Lecture Springsemester 2015 M. Dittmar
Energy and environment in the 21. century: Part II
http://ihp-lx2.ethz.ch/energy21/
March 6(March 11), 2015

Lecture 3

Block I: What is unsustainable today: (Energy)Resources are very finite

- **Scientific (physics) facts and laws**
- **Carrying Capacity and ghost-carrying capacity:**
  How large is our dependence from non renewable resources: from qualitativ ideas to (physically) quantifiable criteria
- **The remaining natural capital: energy resources, non renewable materials and in principle renewable resources.**
- **Substitution through new renewable energies, materials and through a different way of life?**
- **Consequences for resource rich and resource poor countries?**

Scientific (physics) facts and laws (0)

Laws from physics and geology:

1. First and second law of thermodynamics: a perpetuum mobile of the first and second kind does not exist!
   (1) Energy in a closed system is a conserved quantity and can not be produced from nothing!
   (2) It is impossible to do work just from the cooling of a reservoir. Heat (energy) can not be transformed by 100% into other forms of energy.

2. The "law of diminishing return":
   (1) easy "resources" will be found and exploited first;
   (2) less concentrated and better hidden resources require more energy and better technology (hidden grey energy http://en.wikipedia.org/wiki/Gray_energy) to search for and exploit it. (3) Resource exploitation must end when it stops being profitable.

3. For the extraction of energy resourcen:
   EROEI(t) = Energy return(t)/Energy invested(t) (for its usage)
   (1) "law of diminishing return" = EROEI(t) must decline over time
   (2) termination of exploitation once EROEI(t) = 1 (for the final user) is reached!

Scientific (physics) facts and laws (3)

- About 0.1% of the incoming sunshine is on average transformed into biomass. Over hundred of millions of years, this solar produced biomass has been transformed and stored by geological processes into the very finite fossile fuels (coal, oil and gas).

- For an average (day and night) solar constant on earth of 350 Watt/m^2 and a conversion efficiency of $\times 0.001$ the average human energy requirement today corresponds to an effective surface of 6000 m^2.
  (thus about 20 000 m^2/person in Switzerland;
  energy needs of 8 million Suisse people use roughly a surface 4 times larger than Switzerland!)

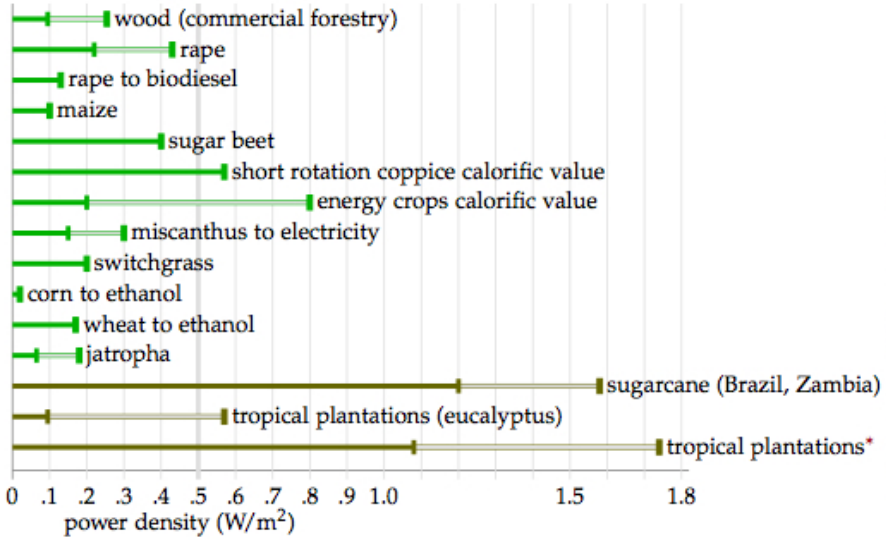


Figure 6.11. Power production, per unit area, achieved by various plants. For sources, see the end-notes. These power densities vary depending on irrigation and fertilization; ranges are indicated for some crops, for example wood has a range from 0.095–0.254 W/m^2. The bottom three power densities are for crops grown in tropical locations. The last power density (tropical plantations*) assumes genetic modification, fertilizer application, and irrigation. In the text, I use 0.5 W/m^2 as a summary figure for the best energy crops in NW Europe.

more at: http://coccweb.cocc.edu/bemerson/public_html/PhysicsSeminar/Resources/Documents/DMcKaySustainabilityCH6.pdf

