofuels will save us
- #4 Coal to liquids will save us
- #5 Shale, Methane Hydrates or other sources will save us
- #6 Renewables will save us: Solar, Wind and Geothermal

  – Common problem: Total Quantity and Quality, i.e. TM *and* EROEI, negative environmental impacts

Summary about Supply

- We will soon reach peak oil in (-4 to 3 years)
- After that we will have less energy for transportation every year than the previous year. This will go on indefinitely!

- Net total surplus energy for all uses will peak in 10 to 20 years
- After that we will have less energy every year than the previous year. This will go on indefinitely!

PEAK OIL

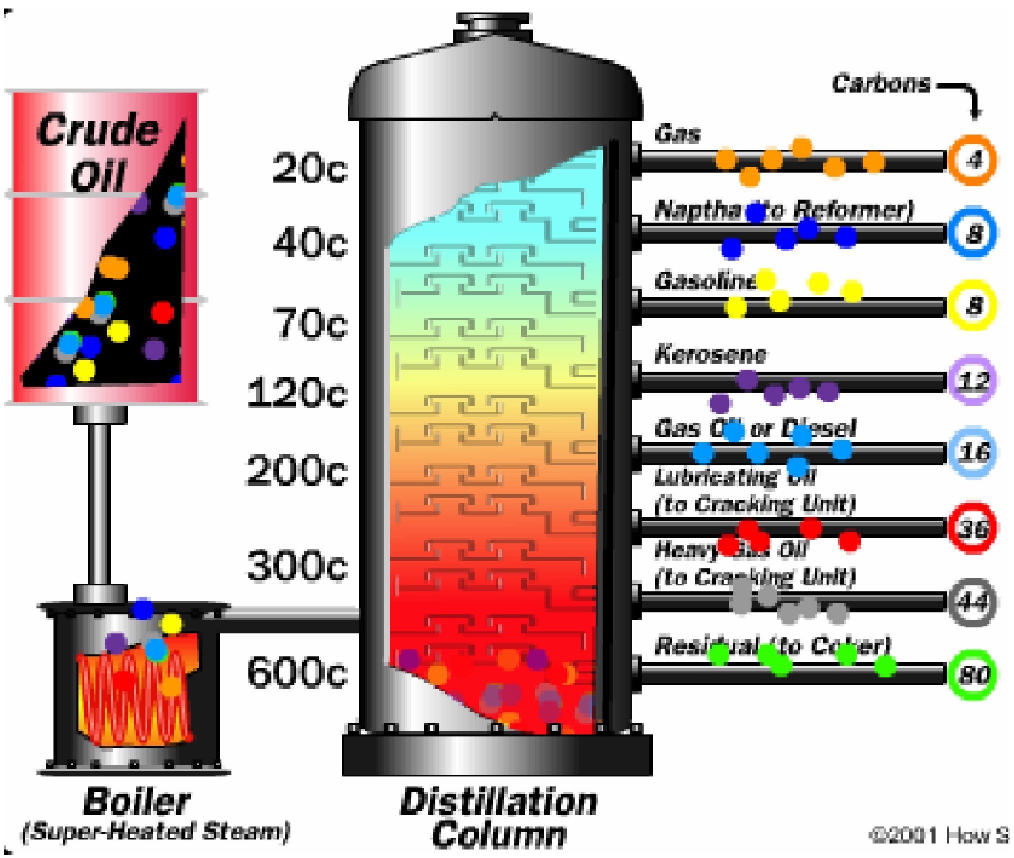
Part 2

- What are the consequences?

- Extremely Serious!

Oil is extremely versatile

The petrochemical industry can refine oil into many different fuels and products.



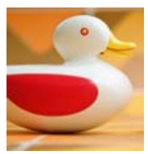
Gas
Naphtha
Gasoline
Kerosene
Diesel
Lubricants

