Our Successful Future

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of IFRES, Université de Liège

Our Successful Future
- Introduction, Summary

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brief CV

to 1984	studied chemical engineering at RWTH Aachen
1984 - 1985	studied with J.M. Prausnitz, UC Berkeley, California
1987	Ph.D. in Chemical Engineering at RWTH Aachen
1995	habilitation at TU Darmstadt
1995 - 2011	full professor, RWTH Aachen
2011 - 2014	full professor, Graz University of Technology
since 2014	full professor, University of Liège

relevant publications

Pfennig, A. (2007). Supporting debottlenecking of global human processes by applying appropriate balances. Biotechnology Journal, 2(12), 1485-1496.

Pfennig, A. (2007). Globale Bilanzen als Wegweiser für nachhaltiges Wirtschaften. Chemie Ingenieur Technik, 79(12), 2009-2018.

Frenzel, P., Fayyaz, S., Hillerbrand, R., Pfennig, A. (2013). Biomass as Feedstock in the Chemical Industry - An examination from an Exergetic Point of View. Chemical Engineering and Technology, 36(2), 233-240.

Frenzel, P., Hillerbrand, R., Pfennig, A. (2014). Exergetical Evaluation of Biobased Synthesis Pathways. Polymers, 6(2), 327-345.

Frenzel, P., Hillerbrand, R., Pfennig, A. (2014). Increase in energy and land use by a bio-based chemical industry. Chemical Engineering Research and Design, 92, 2006-2015.

Frenzel, P., Pfennig, A. (2014). Bewertung der steigenden Nachfrage nach Diesel-Kraftstoffen hinsichtlich ihrer CO2-Emissionen. In U., Bachhiesl (Ed.), Innehalten und Ausblick: Effektivität und Effizienz für die Energiewende (pp. 1-9).

Pfennig, A. (2018). So gelingt unsere Zukunft. Books on Demand, Norderstedt

agenda

- introduction, summary
- world population ⇒ driving force
- sustainable energy transition ⇒ time scale
- food vs. bioeconomy, hunger ⇒ limiting criteria
- a word on IPCC scenarios
- exergy to quantify energy
- bio- or CO_2-economy→ fuel & material ⇒ options
  bio-economy ⇒ chances & challenges
- individual and political consequences

philosophy:

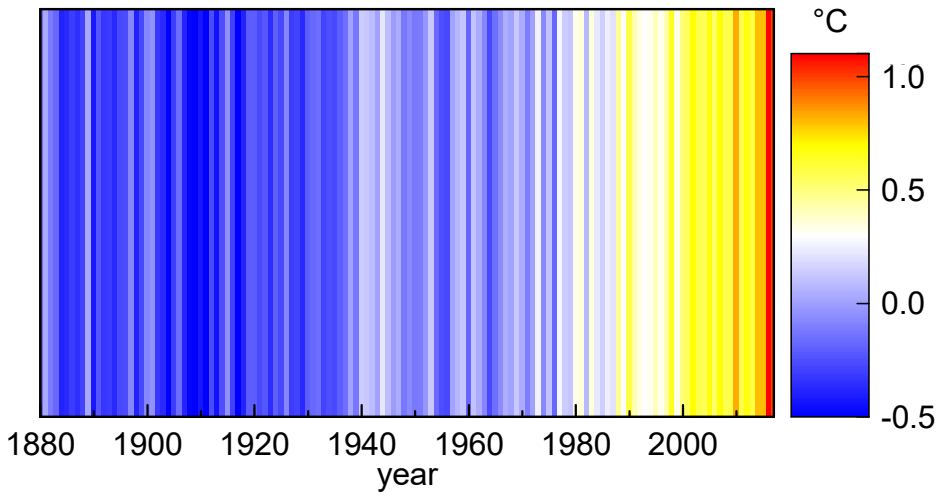
- physical basis
- causality
- conscioness
- free will and responsibility

the playlist on YouTube

https://www.youtube.com/
search on YouTube:
andreas pfennig sustainability

www.chemeng.uliege.be/successfulfuture

global mean temperature



GISTEMP Team, 2018: *GISS Surface Temperature Analysis (GISTEMP)*. NASA Goddard Institute for Space Studies. Dataset accessed 2018-11-14 at https://data.giss.nasa.gov/gistemp/

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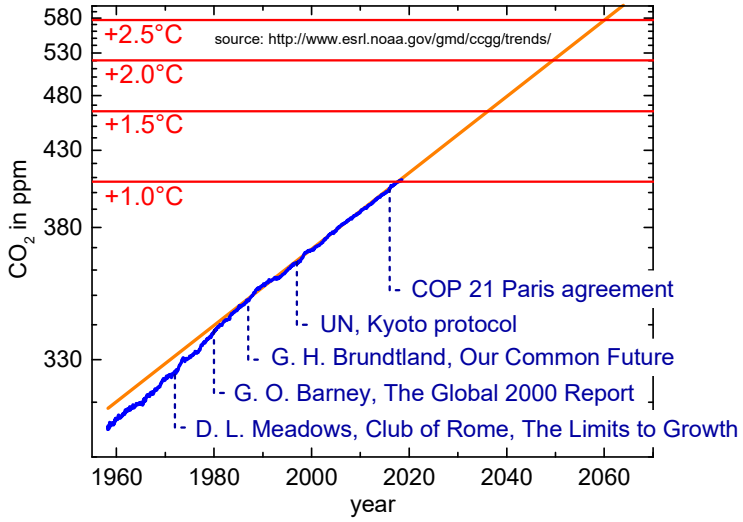
CO_2 content of the atmosphere



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UN Climate Conference 21, 2015, Paris

Article 2.1:

This Agreement ... aims to strengthen the global response to the threat of climate change ... by:

Holding the increase in the global average temperature to **well below 2 °C** above pre-industrial levels and to **pursue efforts to limit** the temperature increase **to 1.5 °C** above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change...

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modelling approach

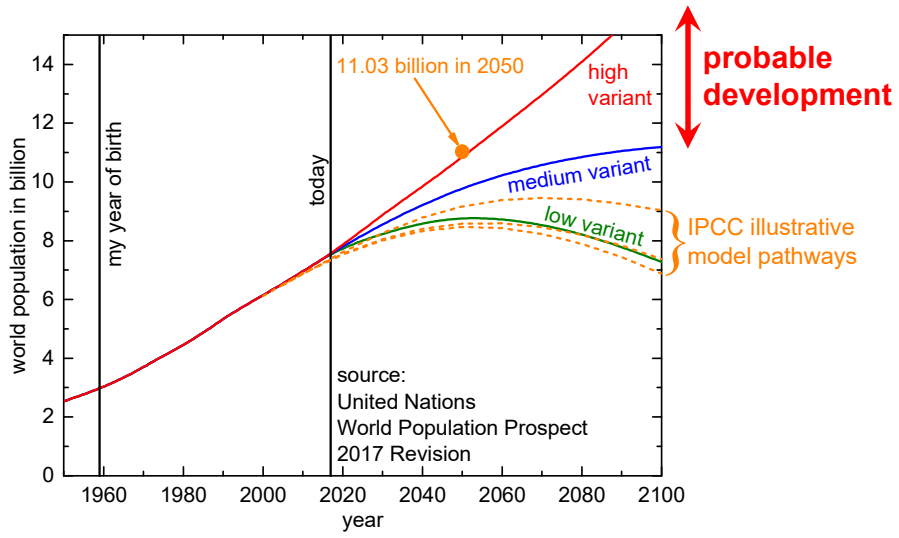
- not an IAM (integrated assessment model)
- based on simple balances:
  - influence of individual parameters directly visible
  - main drivers easy to realize

negative influence of too detailed models:

K. Sundmacher, A. Kienle: Reactive Distillation Status and Future Directions. Wiley-VCH, Weinheim, 2003

the system, scale-down factor 10 000 000

world population scenarios



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population growth eating up progress

since 1990:

- additional people fed: 2.5 bn
- population increased by: -2.3 bn
- undernourishment decreased by 0.2 bn

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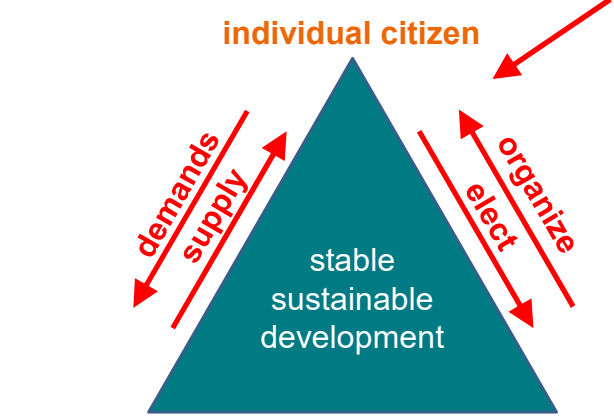
individual actors



media, NGOs, religion, ...
- legitimation?
- representing whom?
- legitimate goals?
- controlled how?
- transparency!

⇒ **systems view essential**

in conclusion

- reaching climate goals is possible with available technology, but systematically applied on larger scale
  - significant **increased global effort** is required, **growth 20 - 30%/a**
  - replace fossil resources annually by up to
    - for +1.5°C goal: **3%/a until 2050**
    - for +2.0°C goal: **2%/a until 2075**
- **food supply is critical**, but **change of individual choices essential:**
  - number of children
  - plant-based vs. animal-based food
- **bio-based or CO_2-based** materials production is feasible, but not solely from third-generation biomass
- **minimize bio-energy:** fuel vs. food
- **systems view** instead of focus on own interests
- **developmental tipping point** is possible
- **individually responsible**, not just question of politics & technology
- it **has to happen now**, otherwise situation will get bad during our lifetime and that of our children

all in one book

Andreas Pfennig, 2018
So Gelingt unsere Zukunft
Books on Demand, Norderstedt
www.bod.de/buchshop/so-gelingt-unsere-zukunft-andreas-pfennig-9783752831870

chapter titles:

1 Leben, Tod und Sterben
2 Evolution
3 Realität, Wissen und Wahrnehmung
4 Lernen und wissenschaftliche Erkenntnis
5 Wissenschaftliche Weltsicht
6 Gehirn, Bewusstsein, Selbst, Kausalität und freier Wille
7 Weltanschauung, Sinn und Ethik
8 Globale Ethik, individuelles Handeln
9 Gelungenes Leben, Menschsein

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- World Population

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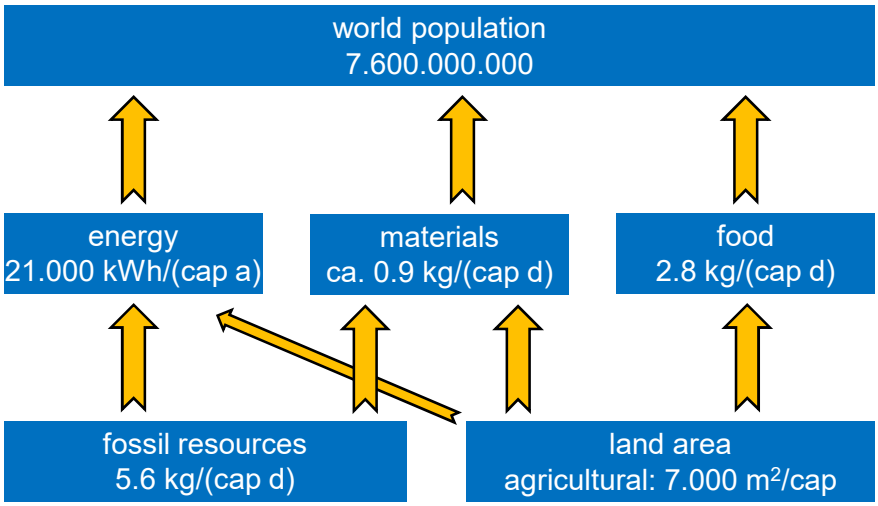
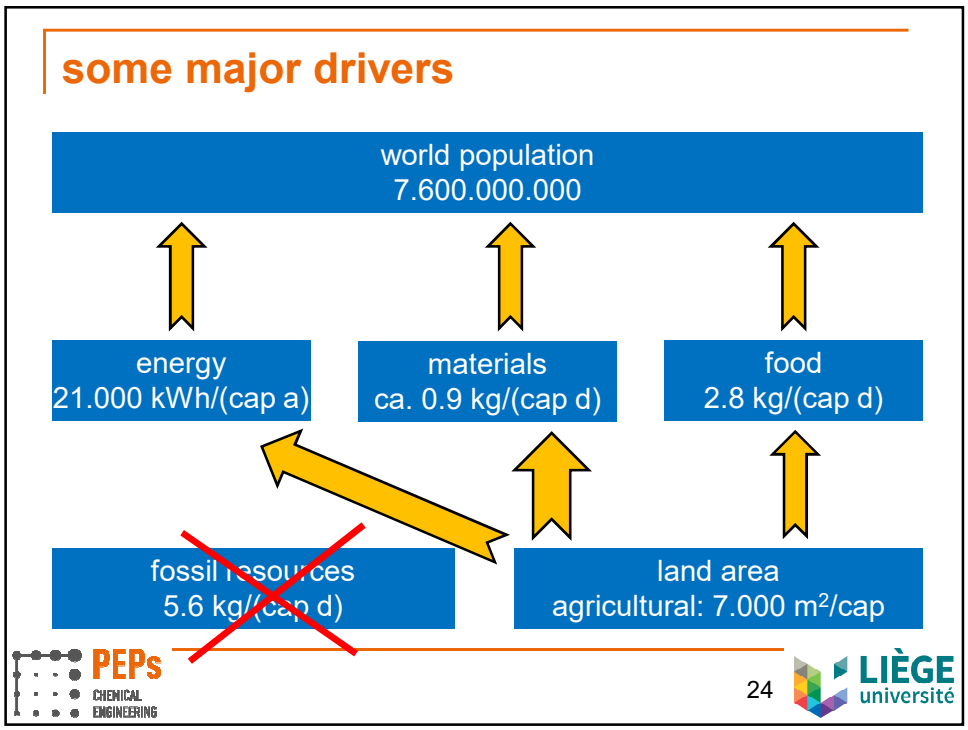
questions to be answered

- Why is world population so important?
- What is known about development of world population?

some major drivers




some major drivers
world population
7.600.000.000
energy
21.000 kWh/(cap a)
materials
ca. 0.9 kg/(cap d)
food
2.8 kg/(cap d)
fossil resources
5.6 kg/(cap d)
land area
agricultural: 7.000 m²/cap
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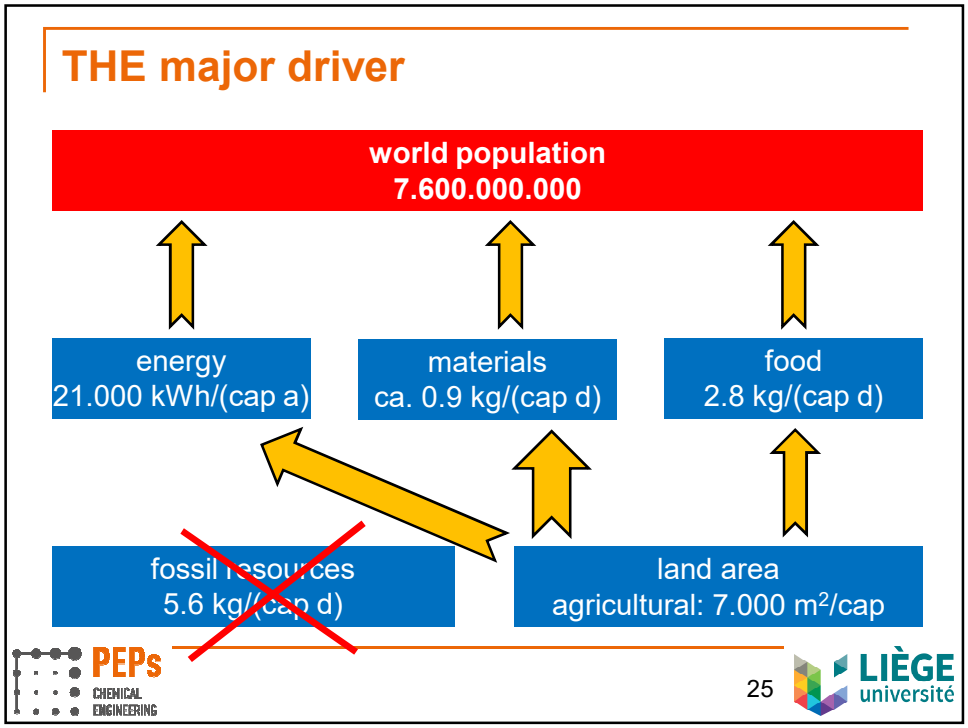
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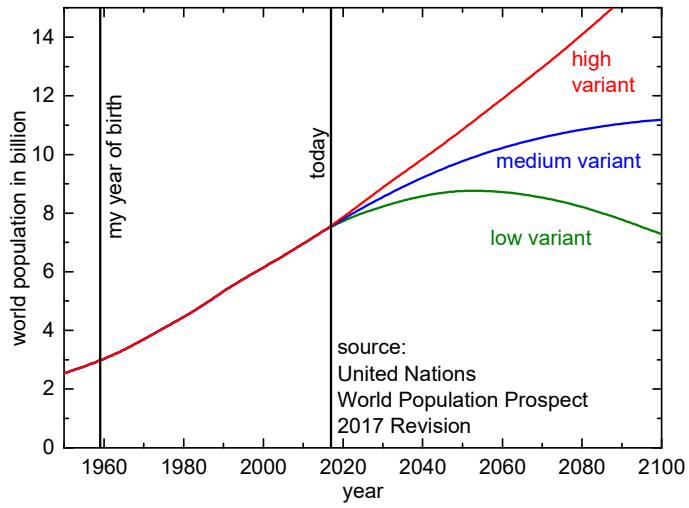
UN world-population scenarios



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data sources

- United Nations, DESA/Population Division, 2017 Revision of World Population Prospects, population.un.org/wpp/, accessed 20.09.2018.

- UN Department of Economic and Social Affairs, Population Division, Long-range World Population Projections: Based on the 1998 Revision, 1998, www.un.org/esa/population/publications/longrange/longrange.htm (accessed 31.07.2018).
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2000 Revision. Volume III. Analytical Report. United Nations, New York 2002.
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2002 Revision. Volume III: Analytical Report. United Nations, New York 2004.
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- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2012 Revision. Volume I: Comprehensive Tables. United Nations, New York 2013, population.un.org/wpp/Publications/ (accessed 20.09.2018).
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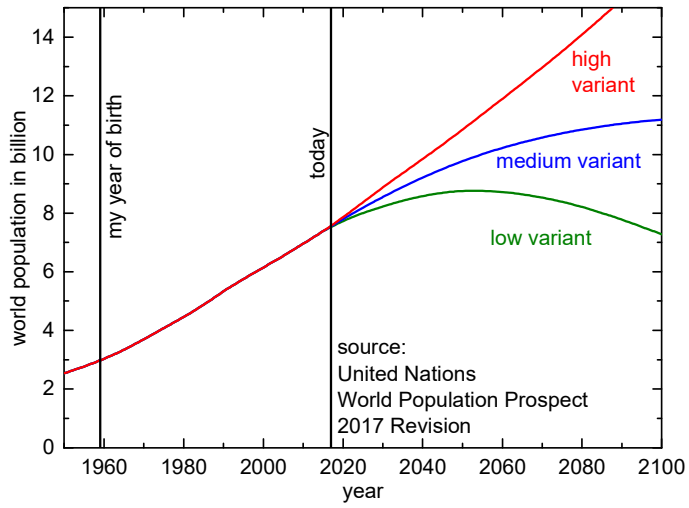

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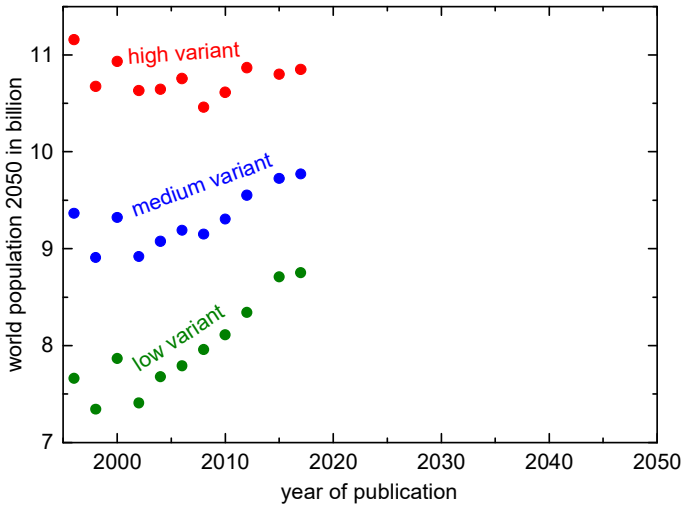
development of UN-WPP predicting for 2050



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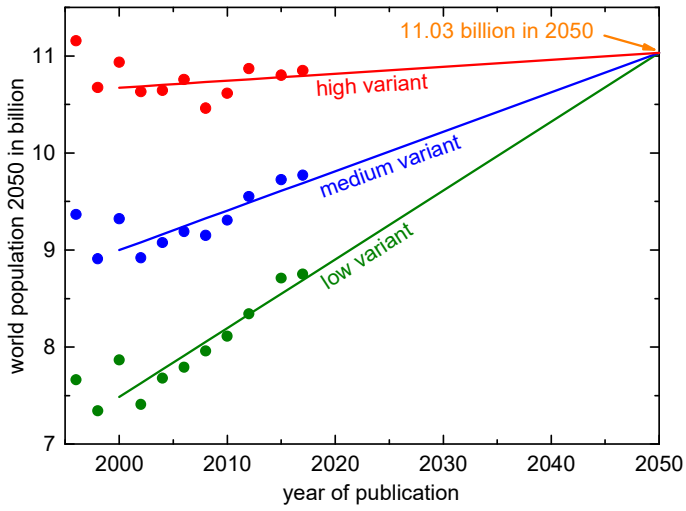

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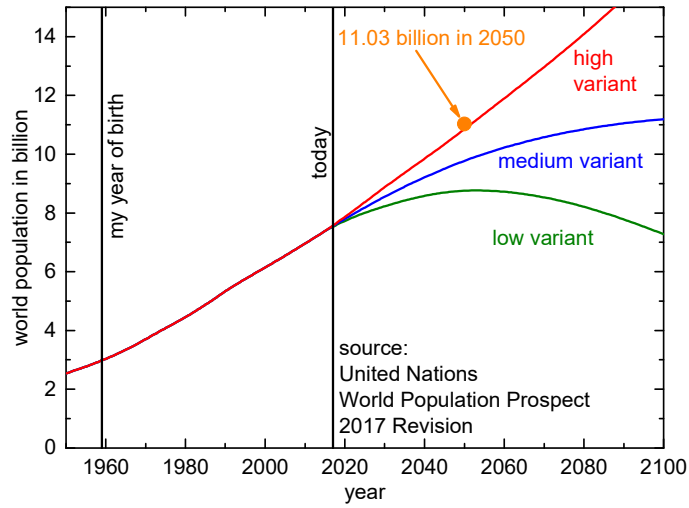
world population scenarios



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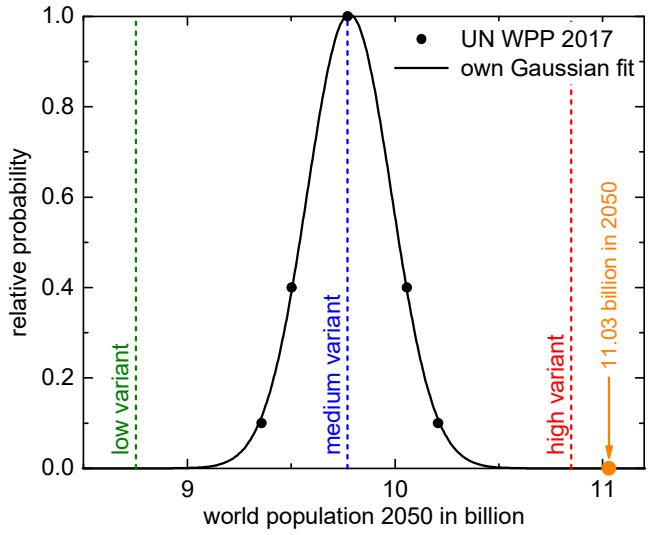
probabilistic evaluation by UN-PD-DESA



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uncertainty vs. ignorance

uncertainty:

- known possible errors
- can be quantified

ignorance:

- lack of knowledge
- decreases over time
- cannot be quantified

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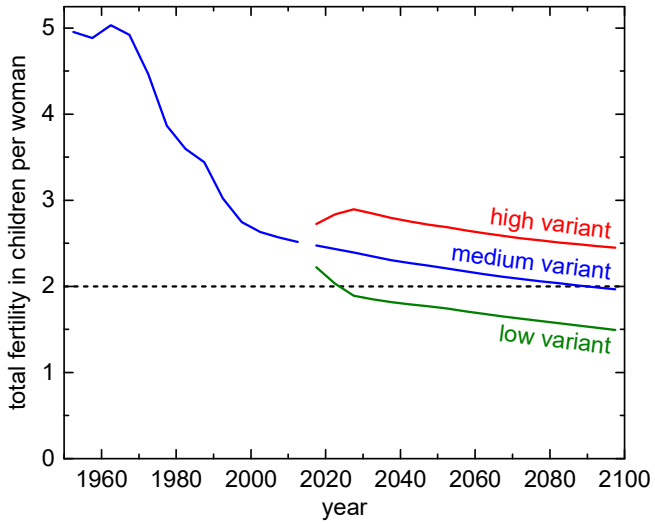
reasons for ignorance (e-mail UN-DESA)

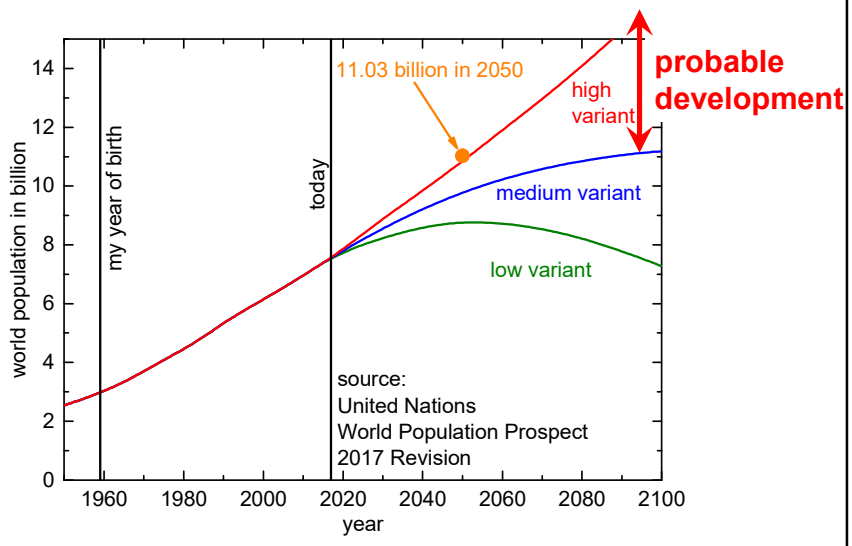
- slower than expected fertility decline in many sub-Saharan African countries
- improved child survival
- slowdown/reversal of the HIV epidemic.