Scientific (physics) facts and laws (5)

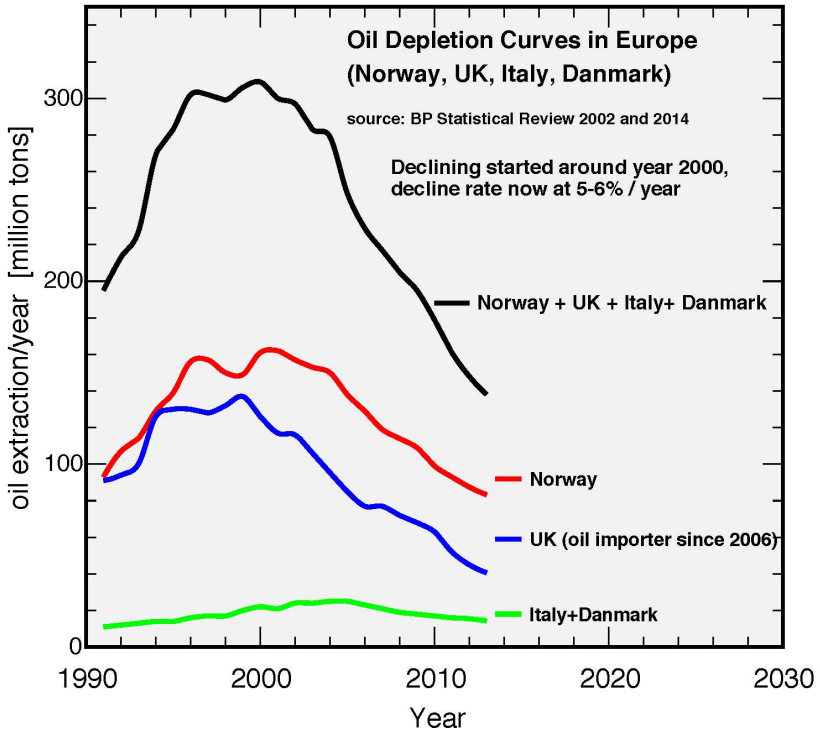
If one accepts that (fossil) energy resources are finite, then one needs a scientific method to quantify the remaining exploitable resources as a function of time and region (locally and globally):

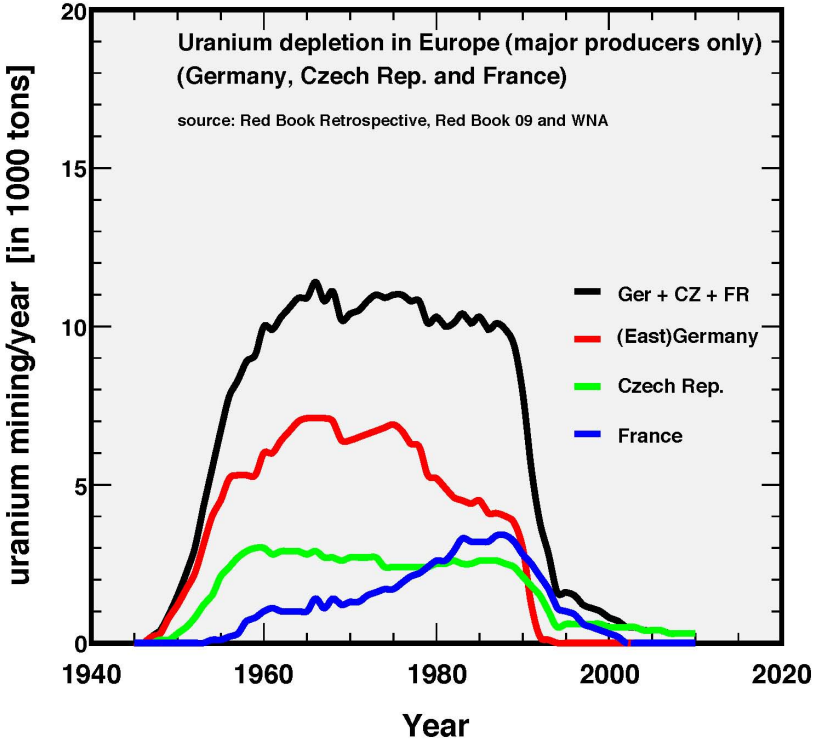
- Local, regional, continental and global resource deposits X
- "Know how" to extract, transport and usage (and about unwanted side effects and costs)
- Local, regional, and global demand and dependence on resource X
- The price(t) is a function of offer(t) and demand(t)
  "Free" markets require some offer - demand balance!
  Is this a correct statement?

