Energy & Environment

Climate Change

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Climate change

Weather, Climate & Climate Change

Weather:

Describes the conditions of the atmosphere over a short period of time, can change several times daily

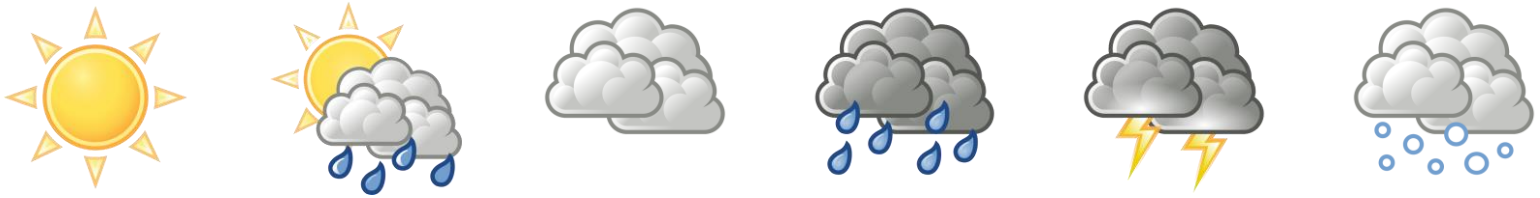
Climate:

Average of weather conditions over a long period of time

Climate Change:

Changes in long-term averages of daily weather

Milankovic cycles: 10.000 / 100.000 years



Climate Change

Change in the statistical distribution of weather patterns when that change lasts for an extended period of time (e.g. decades to millions of years).

- Change in average weather conditions
- Time variation of weather around longer-term average conditions (e.g. more or fewer extreme weather events)
- Cause:
  - Biotic processes
  - Variations in solar radiation received by earth
  - Plate tectonics and volcanic eruptions
  - Human activities (global warming, anthropogenic climate change)

Climate Change

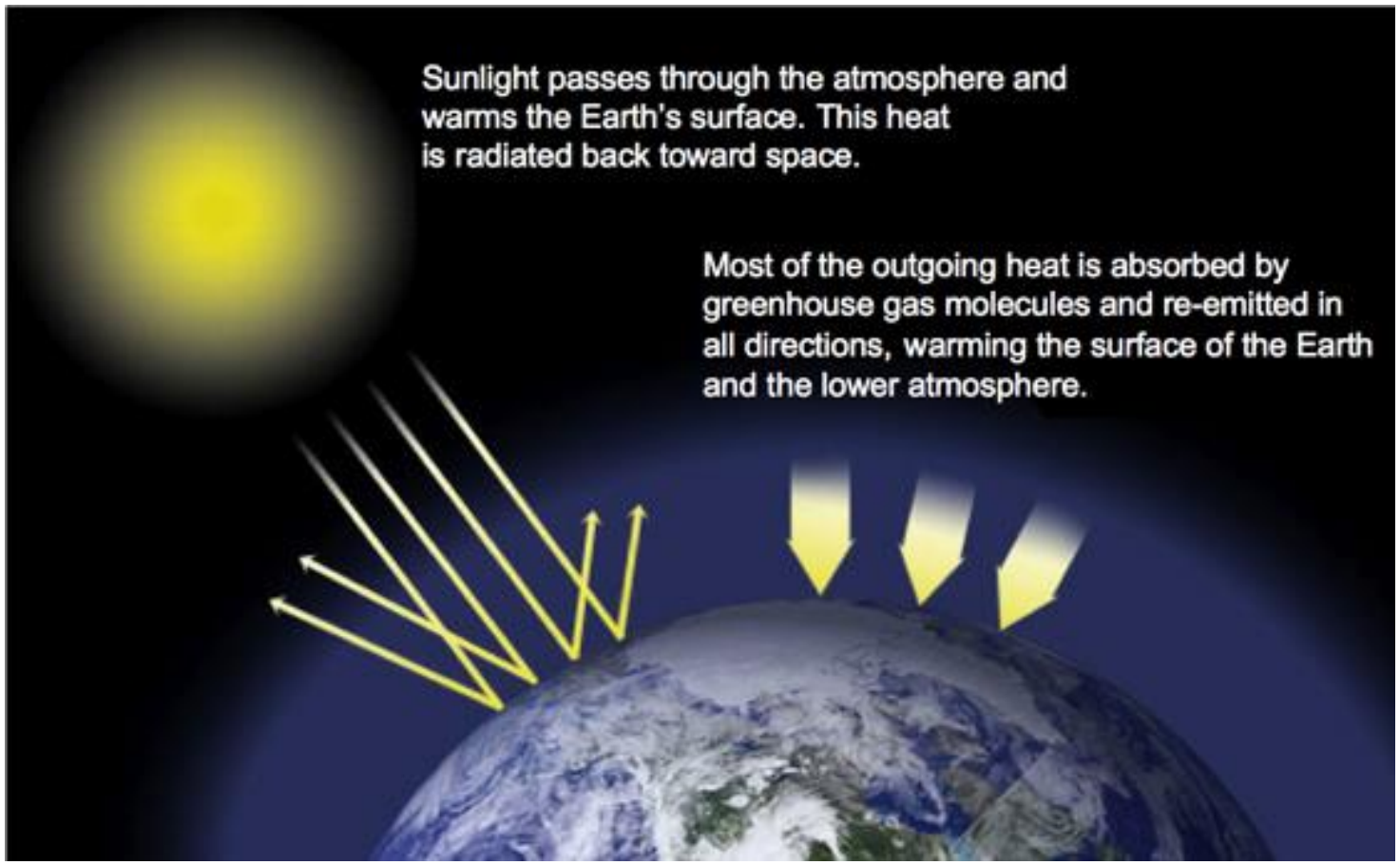
Consequences:

- Change in local climate
- More extreme weather events
- Intensification of hydrological cycle
- Reduction of areas covered with snow and ice (temporal and spatial)
- Sea level rise
- Loss of biodiversity
- Change in land use patterns

In our area:

- Warmer and drier summers (and mild and humid winters)
- Melting of glaciers
- Higher pollution concentrations
- Change in crop/food production

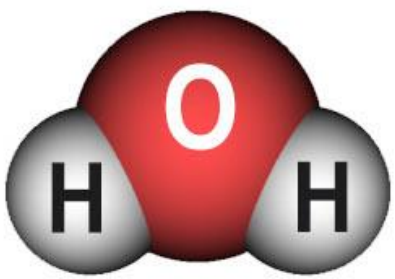
Natural Greenhouse Effect



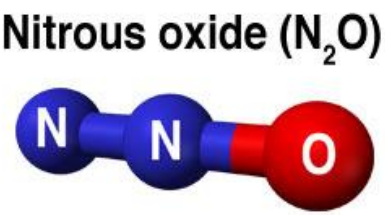
Source: NASA. *Global Climate Change.*

Greenhouse Gases

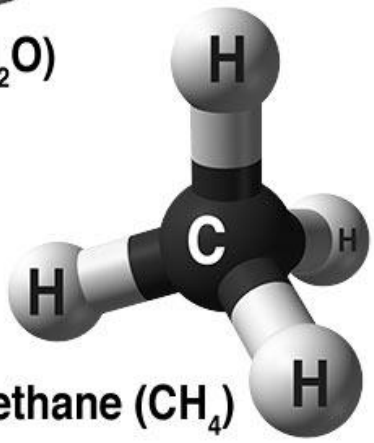
- Water vapor
- Carbon dioxide
- Methane
- Nitrous oxide
- Chlorofluorocarbons



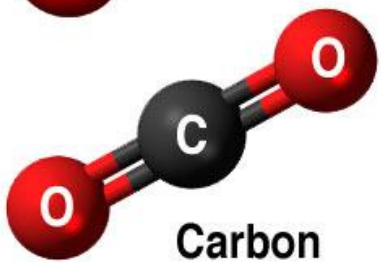
Water vapor (H_2O)



Nitrous oxide (N_2O)



Methane (CH_4)



Carbon dioxide (CO_2)

Source: NASA. *Global Climate Change.*

Global Warming Potential

- A relative measure of how much heat a greenhouse gas traps in the atmosphere
- Compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of CO_2
- The larger the GWP, the more a given gas warms the Earth compared to CO_2

$$GWP = \frac{\int_0^n a_i \cdot c_i dt}{\int_0^n a_{CO2} \cdot c_{CO2} dt}$$

a_i…the instantaneous radiative forcing (see below) due to a unit increase in the concentration of trace gas i.

c_1… concentration of the trace gas i, remaining at time t after its release.

