CERN, August 24, 2006

The Energy Question
Myths, Folktales and Fairy Tales

M. Dittmar ETH Zurich

- Some media headlines.
- Facts and Physics about using energy.
- What is the energy problem?
- Myths and Folktales about energy sources and the current energy discussions.
- Fairy Tales about the energy problem.

"Physicists learned to realize that whether they like a theory or they don't like a theory is not the essential question. Rather, it's whether or not the theory gives predictions that agree with experiment."
Richard Feynman

Introduction: Oil (Energy) in the Media

some headlines: (mis?)informations for intellectuals?

"Gasoline Pump prices hit all-time High" (Reuters 23 March 2004)

"Oil reserves enough for decades" (Spiegel 21. May 2004)

"Is the world's oil running out fast?" (BBC News 7. June 2004)

"Oil is running out fast" (Guardian 8. June 2004)

"Why oil will hit 100 dollar a barrel" (BBC News 15. February 2006)

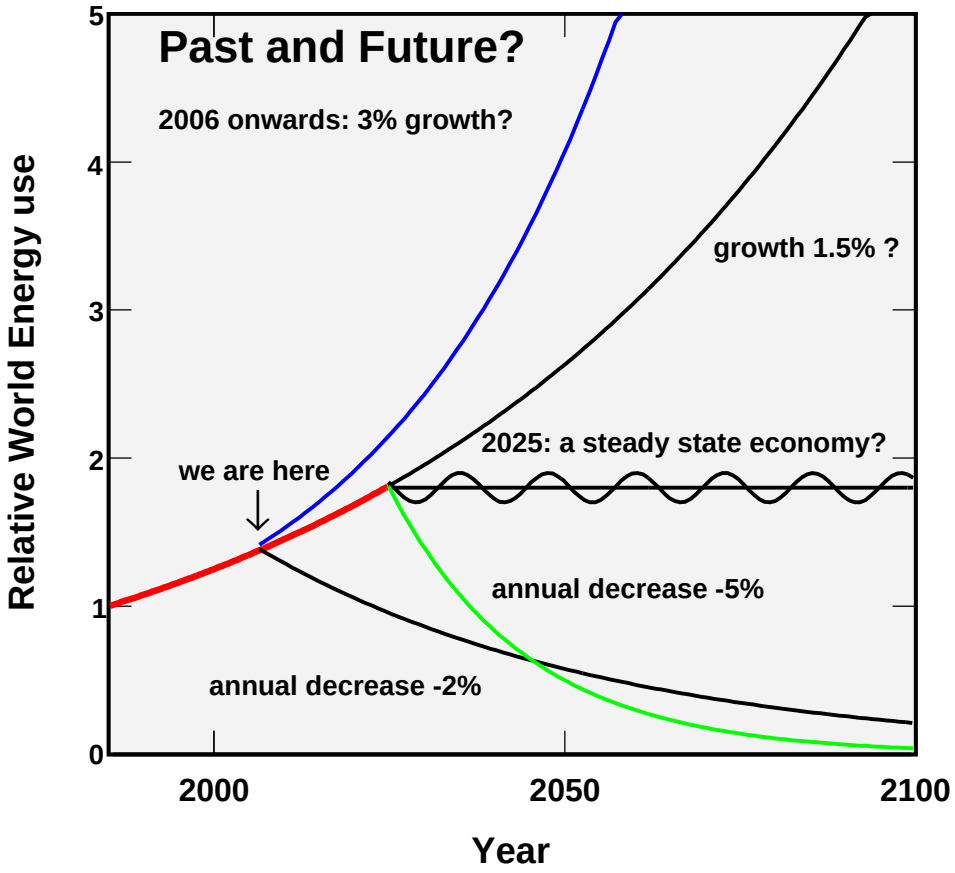
"Oil price climbs to 75 dollar" (Spiegel 21. April 2006)

"Uranium shortage forces commodity price up"
(ABC News Online 26. July, 2006)

"Mid-East crisis could push oil to 125 dollar" (BBC News 28. July 2006)

Some hypothetical visions for our future

"Anyone who believes exponential growth can go on forever in a finite world, is either a madman or an economist." *Kenneth Boulding, Prof of Economics*



How we use energy I

Energy use of the (four person) Dittmar family in 2005

- Electricity and heating: with (French) nuclear power 17500 kWh and wood $\approx$ 5000 kWh(therm): 22500 kWh/year;
- Cooking with natural gas (bottles) 50 kg/year:
  $\rightarrow 50 \times 5 \times 10^4$ kJoule = 2.5 GJoule = 700 kWh;
- Car driving: 15000 km (9.5 l/100 km) + 12000 km (5.5 l/100 km)
  total $\approx$ 2000 liter petrol = 24000 kWh;
  (car driving needs $\approx$ 0.3-0.86 kWh/person/km)
- Train: 20000 km (0.25-0.78 kWh/person/km) = 8000-10000 kWh
  Flying: 0 km (0.42-0.70 kWh/person/km) = 0 kWh
- Food (in "rich" countries): 1 Calorie "contains" $\approx$ 10 Calories from fossil fuels (production and transport). (We are working on that ..)
  2500 Calorie $\times 10 \times 365 \approx$ 37 GJoule/year/person $\approx$ 10000 kWh
- Energy for production and transport of consumer goods and services:
  unknown(?) making a car needs $\approx$ 25000 kWh (or $\approx$ 1.2 kWh/FS?)
- Working at CERN (together with roughly 3000 other people)
  $\approx$ 600 GWh $\rightarrow$ 200 MWh/person = 200000 kWh!
  (hm.. so much! Should one divide by 6.5×10^9 people?)

How we use energy (a comparison) II

M.D.: roughly 40000 kWh/year (+ working at CERN: 240000 kWh),

an average person in Western-Europe: 50000 kWh/year
(including work and consumption)

an average human being (6.5 billions today): 17000 kWh/year.

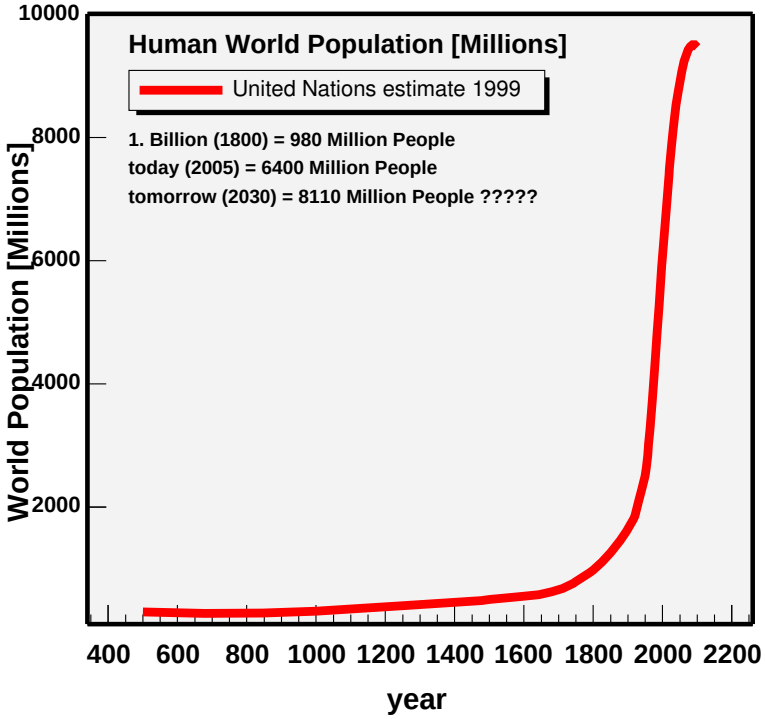
an average person in China (1.3 billions today): 9400 kWh/year.

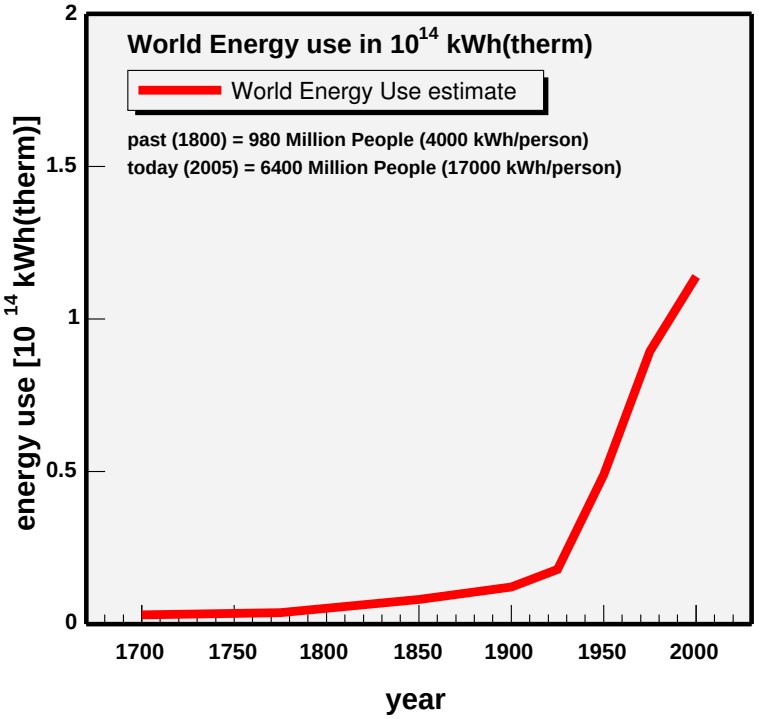
an average person in India (1.1 billions today): 3700 kWh/year.

6.5 Billion humans need energy for XYZ

$\approx$ 129 Million children born/year and $\approx$ 56.5 Million humans die/year (10 Million from hunger and hunger related problems).

The energy use per person varies by orders of magnitude
$\approx$ 2 Billion people live without electricity!



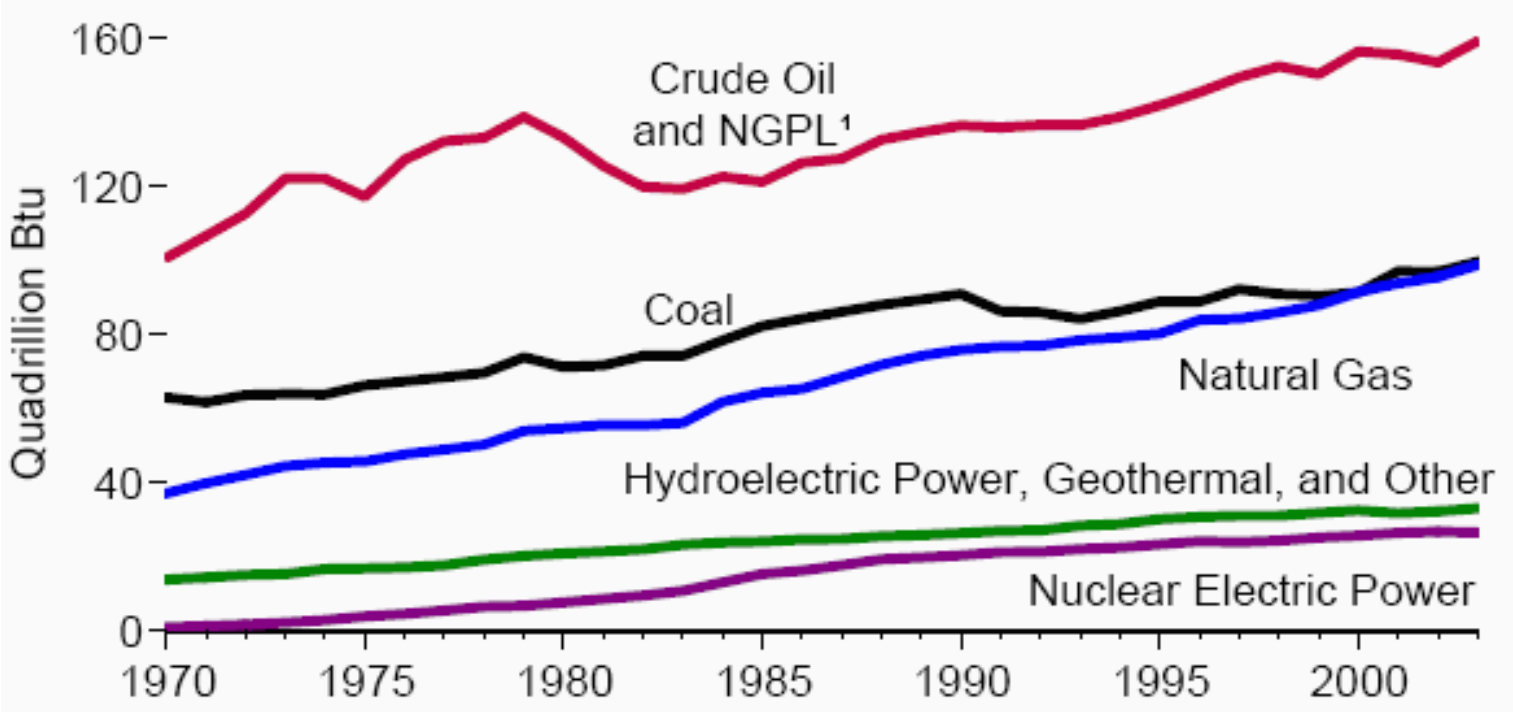


World energy use (2002) $\approx$ 100000 TWh (therm)

fossil fuels: 40% from oil, 22% natural gas and 23% coal

fraction from renewable energy sources (mainly hydropower) 8%

16.6% of the worlds electricity comes from nuclear energy
electric energy makes only 16.1% of the worlds total energy mix.



Source: www.eia.doe.gov/aer/pdf/perspectives.pdf

The Energy Conservation Law (or the first law of thermodynamics):

Energy can be transferred from one system to another in many forms, but Energy can not be created nor destroyed.

$$\mathbf{E_{in} - E_{out} = \Delta E_{syst}}$$

in short:

Energy can not be created!

The Law of Energy Transformations (or the second law of thermodynamics):

Each time energy is converted from one form to another, some of the energy is always degraded to a lower-quality, more dispersed, less useful form.

