Our Global Energy Problem: through the eyes of a physicist

M.Dittmar (ETH-Zürich)

- Introduction: Physics and Society?
- The Global Energy Problem: not just electric energy!
- Electric energy: the "devil" is in the details!
- From European to global energy realities?
- Summary: Which way into a sustainable future?

Introduction: Physics and Society through the eyes of a physicist(0)

- Born 1956 in Hamburg, (West-)Germanny in a "middle class family".

- School/High school in Hamburg (1963-1975):
  Heard confusing stories about History, Germany and the Planet:
  Rising and disappearing empires, slavery, colonialism, lots of wars; that Germany started WW I and WW II and atom bombs destroying Hiroshima and Nagasaki.
  That economic growth will bring peace and end poverty and that other problems of the planet will always be solved by technology using the never ending scientific progress.

- Learned from great teachers about "science results" which changed world views:
  Galileo's discovery of the Jupiter moons, Darwin's (and Wallace) evolution theory; that a Perpetuum Mobiles of the first and second kind are impossible and also about Quantum Mechanics, Einstein's Relativity theory and the origin of the universe.

- Also learned about the exponential function and that infinite economic grow on a finite planet is impossible and about 20 000 nuclear war heads waiting for their destiny.

→ Disappointed with "social science and German politics" I studied physics dreaming about making a little contribution to:

"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 http://en.wikipedia.org/wiki/Gustave_Le_Bon

Introduction: Physics and Society through the eyes of a physicist(I)

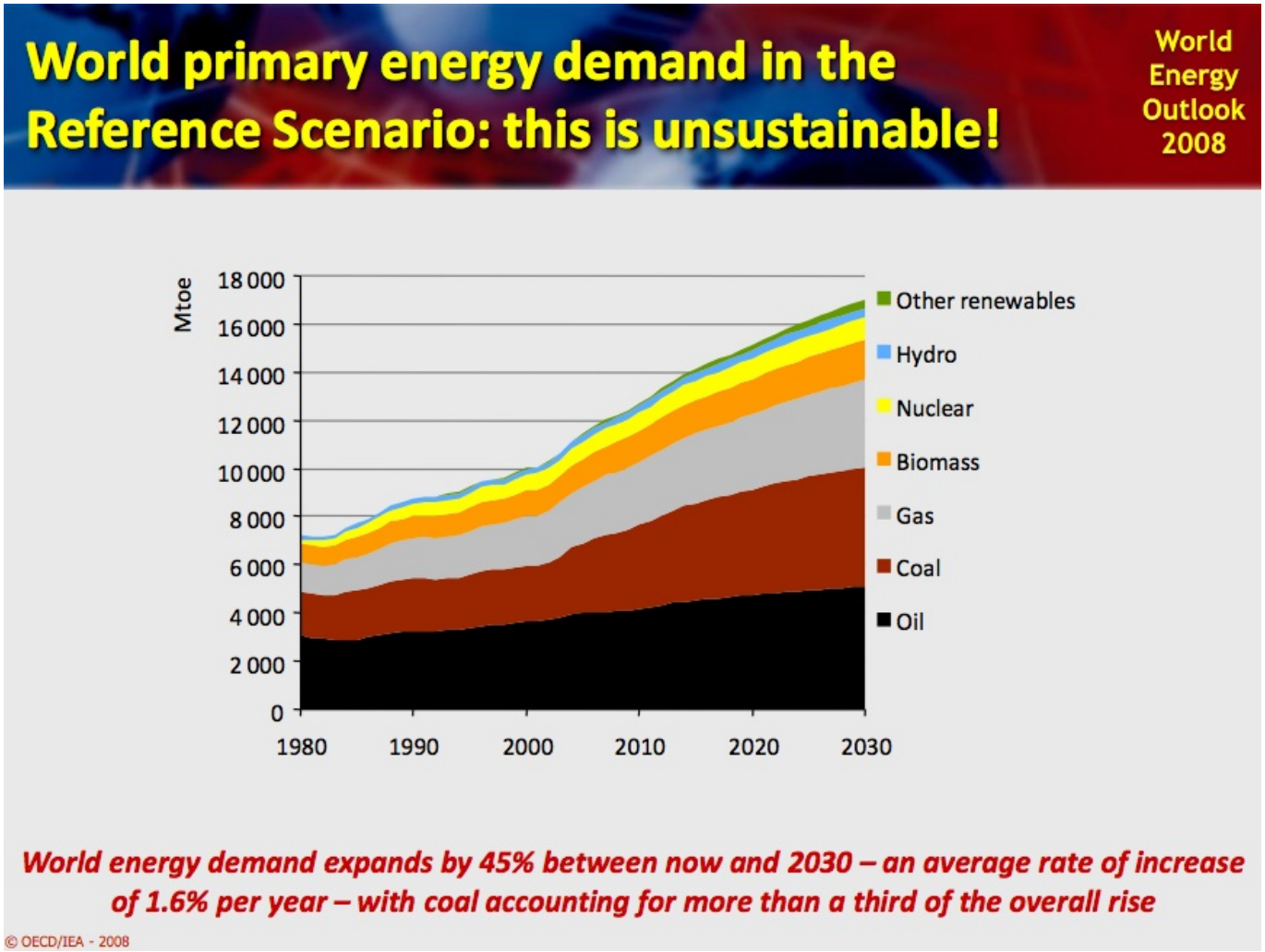
Natural laws define boundary conditions for "our future": Such laws can not be changed, but physics and other sciences help us to understand them.

Social laws to organise our "way of living together": Such laws can be changed, ignored and even be violated!

"Physicists learned to realise 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, 1985

Introduction: Physics and Society through the eyes of a physicist(II)

"Our future energy scenario is unsustainable" (IEA 2008)
unsustainable = it can not function, still "we" believe it!



Ok, the global energy system is unsustainable, but why should we care about the future?

"My interest is in the future because I am going to spend the rest of my life there." http://en.wikiquote.org/wiki/Charles_Kettering

or with little variations for this lecture:

- *"We are especially interested in where we have our "roots", because most of us are going to spend the rest of our life there."*
- *"We are interested in a healthy and beautiful local and global environment, because our life depends on it."*
- *"We should be interested in finding a path towards a sustainable way of living, because of our moral and ethical responsibilities with respect to the biosphere and the well being of future generations."*

or because *"The good life is inspired by love and guided by knowledge"* **Bertrand Russell**

The Energy Problem: through the eyes of a physicist(1)

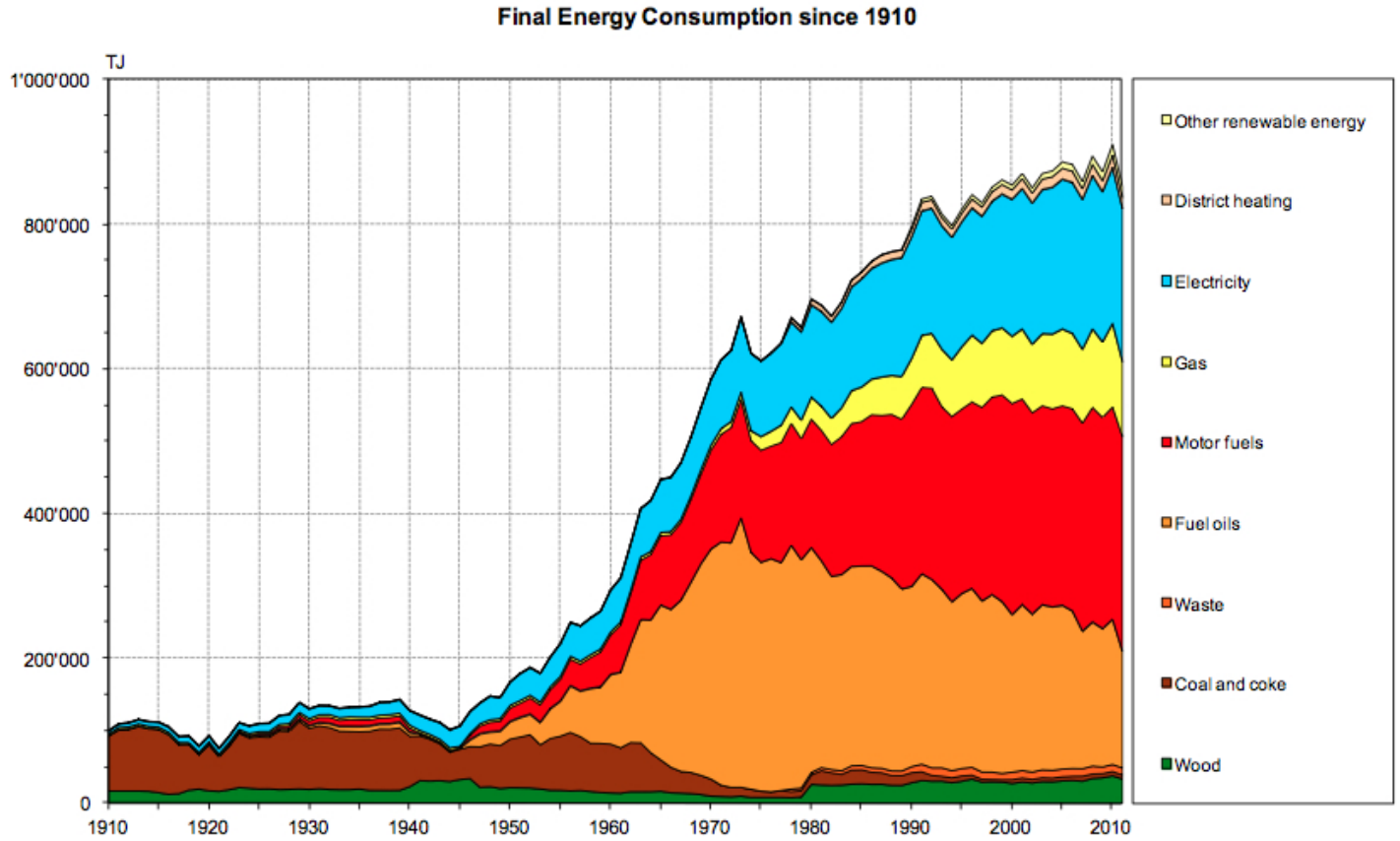
Industrialised globalised "way of life" needs energy to:

- produce, transform and transport our food;
- make heat and stuff (industrial processes);
- move us and stuff around and
- transform other energy forms into electric energy (with thousands of useful and useless applications)

Almost nothing works today without electric energy and almost nothing moves without oil!