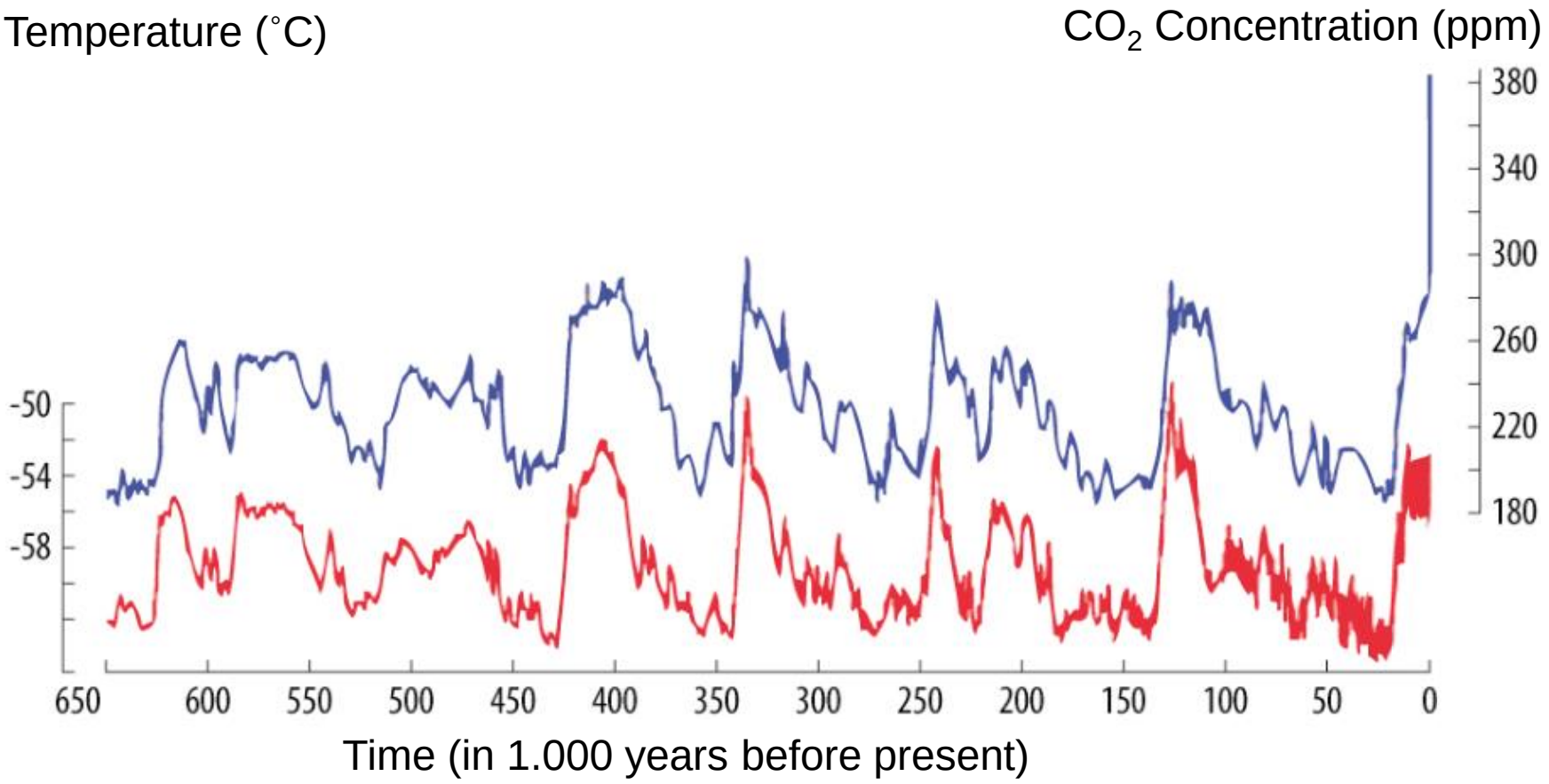
n…the number of years over which the calculation is performed

Global Warming Potential

GHG	Source	GWP acc. to IPPC AR5
Carbon dioxide CO_2	Burning of fossil fuels	1
Methane CH_4	Rice growing, cattle breeding, landfills	28
Nitrous oxide N_2O	Nitrogen fertilizer in agriculture	265