http://science.howstuffworks.com

Including plastics, textiles, pharmaceuticals, paints, dyes, asphalt

No easy scalable substitute for oil

Easy means low EROEI

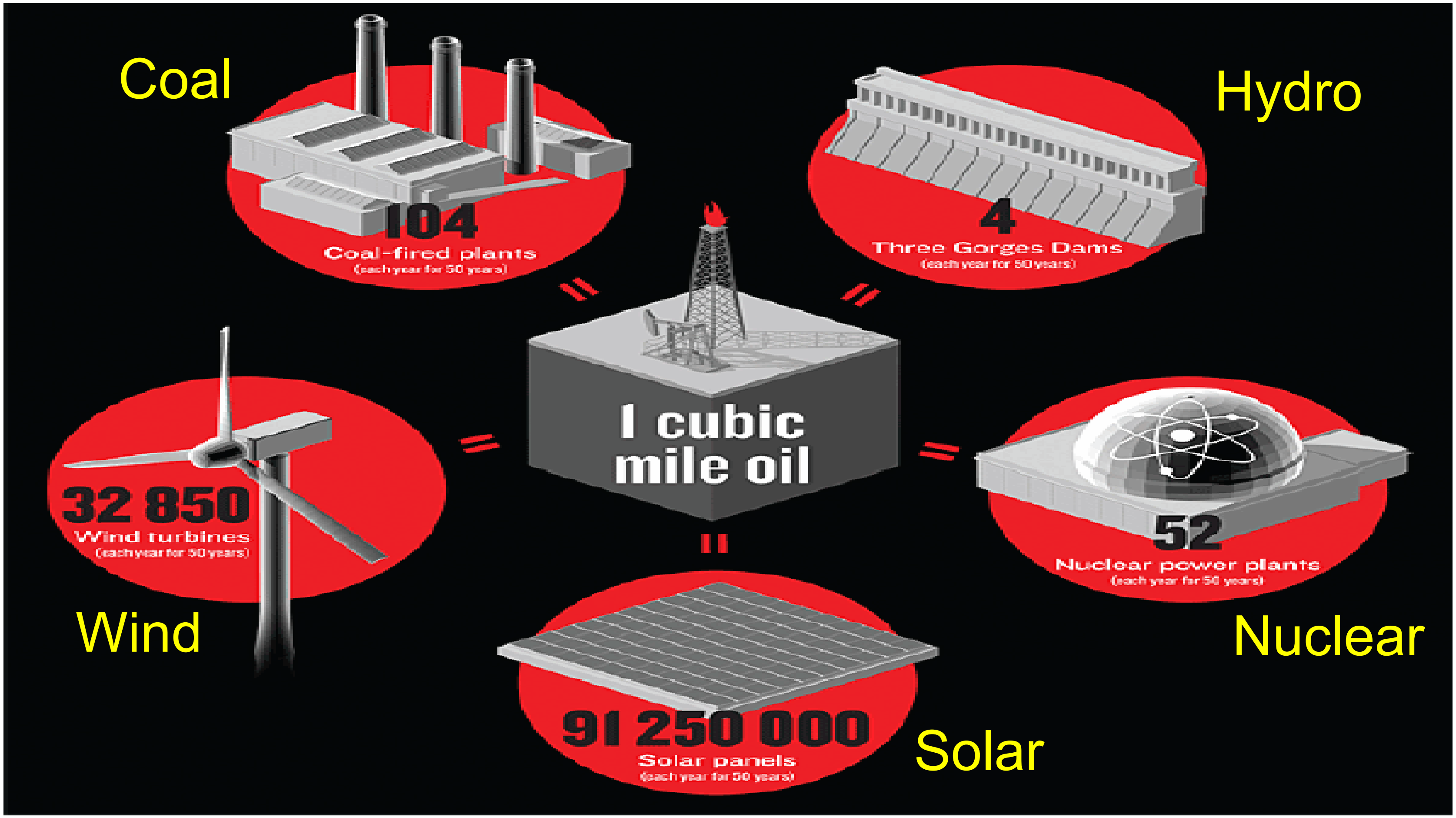









Per year oil consumed = 1 mile^3 = 50 years of power of each of these!!



Source: H. Goldstein and A. Sweet, IEEE Spectrum Online, Jan. 2007.

Oil has high energy per unit mass!

- 1 gallon = 37.63 kW-hr = 32408.3 Food-cal
  = 11 able-bodied young men working a full day.

- World yearly consumption
- 31 GBa/yr = 4.216 Gtoe = 5.593 TW-yr/yr

- US yearly consumption
- 7.665 GBa/yr = 1.04244 Gtoe/yr = 1.382 TW-yr/yr = 3 times the US yearly electricity consumption.

1 toe = 4.1868 x 10^{10} Joules; 1 Ba = 42 gallons = 0.136 toe

1 Ba = 0.136 X 4.1836 X 10^{10} J = 5.6896 GJ = 1.5805 MW-hr = 65.85 kW-day = 180.42 W-yr

Material Wealth means a type of Order

- Wealth for a mushroom is decaying matter
- Wealth for a plant is fertile soil, water, sunlight

- Wealth for a deer is green grass, water
- Wealth for a lion is lots of deer, water

- Wealth for humans is a certain type of order in the nearby environment. Of course this means creating more disorder elsewhere.