Energy use: Switzerland as a typical example

1910-1950: "constant energy use", dominant energy source = coal!
(during the war years: strong reduction of energy (coal) imports → "deforestation")
1950-1973: period of strong growth 5-10%/year(!), oil becomes dominant energy source.
1973-1993: growth still 2-3% /year! "Termination" of coal. Oil allows cheap mass transport.
1993-2008: Growth now 1-2% /year! Globalized transport of people and consumer goodies thanks to oil.
2009-2015: "Stagnation" and steeply increasing prices for oil and other energy resources!
2016-2050: What do we know about realistic resource based options?



source and more http://www.bfe.admin.ch

Global energy demand: 1965-2035?

BP (British Petroleum, January 2014) expects:

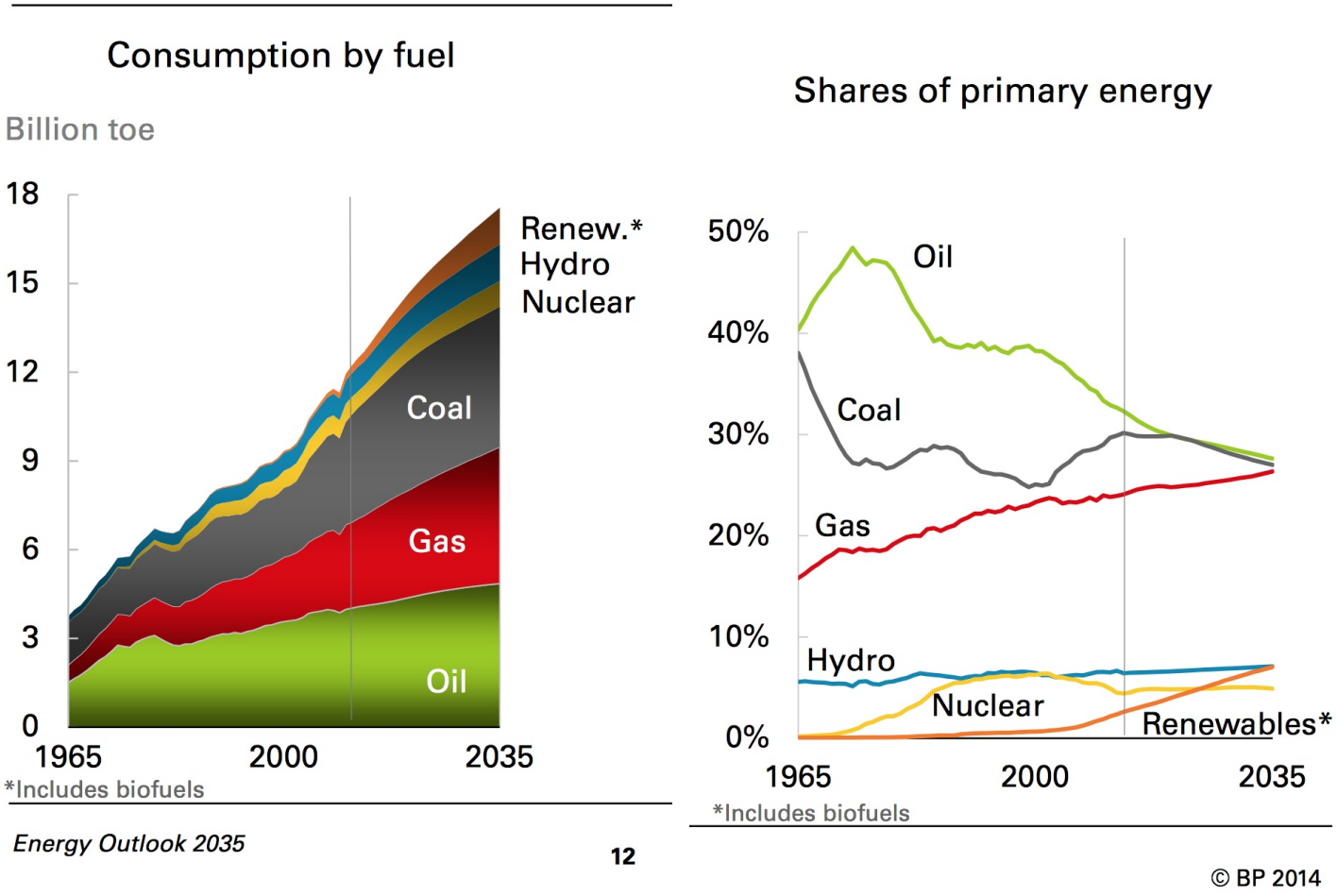
(Finite resources are not imaginable for most economists: "The show must go on")

Large increase in new renewables (sun and wind) factor 3-4, nuclear constant

but absolute global growth comes from oil, gas and coal (thus even more CO2!)

http://www.bp.com/en/global/corporate/press/press-releases/energy-outlook-2035.html

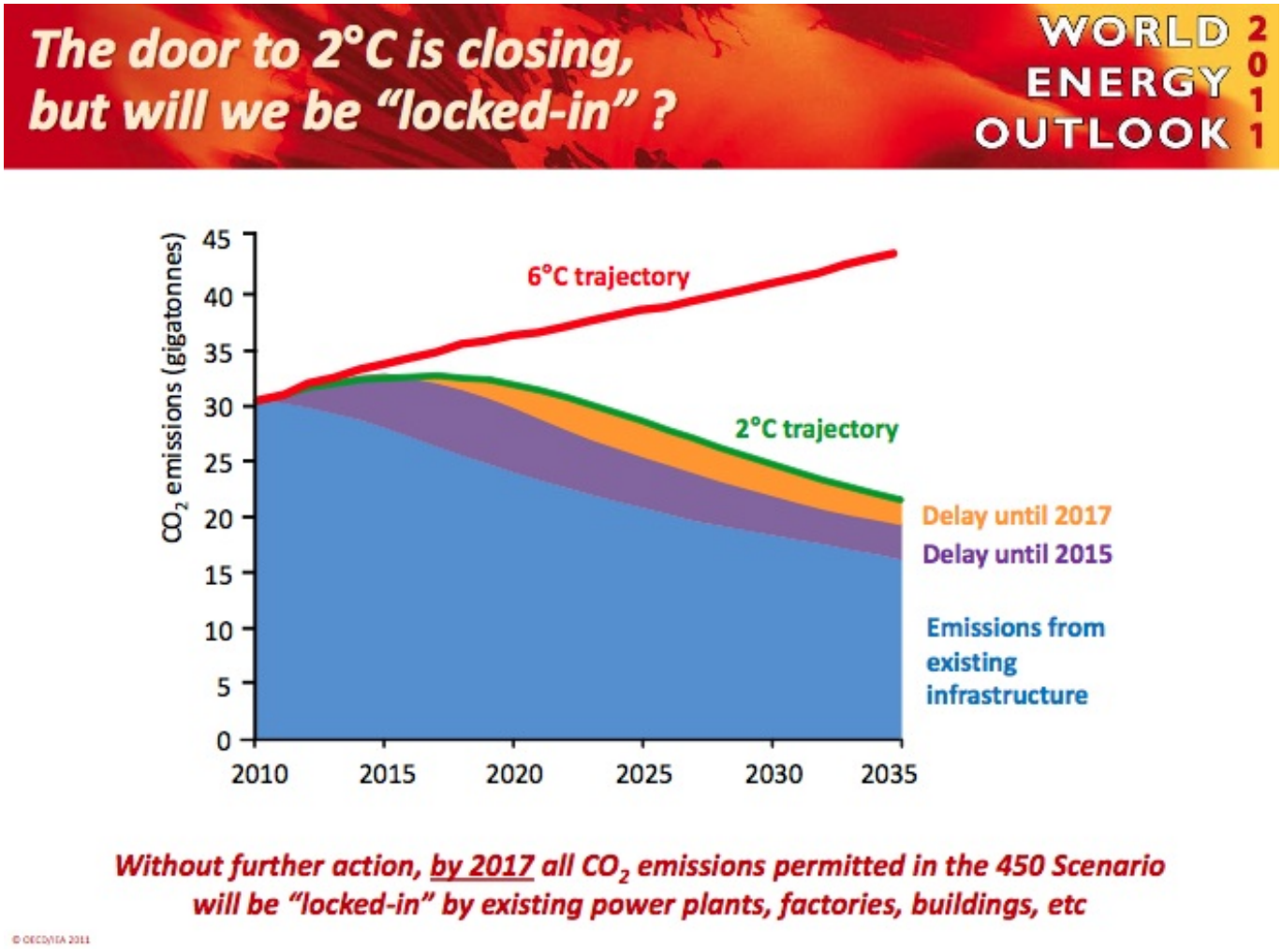
Will try to show that such growth scenarios are impossible (and not wanted!)



The Energy Problem: through the eyes of a physicist(2)

The "hidden agenda(?)" of world leaders (G7/BP/IEA(etc)): +6 degree C warming: The path to man made global hell!

CO_2 emissions in 2013 $\approx$ 36 Gtons even higher than the IEA (May 2011 scenario)
http://www.reuters.com/article/2013/11/19/us-global-carbon-emissions-idUSBRE9AI00A20131119



The Energy Problem: through the eyes of a physicist(3)

(my) personal energy use (2014)

- Modern food energy $\approx$ 2500 Cal/day = 10×1000 kWh/year/person
  factor 10 = oil and gas needed for production, transport and preparation.
  reduction achieved: -2500 kWh (1/4 food from our garden).

- Home heating (electric and wood) $\approx$ 2000 kWh(electric) + 1500 kWh(thermal)
  (some 20% reduction achieved but stable since years now)

- non heating Electric energy (at home) $\approx$ 2000 kWh(electric).
  we (4 persons) use 15 kWh/day (summer) and 30 kWh/day (Winter)

- Oil (car mobility) $\approx$ 1000 liter/year $\approx$ 12 000 kWh(thermal).
  plus (2014 flying to Cuba/Berlin) $\approx$ 18 000 km and roughly 900 liter.

- Electric energy (train mobility) $\approx$ 10 000 kWh(electric).

