

Development towards sustainability? “What do we want/need to do?”

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CHIPP Workshop 2023 in Sursee
June 14, 2023
for many more details see
<http://ihp-lx2.ethz.ch/energy21/Links.html>

- Introduction, overview and the IPAT equation
- Defining sustainability and why is it important?
- Sustainability understood from physics principles (or as understood from one physicist?):
The connection with other scientific disciplines.
Local and/or global sustainability?
- What is unsustainable today?
The global human impact ($I = PAT$) is too large!

Living sustainable: only a moral obligation?

**Nature can live without humans,
but humans can not live without nature!**

ETH Energieleitbild Dezember 2012:

https://www.ethz.ch/content/dam/ethz/common/docs/publications/Energieleitbild/eth_energy_concept_en.pdf

12 Topics for direct action and measures:

1) ETH Zurich conducts and fosters fundamental research for sustainable energy supply that meets the highest international standards.

8) ETH Zurich defines paths for the reduction of its own final energy use, of the use of non-renewable energy, and of its CO₂ emissions. These reduction paths include target values for 2020 and 2035.

11a) Research:

Support for basic research and interdisciplinary research and the development of competence in understanding the energy system.

11b) Teaching: Support for thesis works related to energy questions, increase the interdisciplinary teaching and create a critical discussion atmosphere about energy relevant topics.

Everybody(?) talks about sustainability and almost everyone means something different.

“Sustainable development” or “Development towards sustainability”?

Our goal: “the permanent conservation of the planetary life support system for Switzerland (locally) and for the entire planet (globally)!”

Sustainability: Important questions (criteria)?

- Sustainability on an “island” in an unsustainable environment?
- Dependence on energy resources (non renewable and renewable)?
- Dependence on mineral resources (non renewable and recycling)?
- Dependence on a healthy(?) natural environment (waste and CO₂)
How much biodiversity is needed for a sustainable culture (society)?
- How large is the carrying capacity as a function of time?
How large is the “Ghost Carrying Capacity” as a function of time?
Population growth and age distribution, population density/km² and the density and distribution of **Towns, Cities and Mega-Cities**
Enough food for humans and other living species (locally and globally)?

Dependence on non renewable (energy-) resources automatically violates the sustainability principle!

Local sustainability with a large import dependence is impossible!

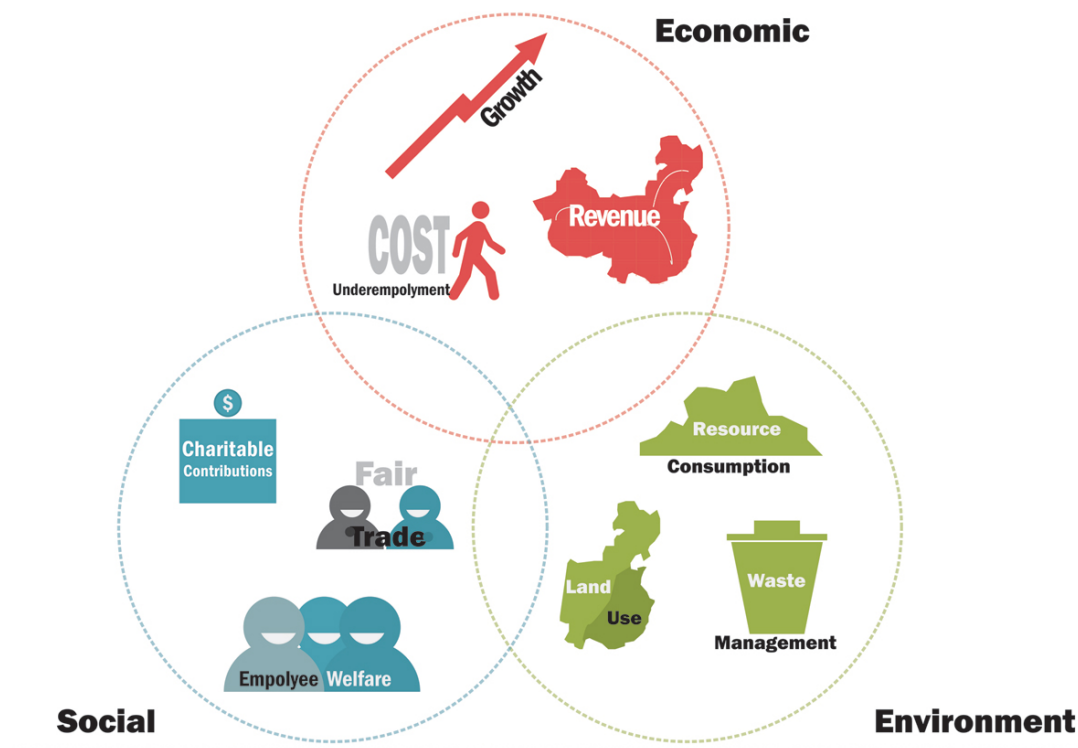
Natural capital: For how long can one live “just a little(?)” unsustainable?

How large is the local/global “Overshoot”?

Pseudo definitions of sustainability?

Wikipedia (<http://de.wikipedia.org/wiki/Nachhaltigkeit>, the three column model of sustainability http://en.wikipedia.org/wiki/Triple_bottom_line “The triple bottom line (abbreviated as TBL or 3BL, and also known as **people, planet, profit** or the **three pillars**”)

- The three column model (1994?) of sustainable development starts with the assumption that sustainable development requires work on the three goals simultaneously and equitable. Only in this way it is possible to achieve and improve the ecological, economic and social stability of a society.
- “critics” claim that the model gives equal importance to all three points, while in reality the ecological sustainability is the basis for economic and social stability. Ecological economist Herman Daly asked, **“what use is a sawmill without a forest?”**



Development towards sustainability? results from the last 20 (40) years

UN meetings Stockholm (1972), Rio (1992) and Rio+20 (2012)

“World Remains on Unsustainable Track Despite Hundreds of Internationally Agreed Goals and Objectives”

Guardian Headline (June 12, 2012)

See latest UNEP “Global Environmental Outlook” reports at <https://www.unep.org/geo/>
some data from the 2012 UNEP reports:

- Population increased from 3.9 billion (1972) to 5.5 billion (1992) to 7 billion 2012; and (without “collapse”) 8.5-9 billion people want to live in 2032.
- Non renewable energy resource consumption almost doubled from 1972 to 2012.
- CO2 levels in the atmosphere: 327 ppm (1972) to 356 ppm (1992) to (2012) 395 ppm. growing since 2012 by about 2.5 ppm/year (about 424 ppm May 2023 plus 4 ppm compared to 2022!).
- The world failed to reach the Millennium Development Goal (MDG) target of a significant reduction in the rate of biodiversity loss by 2010.
- **Economic growth has come at the expense of natural resources and ecosystems.** “As human pressures within the Earth System increase, several critical thresholds are approaching or have been exceeded, beyond which abrupt and non-linear changes to the life-support functions of the planet could occur. This has significant implications for human well-being now and in the future.”

What did change since 2012? results 2012-2022?

UNEP 2023

another decade of failures:

From “Global Environmental Outlook 7 (in preparation) ”, UNEP (2023)
at <https://www.unep.org/geo/global-environment-outlook-7>

- Current policies cannot keep pace with the rate of environmental degradation we face today.
- With current policies none of the environmental SDGs will be achieved and none of the main internationally agreed environmental goals (e.g. Paris Agreement, Aichi Targets, etc.) will be achieved.
- Because of this we face a triple planetary crisis of climate change, biodiversity loss and pollution.

30 years of global “sustainable development” since Rio 1992 made “our” life even less sustainable!

“If lost in the forest/high mountains”

If lost: apply the **STOP** principle!

from the scouts handbook <http://www.hikingdude.com/hiking-lost.php>

- S** for **Stop** (As soon as you realize you may be lost, stop, stay calm, stay put.)
- T** for **Think** (Go over in your mind how you got to where you are.)
- O** for **Observe** (Get out your compass and determine the directions from where you are currently sitting.)
- P** for **Plan** (Based on your thinking and observations, come up with some possible plans and then act on one of them.)

A quantifiable definition of sustainability

Sustainability and sustainable development are difficult to define:
lets try a well known scientific method:

Definition through negation:

“Though it seems a contradiction of terms, it is actually possible to give meaning to a term, not only by describing what it is, but also by describing what it is not. This exercise may work better with terms that are abstract or somewhat complicated.”

<http://english.tjc.edu/jbru/1301/negation.htm> and <http://en.wikipedia.org/wiki/Negation>

Ansatz (we only have two possibilities!):

We live **sustainable** or **unsustainable!**

We need to identify unsustainable aspects in our way of life!

Ansatz: unsustainable aspects in our way of life?

Unsustainable aspects of our society (culture/way of life):

- the growth of the global population
- using “non renewable” energy resources (oil, gas, coal, uranium)” and the use of non renewable mineral resources (as long as recycling is based on cheap unsustainable energy resources);
- unsustainable use of renewable (energy) resources (water, timber, sun, wind etc), e.g. the natural forest destruction for our timber needs;
- industrial agriculture destroys the soil, poisons the water and is functioning only because of cheap fossil fuels);
- non compostable waste with a long lifetime (like asbestos, plastics, toxic chemical waste, radioactive waste, CO₂)
reduce/destroy the remaining natural capital.

A quantifiable/measurable definition: “Development towards sustainability”

- if parts of the system are unsustainable, the entire system is unsustainable.
- if parts of the system (our way of life) become less unsustainable within a time interval, one can begin to talk about a “development towards sustainability”!