⇒ our knowledge increases continually

fertility: history and scenarios



world population scenarios



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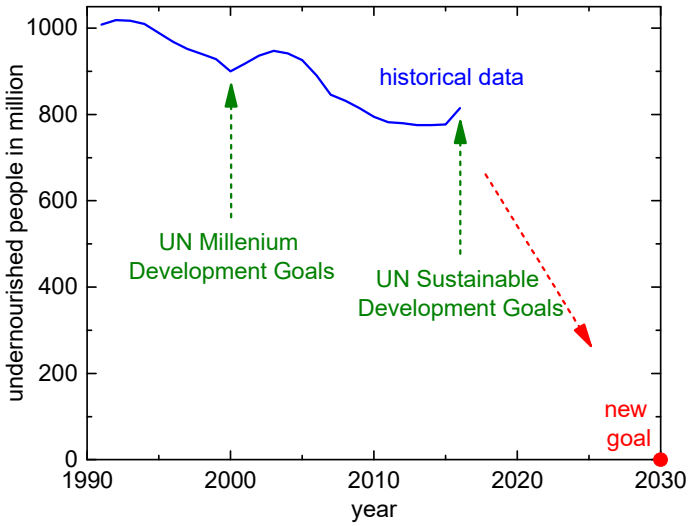
world hunger



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population growth eating up progress

since 1990:

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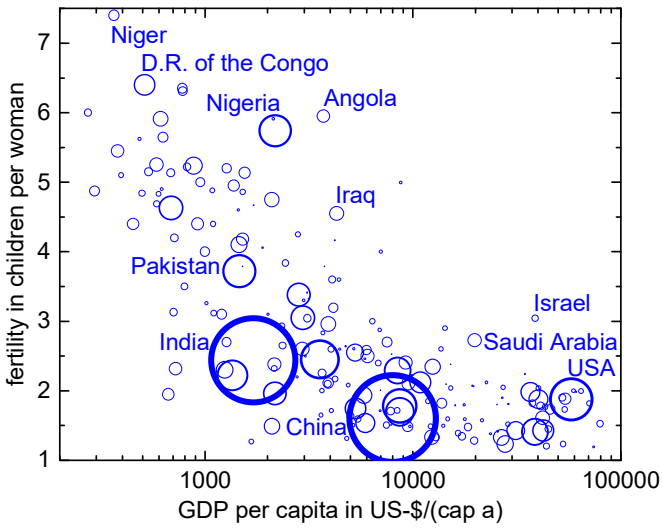
strong influence of GDP on fertility



conclusion

UN high-population variant equally realistic as medium variant

in 2050 between 9.7 and 11 billion people

in 2100 between 11.2 and 16.5 billion people

⇒ strong effect on resource consumption & waste production

⇒ strong effect on world hunger

Our Successful Future - World Population

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Our Successful Future
- Sustainable Energy Transition

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questions to be answered

- What is the current status of the sustainable energy transition?
- How fast do we need to change to reach climate goals?
- What happens, if we wait before fostering sustainable energy transition?
- Can we realistically reach the 1.5°C climate goal?

databases used and copyrights

copyrights:

- IPCC illustrative model pathways:
  Daniel Huppmann, Elmar Kriegler, Volker Krey, Keywan Riahi, Joeri Rogelj, Steven K. Rose, John Weyant, et al.,
  IAMC 1.5°C Scenario Explorer and Data hosted by IIASA.
  Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018.
  doi: https://doi.org/10.22022/SR15/08-2018.15429
  url: https://data.ene.iiasa.ac.at/iamc-1.5c-explorer, release 1.0
- UN WPP population prospects:
  United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.
  https://population.un.org/wpp/
- BP Statistical Review of World Energy 2018
  https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html
- FAOSTAT: FAO, 2018, data on food production and land-area use,
  http://www.fao.org/faostat/en/#data, accessed on various dates 2018
- CDIAC: CO_2 historical data obtained from
  http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html

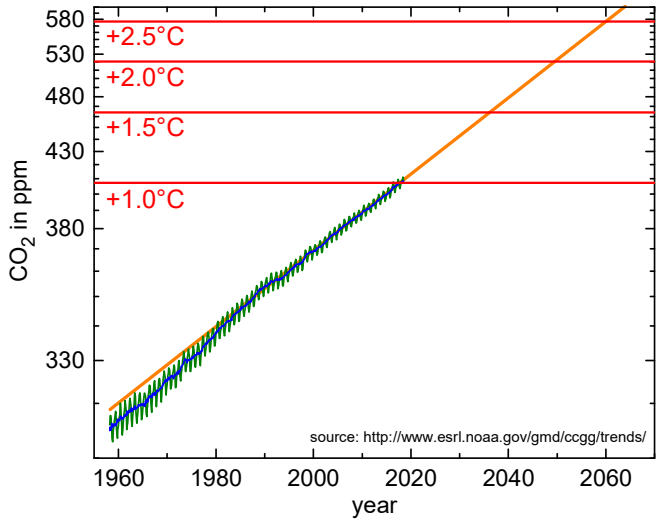
modelling approach

- not an IAM (integrated assessment model)
- based on simple balances:
  - influence of individual parameters directly visible
  - main drivers easy to realize

negative influence of too detailed models:

K. Sundmacher, A. Kienle: Reactive Distillation Status and Future Directions. Wiley-VCH, Weinheim, 2003

CO_2 content of the atmosphere



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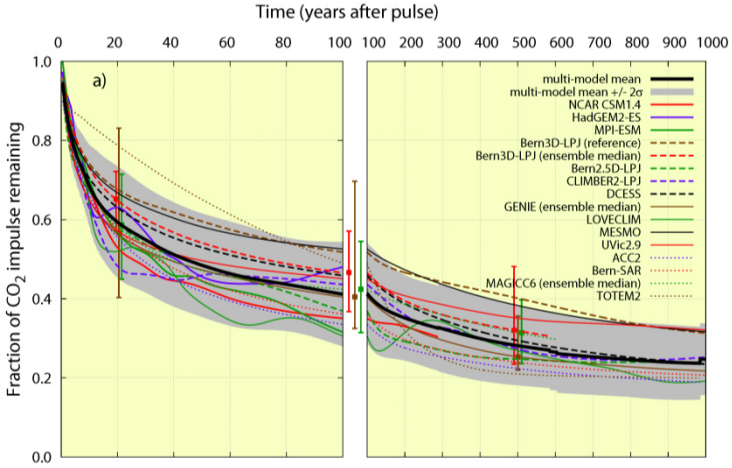
response to 100GtC pulse emission



source: Joos, F., et al.: Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis. Atmos. Chem. Phys., 13 (2013) 2793-2825.

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the system, scale-down factor 10 000 000

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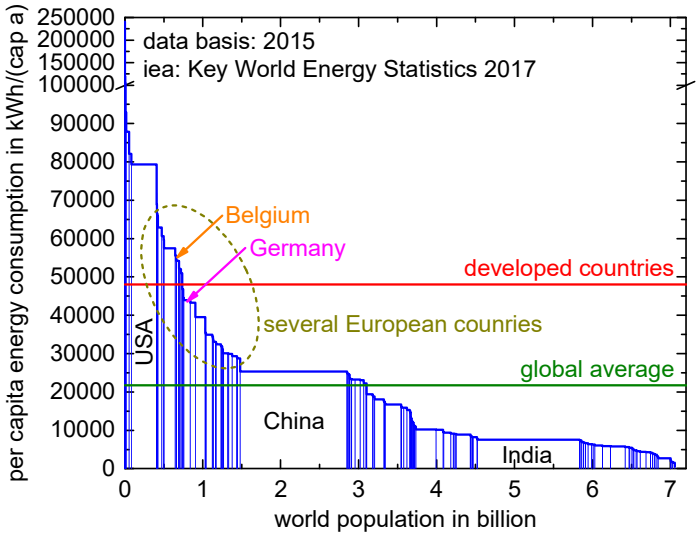
annual primary-energy consumption



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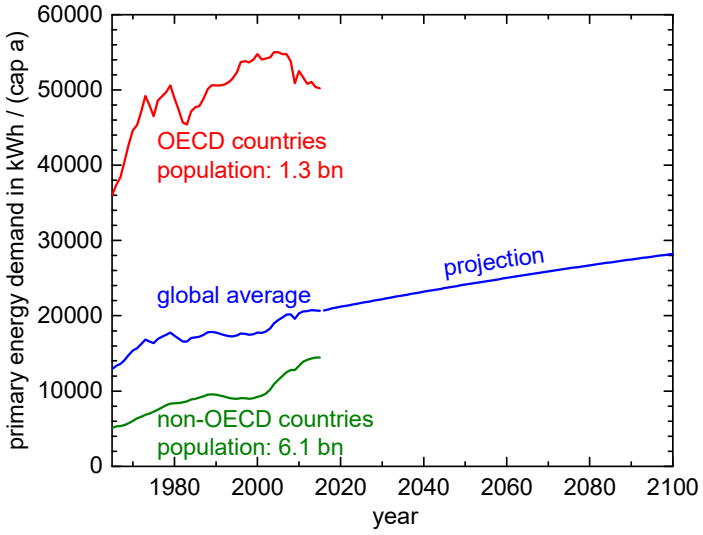
development of per-capita demand



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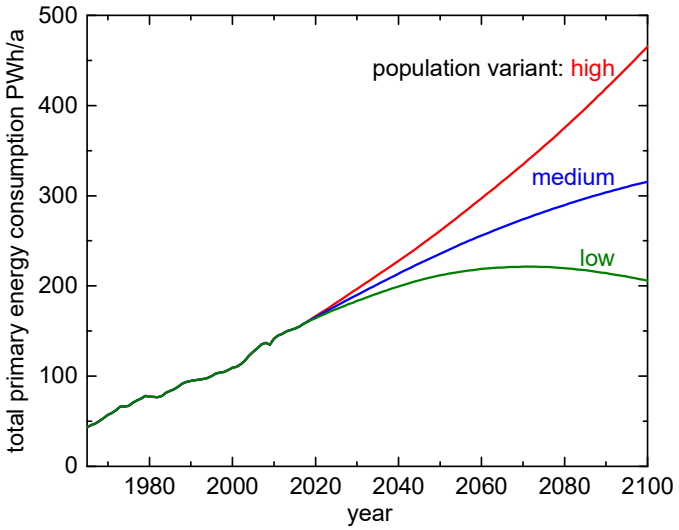
development of primary energy demand



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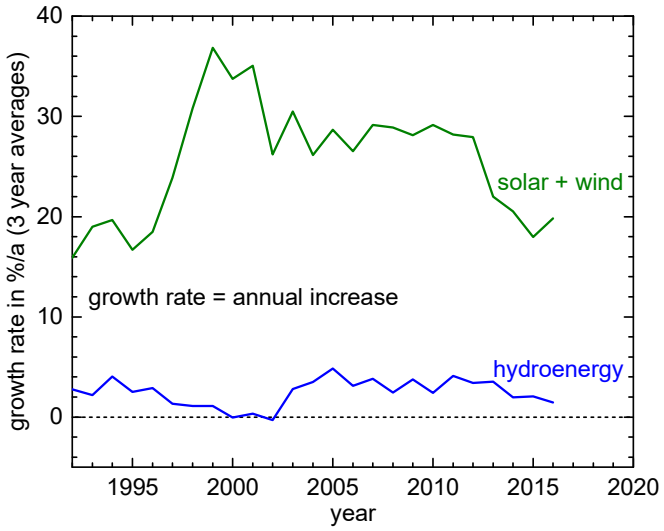
annual global growth rates



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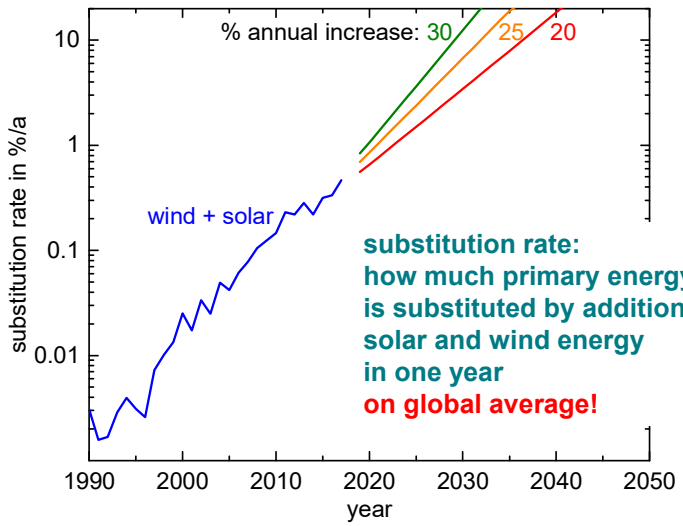
future growth scenarios of wind & solar



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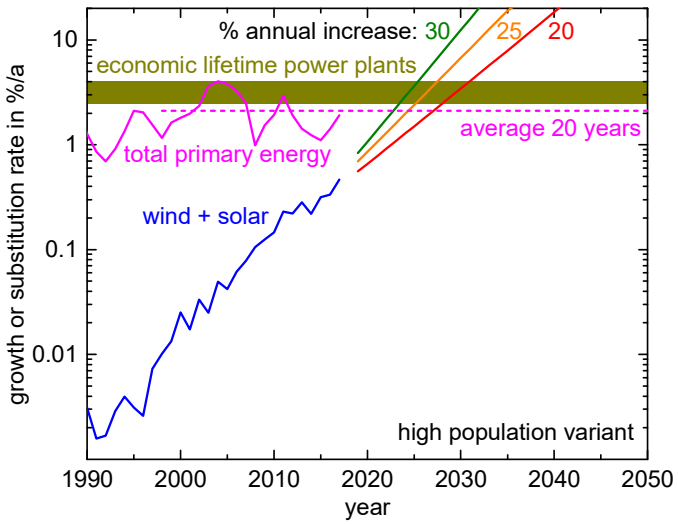
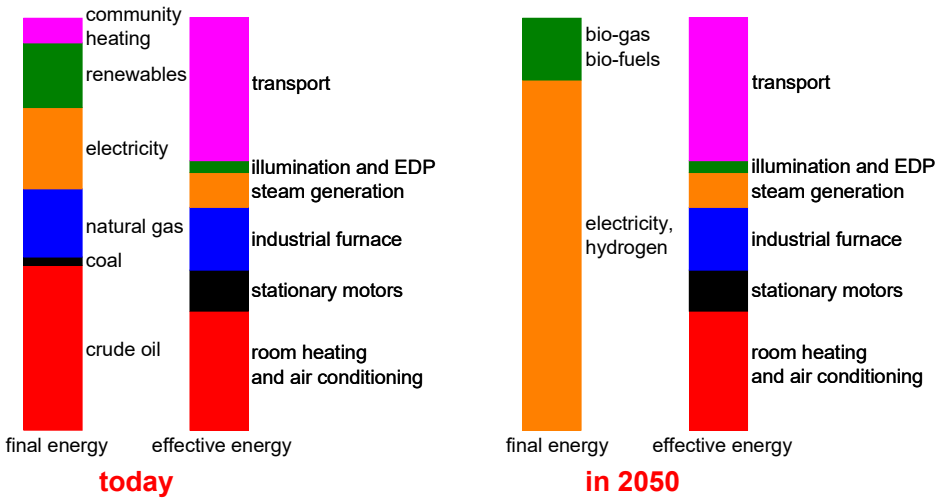
economic lifetimes and life spans

	lifetime	annual substitution rate
	a	% / a
electrical power plants	25 to 40	4 to 2.5
passenger car	10	10
truck	10	10
oven, heating	15 to 25	4 to 7
house insulation	50 to 100	1 to 2

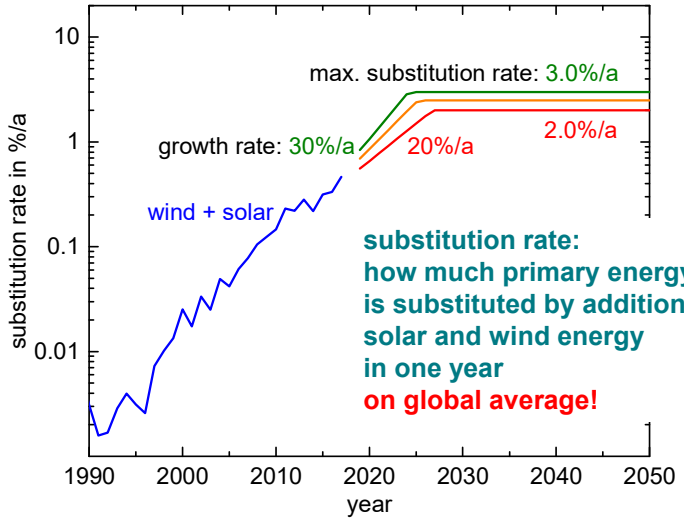
maximum substitution rates



change in energy system

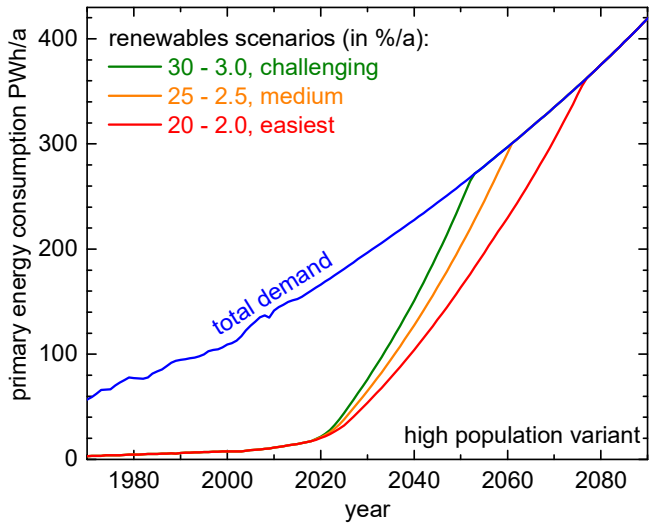


defining three future scenarios



substitution rate:
how much primary energy supply is substituted by additional solar and wind energy in one year on global average!

three energy scenarios



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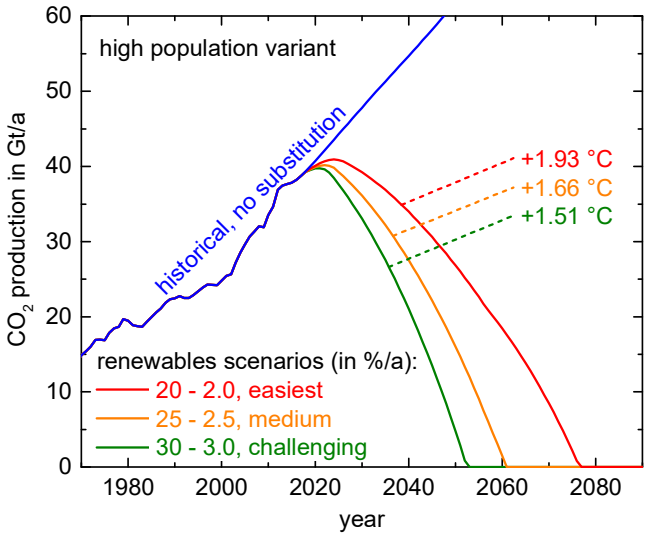
CO_2 according to three scenarios



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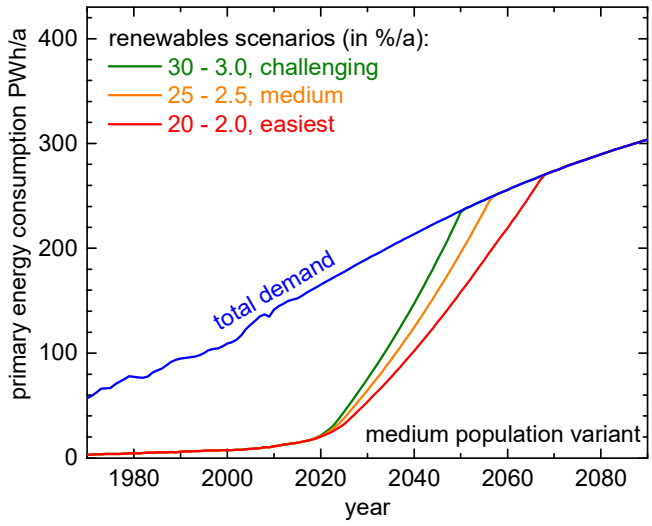
influence of population variant



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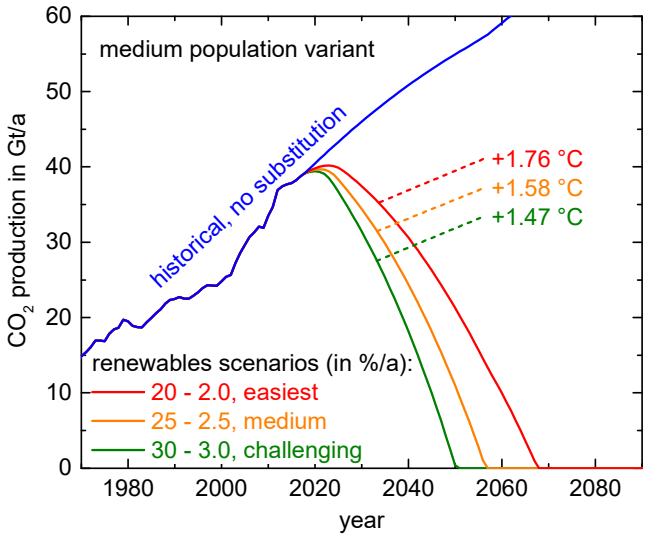
CO_2 emissions for medium pop. variant



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comparison of energy-transition scenarios

energy transition scenario:		UN WPP population variant			
		medium		high	
	rates	temp.	end	temp.	end
	% / a	°C		°C	
easiest	20 - 2.0	+1.76	2068	+1.93	2077
medium	25 - 2.5	+1.58	2057	+1.66	2062
challenging	30 - 3.0	+1.47	2051	+1.51	2053

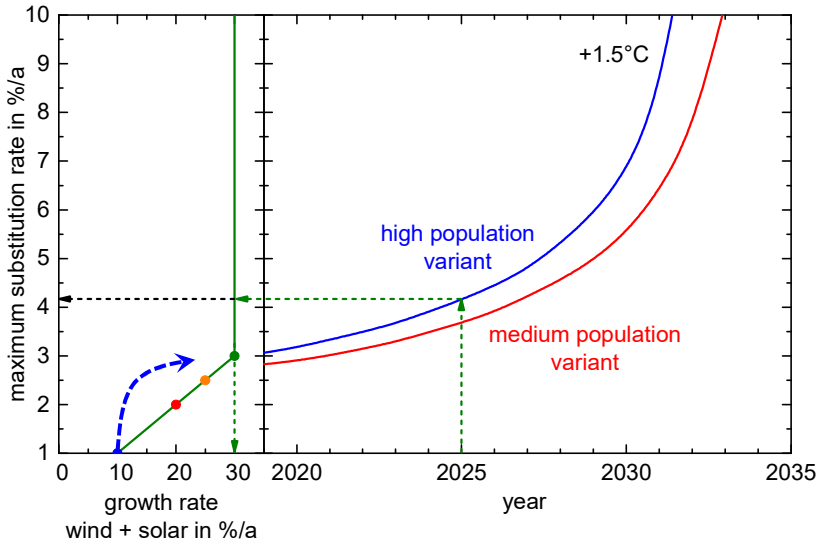
negative-emission technologies

- **CDR**: carbon-dioxide removal
- **CCS**: carbon capture and sequestration/storage
- **BECCS**: bio-energy with CCS
- **DACCS**: direct air carbon capture with storage
- **AR**: afforestation and reforestation
- **AFOLU**: agriculture, forestry and other land use

not included because:

- business case only, if trading of CO_2 emission rights
- debt for the future
- bet on future political and technological development
- IPCC SR15:
  ...is subject to multiple feasibility and sustainability constraints.

