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## Our Successful Future

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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)



recorded at studios and with support  
of IFRES, Université de Liège



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## Our Successful Future - Introduction, Summary

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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)



## 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



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## 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 CO<sub>2</sub>-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



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## agenda

- introduction, summary
- world population  $\Rightarrow$  driving force
- sustainable energy transition  $\Rightarrow$  time scale
- food vs. bioeconomy, hunger  $\Rightarrow$  limiting criteria
- a word on IPCC scenarios
- exergy to quantify energy
- bio- or CO<sub>2</sub>-economy  $\rightarrow$  fuel & material  $\Rightarrow$  options  
bio-economy  $\Rightarrow$  chances & challenges
- individual and political consequences

### philosophy:

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

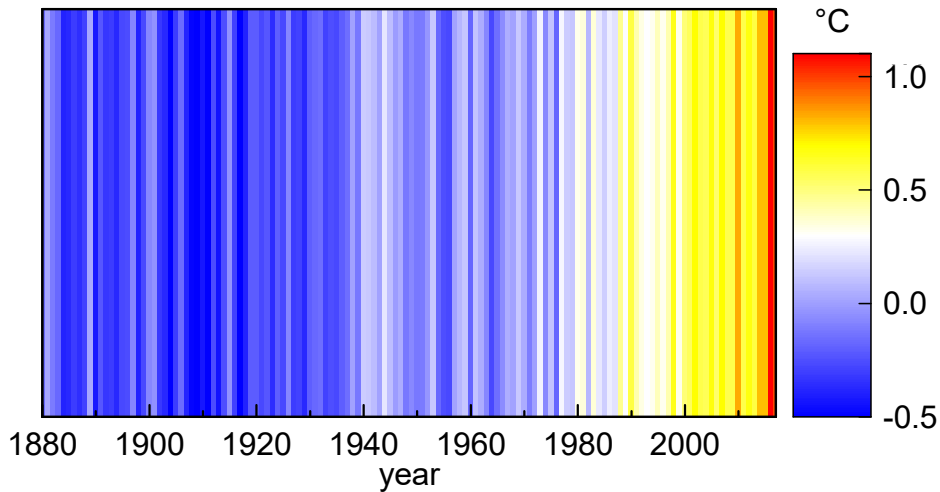
## the playlist on YouTube

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

[www.chemeng.uliege.be/successfulfuture](http://www.chemeng.uliege.be/successfulfuture)

new website:  
[www.vision3000.eu](http://www.vision3000.eu)

## global mean temperature

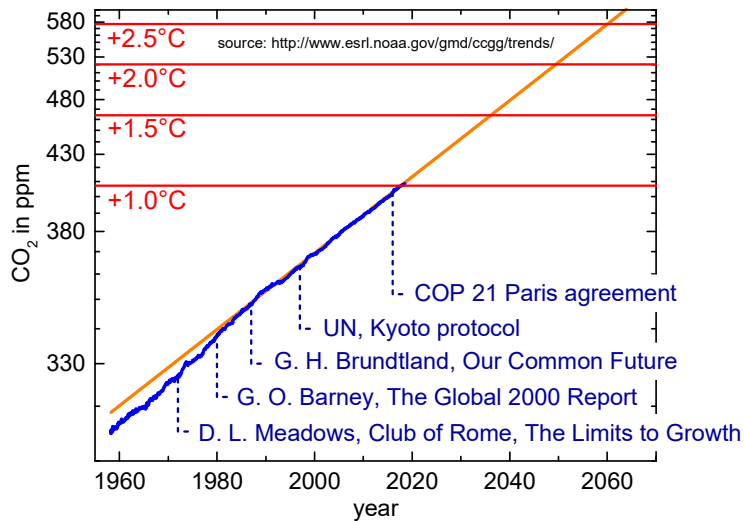


GISTEMP Team, 2018: *GISS Surface Temperature Analysis (GISTEMP)*.  
NASA Goddard Institute for Space Studies. Dataset accessed 2018-11-14 at  
<https://data.giss.nasa.gov/gistemp/>

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## CO<sub>2</sub> 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...



## modelling approach

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

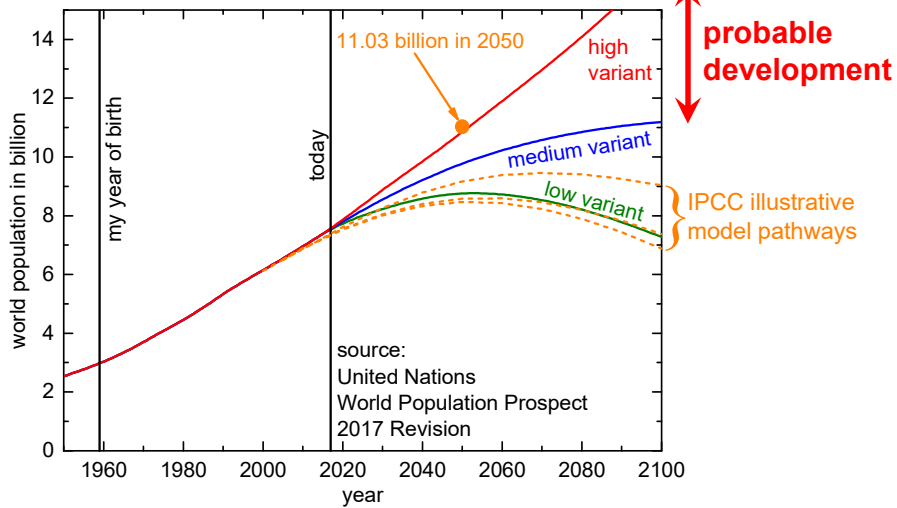
negative influence of too detailed models:

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

## the system, scale-down factor 10 000 000



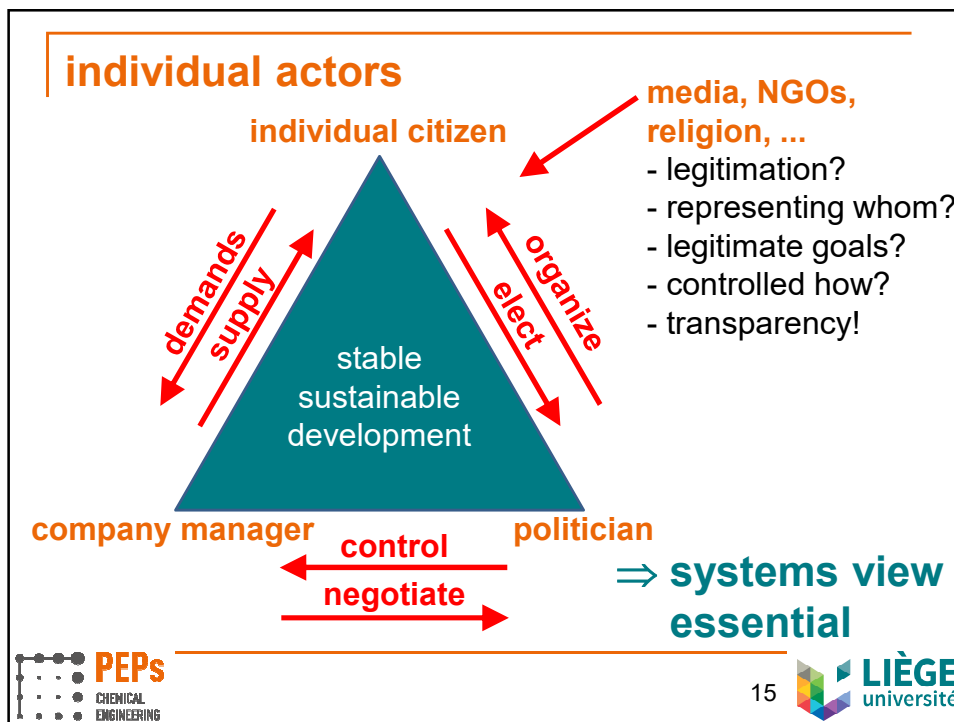
## world population scenarios



## population growth eating up progress

since 1990:

■ additional people fed:	2.5 bn
■ population increased by:	-2.3 bn
■ undernourishment decreased by	<u>0.2 bn</u>



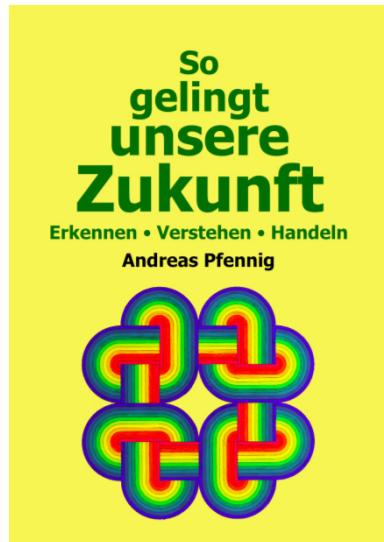
## in conclusion

- 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<sub>2</sub>-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

Bottom left: **PEPs** CHEMICAL ENGINEERING

Bottom right: 16 **LIÈGE** université

## 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](http://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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## Our Successful Future - World Population

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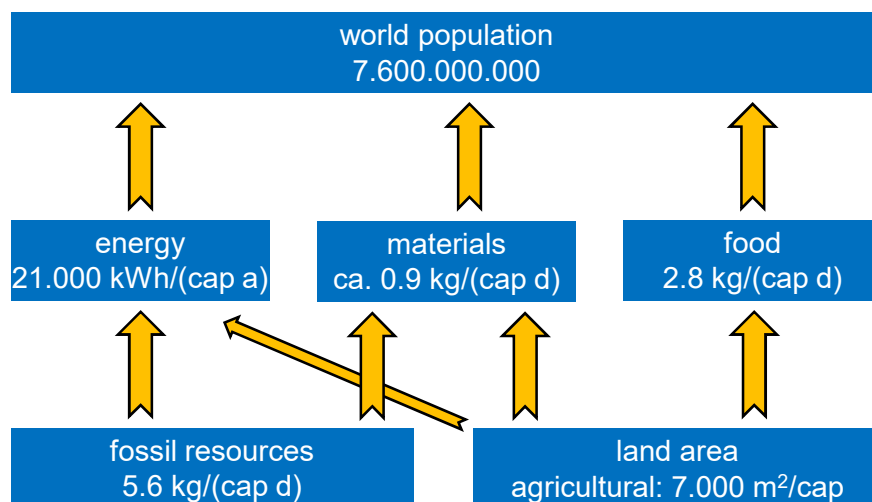
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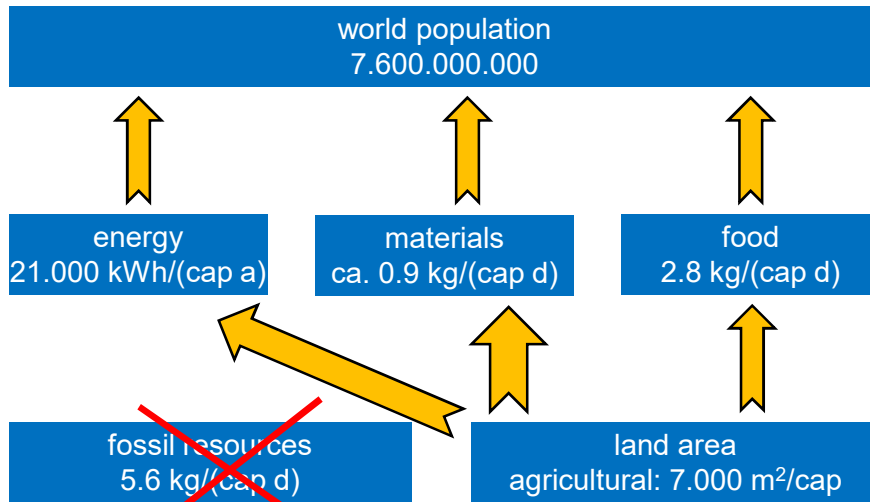
## questions to be answered

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

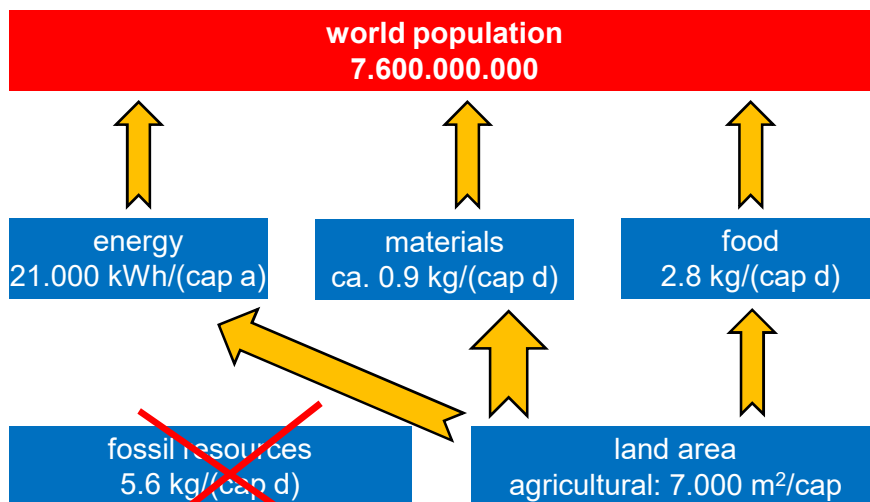
## some major drivers



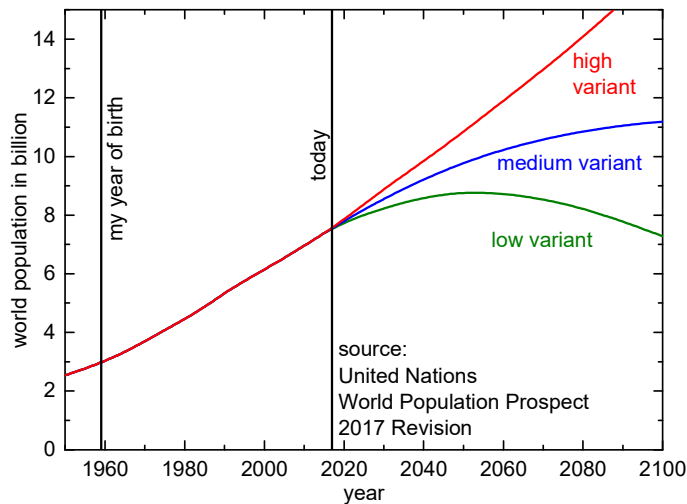
## some major drivers



## THE major driver



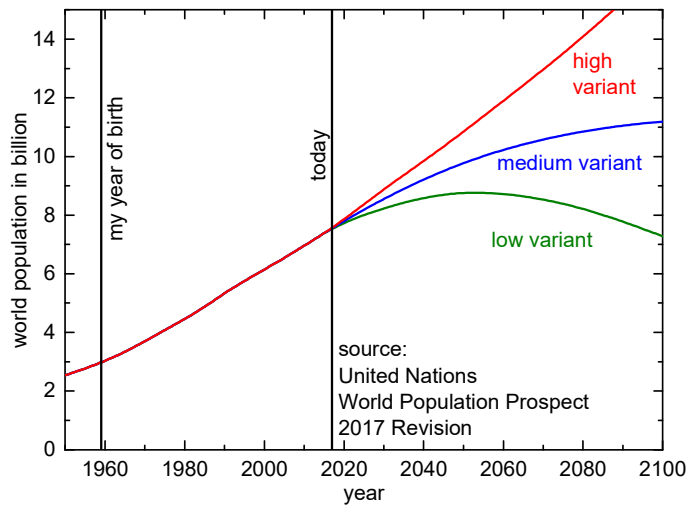
## UN world-population scenarios



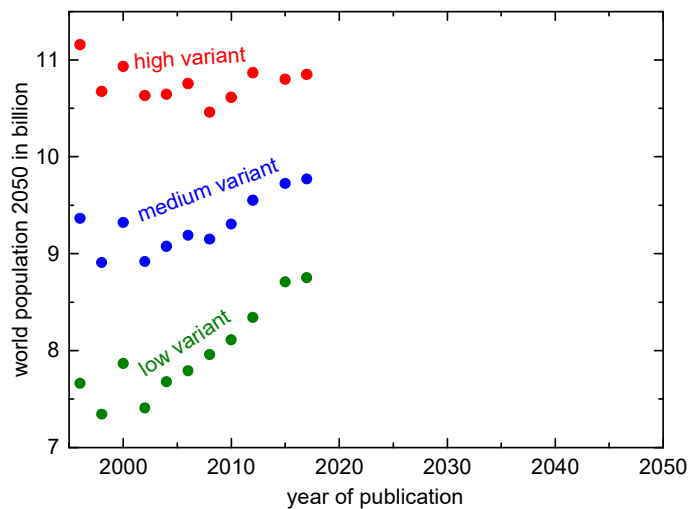
## data sources

- United Nations, DESA/Population Division, 2017 Revision of World Population Prospects, [population.un.org/wpp/](http://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](http://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.
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2004 Revision. Highlights. United Nations, New York 2005
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2006 Revision. Highlights. United Nations, New York 2007.
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2008 Revision. Highlights. United Nations, New York 2009.
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2010 Revision. Volume I: Comprehensive Tables. United Nations, New York 2011.
- 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/](http://population.un.org/wpp/Publications/) (accessed 20.09.2018).
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2015 Revision. Volume I: Comprehensive Tables. United Nations, New York 2015, [population.un.org/wpp/Publications/](http://population.un.org/wpp/Publications/) (accessed 20.09.2018).
- UN Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2017 Revision. Volume I: Comprehensive Tables. United Nations, New York 2017, [population.un.org/wpp/Publications/](http://population.un.org/wpp/Publications/) (accessed 20.09.2018).

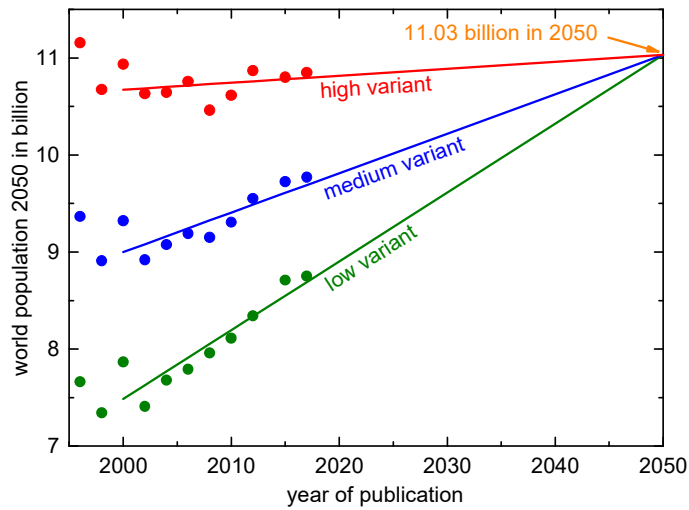
## UN world-population scenarios



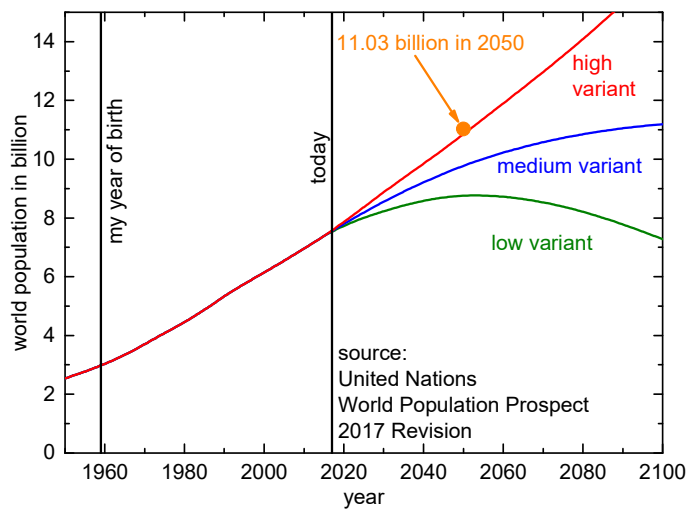
## development of UN-WPP predicting for 2050



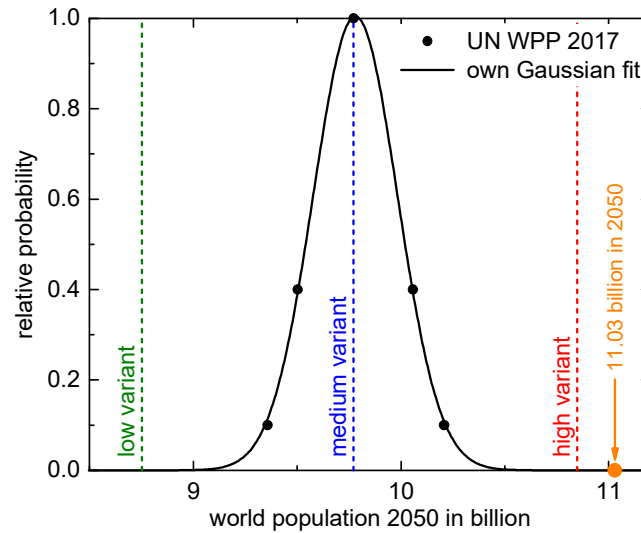
## development of UN-WPP predicting for 2050



## world population scenarios



## probabilistic evaluation by UN-PD-DESA



## uncertainty vs. ignorance

### uncertainty:

- known possible errors
- can be quantified

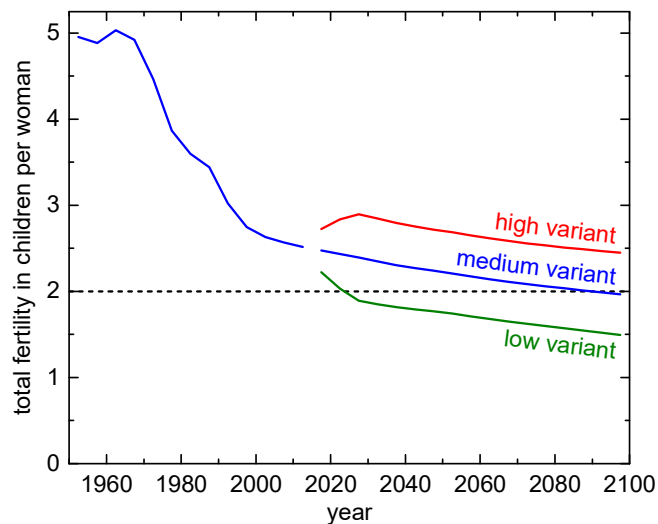
### ignorance:

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

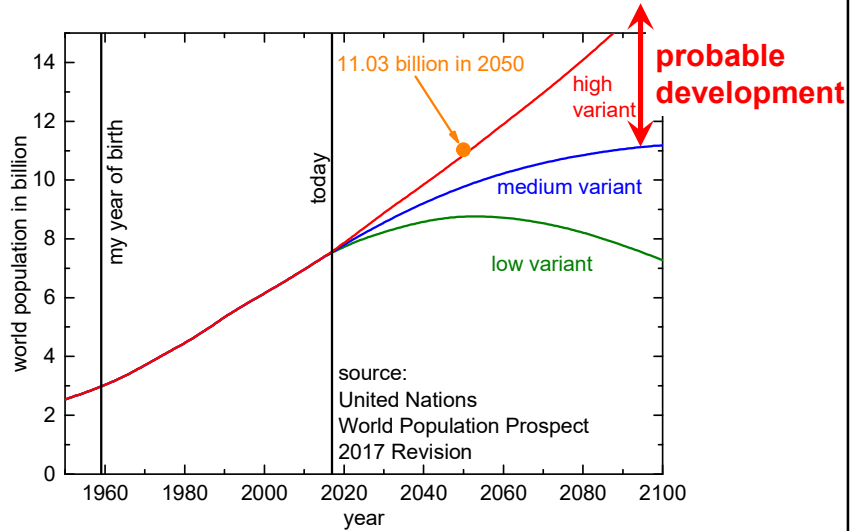
## reasons for ignorance (e-mail UN-DESA)

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

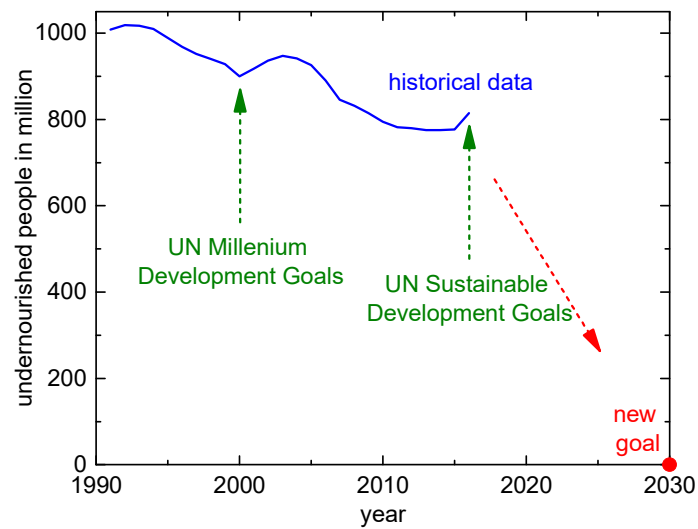
## fertility: history and scenarios



## world population scenarios



## world hunger

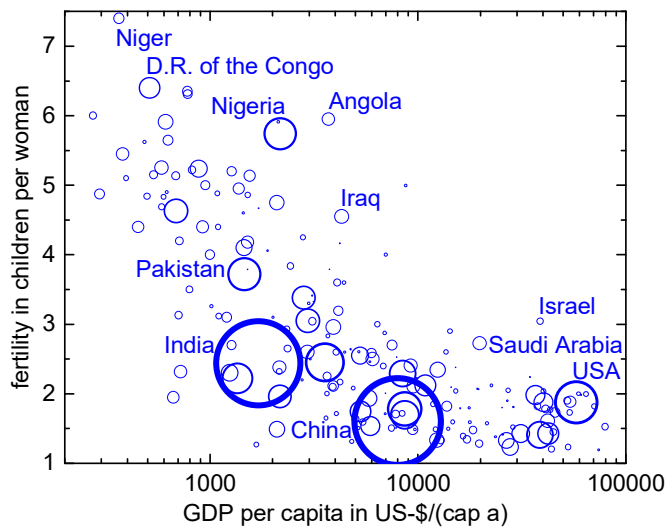


## population growth eating up progress

since 1990:

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

## 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?



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## 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<sub>2</sub> historical data obtained from  
[http://cdiac.ess-dive.lbl.gov/trends/emis/meth\\_reg.html](http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html)

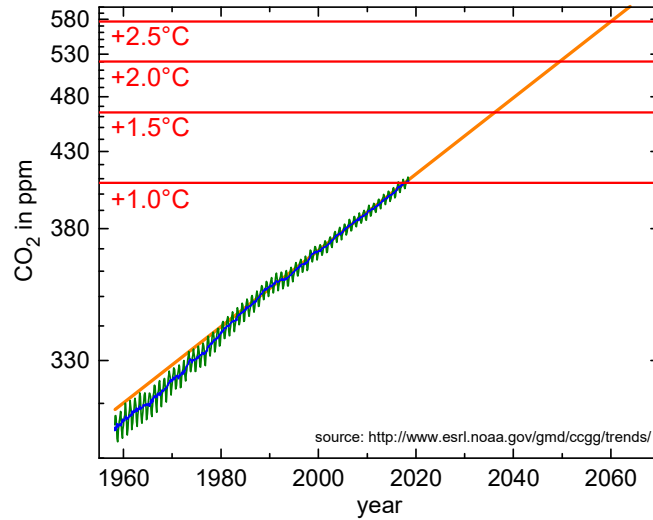
## modelling approach

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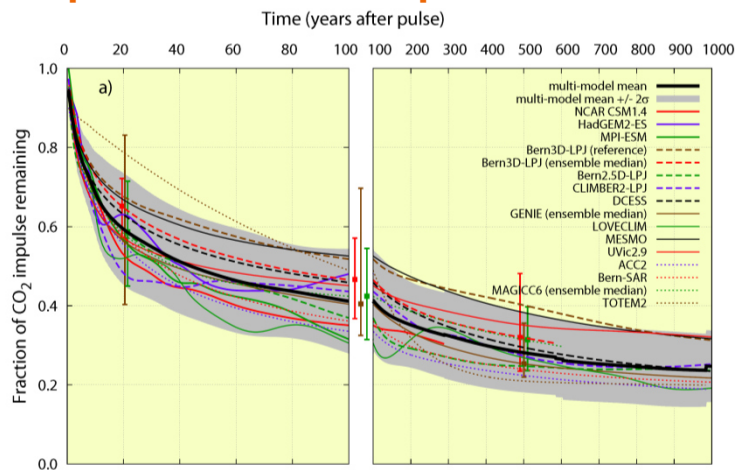
negative influence of too detailed models:

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

## CO<sub>2</sub> content of the atmosphere



## response to 100GtC pulse emission



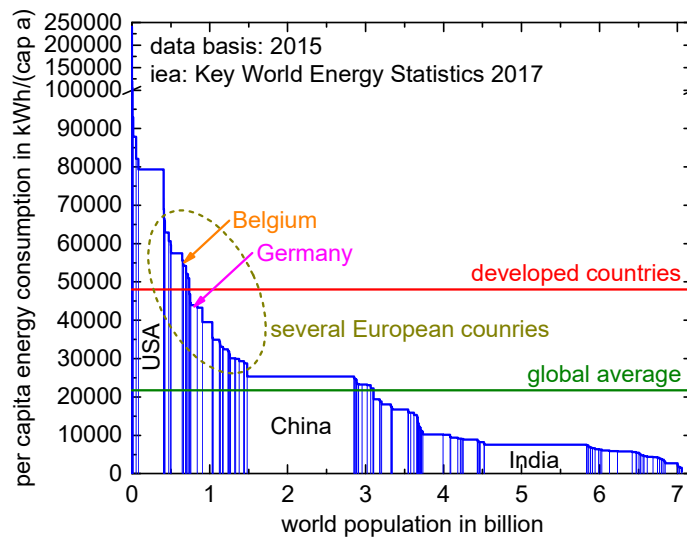
source: Joos, F., et al.: Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis. Atmos. Chem. Phys., 13 (2013) 2793-2825.

© Author(s) 2013. CC Attribution 3.0 License

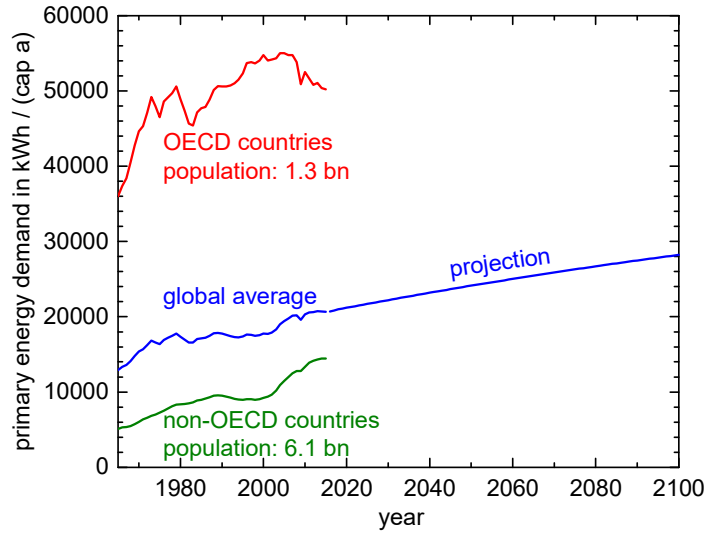
## the system, scale-down factor 10 000 000



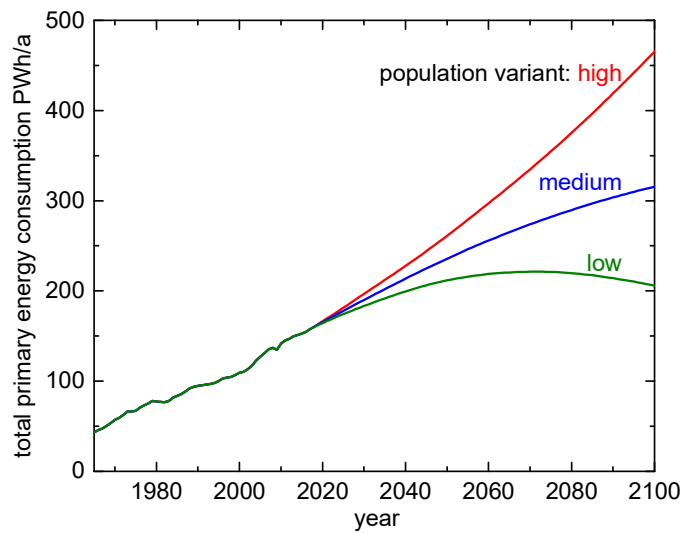
## annual primary-energy consumption



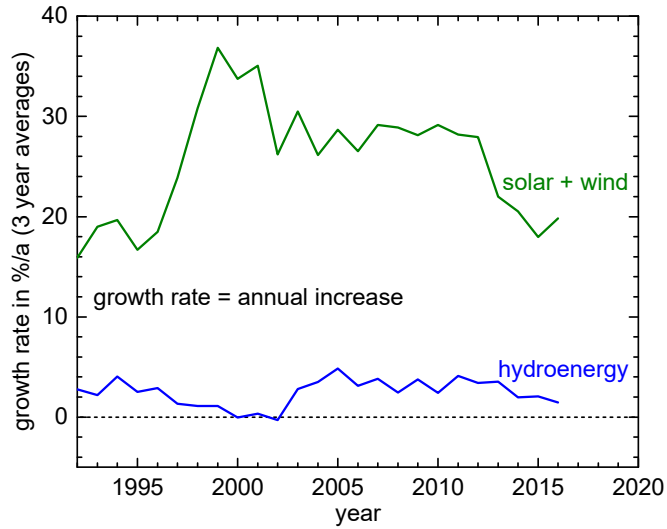
## development of per-capita demand



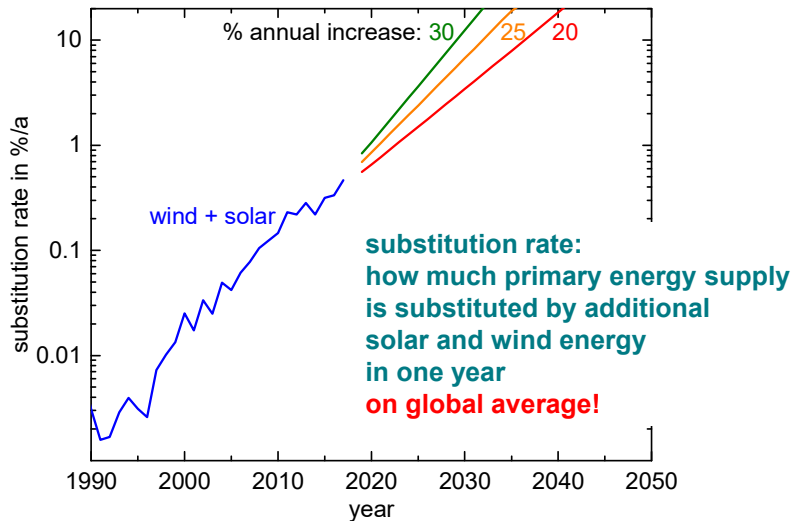
## development of primary energy demand



## annual global growth rates



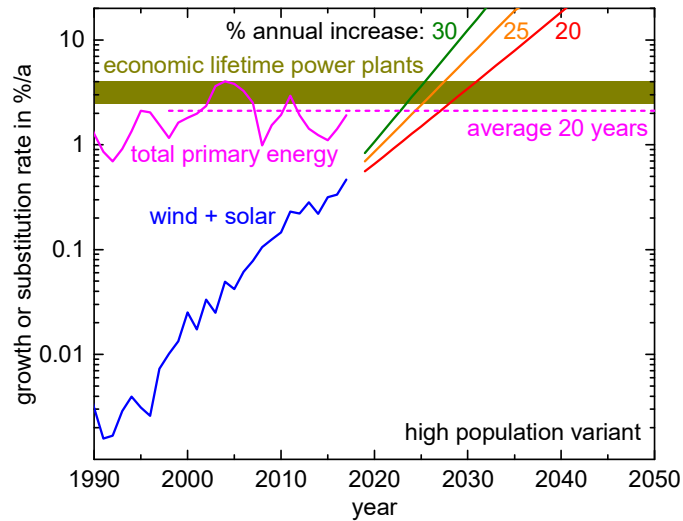
## future growth scenarios of wind & solar



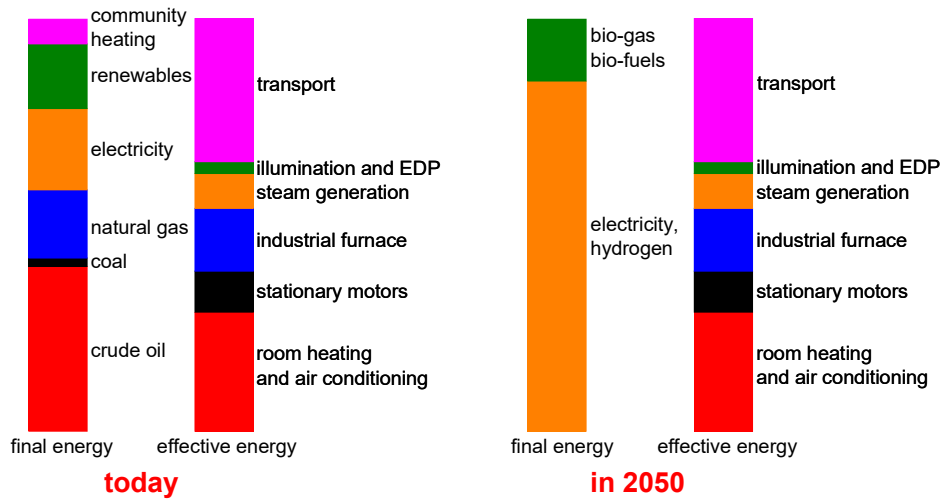
## economic lifetimes and life spans

	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

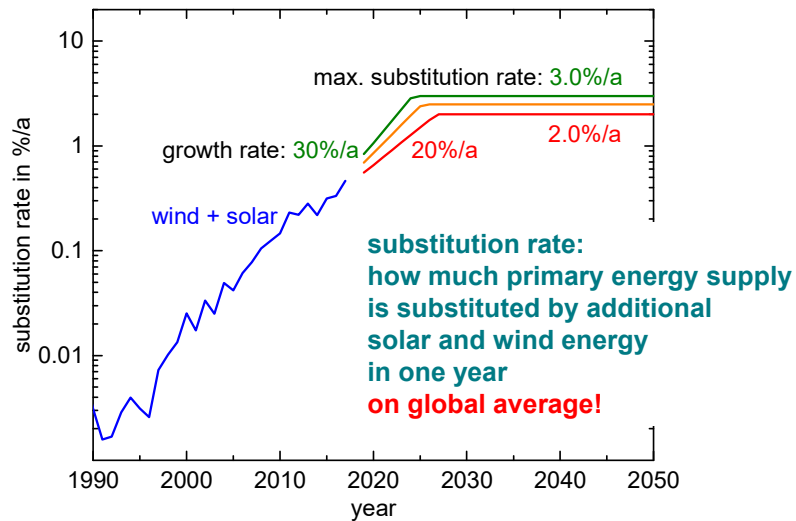
## maximum substitution rates



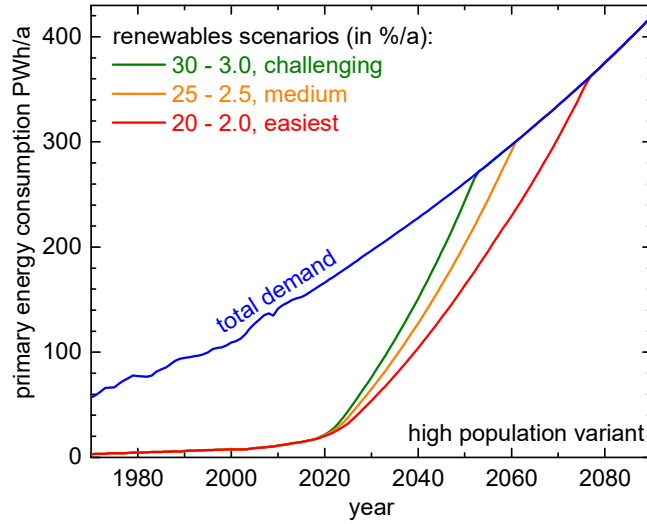
## change in energy system



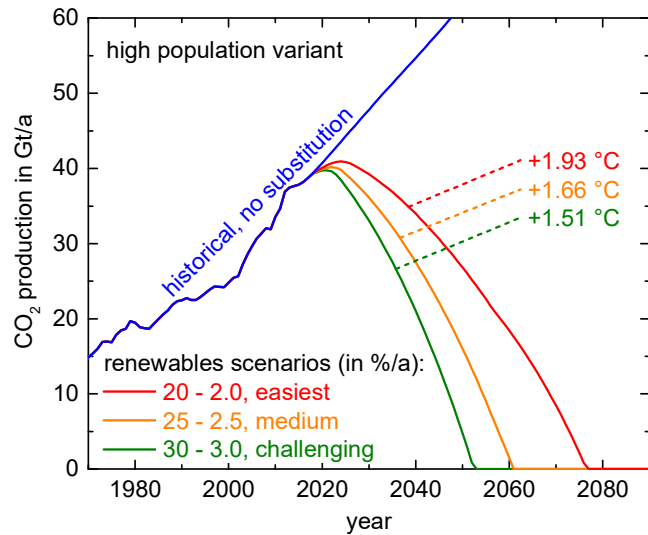
## defining three future scenarios



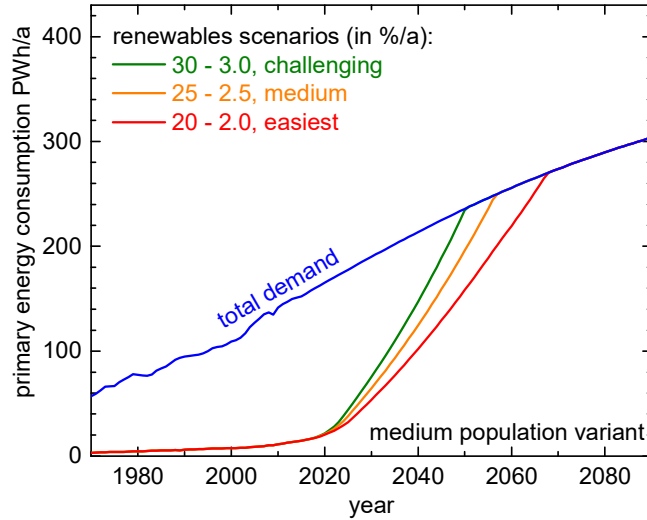
## three energy scenarios



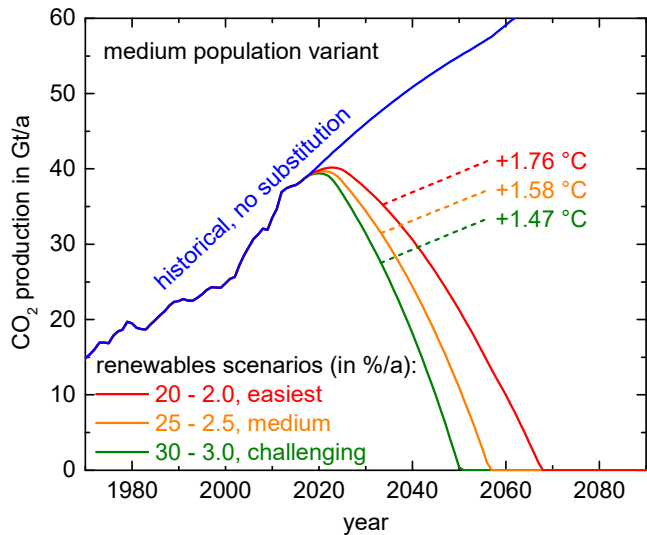
## CO<sub>2</sub> according to three scenarios



## influence of population variant



## CO<sub>2</sub> emissions for medium pop. variant



## comparison of energy-transition scenarios

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

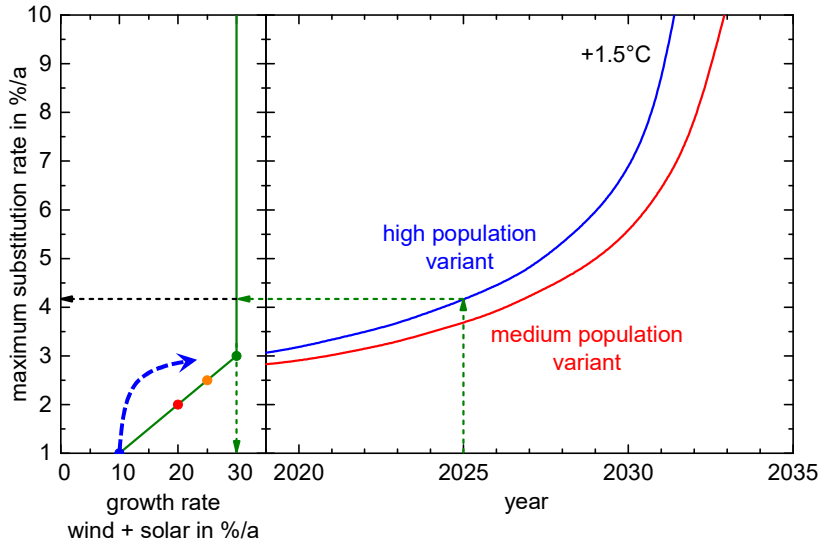
## negative-emission technologies

- **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

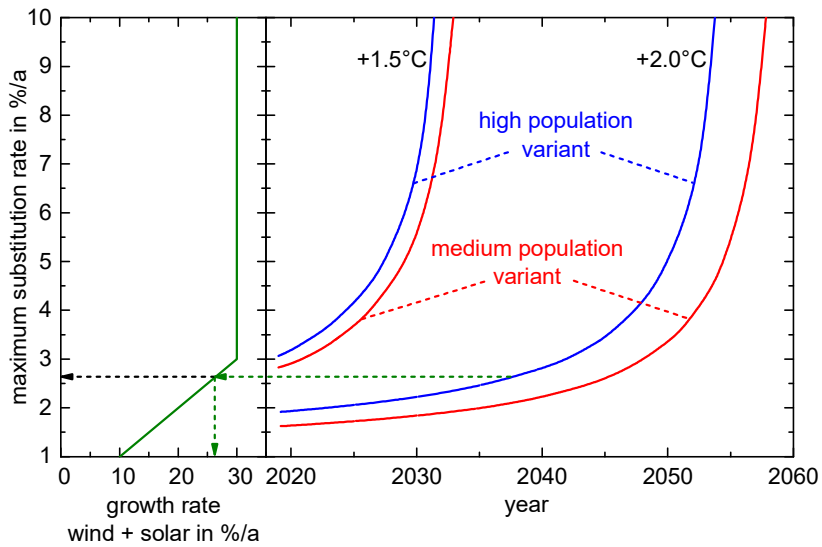
not included because:

- business case only, if trading of CO<sub>2</sub> 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



## consequences of a delay



## 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 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?



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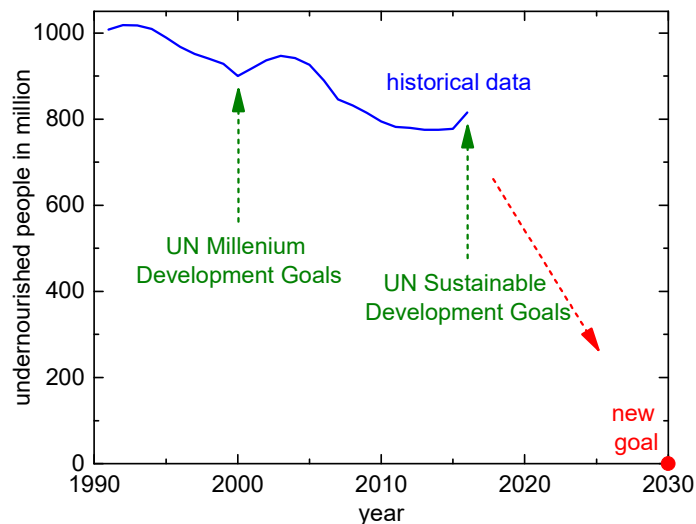
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Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018.  
doi: <https://doi.org/10.22022/SR15/08-2018.15429>  
url: <https://data.ene.iiasa.ac.at/iamc-1.5c-explorer>, release 1.0
- UN WPP population prospects:  
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<sub>2</sub> historical data obtained from  
[http://cdiac.ess-dive.lbl.gov/trends/emis/meth\\_reg.html](http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html)



79



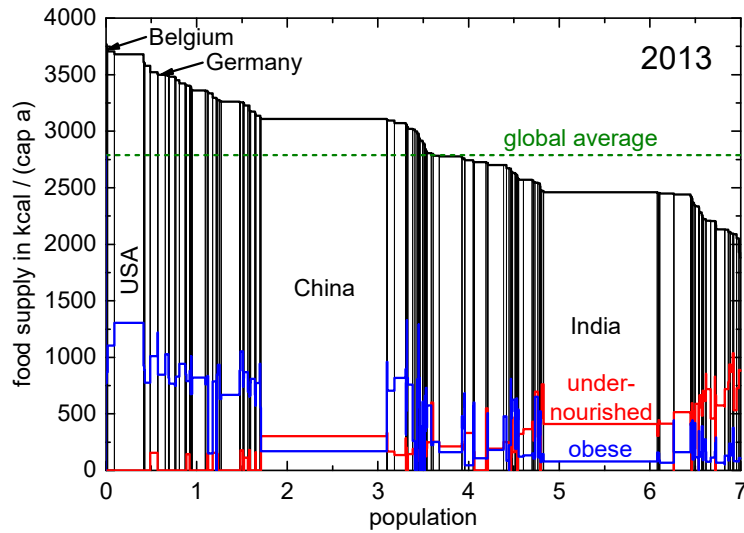
## world hunger



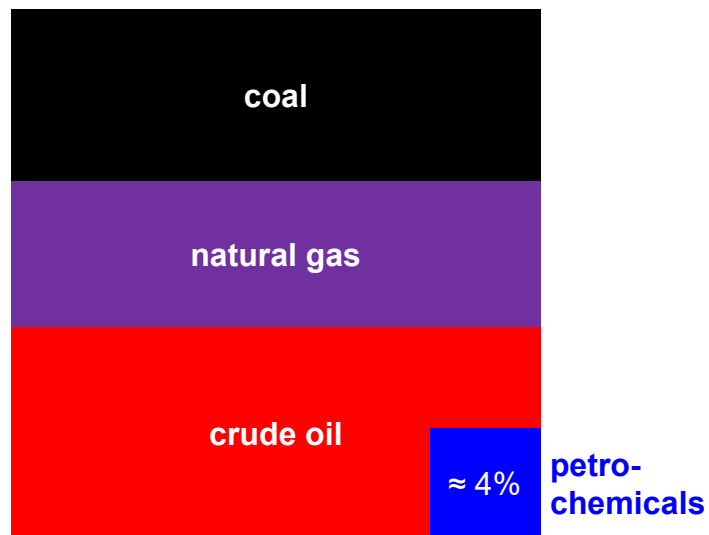
80



## food supply by country



## petrochemicals $\approx$ 4% of fossil resources



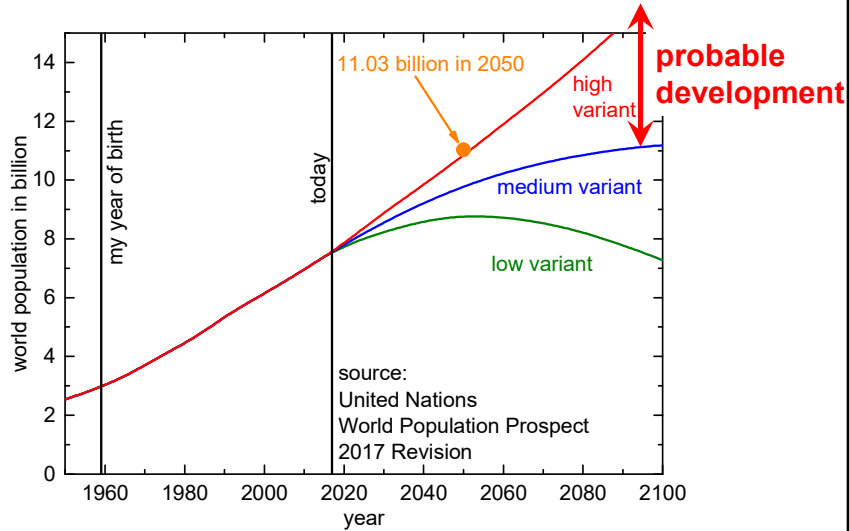
the system, scale-down factor 10 000 000



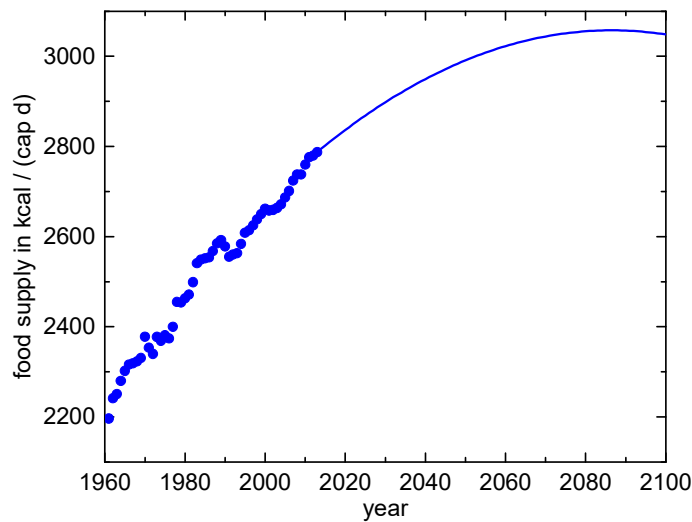
assumptions for scenario analysis

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

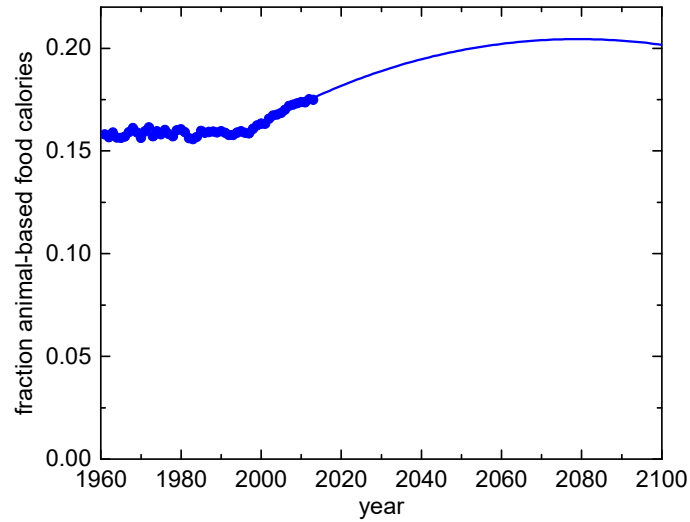
## world population scenarios



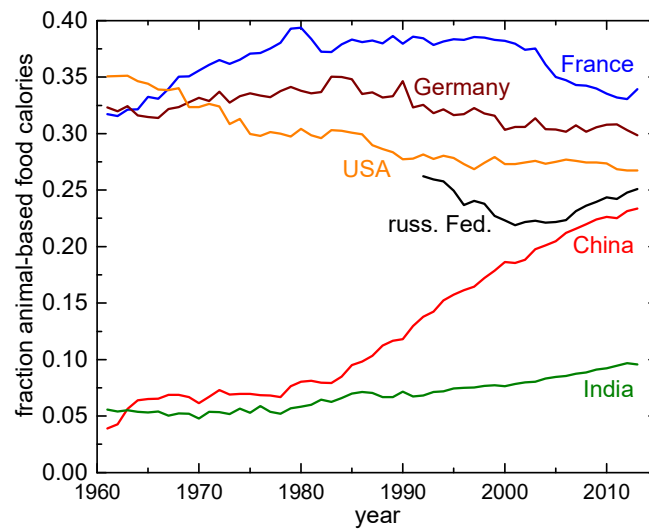
## caloric food supply



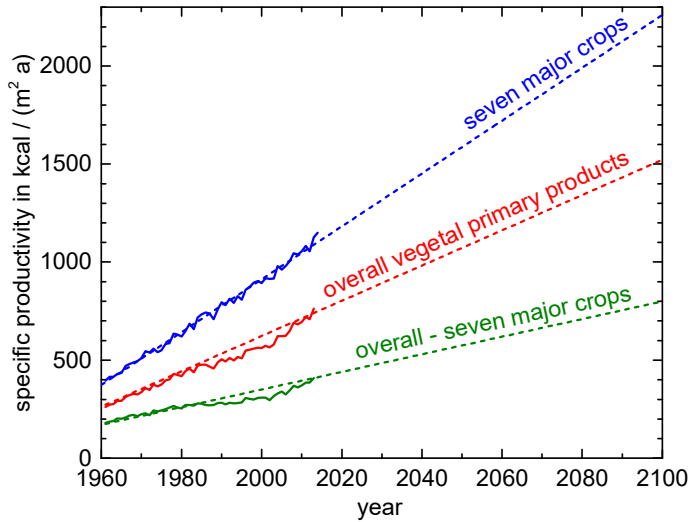
## fraction animal-based calories supply



## fraction animal-based calories supply



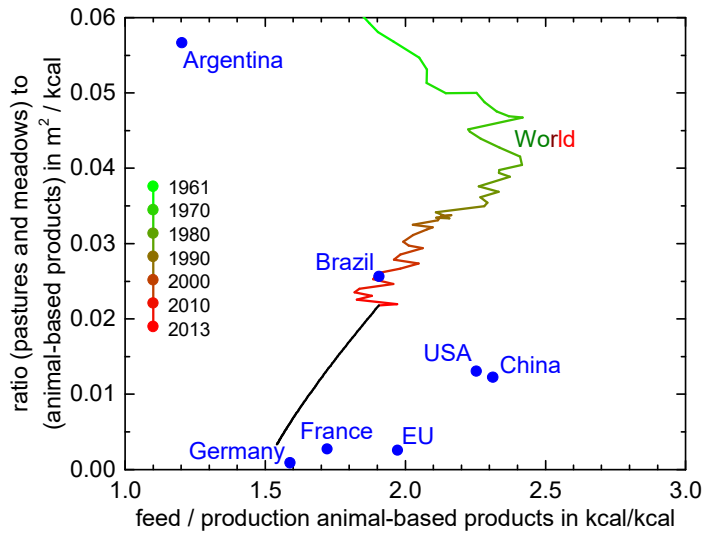
## land-area specific agricultural productivity



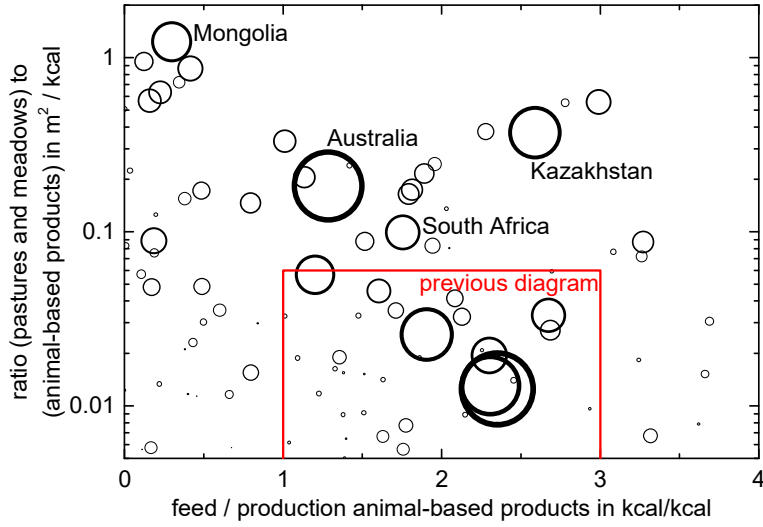
### seven major crops:

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

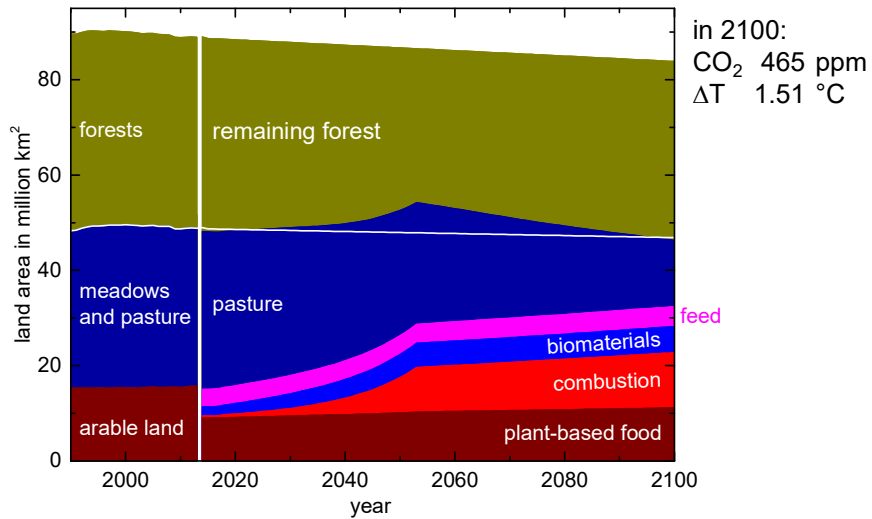
## intensity of animal-based food production



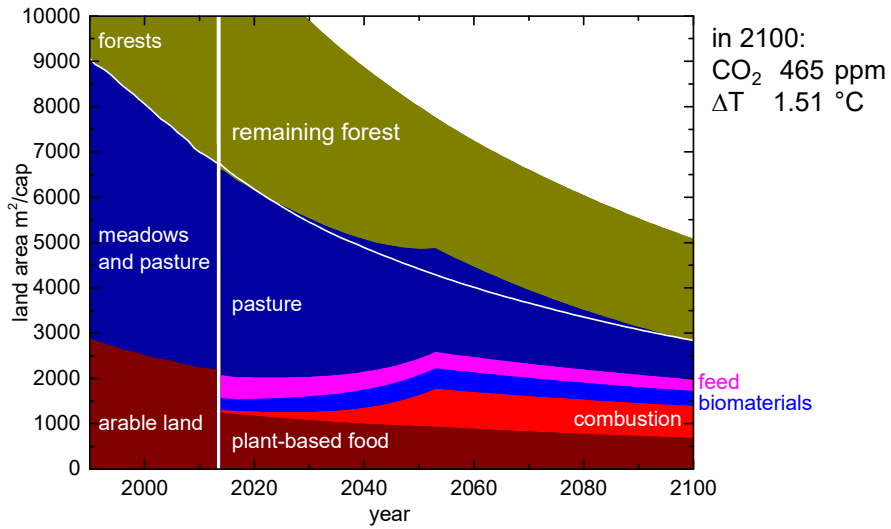
## intensity of animal-based food production



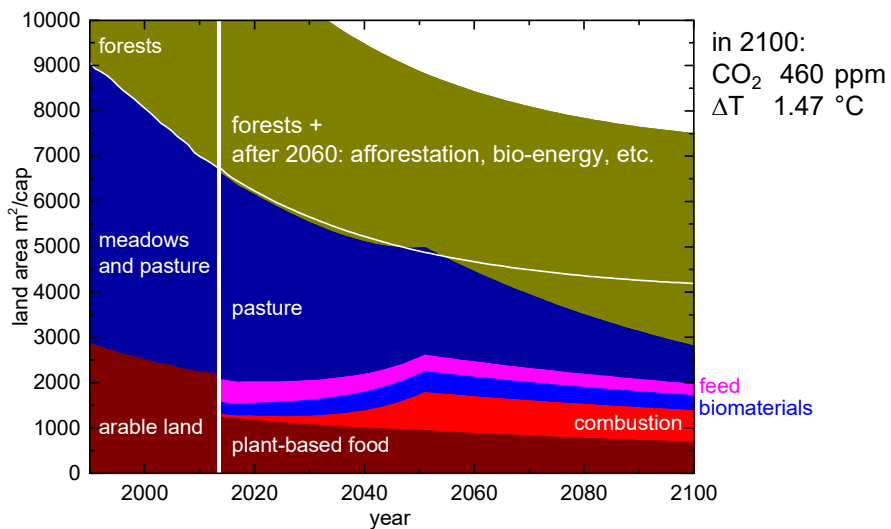
## land-area: challenging, high pop. variant



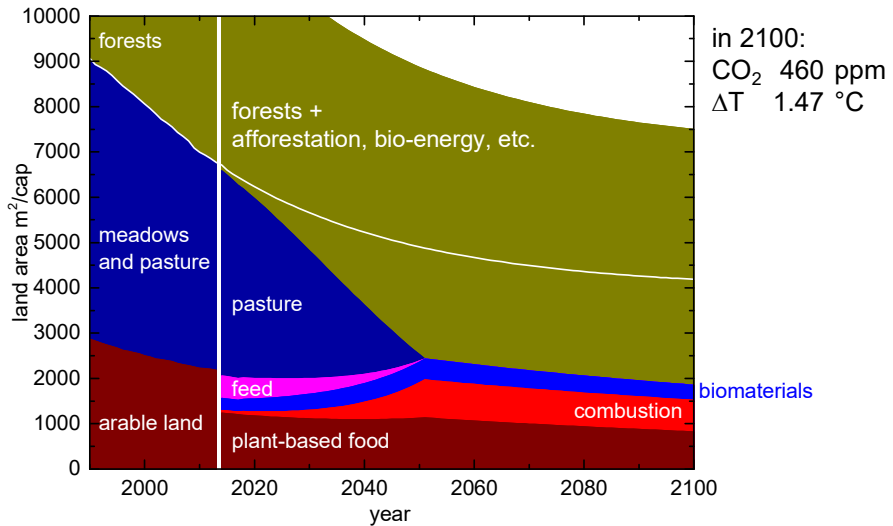
## land-area: challenging, high pop. variant



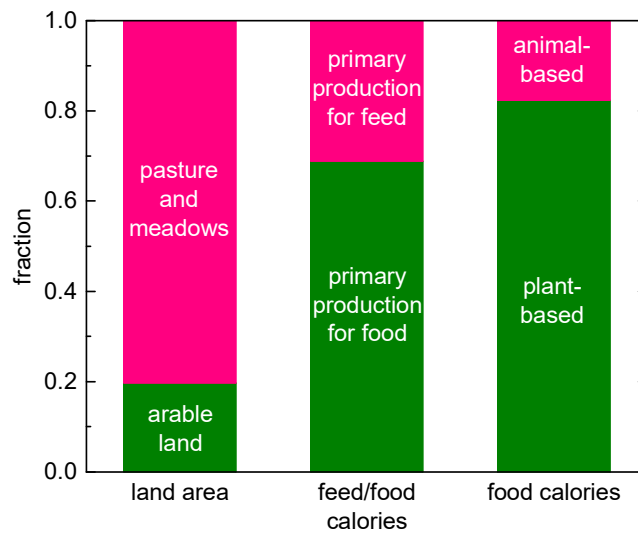
## land-area: challenging, medium pop. variant



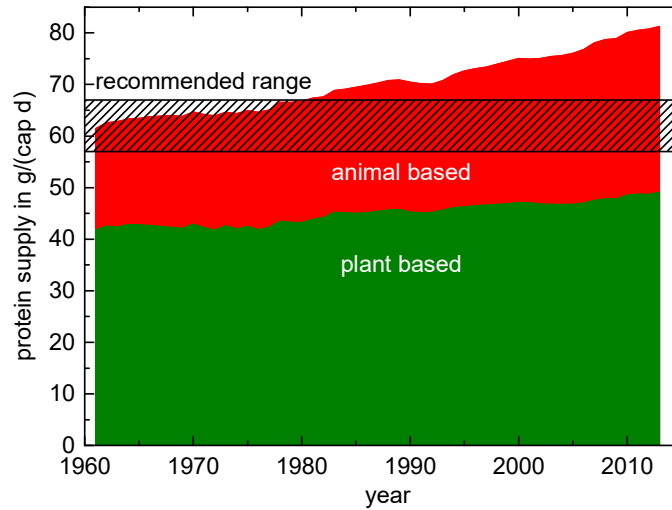
## land-area: challeng., medium pop., vegetal