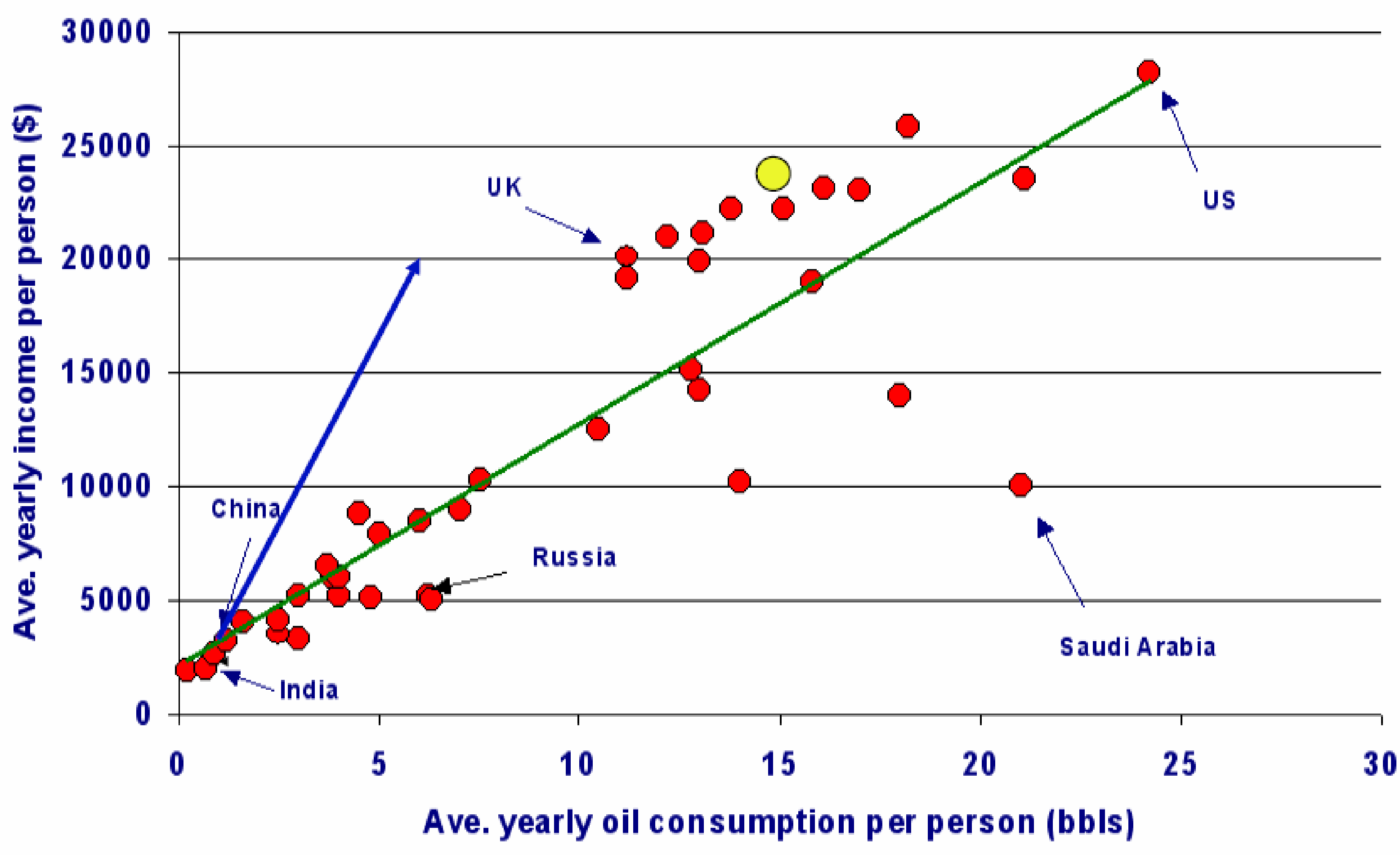
Material Wealth for Humans

- Is an individual's claim on human, plant or animal output, or inanimate material
- Has a purpose or intent for final consumption
- For societies it is a type of desired order within humans and the environment.
- Money or currency is an irrelevant distraction for our discussion