consequences of a delay



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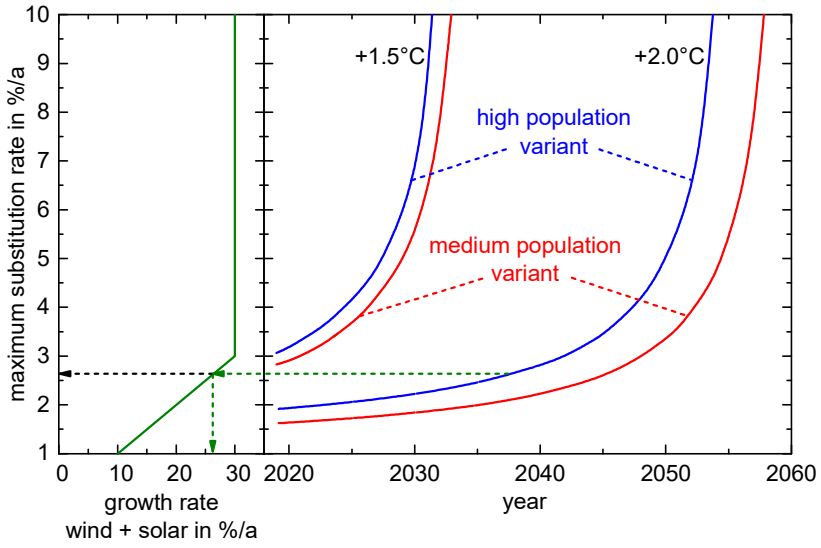
consequences of a delay



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conclusion

- time-scale: turning point in 2 to 10 years
  strong effect in 5 to 20 years
- volatile prices of fossil feedstock foreseeable
- we overslept the 1.5°C climate goal!
- urgent concerted action required to reach 2.0°C goal
- not only more solar and wind,
  but also change of end-use technologies
- complete and quick restructuring of major industries required
- reducing population growth simplifies transition

⇒ bio-energy, bio-materials could help

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Our Successful Future
- Sustainable Energy Transition

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Our Successful Future
- Sustainable Economy
- Food vs.
Bio-Energy & Bio-Materials

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questions to be answered

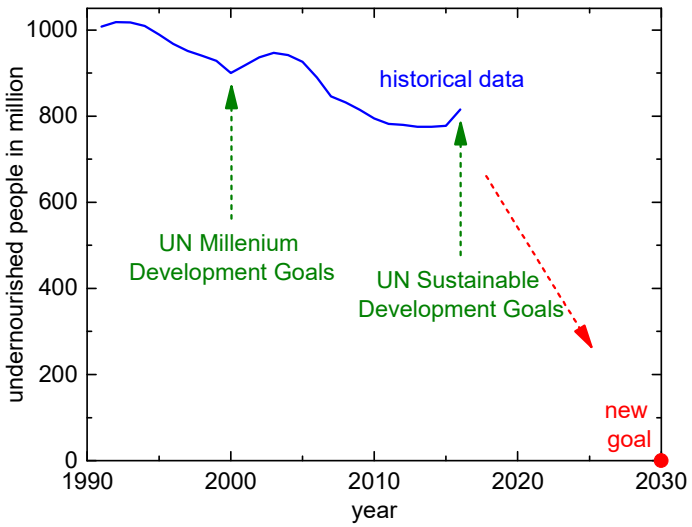
- food or fuel: How will the competition between food production and feedstock generation for bio-energy and bio-materials work out?
- What are consequences for our wellbeing?

databases used and copyrights

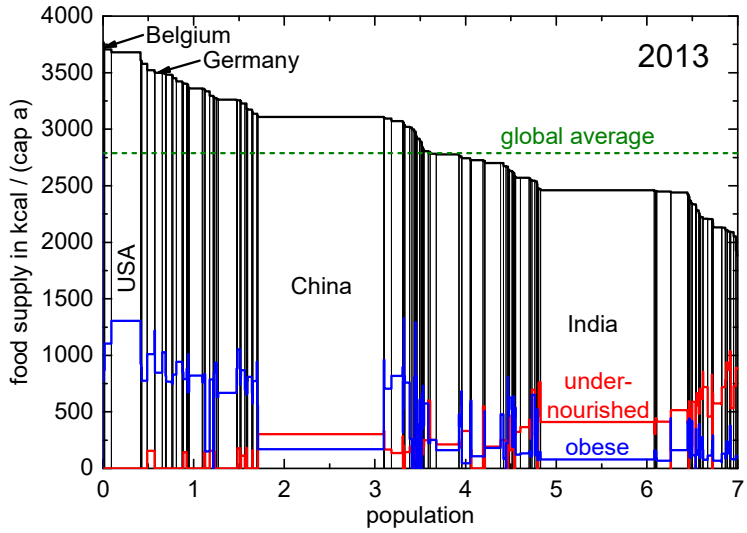
copyrights:

- IPCC illustrative model pathways:
  Daniel Huppmann, Elmar Kriegler, Volker Krey, Keywan Riahi, Joeri Rogelj, Steven K. Rose, John Weyant, et al.,
  IAMC 1.5°C Scenario Explorer and Data hosted by IIASA.
  Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018.
  doi: https://doi.org/10.22022/SR15/08-2018.15429
  url: https://data.ene.iiasa.ac.at/iamc-1.5c-explorer, release 1.0
- UN WPP population prospects:
  United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.
  https://population.un.org/wpp/
- BP Statistical Review of World Energy 2018
  https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html
- FAOSTAT: FAO, 2018, data on food production and land-area use,
  http://www.fao.org/faostat/en/#data, accessed on various dates 2018
- CDIAC: CO_2 historical data obtained from
  http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html

world hunger



food supply by country



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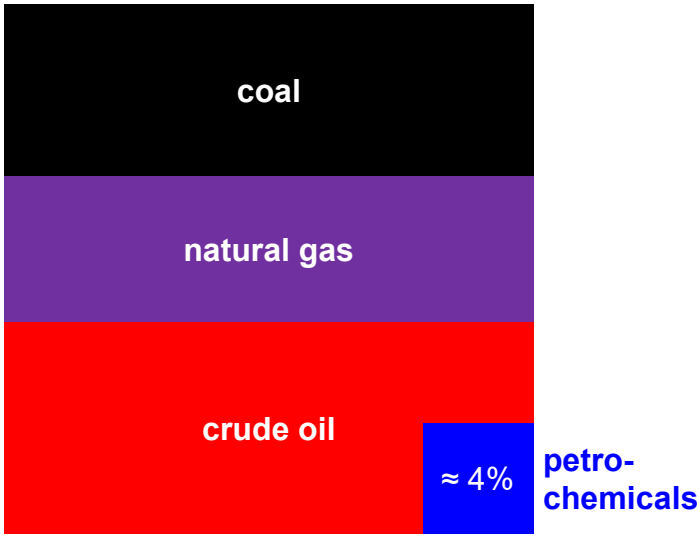
petrochemicals ≈ 4% of fossil resources



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the system, scale-down factor 10 000 000

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assumptions for scenario analysis

- continue trends
- slow increase of per capita kcal-supply
- increase agricultural productivity
- intensify animal production
- 10% primary energy bio-based

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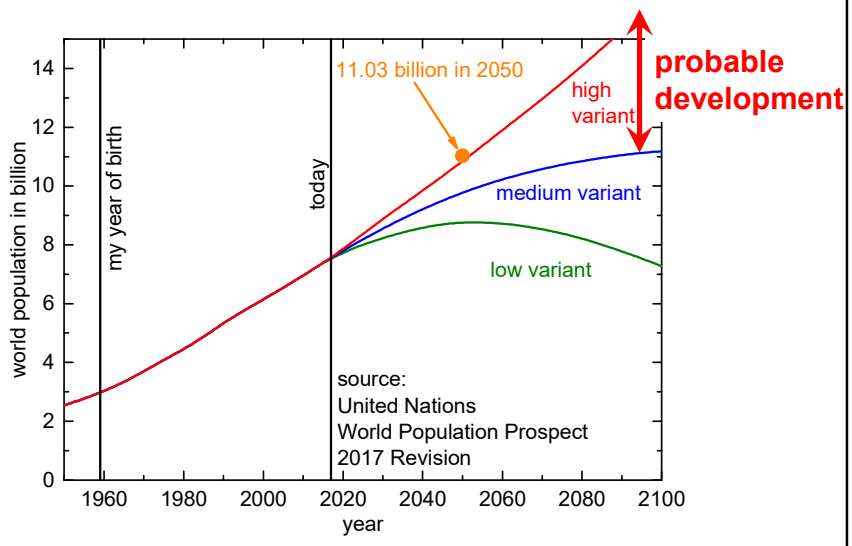
world population scenarios



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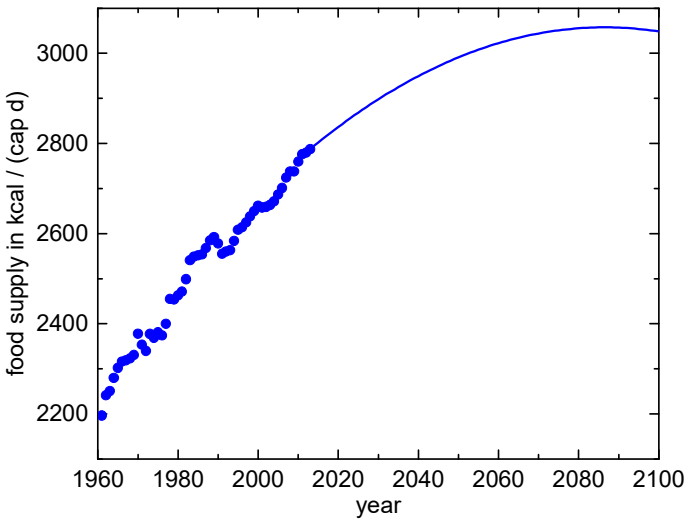
caloric food supply



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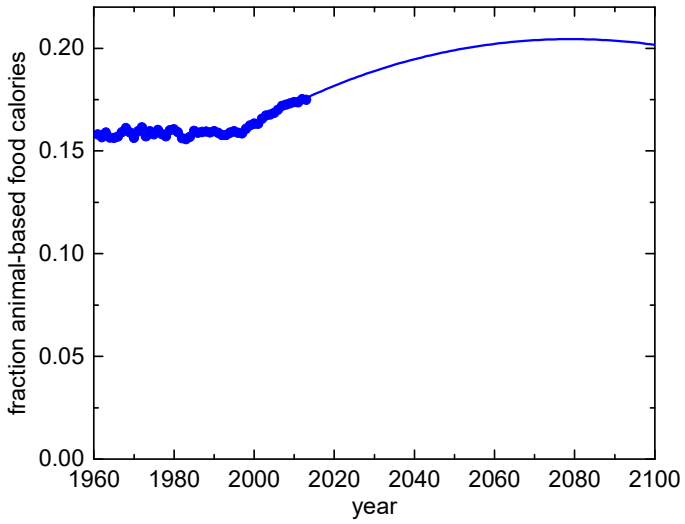
fraction animal-based calories supply



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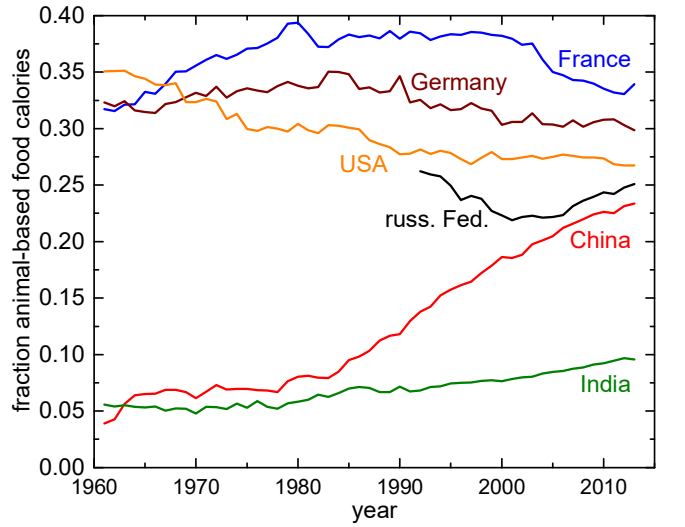
fraction animal-based calories supply



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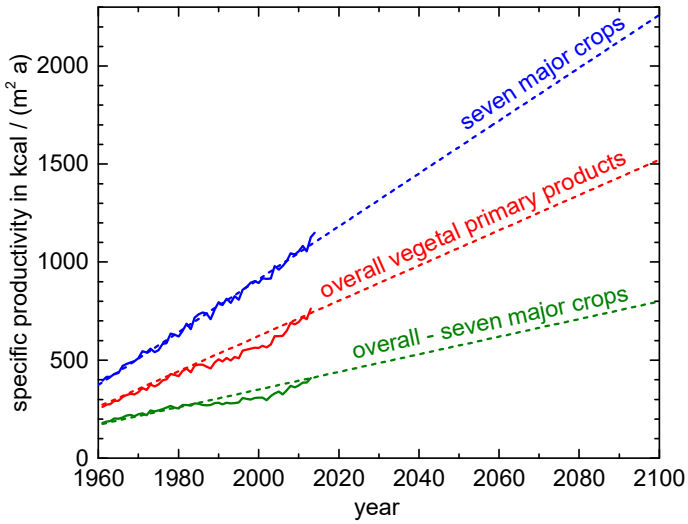
land-area specific agrigultural productivity



seven major crops:

- barley
- corn
- oil palm
- rice
- soybeans
- sugar cane
- wheat

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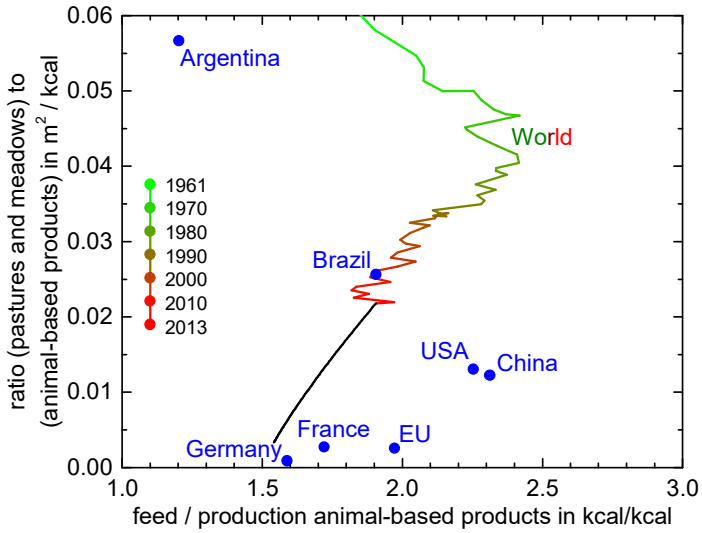
intensity of animal-based food production



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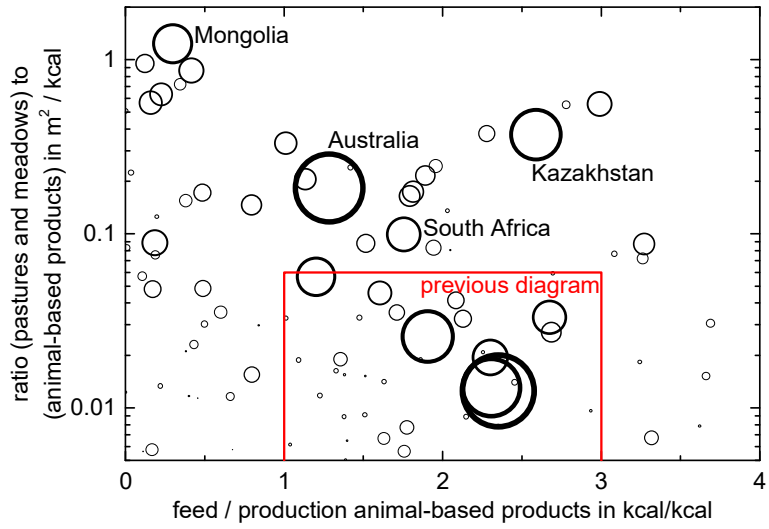
intensity of animal-based food production



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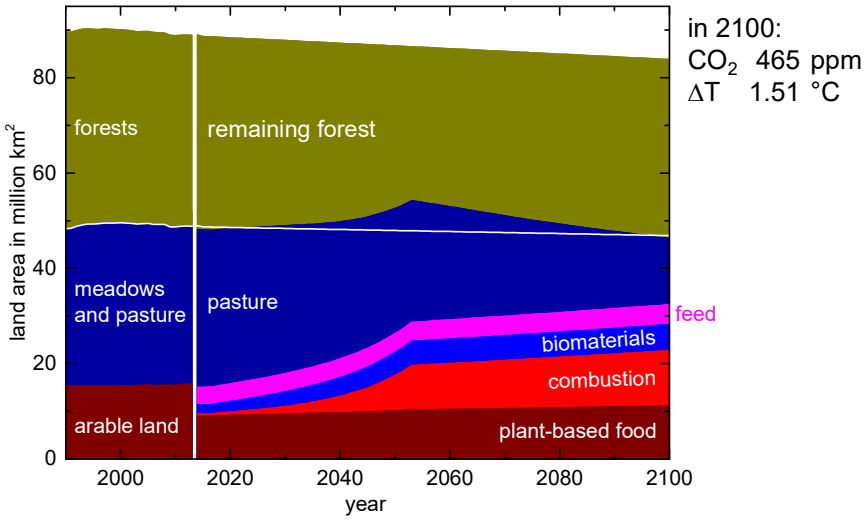
land-area: challenging, high pop. variant



in 2100:
CO_2 465 ppm
ΔT 1.51 °C

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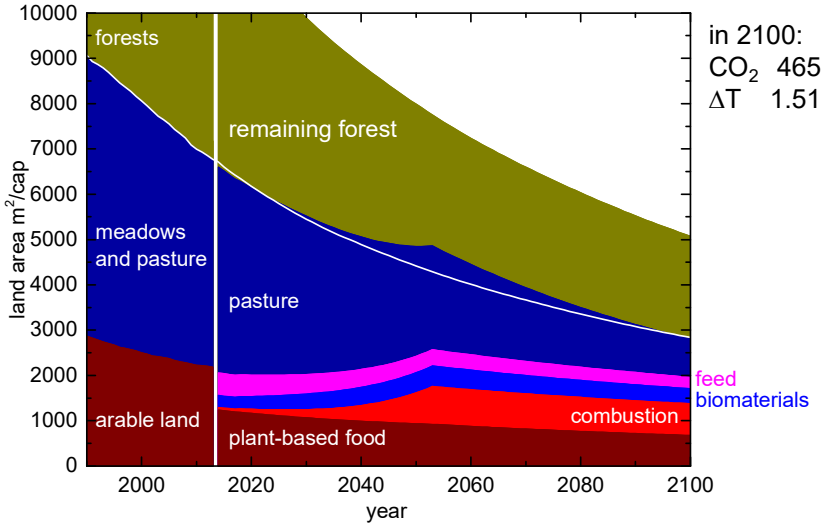
land-area: challenging, high pop. variant



in 2100:
CO_2 465 ppm
ΔT 1.51 °C

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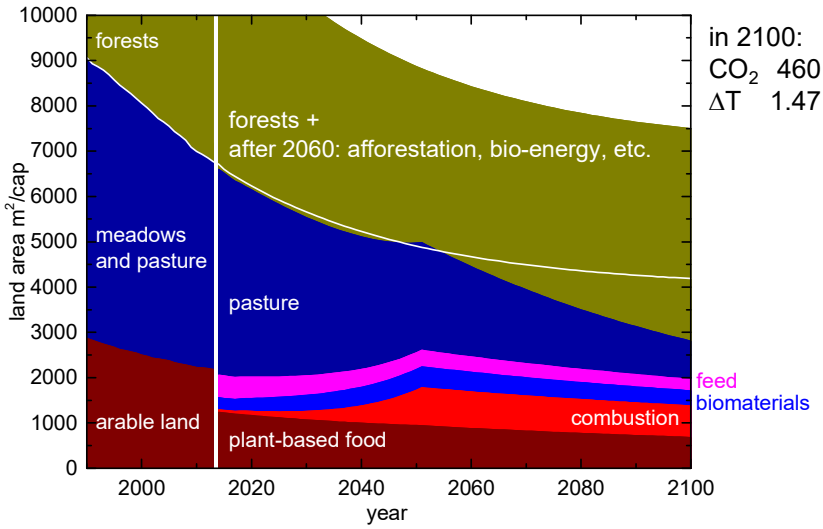
land-area: challenging, medium pop. variant



in 2100:
CO_2 460 ppm
ΔT 1.47 °C

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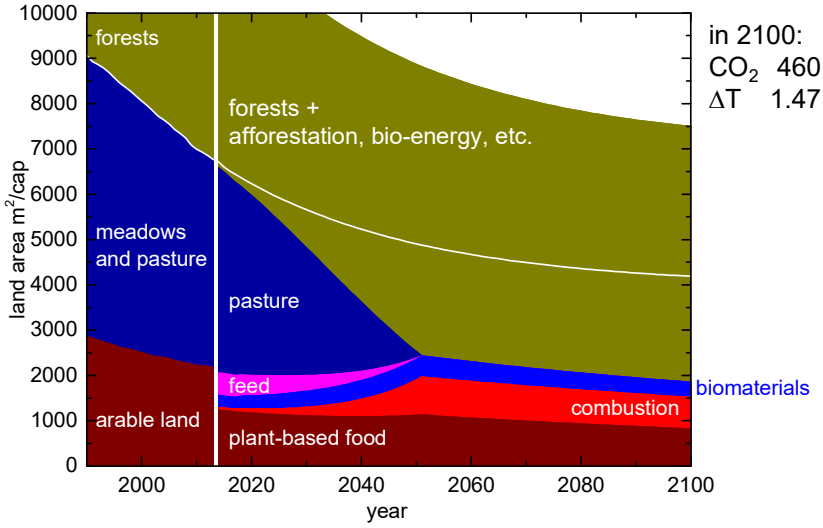
land-area: challeng., medium pop., vegetal



in 2100:
CO_2 460 ppm
ΔT 1.47 °C

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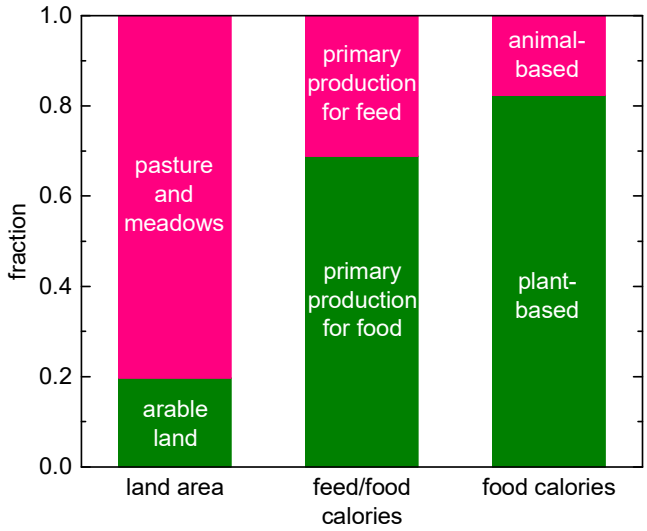
inefficiency of animal-based food supply



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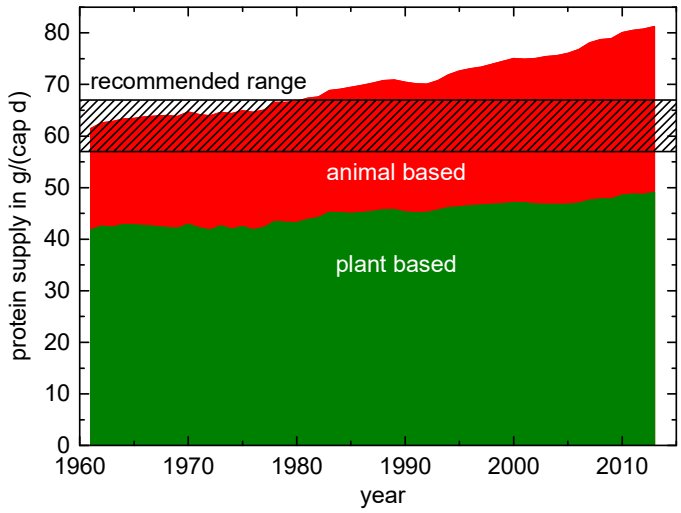
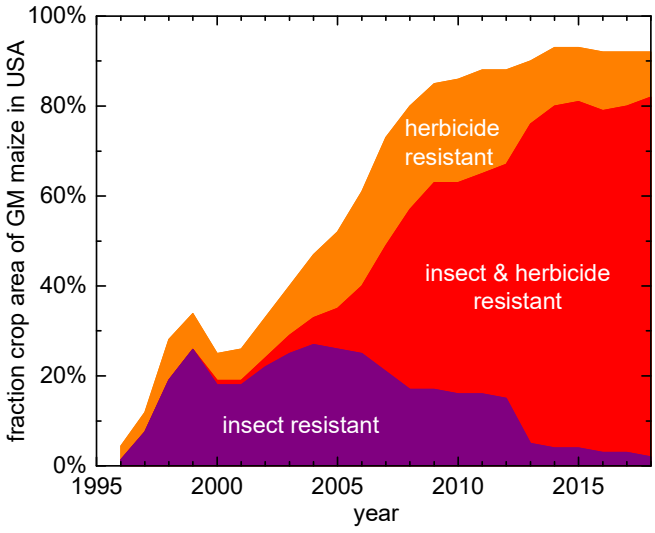
global protein supply



workarounds?

fraction of GM maize in USA



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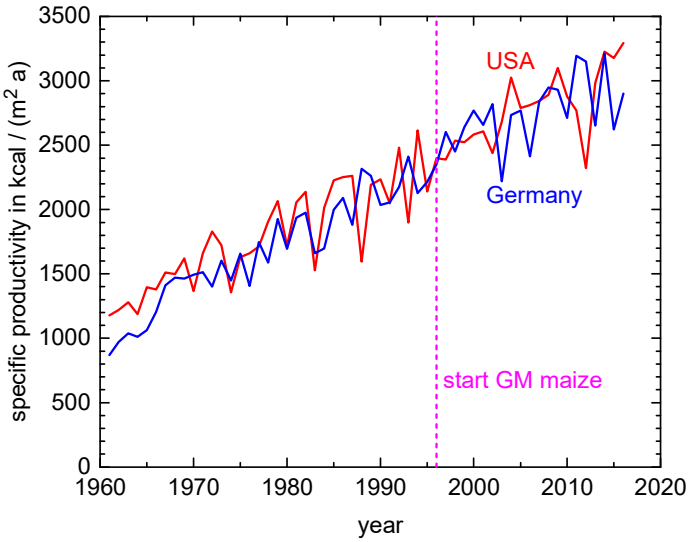
productivity of land area GM vs. non-GM



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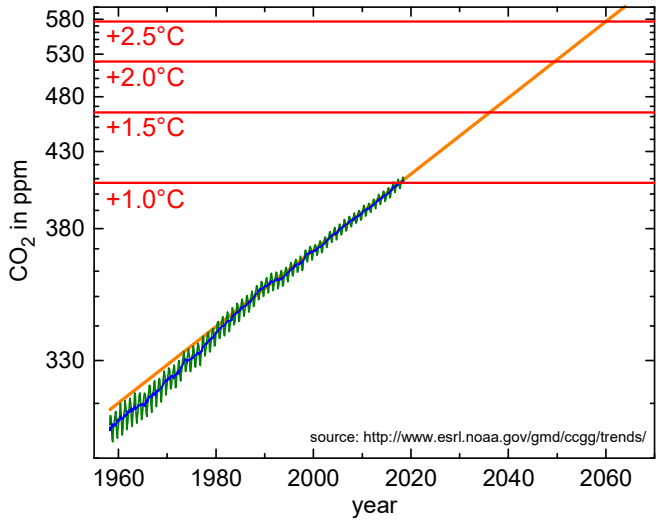
CO_2 content of the atmosphere



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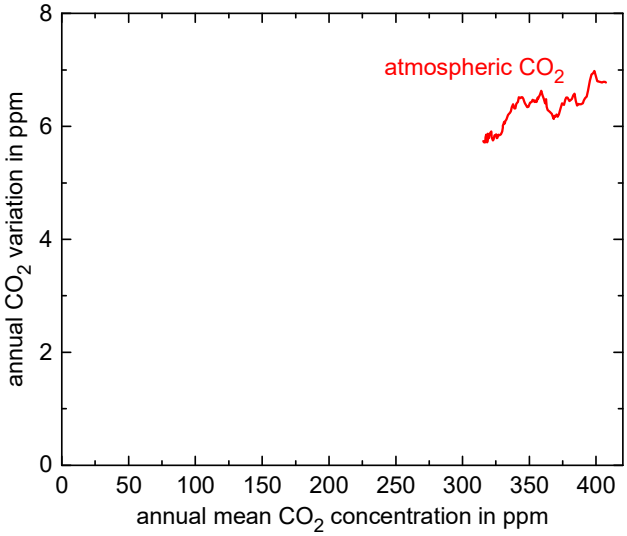
is higher CO_2 concentration beneficial?