**Result: a new and quantifiable definition!
and a publication in February 2014 (out of the 2013 ETH lecture)**

<http://ihp-lx2.ethz.ch/energy21/sustainabilitypublished.pdf>

Development towards sustainability means:

We need to live less and less **”unsustainable”**!

What is still missing: problems for the scientists within us all:

(1) Understand the remaining resources of the natural capital (e.g. oil).

(2) Define the “Carrying capacity” as a function of the natural capital.

(3) Identify **uncontrollable “Tipping Points” of the “Titanic”?**

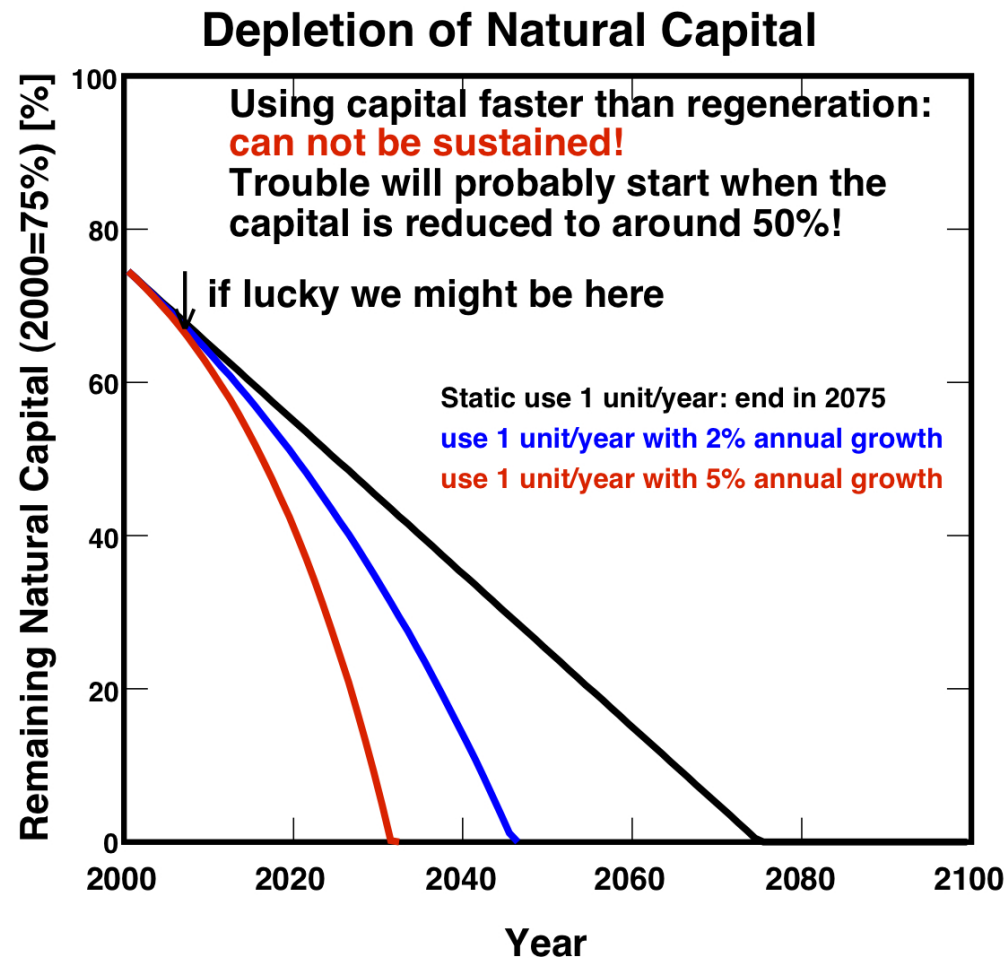
How distant are those icebergs? (e.g. What is the CO₂ concentration which results into the “Runaway” global warming?)

(4) Is it possible to help (speed up) the regeneration of natural capital?

The remaining natural capital? Local and global?

non renew. Natural Capital(t) = non renew. Nat. Cap.(0) × (1 - loss(t))

renewable Nat. Cap. (t) = Nat. Cap.(0) × (1 + yield(t) - loss(t))



our unsustainable oil usage as an example.. (what are the original resources?)

Sustainability from the perspective of physics and natural science?

Physics is great to understand/describe how parts of a system function (laws of energy conservation, EROEI, law of the diminishing energy return, the physics of the atmosphere etc)

To describe complex systems one needs many other domains of natural science (for example: why do we need biodiversity?)



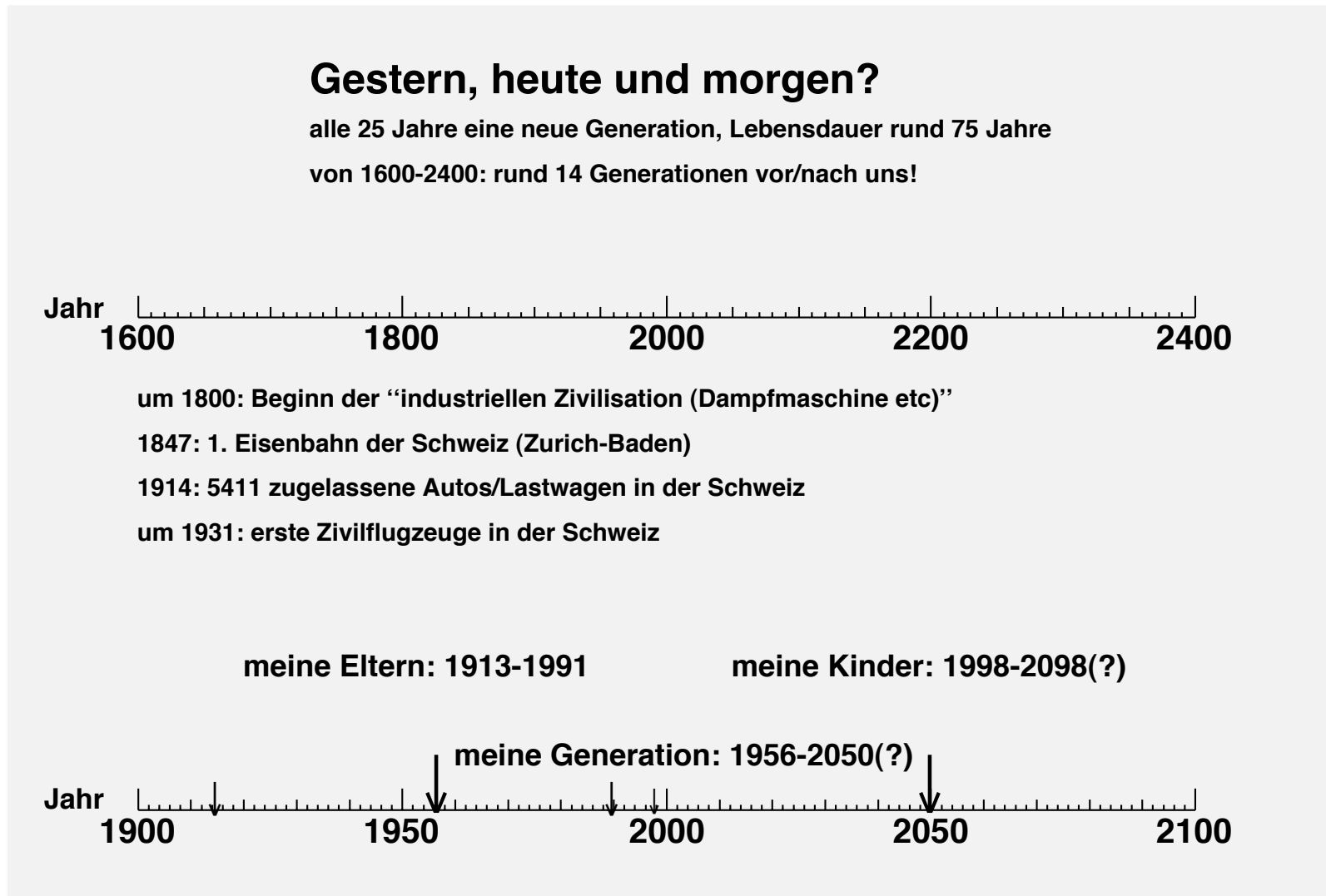
to describe human nature much more is required!

<http://www.youtube.com/watch?v=GLj0IZFLKvg&feature=topics>

the connection with human nature?

Fact: an individual life is unsustainable!

Still we are thinking about other “ways of life” and about future generations!



2min B. Russell <http://www.youtube.com/watch?v=ihaB8AF0hZo>

different hypothetical visions about the future

1. Growth (sustainable or not) as long as possible!
We do not care about a possible system collapse
("Après nous le déluge").
BAU-(business as usual) scenario and the IEA world energy outlook)
2. Achieve sustainability through less growth and with the help of
"techno fixes and techno wonders"
(Green-Economy, 2000 Watt society etc)
3. the path into sustainability through a rational decent into the valley.
(no known organisation/group/country tries this idea)
→ this must be an "impossible" vision!
4. The (ugly) path into sustainability through the system collapse.
Many cultures and empires found this path .. (easter islands, the Romans, the Maya etc.)

What would happen if the Suisse population, after an open and honest discussion could only choose between vision 3 and vision 4?
Could option 3 perhaps become more attractive?

Growth until the last barrel of oil?