Scientific (physics) facts and laws (7)

oil for Western Europe = EU + Norway + Switzerland

- oil import dependence: 100% (Switzerland) and 75% (Western Europe)!
- Extraction decline from European oil resources: -6% decline per year)
  Production: EU(2013)/EU(2001) = 73.0 Mtons/155.6 Mtons und
  Norway(2013)/Norway(2001)= 83.2 Mtons/162 Mtons
  (extraction of uranium in Western Europe terminated since the year 2000!)



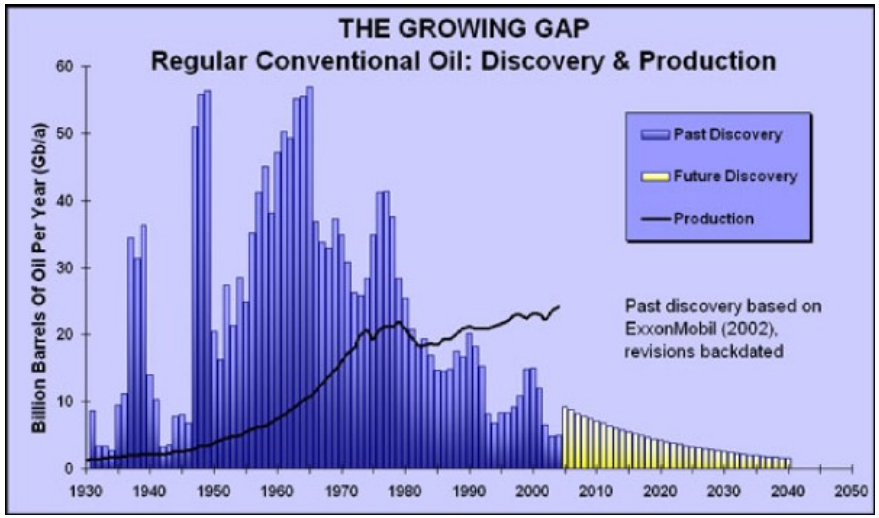


Data about resources, extraction and usage from BP at http://tinyurl.com/lxu3jmj

Scientific (physics) facts and laws (8)

The most important scientific (geological) energy question:
How large are the remaining (energy)-resources and their corresponding EROEI(t)?

- "Political" and "economical" interest influence resource knowledge!
  Official numbers are inaccurate and need to be studied with great attention!
- Geological accurate resource data are often company and state secrets.
- There is a huge confusion about quality of resources (oil for example):
  EROEI (conventional oil) $>>$ EROEI (deep sea oil) $\geq$ EROEI (oil sands and shale oil)
- Extraction and transport capacities of "all" resources is based on the still cheap transport oil (as long as cheap oil is available!).



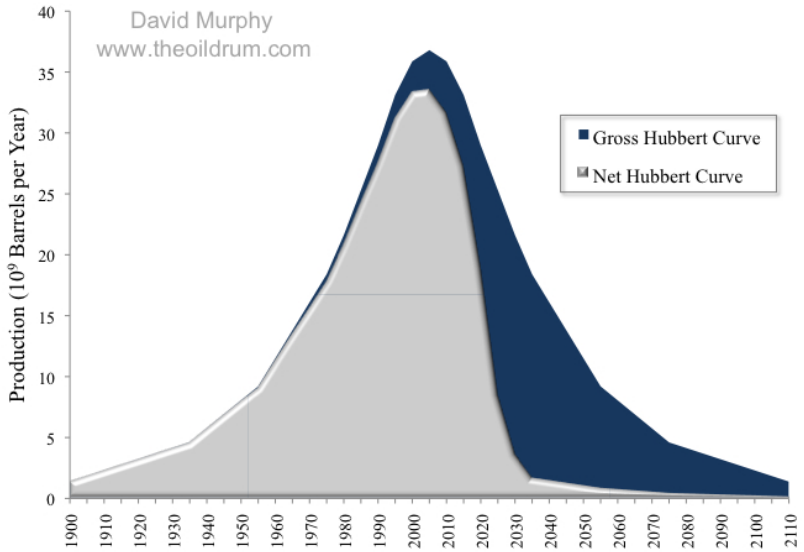
energy resources, extraction and consumption data in a handy format from:
BP Statistical Review 2014 (for the year(s) 2003-2013 http://tinyurl.com/lxu3jmj