- Production and transport of consumer goods and services: unknown(?)

- Working at CERN (together with roughly 5000 other people)
  $\approx$ 1000 GWh(electric) $\rightarrow$ 200 000 kWh(electric)/person
  (hm.. so much! Should one divide by 7×10^9 people?)

How humans use energy (a comparison)

M.D./year: 40 000 kWh$_{therm}$/year (add work: +200 000 kWh$_{el}$)
average person (EU+CH): 30-50 000 kWh/year (including work/consumption)
M.D. (direct use): "15 000" kWh$_{el}$ and "1000" liter oil per year
average person (7.3 billions today): 2900 kWh(el) and 720 liter oil per year.

Country	electricity use kWh/year/person	oil* consumption liter/year/person	oil* production liter/year/person
World	2 900	720	720
Europe/USA			
Switzerland	7800	1740	0
Germany	6700	1720	0
France	6850	1500	0
USA	12100	3420	2040
BRICS			
Brazil	2350	880	740
Russia	7300	1300	4300
China	4000	460	180
India	600	150	35
Latin America			
Venezuela	3300	1570	5000
Bolivia	648	650	340
Cuba	1470	790	270
Africa			
Algeria	1100	550	2550
Angola	240	390	5500
Nigeria	140	100	755

sources: CIA world fact book and BP yearly report 2014 oil* = oil equivalent liquids

The Energy Problem: through the eyes of a physicist(4)

Population and Energy: Brazil and South/Central America

Brazil 2015: 204 Million humans, growing by about 0.9%/year

South and Central America: $\approx$ 500 Million, growing about 1%/year

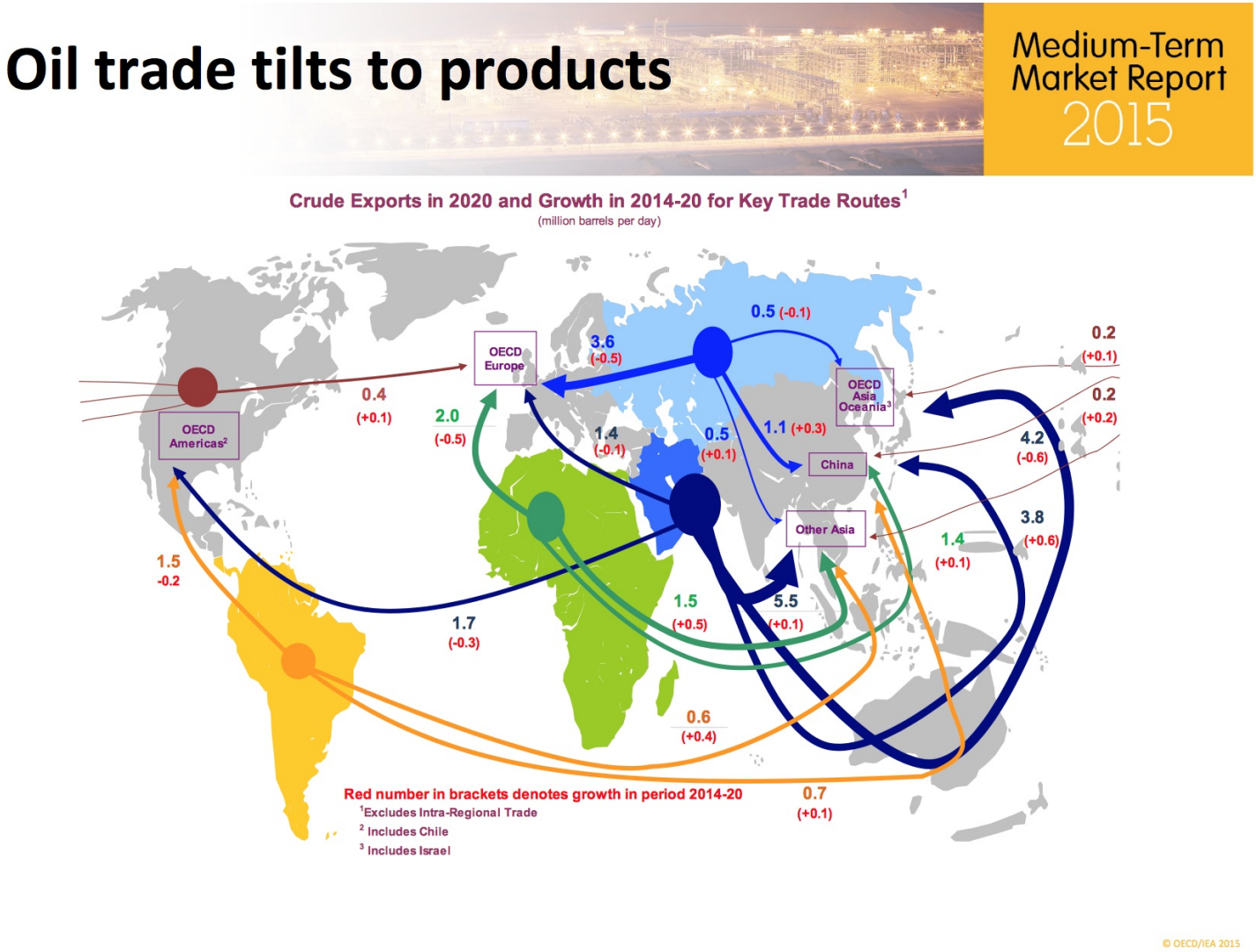
All countries with a small per capita energy consumption combined with very small country reserves of oil*, gas and coal!
(Transport) Oil the most important energy career in South America!
according to BP 2015: Remaining known reserves
(in Million Tons of oil equivalent (MTOE))
oil* = conventional easy to get oil!

Country	oil reserves MTOE	gas res. MTOE	coal res. MTOE	oil consumption MTOE/year	gas+coal cons. MTOE/year
Argentina	300	270	-	31	42 + 1
Brazil*	2300	450	2200	142	36 + 15
Chile	-	-	-	17	4 + 7
Colombia**	400	180	4500	15	10 + 4
Venezuela***	12 000-47000	5000	320	59	26 + 0.2
South/Central Am.	16 600-51 600*	7000	8000	326	153 + 32

* Brazil: oil reserves (difficult to extract) deep sea oil. Lignite coal reserves (dirty coal)
** Colombia: Oil reserves 7 years(!?) current production. anthracite coal reserves (less dirty)
*** Venezuela: unconventional/difficult to extract oil sands

The oil transport Problem: through the eyes of a physicist(5)

How to get oil from producers to consumers?
Pipelines and ocean transport (up to 3 million barrels of oil/tanker)



Electric energy: World, Switzerland and Brazil

Worldwide: 4500 GW_{el} installed power plants (1990 = 2700 GW_{el})

- **World: Electric energy ≈ 16% of the global energy mix**
  22 000 TWh_{elec} (3000 KWh/capita)

  fossile power plants = 67% (41% coal, 22% gas, 5% oil), hydroelectric = 18%,
  nuclear fission = 11%, other (wind, sun etc) = 4%

- **Switzerland: Electric energy ≈ 25% of the total energy mix**
  60 TWh_{elec} (8000 KWh/capita)
  fossile power plants = 5%, hydroelectric = 56%,
  nuclear fission = 38%, solar/wind etc = 1%

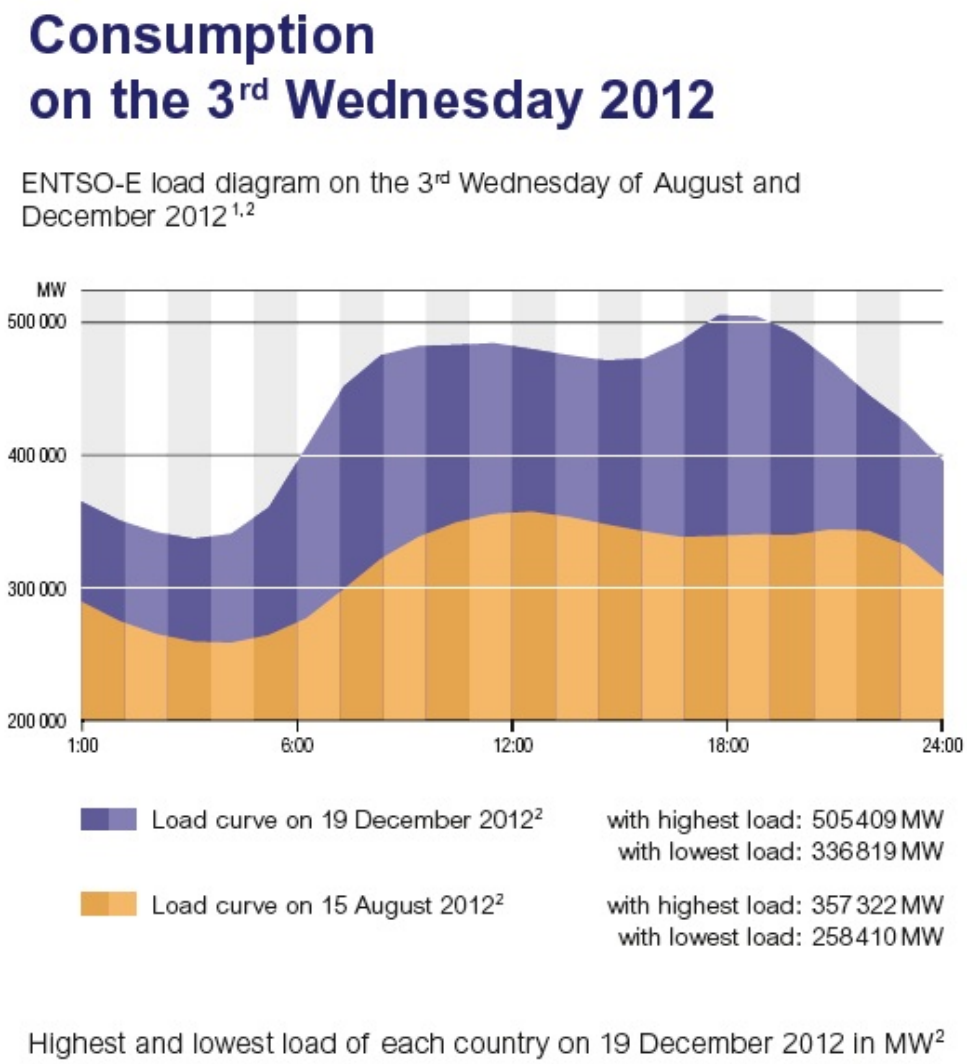
- **Brazil: Electric energy ≈ 15% of the total energy mix**
  550 TWh_{elec} (2500 KWh/capita)
  fossile power plants = 14%, hydroelectric = 75%,
  nuclear fission = 3%, solar/wind etc = 1%

sources: http://www.iea.org/publications/freepublications/publication/kwes.pdf
and http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=7

Electric energy: the "devil" is in the details!