Maximal efficiency (Carnot) to transform heat into mechanical motion:

$\eta_{\mathrm{max}} = 1 - \frac{\mathrm{T_{min}}}{\mathrm{T_{max}}}$ **[T in Kelvin]:**

in short:

Energy transformation is always a "loss" !

Power "to do work" or "service"

Power describes how fast **energy** can be transfered from one system to another system (Tipler)

Installed (Wind) Power is different from available power!

each "Swiss/German/French" citizen
uses an average power of about 5000 Watt!

If you can climb 1000 m in one hour
your muscles "deliver" an average mechanical power of $\approx$ 150 Watt!

in short:

we benefit from
"80 never tired slaves"

"NER" or "EROEI" of energy sources:

Net Energy Return: NER = energy return - energy invested

$$\mathrm{EROEI(gain\ \ factor)} = \frac{\mathrm{energy\ \ return}}{\mathrm{energy\ \ invested}}$$

Energy costs of energy sources:

- Energy needed to search, extract and transport the energy source to the user.
- How much is "lost" when the stored energy is transformed into the right final energy form?

Energy gain calculations are different from Dollar/Euro calculations!

Thus: Subsidized bio-alcohol might be "economic" and at the same time energetic nonsense!

The law of diminishing returns (the law of decreasing EROEI)

- Easy and big sources will be found and used first. Followed by more and more difficult finding and extraction of the resources!

- "Keep on going" with better technique.

- The end (for energy sources): EROEI = 1!

The quality of energy sources:

- Energy density [thermal kWh/kg]:
  biomass (dry wood) $\approx$ 5, coal $\approx$ 8, oil $\approx$ 11.6 (1 liter oil $\approx$ 0.86 kg),
  gas (Methane) 9.5 kWh/m^3 (1 m^3 gas $\approx$ 0.8 kg)
  in comparison: a modern (car) lead battery allows to store about 0.050 kWh/kg.

- "Burning" temperature of biomass (wood) = 593^{0}C,
  "technology" often needs higher (melting) temperatures
  iron = 1535^{0}C, cooper = 1083^{0}C!

- The simplicity of use: self service at the petrol station, risk of explosions, and different types of applications (like diesel generators)

- "Easy" transport from the "source" to the user?

- Environmental impact (costs): Who "pays" for them?

Energy forms and their use for "services"

Electric energy has the best transformity:

Electricity can be used for heating, transport, information transfer and even particle physics! But:

Electricity is neither an energy source nor can it be stored efficiently.

Oil is by far our best known "energy source"!

Storage, transport and simplicity of use!

Today almost everything is "moved" with oil !

What is the Energy Problem? I

As shown by C. Rubbia, IAEA Fusion Energy Conf. Oct. 2000
Original plot probably made around 1971 by Dr. M. King Hubbert (1903-89) (geophysicist)

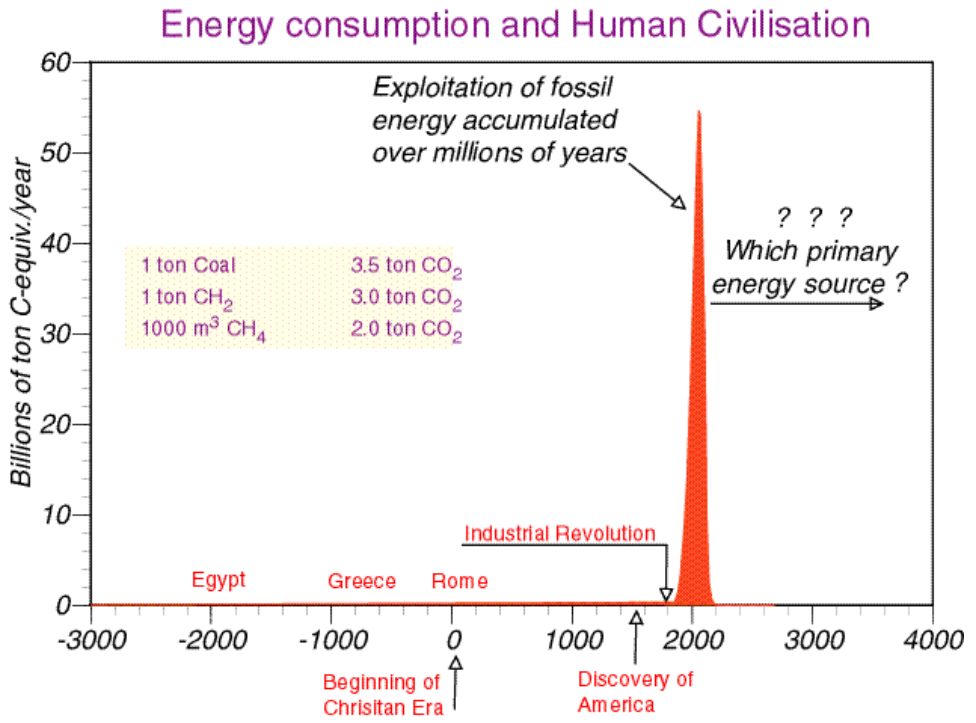


Figure 4.

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What is the Energy Problem? II

Standard Question: "How many years of oil, gas and coal remain?"
(assuming no further growth: "with todays use")

- **Oil $\approx$ 40 years (fraction of world energy mix 40%);**
- **Gas $\approx$ 65 years (fraction of world energy mix 22%);**
- **Coal $\approx$ 250 years (fraction of world energy mix 23%).**

(source BP World Energy Review 2004 and EIA Report 2004)

Are these numbers correct?

What do these numbers mean in "energy growth" scenarios?
Are there other fundamental limits?

(like Hubbert's oil peak and the law of dimishing return)

What is the Energy Problem? III

Todays "modern", "civilized" and "industrialized" way of life depends on huge amounts of oil, gas and coal ($\approx$ 85% of the energy mix)!

oil required for the transport of almost "everything"

and almost nothing works today without electricity!

Imagine your life with regular shortages of oil and electricity.

In addition:

1. If one wants our ("reasonable(?)") living standard for "all"
   $\rightarrow$ increase the energy use by at least a factor of 3!
   World population still grows by about 1% per year (70 Million people!)

2. World's CO_2 production from fossil fuel burning is already too large!

3. Earth is finite! $\rightarrow$ limited resources (not only for oil, gas, and coal).

Three Myths about the Energy Problem

"Myths" are stories of forgotten or vague origin, basically religious or supernatural in nature, which seek to explain or rationalize one or more aspects of the world or a society (www.pantheon.org).

1. Electricity comes out of the plug.

2. Switching from one energy source to another better one.

3. Oil will always last for another 40 years.

Myth I: Electricity comes out of the plug

The European grid produced a total of 2448.1 TWh electric energy in 2004.

2004: 9.3% (25 TWh) of Germany's electric energy from Wind power,

but demand has large variations (some numbers for Germany):

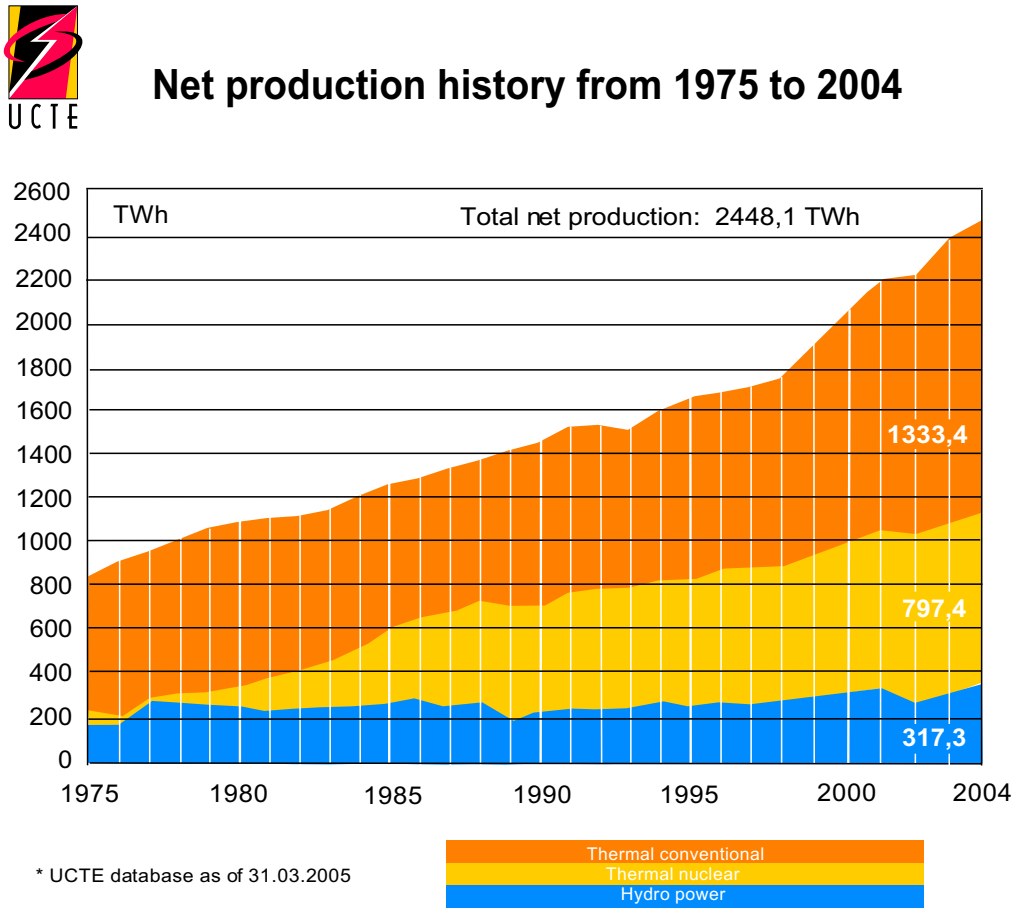
June 2004: Min. (night) $\approx$ 40 GW Max. (noon) 68 GW

January 2005: Min. (night) $\approx$ 55 GW Max. (noon) 71.5 GW.

- Nuclear power plants are difficult to regulate (running always at 100%).
- Gas and Hydropower are "perfect" to balance demand fluctuations.
- Wind and Solar fluctuations are huge! Efficiency of German wind farms, with installed power of 16000 MW (2004), in the good wind year (2004) was roughly 18%.

Electricity comes out of the plug II

2-3% growth per person and year in Europe (www.ucte.org)



Electricity comes out of the plug III

Expectation of European futurologists (future will be like the past!):

average yearly electricity demand will continue to grow by roughly 2% per year!

Skeptics look into the possible production:

- Age structure of power plants:
  e.g. the 150 nuclear power plants in Europe are roughly 25-30 years old.

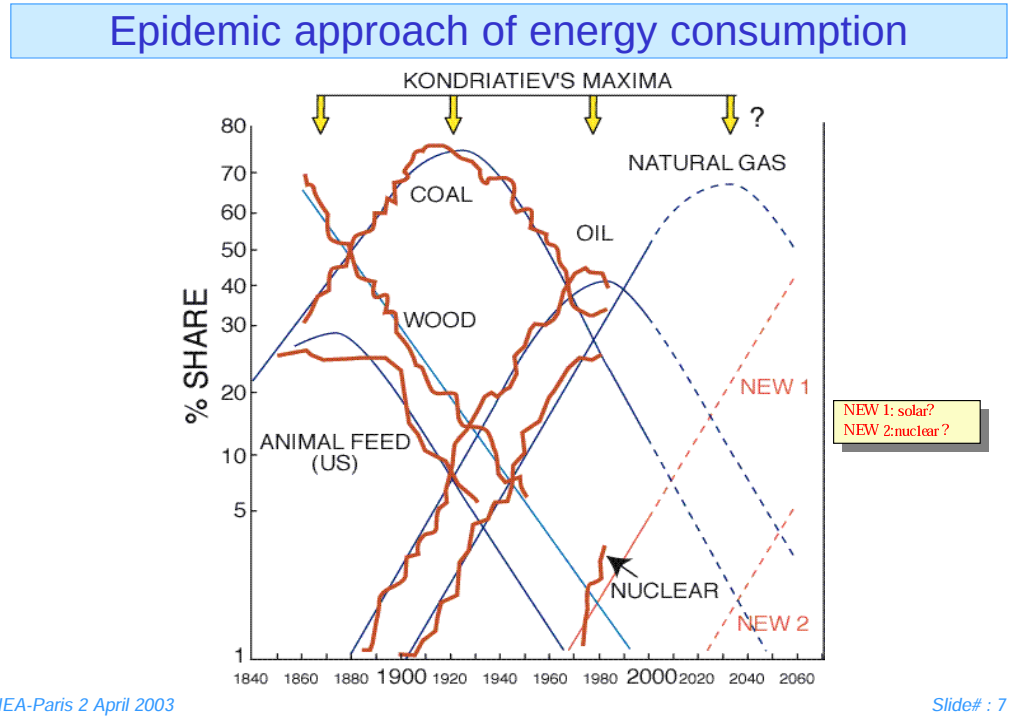
- The construction time for new power plants is 5-10 years and at least 100 additional new big (nuclear?) power plants are required to satisfy 2% demand growth by 2015. But no concrete plans have been decided so far!