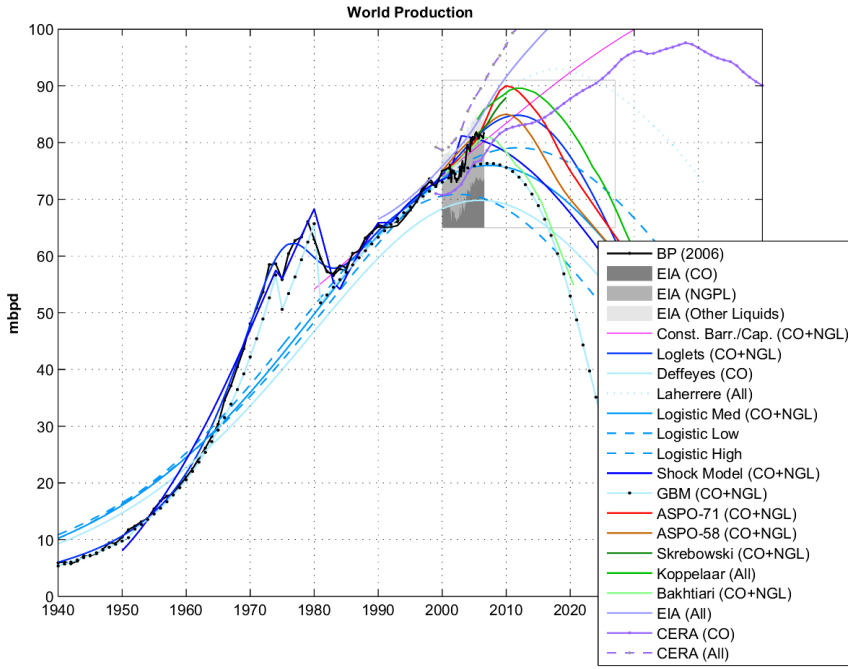
Scientific (physics) facts and laws (9)

Need to answer the scientific and geological question:
How large are the remaining (Energy)-Resources as a function of the EROEI and the geographical location?

- Conventional oil (with the highest EROEI!) dominates (about 80%) dominates the global oil market and peaked around the year 2006.

- "Hubbert" (gaussian-like) curves" describe discovery and extraction of finite resources! When will the local and global extraction maxima of different resources be reached?





Sources for oil: http://netenergy.theoildrum.com/node/5500 and
Wikipedia (Peak-Oil) http://en.wikipedia.org/wiki/Peak_oil

Scientific (physics) facts and laws (10)

Even if the "global peak oil 2015± x" is not proven beyond doubt, the fundamental importance of oil for Switzerland and the EU: We need a rational and scientific analysis about the future global oil supply limits.
In addition to better global resource data, the following problems need to be studied in detail:

- Increasing oil prices increase the richness in oil exporting countries and thus higher internal oil consumption. Exports from these countries will decrease and prices will continue to increase.

- Which export products offer a valuable exchange for raw materials?

- Is it true that: "We in Switzerland can easily (without problems) pay a factor of 2(5?) more for our oil needs?"

- What happens when egoistic reasons will force friendly neighbouring countries to limit the free "oil" flux into Switzerland (the EU, Japan, China or the USA)?

- Which countries will get the access to the remaining huge conventional oil reserves in the Middle East?

- For how long will Russia deliver enough oil and gas to Western Europe? The oil peak in Western Siberia combined with increasing Russian consumption might reduce the export already this year!

Carrying Capacity + Ghost-carrying capacity (1)

Right or wrong?

- Today, the transformation of raw materials into luxury goods is more profitable than the export of raw products. Is this also valid tomorrow?
- Thanks to imports of resources, the life of most people in Western Europe and into Switzerland became "more attractive" than 100-200 years ago.
- thanks to cheap oil and electric energy our European "average way of life" became very comfortable (often combined with unsatisfactory(?) and wasteful luxuries)
- We have achieved a scaring oil dependence. Our industrial high yield global agriculture is based on cheap oil and 50% of our food is transported and imported thanks to oil!

The "Carrying Capacity" without oil and electric energy? How many people in Switzerland and the EU can theoretically live without oil?