1,1,1,2-Tetrafluoroethane $C_2H_2F_4$	Refrigerant in cooling systems	1.300
Chlorofluorocarbon (e.g. $CCIF_3$)	Spray cans, refrigerant in cooling systems	13.900
Nitrogen trifluoride NF_3	Production of semiconductors, solar cells	16.100
Sulphur hexafluoride SF_6	Insulation gas in high-voltage switchgears	23.500

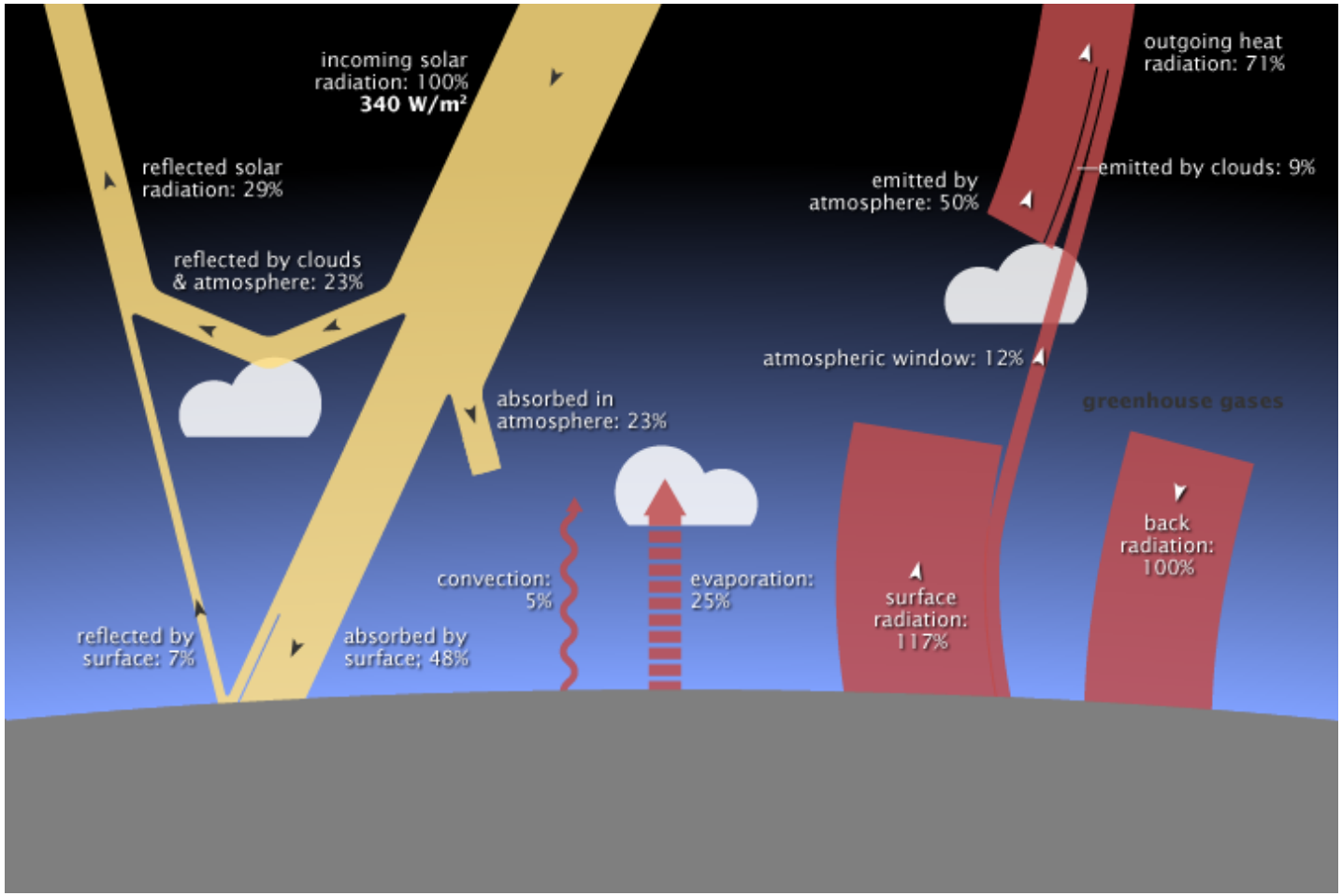
http://unfccc.int/ghg_data/items/3825.php