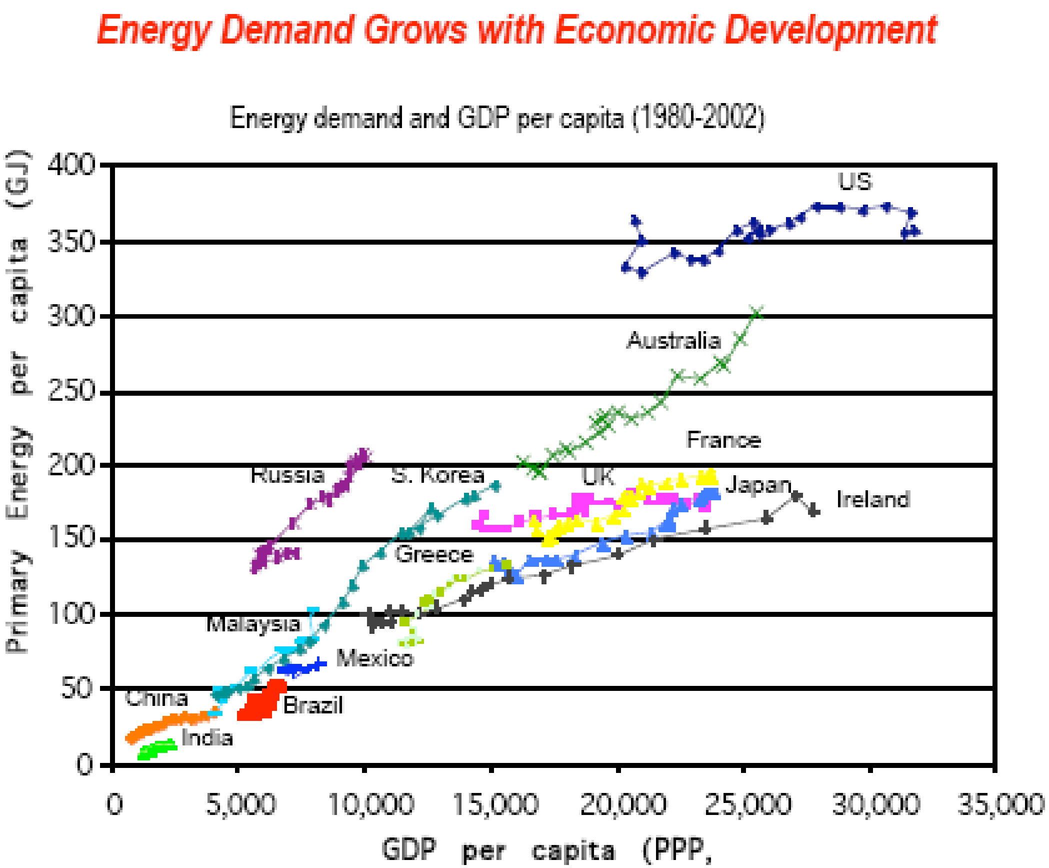
To Maintain Order We Need Energy

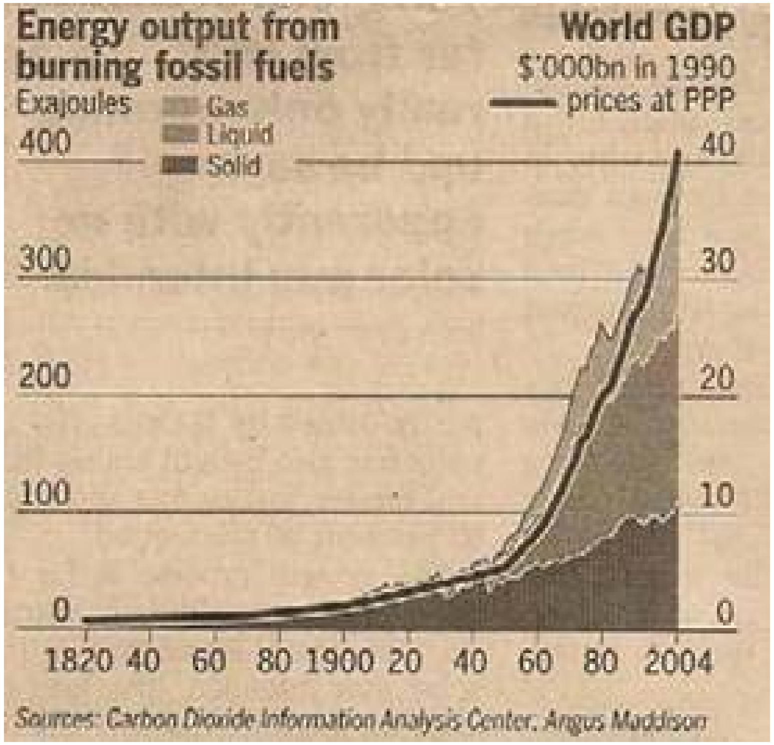
- $dF = dU - TdS$; natural systems want to minimize dF.
- If we want to oppose this trend we need constant input of energy $dQ = dU + dW$.
- Life and material richness is impossible without energy.
- Sustainable GDP growth with decreasing energy is an oxymoron or nonsense

GDP vs. Energy Consumption at a Fixed Time



Energy consumption vs. GDP – Time evolution





Decreasing Energy = Decreasing GDP = Decreasing Material Wealth

Net Surplus Energy (NSE)

TM = Total mass of energy providing material
e.g., oil, coal, gas, wind turbine, PV modules

EPM = Energy produced per unit mass; E_{out} = TM x EPM

Correct Calculation

EROEI = Energy Returned on Energy Invested = $\frac{E_{out}}{E_{in}}$

NSE = $E_{out} - E_{in} = E_{in}\left[\frac{E_{out}}{E_{in}} - 1\right]$

We are running out of *both* TM *and* EROEI

This means all occupations in society that do not generate NSE are threatened!

This includes a majority of today's occupations.

Tourism only exists because cheap oil is available

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)

EROEI ↓ = Less house/person

- Recent statistics from the **U.S. Census Bureau** found that the number of parents who've moved into their adult children's homes increased 67 percent, from about 2.1 million in 2000 to 3.6 million in 2007.

- Apply this to processed food, extra clothes, house sizes, all other hobbies and discretionary spending, including large parts of higher education.

Effect on Higher Education

- Society will not have energy surpluses to send ¼ of the young population (18 – 24 year) to learn non-energy-producing activities
- Enrollments/population ratio will be shrinking in most disciplines
- Student/teacher and faculty/administrators ratios will increase
- Distance learning through video technology will significantly increase
- There will be far less research-$/faculty in most areas
- Many departments will have to choose to become a pure teaching or pure research departments. Teaching and research will be in conflict.