The "devil" is the varying demand over the day(s) and seasons!

Peak Loads in Western Europe (2012): August 15, and December 19.



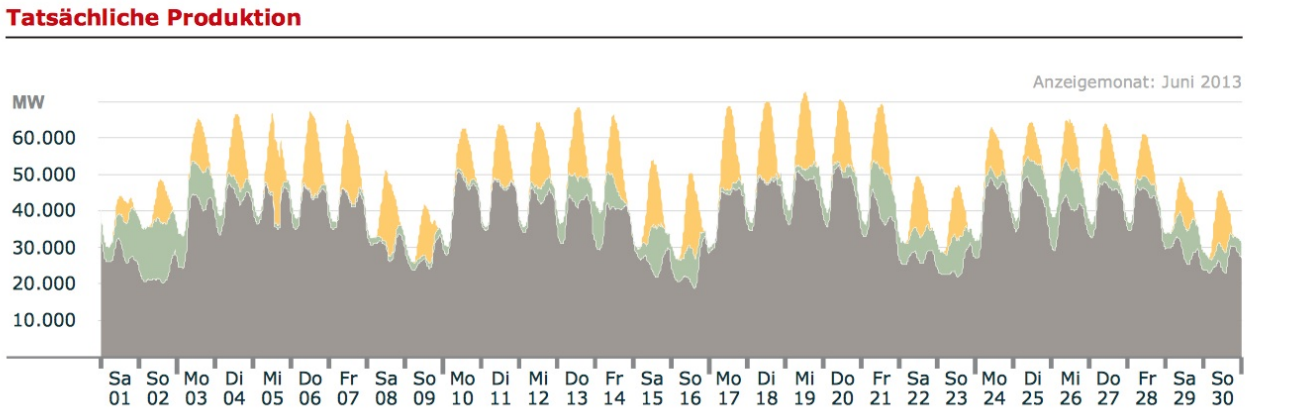
Source https://www.entsoe.eu/

new renewables in Germany: Wind and Solar a surprising development, but (I)

installed solar power (2013) = 35.6 GWe with 29.7 TWhe
installed wind power (2013) = 32.5 GW with 47.2 TWhe
during 2013: 5.3% and 8.4% contributions to the electric energy mix
(installed nuclear power = 12 GWe with ≈ 90 TWhe)

June, when the sun is shining ..
http://www.ise.fraunhofer.de/de/daten-zu-erneuerbaren-energien

Stromproduktion: Juni 2013



	Max. Leistung	Datum max. Leistung	Monatsenergie
Solar	23,2 GW	17.06., 13:15 (+2:00)	4,3 TWh
Wind	16,8 GW	02.06., 10:45 (+2:00)	3,4 TWh
Konventionell > 100 MW	52,5 GW	20.06., 11:00 (+2:00)	26,4 TWh

Grafik: B. Burger, Fraunhofer ISE; Daten: Leipziger Strombörse EEX, http://www.transparency.eex.com/de/

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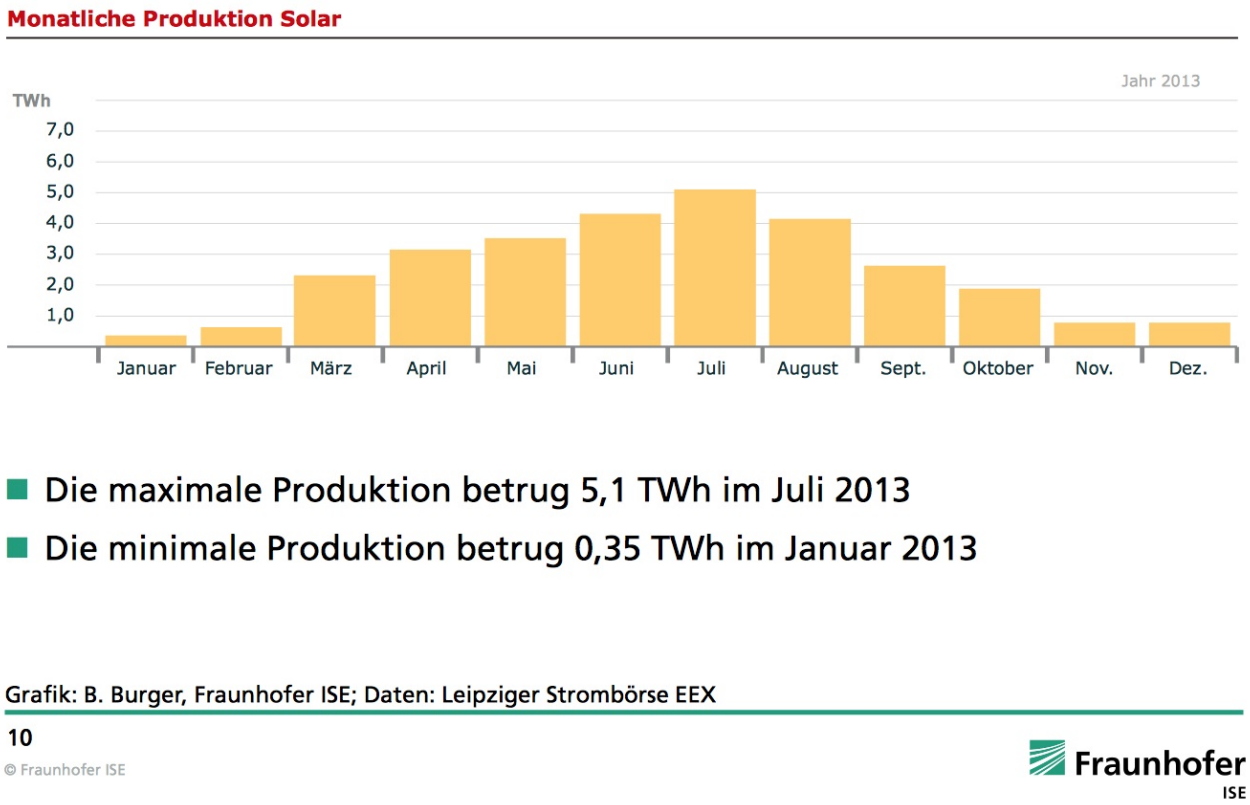
Fraunhofer ISE

new renewables in Germany: Wind and Solar a surprising development, but (II)

What to do in the evening and during the long, cold and dark winter days?
http://www.ise.fraunhofer.de/de/daten-zu-erneuerbaren-energien

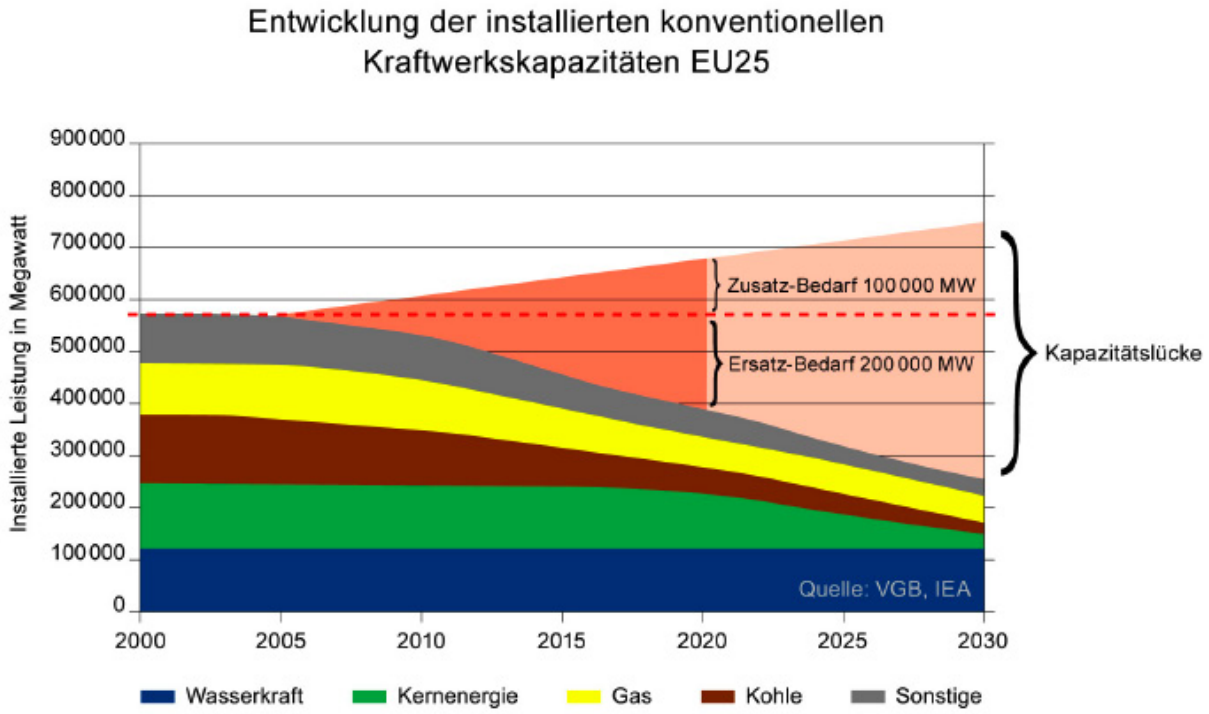
Monatliche Produktion Solar



Electric energy in Europe and on the Planet, an uncertain future not only for Western Europe.