Carrying Capacity + Ghost-carrying capacity (2)

Carrying Capacity:(Wikipedia):
"The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment."

Derrick Jensen quoting Prof. William R. Catton, Jr. "Overshoot: The Ecological Basis of Revolutionary Change"

"Any environments carrying capacity, he states, is the number of creatures living a certain way who can be supported permanently on a certain piece of land, for example how many deer could live on a certain island without overgrazing and damaging the capacity of that island to grow food for them."

*"Permanently is the key word here, because its possible to overshoot carrying capacity -to temporarily have more creatures than the land can support-
but doing so damages the land, and permanently lowers future carrying capacity. This is true when we talk about nonhumans, and its just as true when we talk about humans."*

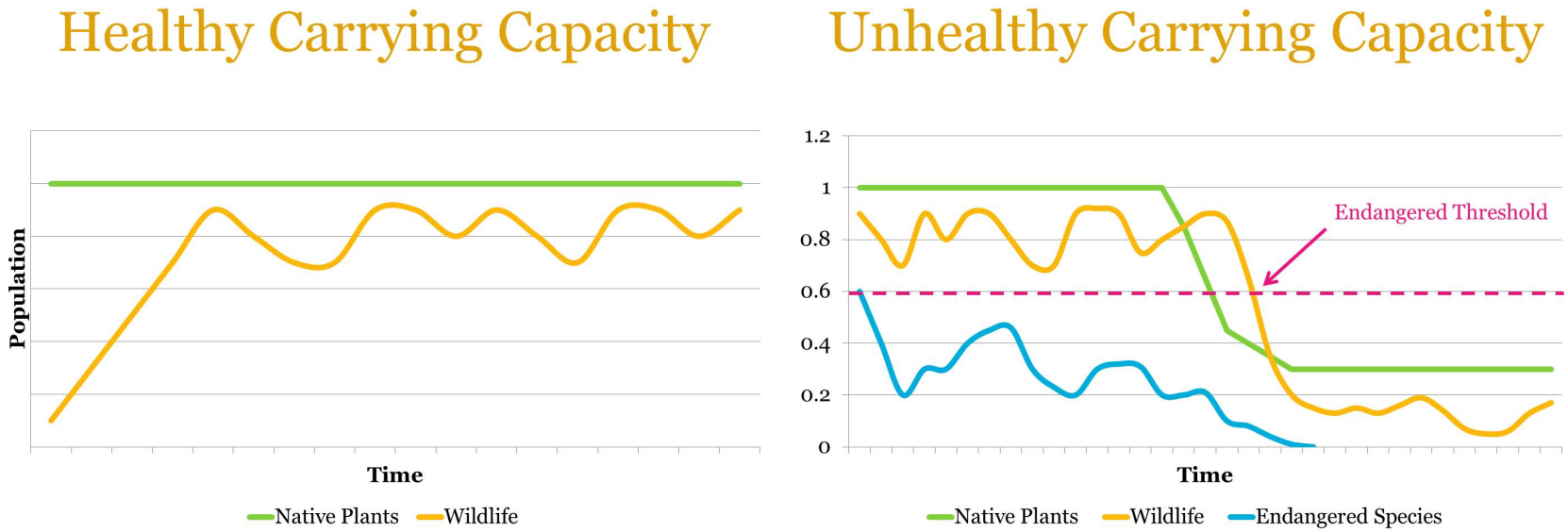
http://www.derrickjensen.org/work/endgame/endgame-excerpt-carrying-capacity-part1/

Carrying Capacity + Ghost-carrying capacity (3)

From qualitativ ideas to quantifiable (scientifically) criteria?

Carrying Capacity is a function of the natural capital:
natural capital (t)) = natural capital(0) $\times$ (1 + "yield"(t) - "loss"(t))
MSY (Maximal Sustainable Use): yield(t) must always be larger than loss(t)!

using finite non-renewable capital(t) = loss(t) - yield(t)($\approx$ 0!) allows the Ghost Carrying Capacity(t). By definition this is never sustainable and leads to overshoot followed by the dieoff catastrophe!



source http://www.nahabitat.com/goals/carrying-capacity/

Carrying Capacity + Ghost-carrying capacity (4)

a quantification of todays carrying capacity?

We have to determine a safe(!) "sustainable yield" (a function of our impact) as a function of the remaining natural capital!