## inefficiency of animal-based food supply

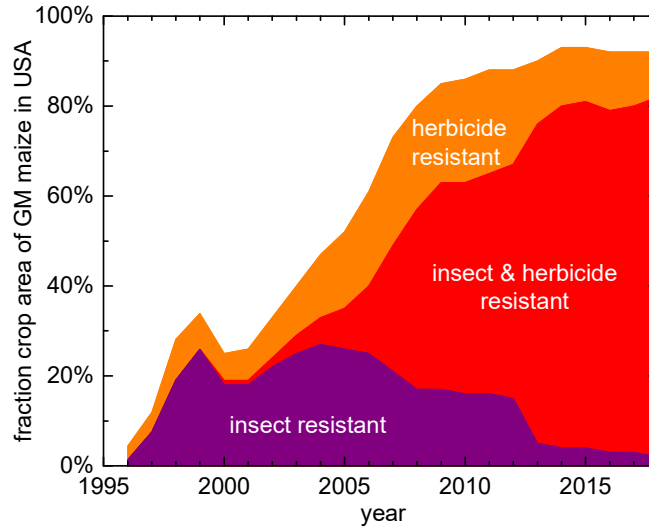


## global protein supply

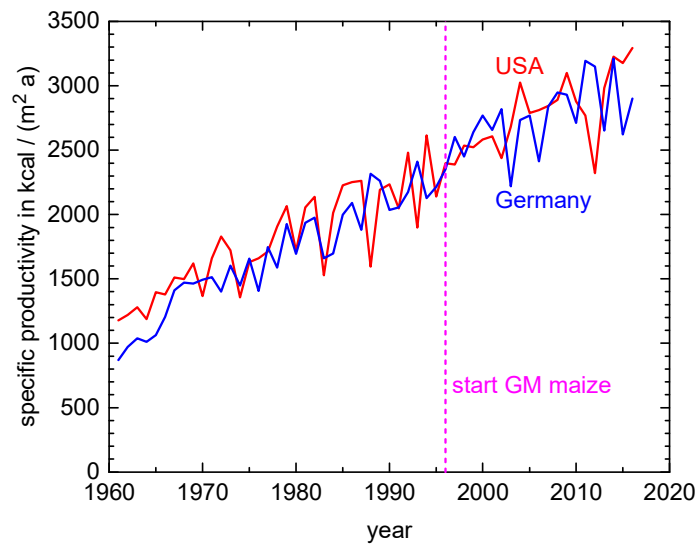


# workarounds?

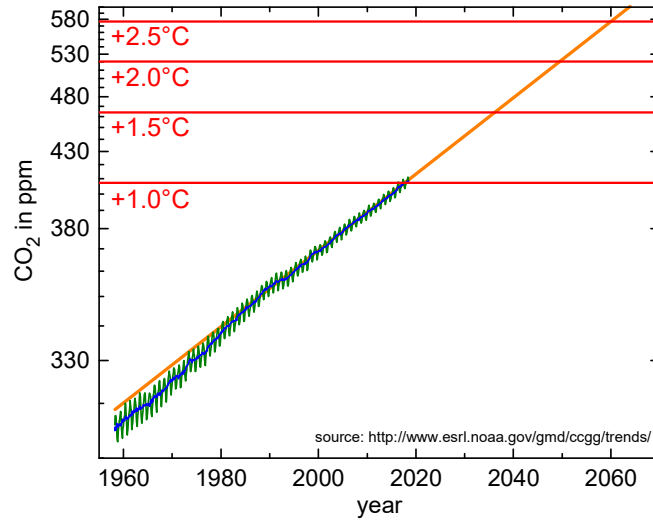
## fraction of GM maize in USA



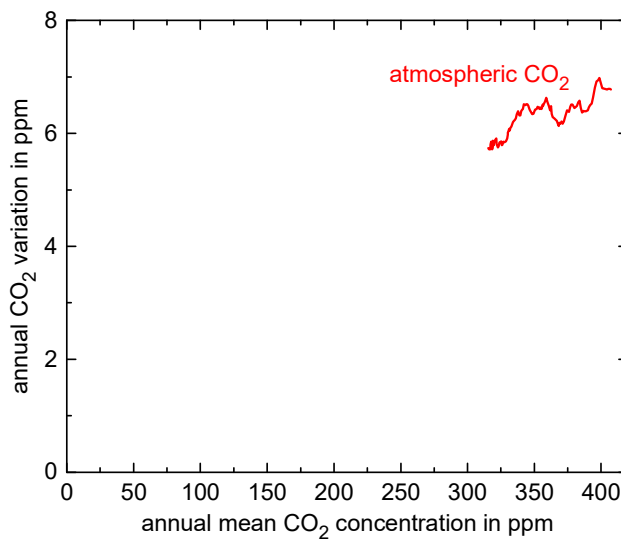
## productivity of land area GM vs. non-GM



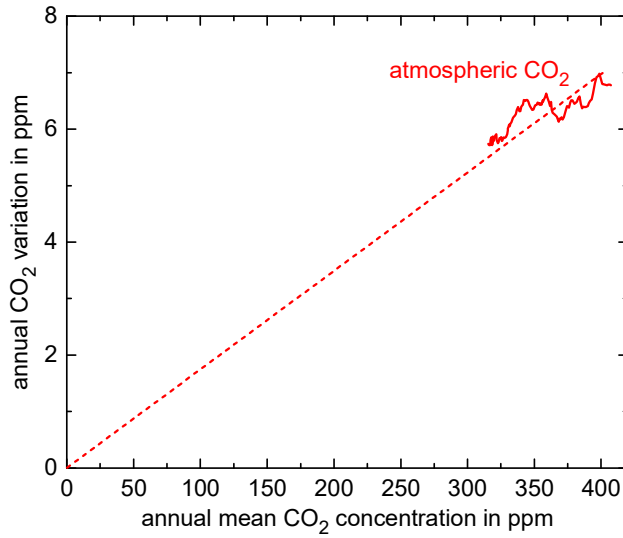
## CO<sub>2</sub> content of the atmosphere



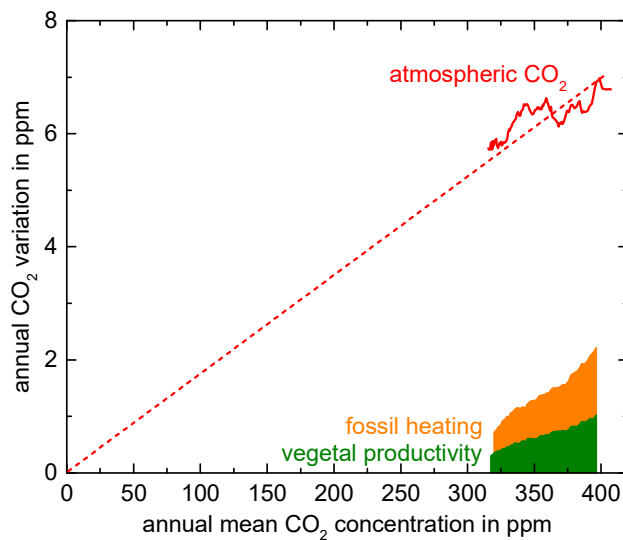
## is higher CO<sub>2</sub> concentration beneficial?



## is higher CO<sub>2</sub> concentration beneficial?



## is higher CO<sub>2</sub> concentration beneficial?



## 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: competition 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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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)



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## Our Successful Future

- A Word on IPCC Scenarios

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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)



## 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<sub>2</sub> historical data obtained from  
[http://cdiac.ess-dive.lbl.gov/trends/emis/meth\\_reg.html](http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html)



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## 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<sub>2</sub> until 2100
- current ambitions stated by countries according 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



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## population projections IPCC AR5

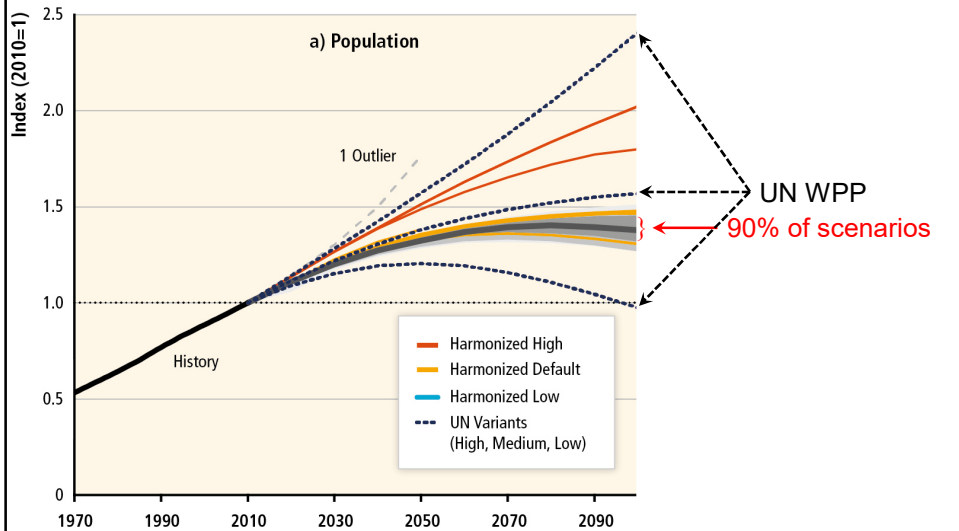
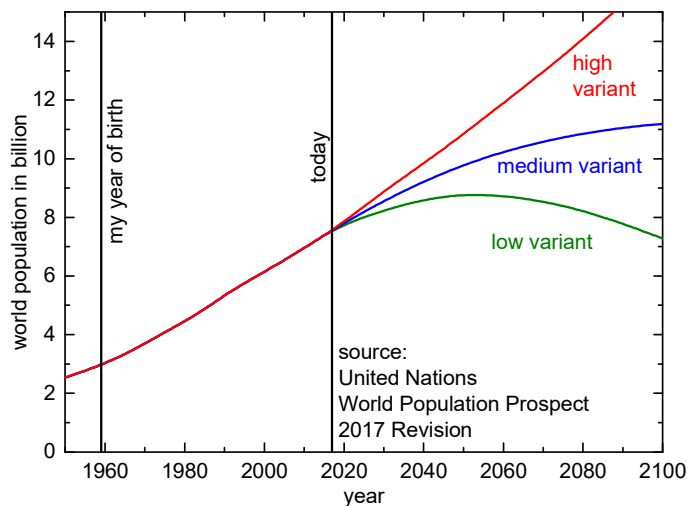


Figure 6.1, p. 425 from: IPCC, 2014: Climate Change 2014: Mitigation of Climate Change

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## UN world-population scenarios



source:  
United Nations  
World Population Prospect  
2017 Revision



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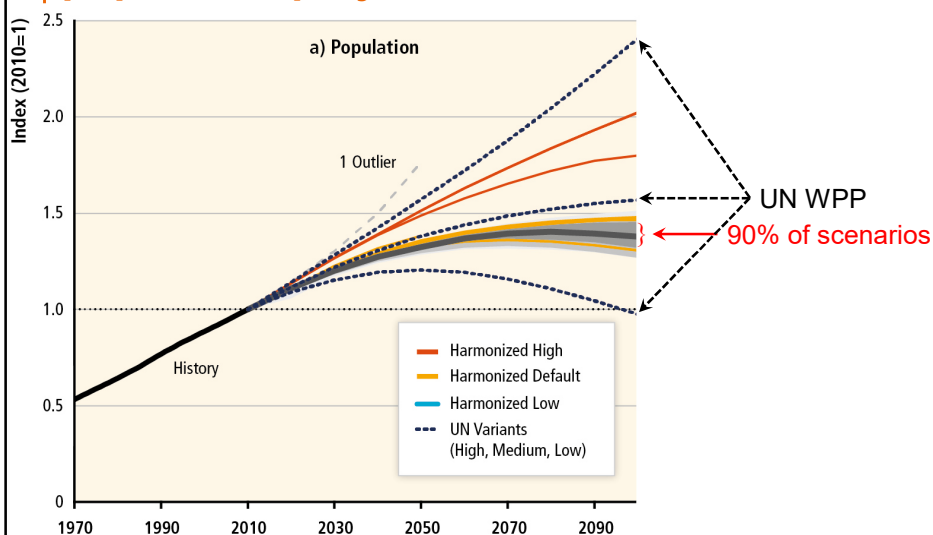


## IPCC AR5, Climate Change 2014, Mitigation

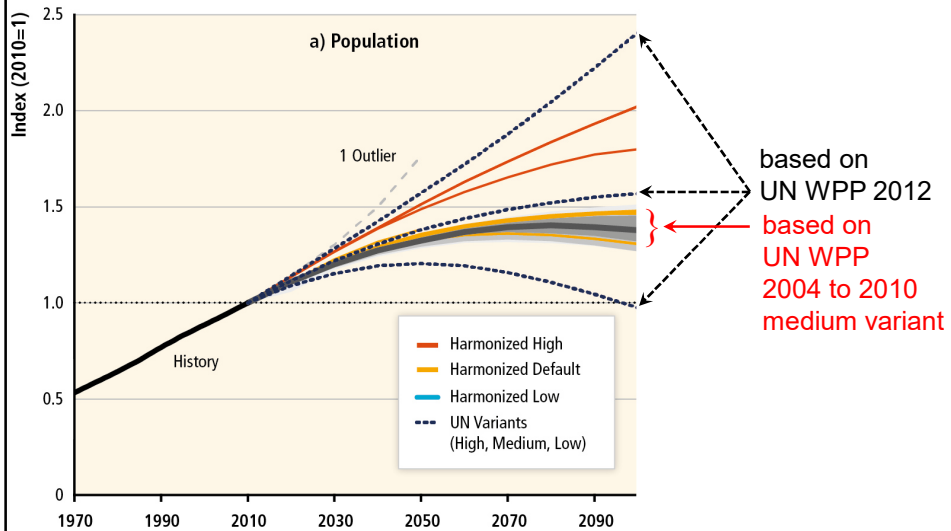
On the one hand, the scenarios assessed in this chapter **do not represent a random sample that can be used for formal uncertainty analysis**. ...

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



## population projections IPCC AR5



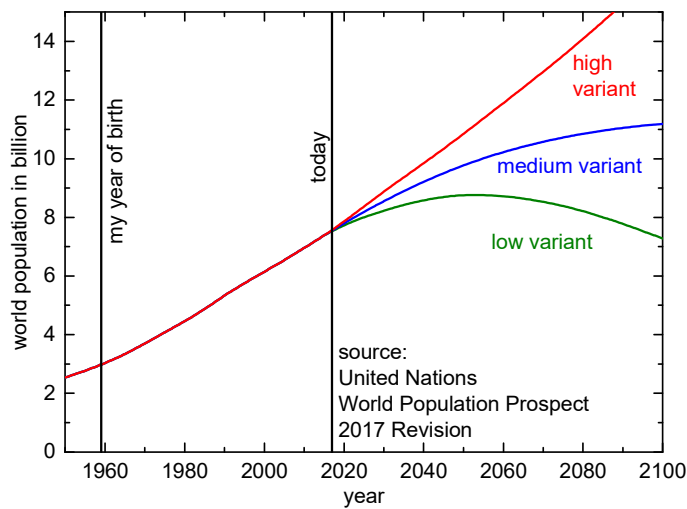
PEPs  
CHEMICAL  
ENGINEERING

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

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## UN world-population scenarios



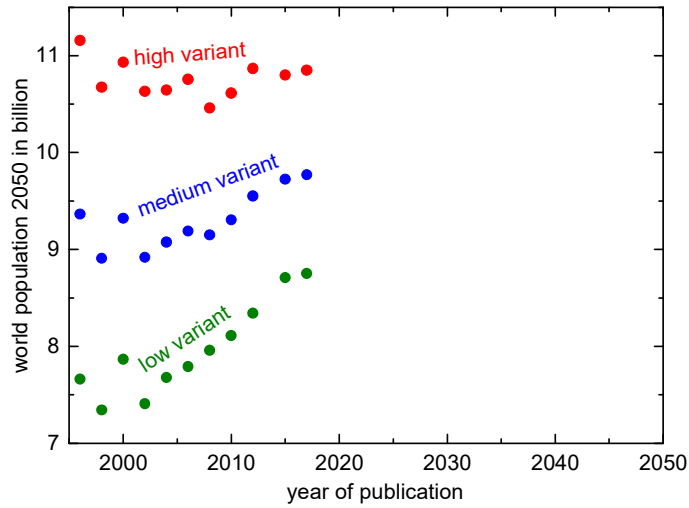
source:  
United Nations  
World Population Prospect  
2017 Revision

PEPs  
CHEMICAL  
ENGINEERING

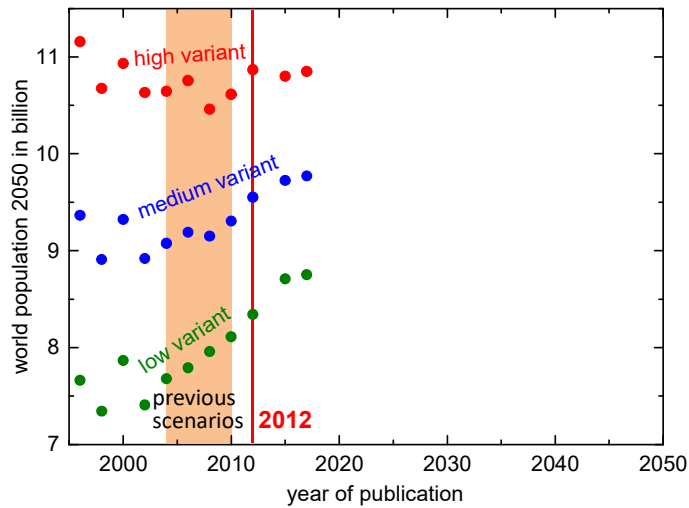
120



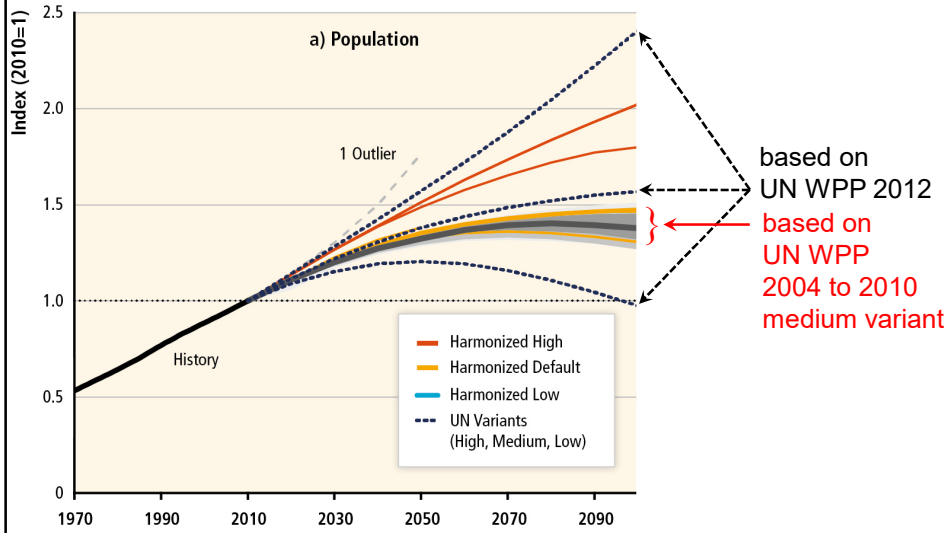
## development of UN-WPP prospects for 2050



## development of UN-WPP prospects for 2050



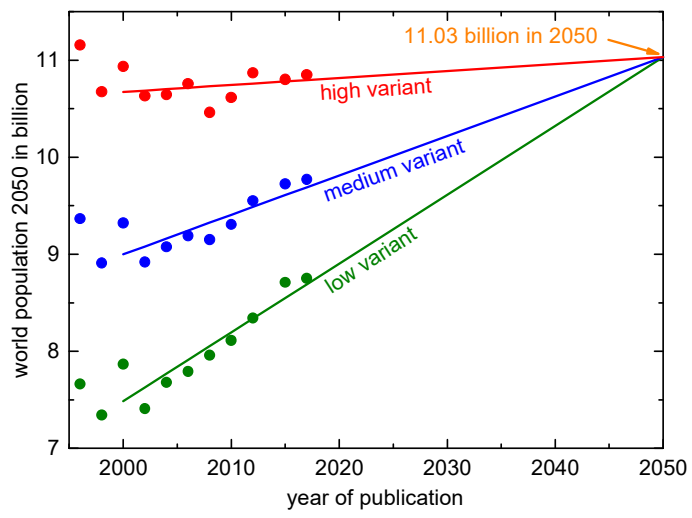
## population projections IPCC AR5



PEPs  
CHEMICAL  
ENGINEERING

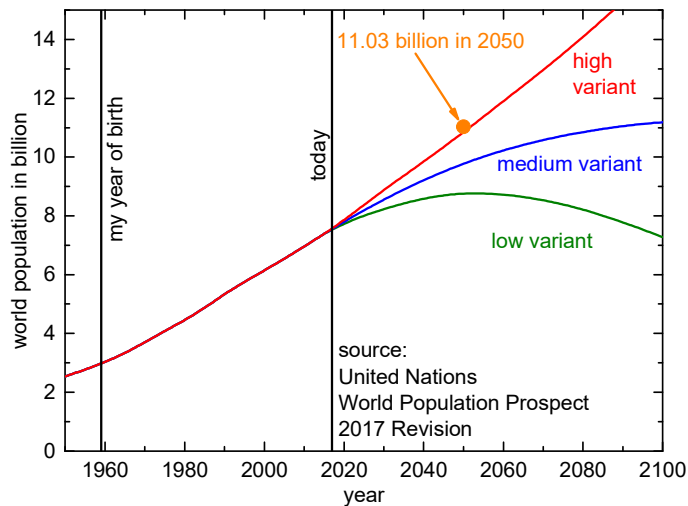
Figure 6.1, p. 425 from: IPCC, 2014: Climate Change 2014: Mitigation of Climate Change

## development of UN-WPP predicting for 2050



PEPs  
CHEMICAL  
ENGINEERING

## world population scenarios



## conclusions

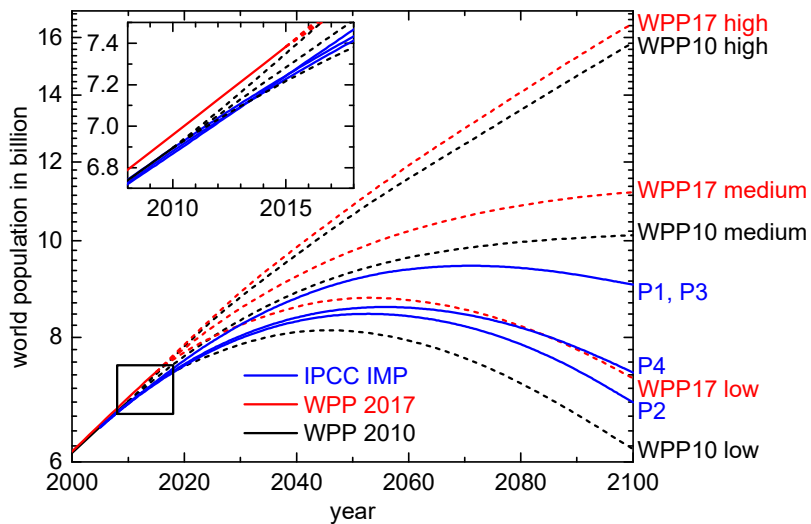
- population may **not** develop **below** WPP **medium variant** as shown in IPCC AR5 diagram
- instead development according to WPP **high variant may be at least as likely** as according to WPP medium variant