Important decisions need to be made during the next years!
Phasing out fossile fuels (CO2 problem) and ageing nuclear power plants

Grosser Ersatzbedarf in Europa



Axpo Holding AG
02.06.2006 / Seite 4

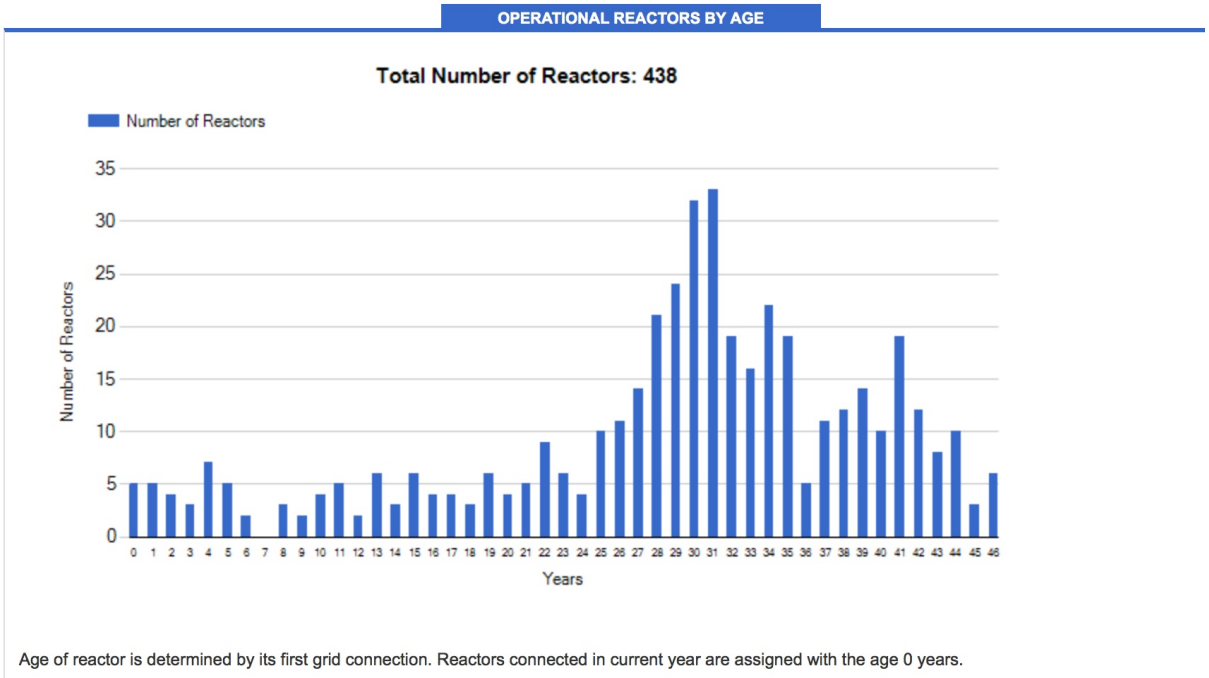
source: AXPO electric energy perspectives 2020 and VGB Powertech 2003
and http://ihp-lx2.ethz.ch/energy21/Axporama_talk.pdf

Electric energy from nuclear fission today

- Nuclear fission power: less than 12% of global electric energy and less than 2.5% in our total energy mix.

- **1980-1985:** 20 to 30 reactors completed per year.
  Since 1990 3-4 reactors completed per year.

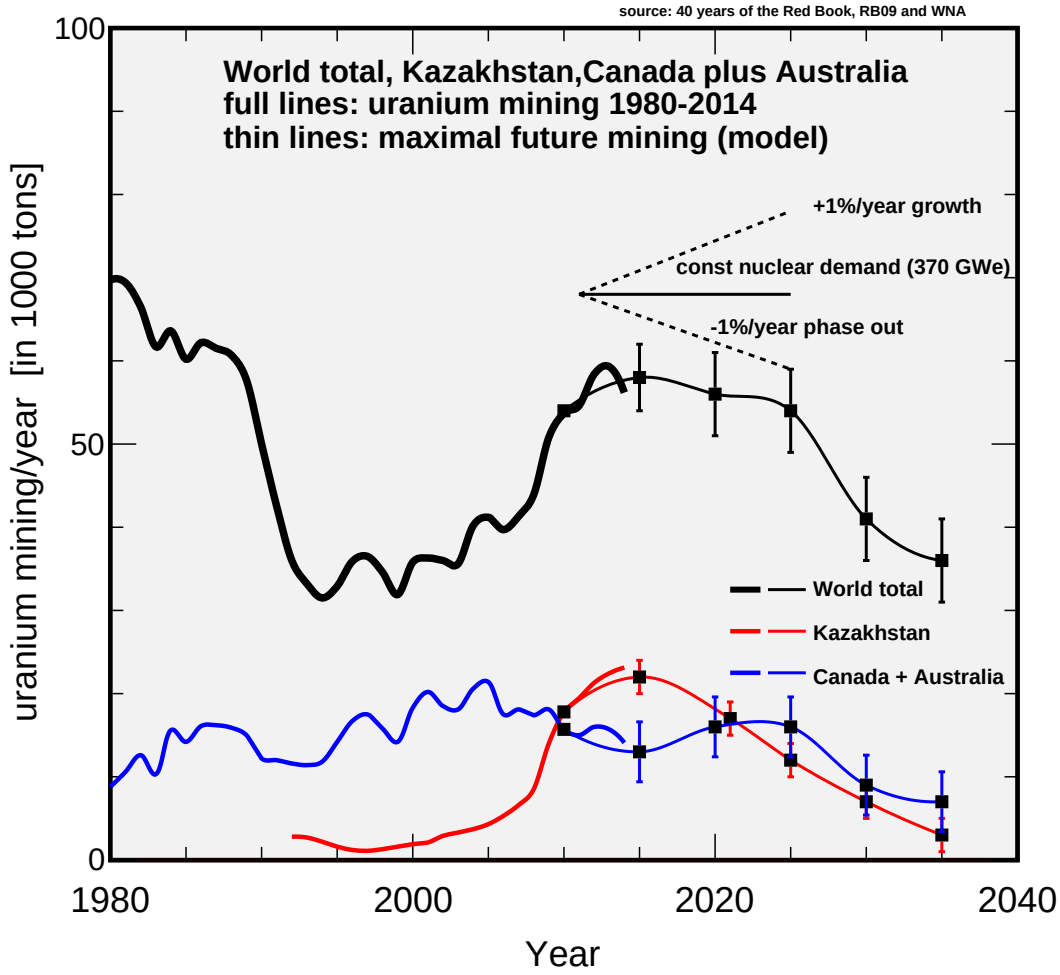
- About 250 reactors are 30 to 46 years old.
  They will reach "retirement" age during the next 10-15 years!



source http://www.iaea.org/PRIS/home.aspx

The future of uranium extraction: A model!

Uran depletion profiles or "a hypothesis about the future":
M.D. "The end of cheap uranium" (published with 2010 data)
http://www.sciencedirect.com/science/article/pii/S0048969713004579
curves updated new uranium mining data 2011-2014!



The future of uranium extraction: WNA (new!)

"Our uranium production methodology has also become more objective. As a result, existing and expected capacity plus secondary supply will be insufficient on current plans to meet reference scenario requirements by about 2024."

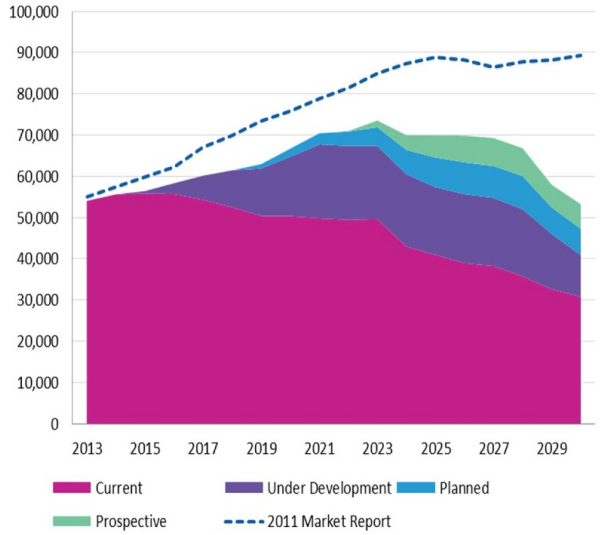
The World Nuclear Association (WNA) 2014 report (IAEA conf. 23-27 June 2014)

http://www-pub.iaea.org/iaeameetings/cn216pn/Monday/Session1/191-Emsley.pdf

Reference Scenario Primary Supply to 2030, tU

Existing capacity incorporates published statements of expected 2030 production (minus approx. 20ktU vs 2011 report)

Planned and prospective capacity changes reflect project cancellations/deferments (eg, Olympic Dam, Trekkopje) (minus approx. 15ktU in 2030 vs 2011 report)