Source: IEA world energy outlook 2012 and <http://www.financialsense.com/contributors/chris-martenson/really-really-big-picture>

Figure 3.15 ▸ World oil supply by type in the New Policies Scenario

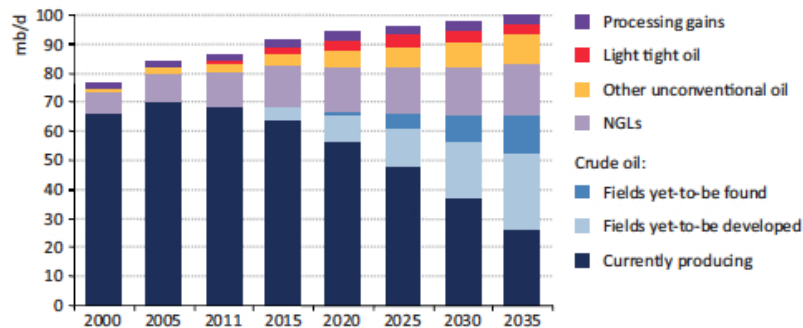
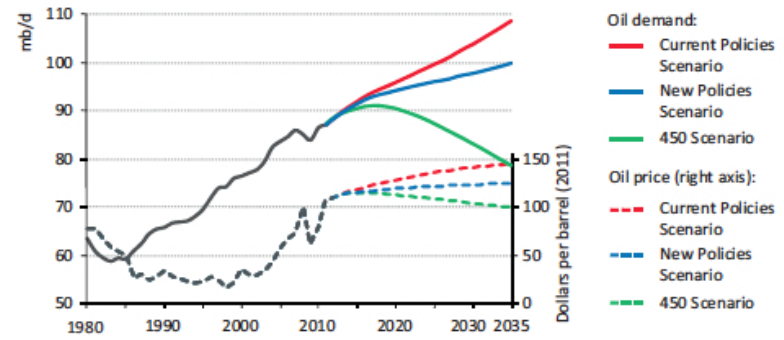
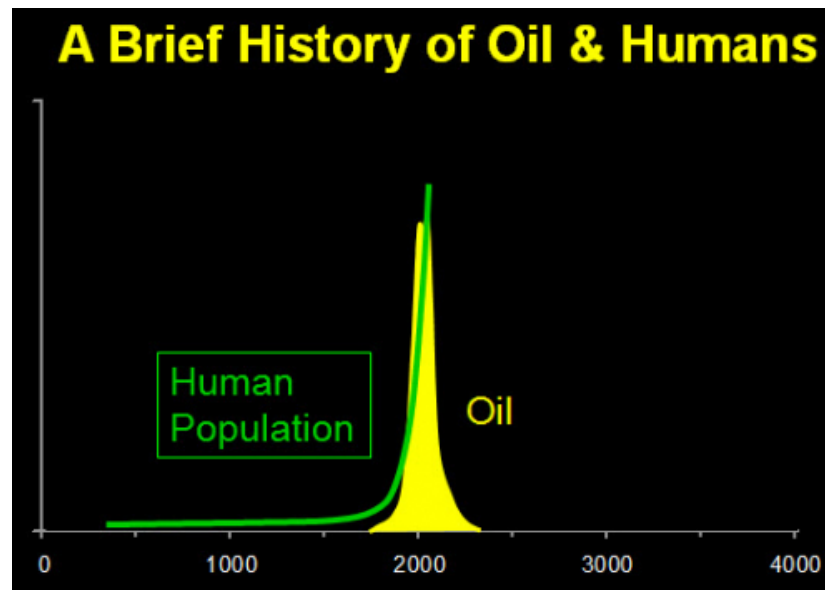


Figure 3.1 ▸ World oil demand and oil price* by scenario



* Average IEA crude oil import price.

A Brief History of Oil & Humans



Growth until the CO₂ maximum?

See: IEA world energy outlook 2012 and 2022 and

<https://www.iea.org/reports/co2-emissions-in-2022>: 36.8 Gtons (+0.9%)

Figure 8.3 ▶ Global energy-related CO₂ emissions by

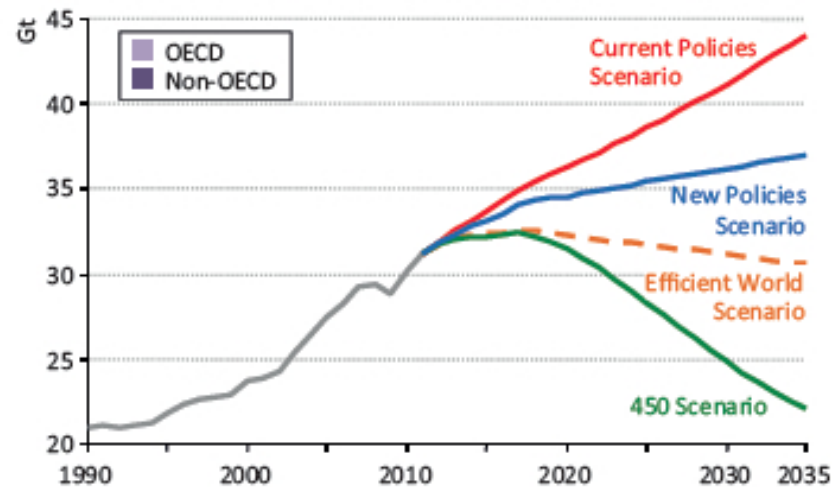
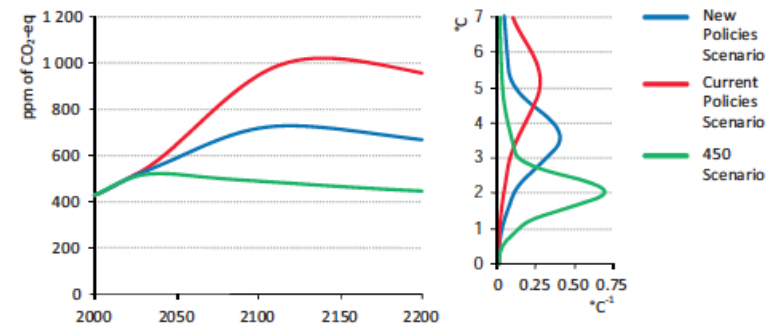


Figure 8.4 ▶ Greenhouse-gas concentration pathways (left) and probability distribution of equilibrium temperature increase above pre-industrial levels (right)



Notes: The median of the temperature distribution in the three scenarios is aligned with the respective greenhouse-gas concentration levels in 2200, where levels are almost stabilised. The probability distribution function for the temperature range was derived based on the equilibrium climate sensitivity distribution given in Rogelj, Meinshausen and Knutti (2012). PPM = parts per million.

Sources: IEA analysis using the MAGICC (version 5.3v2) and OECD ENV-Linkages models.

<http://video.nationalgeographic.com/video/news/environment-news/six-degrees-wcvin/>

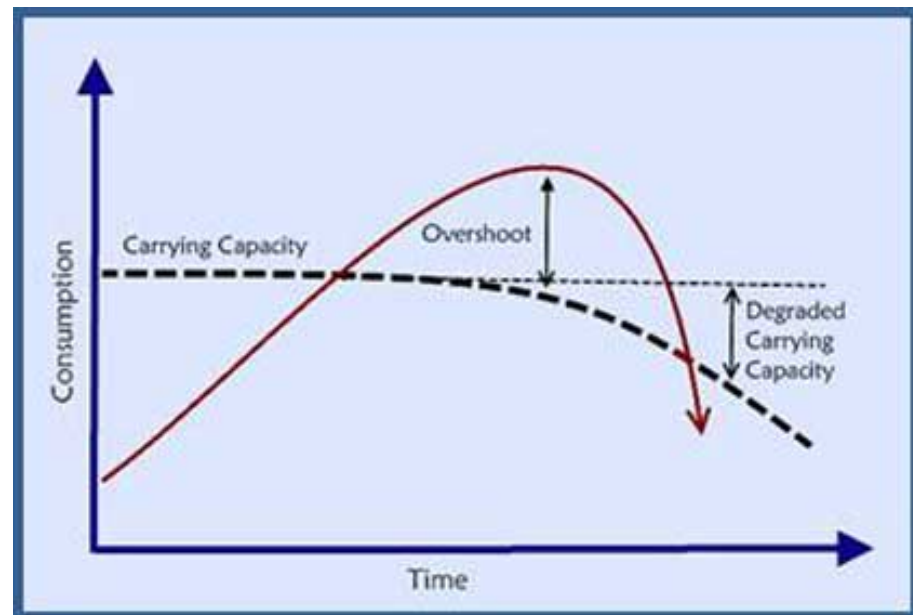
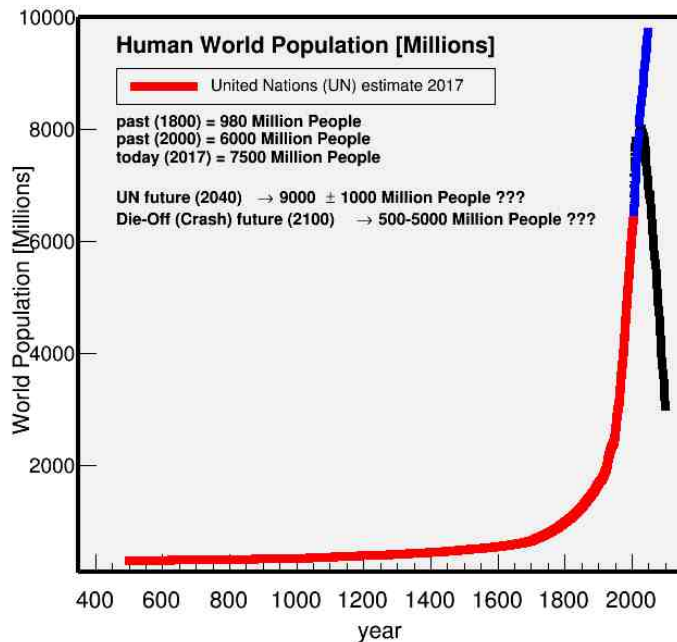
Growth of the global population and Overshoot?