CO_2-Concentration



Source: Bundeszentrale für politische Bildung (2013). *Wetter, Klima und Klimawandel.*

Radiative Forcing



Source: NASA. *The Atmosphere's Energy Budget.*

Radiative Forcing

„A process that alters the energy balance of the atmosphere system is known as a radiative forcing mechanism.“

$$RF = R_i - R_o$$

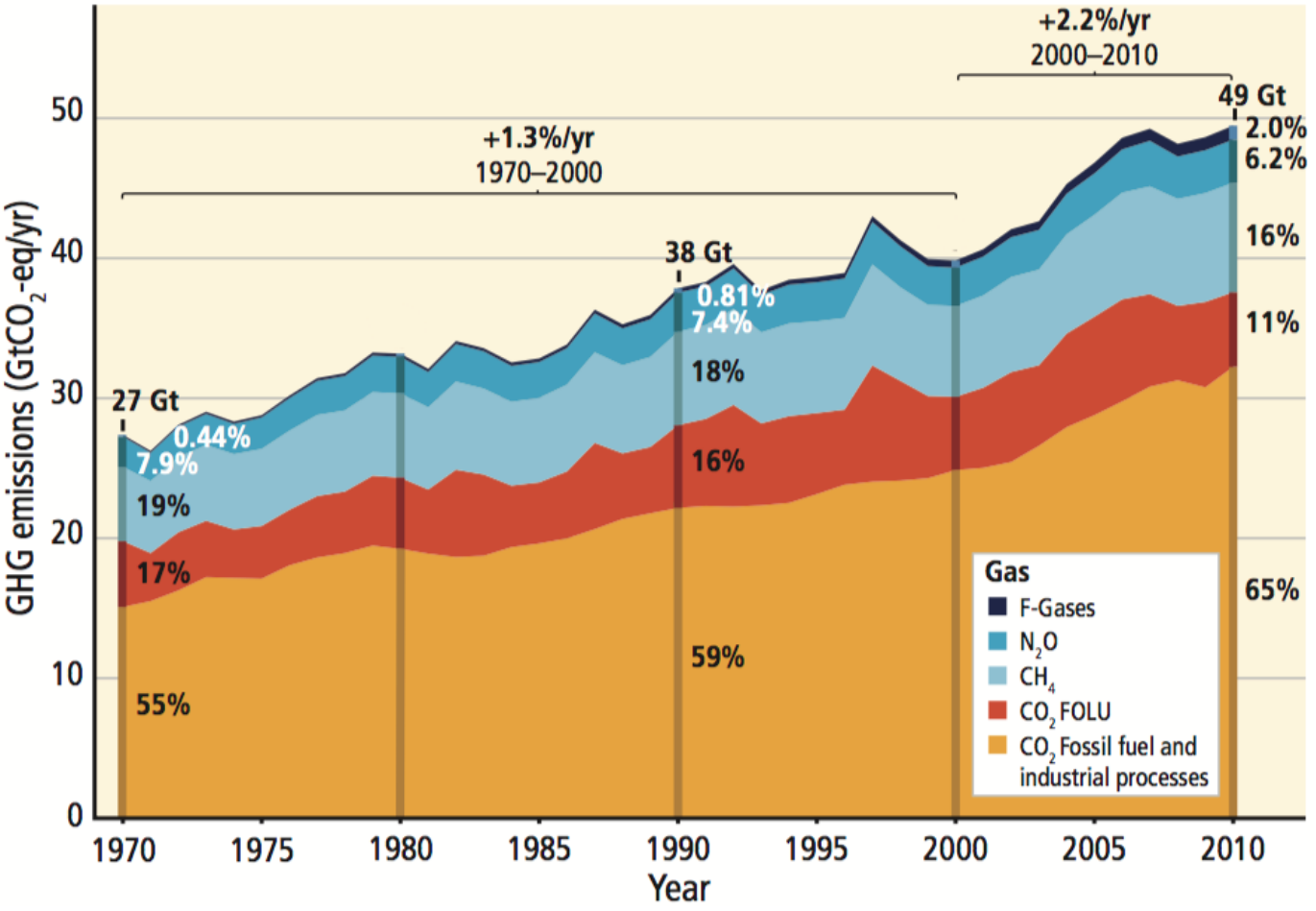
Balance: RF = 0

Greenhouse gases block energy from going back to space