World Nuclear Association | WNA Fuel Market Report
Ian Emsley

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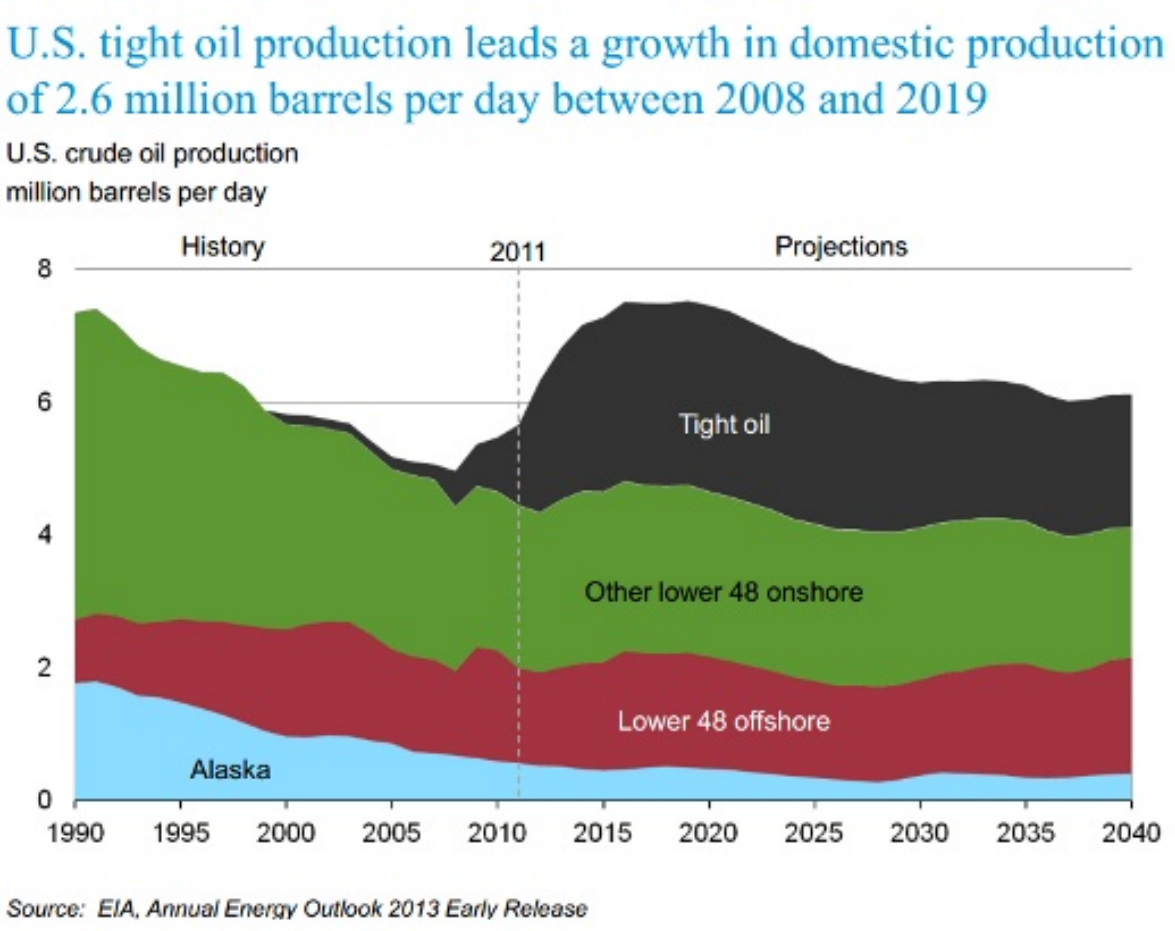
There is no shale oil "revolution" (I)

The real facts: the view of the USA Energy Agency?
Shale Oil: "production 4 mbd" (2014-2020) a short period!

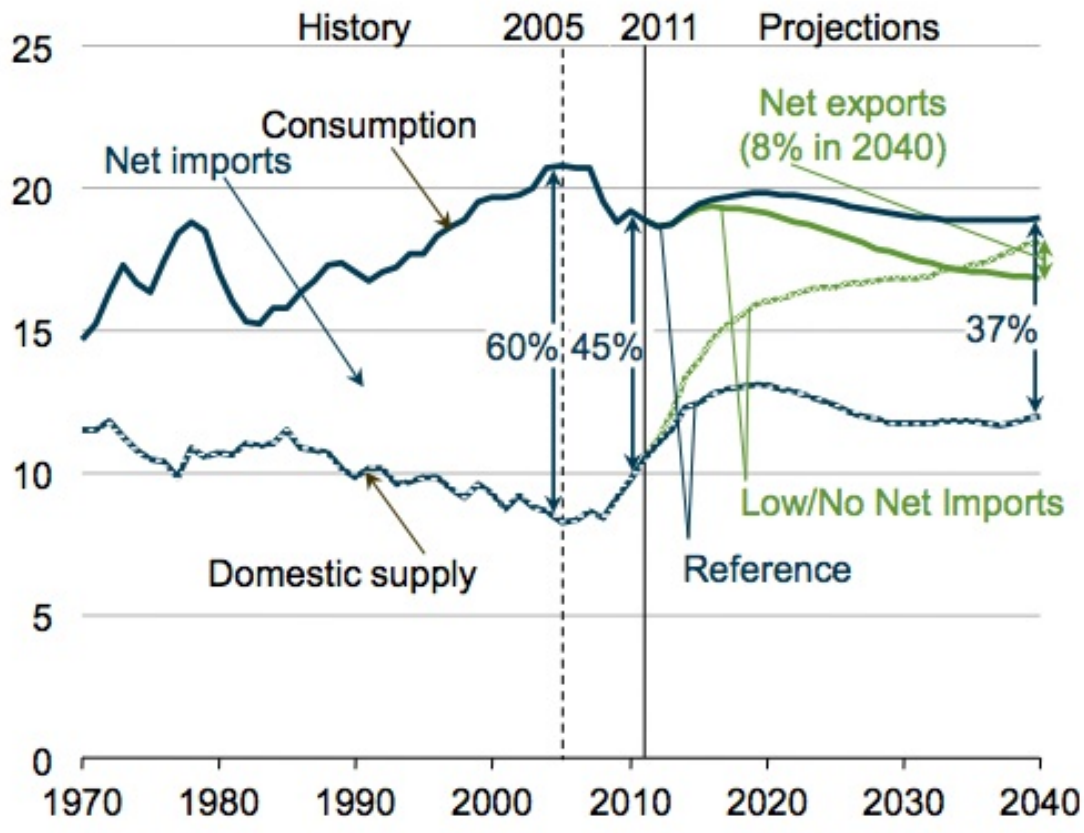


sources http://www.eia.gov/forecasts/ieo/liquid_fuels.cfm and http://www.eia.gov/analysis/studies/worldshalegas/

There is no shale oil "revolution" (II)

The real facts: the view of the USA Energy Agency?
Shale Oil: never enough to make the USA an oil export country!

Figure 1. Net import share of U.S. liquids supply in two cases, 1970-2040 (million barrels per day)



sources http://www.eia.gov/forecasts/ieo/liquid_fuels.cfm and http://www.eia.gov/analysis/studies/worldshalegas/

Western Europe (EU+Nor+CH) realities (I)

Western Europe has used already a large fraction of its formerly rich resources!

- European uranium extraction terminated in the year 2000
  (and nuclear power plants are reaching retirement ages).

- Europes oil extraction declines rapidly since 2000 (5-6% decline per year!)
  Produktion: EU(2013)/EU(2001) = 68.4 Mtons/155.6 Mtons and
  Norway(2013)/Norway(2001)= 83.2 Mtons/162 Mtons
  Oil import dependence: Switzerland = 100% (Western Europe = 74%!)

- Gas and coal extraction declining: -2-3%/year
  imports growing!

data about fossil fuel resource extraction from June 2014 BP review http://tinyurl.com/pfxy96q
and IAEA Red Book (uranium)

Western Europe (EU+Nor+CH) realities (II)

Oil production/consumption realties in Western Europe:

- Consumption 2013: 13.3 mbd
  (= 5 Giga barrel/year) Peak consumption 2006 = 15.5 mbd

- Produktion 2013: 3.28 mbd
  ("internal" oil production covers only 25% of the "needs")

- remaining official reserves: 16 Giga Barrel
  at current production 13 years (or 3.25 years current consumption)

source: June 2014 BP review http://tinyurl.com/pfxy96q

Western Europe (EU+Nor+CH) realities (III)

2013 oil imports: Russia (39%) , Kazakhstan (7%), Azerbaijan (5%), Algeria (5%), Libya(7%), Nigeria(10%), Angola(3%), Saudi Arabia(11%) and Iraq(4%). What about the future?

- Russia (official static reserves) 93 Giga Barrel
  23.6 years with current production $\approx$ 3.94 Giga barrel/year.
  - Oil production reached a plateau around 10.6 mbd (2011-2013);
  - internal consumption about 3.3 mbd (increases by 2-3%/year)
    $\rightarrow$ Exports to Western Europe will decline during next years!

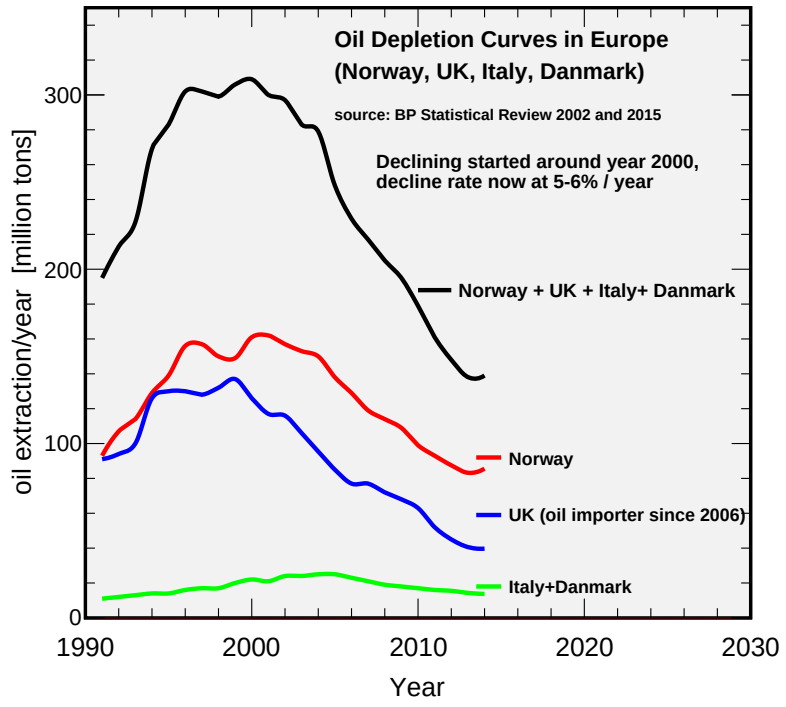
- Libya+Algeria (official reserves) 48+12 Giga barrel reserves
  12 years of Western European "needs"!
  - production in Algeria declining since 2008;
  - consumption in North Africa rising (+5%/Jahr in Algeria).