- How stable are the input energy sources for all power plants?
  For how long will we get natural gas from Russia?
  (Gasprom considers reductions if the EU does not respect .. Spiegel April 20, 2006)

Myth II: Switching from one energy source to another better one

(All) odd numbers are prime numbers: 1,3,5,7,9*,11,13,15*,17,19 (* measurement error)

Marchetti-Nakicenovic Functions as shown by C. Rubbia, talk at IEA Paris 2003



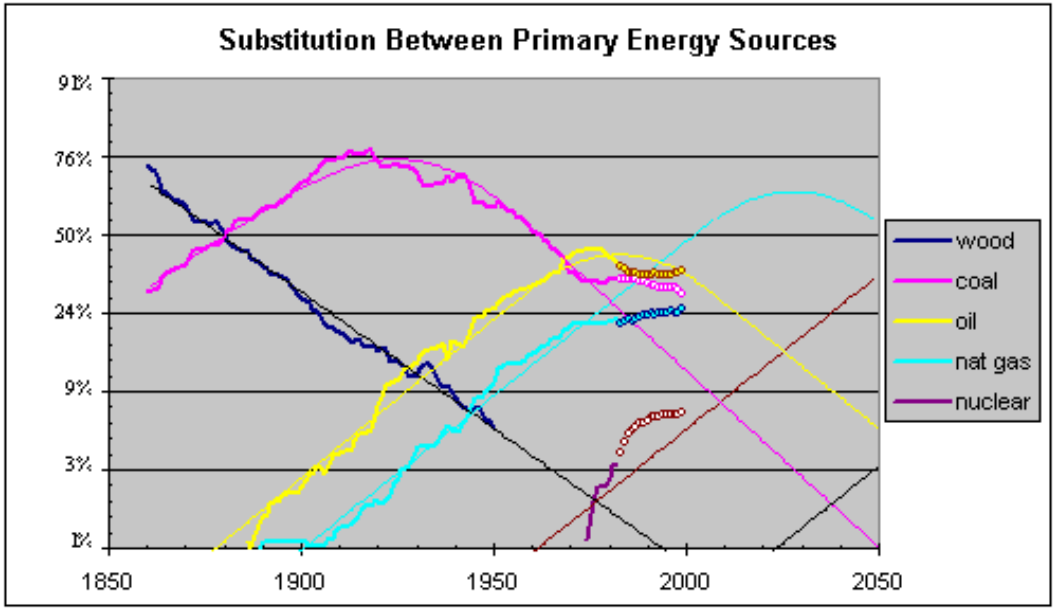
Myth II: Switching from one energy source to another better one

Obviously not all odd numbers are prime numbers (never base a model on small statistics)!

Marchetti-Nakicenovic Functions do not describe the real world!

Why do some physicist's still show outdated wrong models?

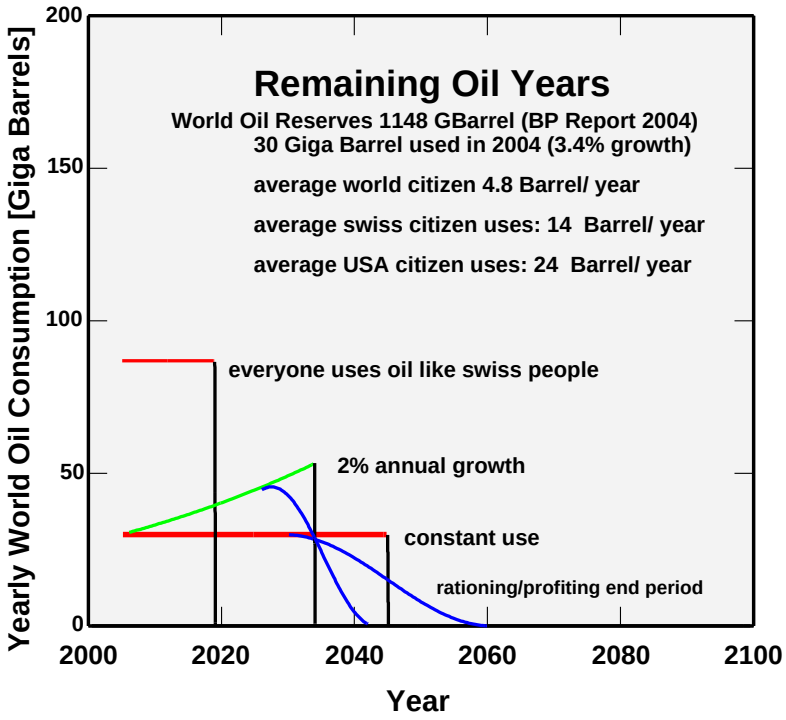
(Even Nakicenovic stopped)?



source http://ourworld.compuserve.com/homepages/tmodis/June18_01.htm

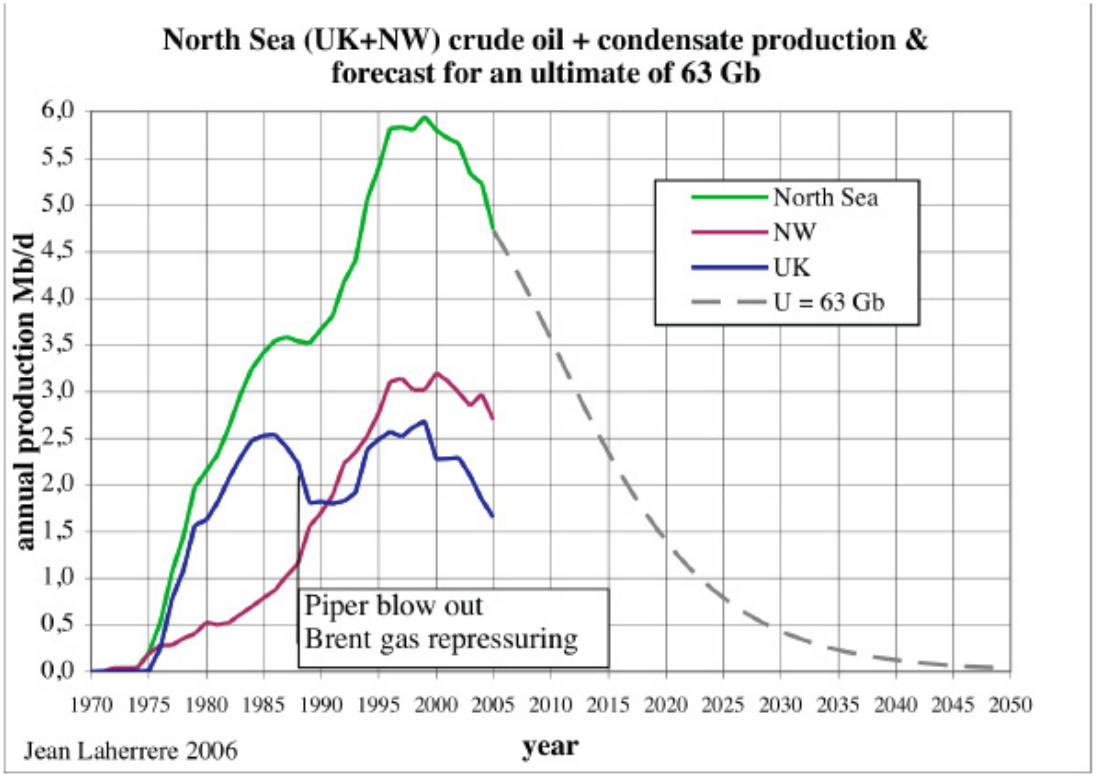
Myth III: Oil will always last for another 40 years

unrealistic ideas about the future oil consumption:

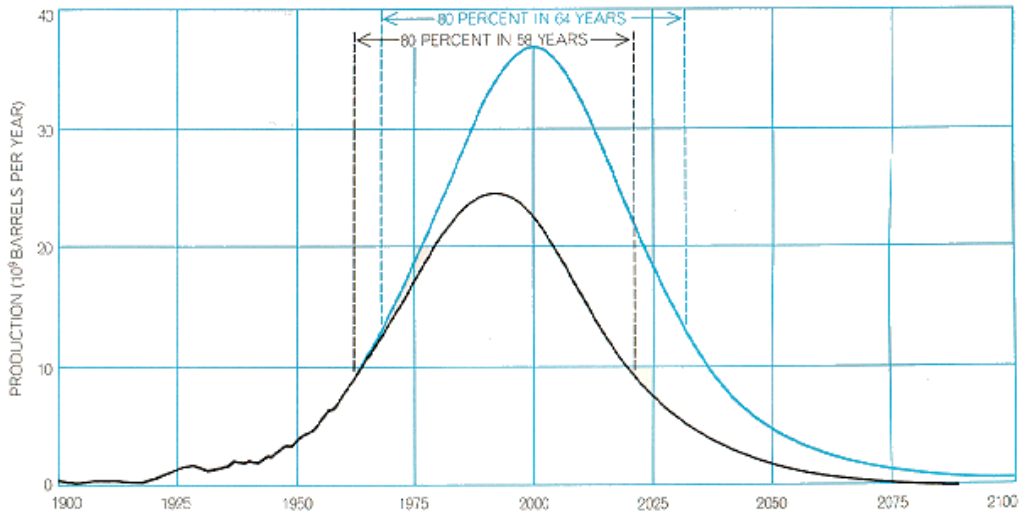


Myth III: Oil will always last ... and the reality of the north sea oil production

"While primary oil demand in European Union (EU) countries is projected to increase by 0.4% per year from now to 2030, North Sea output peaked in 1999 and has been on the decline ever since."
Source: Institute for the Analysis of Global Security 24.5.2004, www.iags.org/n0524043.htm



Myth III: Oil will always last ...
King Hubbert's Peak Oil prediction



CYCLE OF WORLD OIL PRODUCTION is plotted on the basis of two estimates of the amount of oil that will ultimately be produced. The colored curve reflects Ryman's estimate of $2{,}100 \times 10^9$ barrels and the black curve represents an estimate of $1{,}350 \times 10^9$ barrels.

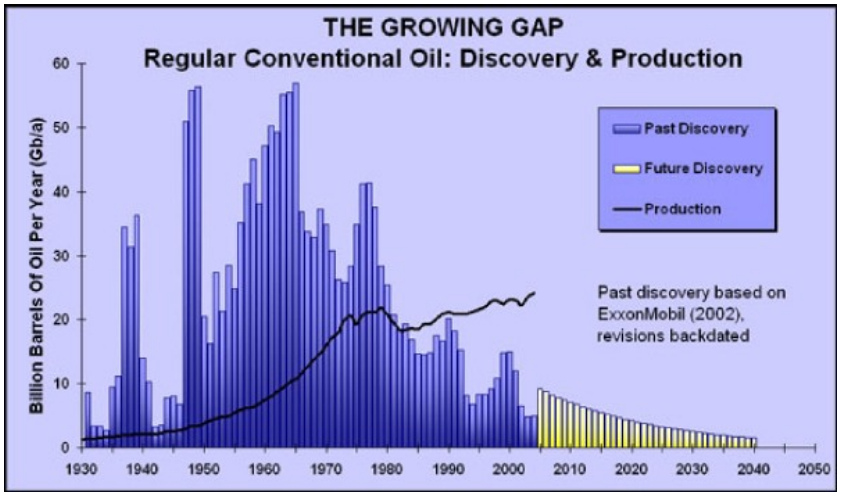
Energy and Power, A Scientific American Book, 1971, pg 39 world oil reserves:
Hubbert estimated maximum extractable total world oil to be about 2100 GBarrel
This number agrees within 5% with the numbers given today by BP, IEA and EIA!

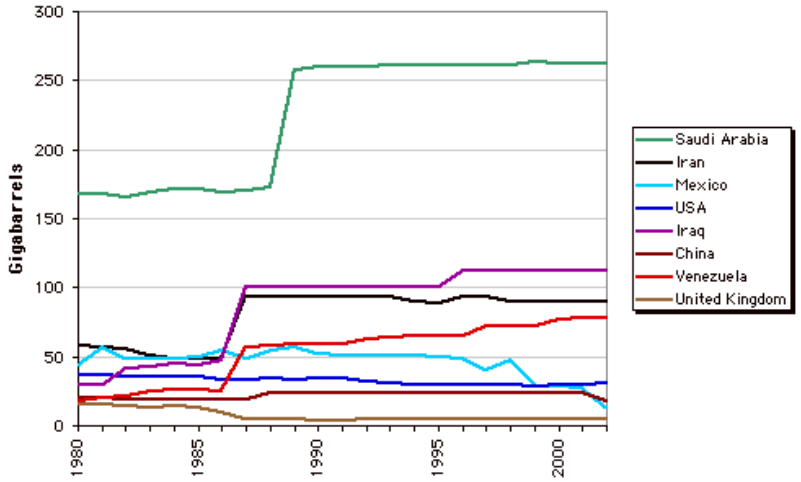
However, the oil growth scenario ($\approx$ 5%/year), used by Hubbert, was wrong!

That could explain why the "oil peak" has not happened yet!

The known(?) oil reserves

One has to find oil before it can be burned
Maximum of oil discoveries 40 years ago (1960-70)!)