The I = PAT equation in relation with the natural capital?
(Impact = Population $\times$ Affluence $\times$ Technology)

Assumption 1: "loss(t)" $\approx$ impact(t)

Natural Capital (t) = Natural Capital(0) $\times$ (1 + yield(t) - loss(t))

Assumption 2: our actual impact(t) >> yield(t)
To avoid the total collapse or a "global" desert (minimum yield from the nat. capital), the loss(t) (= Impact) has to decrease (but how much time is left?)

development towards sustainability(t):
the total human impact(t) has to become smaller than the sustainable yield(t) in order to achieve resilience against "natural catastrophes":

Our goal our impact has to become smaller than the yield(t) > Impact(t)

Sustainability requires to grow (increase and repair) the natural capital (t) and we have to learn to use less and less non-renewable resources and only in emergencies. Capital Growth(t) = Yield(t) - Loss(t) > 0!

Carrying Capacity + Ghost-carrying capacity (5)

Natural Capital (t) = Natural Capital(0) × (1 + Yield(t) - Loss(t))

to fill the equation with life (facts): what needs to be known?
An incomplete list:

- How large is the remaining non renewable capital?
  How fast do we have to change?
- How can we reduce our non renewable natural capital dependence without increasing our local impact (unsustainable timber usage to replace fossil fuels)?
- How large was the original natural capital
  (with the "maximal sustainable yield")?
- How large is the remaining renewable natural capital?
  (remaining sustainable yield?)

We need more research to answer these question and we need development (changes!) to (1) increase the natural capital(t) and (2) to reduce the (human) impact.

The remaining capital: non renewable (energy) resources

Easy to answer for Switzerland and Western Europe:

assuming that the reports from BP and the US geological survey (USGS) are roughly accurate:
BP Stat. Review 2013 http://tinyurl.com/kwyl98h and
http://minerals.usgs.gov/minerals/pubs/country/europe.html#sp

remaining non renewable natural capital (energy resources):

- Switzerland: ≈ 0! (no significant resources!).
  oil consumption ≈ 0.085 Gbarrel/year

- Western Europe (todays usage) (oil consumption: 5 Gbarrel/year): oil reserves = 14.3 Gbarrel, uranium practically terminated! at current production: gas resources for 8 years and "coal" resources (60 years).
  Iron and cooper etc .. the most interesting deposits are depleted.

- Russia (FSU) as Western Europe's oil, gas and uranium export country:
  oil = 87.2 Gbarrel (= 22.4 years) and gas= 56 years (todays extraction)
  Attention: (1) less in Western Siberia, (2) the Russian consumption increases by 3-5%/year and the oil export peak to the EU seems to be now!

- Libya + Algeria (oil and gas exports to France, Italy, Spain and Switzerland):
  remaining oil = 48+12 Gbarrel (about 50 years(?) at todays production)
  remaining gas = about 80 years (todays production)

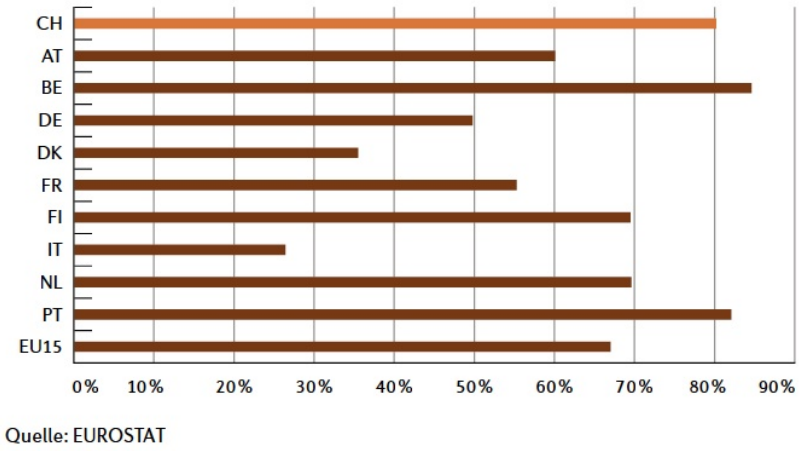
- our planet (todays extraction)?
  good conventional oil (without Venezuela and Canada) = 38 years!
  (about 1195 Gbarrel reserves if one believes the OPEC numbers)