Global population (November 2022): \approx 8 billion humans,
annual growth about 0.84% (about +67 millions more humans/year).

Predictions (UNO): 9 billions (2037) and about 10 billions (2057!)

If the “average” human today requires more resources than produced sustainable, it follows that “we” are not living sustainable. Future growth (and even a consumption plateau) leads directly to the global system collapse.

<http://www.worldometers.info/world-population/>, http://en.wikipedia.org/wiki/World_population
and <http://www.countercurrents.org/chefurka201109.htm>



Mega Cities with little energy/capita

Not really **“The World We Want”**!



Energy use in Switzerland: Last hundred years

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.

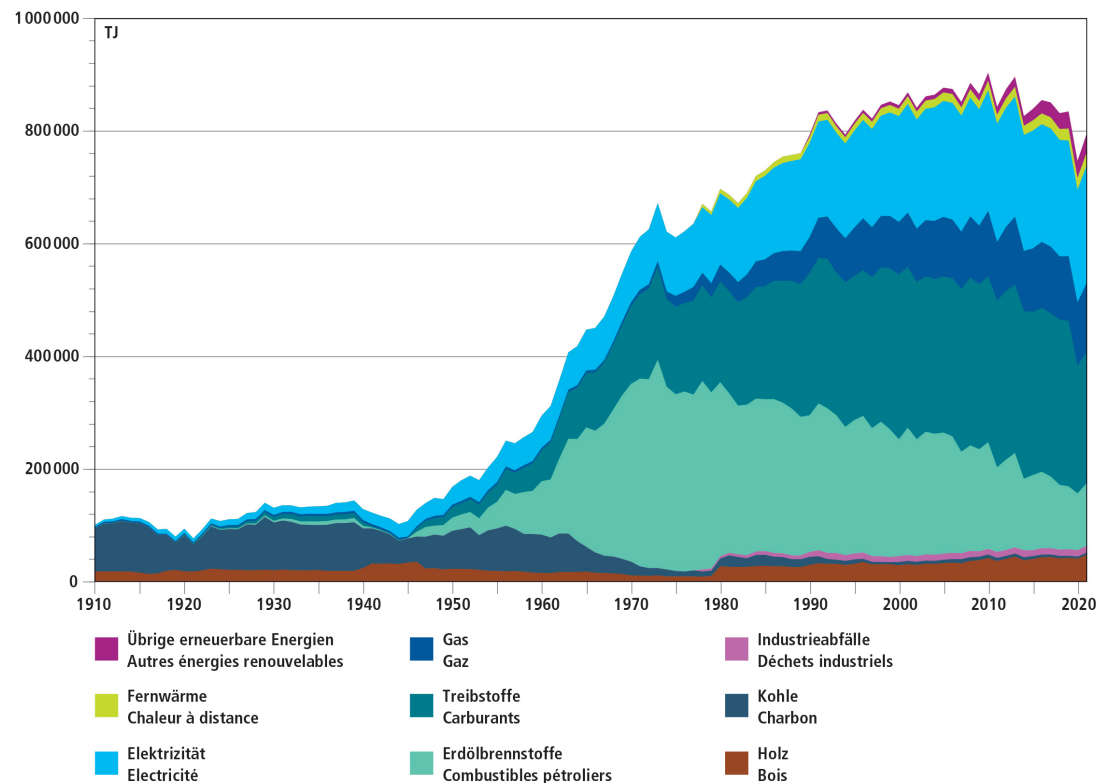
1973-1993: growth still 2-3% /year! “Termination” of coal. Oil allows cheap mass transport.

1993-2008: Growth now 1-2% /year! Globalized transport of people and consumer goodies thanks to oil.

2009-2020: “Stagnation” and a beginning decline?

2021-2050: the promised land: terminate the use of oil, gas and coal by 2050!

Fig. 1 Endenergieverbrauch 1910–2021 nach Energieträgern
Consommation finale 1910–2021 selon les agents énergétiques



BFE, Schweizerische Gesamtenergiestatistik 2021 (Fig. 1)
OFEN, Statistique globale suisse de l'énergie 2021 (fig. 1)

more at: <http://www.bfe.admin.ch>

Overshoot, global and locale sustainability (1) (some unhappy thoughts)

actual carrying capacity(t) = carrying capacity(t) + ghost-carrying capacity(t)

if we are using more than our regular income we are not living sustainable!

we have exceeded the global “carrying capacity”!

- No unique method to estimate the “carrying capacity” of planet earth!
0.1 billions?, 1 billion(?) or 5 billions(?) humans
- Before using fossile fuels: human population was less than 1 billion
(and only rarely(?) they lived “sustainable”)
- According to the “EcoFootprint” concept we are using about 1.4 Planets annually: the Earth has space for about 5 billions average humans (ignoring the “Ghost carrying capacity”). increasing living standard for everyone (to Suisse/EU average) would increase the impact to 4 planets the planet would provide “space” for 1.75 billion people!.
- the EcoFootprint concept ignores the Ghost Carrying Capacity and the limited (energy) resources.
The real carrying capacity is much smaller!
- Even the Ghost-Carrying Capacity expected decline!
Energy and water etc resources are finite and not only CO2 pollutions increase!

Overshoot, global and locale sustainability (2)

(“happier” thoughts, I want to believe!)

real carrying capacity(t) = carrying capacity (t) + ghost-carrying capacity (t)

(1) For a good life our Impact (**Impact = P x A x T**) does not have to be so large and

(2) (in theory) we could increase the carrying capacity by ”repairing” the damage done in the past!

- Many reports and studies indicate that (as long as minimal requirements are fulfilled): **Affluence and quality of life are not correlated!**
- Examples demonstrate that the local (and global) “carrying capacity” can be increased and repaired (“greening the desert”)
<https://www.youtube.com/watch?v=2xcZS7arcgk>

What if we change <http://www.youtube.com/watch?v=6iJKiFSQLn4>

- Humans can be destructive or constructive!
We can turn “forests into deserts or deserts into “Food Forests” .
The “deserts” in Switzerland are relatively small!
- Successful examples of “developments towards sustainability” in a well functioning community give people power, energy and enjoyment in life!
- Suisse mountain adventurers (guides) have in general a fulfilling life!
http://en.wikipedia.org/wiki/Happy_Adventure.

Instead of a summary: Our current way of life is unsustainable!

Our globalised civilisation appears as a nightmare:
perhaps like a Titanic travel (and many of us as first class passengers!)
and the loudspeakers confirm permanently: “there is nothing better and
(Tina = There Is No Alternative)



but: the “iceberg” collision has not yet happened! Is there really no alternative?

Some additional material for further discussions

and much more at <http://ihp-lx2.ethz.ch/energy21/>

Pseudo definitions of sustainability? example

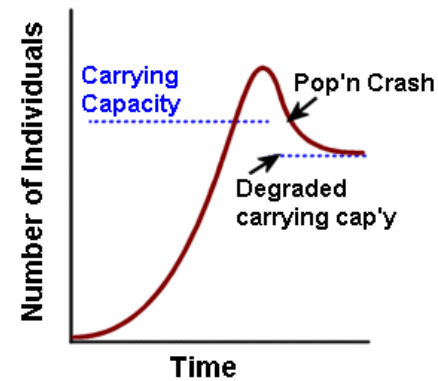
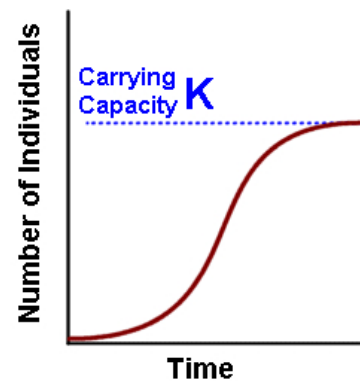
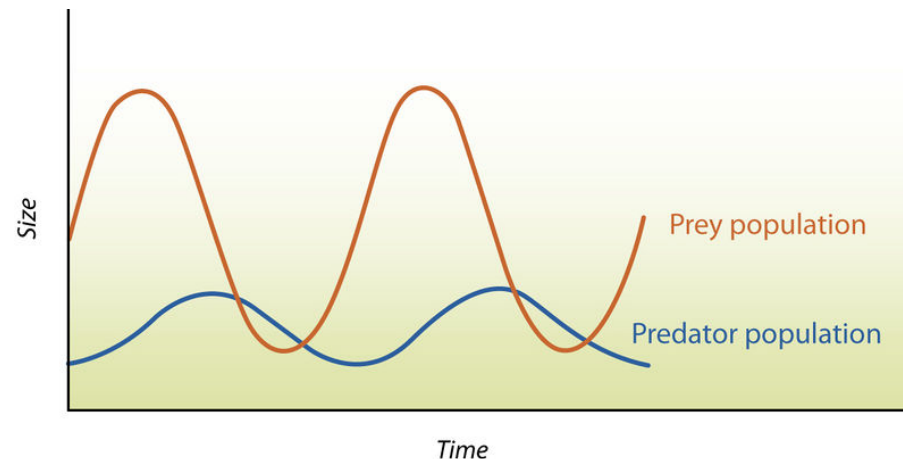
- “scientific” discussions about sustainability distinguish between “weak” and “strong” sustainability:
 - **weak sustainability**: It is assumed that ecological, economic and social resources can be weighted against each other. For example it might be ok to destroy natural resources if sufficient human capital can be created by the process and the economy capital can compensate the missing natural capital).
 - **strong sustainability** assumes that natural capital can not really be replaced with human or monetary capital.