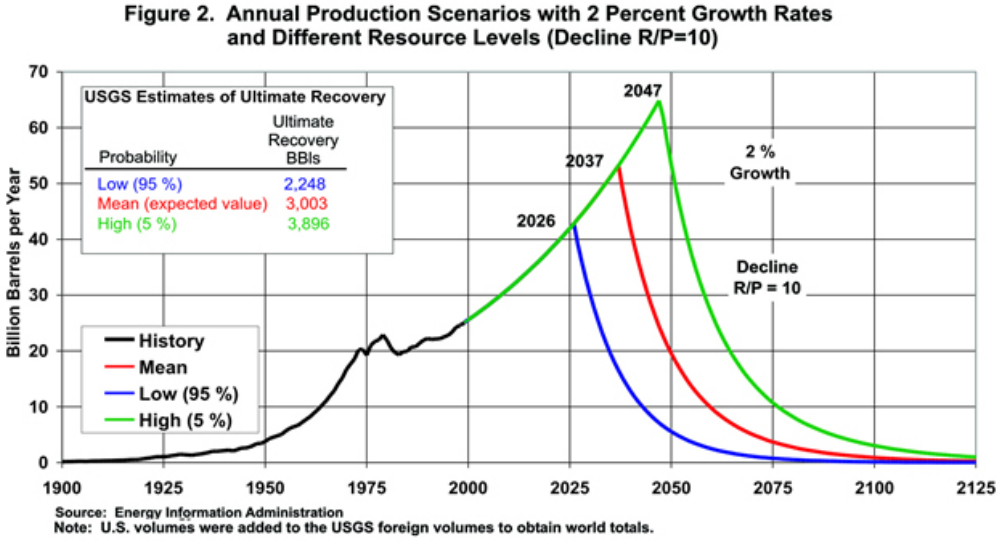
are the OPEC numbers correct?
(what happened around 1988 and why are reserves constant?)
(OPEC = oil producing and exporting countries)

Source ASPO Ireland and www.wolfatthedoor.org.uk

Most quoted oil reserve study: 10 years later

World Petroleum Accessment 1995-2025

the U.S. Geological Survey (USGS) studies from 1996 (and 2000)

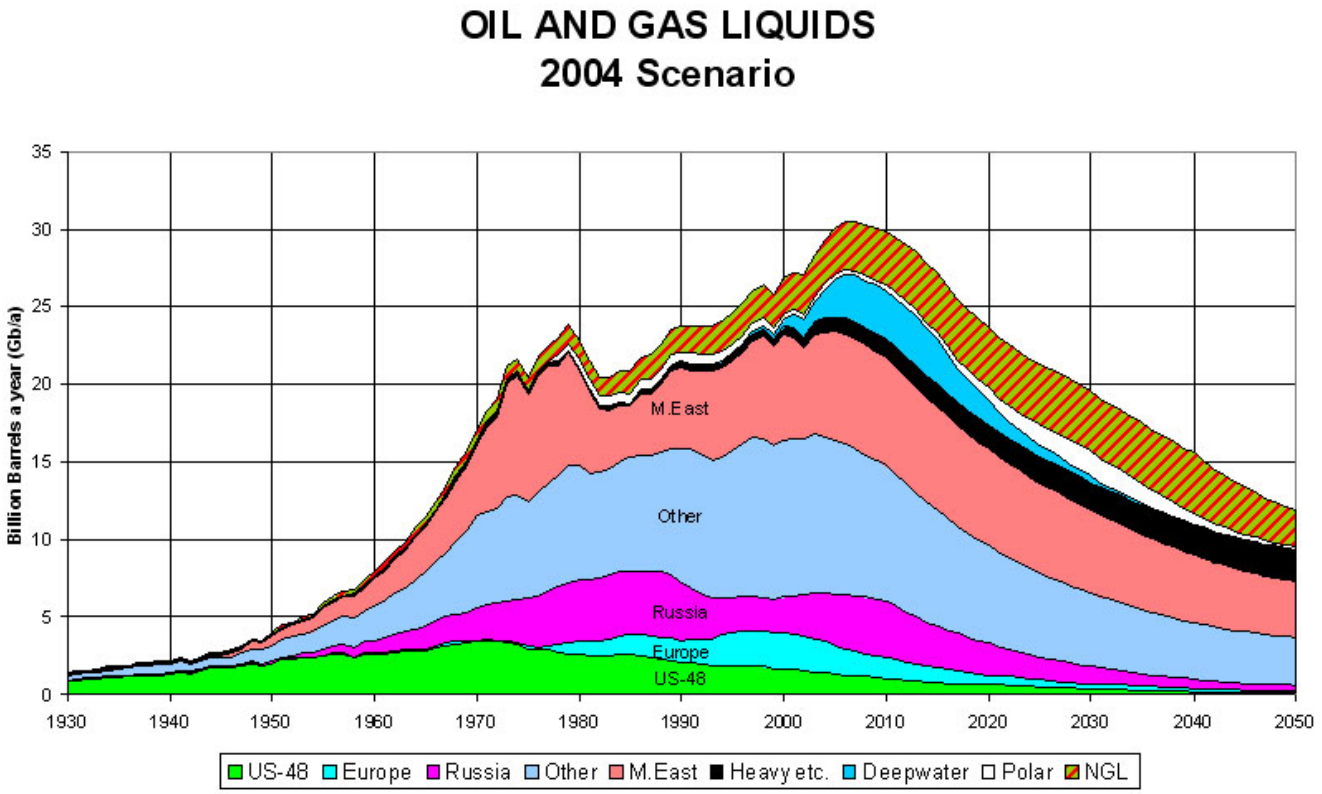


attention I: exponential rise (with unphysical peak) followed by a fast drop!
attention II: the real oil discoveries between 1995 to 2003 agree with the numbers labeled "95%" probability!
(Believing OPEC numbers) Worlds total extractable oil: 2248 Giga Barrel (in agreement with Hubberts (1971) estimate)!
1/2 of this oil (EROEI $\geq$ 1) has already been burned!

World's Oil extraction as seen by geologist's (using Hubbert's model!)

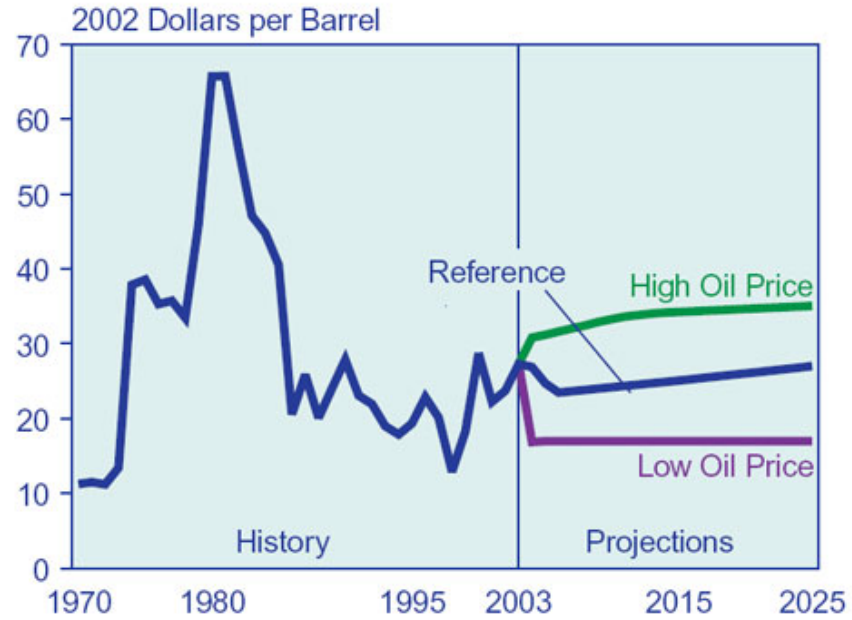
Oil extraction: Past and Future for different countries

The 2004 ASPO scenario (Colin J. Campbell et al., 2004-05-15 www.peakoil.net/uhdsg/Default.htm)



Using the dollar price as an indicator (2001 EIA predictions for the oil price)

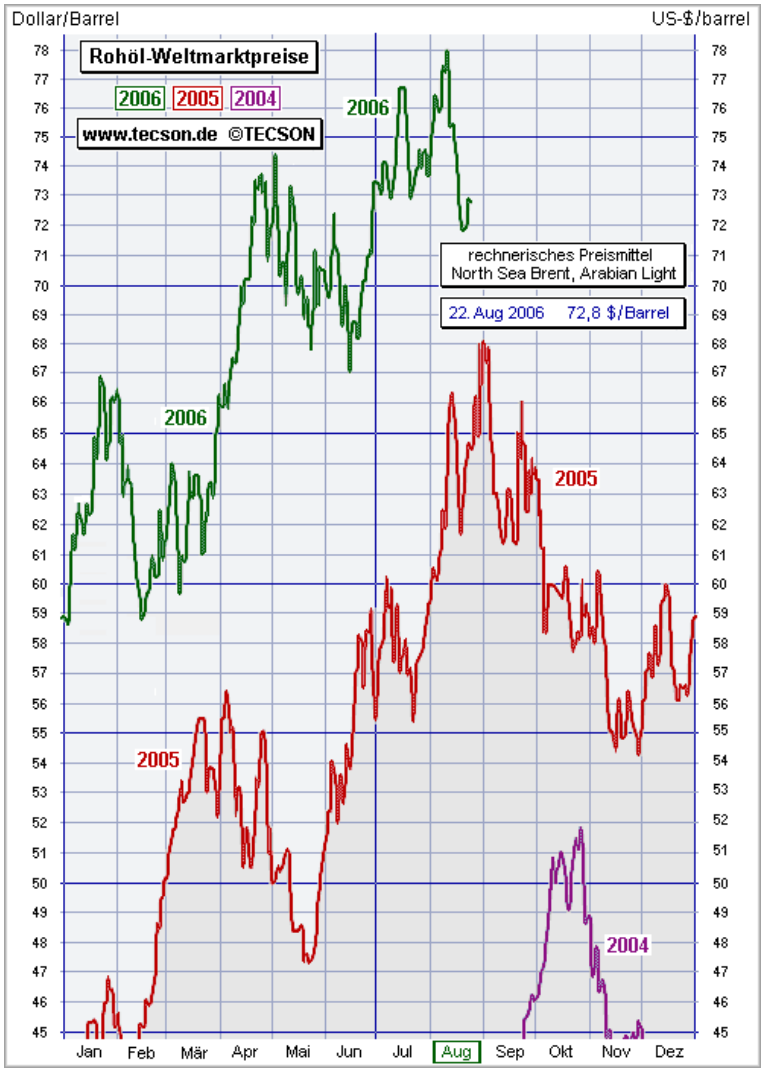
Figure 26. World Oil Prices in Three Cases, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www. eia.doe.gov/iea/. **Projections:** 2003-2004—EIA, *Short-Term Energy Outlook*, on-line version (April 2004), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2004-2025—EIA, *Annual Energy Outlook 2004*, DOE/EIA-0383 (2004) (Washington, DC, January 2004).

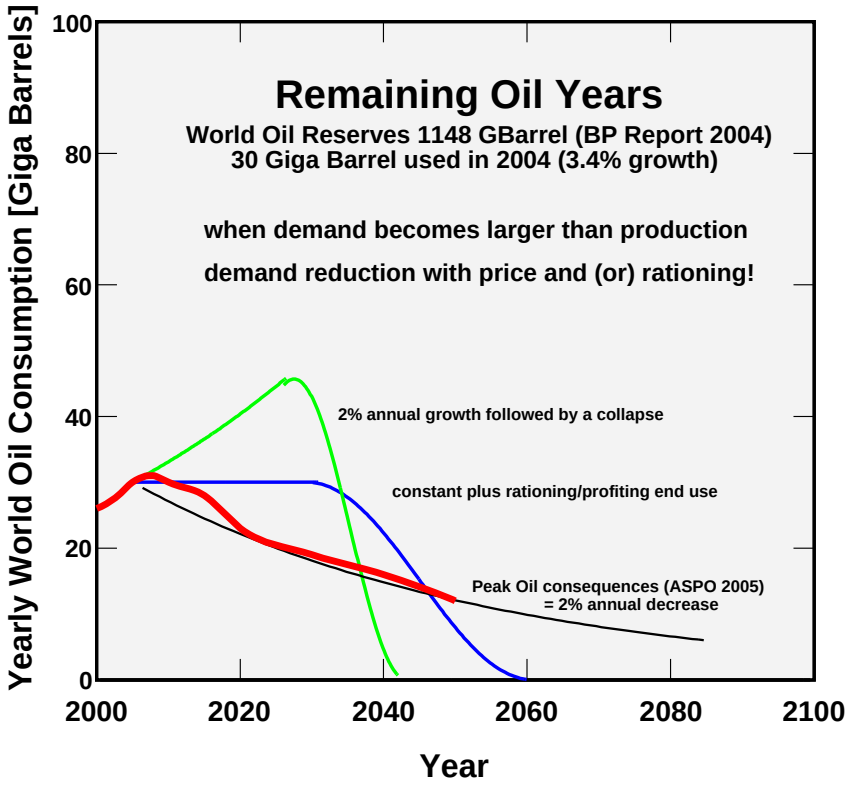
The oil price reality: 2004/05/06

latest oil price from www.tecson.de/prohoel.htm



Resource based scenarios for the world wide oil consumption:

Accepting "Peak Oil" as a natural law means that we all have to adapt soon (how many years?) to a life with less and less oil!



Folktales about the Energy Problem

Folktales *are traditional and orally transmitted stories that may or may not be based on fact (www.anthro.wayne.edu/ant2100/GlossaryCultAnt.htm)*

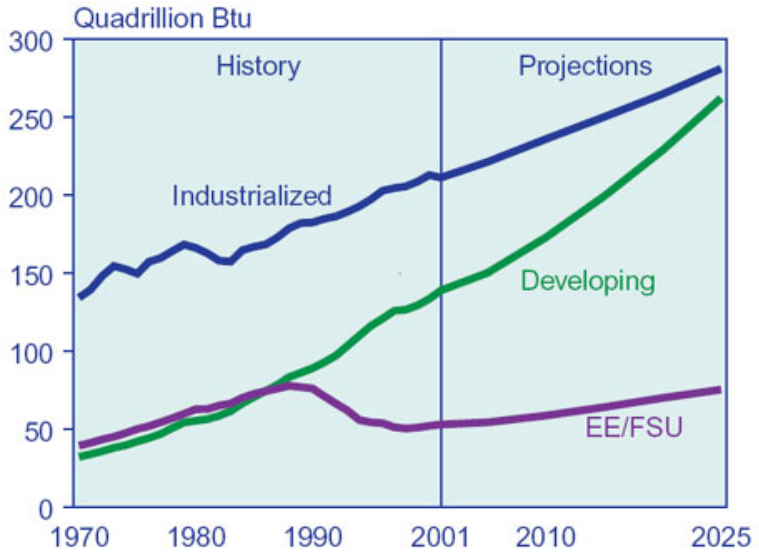
Todays high oil/gas prices are temporary problems:

1. **China's and India's unexpected rapid demand growth or its "only" a refinery problem.**
   Wrong: Third world growth was predicted (figure)!

2. **The bad/stupid guys (Oil Multis, Chinese, Russian's, American's, Arab's)?**
   It helps to blame others! But oil reserves are still finite!