## IPCC SR15: illustrative model pathways

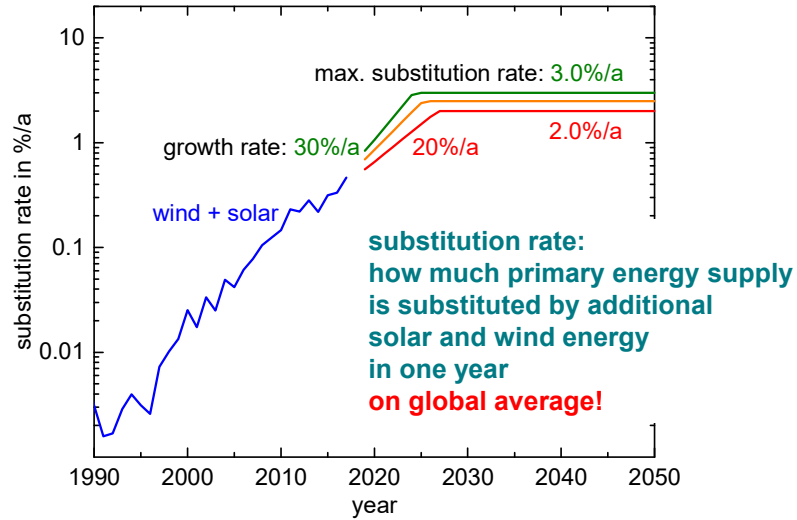
scenario:	P1	P2	P3	P4
population:	low to medium	below low	low to medium	low
BE/arable land '50:	1.2%	5%	15%	40%
description:	a down-sized energy system enables rapid decarbonisation of energy supply	a broad focus on sustainability including energy intensity, human development...	<b>middle-of-the road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

BE: bio energy

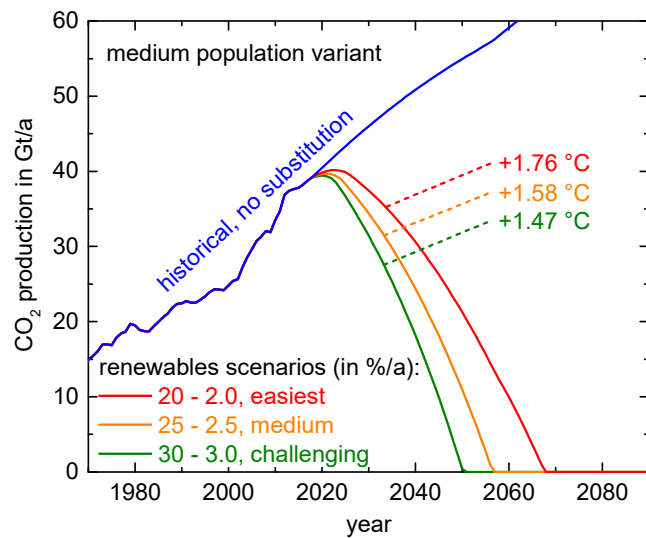
## IPCC SSP scenarios ↔ UN WPP projections



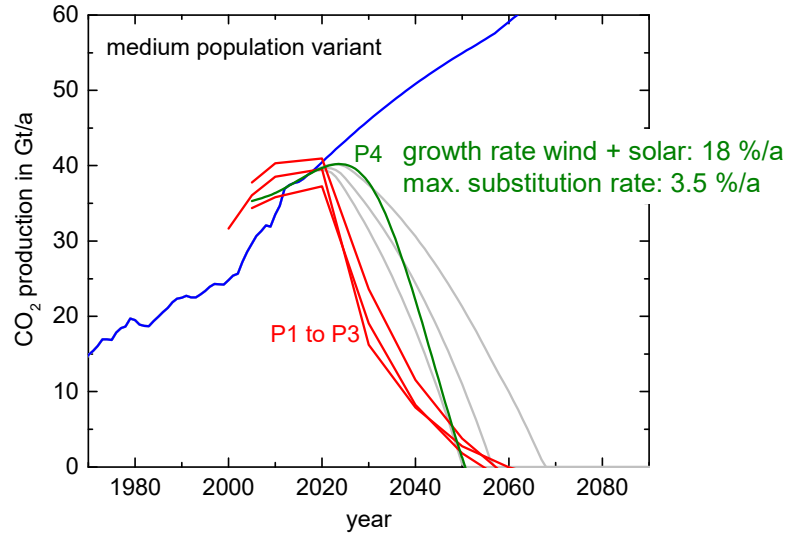
## defining three future scenarios



## CO<sub>2</sub> emissions for medium pop. variant



## IPCC SR15 illustrative model pathways



Daten:

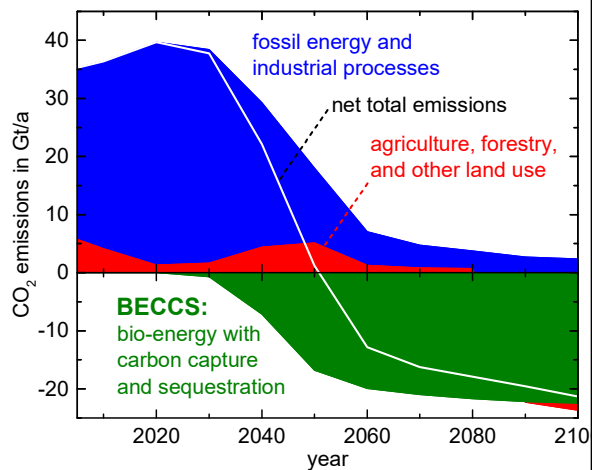
<https://data.ene.iiasa.ac.at/iamc-1.5c-explorer>, <https://population.un.org/wpp/>  
<https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html>

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## IPCC SR15 of October 6, 2018

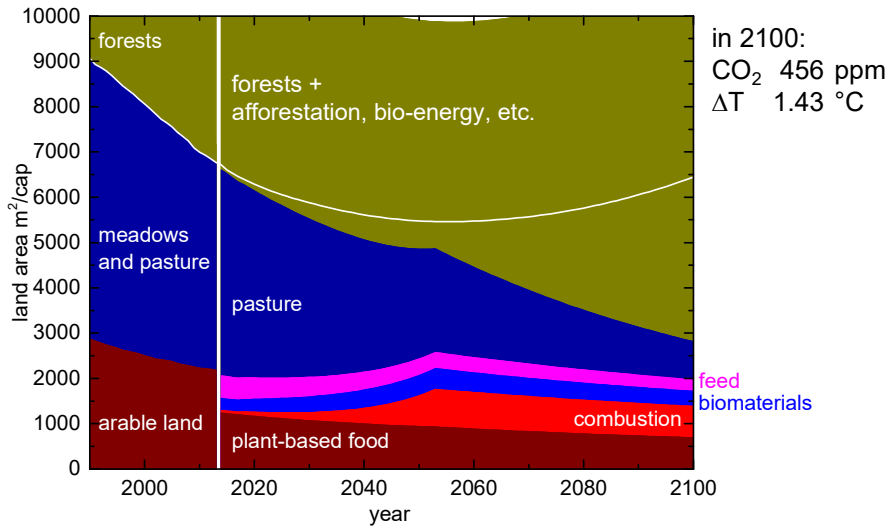
scenario: P4  
scen. chap. 2: S5  
population: low  
energy: manageable  
BE/arable land '50: 40%  
description: adoption of  
greenhouse-gas  
intensive  
lifestyles



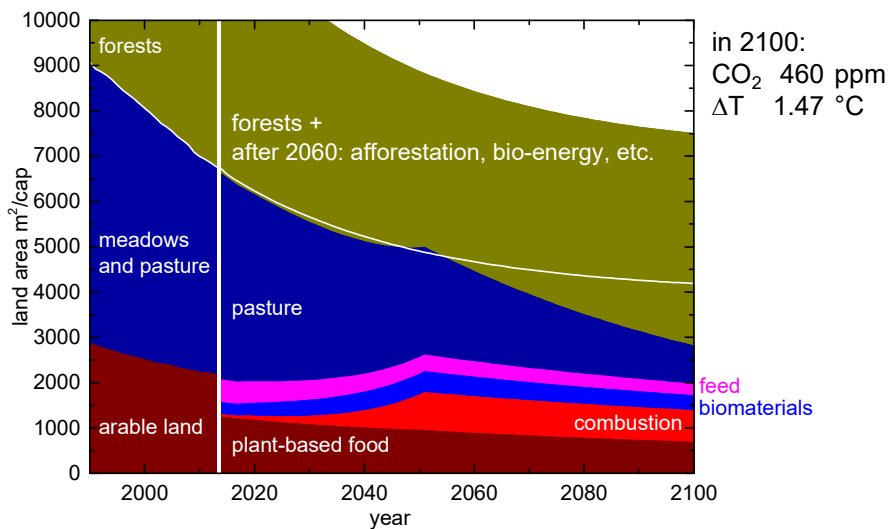
138



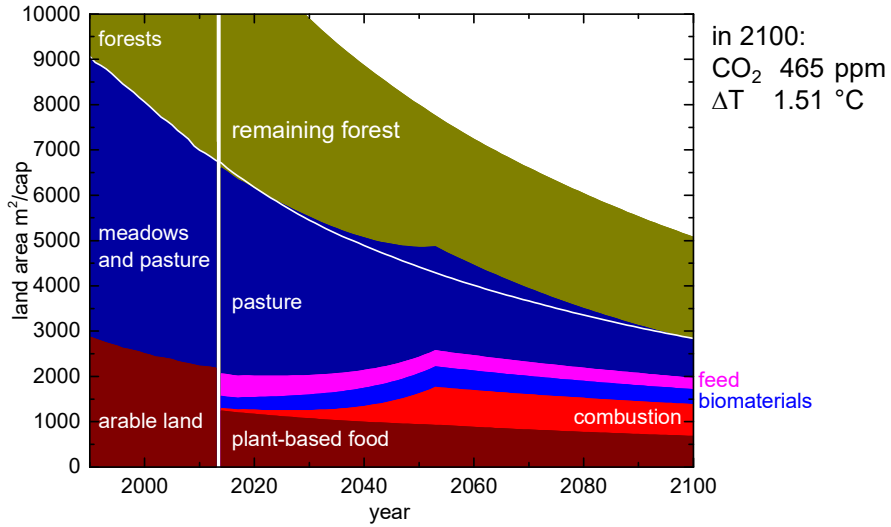
## land-area: challenging, low pop. variant



## land-area: challenging, medium pop. variant

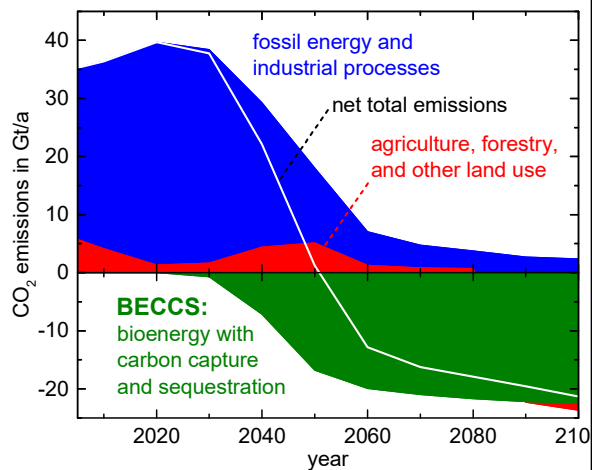


## land-area: challenging, high pop. variant

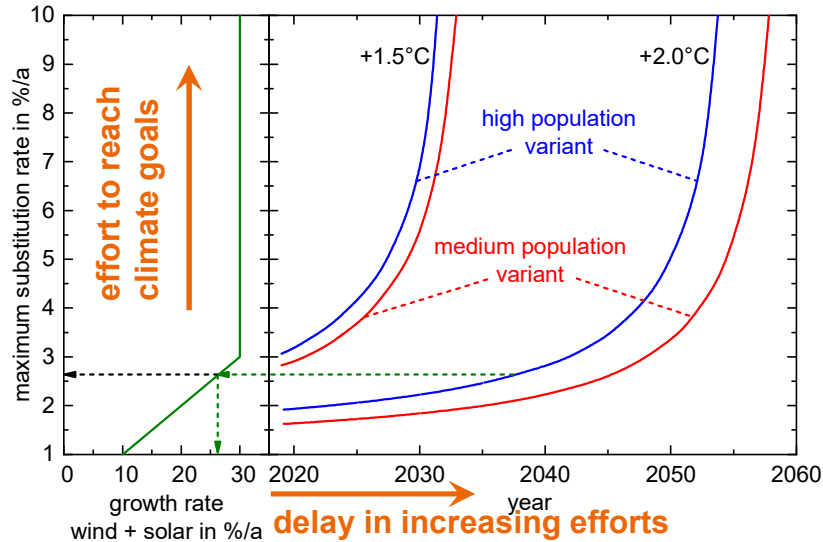


## IPCC SR15 of October 6, 2018

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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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)

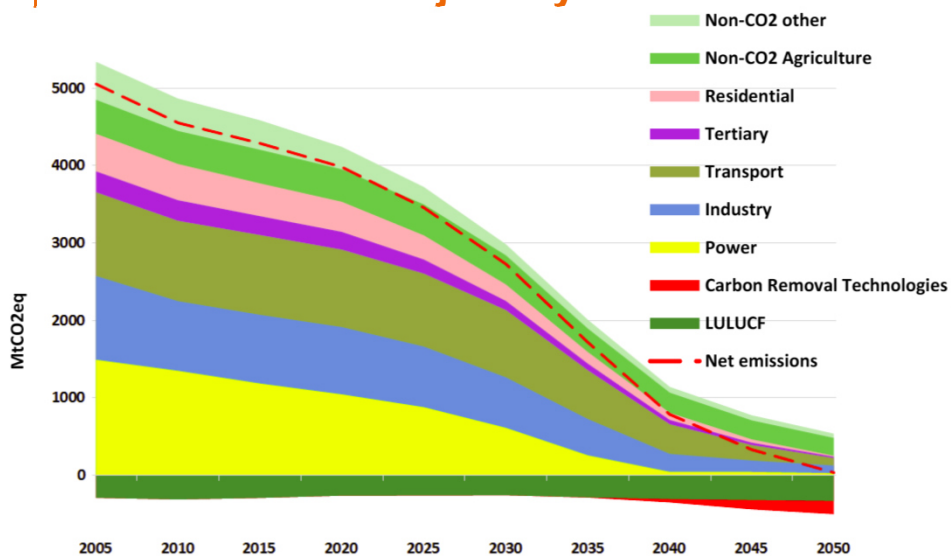
# Our Successful Future

## A Short Word on EU Sustainable Energy Strategy of November 28, 2018

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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)



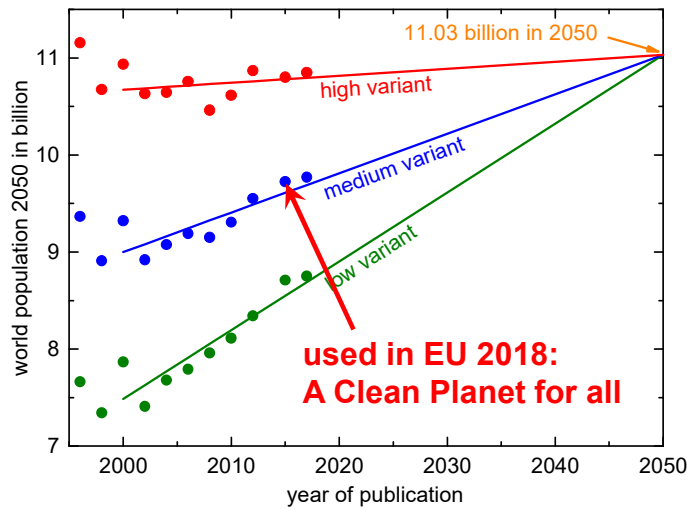
### GHG emissions trajectory in 1.5°C scenario



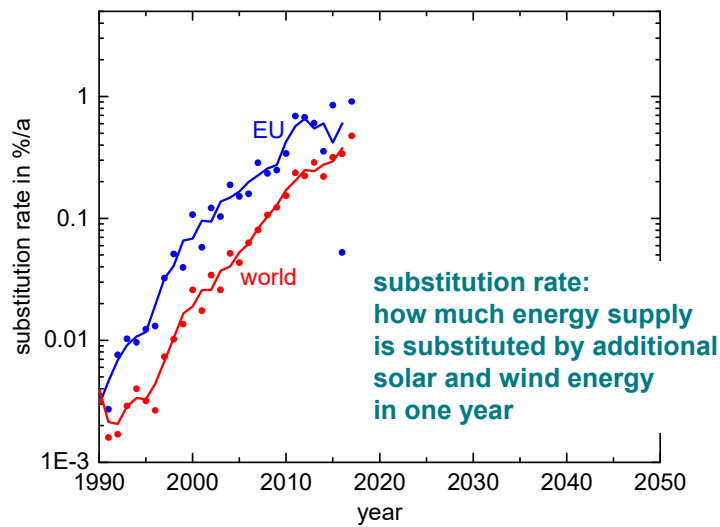
European Commission, A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Brussels, 28.11.2018, COM(2018) 773 final



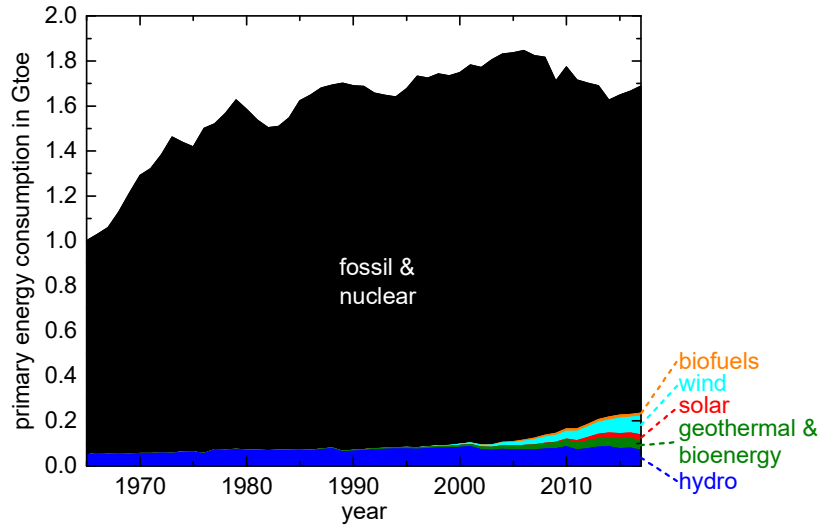
## development of UN-WPP predicting for 2050



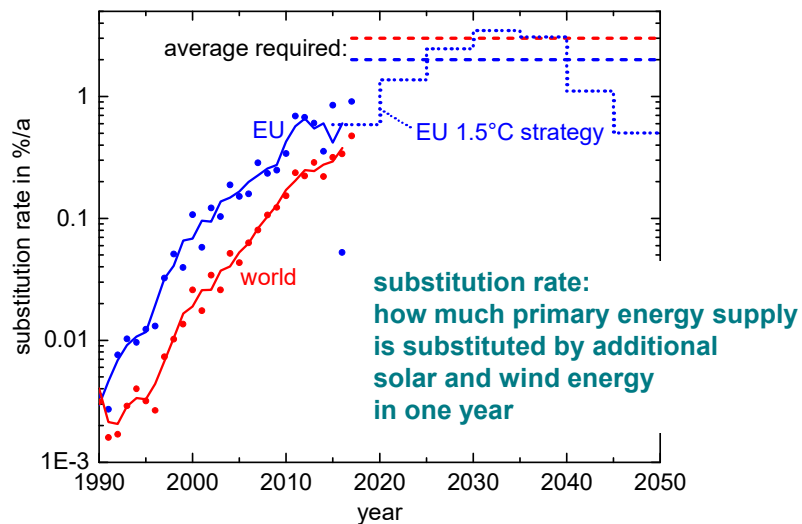
## substitution rates solar & wind



## EU primary energy consumption



## substitution rates solar & wind



## 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!**



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## 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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[andreas.pfennig@uliege.be](mailto:andreas.pfennig@uliege.be)



## questions to be answered

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

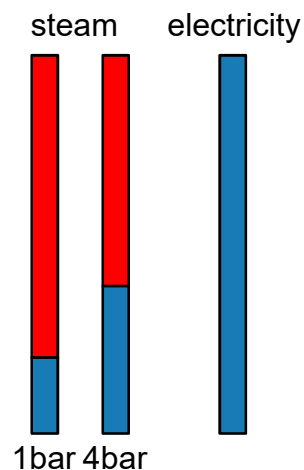


## relevant publications

- 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.
- 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 CO<sub>2</sub>-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

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

chemical exergy of a material stream

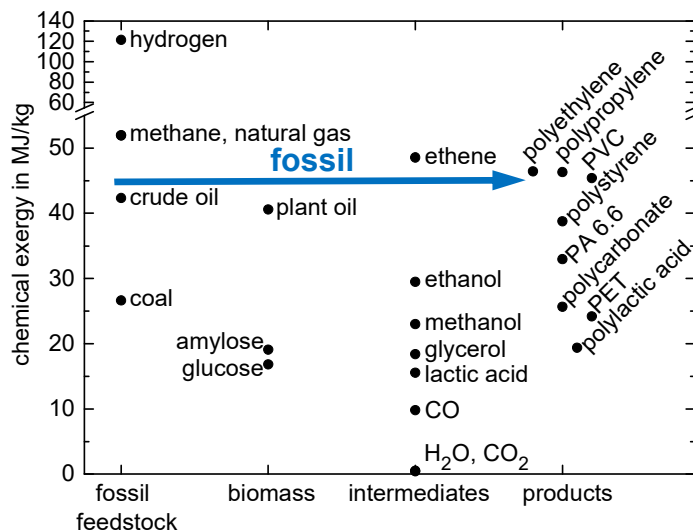
$$E_{i,\text{chem}} = \Delta^{\circ} G_i + \sum_{j=1}^J \nu_{i,j} E_{j,\text{chem}}^{\circ}$$

physical exergy of a material stream

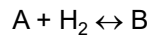
$$E_{i,\text{phys}} = \int_{T_U}^{T_R} C_i(T) dT + V_i^i F (P_R - P_U) - T_U \int_{T_U}^{T_R} \frac{1}{T} C_i(T) dT$$