In addition: **Circles of sustainability** is a method for understanding and assessing sustainability, and for managing projects directed towards socially sustainable outcomes and adds a fourth column (dimension): **“culture”** see Wikipedia (http://en.wikipedia.org/wiki/Circles_of_Sustainability)

Population as a function of time; Population dynamics (biological basics)

Population dynamics and population ecology

$$\text{Pop}(t) = P(0) + (\text{birth rate}(t) + \text{immigration}(t)) - (\text{death rate} + \text{emigration}(t))$$



St Matthew Island Reindeer: http://www.youtube.com/watch?v=gS-jZp_cvqY

Impact=Population x Affluence x Technology (1)

the Human I=PAT equation: http://en.wikipedia.org/wiki/I_%3D_PAT

P.R. Ehrlich, J.P. Holdren, Impact of population growth, Science, 1971

“Human Impact (I) on the environment equals the product of P= Population, A= Affluence, T= Technology. This describes how our growing population, affluence, and technology contribute toward our environmental impact.”

- **Impact:**our “environmental impact”
- **Population:** “Since the rise of industrial societies, human population has been increasing exponentially.”
- **Affluence:** “average consumption of each person in the population. As the consumption of each person increases, the total environmental impact increases as well.”
- **Technology:** “how resources are used to produce our affluence. (Increases in efficiency can reduce overall environmental impact. However, with P increasing exponentially, T would have to decrease drastically (doubling efficiency each time the population doubles))”

If, on average, we use more natural capital (Impact) than is regenerated, then we violate the local and global sustainability principle!

Is it really possible that the global population can increase from 7.5 billions to 9-10 billions?
Is it really possible that the population in Africa can grow from 1 billion today to 3.5 billions?

(what will happen to the Gorillas, Chimps, Bonobos, Elephants, Lions etc?)

Impact=Population x Affluence x Technology (2)

a new modified and quantifiable Impact Equation: M.D. 2013!
Impact in relation to Carrying Capacity (CC) (natural capital)

$$CC(\text{time}) = CC(t=0) - \text{Impact}(t) + \text{Restoration}(t)$$

Impact (t) = natural reduction (like volcano eruptions) + I(=PAT (human))
Restoration(t) = nat. Rest. (e.g. tree growth) + Rest. (Human help!)

Using the natural capital faster than its regeneration violates the local and global sustainability principle!

Huge Ghost carrying capacity “thanks” to non renewable resources

Switzerland: Without oil and electric energy almost nothing functions today.

Overshoot = the Suisse “footprint” (impact) is about 4 times larger than the Suisse natural restoration. Adding the Ghost Carrying capacity impact (imagine to replace oil with timber): the overshoot is at least 40 times larger.

We need to quantify the situation with the remaining resources!

Overview: modern(?) humans today

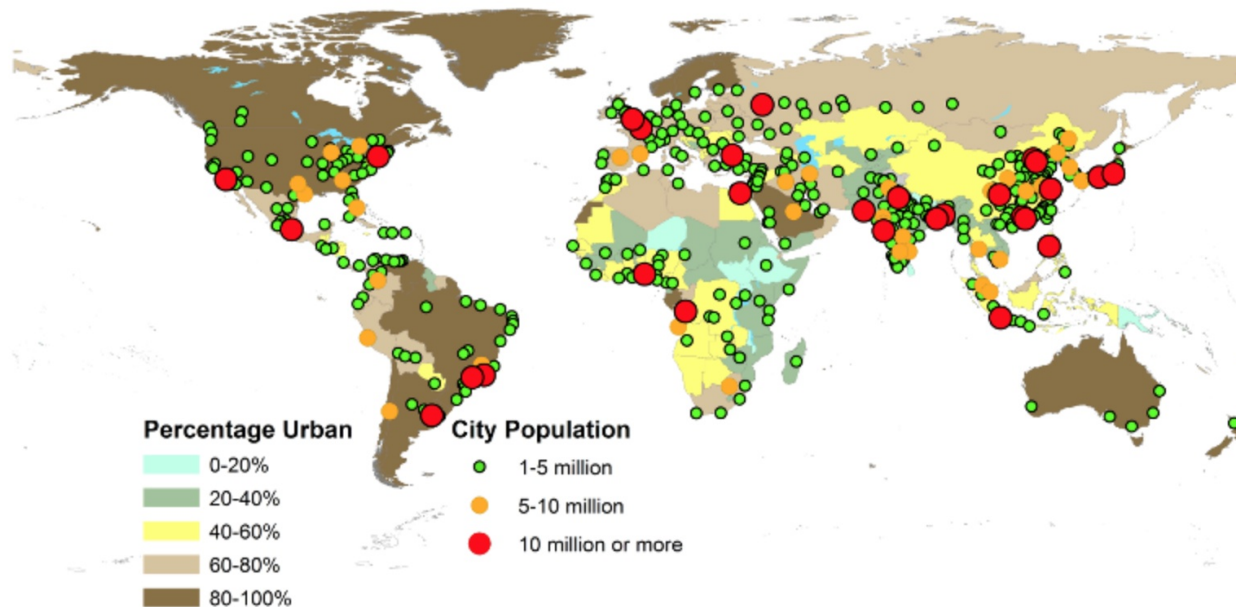
Quote: “That cause, in the case of the Sixth Extinction, is ourselves – Homo sapiens. This means we can continue on the path to our own extinction, or, preferably, we modify our behavior toward the global ecosystem of which we are still very much a part.” “Homo sapiens became the first species to stop living inside local ecosystems. All other species, including our ancestral hominid ancestors, all pre-agricultural humans, and remnant hunter-gatherer societies still extant exist as semi-isolated populations playing specific roles (i.e., have “niches”) in local ecosystems. This is not so with post-agricultural revolution humans, who in effect have stepped outside local ecosystems(is it true??).”

Text from <http://www.actionbioscience.org/evolution/eldredge2.html>

Percentage urban and urban agglomerations by size class

1970 1990 2014 2030

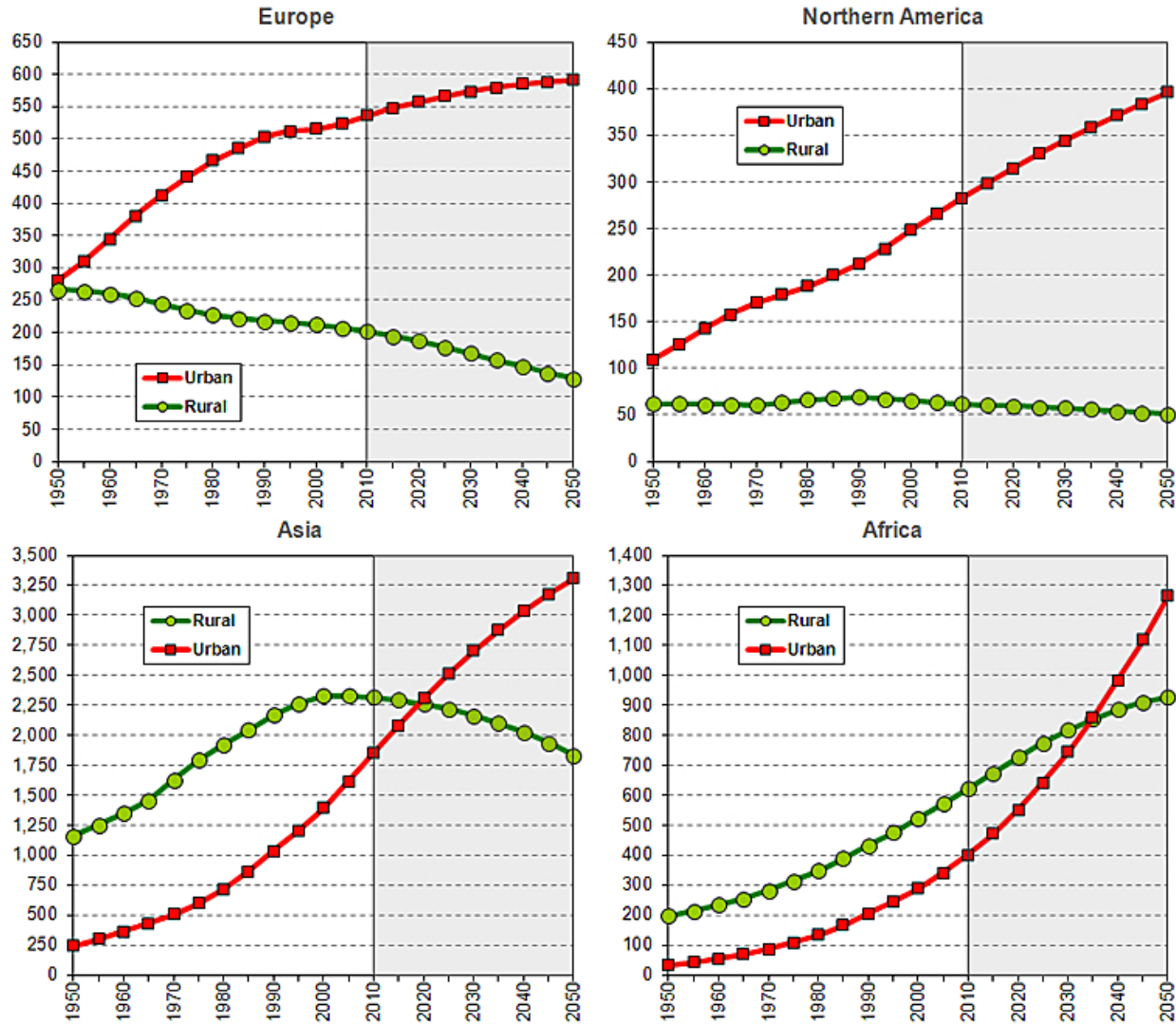
(click on the image to open a full version of the map, in PDF)