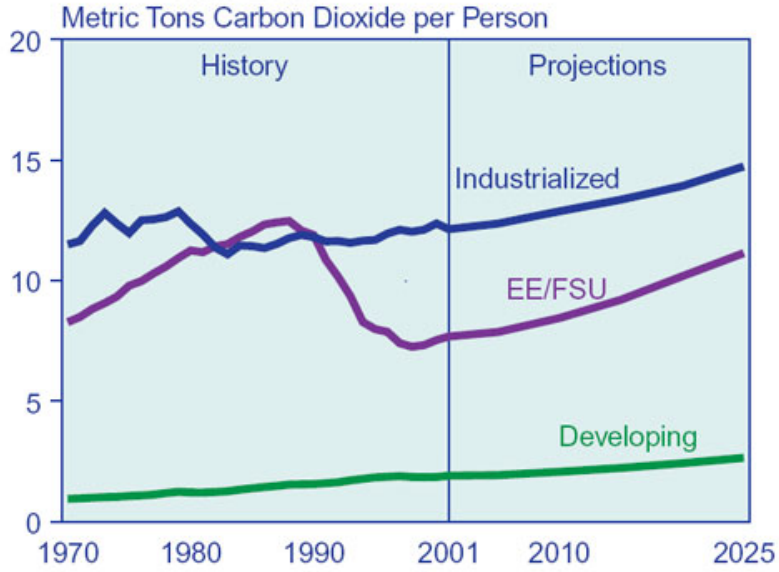
Energy growth in China and elsewhere was expected!

Figure 13. World Energy Consumption by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Figure 19. Energy-Related Carbon Dioxide Emissions per Capita by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

More Folktales about the Energy Problem

Yes, the oil/gas/coal/uranium price will get higher, but:

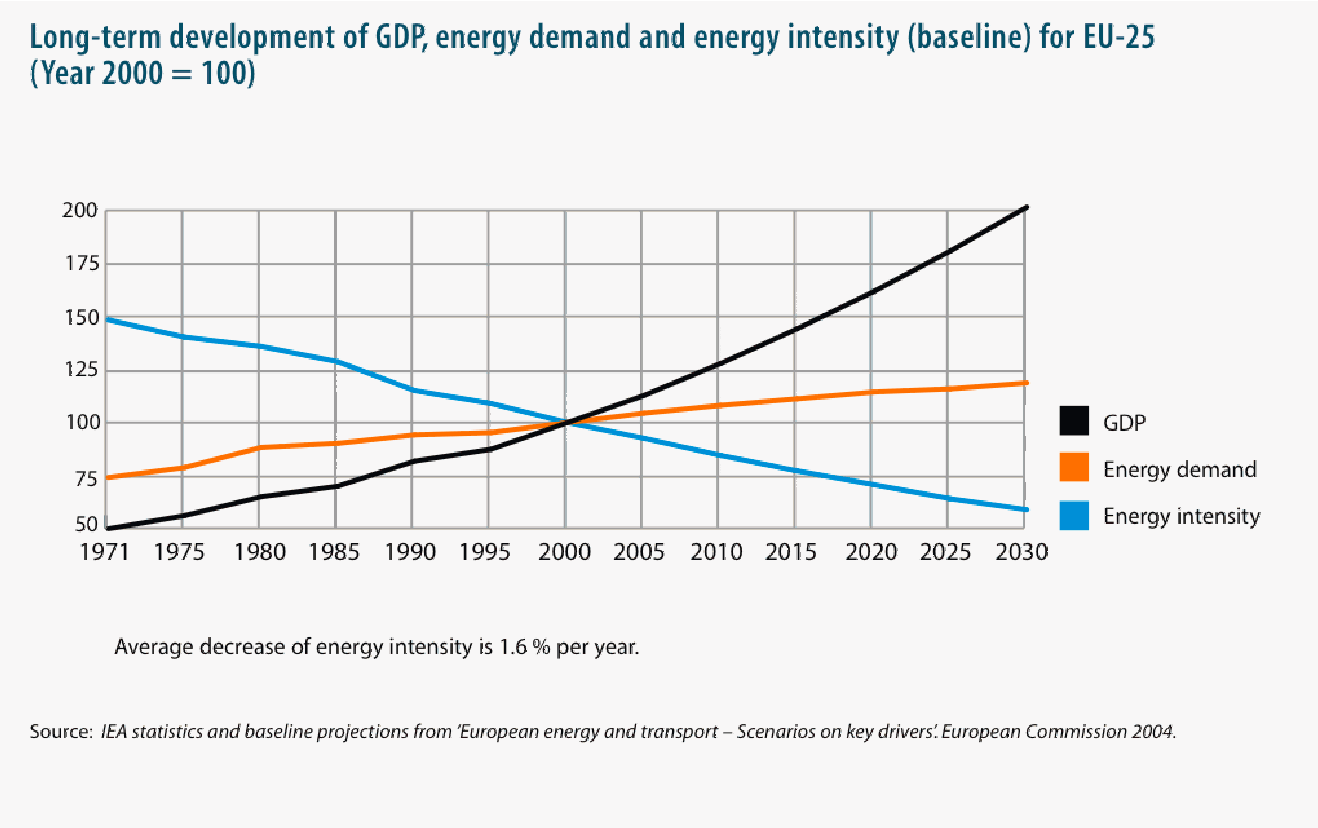
1. "Smaller oil fields can now be exploited → more oil!"
   The "law of diminishing return" will be the final limit!

2. "Renewable energy sources will become competitive!"
   Only if not subsidized by (cheap) fossil fuels!

3. "We will use oil and other energy sources more efficiently."
   Limited by second law of thermodynamics! → Figure..

EU fantasies about improving efficiencies!

"Bundesregierung (Frau Merkel) wants to improve "Energy efficiency" by at least a factor of two in every sector (from 1990 to 2020)" Berliner Zeitung (March 1, 06)



source: EU commission "Green paper on energy efficiency" (2005)

Fairy tales about the Energy Problem

Fairy tales often involve princes and princesses, and modern versions usually have a happy ending. (en.wikipedia.org/wiki/Fairy_tales)

Alice: "Would you tell me, please, which way i ought to go from here?"
Cat: "That depends a good deal on where you want to get to"
Alice: "I don't much care where"
Cat: "Then it doesn't matter which way you go"
Alice: "so long as I get somewhere"
Cat: "Oh, you are sure to do that, if you only walk long enough!"
"Alice in Wonderland"

Our (short/long term) future:

1. Reality and the wisdom/stupidity of demand predictions

2. The Emperor's New Suit (H.Ch. Anderson 1837) or
   Why nuclear fission and fusion will not solve the energy problem!

3. Star Talers (Grimm's) or when oil, gas, coal and uranium are gone
   10 billion humans will be rich, peaceful and happy or
   Dreams about filling our "European(?)" Sahara with solar power plants!

4. Our future: "Welcome on the Titanic" or "Hans in Luck" (Grimm's)

Predictions ($\approx$ 1975) about (nuclear) energy

Energy type	Predictions for the year 2000 [Quad] Model 1	Model 2	Model 3	Reality 2001 [Quad]
Total	609	528	540	403
nuclear energy	86	80	108	26.5
coal	143	125	116	95.9
oil	225	185	184	156
gas	96	87	83	93
renewable	60	51	50	32

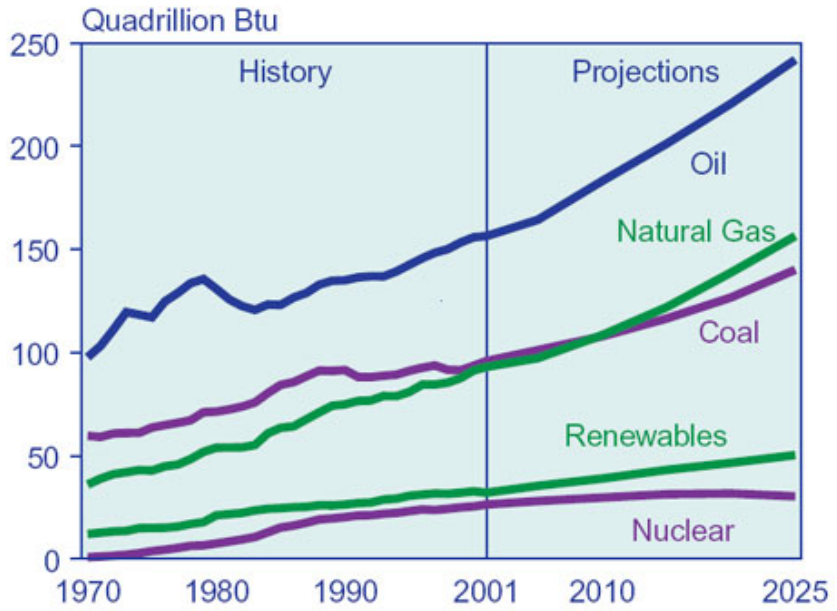
Predictions: Workshop on alternative Energy Strategies for the year 2000, MIT Press 1977 (Global 2000 Report) and EIA Report (2004).
(1 Quad = 10^{15} Btu = 1.055 $\times 10^{18}$ Joule = 2.93 $\times 10^{11}$KWh)

Demand based predictions for the energy use in the year 2000 were completely wrong!

What does this tell us about todays demand predictions?

Today's (demand based) "energy" predictions.

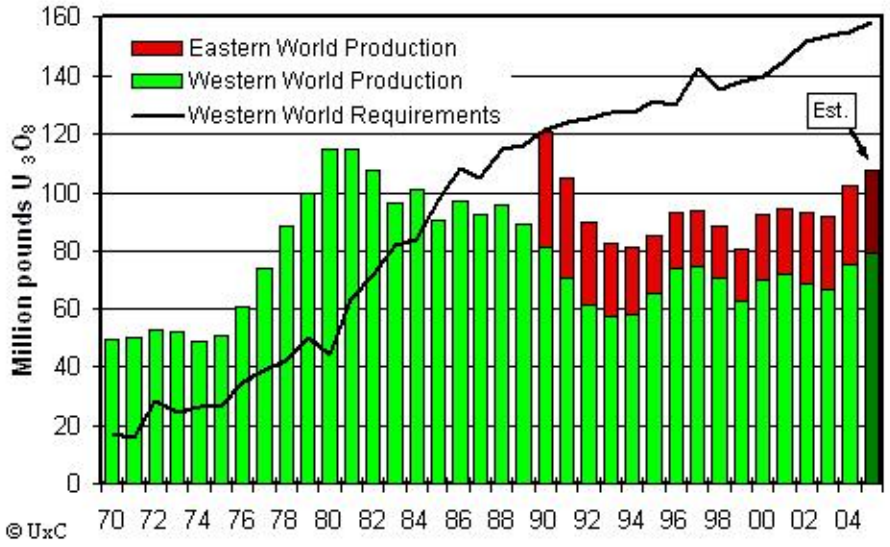
Figure 14. World Primary Energy Consumption by Energy Source, 1970-2025

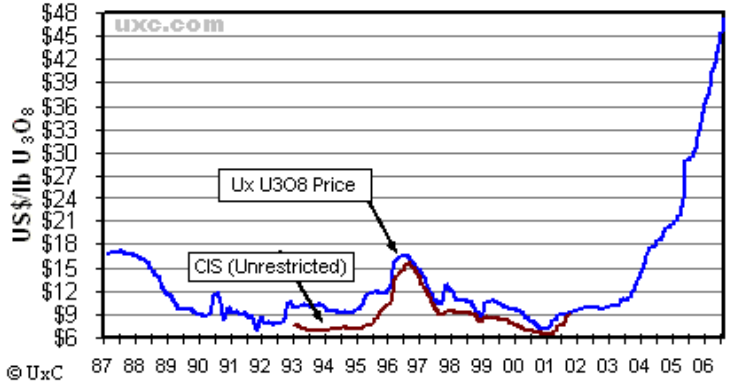


Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Uranium demand development and origin

Ux Consulting Company, LLC (UxC) writes (2005) (www.uxc.com/products/rpt_usa.html): "Are you prepared? The decline in global commercial uranium inventories is rapidly shifting an inventory-driven market to one that is production-driven. Consolidation over the last several years has squeezed the number of uranium suppliers, reduced geographical diversity, and now several existing and future uranium production centers are in question. **In the interim, long-term indicators are pointing toward a demand curve that will exceed supply within the next several years and ultimately lead to higher prices."**





EU Fusion optimist's or: "It will always take 50 years to realize stable fusion"!

European Strategy Group (June 2000): (http://www.efda.org/)

- ITER- the "Next Step" (start construction 200x–2030)
  - Fusion Power: 500 MW_{therm}
  - Long-Duration burning plasma
  - Test blankets concept
- DEMO- the demonstration Step (start construction 2020?–2040?)
  - Fusion Power: 2000 MW_{therm}
  - Net electricity production
  - Tritium self sufficiency
  - High reliability of operation
- PROTO- the prototype power station (start construction 2040?–2060?)
  - Electric Power: 1500 MW_{el}
  - Improved commercial electricity production

"The Emperor's New Suit" or Illusions of large scale Deuterium-Tritium Fusion!

Idea: Deuterium + Tritium $\rightarrow$ Helium + n + 17.6 MeV
and using "every" neutron n+ Lithium $\rightarrow$ Helium +Tritium + 4.8 MeV

3 GW_{therm} reactor needs to "burn" 50 Kg Tritium / year
(JET experiment used 20 gr Tritium and achieved 4 MW for 4 sec.!)

- Tritium breeding exists only in computer models (with marginal TBR of 1.15)!
  Minimal and idealized experiments show: TBR(calc)/TBR(exp.) $\approx$ 1.14.
  Details by M. E. Sawan and M.A. Abdou, (in Fusion Engineering and Design, Dec 27, 2005)
  "The large overestimate from the calculation is alarming and implies that an intensive R&D program is needed .."

- No material is known which can stand the extremely high neutron flux.

- 5 Billion Euro and at least 15 years to construct ITER
  (a small prototype with 400 $MWatt_{therm}$ and a plasma Volume of 800 m^3):
  goal a 2000 sec steady state fusion reaction.
  Original ITER design was 1500 $MWatt_{therm}$ with a plasma Volume of 2000 m^3

- More criticism: "Fusion Power: Will it ever come?" by W. E. Parkins former chief scientist at Rockwell international, (Science Vol 311, page 1380, 10 March 2006).