+ exergy losses in processes and equipment

## chemical exergy of various materials

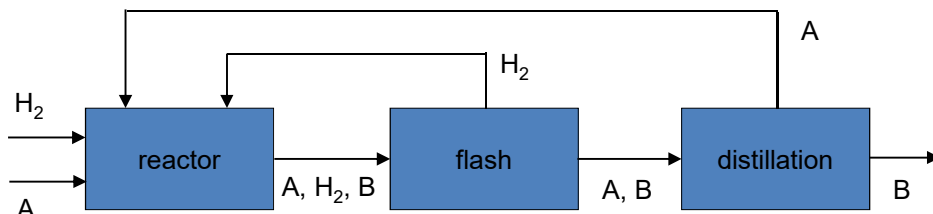


## general H<sub>2</sub>-process

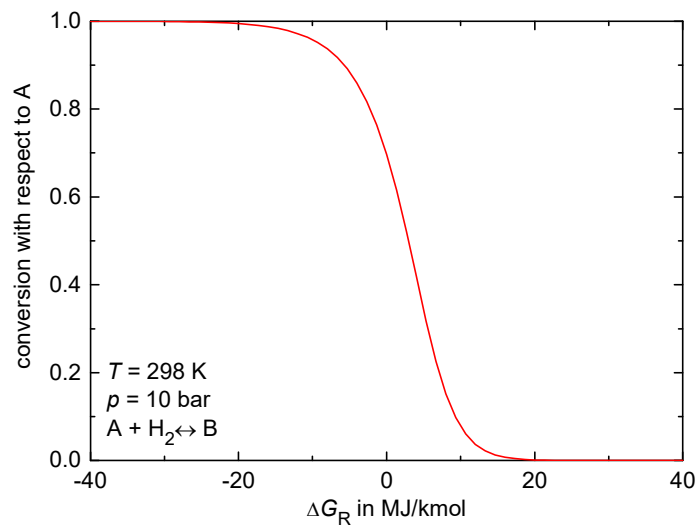


$$T = 298 \text{ K}$$

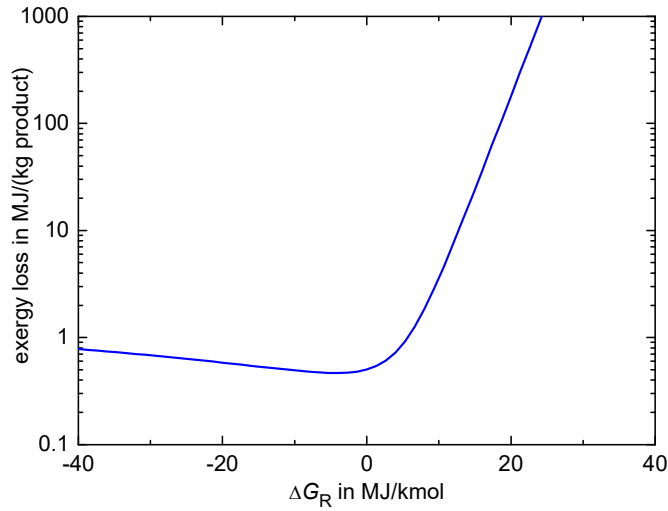
$$p_{\text{reactor}} = 10 \text{ bar}$$



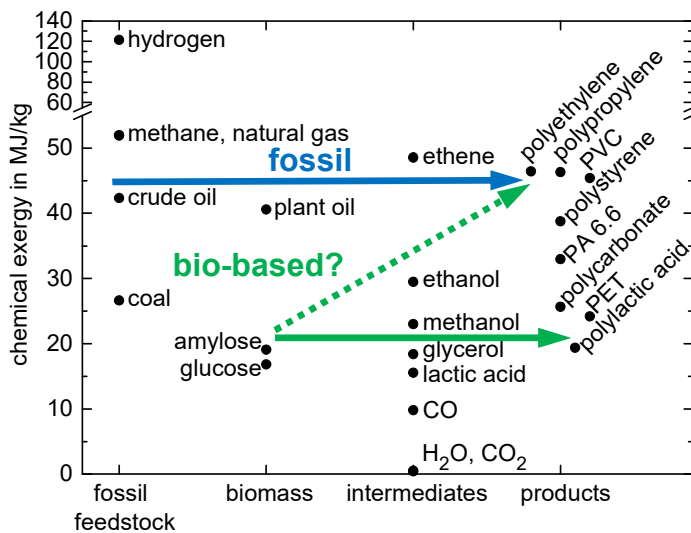
## conversion of A in general H<sub>2</sub> process



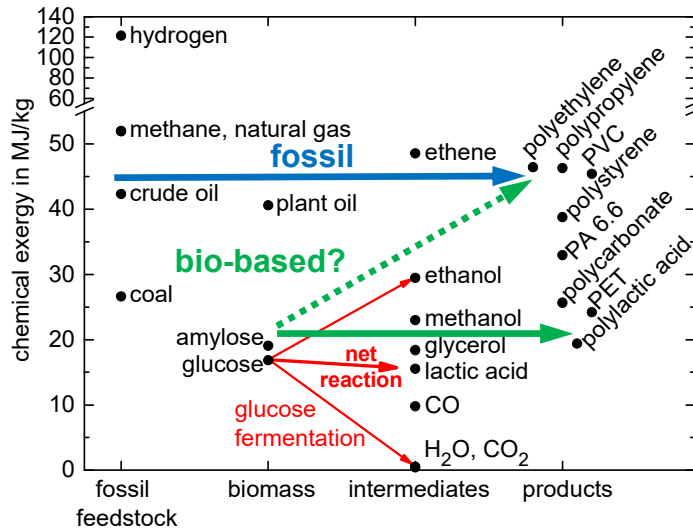
## exergy loss for a general H<sub>2</sub> process



## chemical exergy of various materials



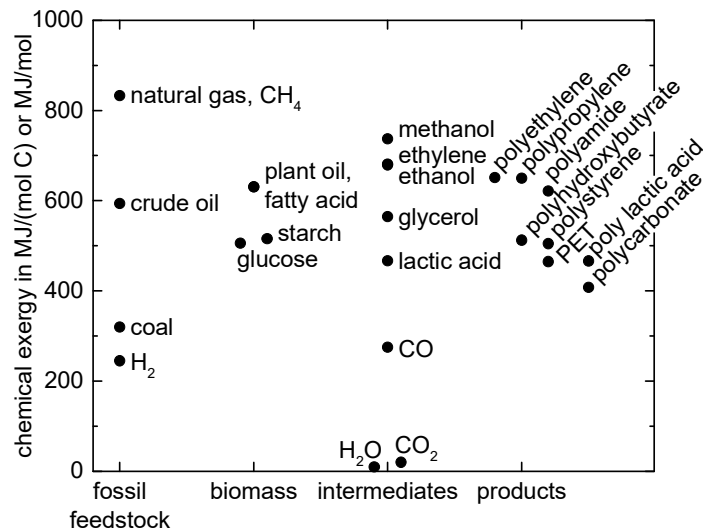
## chemical exergy of various materials



after: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:  
Increase in energy and land use by a bio-based chemical industry. 168  
Chemical Engineering Research and Design 92 (2014 ) 2006-2015



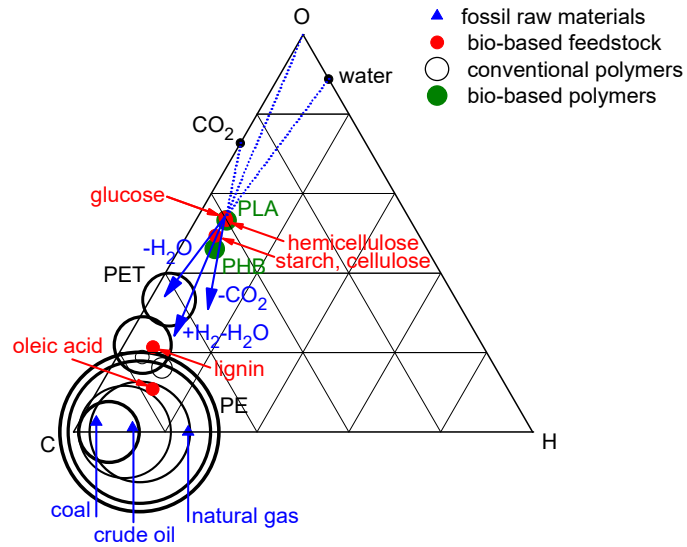
## exergy per mol of carbon



169



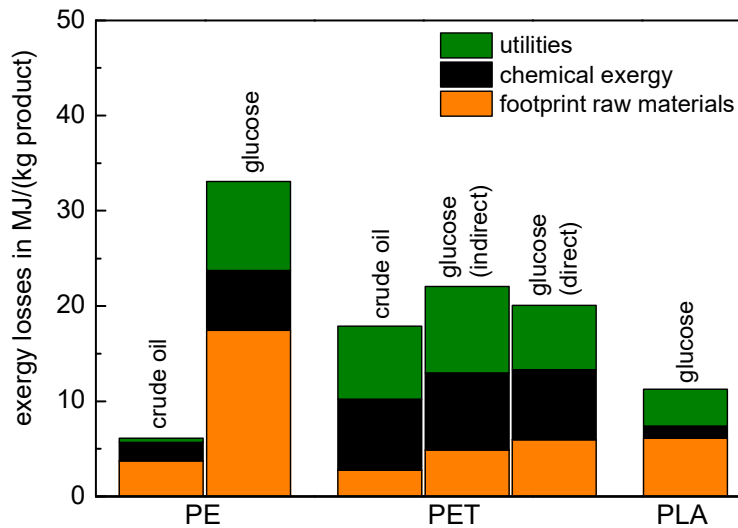
## elements in chemical industry by weight



source: Philipp Frenzel, Rafaela Hillerbrand, Andreas Pfennig:  
Increase in energy and land use by a bio-based chemical industry. 170  
Chemical Engineering Research and Design 92 (2014 ) 2006-2015



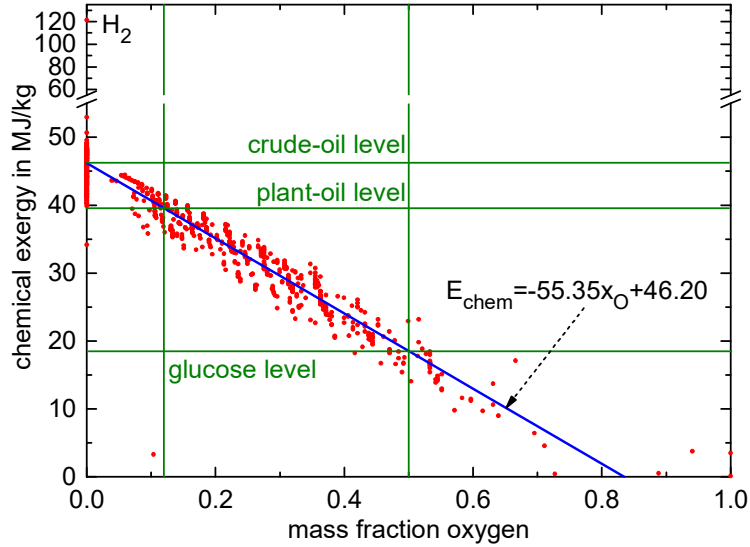
## comparison of the processes



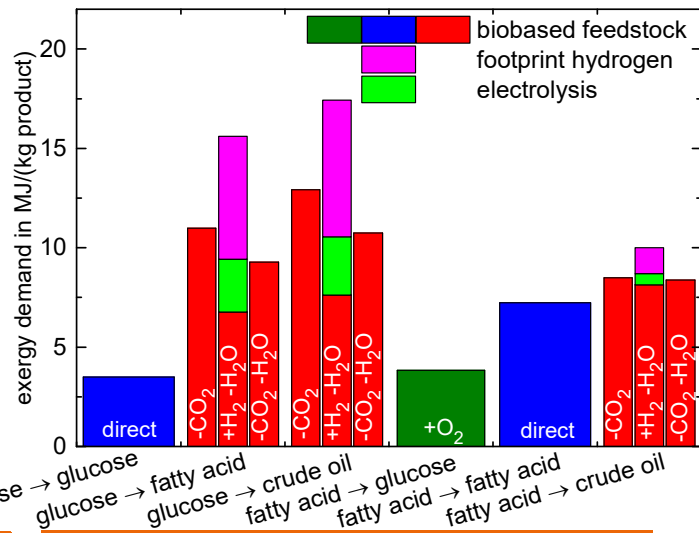
171



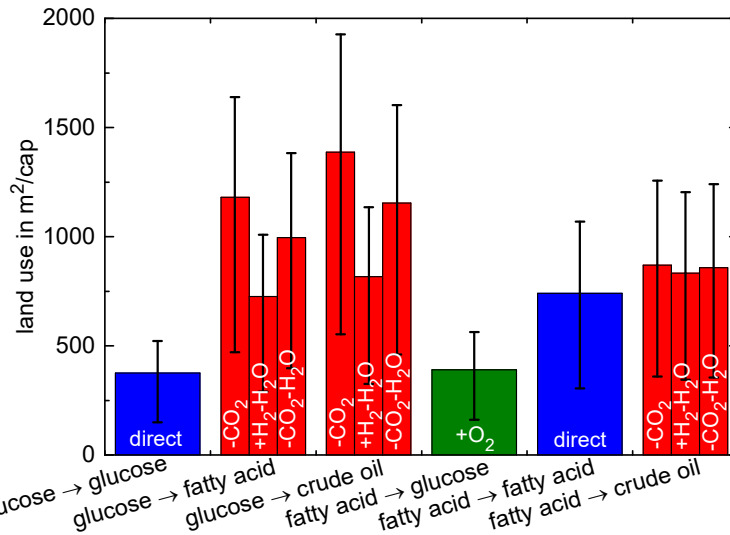
## chemical exergy



## exergy demand for different routes



## 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. 174  
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



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## Our Successful Future

- Sustainable Economy
- Exergy to Quantify Energy

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## Our Successful Future

- Sustainable Economy
- Bio- or CO<sub>2</sub>-Economy

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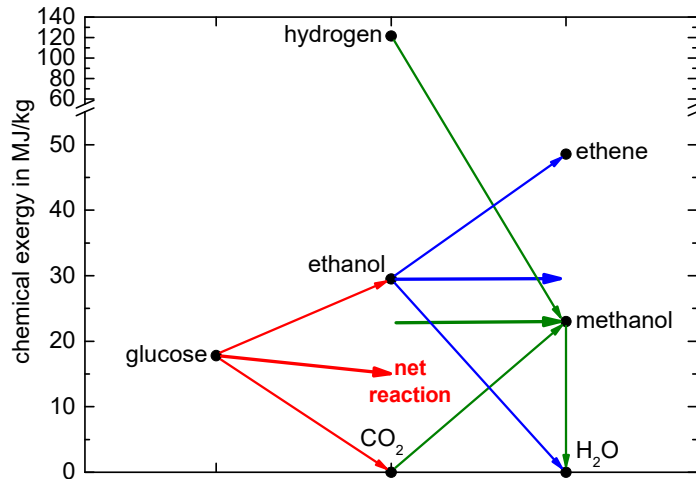
## questions to be answered

- What are the boundary conditions for a bio-based or a CO<sub>2</sub>-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.
- Frenzel, P., Hillerbrand, R., Pfennig, A. (2014). Exergetic 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.
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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

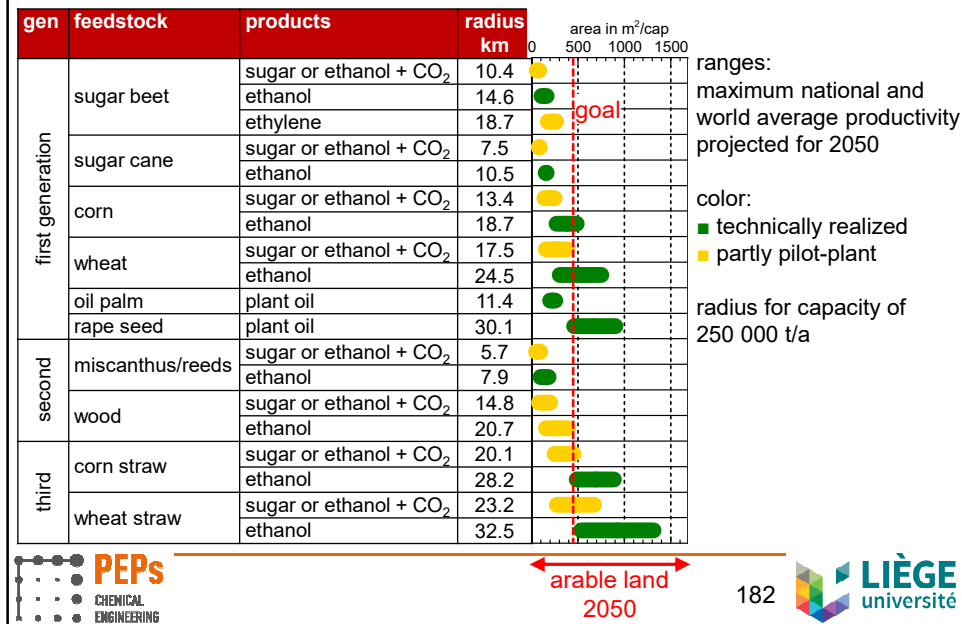
fossil feedstock today used for:

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

in scenarios for 2050:

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

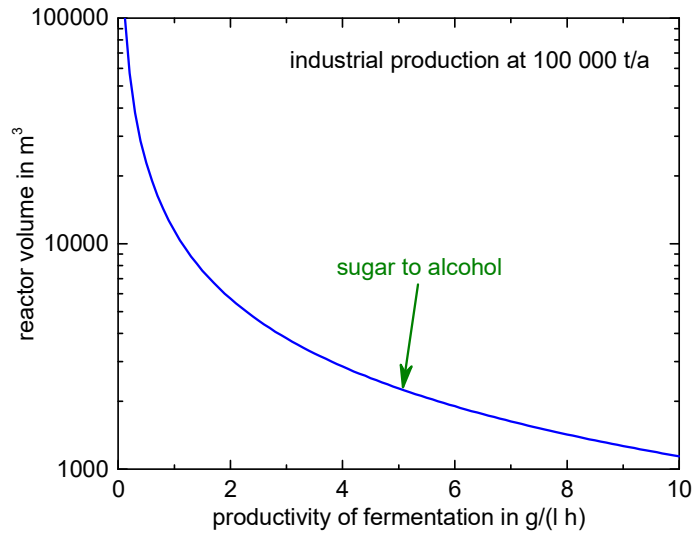
## options for bio-based chemicals 2050



## bio- vs. CO<sub>2</sub>-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<sub>2</sub>-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



## big aerobic fermenter



Bayer-Lanxess  
tower technology

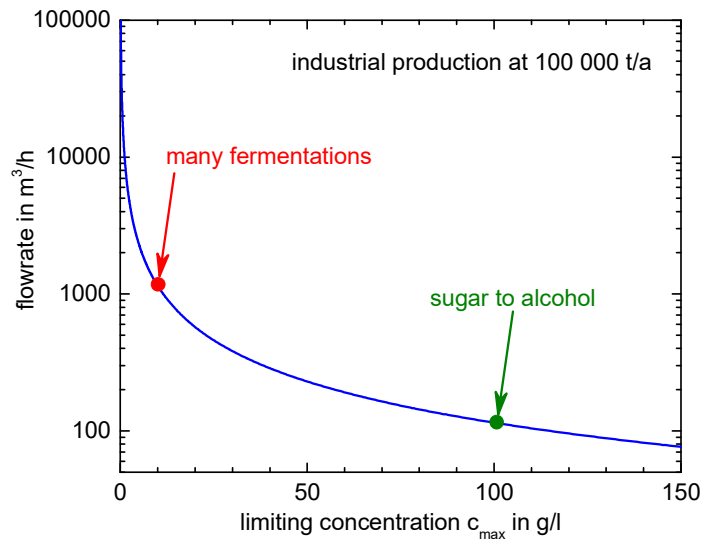
volume 13 000 m<sup>3</sup>  
flowrate 650 m<sup>3</sup>/h

**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!

## feasibility of large-scale biotechnology



## typical area/equipment demand

land area required m <sup>2</sup> / (t/a)	feedstock & technology
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<sub>2</sub>, sugar cane, sugar beet, corn, palm oil, miscanthus/reeds, possibly wood
- bio-based or CO<sub>2</sub>-based: both possible
- bio-based: preferably either sugar chemistry or co-utilization of CO<sub>2</sub>
- 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<sub>2</sub>-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)

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## Our Successful Future

- Sustainable Economy
- Bio- or CO<sub>2</sub>-Economy

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## Our Successful Future

- Individual and Political Consequences

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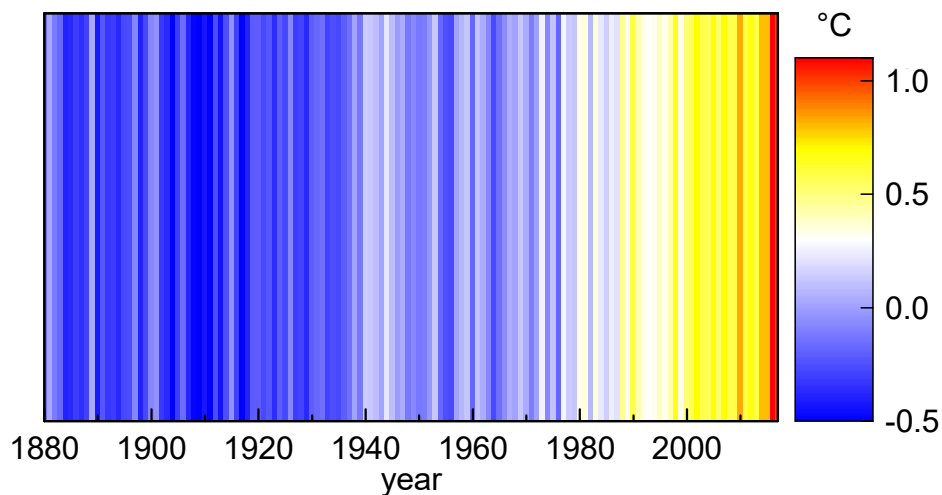
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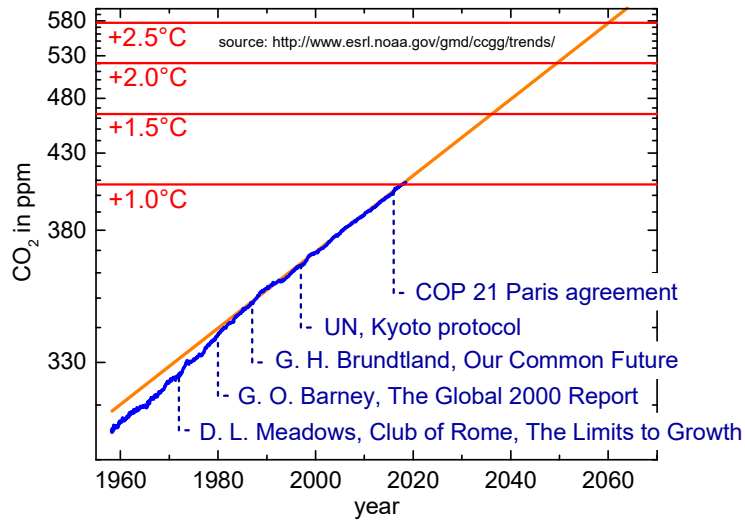
## questions to be answered