Effect on Food Availability

- Abundant food surpluses (> 60 days of grain supply/capita) in last thirty years was possible due to:
  - Better seed quality (not energy dependent)
  - Irrigation (energy dependent)
  - Fertilizers (derivative of natural gas and other materials)
  - Pesticides (derivative of crude oil)
  - Massive farm equipment (crude oil dependent)
  - Transportation from farm to consumer (crude oil dependent)

Fossil Fuel and Agriculture

- On average, the food industry uses 10 calories of fossil fuel energy to produce 1 calorie of food.
- For pork, it's 68 calories for 1 calorie on your plate.
- For beef, it's 35 calories for 1 calorie on your plate. [1]

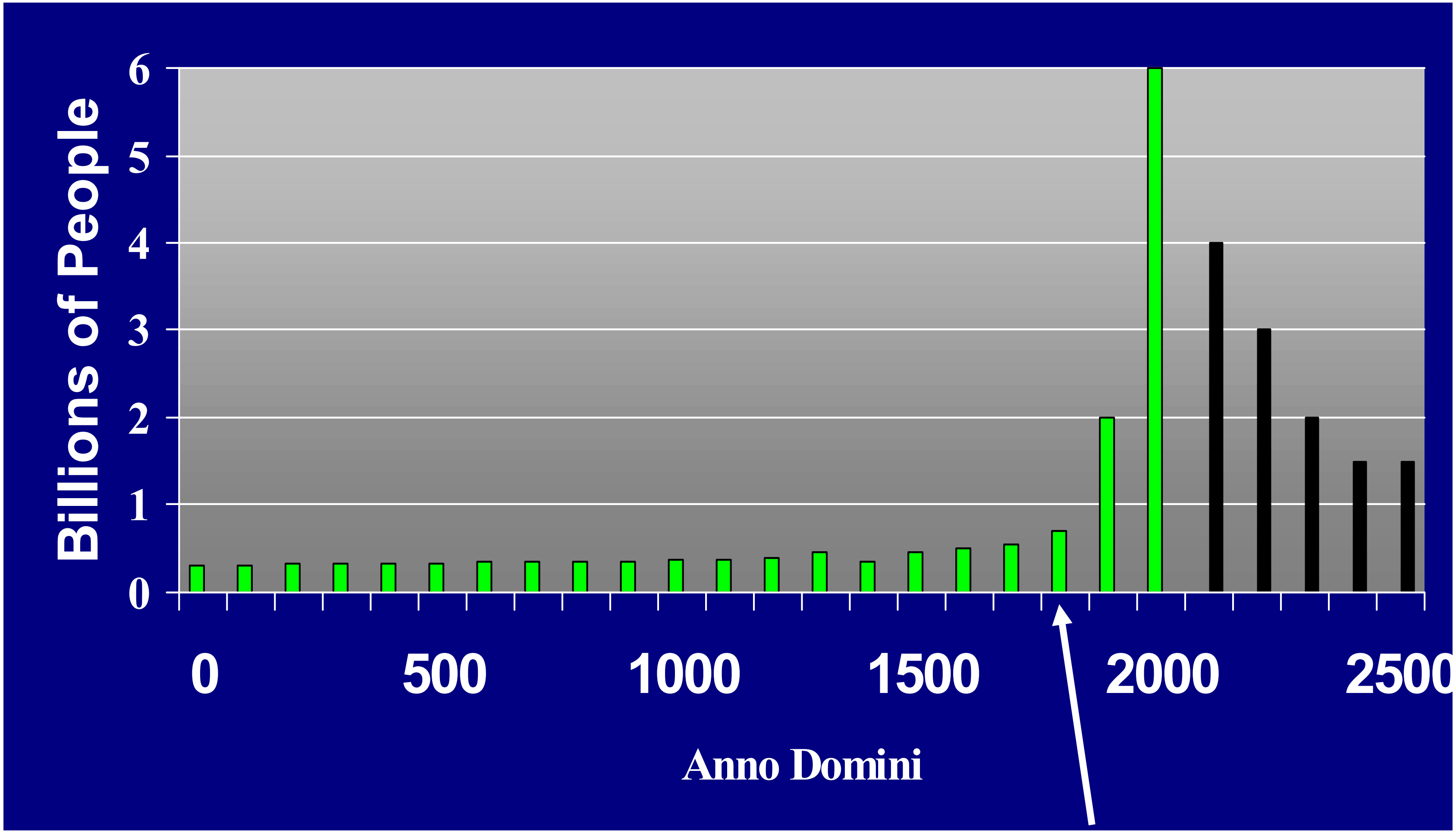
[1] Richard Manning; "The Oil We Eat", Harpers, 2005.

Resource Wars for Oil have started!