Hans in Luck: an alternative to the Titanic!

Ideas from Prof. H. Odum and E. Odum in "A prosperous way down" 2001:

- Eliminate wasteful use of energy (wasting energy is not the same as abstinence!)
  → (1) reduce unneeded "horsepower",
  → (2) reduce cars with simultaneous changes in the necessity to move long distances.

- Transform agriculture to local and less energy intense forms.

- A sustainable use of land and water requires the "return" of forest, swamps etc.

- Global information exchange and cooperation need to replace restrictions and destructive competition.

- The society has to find a way (using perhaps the universities) for a selective conservation of important "knowledge" (for the time with less energy) and for a long time.

- The functioning of the "Global information Network" must have the highest priority in the use of electric hydropower.

- Education for the future: Children need to be prepared for the "low energy" future. We have to explain and describe this development to them.
  To prevent chaos, we all have to understand what and why this is happening and how everybody can find a place in this new environment!

Some quotes to end:

- **Science promised us truth, or at least a knowledge of such relations as our intelligence can seize: it never promised us peace or happiness.** *Gustave Le Bon*

- **"Our ignorance is not so vast as our failure to use what we know."** *K. M. Hubbert*

- **The problems that exist in the world today cannot be solved by the level of thinking that created them.** *A. Einstein*

- **Concern for man and his fate must always form the chief interest of all technical endeavors. Never forget this in the midst of your diagrams and equations.** *A. Einstein*

My preparation for your comments, questions and the coming oil/energy crisis

Special thanks to W. Tamblyn and his "Energy Round Table" (yahoo discussion) group

books about energy and the energy problem/crisis

- "Die Energiefrage", K. Heinloth 2003,
- "Energy, Resources and Policy", R. Dorf 1978
- "Geodestinies: The inevitable control of Earth resources over nations and individuals", Walter Lewellyn Youngquist 1997
- "Twighlight in the Desert" M. Simmons 2005
- "The Party is over" and "Powerdown" R. Heinberg;
- "A prosperous way down" by Howard T. Odum, Elisabeth C. Odum
- "Overshoot" by W. Catton.
- more at: www.hubbertpeak.com/library

Webpages about the energy crisis:

- http://www.energiekrise.de/
- http://www.energyskeptic.com/Energy_In_A_Nutshell.htm
- http://www.hubbertpeak.com/index.asp
- http://quasar.physik.unibas.ch/ fisker/401/oil/oilsearch.html
- Discussion groups:
  http://groups.yahoo.com/group/EnergyRoundTable/ and
  http://groups.yahoo.com/group/energyresources/messages/

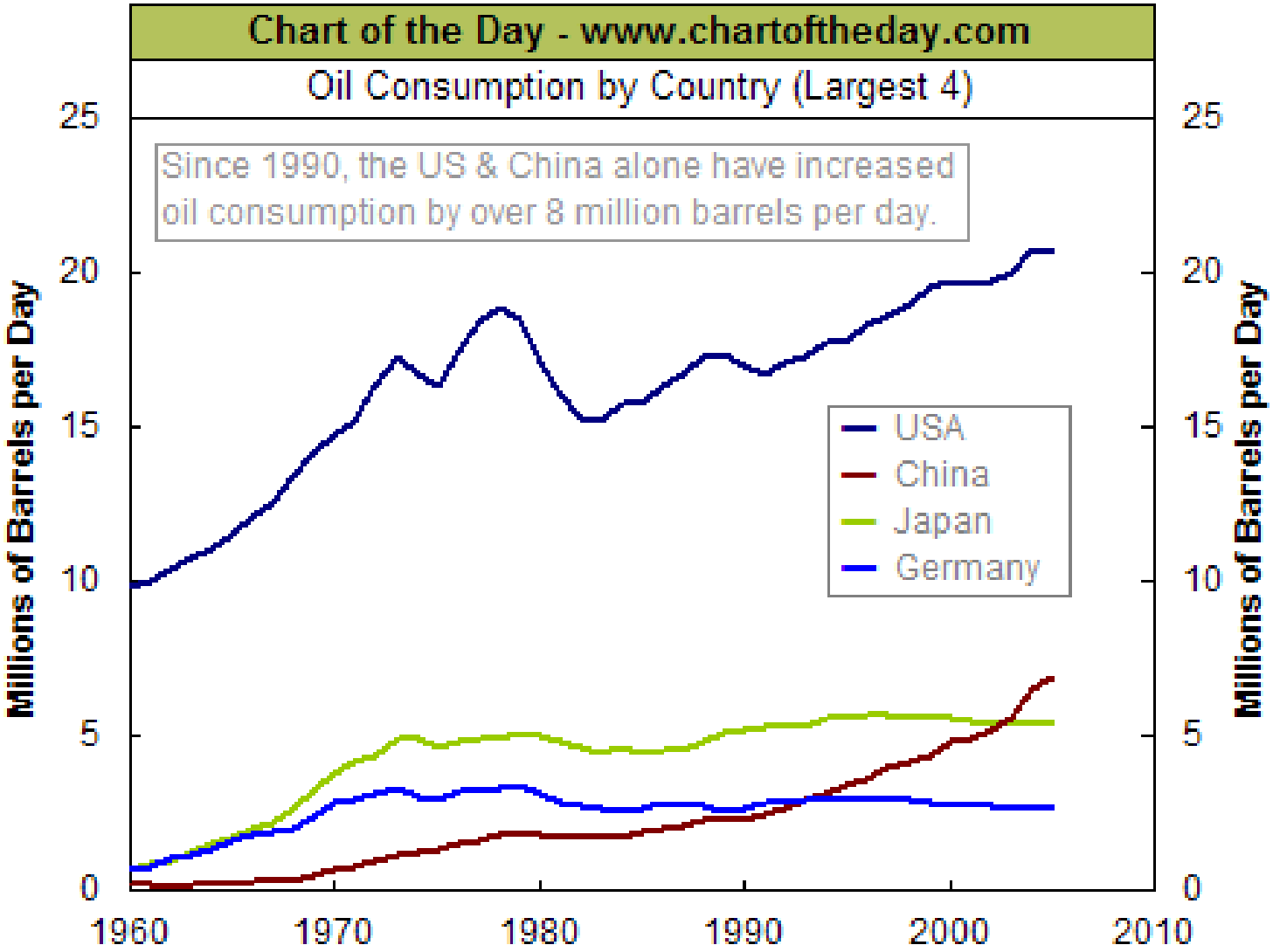
Some more backup slides

Various diagrams on oil extraction realities,

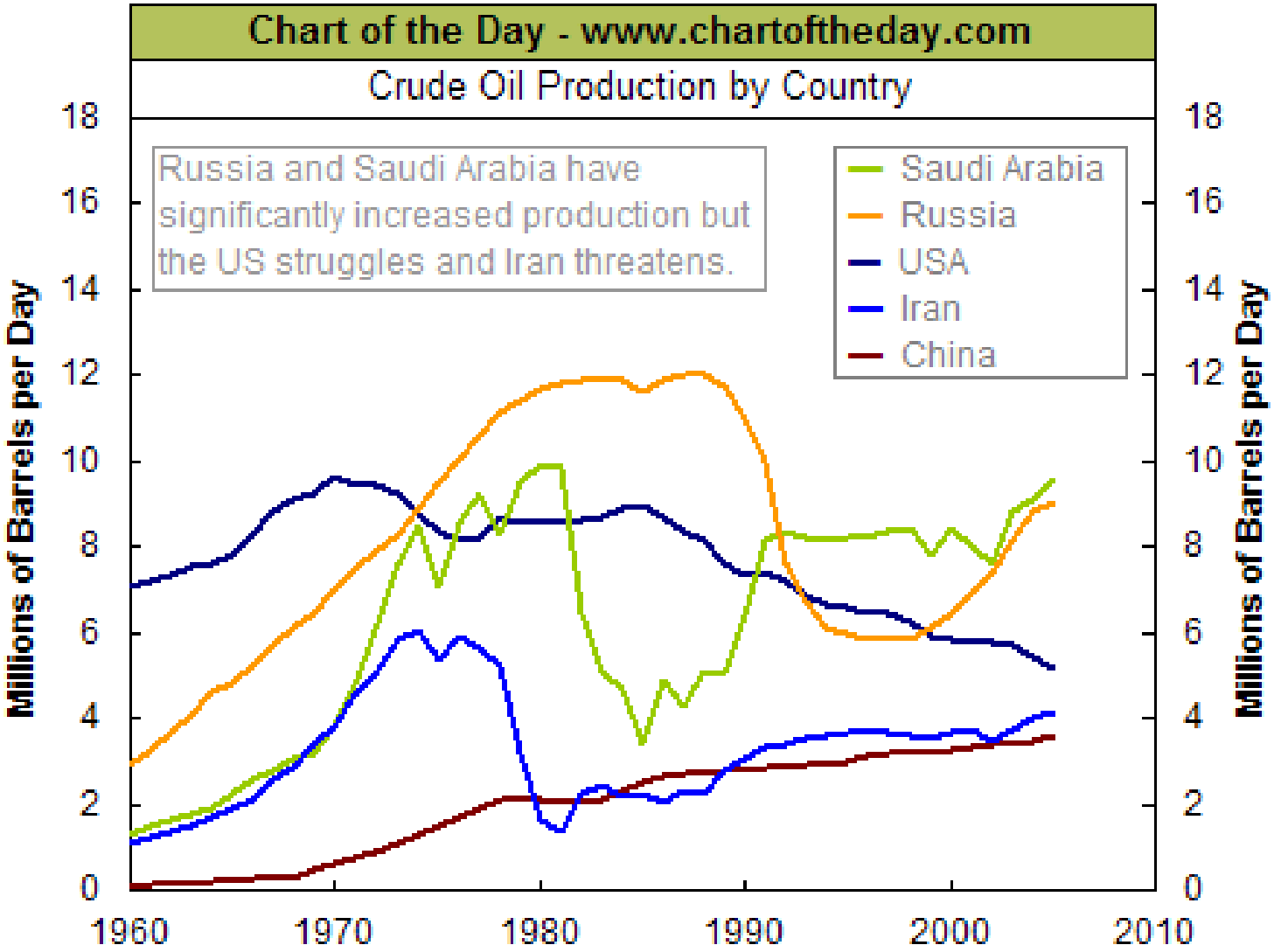
economic dreams about growth forever and

some on nuclear energy.

Oil consumption growth by different countries

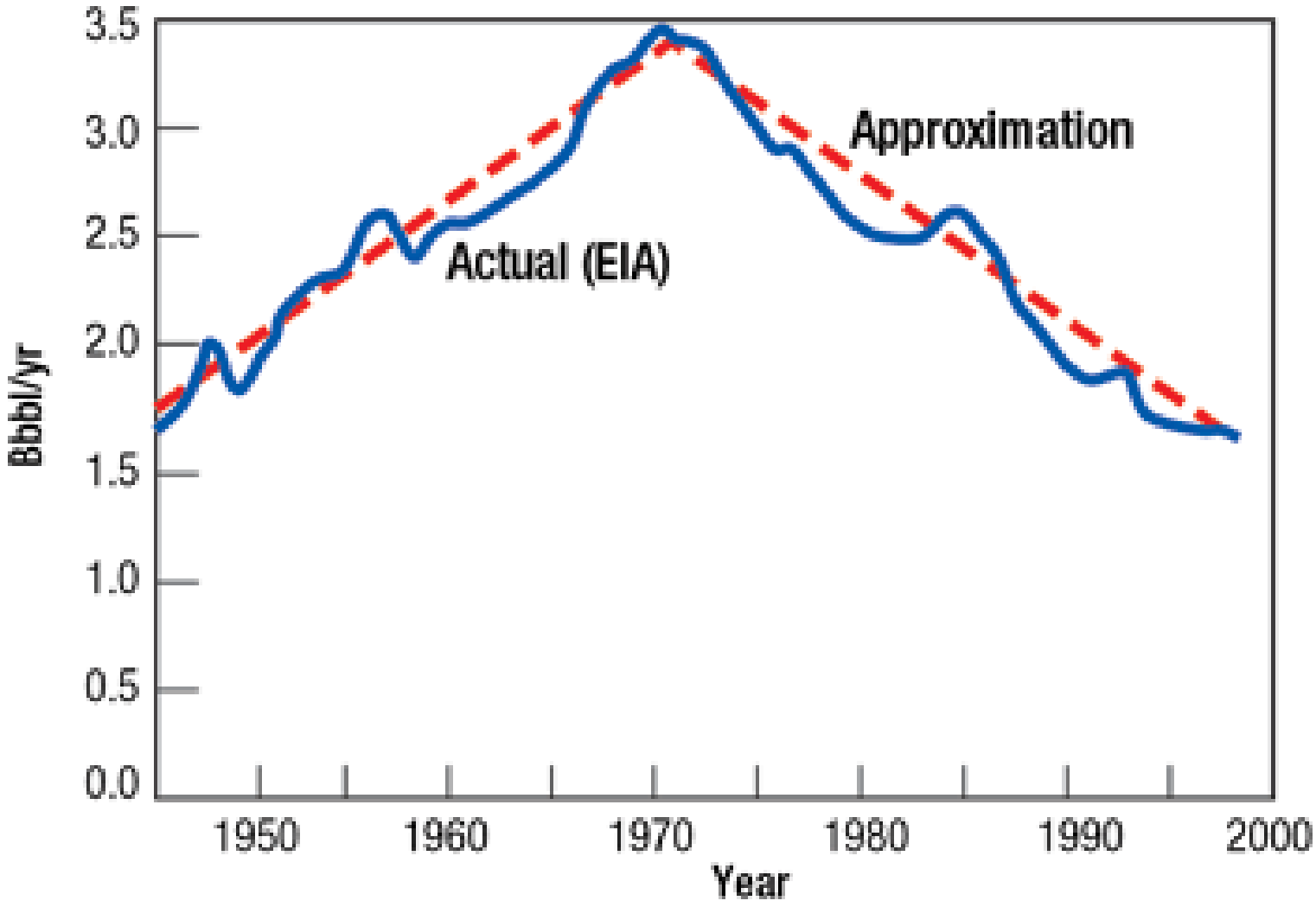


Oil extraction in different countries



from "Shaping the peak of world Oil production"

source: R. Hirsch, World oil magazine, October 2005



from "Shaping the peak of world Oil production"