➔ R_o gets smaller

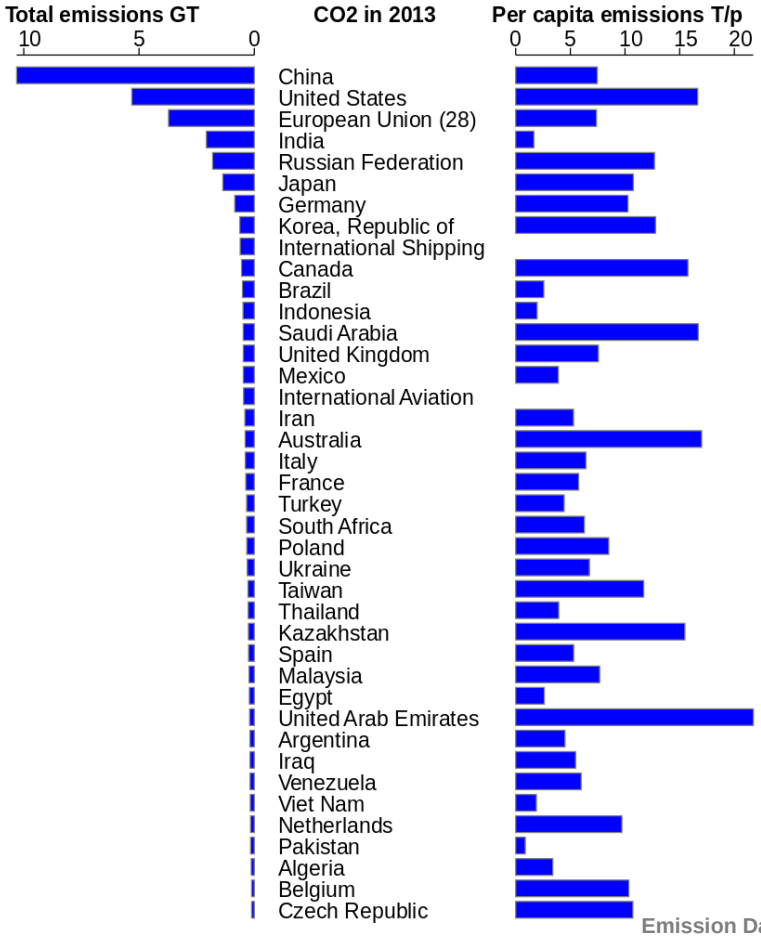
➔ RF not 0 anymore

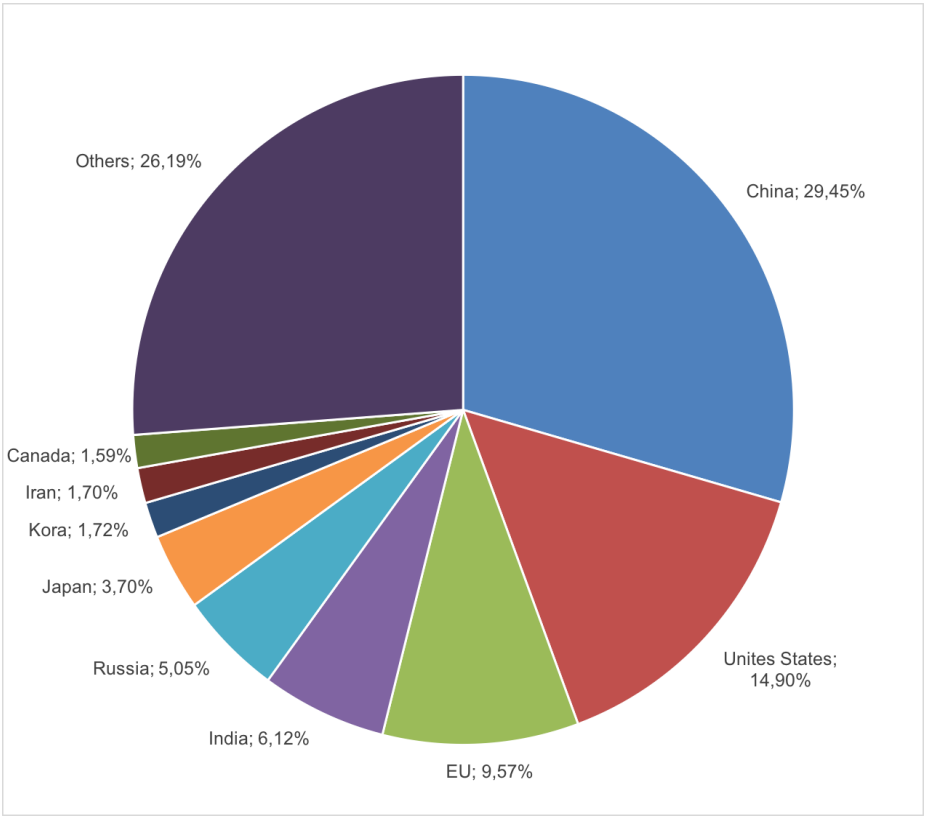
GHG Emissions



Source: IPCC. *Climate Change 2014: Synthesis Report.*

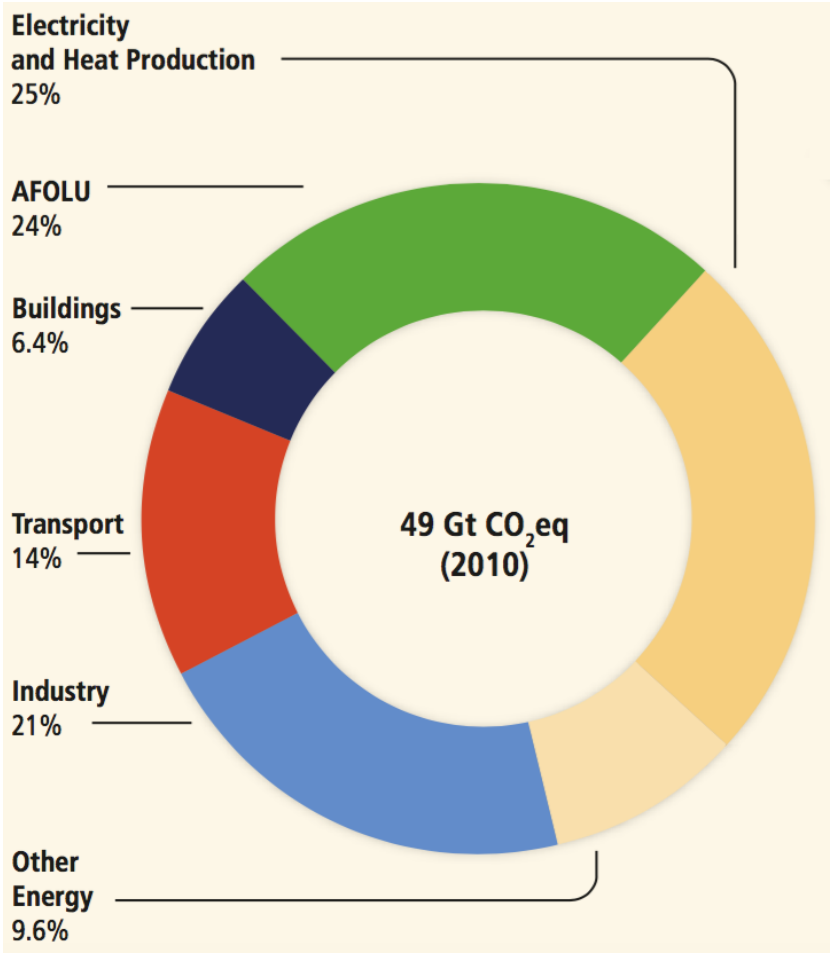
CO_2 Emissions by country





Source: Wikipedia. *List of countries by carbon dioxide emissions.* Emission Database for Global Atmospheric Research (Edgar). *CO2 time series 1990-2014 per region/country*