Note: Designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

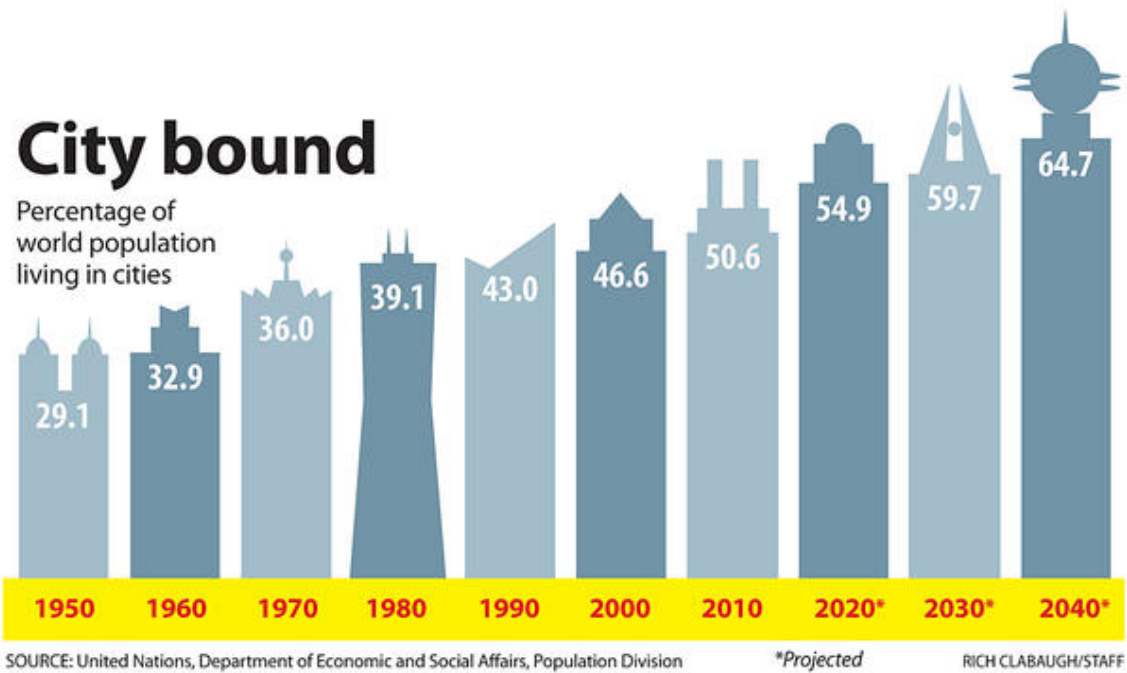
Source <http://esa.un.org/unpd/wup/Maps/CityDistribution/CityPopulation/CityPop.aspx>

Our future: Rural or Urban?



Source: http://esa.un.org/wpp/unpp/panel_population.htm
original version of plots was http://esa.un.org/unpd/wup/Analytical-Figures/Fig_6.htm

Overview: the Mega Cities(1)



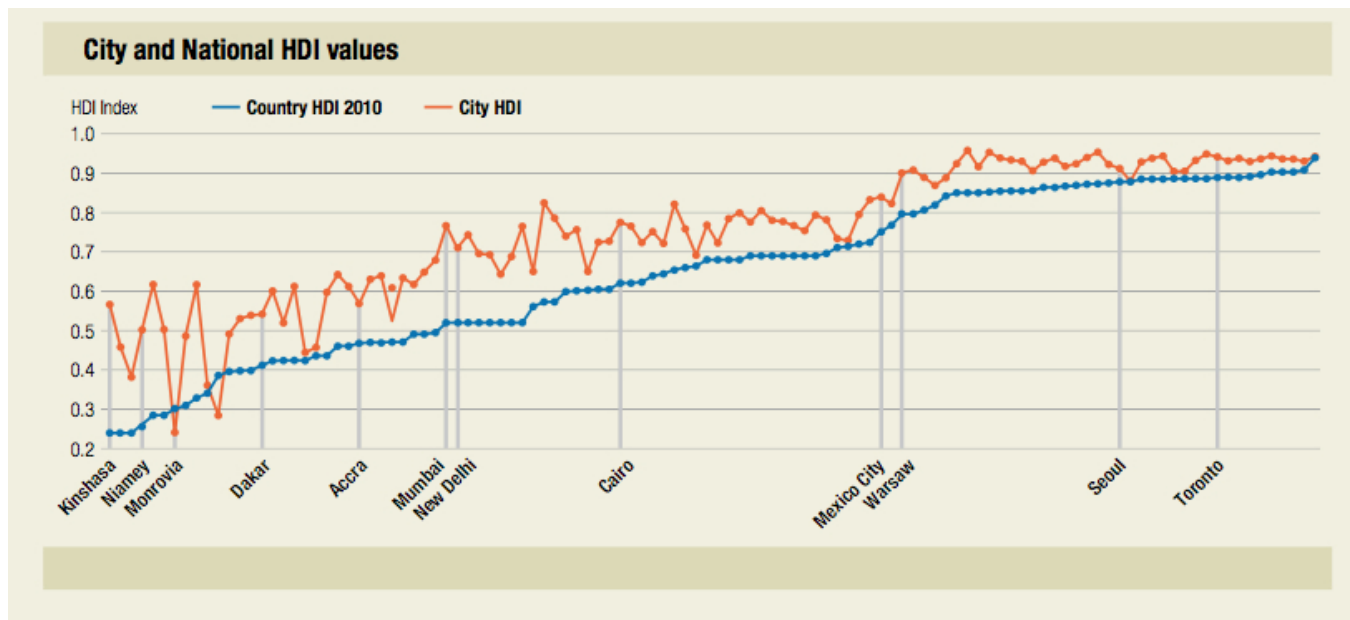
Overview: the Mega Cities(2) (1990-2010)

HDI (human development index) and Mega Cities?

the growth of the Urban Slum Population:

Developing Regions: 650 Millionen (1990) → 862 Millionen (2012)

Sub-Saharan Africa: 102 Millionen (1990) → 213 Millionen (2012)



Plot from (the Slum numbers are from the "small print" appendix, table 2 and 3)

<http://unhabitat.org/books/prosperity-of-cities-state-of-the-worlds-cities-20122013/>

Overview: the Mega Cities(3) (2010-2025?) are the UN expectations even possible?

Andrew Marr's Megacities Cites on the Edge Episode 2

<https://www.youtube.com/watch?v=uXX8IaPesBs> (Dhaka min 50)

example Mexiko-City <http://www.youtube.com/watch?v=4nwsj4Q08Go>

Megacity slums <http://www.youtube.com/watch?v=xoo4YKqwFbM>

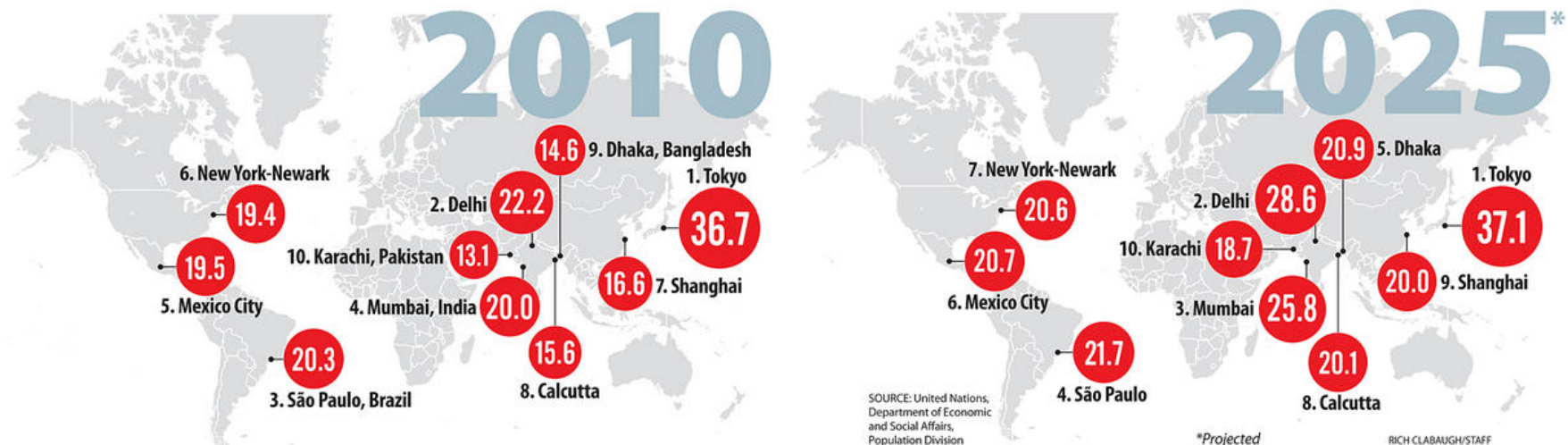
Air pollution in China <https://weather.com/science/environment/video/shocking-before->

Delhi 22.2 Mill. (2010) → 28.6 Mill (2025)

Dhaka 14.6 Mill. (2010) → 20.9 Mill (2025)

Africa: Cairo 7.8 → 13.5 Mill.; Lagos 7.9 → 15.8 Mill; Kinshasa 5.5 → 15.0;