Small or large resource wars will increase

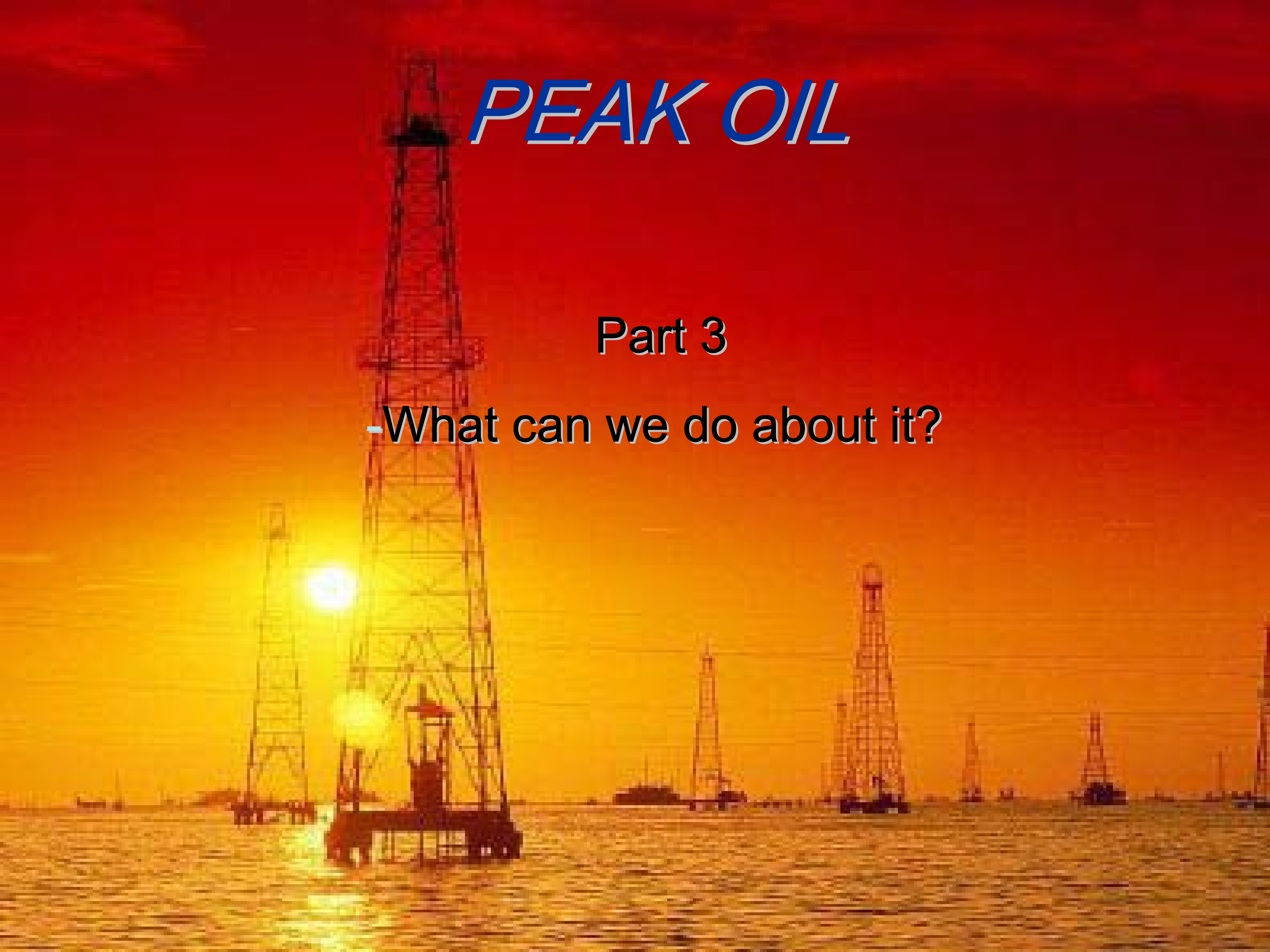
Crime will increase

Population



OIL (1859)

From: Ugo Bardi, in Italian.



PEAK OIL

Part 3

-What can we do about it?

Business as Usual: Is there an easy solution?

- No, not in reality [Meaning: New sources are not scalable and have low EROEI].
- Conservation is the biggest part of the solution.
- Alternative fuels (solar, wind, geothermal) are likely to provide help but gradually.
- New technology like battery-operated cars are likely to help in the long run (> 20 years).
- Demand Reduction: We will unwind good portion of globalization; go back to simpler life styles, technologies that worked before.

Solutions: Most important step

- A *Depletion Protocol* between all oil importing countries to cut imports to match depletion rate

