Energy resource constraints for the transition towards sustainability

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- Energy use: through the eyes of a physicist
- Electric energy: the “devil” is in the details!
- Western Europe: Energy realities.
- The future of oil and uranium usage in Western Europe
Energy use: through the eyes of a physicist

“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

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
Energy use: through the eyes of a physicist (2)

(Energy-)Resources (like oil) move things!

As long as we can pay: “Food from the supermarket, oil from the gas station and electricity out of the plug”

(In Western Europe) we believe that money allows us to ignore problems!

Energy, much more than just electric energy!

A globalised world needs huge amounts of (oil)energy:

- to produce, transform and transport our food;
- to make heat and stuff (industrial processes);
- to move us and stuff around and,
- to transform other energy forms into electric energy (with thousands of useful and useless applications)
Energy use: through the eyes of a physicist (3)

“Energy” and ”Power”
(First and Second Law of Thermodynamics)

• The Energy Conservation Law:
  Energy can not be created!

• The Law of Energy Transformations:
  Energy transformation is always a “loss”!

• Power “to do work” or “service”:
  “Power describes how fast energy can be transferred from one system to another system” (Tipler)
  Attention: Installed (solar/wind/..) power is different from available power!
Energy use: through the eyes of a physicist (4)
The law of diminishing returns

Energy return over Energy invested: \( \text{EROEI}(\text{gain factor}) = \frac{\text{energy return}}{\text{energy invested}} \)

- 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): \( \text{EROEI} = 1! \) no matter how much money you have!

Money helps to move “people”, but it is “Energy” which moves things!
Energy use: through the eyes of a physicist (5)
What is the Energy Problem?

Fossil fuels and uranium are limited and non renewable. Our global energy use is unsustainable!

As shown by C. Rubbia, IAEA Fusion Energy Conf. Oct. 2000
Original plot made around 1971 by Dr. M. King Hubbert (1903-89) (geophysicist)
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.
1993-2008: Growth now 1-2% /year! Globalized transport of people and consumer goodies
thanks to oil.
2009-2013: “Stagnation” and steeply increasing prices for oil and other energy resources!
2014-2050: What do we know about realistic resource based options?

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.

Consumption on the 3rd Wednesday 2012

ENTSO-E load diagram on the 3rd Wednesday of August and December 2012

- Load curve on 19 December 2012
  - with highest load: 506,409 MW
  - with lowest load: 336,819 MW

- Load curve on 15 August 2012
  - with highest load: 357,322 MW
  - with lowest load: 256,410 MW

Highest and lowest load of each country on 19 December 2012 in MW

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 $\approx$ 90 TWhe)

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

Stromproduktion: Juni 2013

<table>
<thead>
<tr>
<th></th>
<th>Max. Leistung</th>
<th>Datum max. Leistung</th>
<th>Monatsenergie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>23,2 GW</td>
<td>17.06., 13:15 (+2:00)</td>
<td>4,3 TWh</td>
</tr>
<tr>
<td>Wind</td>
<td>16,8 GW</td>
<td>02.06., 10:45 (+2:00)</td>
<td>3,4 TWh</td>
</tr>
<tr>
<td>Konventionell &gt; 100 MW</td>
<td>52,5 GW</td>
<td>20.06., 11:00 (+2:00)</td>
<td>26,4 TWh</td>
</tr>
</tbody>
</table>

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

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**Monatliche Produktion Solar**

Die maximale Produktion betrug 5,1 TWh im Juli 2013
Die minimale Produktion betrug 0,35 TWh im Januar 2013

*Grafik: B. Burger, Fraunhofer ISE; Daten: Leipziger Strombörse EEX*

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How and how much electric energy? An uncertain future for Western Europe.

Important decisions need to be made during the next years!

source: AXPO Stromperspektiven 2020 und VGB Powertech 2003
and http://ihp-lx2.ethz.ch/energy21/Axporama_talk.pdf
Nuclear Fission Energy today

- Nuclear fission power makes only 12% of the 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 200 reactors are 30 to 45 years old. They will reach “retirement” age during the next 10-15 years!

source [http://www.iaea.org/PRIS/home.aspx](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. 2011-13 “The end of cheap uranium” (published)
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)


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)
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 extractions also started to decline.

![Uranium depletion in Europe](image1)

![Oil Depletion Curves in Europe](image2)

Data about fossil fuel resource extraction from June 2014 BP review [http://tinyurl.com/pfxy96q](http://tinyurl.com/pfxy96q) 
and IAEA Red Book (uranium)
Western Europe (EU+Nor+CH) realities (II)

Oil production/consumption realities in Western Europe:

- Consumption 2013: EU + Norway + Ch = 13.3 (12.8+0.24+0.25) mbd
  (= 5 Giga barrel/year) Peak consumption was 2006 = 15.5 mbd

- Produktion 2013: EU + Norway + CH = 3.28 (1.44 + 1.84 + 0) mbd
  (“internal” oil production covers only 25% of the “needs”)

- remaining official reserves: EU + Norway = 16. (6.8 + 9.2) 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 ≈ 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)
    → 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 decline 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)

Decline of oil imports by 5-6% per year (starting essentially now) 
curves perhaps with ±2 years uncertainty. (my new 2014 estimate for Western Europe)

must learn to live with 5-6%/year oil consumption decline in Western Europe!
There is no shale oil “revolution” (I)

The real facts: the view of the USA Energy Agency?
Shale Oil: “peak production 2.6 mbd” (2015-2020) a short period!

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)

Some important points to be discussed

Energy resources and especially oil (and in Western Europe) are much more finite than we want to believe!

- Is it really true that: “We, in rich countries” have no problem paying a factor 2-x higher oil price? (if true, why can’t one even put higher CO$_2$ taxes on oil?)

- We do not know any substitution for our oil based globalised world!

- Energy resources in Western Europe are depleted and production declines.

- Russian oil is of fundamental importance for our life in Western Europe! For how long will and can Russia deliver todays amount of oil (and gas) to Western Europe? Available data indicate that oil production in Western Siberia starts to decline now. Expect that oil exports to Western Europe and our consumption will decline by 5-6%/year (starting basically now!). (Who will benefit from todays EU-Russia conflict?).

- What happens if friendly countries limit the “free oil (and gas) flow” into neighbouring richer countries?

- Which countries will get the access to the only large remaining conventional oil resources in the Middle East (about 60% of the exploitable oil).