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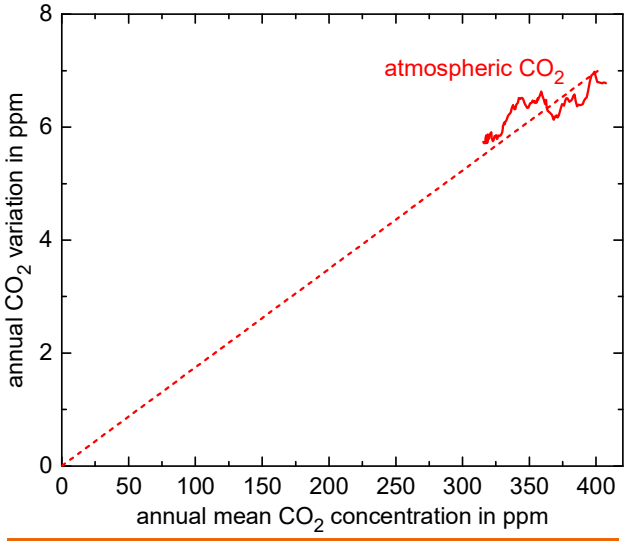
is higher CO_2 concentration beneficial?



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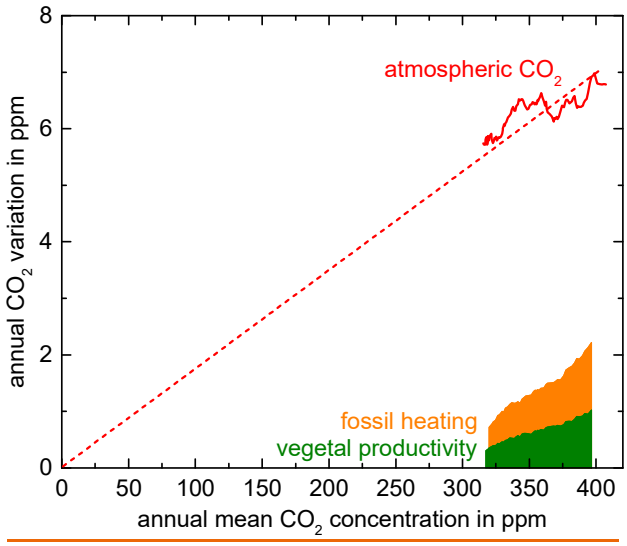
is higher CO_2 concentration beneficial?



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conclusion

no workarounds!

with behaviour change:
available technology allows sustainable wellbeing

without behaviour change:
technologies continually pushed to limits or
more people undernourished

⇒ change of behaviour essential

conclusion

to feed the world, change in behavior essential:
- maximum 2 children per family
- exclusively plant-based food

⇒ support for less developed countries

nevertheless: competiton for land area between
- feedstock for bio-fuels and bio-materials
- food production.

⇒ land-area demand for feedstock to produce bio-energy and bio-materials is essential criterion for selection of process routes!

Our Successful Future
- Sustainable Economy
- Food vs.
Bio-Energy & Bio-Materials

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Our Successful Future
- A Word on IPCC Scenarios

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questions to be answered

- How realistic are the IPCC illustrative model pathways?
- Which goals can actually be reached?

reference to IPCC reports used

- **IPCC - Intergovernmental Panel on Climate Change** established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988
- **AR5**: IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- **SR15**: GLOBAL WARMING OF 1.5 °C an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty http://www.ipcc.ch/report/sr15/ (accessed 08.10.2018)

databases used and copyrights

copyrights:

- IPCC illustrative model pathways:
  Daniel Huppmann, Elmar Kriegler, Volker Krey, Keywan Riahi, Joeri Rogelj, Steven K. Rose, John Weyant, et al.,
  IAMC 1.5°C Scenario Explorer and Data hosted by IIASA.
  Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018.
  doi: https://doi.org/10.22022/SR15/08-2018.15429
  url: https://data.ene.iiasa.ac.at/iamc-1.5c-explorer, release 1.0
- UN WPP population prospects:
  United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.
  https://population.un.org/wpp/
- BP Statistical Review of World Energy 2018
  https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html
- FAOSTAT: FAO, 2018, data on food production and land-area use,
  http://www.fao.org/faostat/en/#data, accessed on various dates 2018
- CDIAC: CO_2 historical data obtained from
  http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html

IPCC SR15 of October 6, 2018

- consequences for climate and wellbeing:
  much larger at 1.5°C than today at around 1.0°C
  much larger at 2.0°C than at 1.5°C
- net-decarbonization required by
  2050 for reaching 1.5°C: rapid and far-reaching transition
  2075 for reaching 2.0°C
- 1.5°C with no or at most limited overshoot only possible with CDR (carbon dioxide removal) of 100-1000 Gt CO_2 until 2100
- current ambitions stated by countries acording to COP21 Paris agreement will not allow to limit to 1.5°C,
  instead 3°C in 2100 further increasing afterwards
- adverse consequences will be hitting especially disadvantaged and vulnerable populations

population projections IPCC AR5

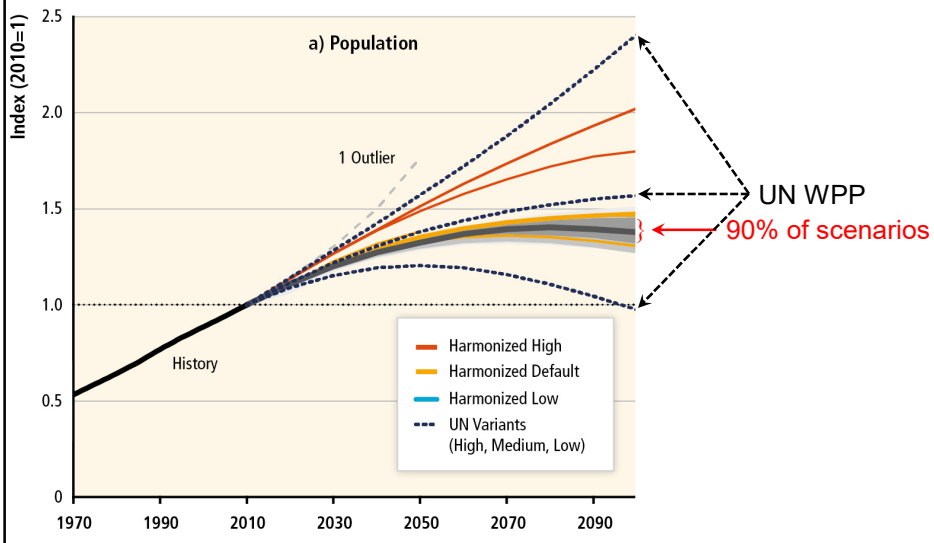
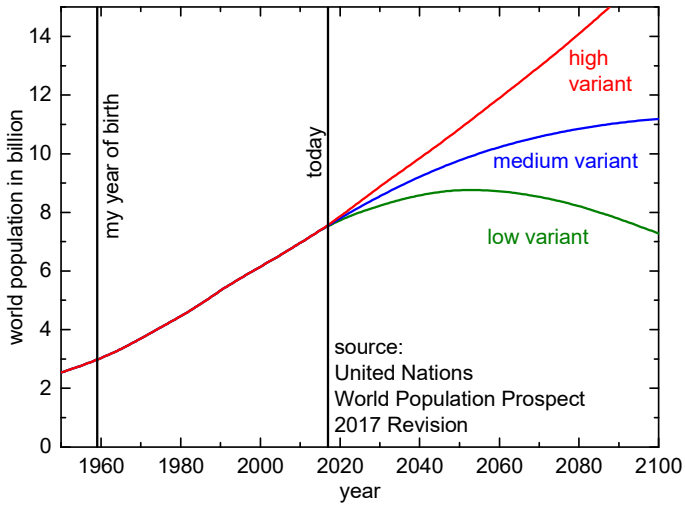


Figure 6.1, p. 425 from: IPCC, 2014:
Climate Change 2014: Mitigation of Climate Change

UN world-population scenarios



IPCC AR5, Climate Change 2014, Mitigation

On the one hand, the scenarios assessed in this chapter **do not represent a random sample that can be used for formal uncertainty analysis**. ...

At the same time, however, ... the scenarios were generated by **experts making informed judgements** about how key forces might evolve in the future and how important systems interact. Hence, although they are not explicitly representative of uncertainty, they do provide **real and often clear insights** about our lack of knowledge about key forces that might shape the future.

population projections IPCC AR5

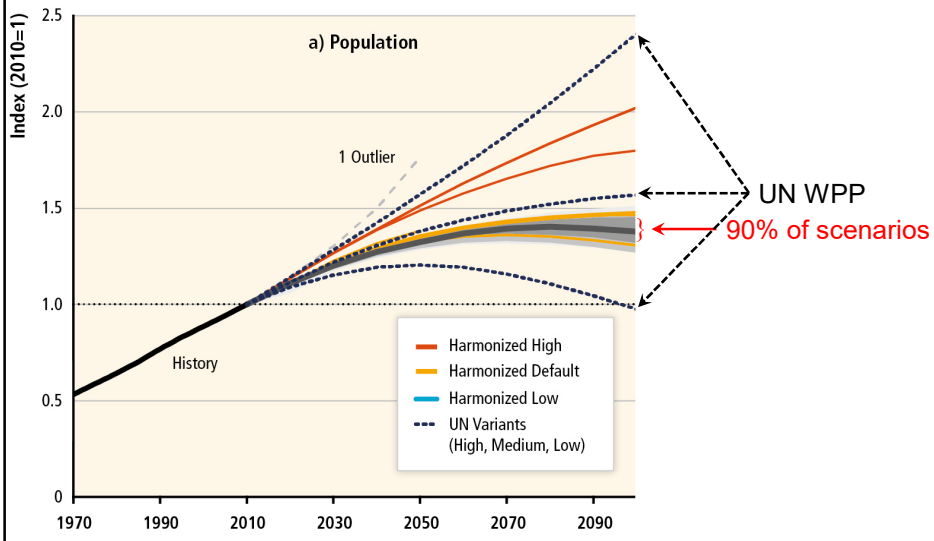
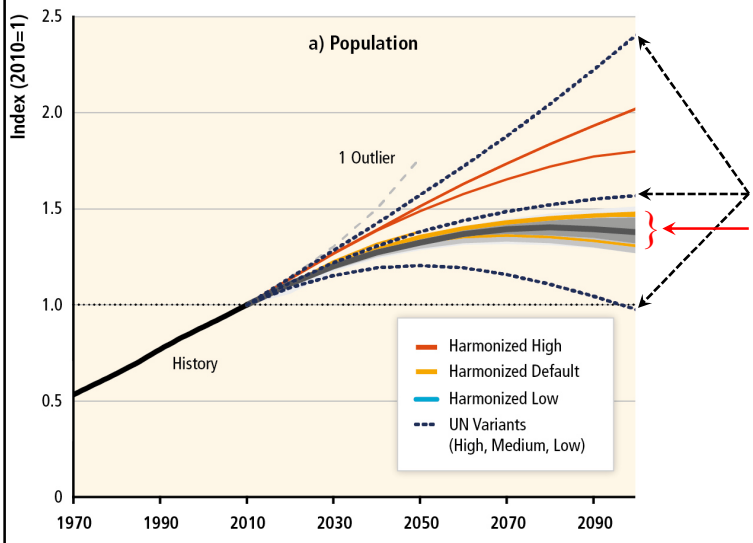


Figure 6.1, p. 425 from: IPCC, 2014: Climate Change 2014: Mitigation of Climate Change

population projections IPCC AR5

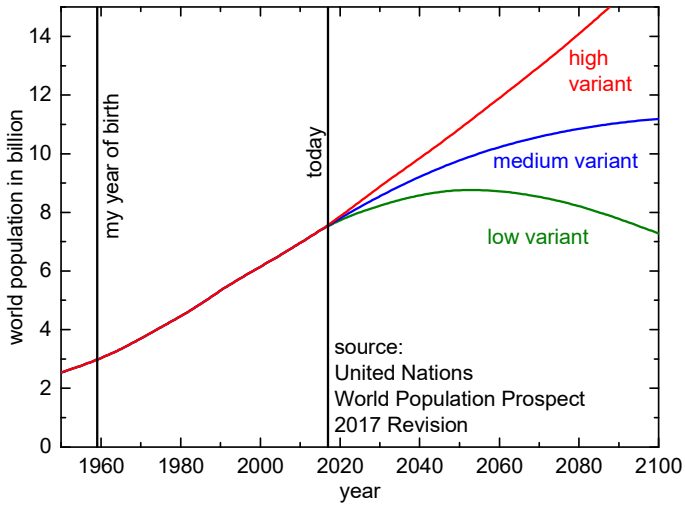


based on
UN WPP 2012

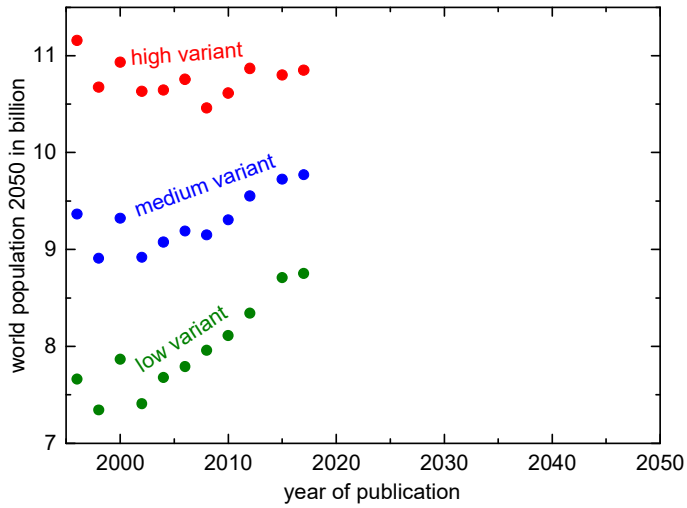
based on
UN WPP
2004 to 2010
medium variant

Figure 6.1, p. 425 from: IPCC, 2014:
Climate Change 2014: Mitigation of Climate Change

UN world-population scenarios



development of UN-WPP prospects for 2050



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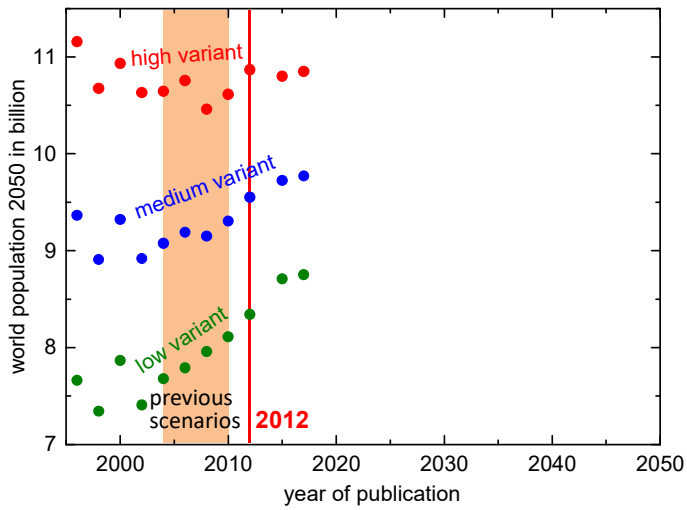
development of UN-WPP prospects for 2050



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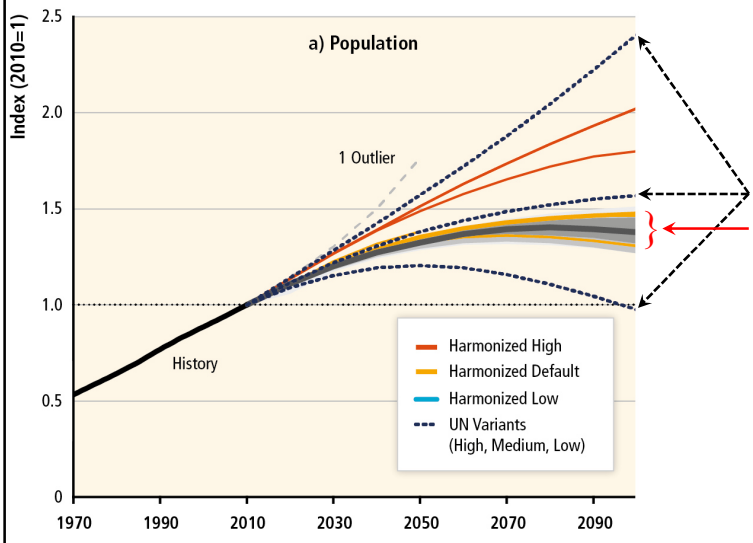
population projections IPCC AR5



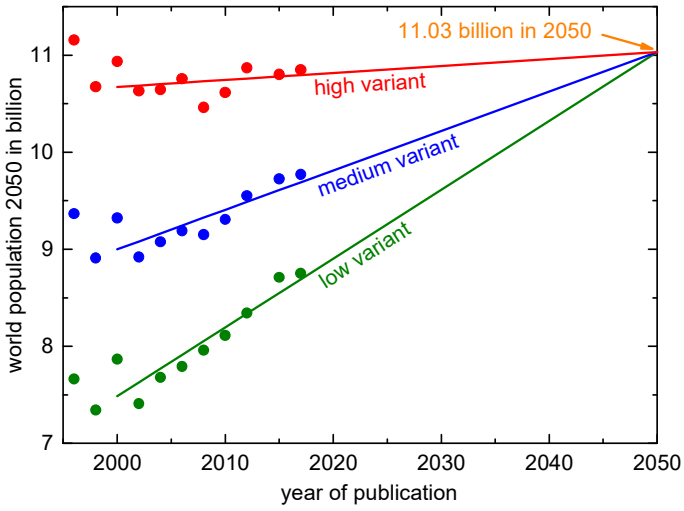
based on
UN WPP 2012

based on
UN WPP
2004 to 2010
medium variant

Figure 6.1, p. 425 from: IPCC, 2014:
Climate Change 2014: Mitigation of Climate Change

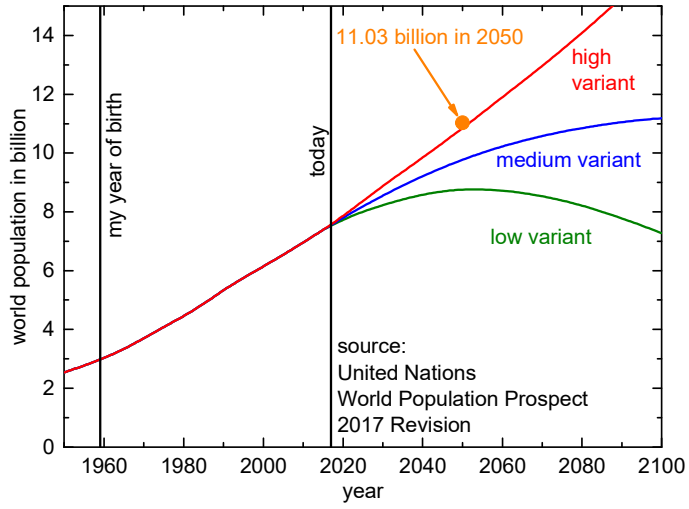
123

development of UN-WPP predicting for 2050



124

world population scenarios



conclusions

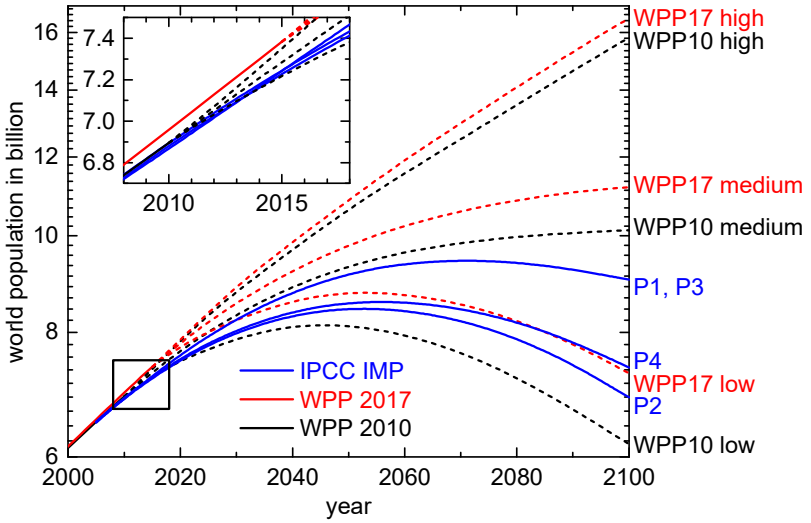
- population may not develop below WPP medium variant as shown in IPCC AR5 diagram
- instead development according to WPP high variant may be at least as likely as according to WPP medium variant

IPCC SR15: illustrative model pathways

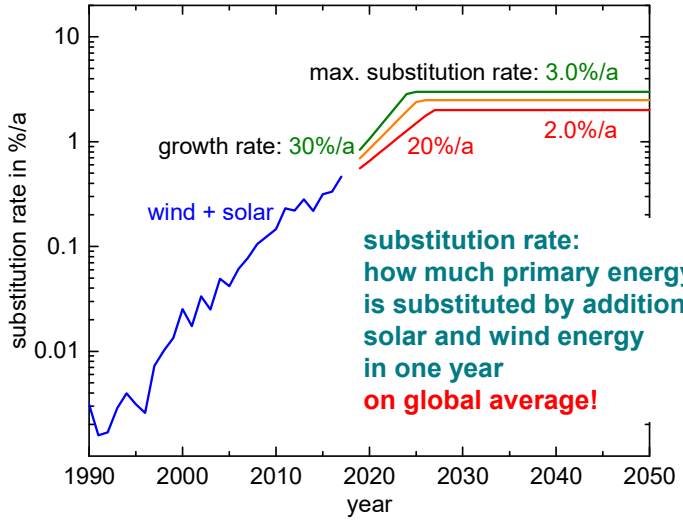
scenario:	P1	P2	P3	P4
population:	**low to medium**	**below low**	**low to medium**	**low**
BE/arable land '50:	1.2%	5%	15%	**40%**
description:	a down-sized energy system enables rapid decarbonisation of energy supply	a broad focus on sustainability including energy intensity, human development...	**middle-of-the road scenario** ...follows historical patterns	adoption of greenhouse-gas intensive lifestyles

BE: bio energy

IPCC SSP scenarios ↔ UN WPP projections



defining three future scenarios



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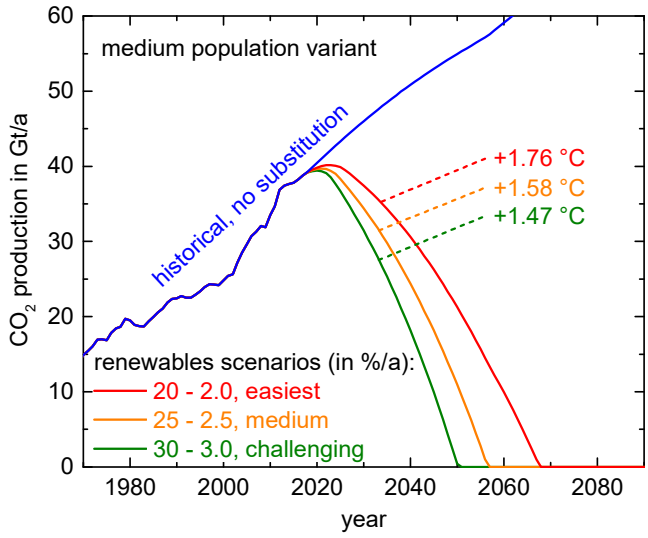
CO_2 emissions for medium pop. variant