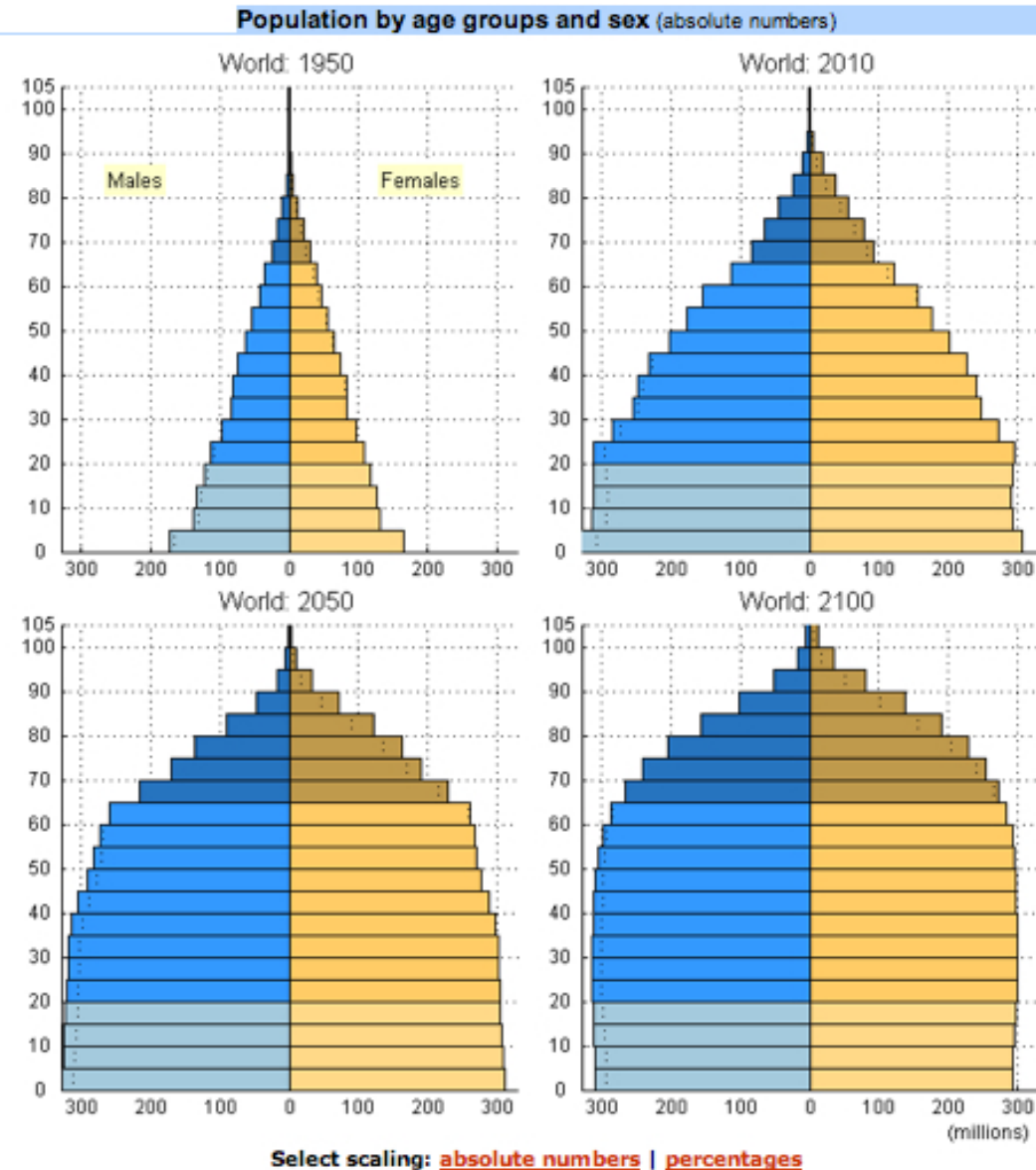
<http://unhabitat.org/books/prosperity-of-cities-state-of-the-worlds-cities-20122013/>



Overview: the global population (1)

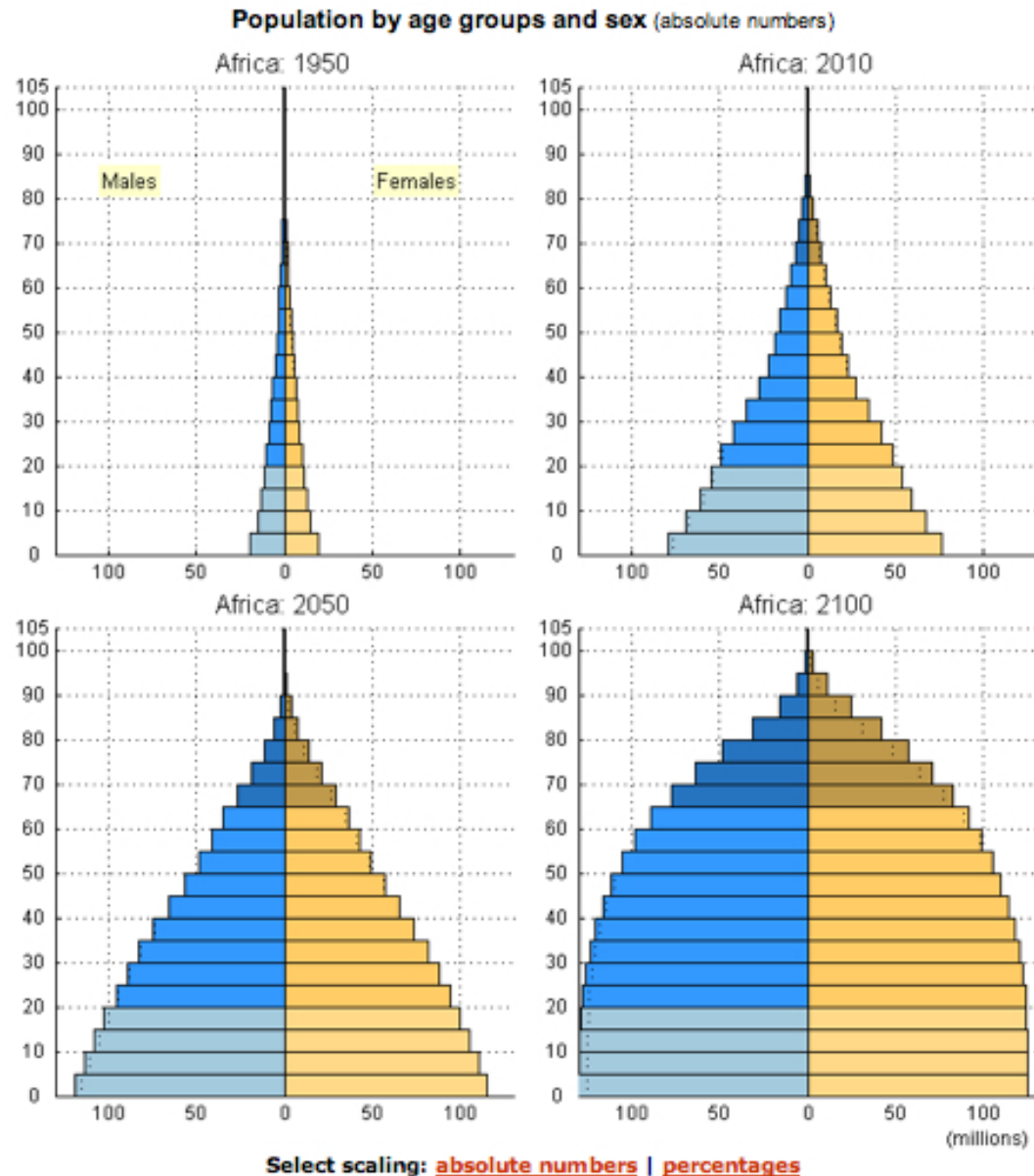
age pyramid changes for the “world population” (UN demographers) and more UN numbers at <http://populationpyramid.net>

Even with 2.1 children/woman (“replacement” birth rate) and no catastrophes, the global population will grow further to about 11 billion by 2100.



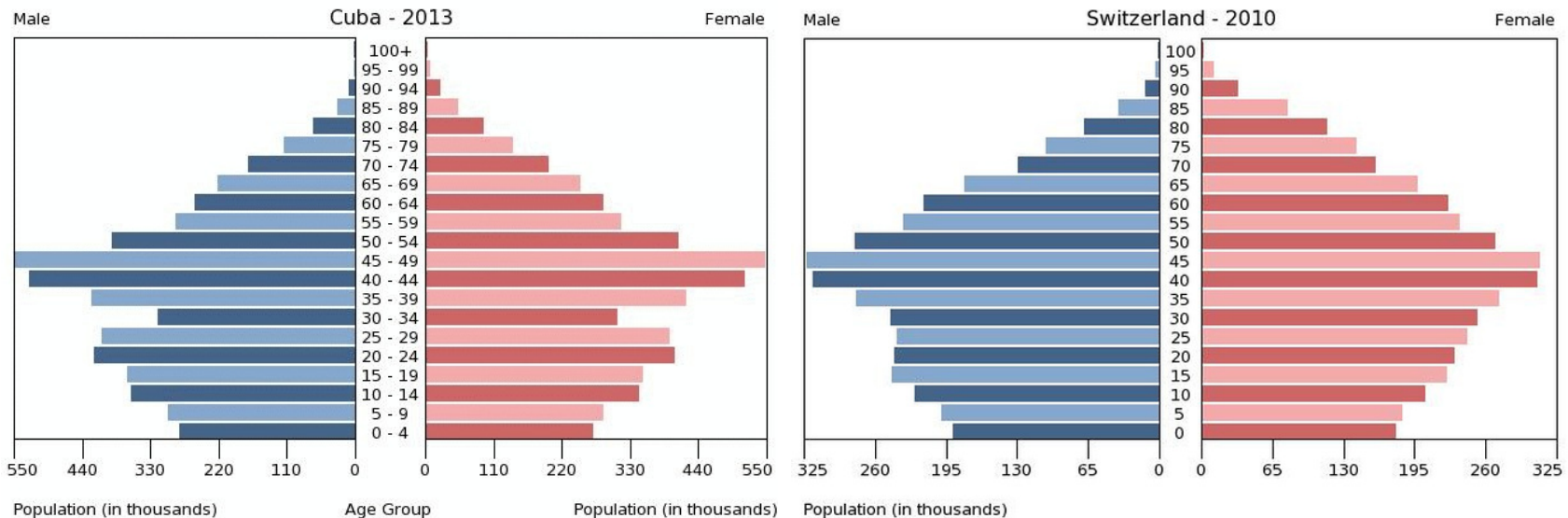
Overview: the population in Africa(1)

age pyramid changes in Africa (UN demographers) “without” catastrophes
african population will grow from 1 billion to 3.5 billion people by 2100!
more numbers at <http://populationpyramid.net/africa/>