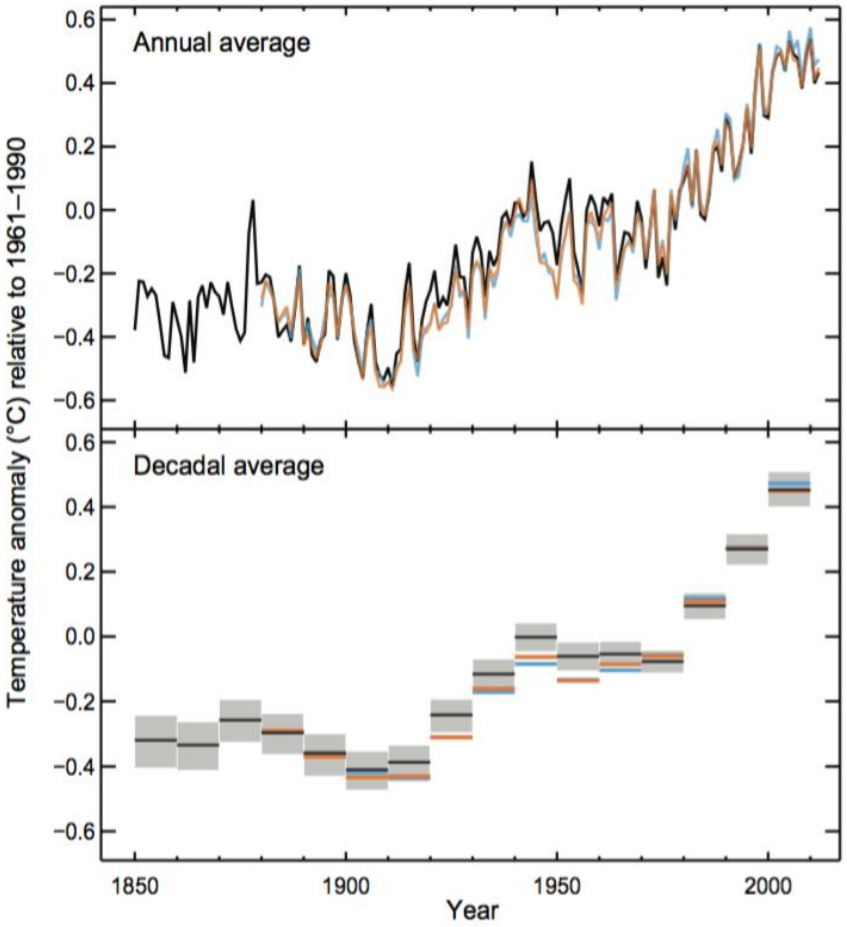
CO_2 Emissions by sector



Source: IPCC. *Climate Change 2014: Mitigation of Climate Change.*

Impacts – Atmosphere

- +0.85°C from 1880 to 2012
- Since 1900 almost every century was warmer than the preceding century
- Number of cold days and nights decreased
- Number of warm days and nights increased
- More heatwaves
- Heavy precipitation events increased