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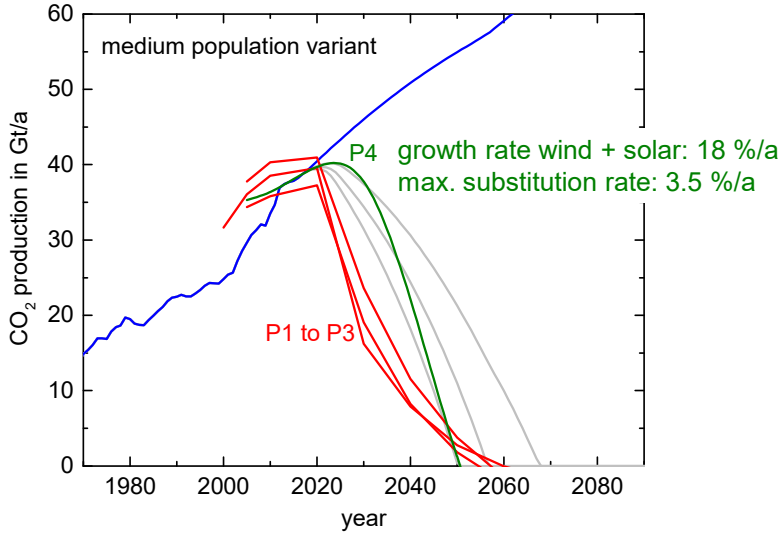
IPCC SR15 illustrative model pathways



Daten:
https://data.ene.iiasa.ac.at/iamc-1.5c-explorer, https://population.un.org/wpp/
https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html

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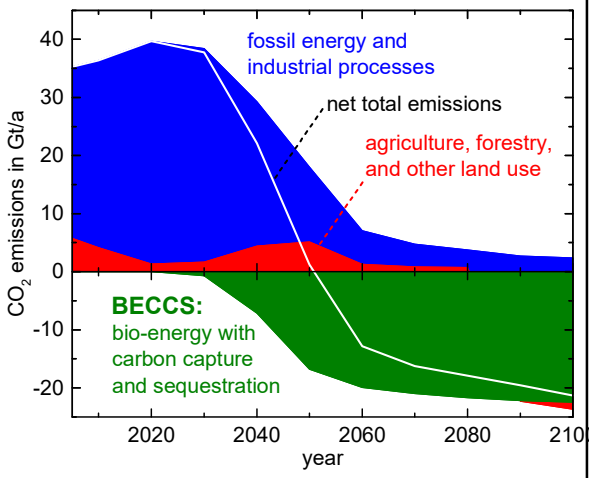
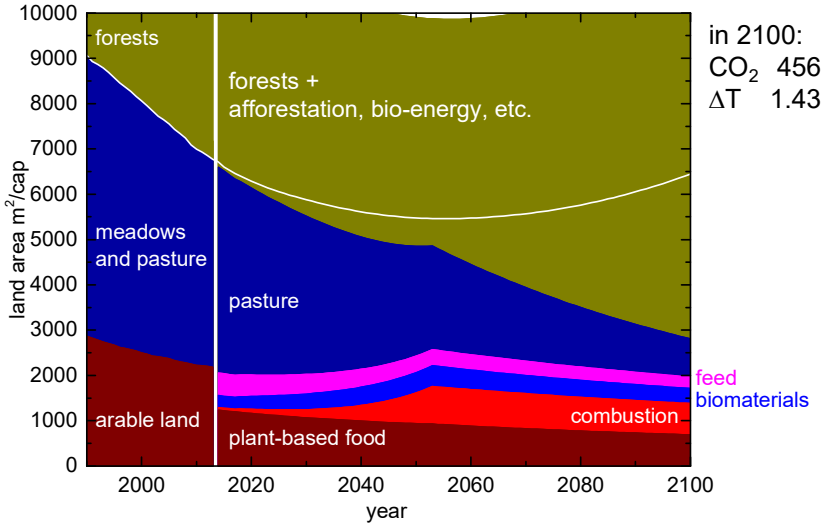
IPCC SR15 of October 6, 2018

scenario: P4
scen. chap. 2: S5
population: low
energy: manageable
BE/arable land '50: 40%
description: adoption of greenhouse-gas intensive lifestyles



138

land-area: challenging, low pop. variant



in 2100:
CO_2 456 ppm
ΔT 1.43 °C

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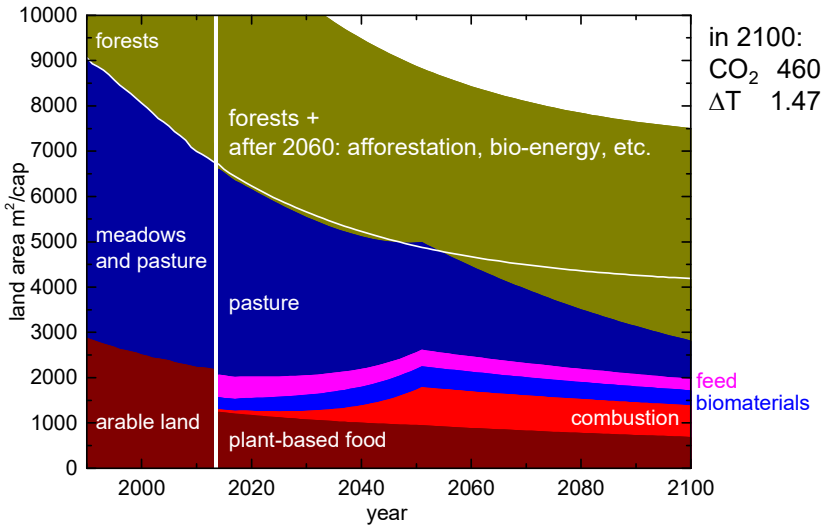
land-area: challenging, medium pop. variant



in 2100:
CO_2 460 ppm
ΔT 1.47 °C

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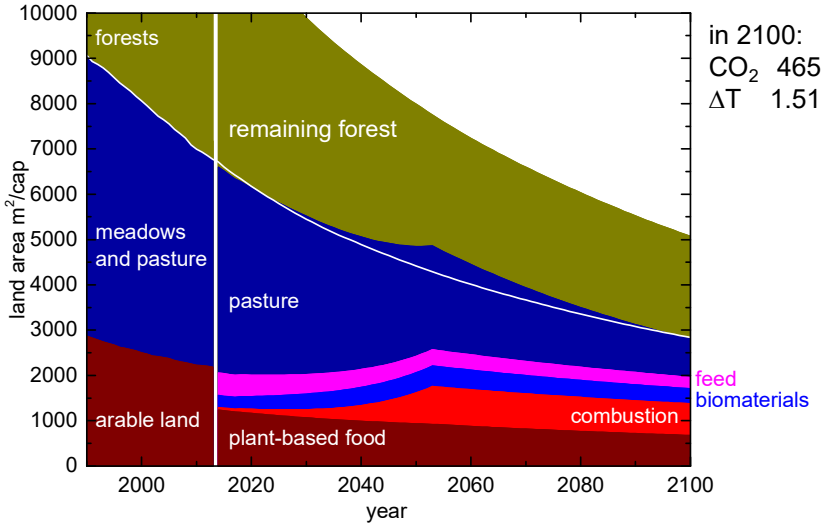
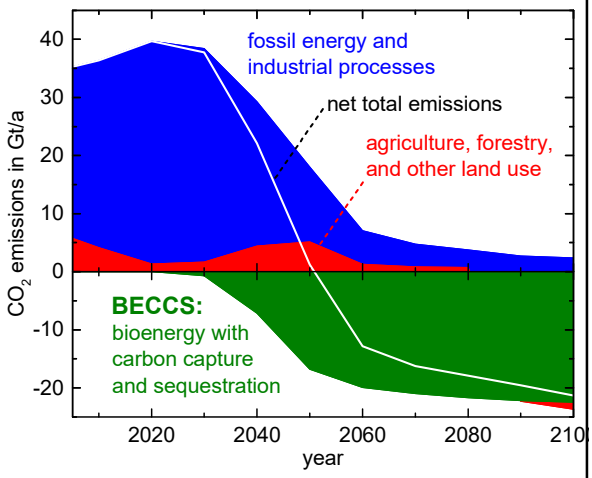
land-area: challenging, high pop. variant



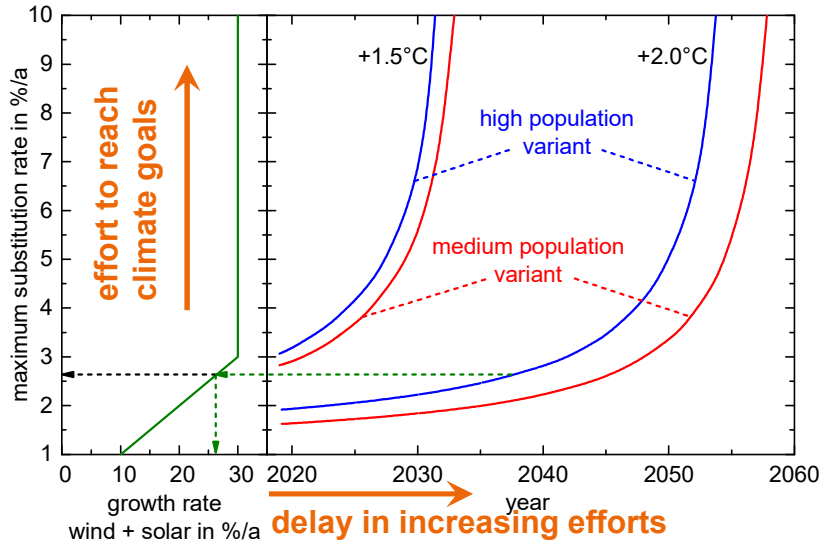
in 2100:
CO_2 465 ppm
ΔT 1.51 °C

IPCC SR15 of October 6, 2018

scenario: P4
scen. chap. 2: S5
population: low
energy: manageable
BE/arable land '50: 40%
description: adoption of greenhouse-gas intensive lifestyles



can 1.5°C climate goal still be reached?



conclusion on IPCC SR15

world population:

- **IPCC perspectives are unrealistic**

illustrative model pathways for energy transition:

- **P1, P2, and P3 cannot be reached**
- **P4 will not work, BECCS ↔ world hunger**

⇒ **IPCC report draws a much too optimistic picture!**

⇒ **1.5°C climate goal overslept with high probability**

⇒ **even to stay below 2°C instantaneous and concerted global efforts are required including change of behavior**

which routes could work for 1.5°C goal?

- no middle path possible
- instead strong and concerted global commitment:
- 30% annual increase in solar + wind energy
- then 3% annual substitution of fossil energy by solar + wind energy until 2050 to reach 1.5°C
- (20%/a - 2%/a until 2075 would currently lead to 2°C)

with change of behavior (2 children, vegetal food):

- BECCS, bio-diversity, eradication of hunger

without change of behavior:

- BECCS not applicable, high danger of more hunger

Our Successful Future
- A Word on IPCC Scenarios

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Our Successful Future
A Short Word on
EU Sustainable Energy Strategy
of November 28, 2018

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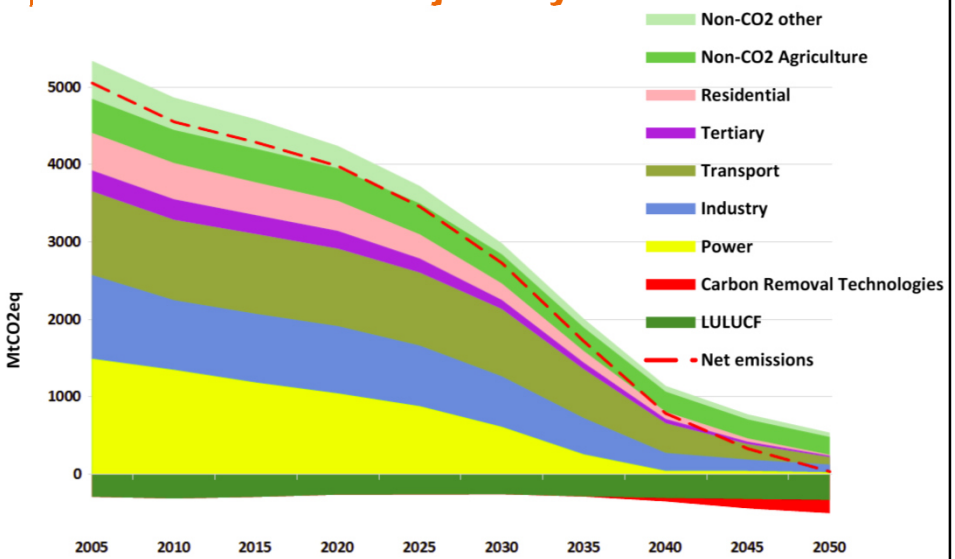
GHG emissions trajectory in 1.5°C scenario



Europen Comission, A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Brussels, 28.11.2018, COM(2018) 773 final

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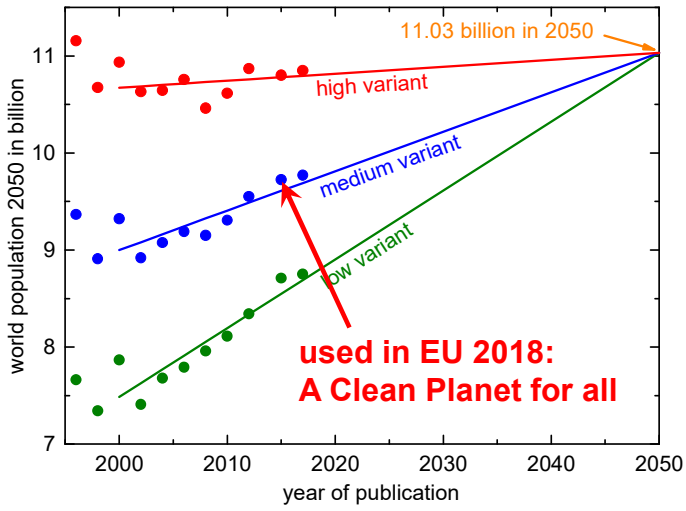
development of UN-WPP predicting for 2050



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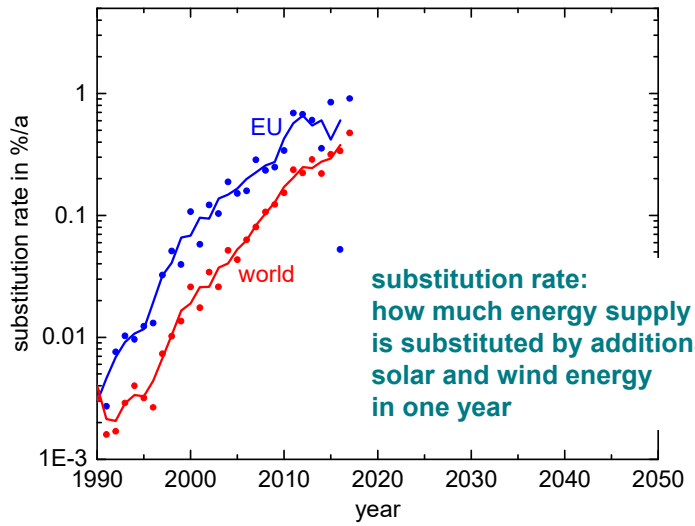
substitution rates solar & wind



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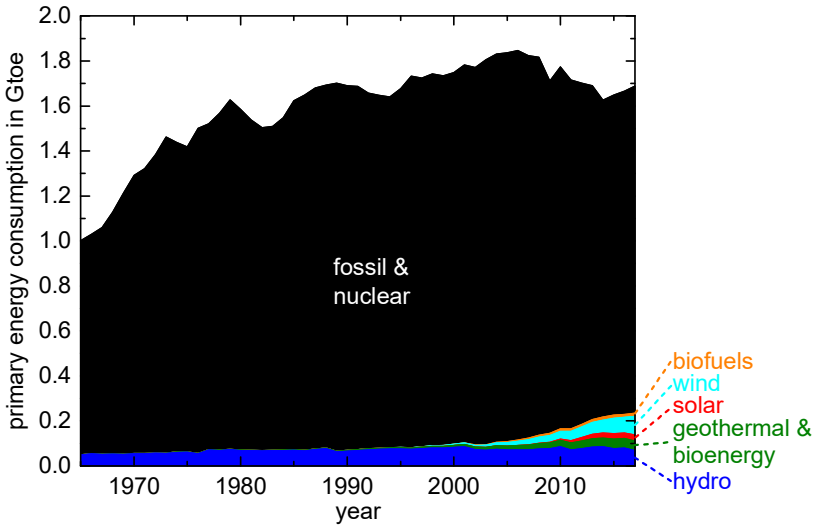
EU primary energy consumption



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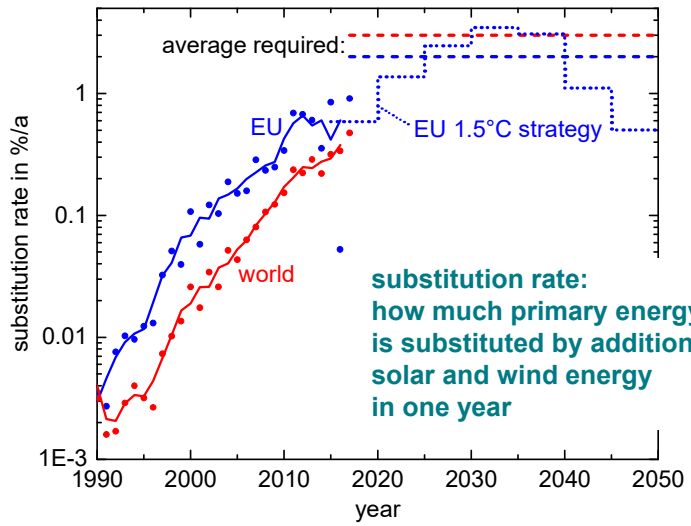
substitution rates solar & wind



substitution rate:
how much primary energy supply is substituted by additional solar and wind energy in one year

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conclusion on EU Sustainability Scenario

world population:

- **high probability for too low population growth**

sustainable energy transition:

- **bio-energy intensification ↔ world hunger**

⇒ EU sustainability goals (Nov. 28, 2018):

- **draw a much too optimistic picture!**
- **significant instantaneous increase in efforts essential!**

Our Successful Future
A Short Word on
EU Sustainable Energy Strategy
of November 28, 2018

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Our Successful Future
- Sustainable Economy
- Exergy to Quantify Energy

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questions to be answered

- How can energy be evaluated, if the future energy system is unknown?
- Which consequences result?

relevant publications

Frenzel, P., Fayyaz, S., Hillerbrand, R., Pfennig, A. (2013). Biomass as Feedstock in the Chemical Industry - An examination from an Exergetic Point of View. Chemical Engineering and Technology, 36(2), 233-240.

Frenzel, P., Hillerbrand, R., Pfennig, A. (2014). Exergetical Evaluation of Biobased Synthesis Pathways. Polymers, 6(2), 327-345.

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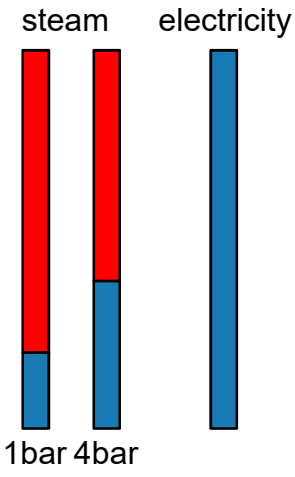
Frenzel, P., Pfennig, A. (2014). Bewertung der steigenden Nachfrage nach Diesel-Kraftstoffen hinsichtlich ihrer CO2-Emissionen. In U., Bachhiesl (Ed.), Innehalten und Ausblick: Effektivität und Effizienz für die Energiewende (pp. 1-9).

what is exergy? why exergy?

- **energy = exergy + anergy**
  - energy is conserved
  - exergy may be lost

- connection cost and exergy
  - crude oil: 1.5 €-cent/MJ
  - sugar: 1.8 €-cent/MJ
  - electricity: 1.7 €-cent/MJ
  - steam: 1 to 2 €-cent/MJ



calculation of exergy

exergy of a material stream

$$E_i = \sum_{i=1}^{N} \left(E_{i,\text{chem}} + E_{i,\text{phys}} \right) + \Delta E_{\text{mix}}$$

chemical exergy of a material stream

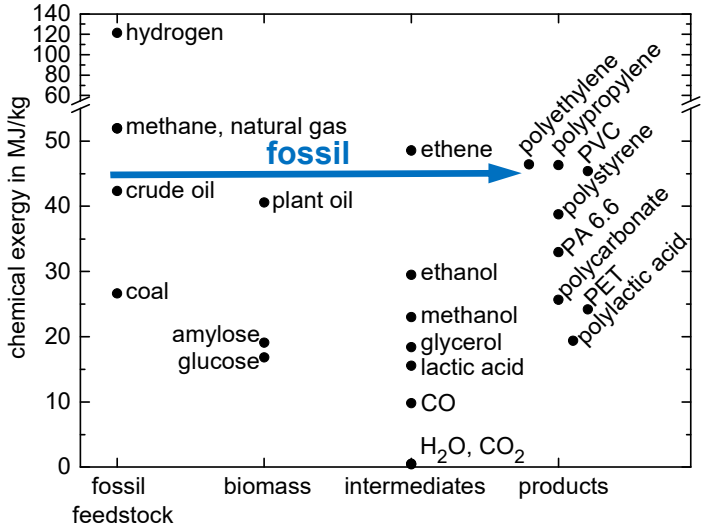
$$E_{i,\text{chem}} = \Delta^{\text{o}} G_i + \sum_{i=1}^{j} \nu_{i,j} E^{\text{o}}_{j,\text{chem}}$$

physical exergy of a material stream

$$E_{i,\text{phys}} = \int_{T_U}^{T_R} C_i(T)dT + V_i^{\text{iF}}(P_R - P_U) - T_U \int_{T_U}^{T_R} \frac{1}{T} C_i(T)dT$$

+ exergy losses in processes and equipment

chemical exergy of various materials



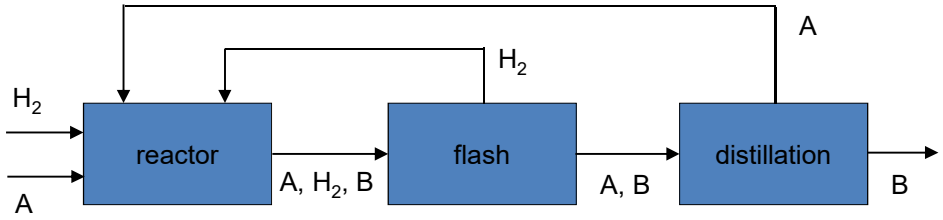
after: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:
Increase in energy and land use by a bio-based chemical industry.
Chemical Engineering Research and Design 92 (2014) 2006-2015

general H_2-process

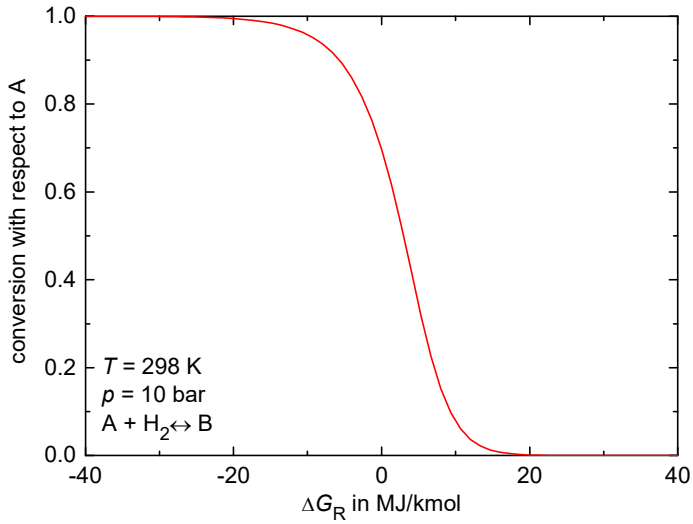
$A + H_2 \leftrightarrow B$

$T = 298$ K

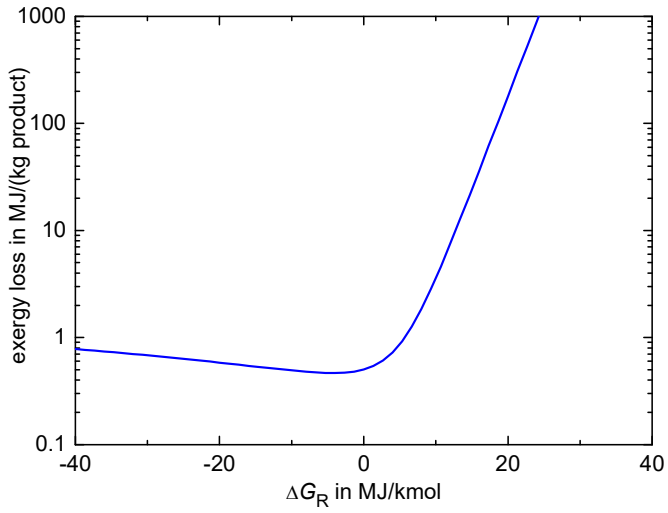
$p_{reactor} = 10$ bar



conversion of A in general H_2 process



exergy loss for a general H_2 process



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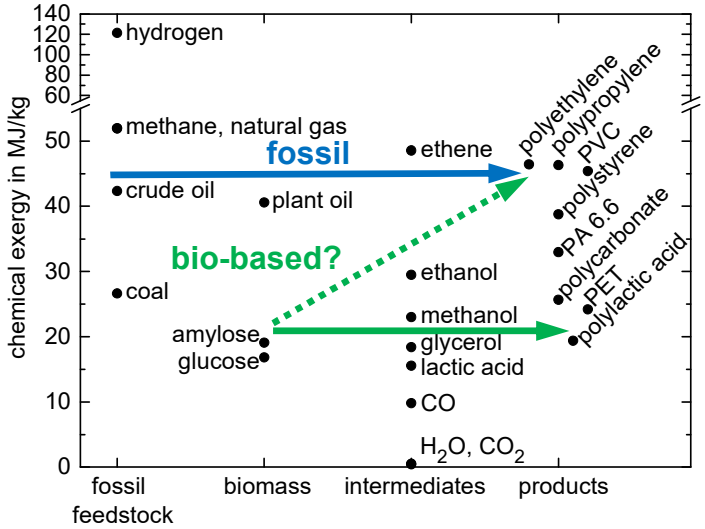
chemical exergy of various materials