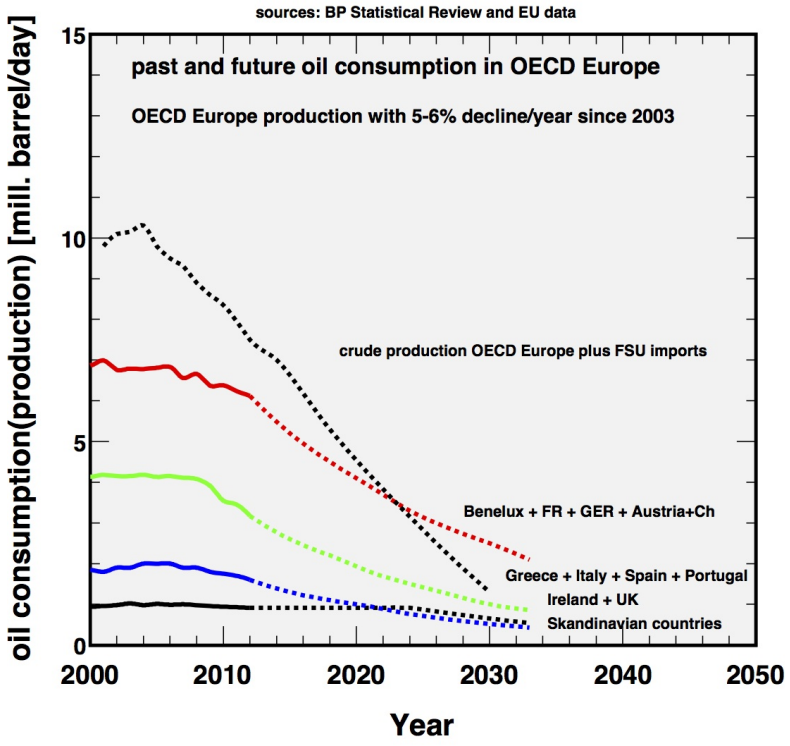
IEA/BP energy outlook scenarios (to 2040) make no sense!
source (data) June 2014 BP review http://tinyurl.com/pfxy96q

Western Europe (EU+CH+Nor) realities (IV)

Expect steeply declining imports from Russia -5-6% per year
curves perhaps with ± 2 years uncertainty.

Oil future in Western Europe (my 2014 estimate)



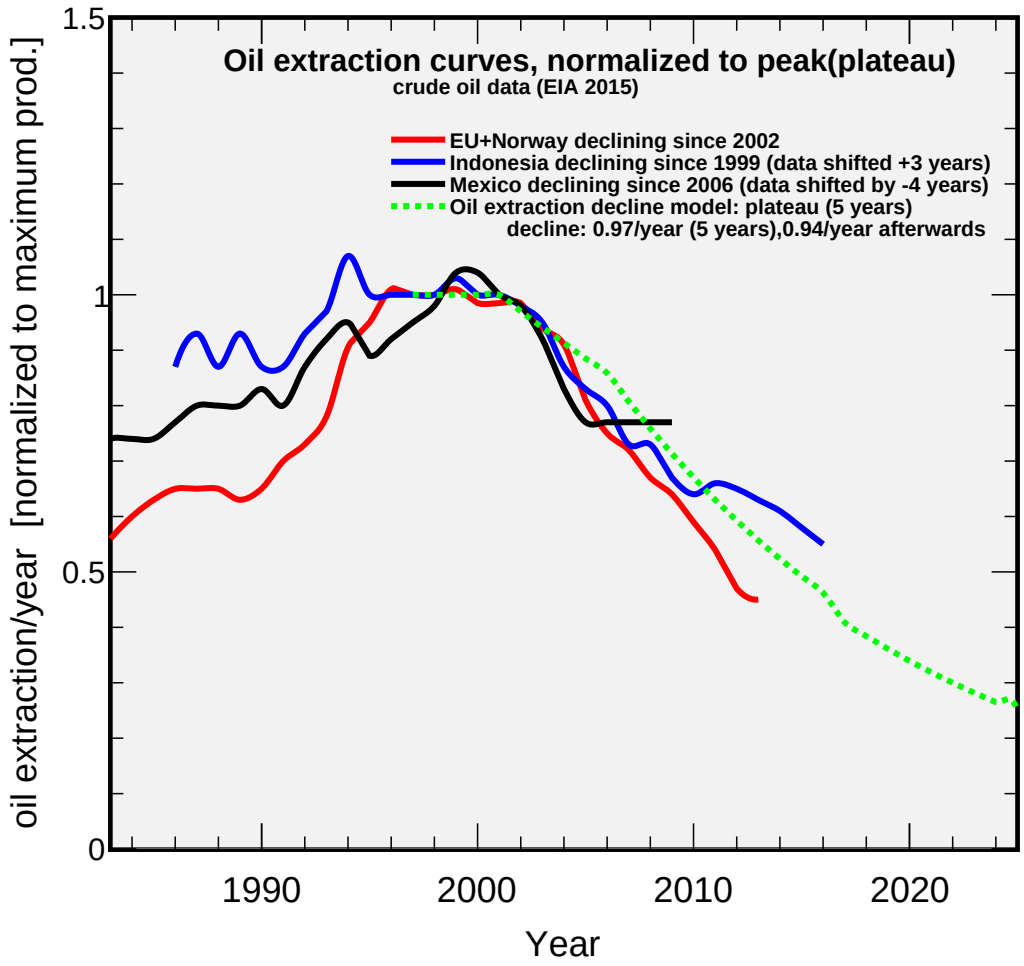


must learn to live with 5-6%/year oil consumption decline in Western Europe!

Towards a global oil production model (1)

A "universal oil extraction decline" function?

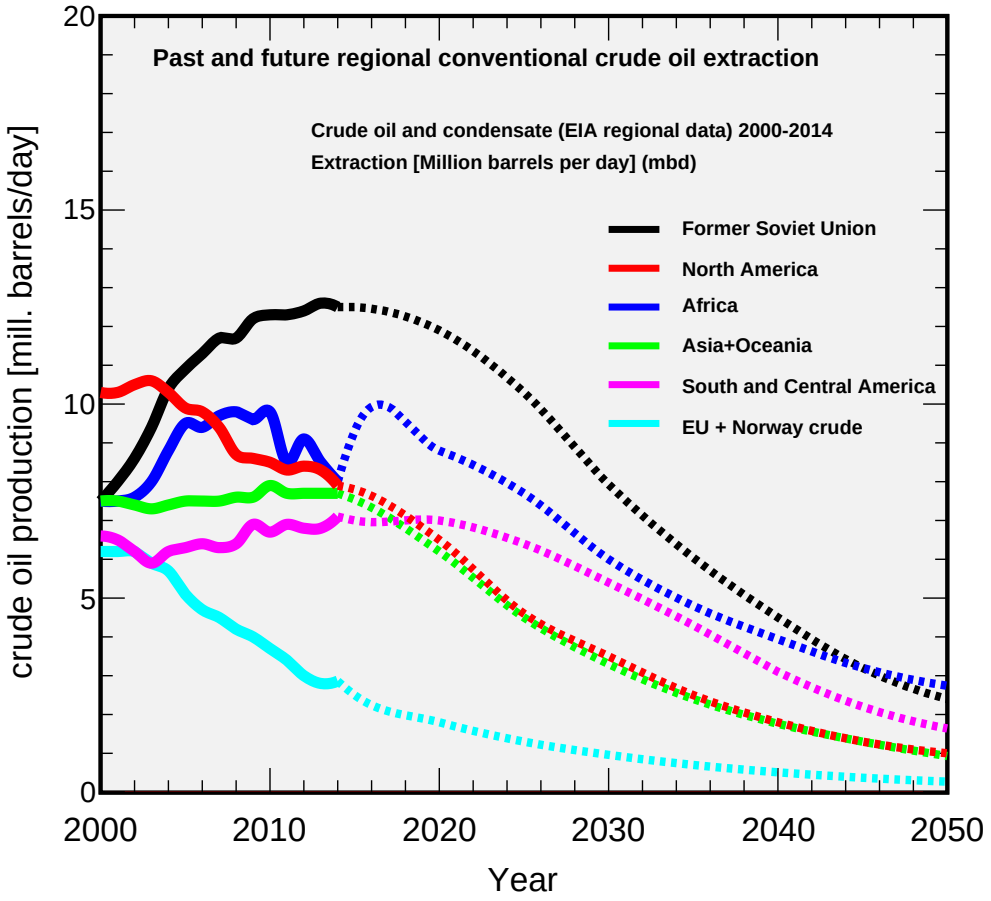
Production grows and stays flat for some years (depending on many things)
Without new fields the plateau ends and production declines first by 5 years with 3%/year production decline and afterwards 6%/year.



Towards a global oil production model (2)

Applying the model (2015-2050): using past oil production trends only!
(Cross check: Integrated production to 2050 is consistent with claimed reserves.)

1) Middle East OPEC countries: many decades at todays level $\approx$ 24 mbd
2) Shale oil, oil sands and other (unconventional) liquids can (perhaps) continue at about todays 20 mbd (about 20-25% of todays global consumption).



Towards a global oil production model (3)
My model results for Brazil and Latin America:

some observations for South and Central America:

- Oil is your most important (transport!) energy source.
  Only Venezuela, Brazil and Ecuador with known significant reserves.
  Some crude oil from Venezuela, Colombia and Ecuador currently exported USA and China.

- Small production increase (7%) during last 5 years, but consumption increased by 14%.

- **Venezuela:** Production is 30% lower today than during the 70ies. Official reserves are a doubtful mixture of oil sands and conventional oil. Expect a roughly constant or small production growth during next decades.

- **Brazil:** Small growth during past years but difficult to predict deep sea exploration future. Expect production decline of -3% from 2016 onwards.

- **Other South and Central America:** Rather constant production during past years. Expect declining production -3%/year (2016-2020) and -6%/year afterwards.

- If exports to other continents will end, expect overall constant oil consumption to 2020 (7 mbd). Followed by consumption decline to 6.4 mbd (2025), 5.4 mbd (2030) and 3.1 mbd (2040).