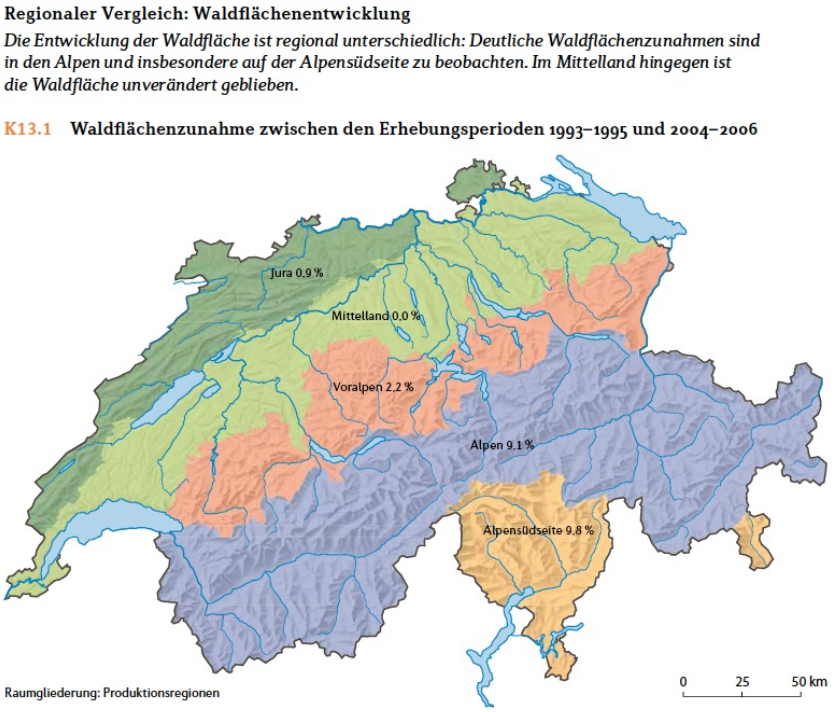
The remaining capital: renewable (energy) resources?

An answer for Switzerland and Western Europe?

the remaining capital biomass (= timber) as material for construction and energy!

- Switzerland and Western Europe: "forests" are growing again (but not the original "primeval forests"
- Destruction of remaining forests in Greece as a consequence of high oil price.
  How do we manage to avoid these problems in the coming decades?
  http://www.youtube.com/watch?v=hllU9NEcJyg and
  http://www.youtube.com/watch?v=M4jhjt1_eyM





more: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-11-137/EN/KS-31-11-137-EN.PDF

The remaining natural capital in Switzerland?

Example: Suisse forests
http://rainforests.mongabay.com/deforestation/

Switzerland 2000 years ago:
a landscape with pristine forests and a maximum productivity (humus etc). Sustainable usage with bears, wolfs, bisons, salmons .. and few humans!

Switzerland today:
31% "forested", about 1% "pristine forests" (40 000 ha).
Maximum usage today has resulted in smallest biodiversity since thousands of years. Since 20 years forests are growing by about 0.5%/year (5000 ha/year): Assuming such (exponentiell) growth, it takes about 200 years to reach the original state.

Difficult to remain on this path if the demand for timber (energy) is increasing:
(1) about 5% of the Suisse "energy" demand comes from timber.
(2) todays timber usage is sustainable, but mainly only in mountain regions and if "timber" imports are not counted.

Substitution through renewable energies, new materials, technology and a different way of life?

(without wonders and other miracles) What Suisse research, industry etc could do for the path into sustainability:

Terminate destructive dependence from other countries and regions replace with cooperation which respects the different cultures.

- Extraction of rare minerals from mountains? (No thanks?)
- (Electro)cars will not be constructed in Switzerland..
  but what about high tech "Swatch"-Bikes etc?
- Independent research and development for new renewable energies?
  a difficult path for a small country!
- Research and development for Min-Energy standards and constructions etc
  basic research about (1) how to educate people about the sustainability problem, (2) how to speed up the natural repair processes and (3) how to live a different sustainable and more satisfactory way of life and for growing fractions of the population (yes please!)
- Research and development for a sustainable forestry and agriculture. (yes please!)
- Research and development for more biodiversity (yes please)
- Direct (basis) democracy with a cantonal structure as an export article for other countries?
  (as a solution for the Palestine conflict.)

and thousand other details!

Consequences for resource "rich" and resource "poor" countries?

The remaining natural capital? Local and global? Where are we today?
When will we reach the global "tipping point" of no return?