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after: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:
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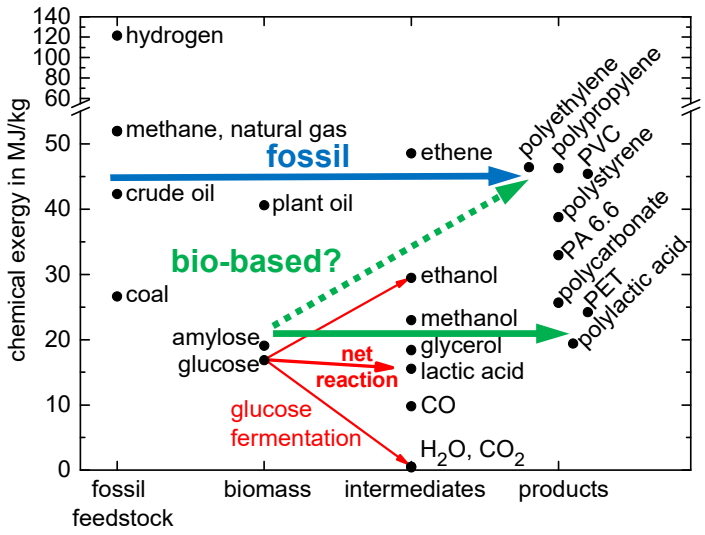
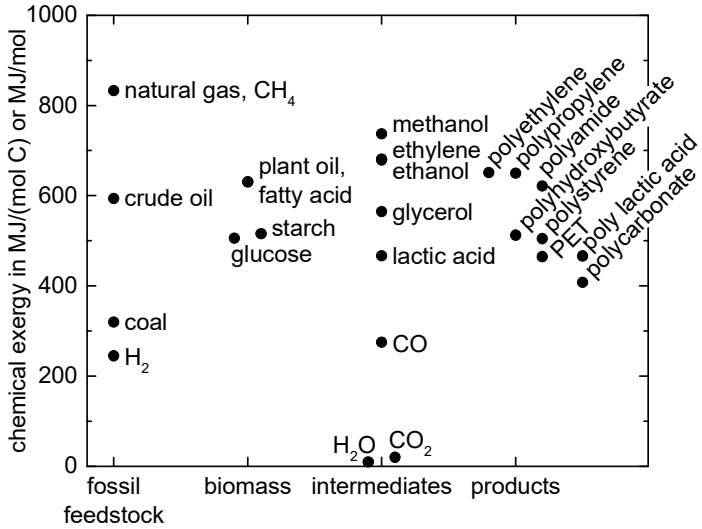
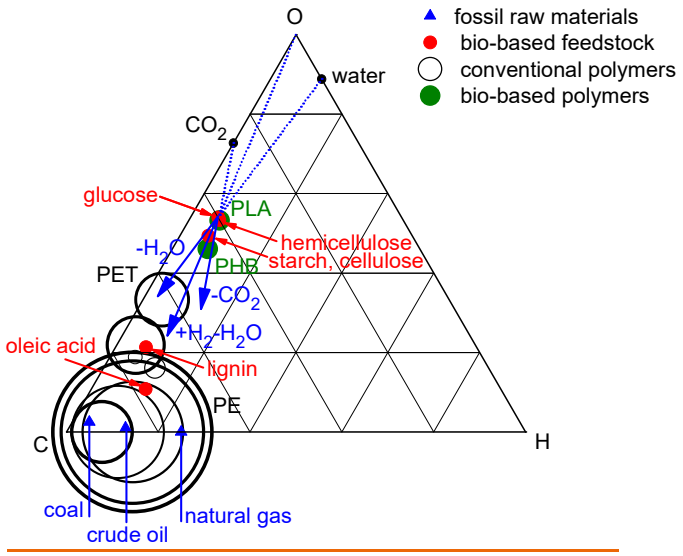


after: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:
Increase in energy and land use by a bio-based chemical industry.
Chemical Engineering Research and Design 92 (2014) 2006-2015

exergy per mol of carbon



elements in chemical industry by weight



source: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig: Increase in energy and land use by a bio-based chemical industry. Chemical Engineering Research and Design 92 (2014) 2006-2015

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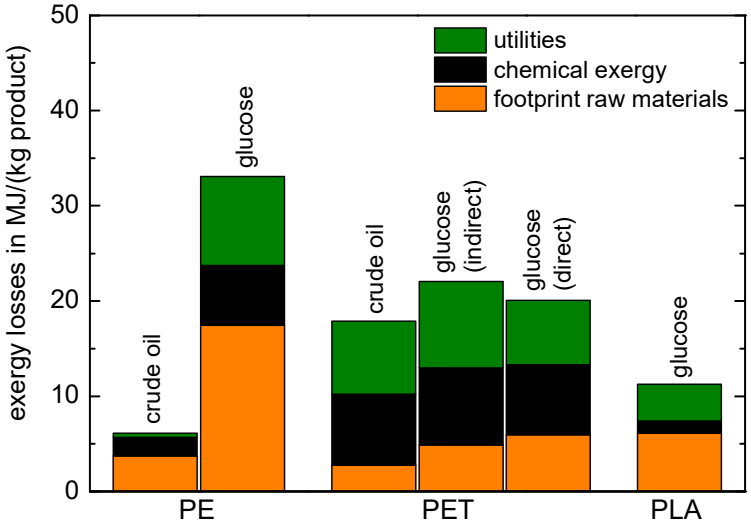
comparision of the processes



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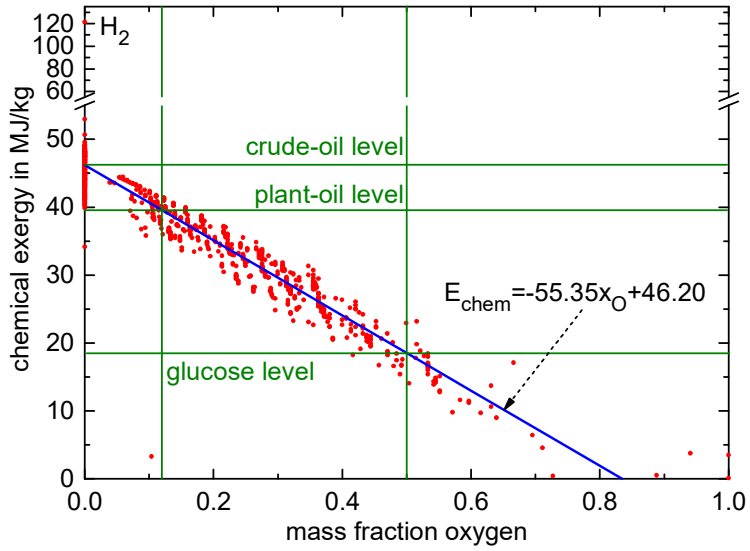
chemical exergy



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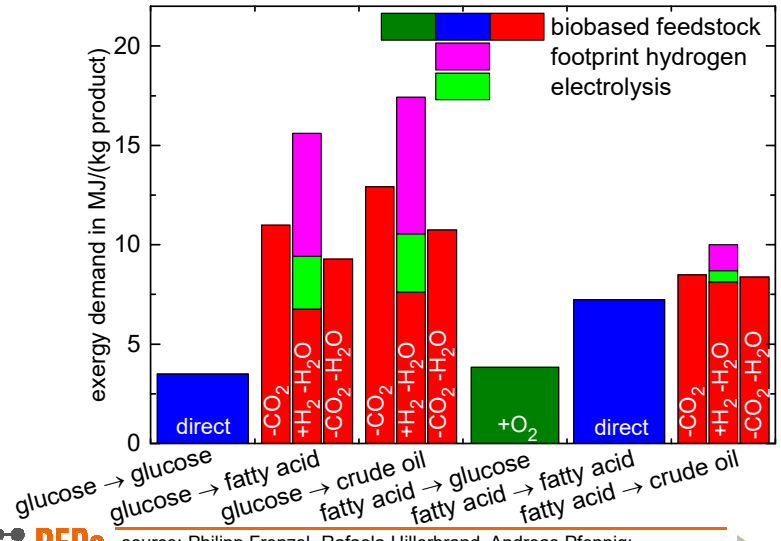
exergy demand for different routes



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source: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:
Increase in energy and land use by a bio-based chemical industry.
Chemical Engineering Research and Design 92 (2014) 2006-2015

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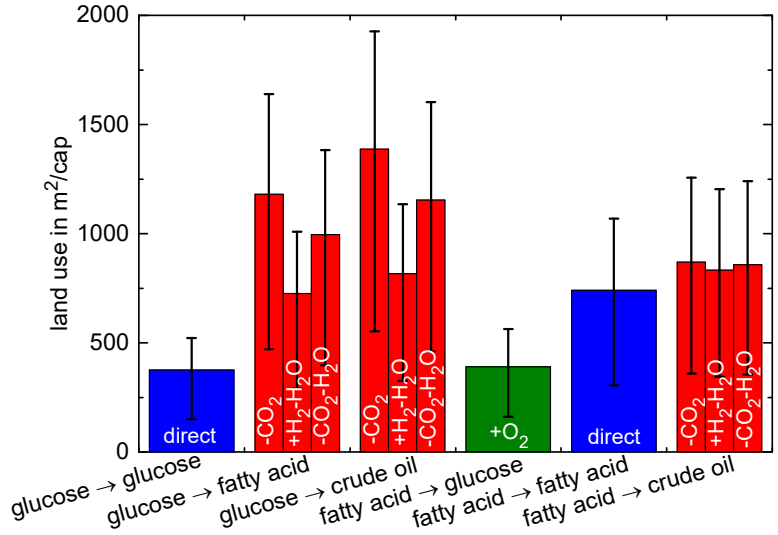
land use 2050 for different routes



source: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:
Increase in energy and land use by a bio-based chemical industry.
Chemical Engineering Research and Design 92 (2014) 2006-2015

in conclusion

- exergy is a universal measure for energy demand
- bio-based economy:
  - avoid carbon losses
  - keep oxygen in products
  ⇒ higher viscosity and lower vapor pressures

Our Successful Future
- Sustainable Economy
- Exergy to Quantify Energy

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Our Successful Future
- Sustainable Economy
- Bio- or CO_2-Economy

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questions to be answered

- What are the boundary conditions for a bio-based or a CO_2-based economy?
- Which options are possible?

relevant publications

Frenzel, P., Fayyaz, S., Hillerbrand, R., Pfennig, A. (2013). Biomass as Feedstock in the Chemical Industry - An examination from an Exergetic Point of View. Chemical Engineering and Technology, 36(2), 233-240.

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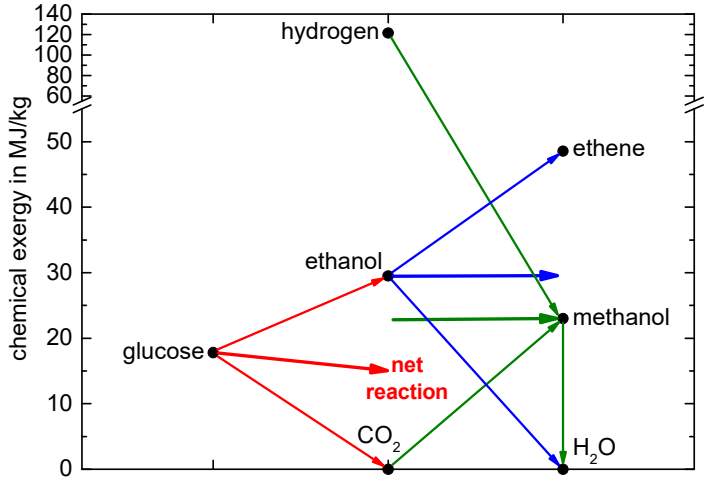
Frenzel, P.E. (2015) Bewertung von Syntheserouten auf Basis von Exergiebilanzen, Ph.D. thesis, RWTH Aachen, Apprimus Verlag, Aachen.

feasible reactions



demand

fossil feedstock today used for:

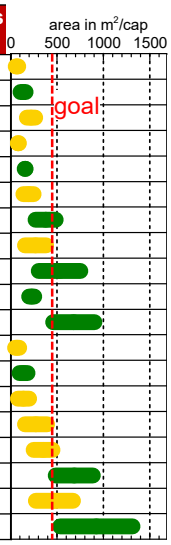
- 4% to petrochemicals
- 2.5% to jet fuel
- x% as combustible or materially in chemical and steel industry

in scenarios for 2050:

- 440 m^2/cap for bio-materials
  plastics ≈ 80 kg/(cap a)
  i.e. intensified recycling
  feedstock all chemicals ≈ 125 kg/(cap a)
- 680 m^2/cap for 10% bio-combustibles

options for bio-based chemicals 2050

gen	feedstock	products	radius km
first generation	sugar beet	sugar or ethanol + CO_2	10.4
		ethanol	14.6
		ethylene	18.7
	sugar cane	sugar or ethanol + CO_2	7.5
		ethanol	10.5
	corn	sugar or ethanol + CO_2	13.4
		ethanol	18.7
	wheat	sugar or ethanol + CO_2	17.5
		ethanol	24.5
	oil palm	plant oil	11.4
	rape seed	plant oil	30.1
second	miscanthus/reeds	sugar or ethanol + CO_2	5.7
		ethanol	7.9
	wood	sugar or ethanol + CO_2	14.8
		ethanol	20.7
third	corn straw	sugar or ethanol + CO_2	20.1
		ethanol	28.2
	wheat straw	sugar or ethanol + CO_2	23.2
		ethanol	32.5



ranges:
maximum national and world average productivity projected for 2050

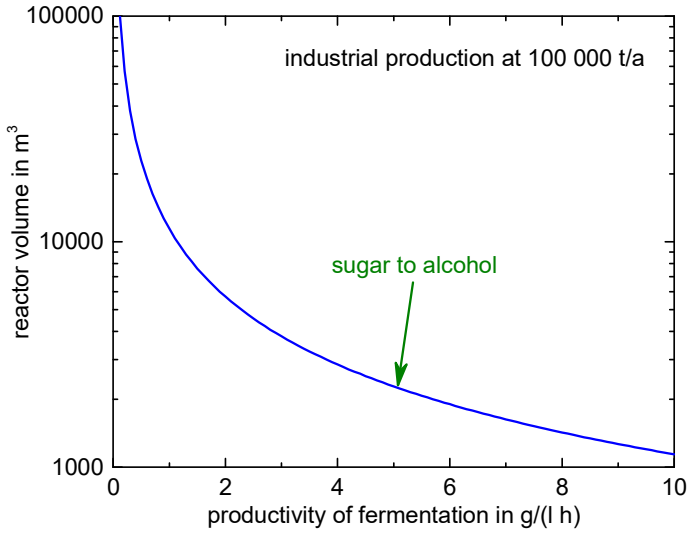
color:
- technically realized
- partly pilot-plant

radius for capacity of 250 000 t/a

bio- vs. CO_2-economy

- **bio-economy:**
  - existing technology, comparable to food processes
  - requires agricultural land area
  - energy requirements comparably small
  - drop-in possible
  - protein to food
  - large side and recycle streams
- **CO_2-economy:**
  - no agricultural land area required
  - requires a lot of energy
  - not yet installed on large scale (economically feasible?)
  - drop-in possible
  - after net-decarbonization mostly from air

feasibility of large-scale biotechnology



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big aerobic fermenter

Bayer-Lanxess
tower technology

volume 13 000 m^3
flowrate 650 m^3/h

example:
for 100 000 t/a
down to 0.87 g/(l h)
up to 17.5 g/l

but: all purification steps will be very big as well!

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by courtesy of Currenta GmbH & Co. OHG

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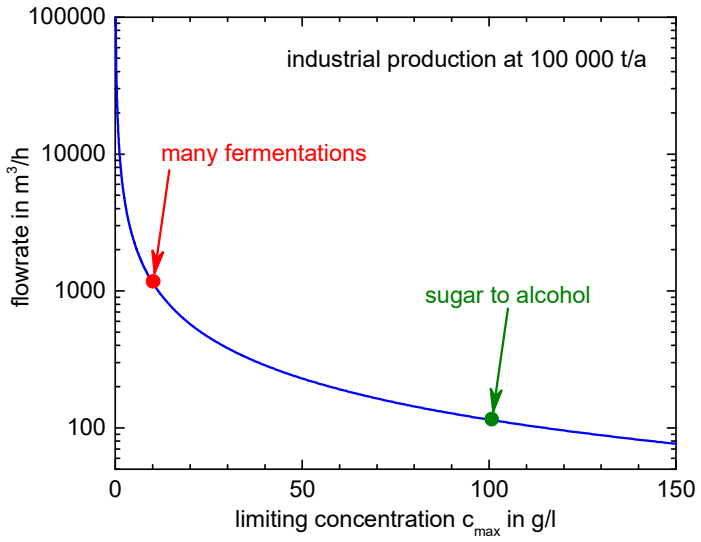
feasibility of large-scale biotechnology



typical area/equipment demand

land area required	feedstock & technology
m^2 / (t/a)	
1 to 3	bio-technological processes (alcohol from sugar)
0.2 to 0.5	direct biomass conversion (sugar from starch)
0.03 to 0.1	chemical process (e.g. steam cracker)

conclusion

- solely third generation bio-processes not feasible
- first and second generation compete for same land area as food
- various options available as feedstock: CO_2, sugar cane, sugar beet, corn, palm oil, miscanthus/reeds, possibly wood
- bio-based or CO_2-based: both possible
- bio-based: preferably either sugar chemistry or co-utilization of CO_2
- cellulose component utilization of 1. generation crops is add-on benefit, but large by-products
- proteins for food
- strong interaction: agriculture ↔ food ↔ chemistry ↔ energy

chances, challenges

- bio-based and CO_2-based chemistry: various options
- bio-economy ≠ only bio-technology
- bio-economy ≠ automatically sustainability
- economics, ecologics, **ethics**
- **big chance**: real circular economy
- all happens in ±30 years (or it is too late)

Our Successful Future
- Sustainable Economy
- Bio- or CO_2-Economy

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Our Successful Future
- Individual and Political Consequences

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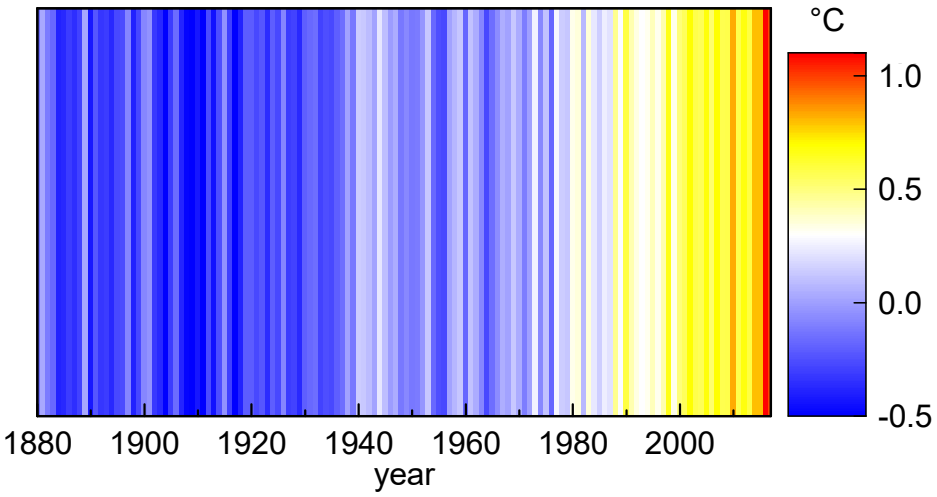
questions to be answered

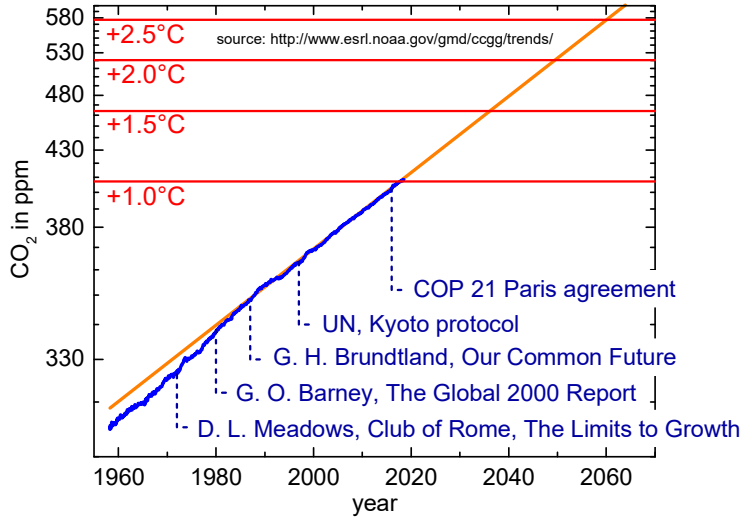
- What are the consequences for us individually, if the sustanable development goals shall be reached?
- What does this mean for policies and politics?

global mean temperature



GISTEMP Team, 2018: *GISS Surface Temperature Analysis (GISTEMP).* NASA Goddard Institute for Space Studies. Dataset accessed 2018-11-14 at https://data.giss.nasa.gov/gistemp/

CO_2 content of the atmosphere



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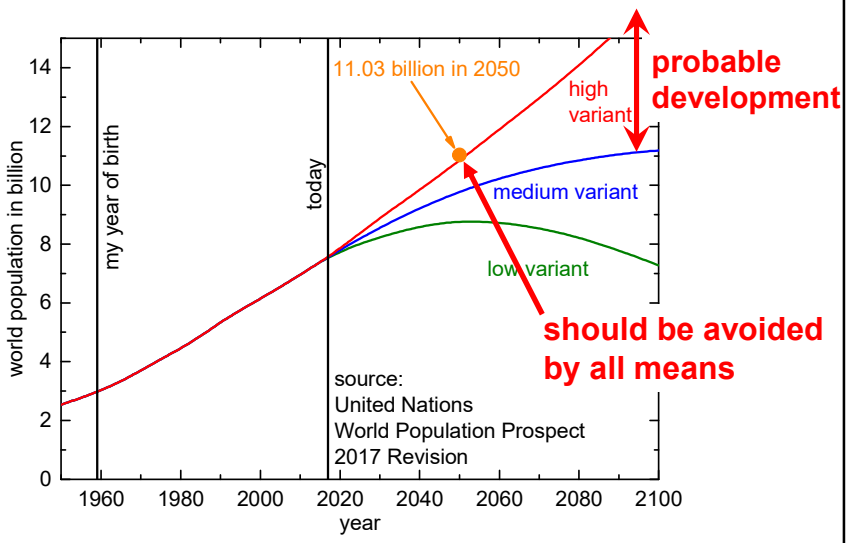
world population scenarios



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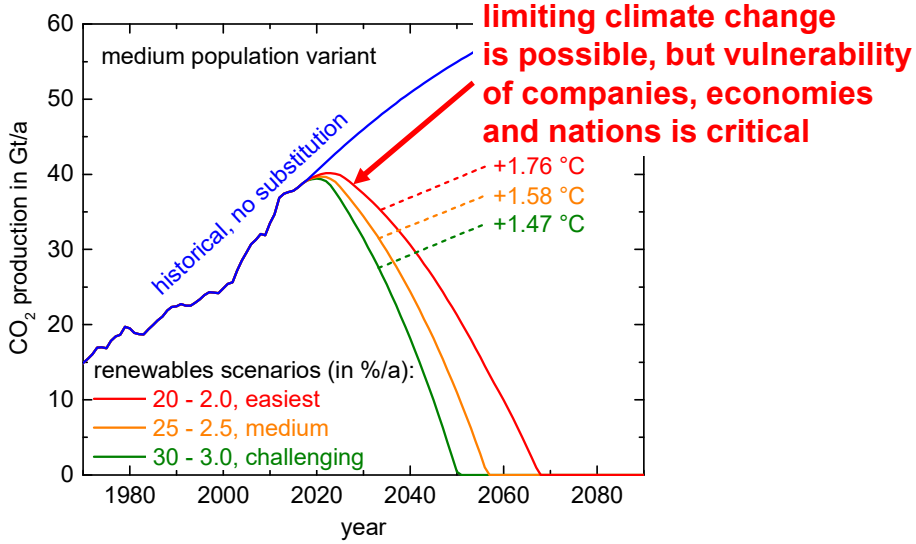
population growth eating up progress

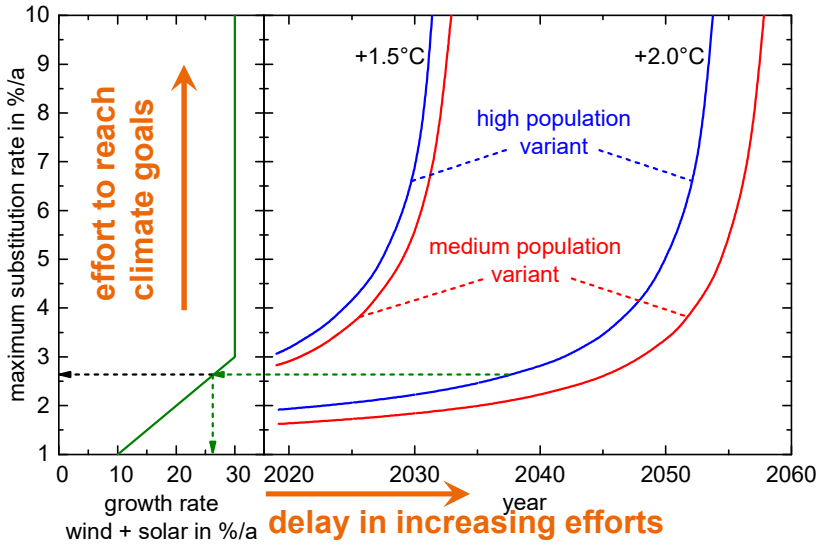
since 1990:

- additional people fed: 2.5 bn
- population increased by: -2.3 bn
- undernourishment decreased by 0.2 bn

CO_2 emissions for medium pop. variant



consequences of a delay



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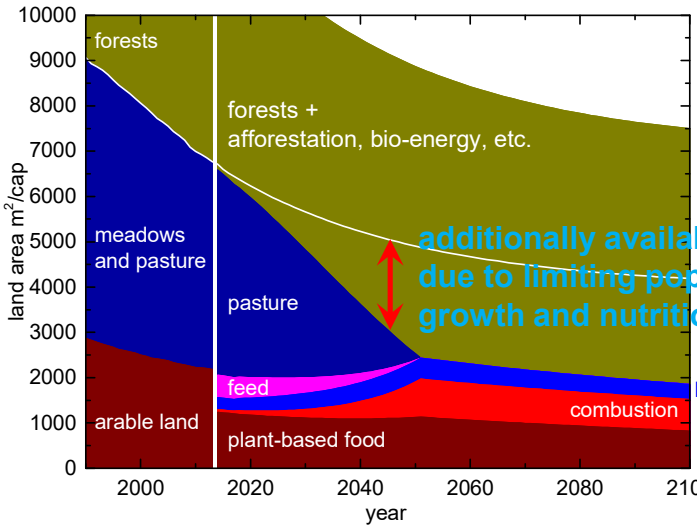
land-area: challeng., medium pop., vegetal



in 2100:
CO_2 460 ppm
ΔT 1.47 °C

additionally available land area due to limiting population growth and nutritional habits

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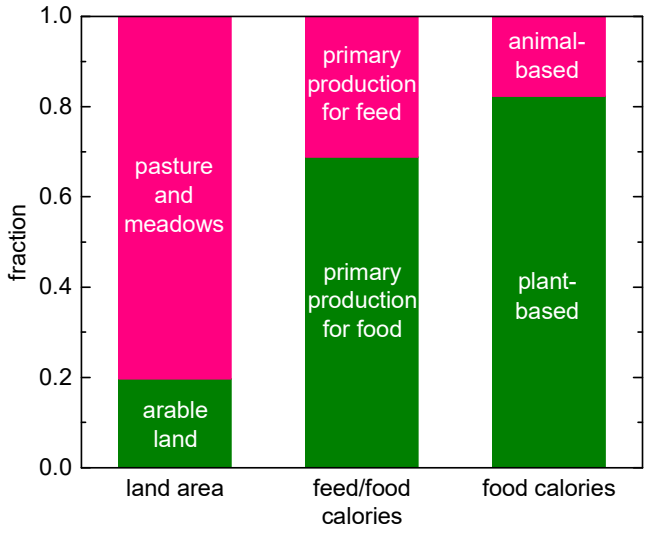
inefficiency of animal-based food supply



main results

two challenges: climate ↔ energy
land area ↔ food, bio-energy, bio-materials
technology ↔ behavior

significant drivers: population growth
vegetal ↔ animal-based food

complete shift required in:
- energy industry
- agriculture
- chemical industry
- etc.

replace fossil resources annually by up to
- for +1.5°C goal: **3%/a until 2050**
- for +2.0°C goal: **2%/a until 2075**
  (solar & wind today: ≈ 0.5%)

steps towards a sustainable future

use of all technological options

questioning all paradigms:

- plant-based nutrition?
- right for how many children?
- alternatives to religion as basis for definition of values of a sustainability ethics?

justice: inter-national, inter-generational, transitorial:

- How is burden for environmental protection distributed?
- How is burden for development distributed?
  How is that linked with reduction to fertility?
- How will trade with nutrition and energy be organized in the future?

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religions

Pope Francis, Ladato Si', 50, May 24, 2015:

... it must nonetheless be recognized
that **demographic growth is fully compatible with an integral and shared development**.
To blame population growth instead of
extreme and selective consumerism
on the part of some, is one way of refusing
to face the issues.

Quran, verse 18.46:

Wealth and **sons** are the adornment of the life of this world.

conflicting human rights

§16.1: Men and women of full age, without any limitation due to race, nationality or religion, have the right to marry and **to found a family**.

§18: Everyone has the right to freedom of thought, **conscience and religion**; this right includes freedom to change his religion or belief, and freedom, either alone or in community with others and in public or private, to **manifest his religion or belief** in teaching, **practice**, worship and observance

§25.1: Everyone has the right to a **standard of living adequate for the health and well-being of himself and of his family, including food**, clothing, housing and medical care and necessary social services, ...

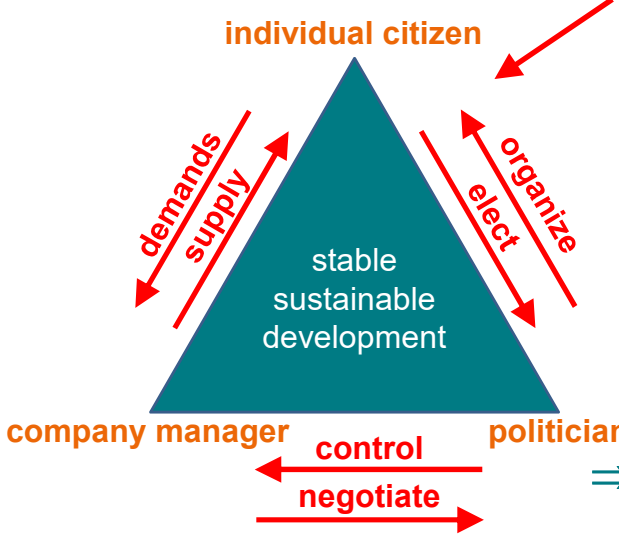
international & individual obligations

§28: Everyone is entitled to a social and **international order in which the rights** and freedoms set forth in this Declaration **can be fully realized**.

§29.1: **Everyone has duties** to the community in which alone the free and full development of his personality is possible.

§29.2: In the exercise of his rights and freedoms, **everyone** shall be **subject only to such limitations as are determined by law solely for the purpose of securing due recognition and respect for the rights and freedoms of others** and of meeting the just requirements of morality, public order and the general welfare in a democratic society.

individual actors



⇒ systems view essential

system

- Does the free interplay of forces automatically lead to a sustainable system?

⇒ systems view essential

⇒ individual is driver, i.e. only entity with freedom of choice

⇒ individual has to be aware of his/her influence on the system

what matters

individual choices determine our future:

- limit number of children
- prefer plant-based vs. animal-based nutrition
- reduce consumption of fossil resources

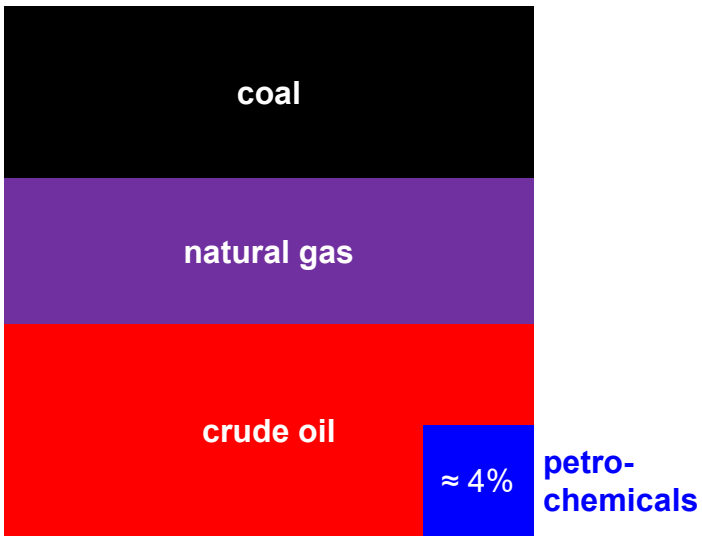
interaction of individuals:

- support politics for sustainability
  even if individual benefits are limited
- developing societal values for sustainability, e.g.
  human rights ↔ individual obligations

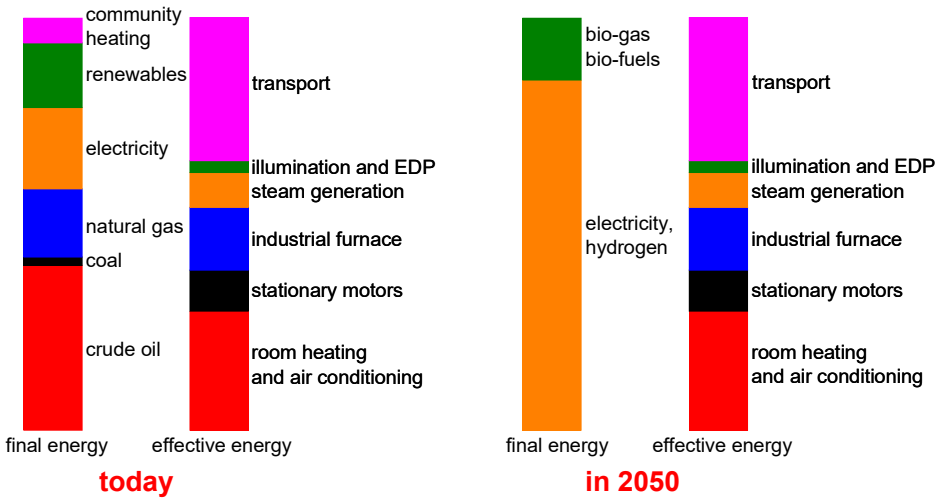
general:

- **the solution cannot be only political (top-down)!**
- support of **development on equal footing**
- support sustainable energy transition and energy saving
- food vs. fuel is critical, depending on scenario
- it happens in our lifetime and that of our children

petrochemicals ≈ 4% of fossil resources



change in energy system



in conclusion

- reaching climate goals is possible with available technology, but has to be systematically applied on larger scale
  - significant **increased global effort** is required, **growth 20 - 30%/a**
  - replace fossil resources annually by up to
    - for +1.5°C goal: **3%/a until 2050**
    - for +2.0°C goal: **2%/a until 2075**
- **food supply is critical**, but **change of individual choices essential:**
  - number of children
  - plant-based vs. animal-based food
- **bio-based or CO_2-based** materials production is feasible, but not solely from third-generation biomass
- **minimize bio-energy:** fuel vs. food
- **systems view** instead of focus on own interests
- **developmental tipping point** is possible
- **individually responsible**, not just question of politics & technology
- it **has to happen now**, otherwise situation will get bad during our lifetime and that of our children

Our Successful Future
- Individual and Political Consequences

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Our Successful Future
Philosophical Aspects
- Physical Basis

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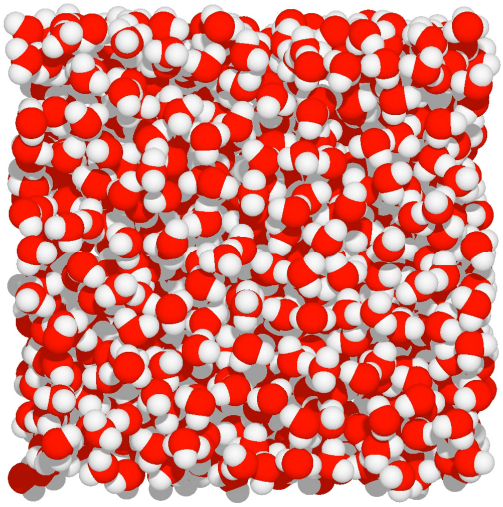
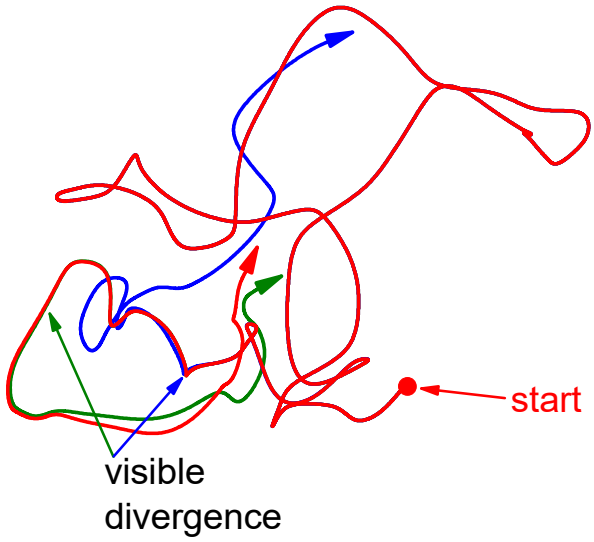
questions to be answered

- How do small perturbations influence molecular motion?
- How do molecules interact over large distances?
- What are the consequences for our world view?
- How does this influence the understanding of the arrow of time?
- Pfennig, A. (2018): On the strong influence of molecular interactions over large distances. European Physical Journal D - Atoms, Molecules, Clusters & Optical Physics, 72 (March, paper 45), 1-8.

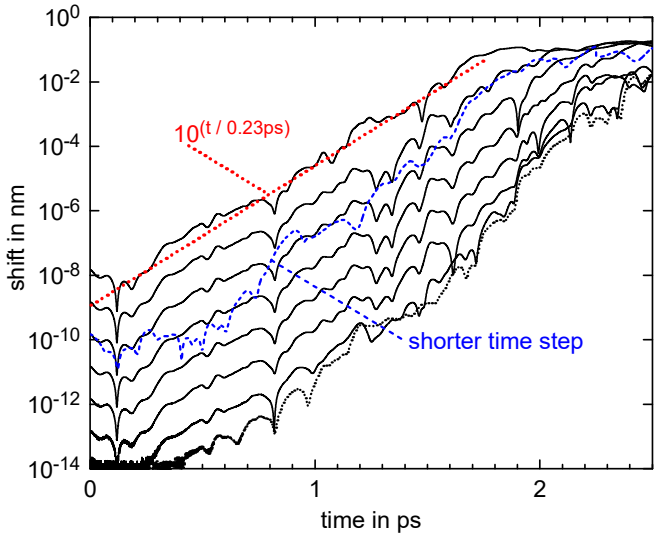
liquid water, 37°C, periodic boundaries



trajectories of molecules with minute shifts



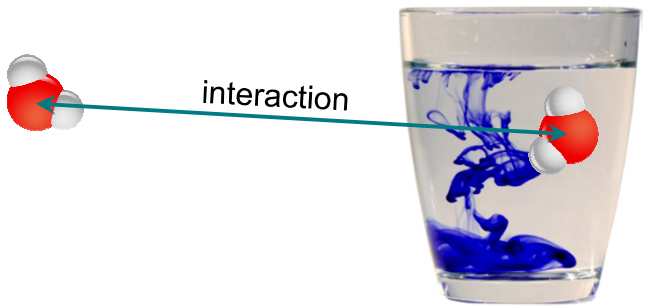
Lyapunov instability in liquid water at 37°C



consequences

- determinsitic chaos, Lyapunov time
- prediction every 0.23 ps further into the future requires one more decimal digit in start coordinates and calculations
- thus: cannot be predicted over intermediate times
- this is statement only about prediction, not about reality itself

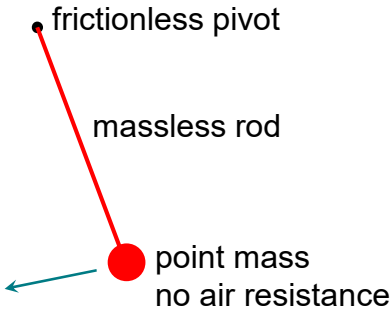
thought experiment



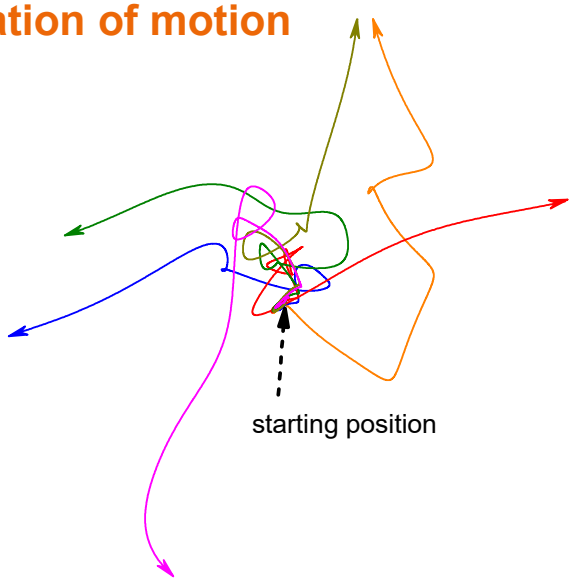
the ideal pendulum

bifurcation:

deterministic motion:

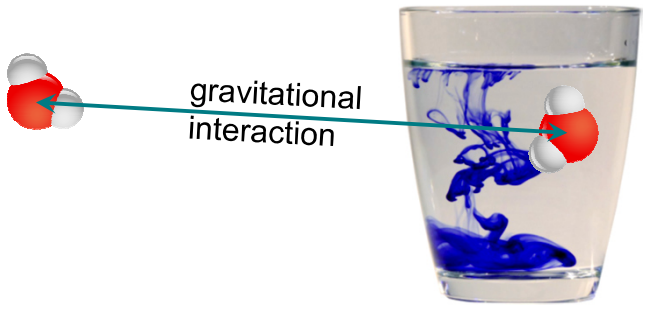


randomization of motion



question:

- How long does it take until the interaction leads to an observable bifurcation?
- bifurcation = shift by molecular diameter



interaction of distant particle 1 for $\Delta t_{interaction}$

$$F = G\frac{m_1 m_2}{r_{1,2}^2}$$

$$F = m_2 a$$

$$a = \frac{\partial^2 s}{\partial t^2}$$

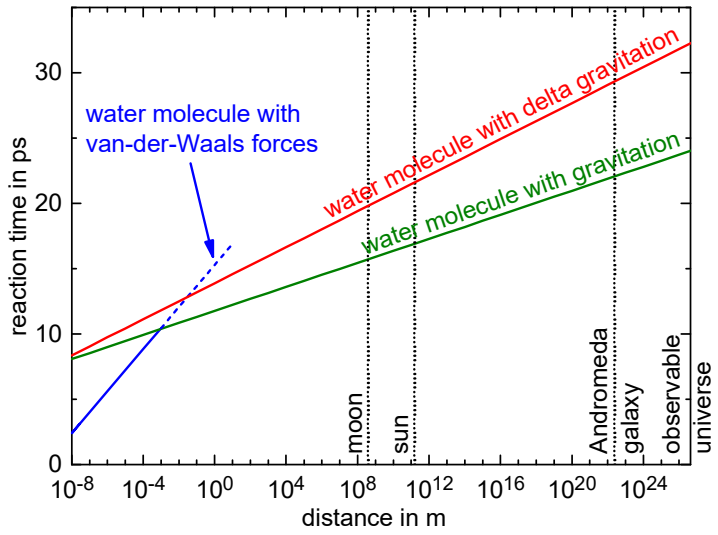
$$\Delta t_{interaction} \Longrightarrow \Delta s_0$$

$$\Delta s = \Delta s_0 10^{t/t_{scale}}$$

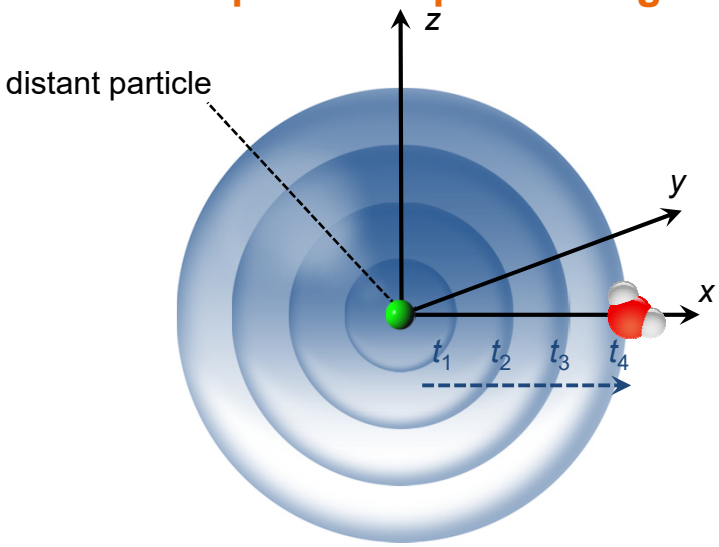
$$\Delta t_{reaction} = t_{scale}\left(\log_{10}\frac{2\Delta s}{G m_1} + 2\log_{10} r_{1,2} - 2\log_{10}\Delta t_{interaction}\right)$$

m_1 – mass of distant particle
m_2 – mass of observed particle
$r_{1,2}$ – distance between particles
F – force acting between particles
t – time
Δs_0 – initial shift of observed particle
t_{scale} – 0.23 ps

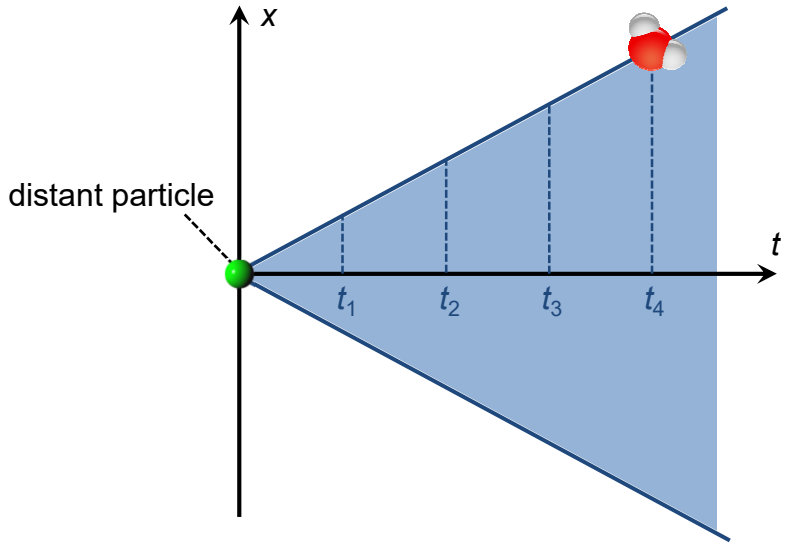
influence between two water molecules



interaction spheres at proceeding time



cone of interaction



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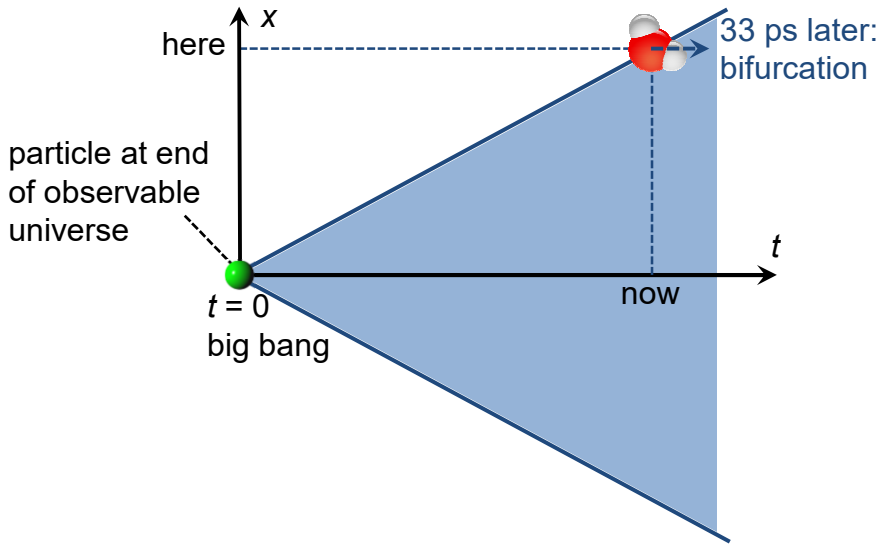
cone of interaction



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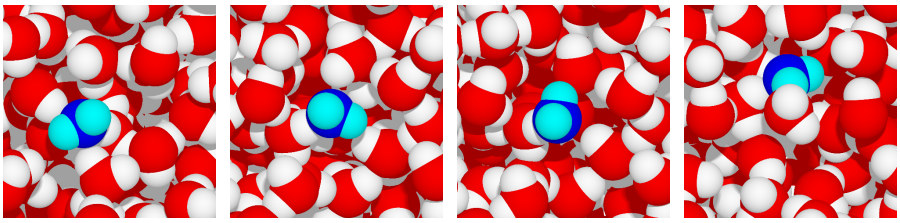
picture