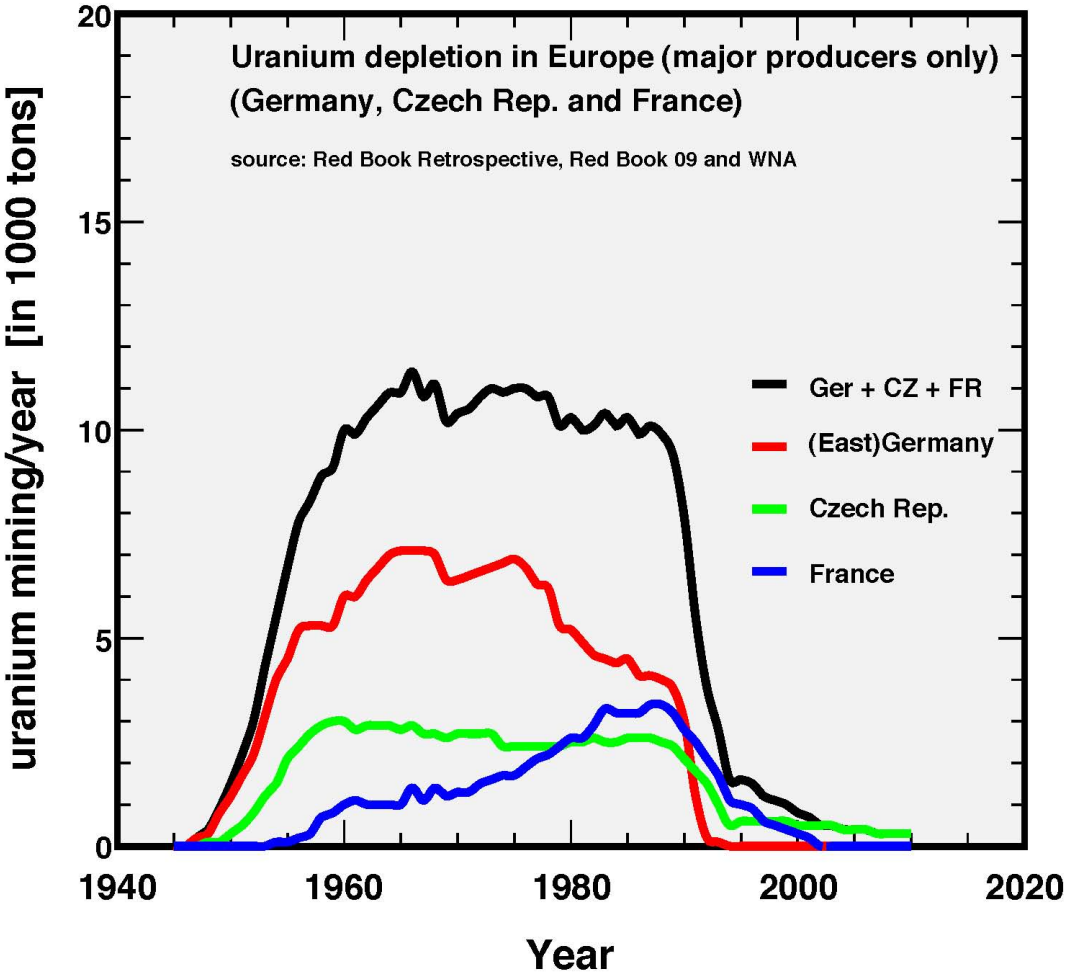
Instead of a summary:
Important points to be discussed/studied

Energy resources and especially oil much more finite than we want to believe! Especially in Western Europe, South America and Africa!

- Nobody knows how to run a globalised and industrialised world without oil!
- Is it really true that: "Rich people and people in rich countries" have no problem paying a factor 2-x higher oil price?
- All(!) energy resources within Western Europe are in production decline. Russian oil is of fundamental importance for "our way of life" in Western Europe!
  For how long will and can Russia deliver todays amount of oil (and gas) to Western Europe? (Who will benefit from todays EU-Russia conflict?)
- African and Latin American countries will never become importers of substantial amounts of oil and other energy resources.
- Which countries will get the access to the only large remaining conventional oil resources in the Middle East (about 60% of the exploitable oil).
- What happens if "friendly" countries limit the "free oil (and gas) flow" into neighbouring (richer) countries?

Western Europe: Uranium terminated

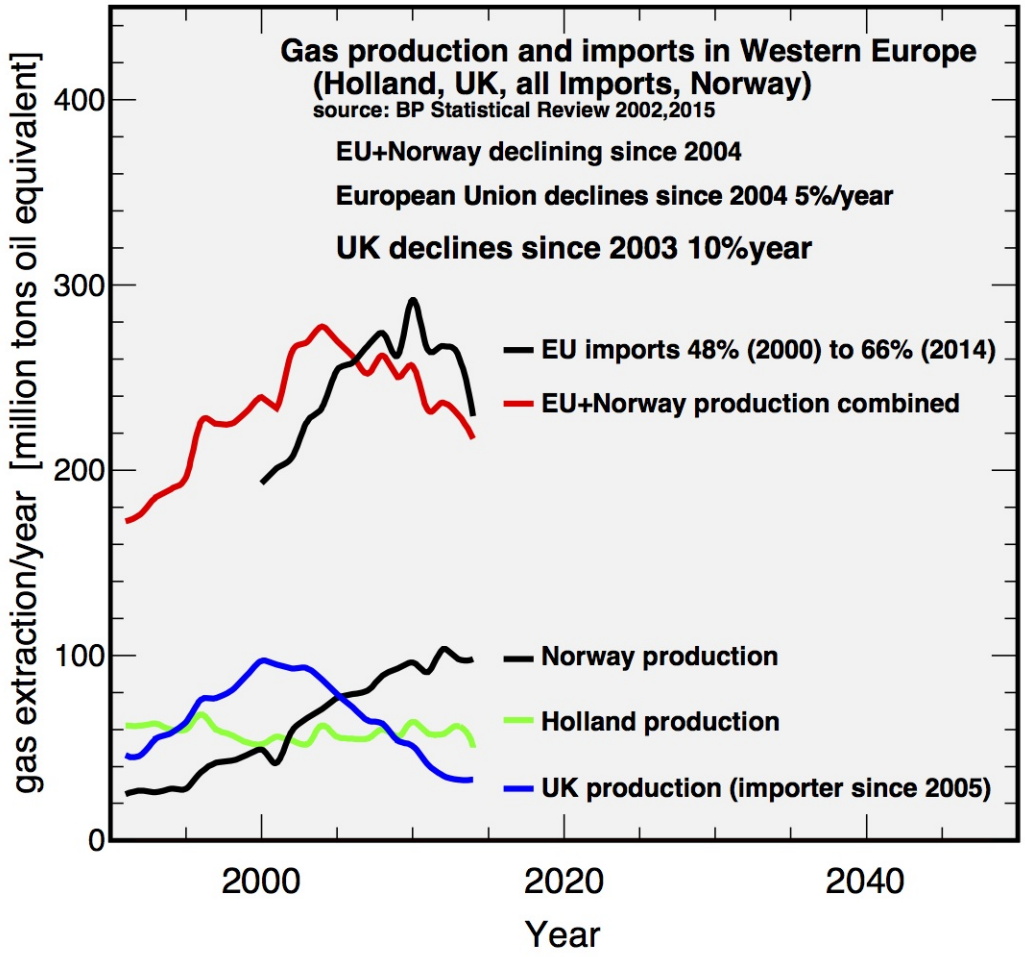
Uranium extraction: stopped since 2000,
despite claims that: (1) uranium price is negligible and
(2) the goal of import independence (100% imports since 2000)
imports in 2013 = 198 Mtoe



(source: IAEA Red Book uranium resources, various years)

OECD Western Europe: Gas 2%/year decline

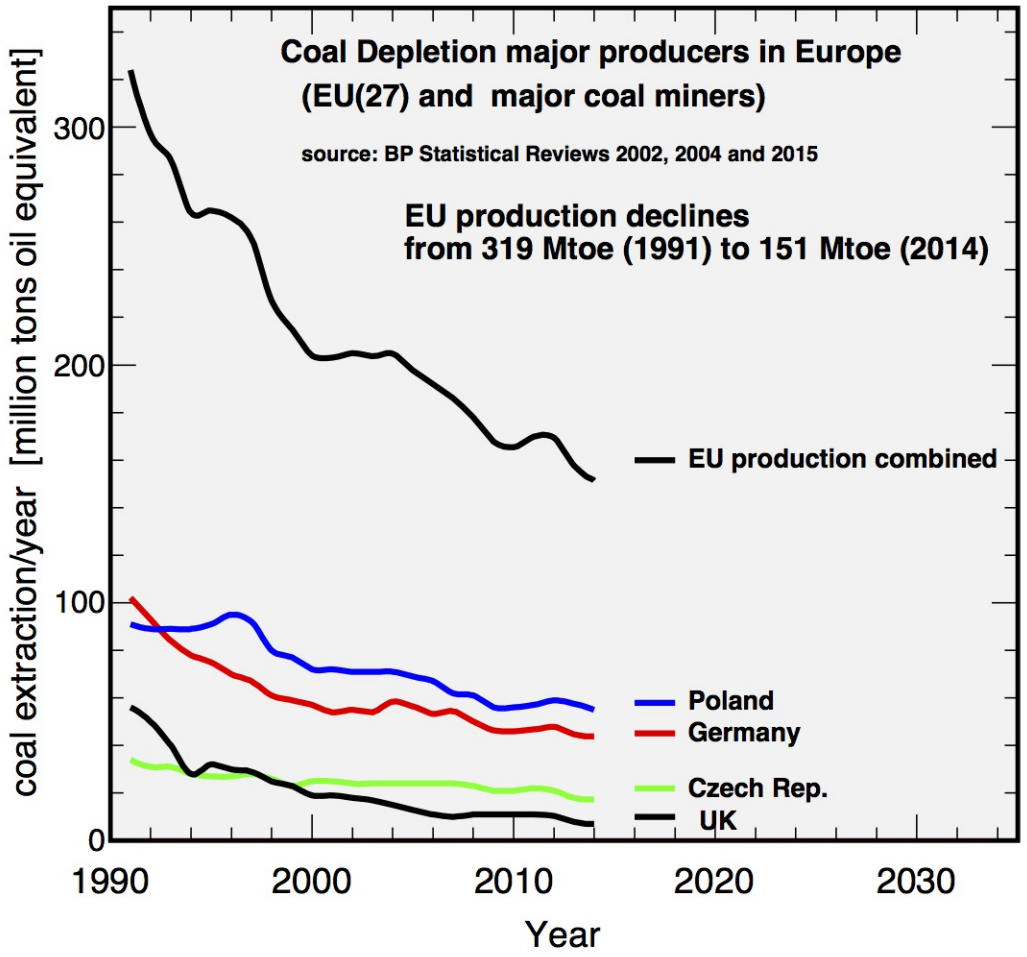
Gas extraction: Major producers plateau or in decline
despite high gas prices and 66% imports (increasing)
Imports in 2014 = 229 Mtoe/year



(source: BP World Energy Review 2015)

OECD Western Europe: Coal 3% decline

Coal extraction: Major producers in decline,
despite high prices and 47% imports (increasing)
Imports in 2013 = 133 Mtoe



(source: BP World Energy Review 2002. 2005, 2015)