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

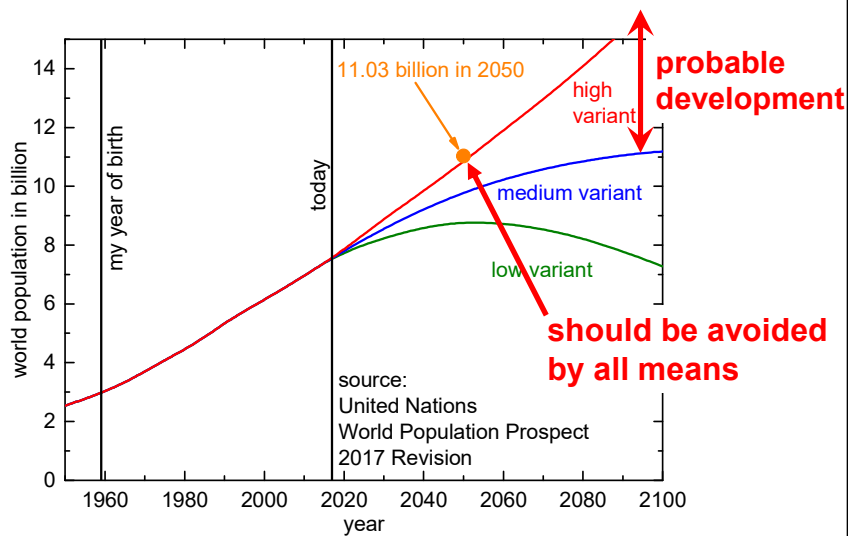
## global mean temperature



## CO<sub>2</sub> content of the atmosphere



## world population scenarios

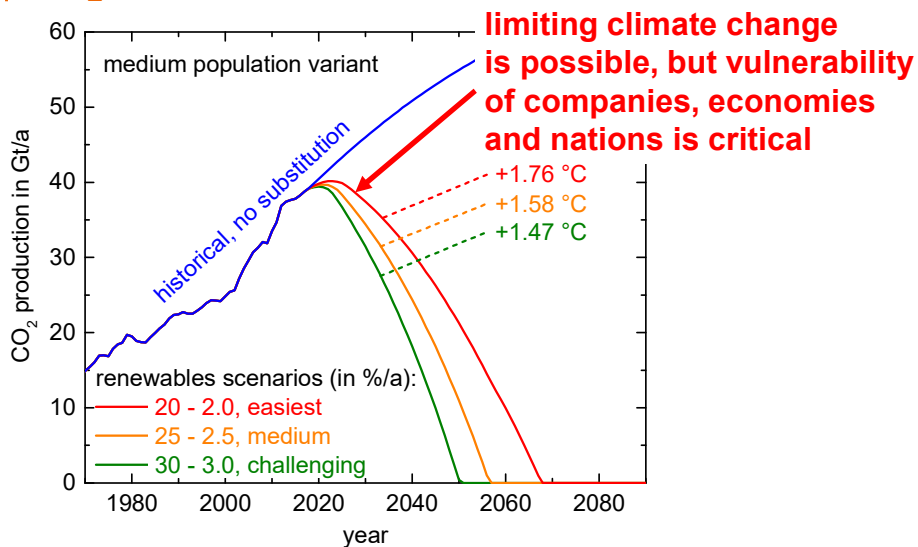


## population growth eating up progress

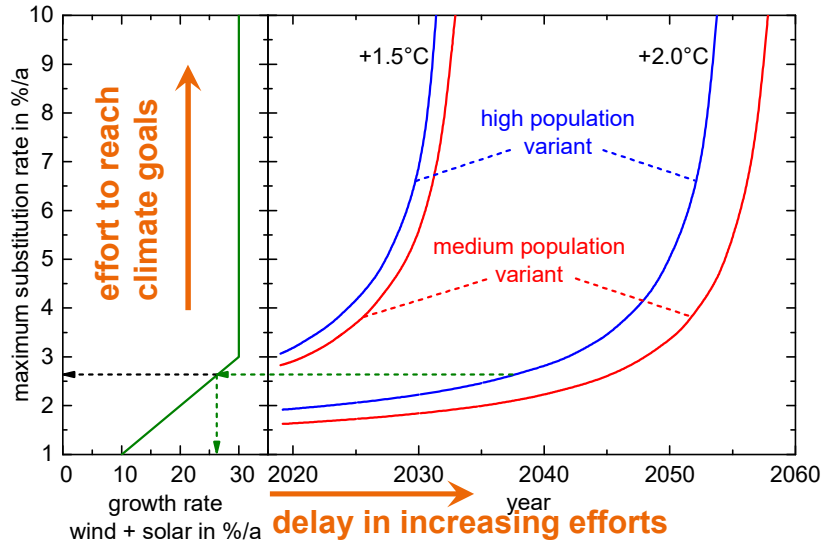
since 1990:

■ additional people fed:	2.5 bn
■ population increased by:	<u>-2.3 bn</u>
■ undernourishment decreased by	0.2 bn

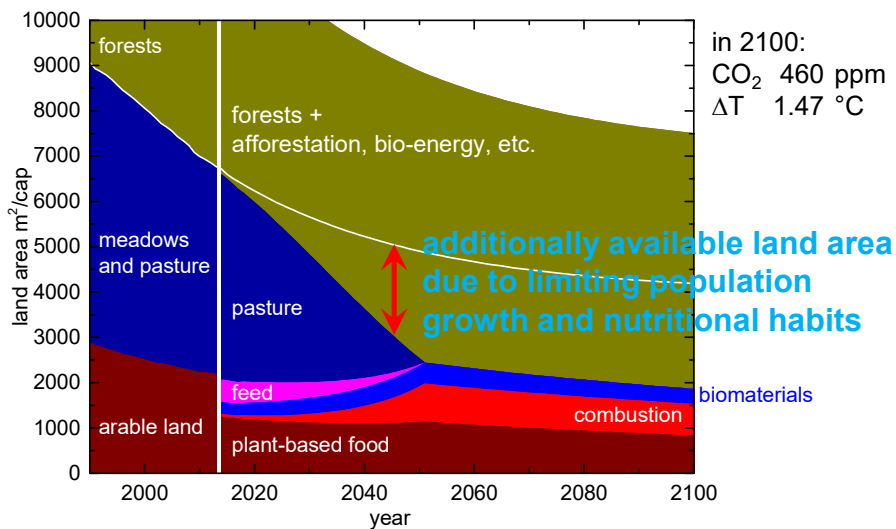
## CO<sub>2</sub> emissions for medium pop. variant



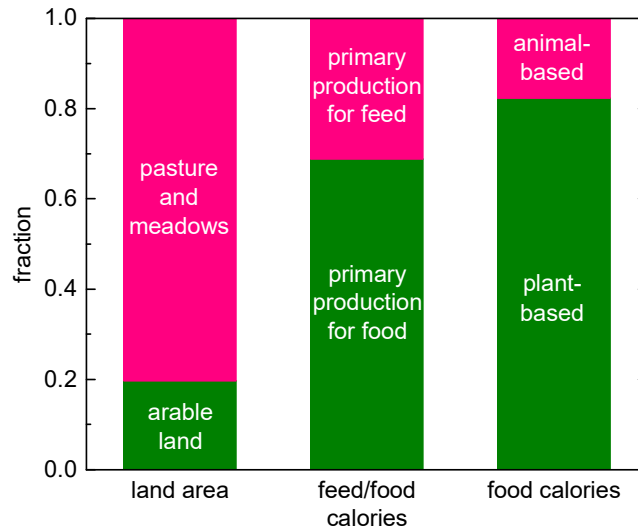
## consequences of a delay



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



## 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?



## 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.



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## 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

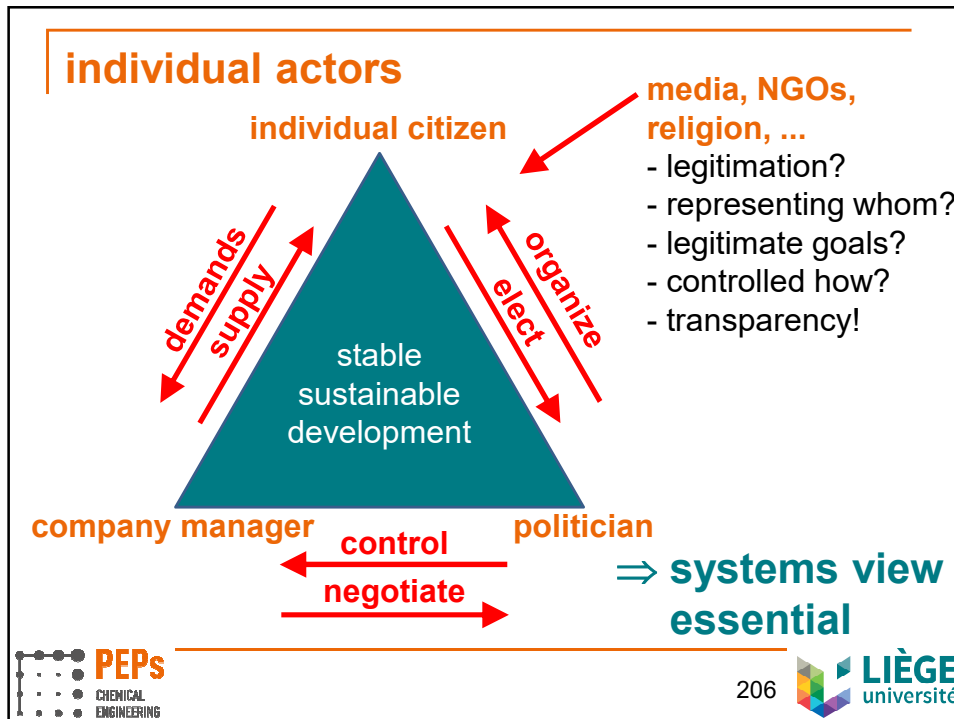
§25.1: Everyone has the right to a **standard of living adequate for the health and well-being of himself and of his family, including food**, clothing, housing and medical care and necessary social services, ...

## 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.



**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**

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CHEMICAL  
ENGINEERING

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## what matters

### individual choices determine our future:

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

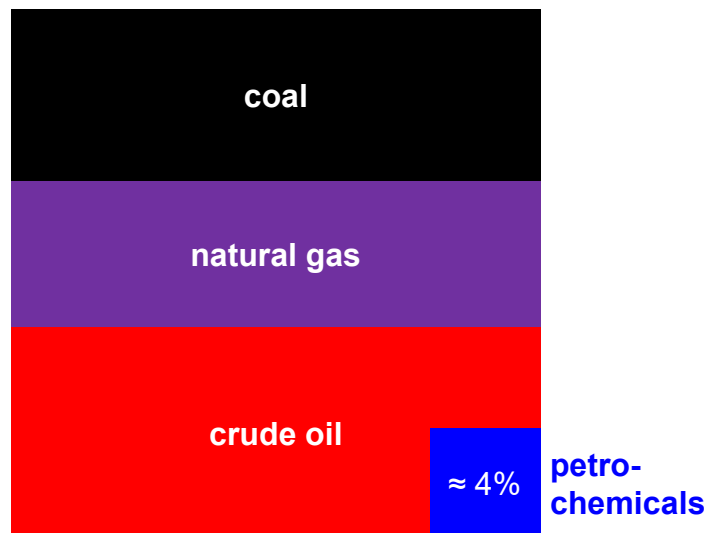
### interaction of individuals:

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

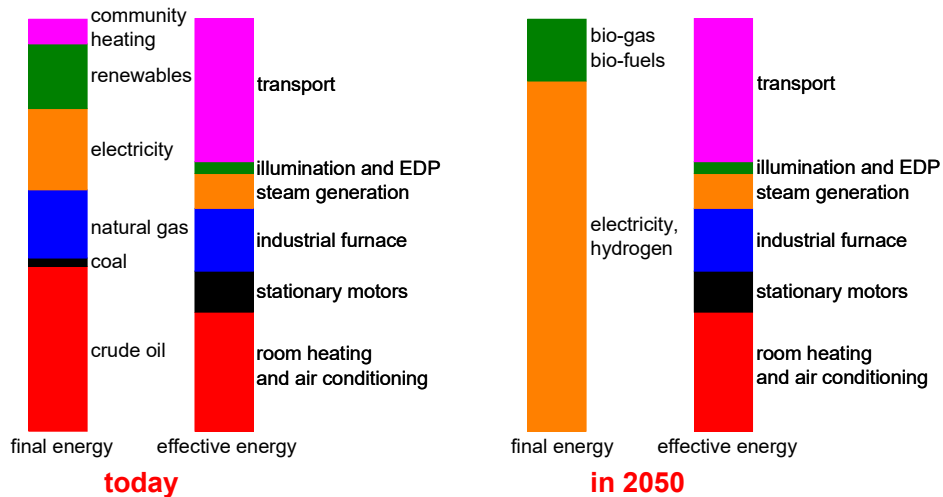
### general:

- **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<sub>2</sub>-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

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## Our Successful Future - Individual and Political Consequences

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## Our Successful Future Philosophical Aspects - Physical Basis

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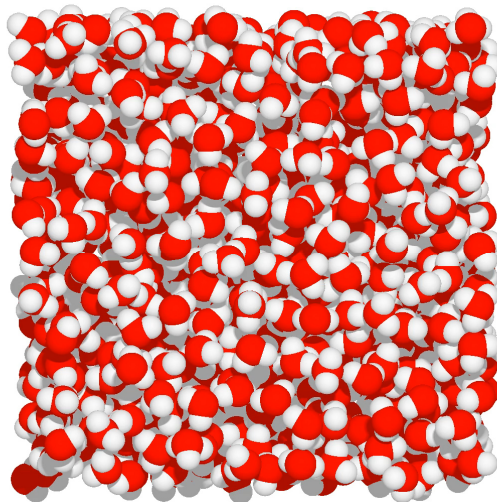
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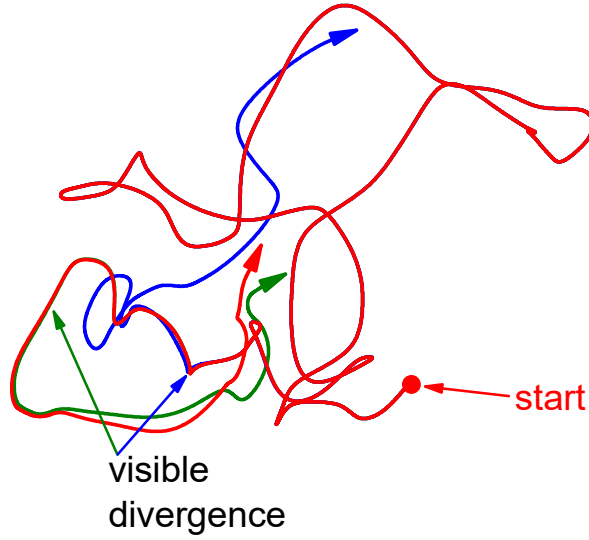
## questions to be answered

- 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.

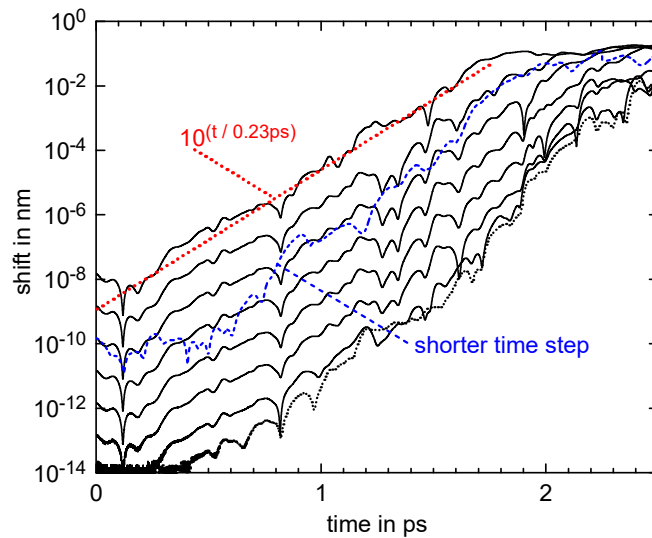
## liquid water, 37°C, periodic boundaries



## trajectories of molecules with minute shifts



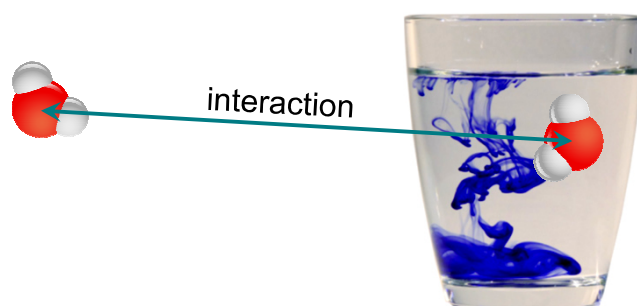
## Lyapunov instability in liquid water at 37°C



## consequences

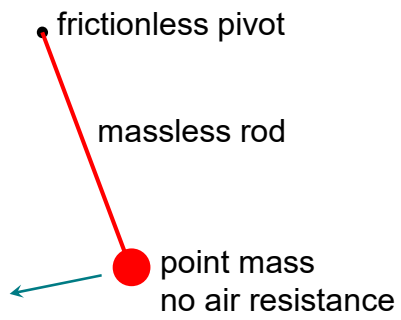
- deterministic chaos, Lyapunov time
- prediction every 0.23 ps further into the future requires one more decimal digit in start coordinates and calculations
- thus: cannot be predicted over intermediate times
- this is statement only about prediction, not about reality itself

## thought experiment

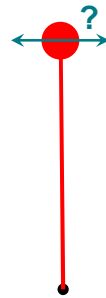


## the ideal pendulum

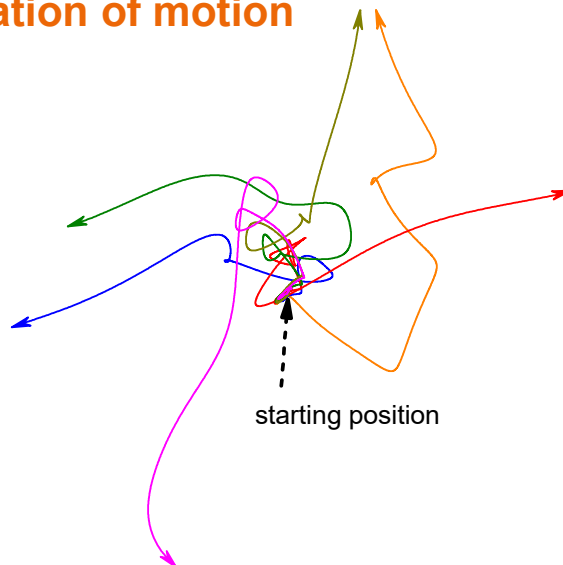
deterministic motion:



bifurcation:

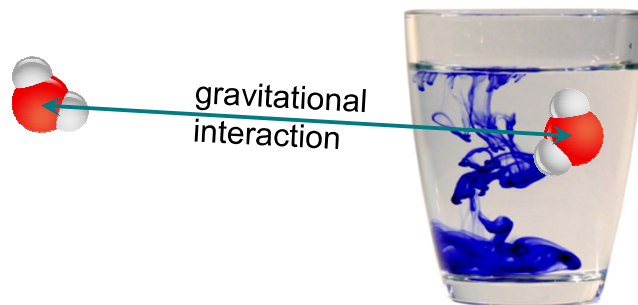


## randomization of motion



## 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 $\Delta t_{interaction}$

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

$$F = m_2 a$$

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

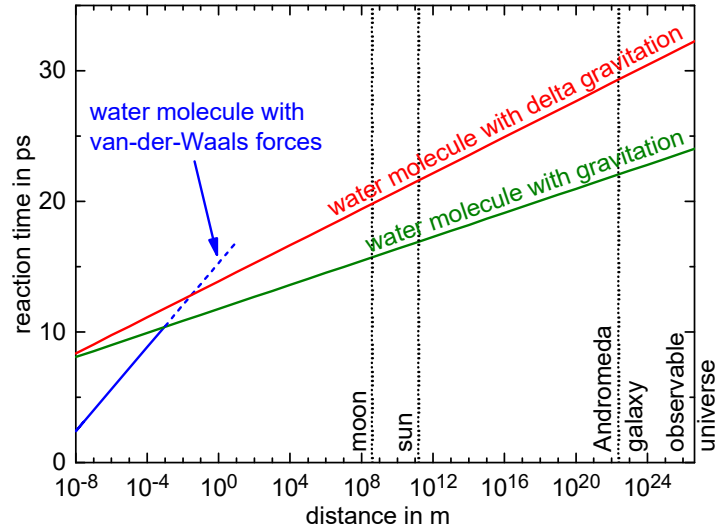
$$\Delta t_{interaction} \Rightarrow \Delta s_0$$

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

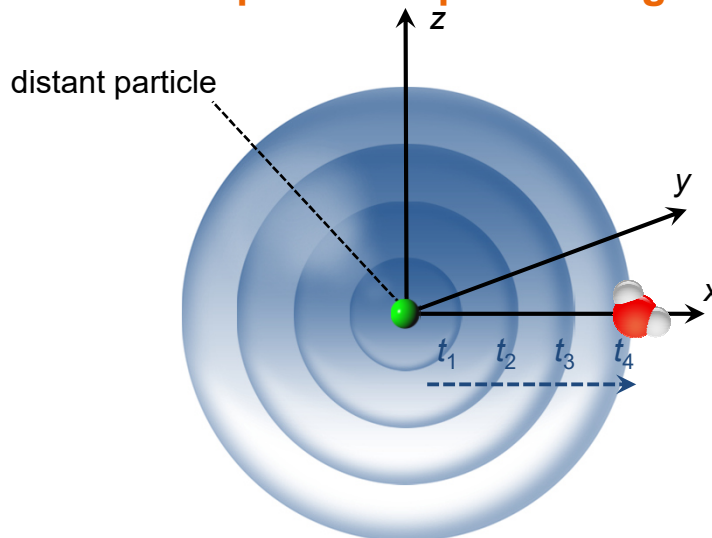
$$\Delta t_{reaction} = t_{scale} \left( \log_{10} \frac{2\Delta s}{Gm_1} + 2 \log_{10} r_{1,2} - 2 \log_{10} \Delta t_{interaction} \right)$$