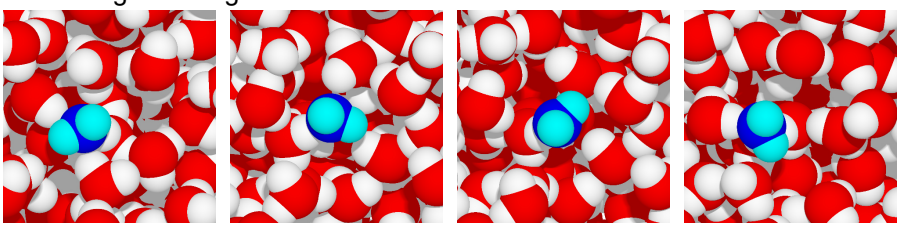
- all particles send information
- travels with speed of light
- any particle experiences at every moment the sum of all interactions with all particles
- reacts to this interaction
- if any faraway particle would have been in a slightly different place, after at most 33 ps the observed particle would react differently at any multi-furcation
- interactions superimpose linearly

influence by a faraway water molecule

isolated system

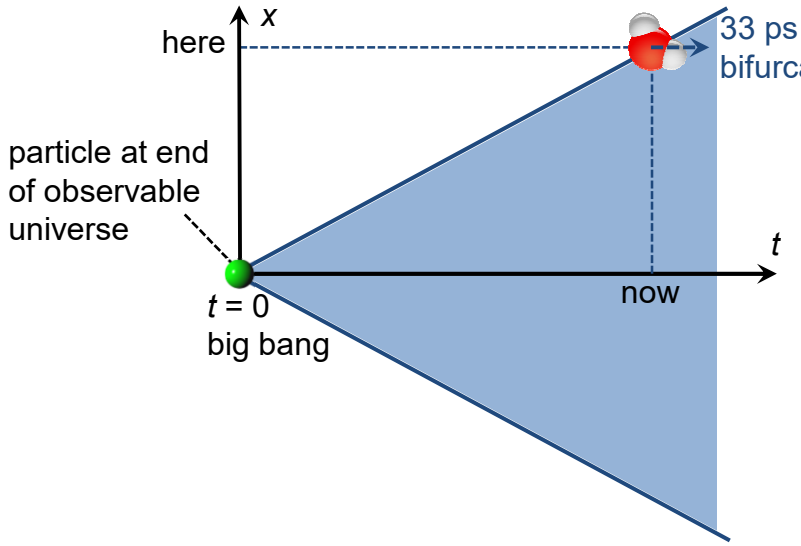


interacting with single water molecule at the end of the observable universe



0.0 ps 31.9 ps 32.0 ps 33.0 ps

cone of interaction



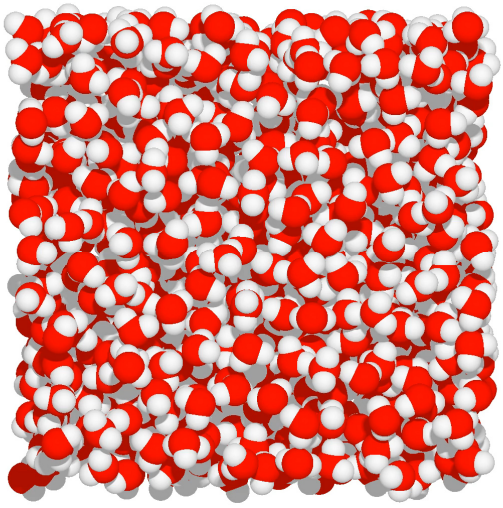
consequences

- all particles influence each other
  within 0 to 33 ps on universal scale
  (possibly much faster)
- but: speed of light
- this is about **interaction in reality**, not only about prediction
- randomizing effect
- even in a fully deterministic world view
- generalization:
  - complex systems show deterministic chaos
  - at bifurcations: system randomly influenced
    by all particles in the universe

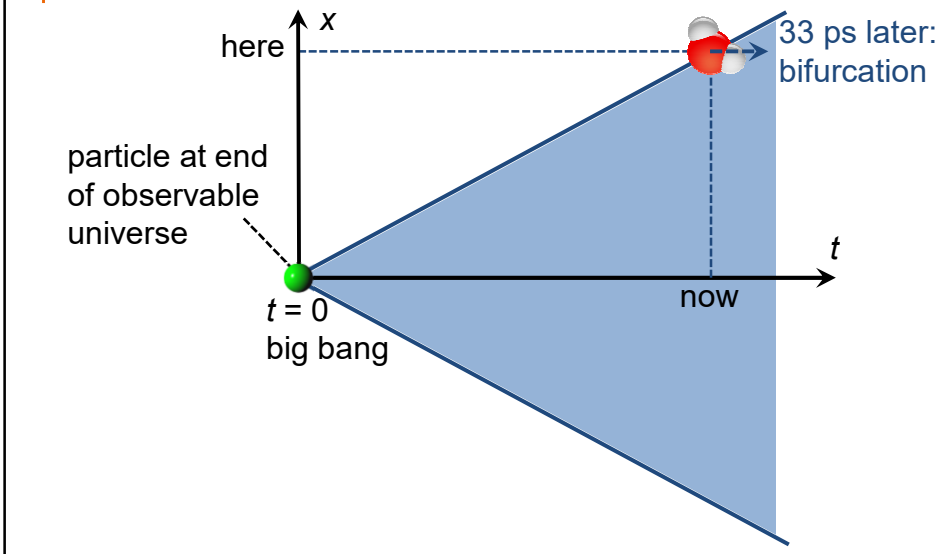
reversal of time

- e.g. conservation of energy and momentum
- Newtons laws of motion
- but entropy reduction improbable:

liquid water, 37°C, periodic boundaries



cone of interaction



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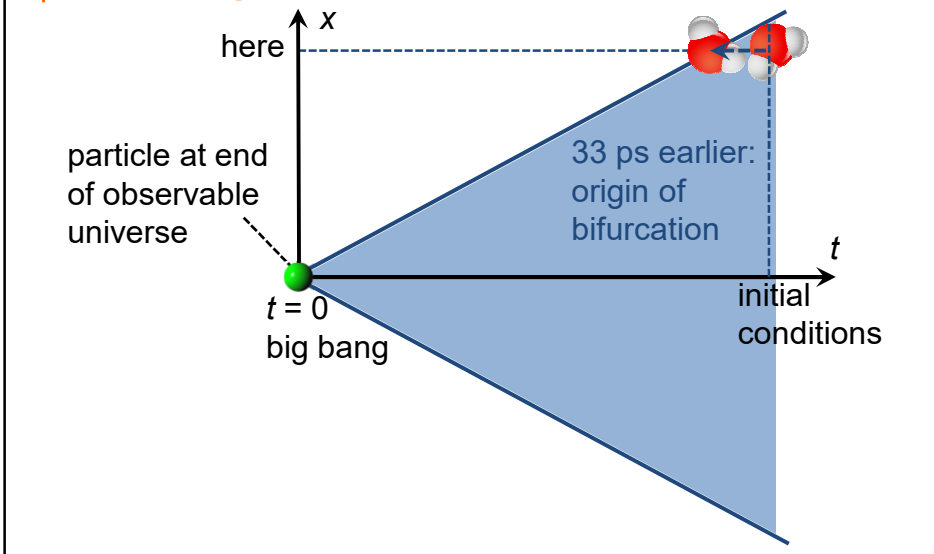
reversing the direction of time



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conclusions

- physical laws may be time reversible
- initial conditions can freely be chosen only in forward direction of time
- in backward direction: vast multitude of conditions, in effect: reversal only possible starting from system that developed in forward direction

Ernst Mach

There is no cause nor effect in nature;
nature has but an individual existence;
nature simply is.

Ernst Mach: The Science of Mechanics.
A Critical and Historical Account of its Development.
Translated by Thomas J. McCormack.
The Open Court Publishing Co., Chicago, 1919.

Our Successful Future
Philosophical Aspects
- Physical Basis

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Our Successful Future
Philosophical Aspects
- Causality

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questions to be answered

- How can cause and effect be physically understood?

cause: **individual trigger** or small set of triggers, inducing an effect, which **would not have happened**, if the triggers would **not have occurred**, irrespective of some **consistent variation** of the surrounding environment

(Honderich, Ted 1988. A Theory of Determinism:
The Mind, Neuroscience, and Life-Hopes. Oxford University Press, Oxford)

causality

levels	relations between different entities of same level
structure with memory	
structure	
macroscopic systems	
molecules	deterministic chaos, continually passing through bifurcations, divergent, universal network of randomizing interactions
quantum objects	

causality

levels	relations between different entities of same level
structure with memory	
structure	
macroscopic systems	
molecules	deterministic chaos, continually passing through bifurcations, divergent, universal network of randomizing interactions
quantum objects	either random or deterministic chaos as for molecules

careful distinction between levels

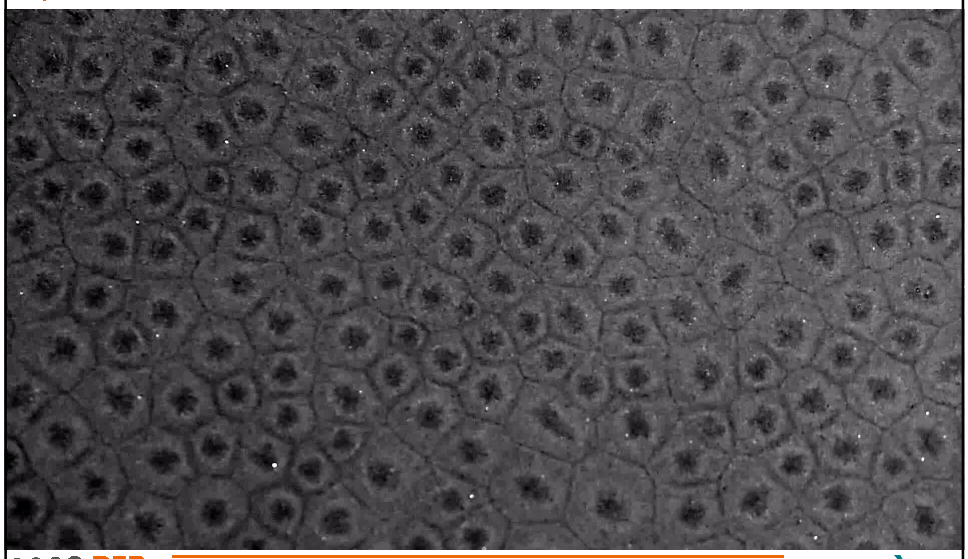
- molecular level
- macroscopic (material) level
- structural level

causality

levels	relations between different entities of same level
structure with memory	
structure	
macroscopic systems	defined properties, physical laws, averaged over many molecules, not causal
molecules	deterministic chaos, continually passing through bifurcations, divergent, universal network of randomizing interactions
quantum objects	either random or deterministic chaos as for molecules

Bénard convection setup

Bénard convection: dissipative structure



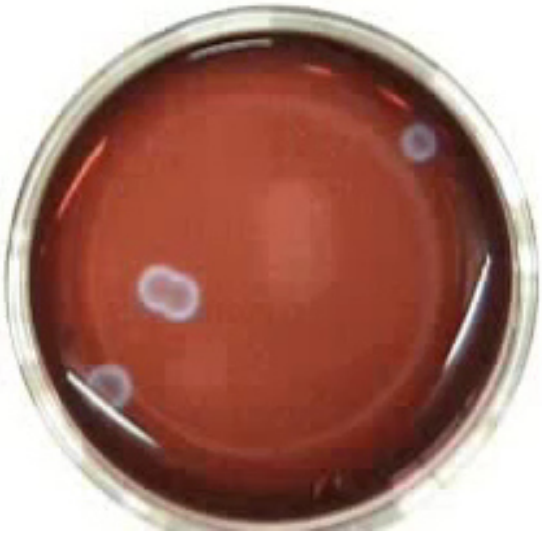
Bénard cells teach us:

- structure ↔ information
- structure causes effects in other structures
- structure determines behavior of matter

causality

levels	relations between different entities of same level
structure with memory	causal, convergent, intentional
structure	causal
macroscopic systems	defined properties, physical laws, averaged over many molecules, not causal
molecules	deterministic chaos, continually passing through bifurcations, divergent, universal network of randomizing interactions
quantum objects	either random or deterministic chaos as for molecules

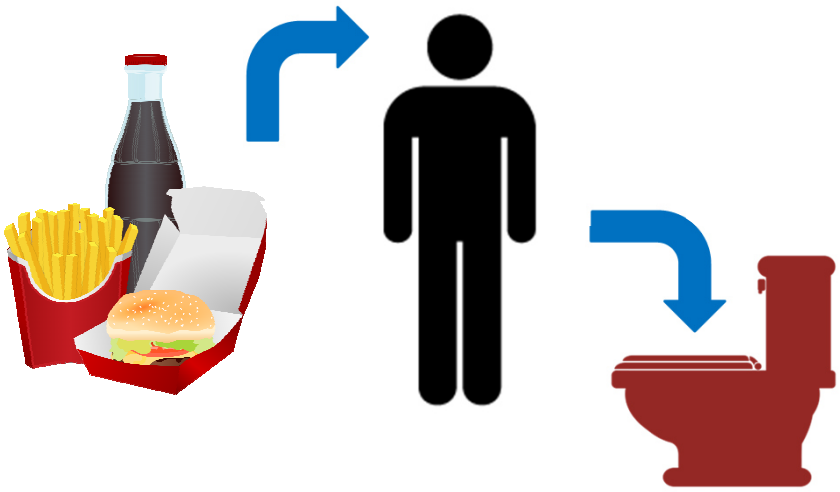
Belousov-Zhabotinsky reaction



continuous,
if reactants are continually supplied, products continually removed

author: Hiroshi Kori
https://www.youtube.com/watch?v=PnOy1fSxBdI

human structure



causality

levels	relations between different entities of same level
structure with memory	causal, convergent, intentional
structure	causal
macroscopic systems	defined properties, physical laws, averaged over many molecules, not causal
molecules	deterministic chaos, continually passing through bifurcations, divergent, universal network of randomizing interactions
quantum objects	either random or deterministic chaos as for molecules

I am fan of Helge Schneider

causality

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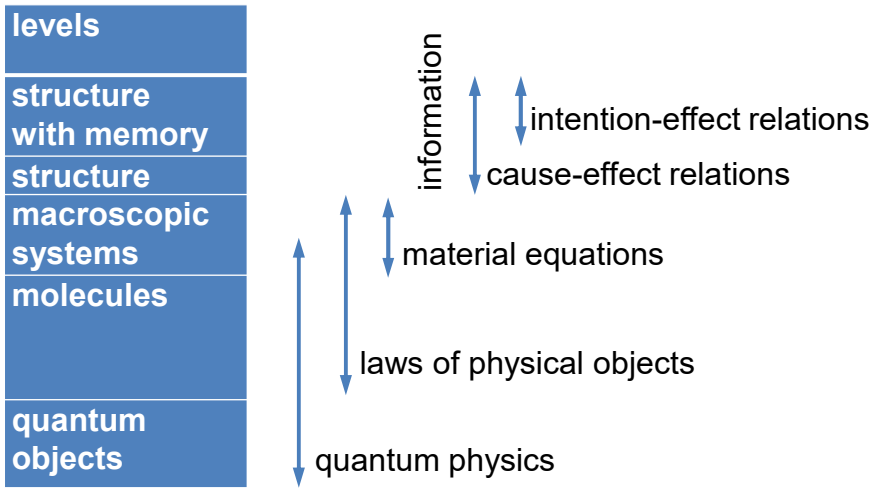
levels of laws we apply



Ernst Mach

There is no cause nor effect in nature;
nature has but an individual existence;
nature simply is.

Ernst Mach: The Science of Mechanics.
A Critical and Historical Account of its Development.
Translated by Thomas J. McCormack.
The Open Court Publishing Co., Chicago, 1919.

conclusions

levels of our description of reality

- cause-effect only on level of structure/information
- molecular level and below: unpredictable, random

human structure

- we as structure can be causal
- structure (mind) controls matter
- our structure influences our decisions
- randomness 'uses' the freedom left,
  free will 'uses' the randomness left

Our Successful Future
Philosophical Aspects
- Causality

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Our Successful Future
Philosophical Aspects
- Consciousness

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questions to be answered

- What is consciousness?

qualities of consciousness

- being conscious
- focus consciousness on sensory perceptions
- consciously feel our body
- consciously control our body
- make conscious decisions

consciousness

- Libet, 1970s:
  conscious 350 ms after readyness potential
- Dehaene, 2014:
  conscious 300 ms after picture appears
- Haynes, 2011:
  predict decision 10 s before conscious with 60% certainty

➢ consciousness lags behind actual decision

➢ unconscious decides

2 principal questions

- Can we be conscious of things, which we in principle cannot remember?
- Can we remember things, which have not been conscious?

here:
memory = pRAM
permanent random-access memory

consciousness

what can in principle be stored in pRAM $\geq$ what is conscious $\geq$ what is stored in pRAM

consciousness

what can in principle be stored in pRAM $\geq$ what is transferred to pRAM $\geq$ what is stored in pRAM

consciousness

what can in principle be stored in pRAM $\geq$ what is transferred to pRAM $\geq$ what is stored in pRAM

working hypothesis:
consciousness = what is transferred in the direction of pRAM

consciousness

what can in principle be stored in pRAM $\geq$ what is transferred to pRAM $\geq$ what is stored in pRAM

working hypothesis:
consciousness = what is transferred in the direction of pRAM

being conscious = being able to remember things
conscious information limited = storage speed limited (MB/s)
varying focus = various aspects can be stored (percenptions)
consciously breathe = remember that we influence breathing
storage comes after content to be stored has been generated

picture

- **now**:
  - 2 to 3 seconds
- **consciousness**:
  - accessing the filing system
  - accessible after 'now'
- **unconscious**:
  - very active system
  - constantly accessing the pRAM filing system
  - e.g. brain processes
  - not accessible after 'now'
  - determines what is sent to pRAM

active impression of consciousness

- unconscious is active but not remembered
  = not accessible to itself
- rubber-hand illusion

the rubber-hand illusion

author: Rick Lax
https://www.youtube.com/watch?v=RaP0MqvkvUw
https://www.facebook.com/realRickLax/videos/861803434001511/

active impression of consciousness

- unconscious is active but not remembered
  = not accessible to itself beyond 'now'
- rubber-hand illusion:
  unconscious can not see itself and thus mistakes the memory as active part, because that is the only thing it can see
- active interaction between memory and unconscious, active loops controlled by unconscious
- since 'now' is 2 to 3 seconds, we can not distinguish what is the active and what is the passive part.

Chalmers: hard problem of consciousness

- Why do we have experiences along with physical processes?
  e.g.: Why do we feel pain when cutting into finger?
- Why do we have exactly those experiences we have?
  e.g.: Why does pain feel like pain and not like some itching?
- What is the difference between us and zombies, who act identically but don't have those feelings?

hard problem of consciousness

- Without getting **memorable** feedback from **body and unconscious**, our evolutionary predecessors would not have survived and we would not have developed. Zombies would have died out.
- Since **evolution is random** (bifurcations influenced by all particles in the universe), any evolutionary result is a consequence of the random bifurcations along the evolutionary path. So there is **no answer to asking for a cause** why pain feels like pain.

conclusions

- now: 2 to 3 seconds
- consciousness = transfer to pRAM memory
- unconscious = active processes, etc.
- unconscious cannot actively 'see' itself
- conscious experience (feelings) = memorable feedback from body and unconscious

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Our Successful Future
Philosophical Aspects
- Free Will and Responsibility

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questions to be answered

- How does free will work?
- Are our free choices predetermined?
- If not, why are they not just random?
- How does a conscious choice work?
- Can we be primary cause by a free choice?

free will

- We could have chosen otherwise!
- How to prove?

free will

- We could have chosen otherwise!
- How to prove? **Impossible!**
- How can we then have the impression of free will?

free will

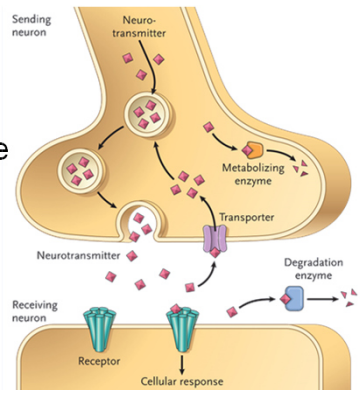
- We could have chosen otherwise!
- How to prove? **Impossible!**
- How can we then have the impression of free will?
  1. it is really random
  2. we don't know the decision beforehand
- ➢ How do **conscious** decisions work?
- ➢ Can we be primary **cause** of our actions?

our brain

- is a complex system
- any decision is a bifurcation
  - any decision randomly influenced by all particles in the universe

can a decision have random aspects?

- brain = complex neural system
- decision = bifurcation
- synapse:
  area 0.04 μm^2
  distance to neuron 20 nm
  concentration 10 to 25 µmol/l Ca^{2+}
  - 7 to 20 ions Ca^{2+} make a difference
  - molecular level involved
  - decision will have random aspects



conscious decision

- What is the role of consciousness in a decision?
  - How does it influence a free-will decision?

conscious decision

- filing system will indeed not know the decision before it has been made
- consciousness is surprised by decision
- interprets: we could have decided otherwise

⇒ impression of free will

  - Why is it our decision?
    Are we the cause for the decision?

different levels of choices

- A or B?
- daily micro-decisions
- spaghetti or salad?
- vegan?

different levels of choices

- A or B?
- daily micro-decisions
- spaghetti or salad?
- vegan?
  - our structure – our personality, preferences – presets probabilities of options from which to choose
  - can vary between random to 0 or 1
  - free will: intricate interplay between randomness and our defining structure/personality
  - **primary** cause because not predetermined

responsibility

- our personal structure defines our preferences
- randomness only within these probabilities
- outcome is to be attributed to our personal structure
- positive or negative feedback has to affect our personal structure
- we are personally responsible, because
  - we are free and primary cause
  - it is our individual personal structure
- responsibility can not be avoided

ethics

- we are the primary cause for our freely chosen actions
- we are automatically responsible
- ethics
  - **discursive**: negotiate with co-humans
  - basis:
    everybody has **equal rights and obligations**
  - account for boundary conditions,
    which **cannot be negotiated**

all in one book

Andreas Pfennig, 2018
So Gelingt unsere Zukunft
Books on Demand, Norderstedt
www.bod.de/buchshop/so-gelingt-unsere-zukunft-andreas-pfennig-9783752831870

chapter titles:

1 Leben, Tod und Sterben
2 Evolution
3 Realität, Wissen und Wahrnehmung
4 Lernen und wissenschaftliche Erkenntnis
5 Wissenschaftliche Weltsicht
6 Gehirn, Bewusstsein, Selbst, Kausalität und freier Wille
7 Weltanschauung, Sinn und Ethik
8 Globale Ethik, individuelles Handeln
9 Gelungenes Leben, Menschsein

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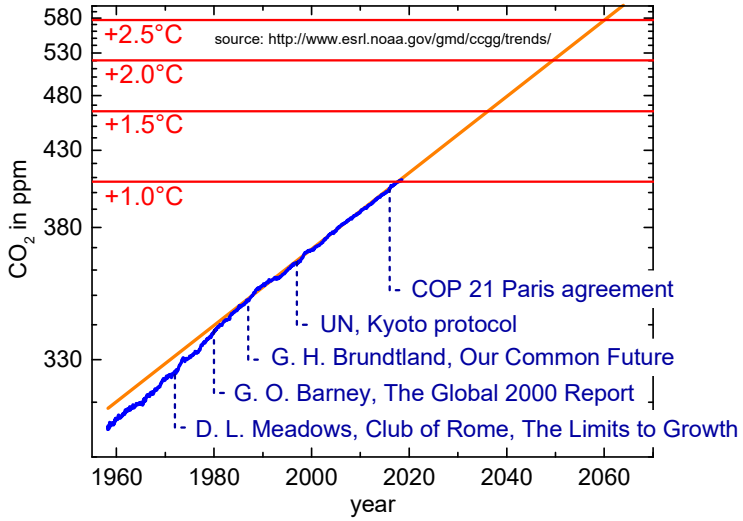
CO_2 content of the atmosphere



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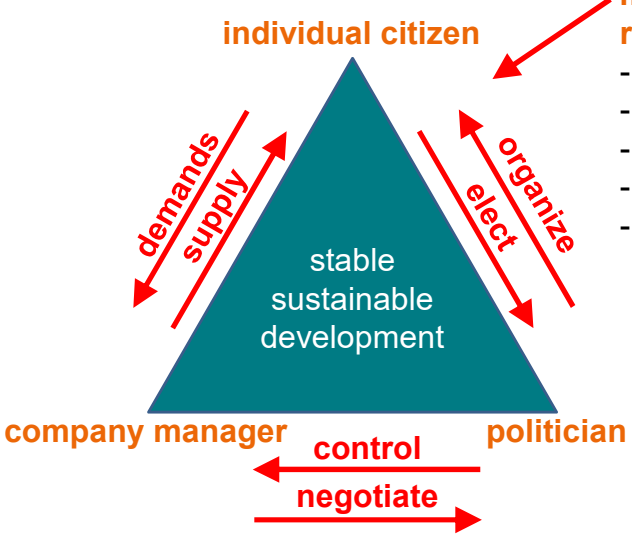
individual actors



system

- **Does the free interplay of forces automatically lead to a sustainable system?**

⇒ **systems view essential**

⇒ **individual is driver, i.e. only entity with freedom of choice**

⇒ **individual has to be aware of his/her influence on the system**

what matters

individual choices determine our future:
- limit number of children
- prefer plant-based vs. animal-based nutrition
- reduce consumption of fossil resources

interaction of individuals:
- support politics for sustainability
  even if individual benefits are limited
- developing societal values for sustainability, e.g.
  human rights ↔ individual obligations

general:
- **the solution cannot be only political (top-down)!**
- support of **development on equal footing**
- support sustainable energy transition and energy saving
- food vs. fuel is critical, depending on scenario
- it happens in our lifetime and that of our children

in conclusion

- reaching climate goals is possible with available technology, but has to be systematically applied on larger scale
  - significant **increased global effort** is required, **growth 20 - 30%/a**
  - replace fossil resources annually by up to
    - for +1.5°C goal: **3%/a until 2050**
    - for +2.0°C goal: **2%/a until 2075**
- **food supply is critical**, but **change of individual choices essential:**
  - number of children
  - plant-based vs. animal-based food
- **bio-based or CO_2-based** materials production is feasible, but not solely from third-generation biomass
- **minimize bio-energy:** fuel vs. food
- **systems view** instead of focus on own interests
- **developmental tipping point** is possible
- **individually responsible**, not just question of politics & technology
- it **has to happen now**, otherwise situation will get bad during our lifetime and that of our children

conclusions

- we have free will (cannot be predicted)
- it is us, who preset preferences as probabilities
- we are fundamentally responsible

- we are also individually responsible
  - for keeping our little planet earth a life-supporting system
  - for ensuring wellbeing of everybody

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