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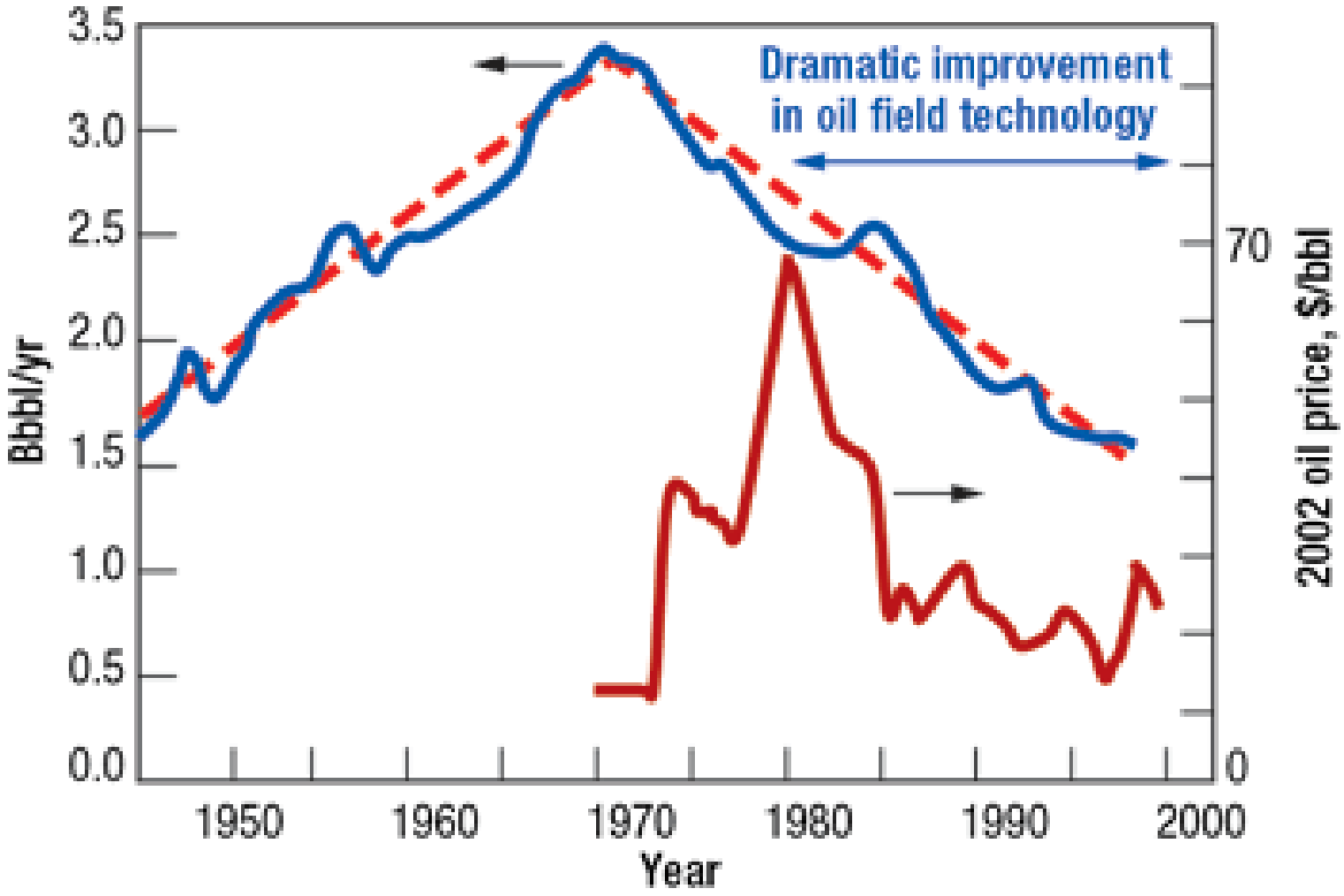


Myth III: Oil will always last ...
and reality of oil production in the north sea:

- BRITISH oil production fell 11% in April (2005),
  continuing the past year's trend of declining production, according to the latest Royal Bank of Scotland Oil and Gas index.
  Quelle: The Scotsman 6 Jul 2005

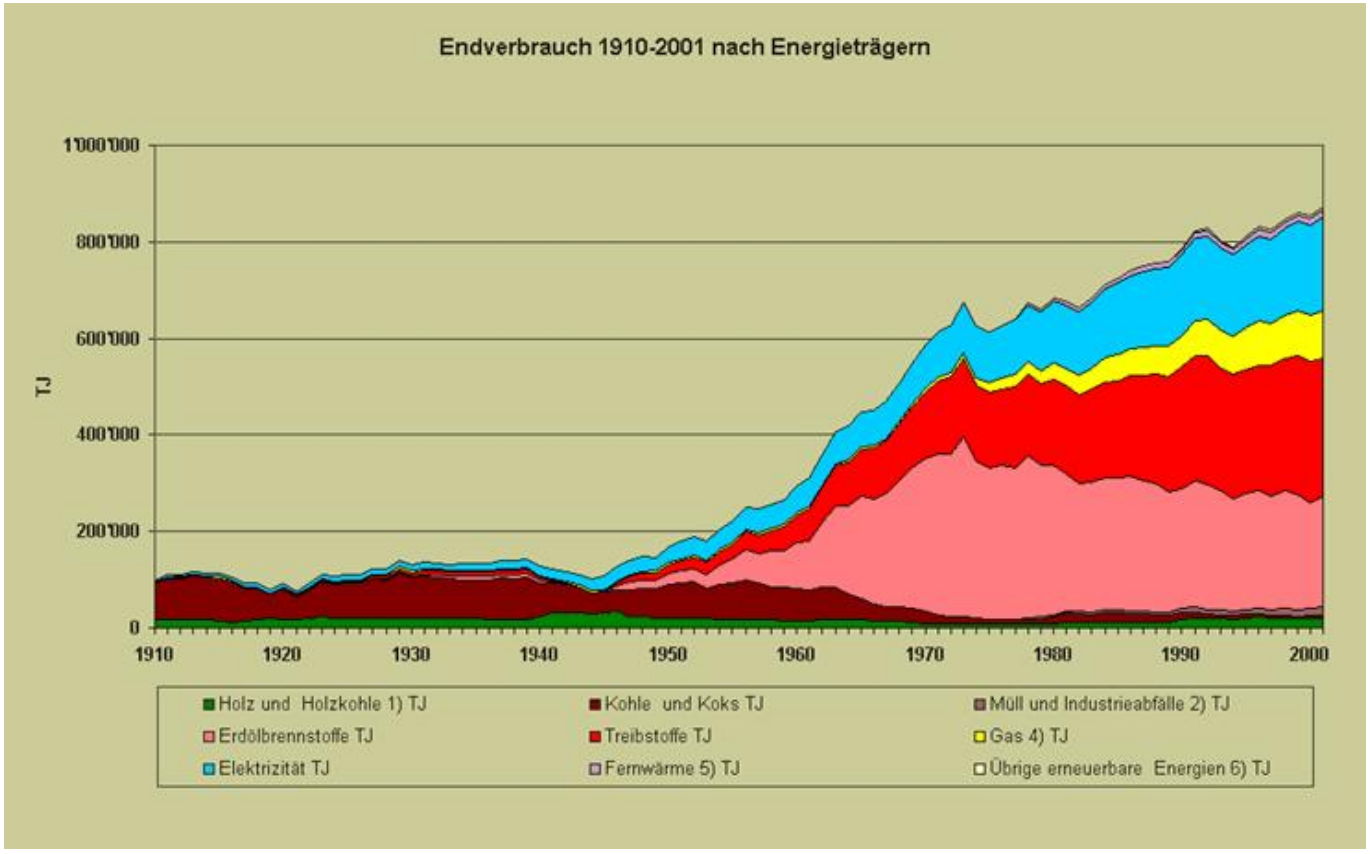
- Norway's monthly oil production fell to an 11-year low
  OSLO - Norway's monthly oil production fell to an 11-year low of 2.29 million barrels per day (bpd) in June, hit by halts of many offshore fields for maintenance, the Norwegian Petroleum Directorate (NPD) said on Tuesday. Production was down from 2.65 million bpd in May and 2.88 million in June 2004.
  Reuters July 19, 2005

- Norway's oil output at 11-year low
  While primary oil demand in European Union (EU) countries is projected to increase by 0.4% per year from now to 2030, North Sea output peaked in 1999 and has been on the decline ever since.
  Institute for the Analysis of Global Security 24.5.2004,
  www.iags.org/n0524043.htm

How we use energy III

drying clothes: either old fashioned(?) with sun and wind

or modern(?) with electric energy (2 kW $\times$ 1 hour = 2 kWh!)?



100 years of energy use in Switzerland (similar in Germany)
source: www.energie-schweiz.ch

Some facts about todays homo sapiens and his energy use

country	energy/person/year [kWh(therm)]	electricity kWh/year/person	oil/year/person [liter]
Switzerland	50000	7167 (19.6 kWh/day)	2259 (6.1 l/day)
Germany	50000	6153 (16.9 kWh/day)	1979 (5.4 l/day)
France	50000	6875 (18.8 kWh/day)	1947 (5.3 l/day)
India	3700	467 (1.3 kWh/day)	116 (0.3 l/day)
China	9400	1009 (2.8 kWh/day)	204 (0.6 l/day)
USA	94000	12295 (33.7 kWh/day)	3892 (10.7l/day)
World	17700	2187 (6.0 kWh/day)	744 (2.0l/day)
"stone age"	2000	0	(biomass)

source: CIA world fact book/BP yearly report 2003

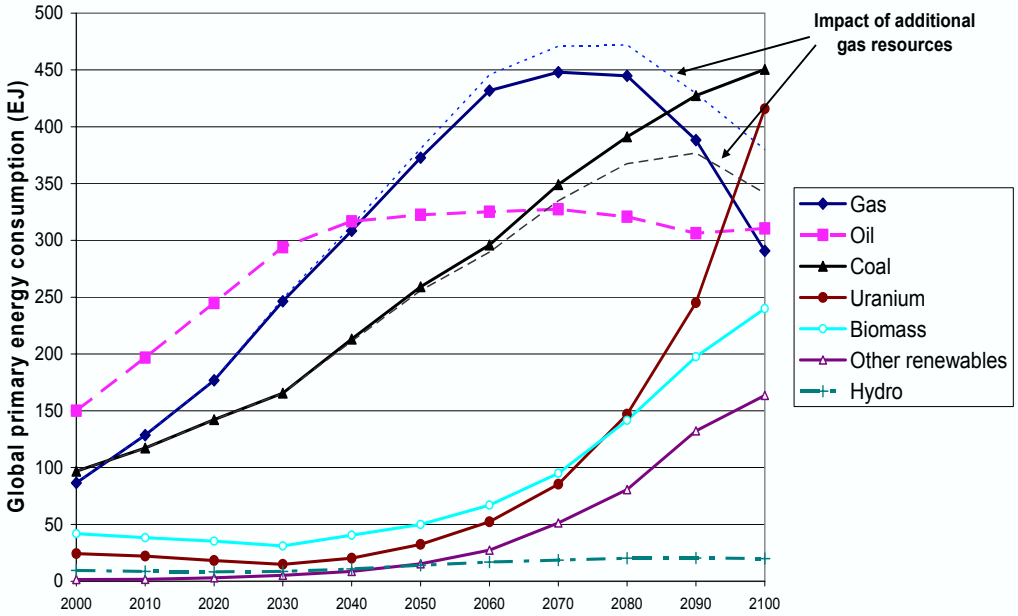
the most extreme (no limit) growth scenario

source: L. Barreto (PSI Energy economics group) talk at 7th European Energy conf, Bergen Norway Aug. 2005