- Will avoid wars

Solutions: Four types of wealth

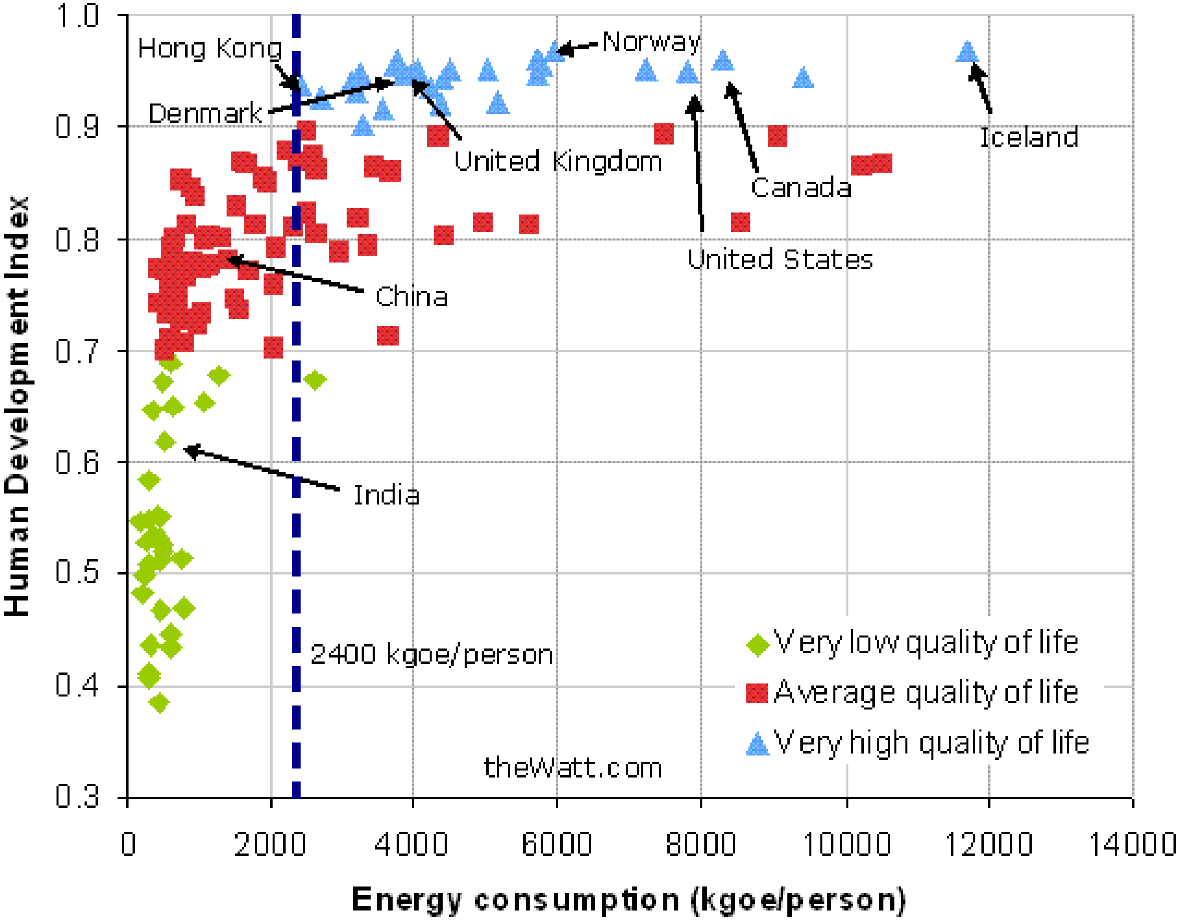
- Human or individual capital (self-actualization, Maslow)
- Social or inter-personal capital
- Natural or ecological capital
- Material capital

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

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)

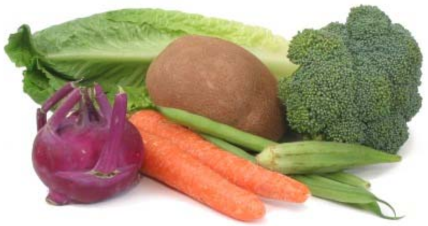
Solutions: Priorities (USA)

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

-Reactivate electric trains, trams, trolleys, buses; Upgrade the 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 oilseeds, willow for wood pellets, forest generation

-Stop corn ethanol immediately

-Tackle population growth

Solutions: What can I do immdediately?

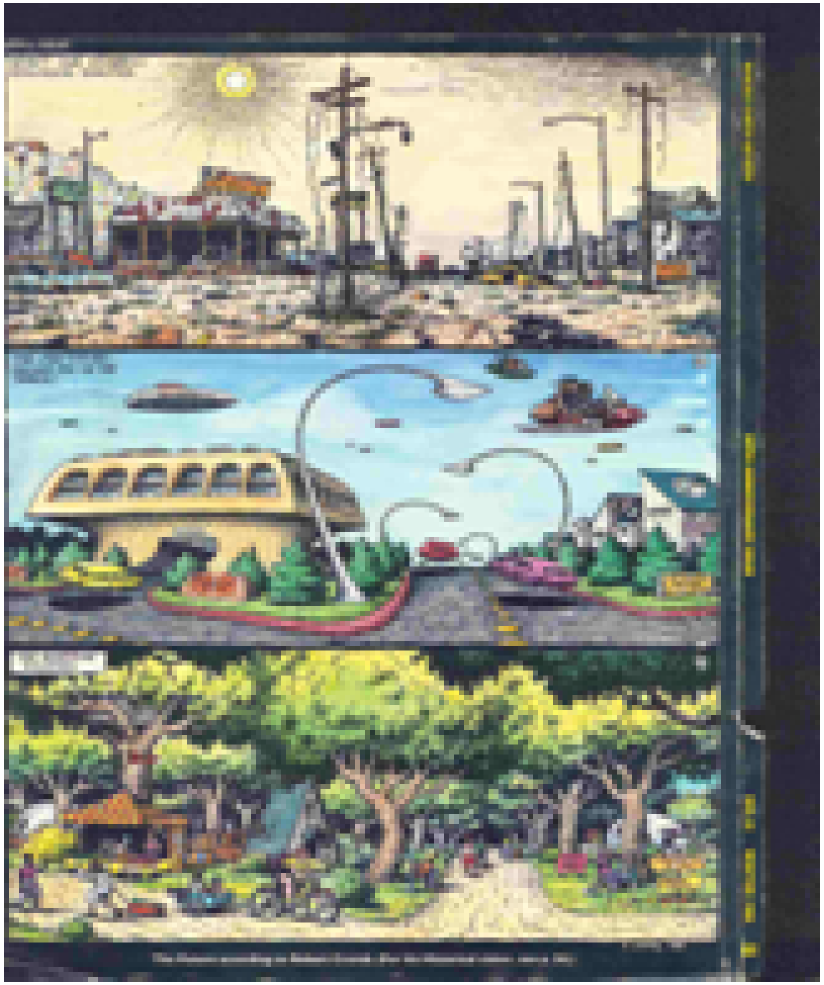
- Worship, Prayer, Secular Meditation
  - Brings about a relaxation neural response, good decision making, avoids panic
- Work on:
  - Getting educated yourself first
  - Reducing your liquid fuels consumption by 50% to 80%
  - Educating family, friends, co-workers, policy-makers
  - Form community support 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