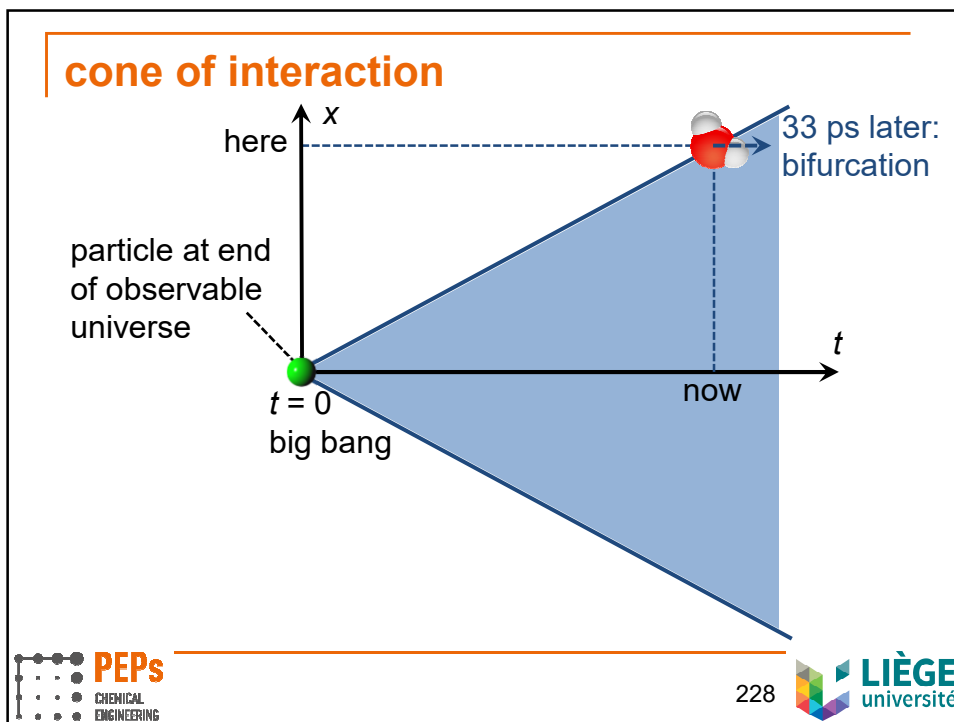
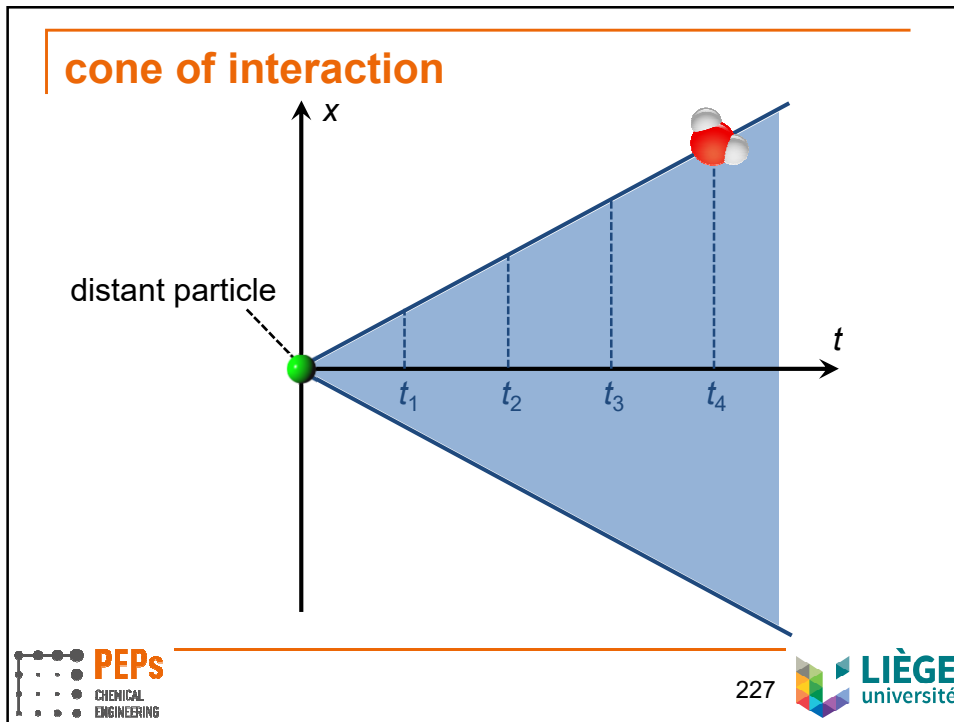
- $m_1$  – mass of distant particle
- $m_2$  – mass of observed particle
- $r_{1,2}$  – distance between particles
- $F$  – force acting between particles
- $t$  – time
- $\Delta s_0$  – initial shift of observed particle
- $t_{scale}$  – 0.23 ps

## influence between two water molecules



## interaction spheres at proceeding time



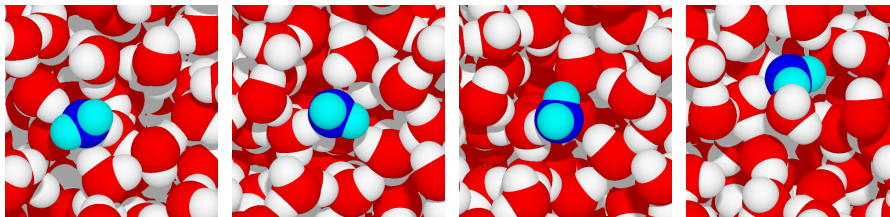


## picture

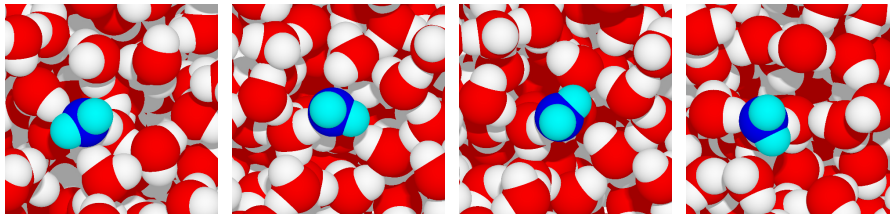
- all particles send information
- travels with speed of light
- any particle experiences at every moment the sum of all interactions with all particles
- reacts to this interaction
- if any faraway particle would have been in a slightly different place, after at most 33 ps the observed particle would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



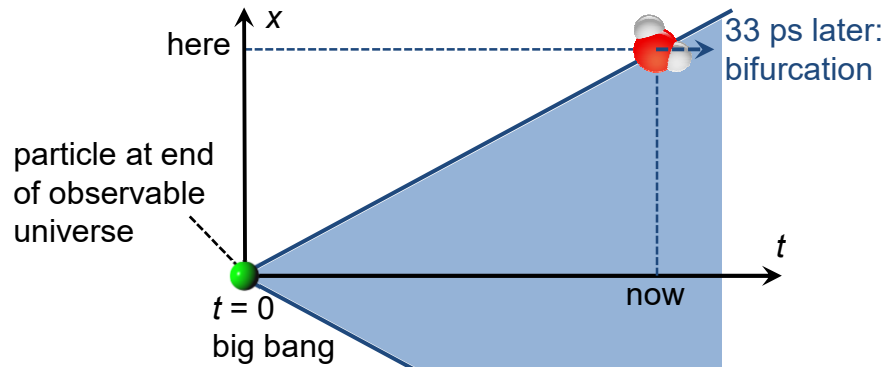
0.0 ps

31.9 ps

32.0 ps

33.0 ps

## cone of interaction



## consequences

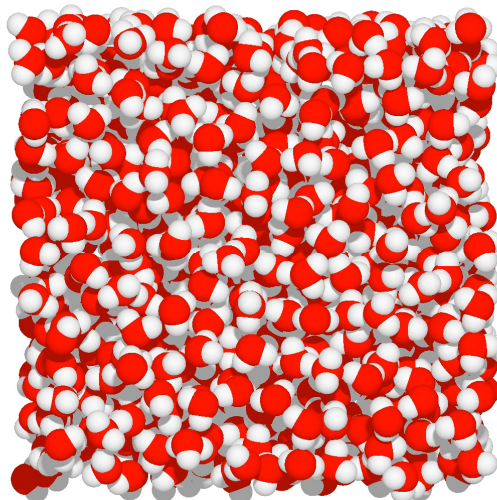
- all particles influence each other within 0 to 33 ps on universal scale (possibly much faster)
- but: speed of light
- this is about **interaction in reality**, not only about prediction
- randomizing effect
- even in a fully deterministic world view
- generalization:
  - complex systems show deterministic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

## reversal of time

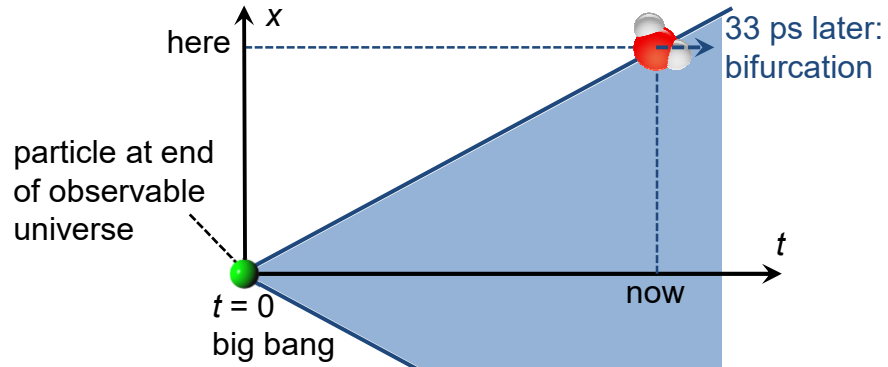
- e.g. conservation of energy and momentum
- Newtons laws of motion
- but entropy reduction improbable:



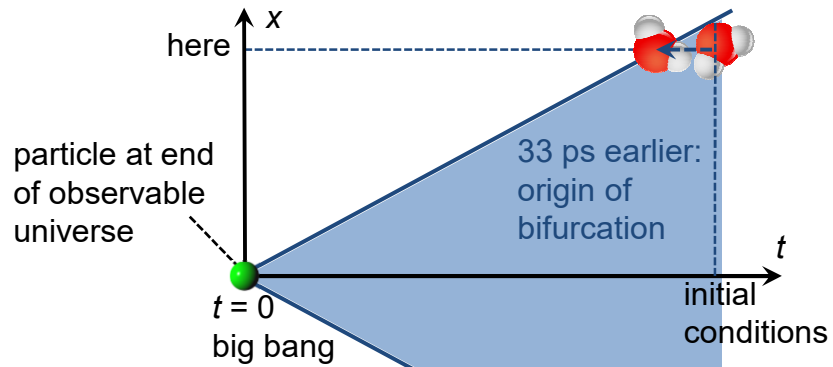
## liquid water, 37°C, periodic boundaries



## cone of interaction



## reversing the direction of time



## 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.

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## 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



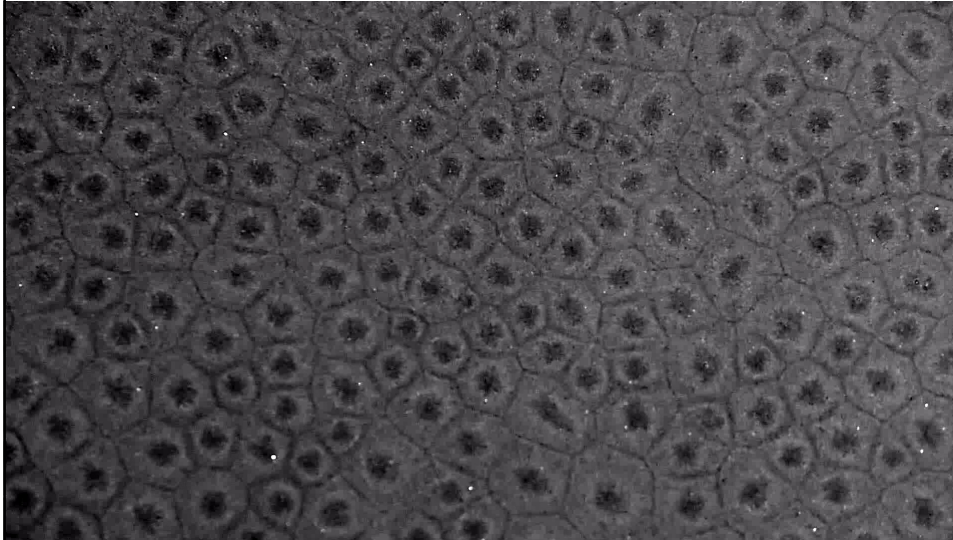
## causality

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



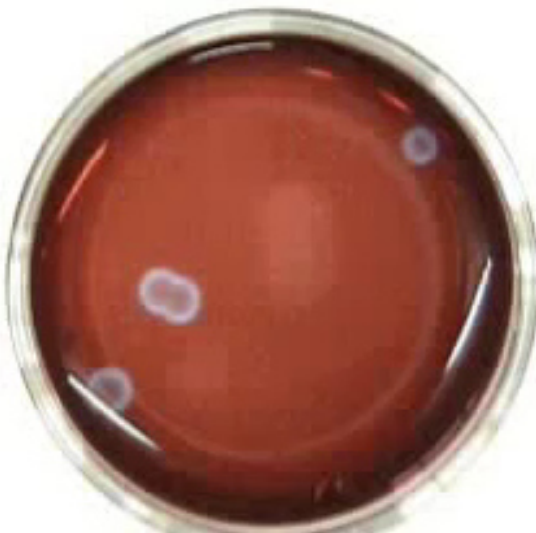
## Bénard cells teach us:

- structure  $\leftrightarrow$  information
- structure causes effects in other structures
- structure determines behavior of matter

## causality

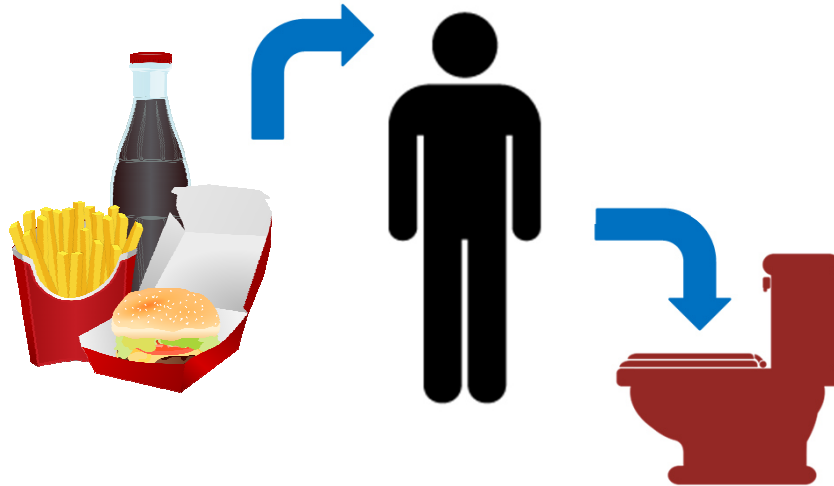
levels	relations between different entities of same level
structure with memory	causal, convergent, intentional
structure	causal
macroscopic systems	defined properties, physical laws, averaged over many molecules, not causal
molecules	deterministic chaos, continually passing through bifurcations, divergent, 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

## 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
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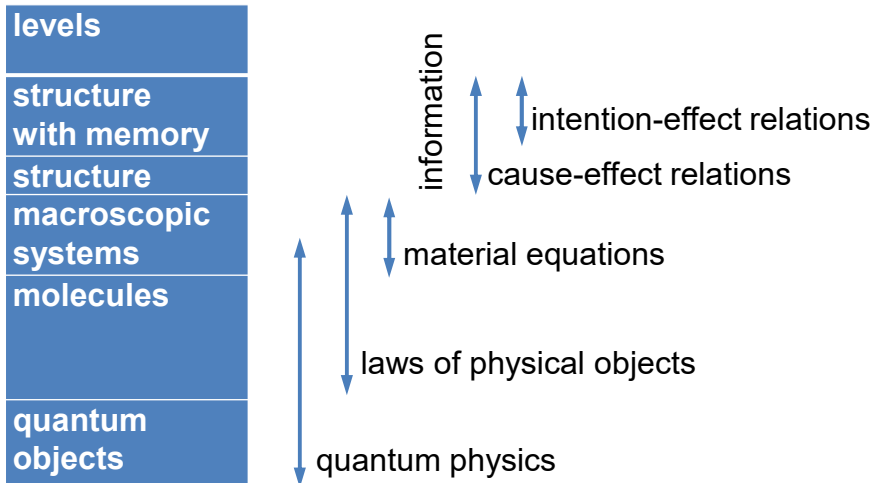
## I am fan of Helge Schneider



## 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

## levels of laws we apply



## Ernst Mach

There is no cause nor effect in nature;  
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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



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## 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?



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## 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 readiness 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  
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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 (perceptions)

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



## 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 - Consciousness

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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

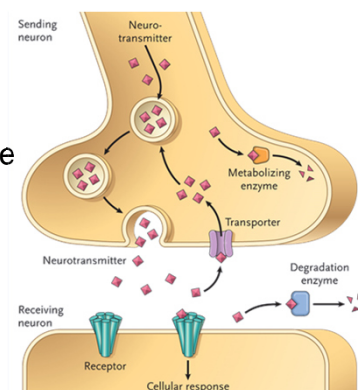
- We could have chosen otherwise!
- How to prove? **Impossible!**
- How can we then have the impression of free will?
  1. it is really random
  2. we don't know the decision beforehand
- How do **conscious** decisions work?
- Can we be primary **cause** of our actions?

## 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  $0.04 \mu\text{m}^2$
  - distance to neuron 20 nm
  - concentration 10 to 25  $\mu\text{mol/l Ca}^{2+}$
- 7 to 20 ions  $\text{Ca}^{2+}$  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

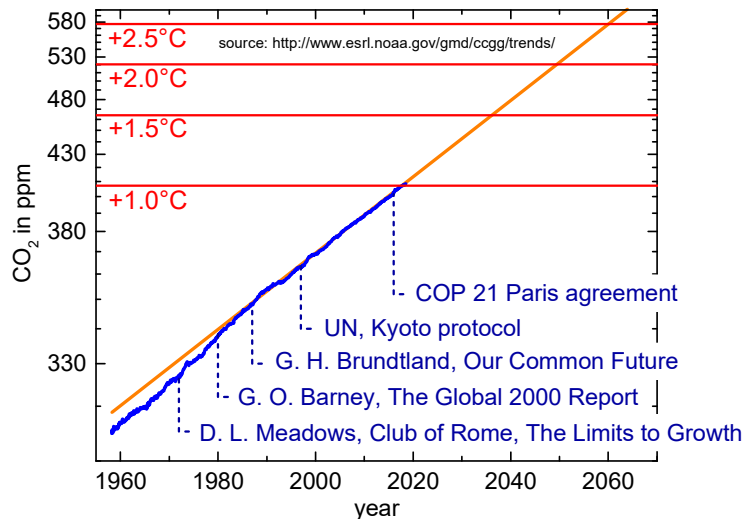


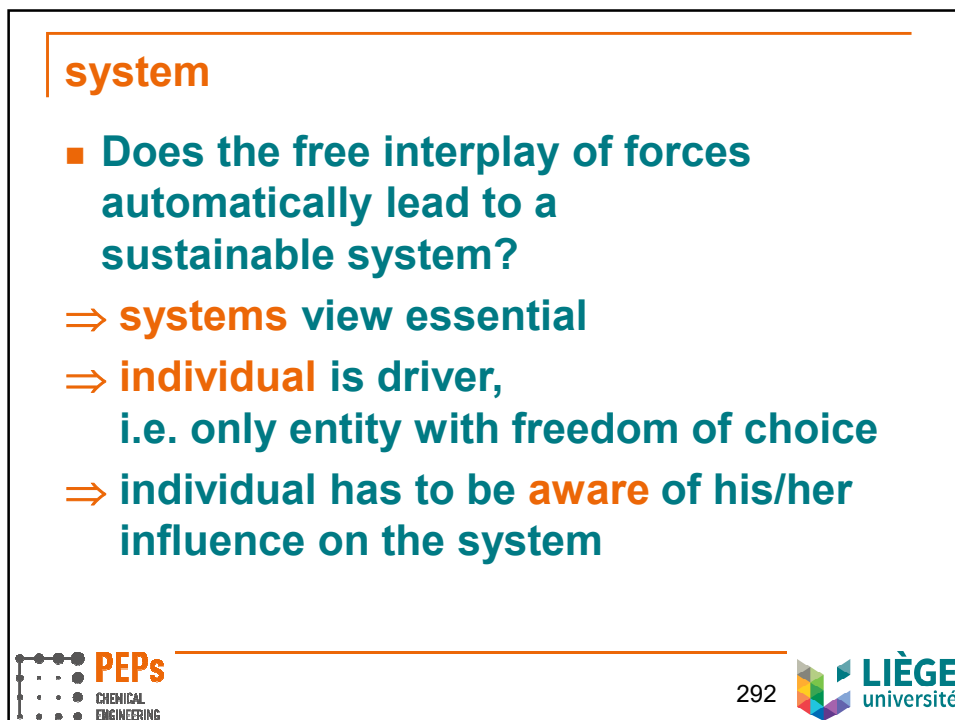
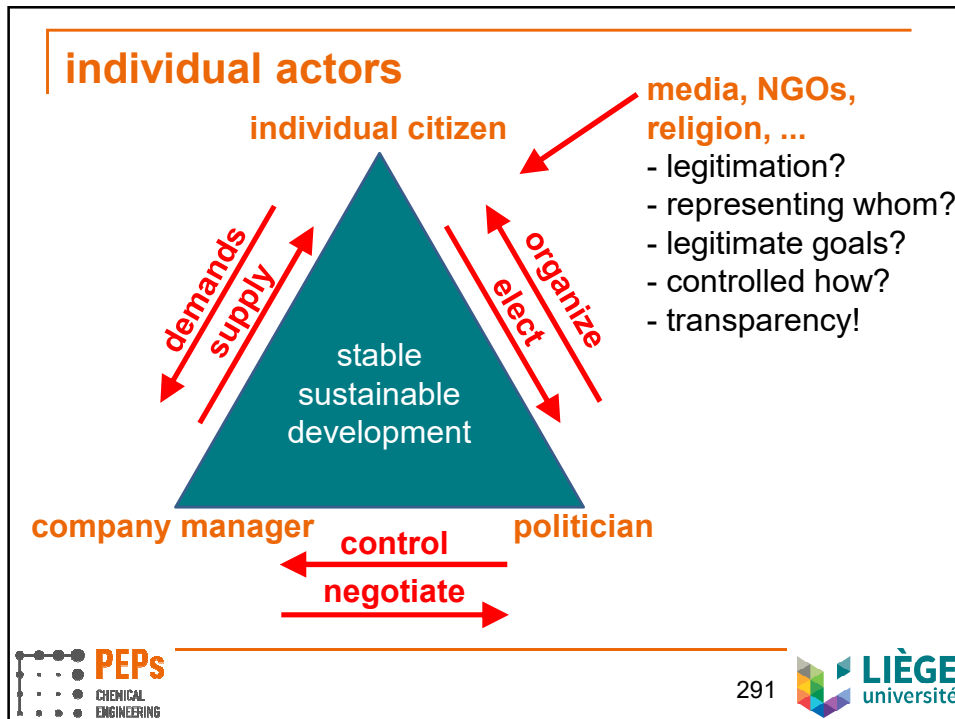
Andreas Pfennig, 2018  
So Gelingt unsere Zukunft  
Books on Demand, Norderstedt  
[www.bod.de/buchshop/  
so-gelingt-unsere-zukunft-  
andreas-pfennig-9783752831870](http://www.bod.de/buchshop/so-gelingt-unsere-zukunft-andreas-pfennig-9783752831870)

chapter titles:

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

## CO<sub>2</sub> content of the atmosphere





## 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<sub>2</sub>-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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## Our Successful Future Philosophical Aspects - Free Will and Responsibility

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## Our Successful Future

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