PAUL SCHERRER INSTITUT PSI

climate

Primary Energy Consumption: Baseline



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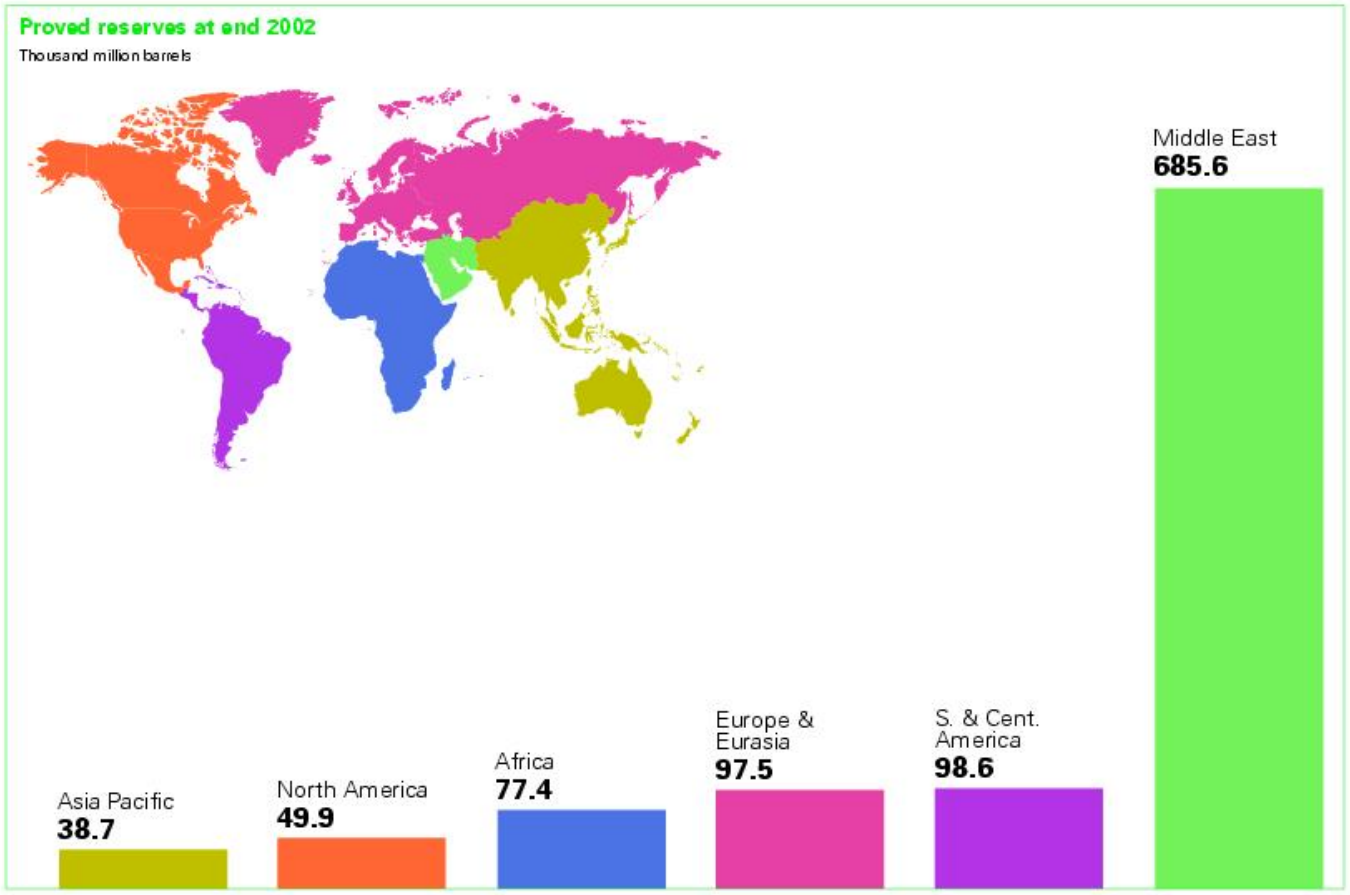
The worlds oil reserves (BP World Energy Review)



Peak oil and the IEA view

World Energy Outlook (IEA 1998) on peak oil: peak outside OPEC $\approx$ 2002!

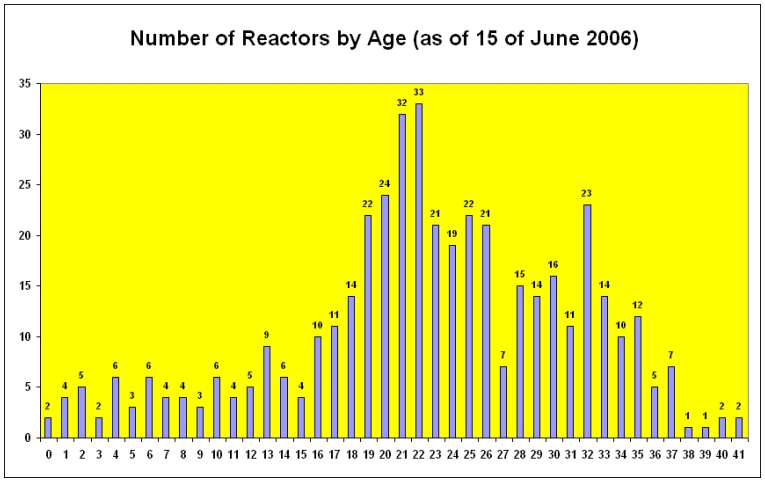
OPEC around 2015 (are OPEC's numbers correct?) and entire world few years earlier!

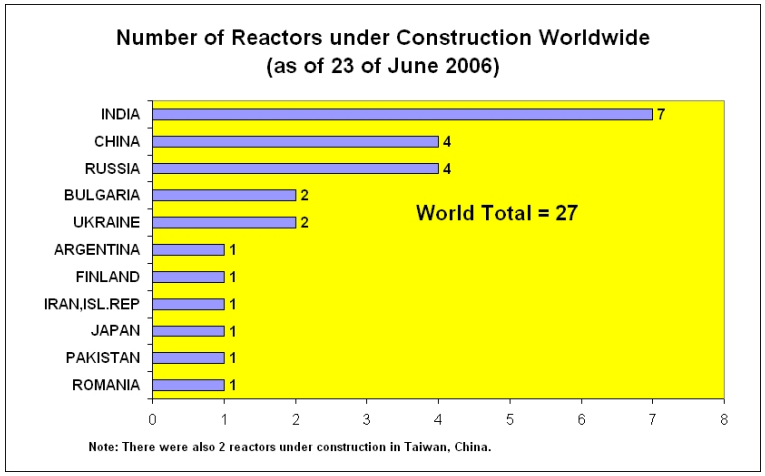
The age structure of nuclear power plants

Very few nuclear power plants are under construction.

The "construction boom" was in the seventies!

It requires at least 5-10 years to build a new nuclear power plant!

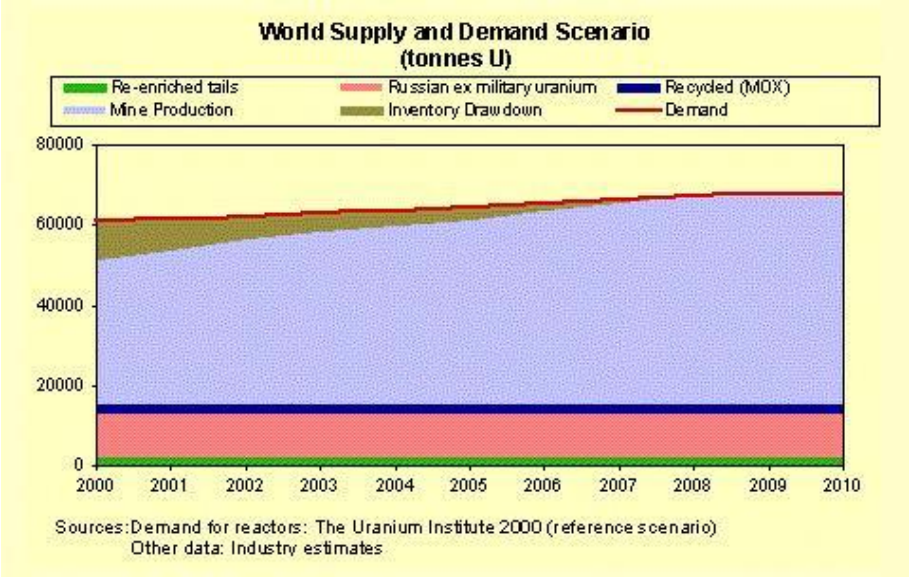




source: www.iaea.org

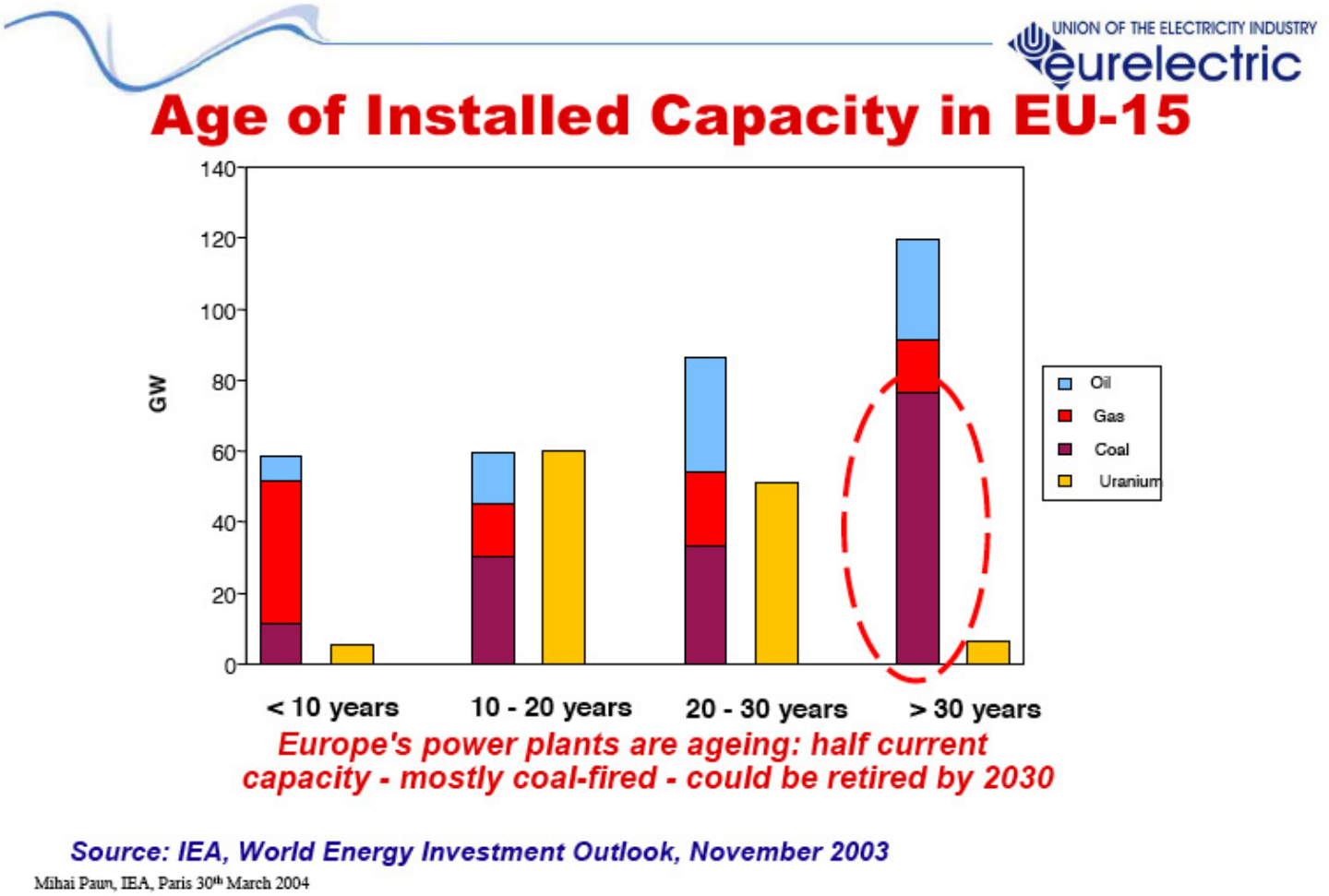
1/3 of todays uranium needs come from the surplus production in the years 1960-1980!

It is perhaps too extreme to say that the situation will become so dire that reactors will be shut down due to lack of fuel or because uranium prices have been pushed too high that it will become uneconomical to run a reactor. In any case, turn our the lights because the party is over! source Uranium consulting company Nov. 3 2003



source: plot from World Nuclear Association

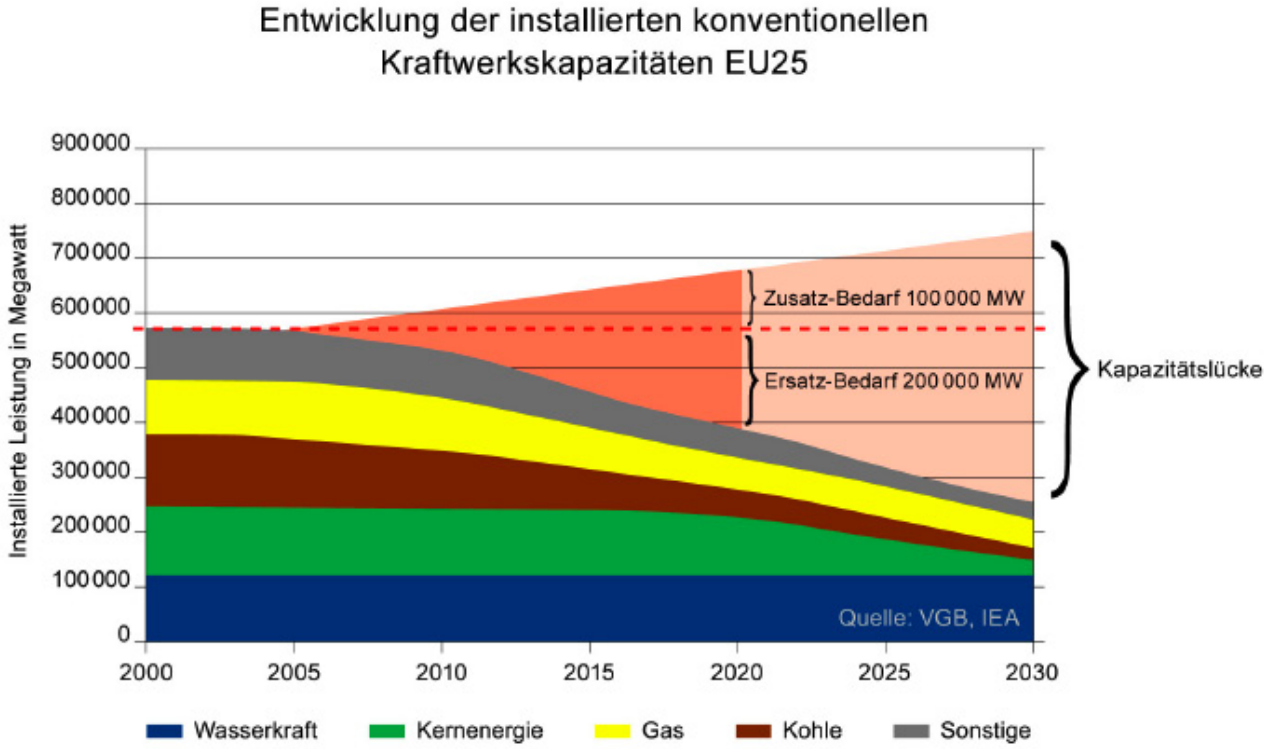
The age structure of european power plants



source: www.iaea.org

Future of the European Electricity grid?

Grosser Ersatzbedarf in Europa



source: www.iaea.org