Our actions will make the future

Which Future?

Mad Max

If we do nothing



Star Trek

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

The Beach

If we work very hard
for 50 years!

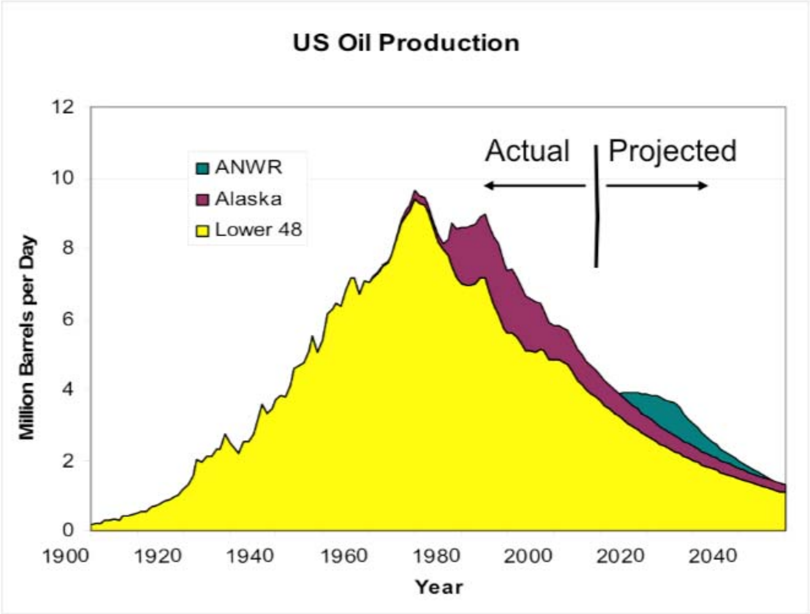
Thank You

References:

- www.theoildrum.com
- www.energybulletin.net
- www.aspo-usa.org
- 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

Myth #1: Drilling in Arctic National Wildlife Refuge will save us

U.S. Oil Production



No other drilling programs seem to have much scalable benefit and high EROEI.

Myth #2: Canadian oil sands will save us

- Hard to see this with current technology
  - Technology known since 1920s
  - Production slow and expensive
- Natural gas is in limited supply
  - Alternatives require more capital
- Most optimistic forecasts equal 5% of current world oil by 2030
  - Even this exceeds available natural gas

Myth #3: Biofuels will save us

- Corn-based ethanol has many problems
  - Raises food prices, not scalable, CO_2 issues, depletes water supply
  - Negative or low (< 1.3) EROEI
- Cellulosic ethanol theoretically better
  - Still does not scale to more than 20% of need
  - Competes with biomass for electric, home heat
  - Low EROEI
- Biofuel from algae might work
  - Not perfected yet
  - Scalability is highly doubtful

Myth #4: Coal to liquids (CTL) will save us

- There is not enough coal. (US coal at or near peak!)
- Without CTL world coal peaks in 20 years
  - With CTL maybe in 5 years
- It has low EROEI < 5.
  - In other words it is very expensive
- CTL is very polluting.

Myth #5: OPEC could produce more if it used current techniques

- International oil companies use same service companies US companies do
- Most are using up-to-date techniques
- Expenditures often are high
- Problem is very old fields
- Overstated reserves raise expectations

Myth #6: A small downturn can easily be made up with energy efficiency

- The quickest impacts are financial
  - Recession or depression
  - Serious recession in 1973 - 75
- Use of biofuels raises food prices
  - Further increases recession risk
- Don’t need peak for recession
  - Only need supply/demand shortfall
  - Likely what we are experiencing now