Cuba and Switzerland: “surprising” similarities and differences

	Cuba	Switzerland	Haiti	Dominik. Rep.
Population	11.4 Million	8.1 Million	10 Million	10.3 Million
Pop/km2	102	188	362	207
urbanisation	76%	74%	53%	70.5%
pop. growth/y	-0.14%	1.1%	1.-1.6%	1.3-1.5%
average age	36 years	40 years	22 years	27 years
life expectancy	77 / 81 years	80 / 85 years	62 / 64 years	72 / 74 years
children/woman	1.5	1.5	3.3	2.5
infant mortality	0.37%	0.47%	5%	2.4%
Med Doc/1000	6.1	3.6	0.25	1.9
cars/capita	0.038	0.57	0.012	0.13



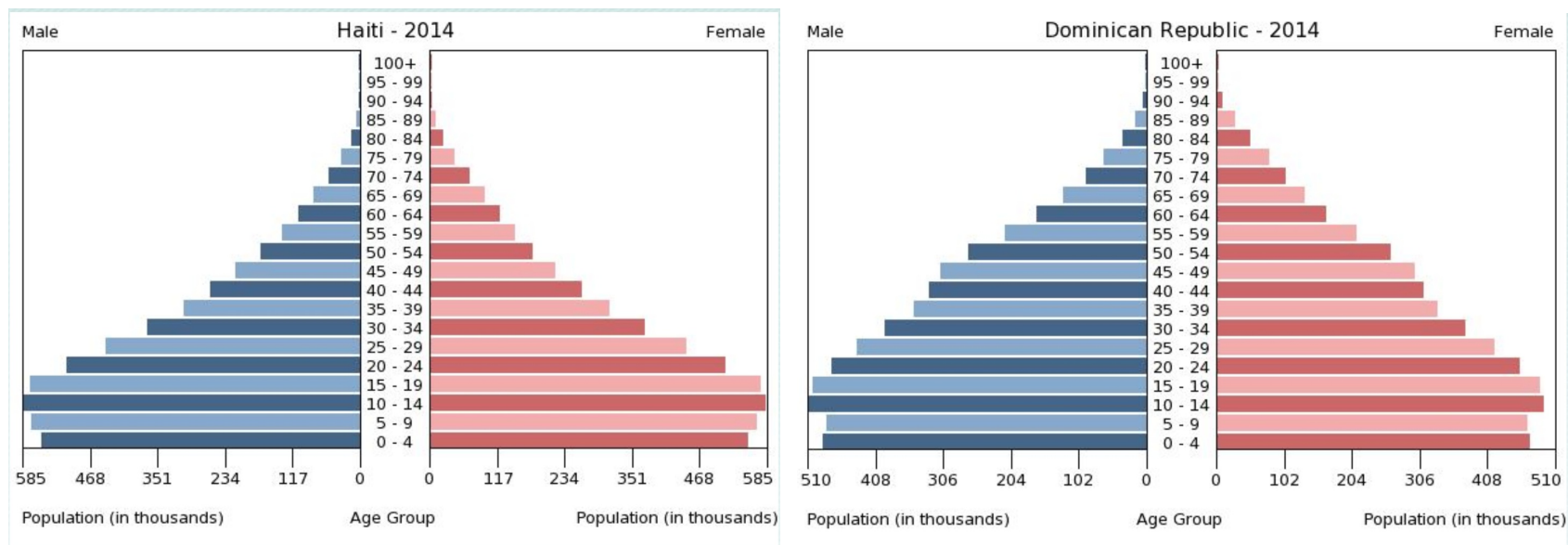
sources: CIA world fact book

Population Pyramids: “surprising” differences” Cuba (Switzerland) and Haiti, Dominican Rep.

With the words from the CIA world fact book:

“After a prolonged struggle, Haiti became the first post-colonial black-led nation in the world, declaring its independence in 1804...”

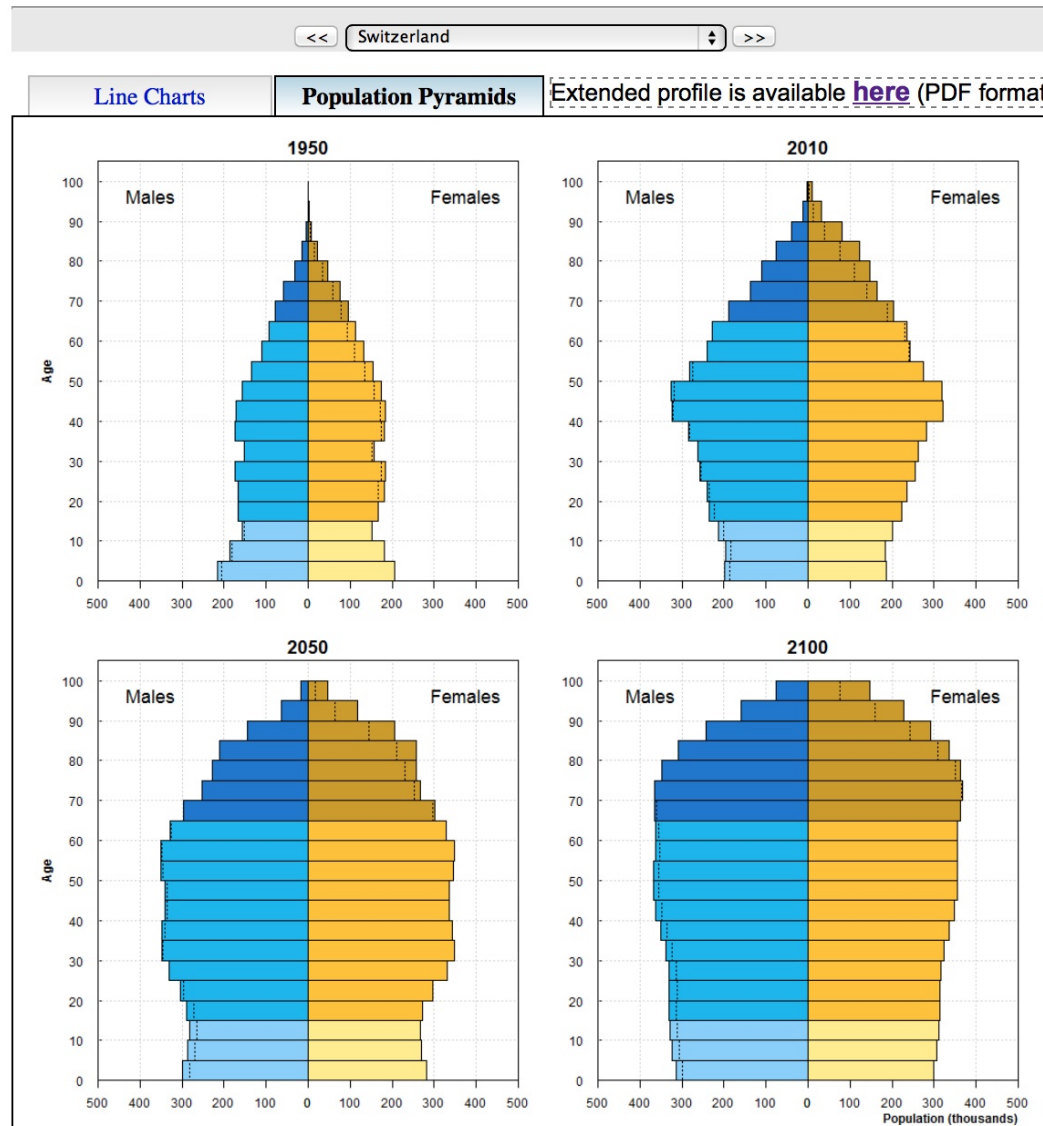
*“Currently the poorest country in the Western Hemisphere”
(a harsh punishment for this 1804 revolution!)*



sources: CIA world fact book

For more details: the Population of Switzerland

the latest UNO 2015 revision plots: modelled age structure in Switzerland <http://esa.un.org/unpd/wpp/Graphs/DemographicProfiles/> und <http://esa.un.org/unpd/wpp/Graphs/Demographic-Profiles/pdfs/756.pdf>



Source: United Nations, Department of Economic and Social Affairs, Population Division (2013). World Population Prospects: The 2012 Revision, Volume II, Demographic Profiles (ST/ESA/SER.A/345)