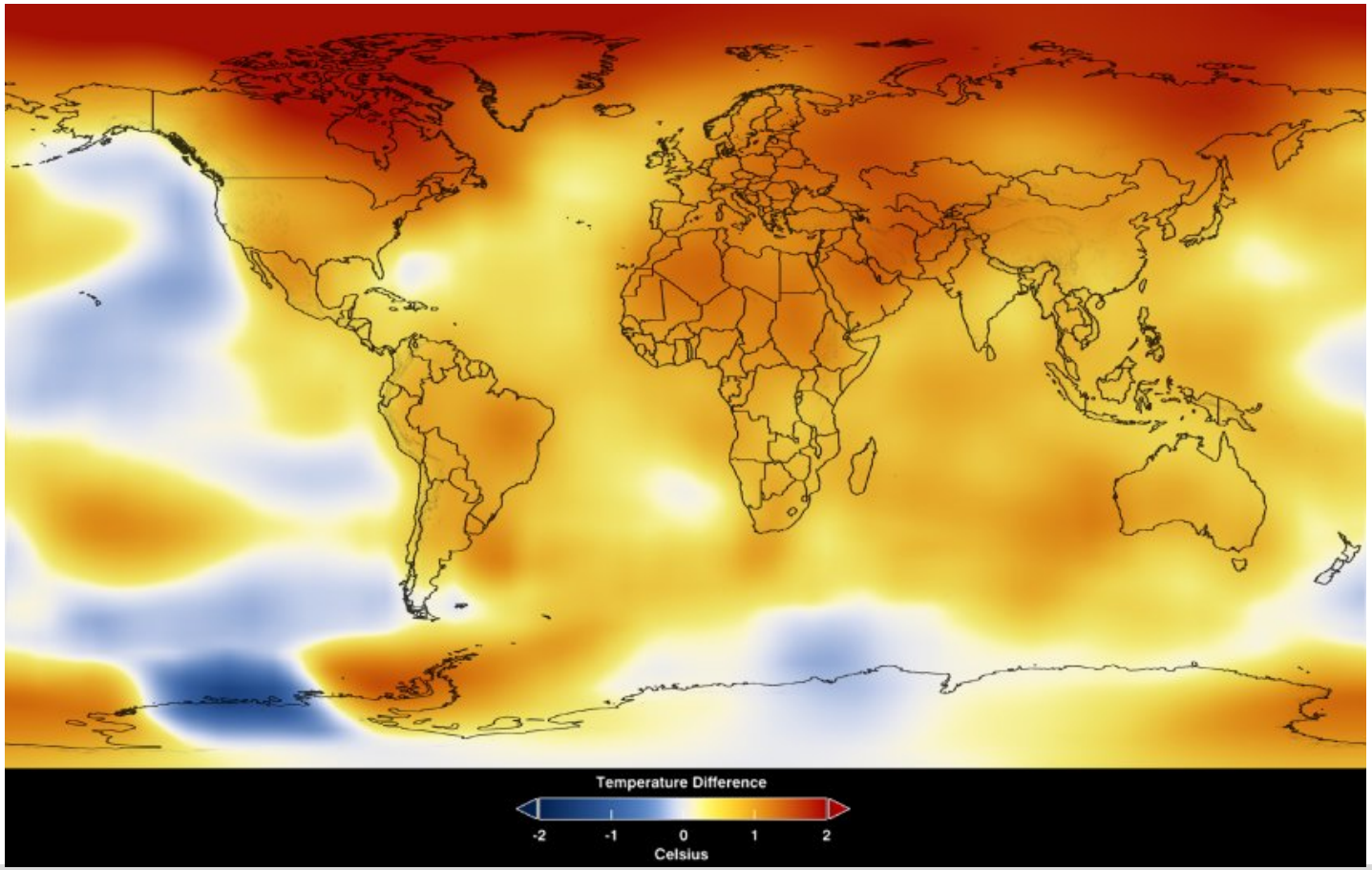


Source: IPCC. *Climate Change 2013: The Physical Science Basis.*

Impacts – Atmosphere

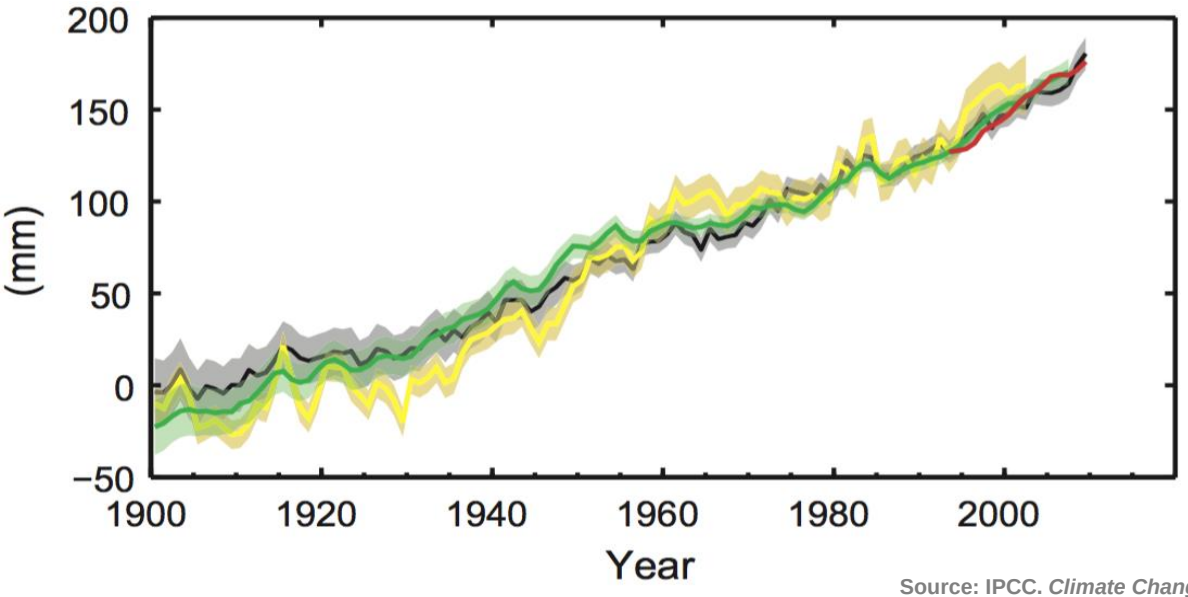
Earth‘s surface temperature (2008-2012)

Orange and red: average yearly temperature higher than long-time average



Impacts – Ocean temperature and sea level

- Ocean warming near the surface up by 0.11°C per decade from 1971 to 2010
- Sea level rose by 190mm from 1901 to 2010



Source: IPCC. *Climate Change 2013: The Physical Science Basis.*

Impacts – Ocean temperature and sea level

- Sea level rise
  - Loss of landmass
  - Loss of living space
  - Loss of fishing grounds
  - Loss of agricultural areas
  - Potential change in water quality (e.g. salt contained in the groundwater)

  ➔ Relocation programmes will become necessary
- If all the ice on our planet would melt, sea level rise would be ~70-75m
  - Antarctic: 65m
  - Greenland: 6-7m
  - Others (mountain glaciers): 15-35cm

Impact – Cryosphere

"Cryosphere describes all of the earths surface that is covered in ice, like sea ice, lake ice, river ice, snow cover, glaciers, ice caps, ice sheets, and frozen ground (Permafrost)."

- Glaciers lost ~226 GT/yr of ice from 1971 to 2009

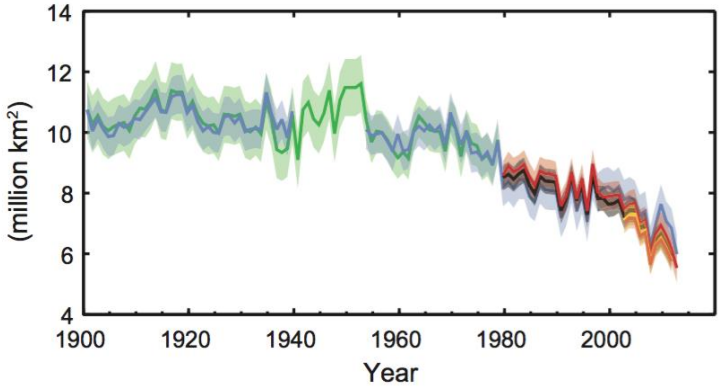
Impact – Cryosphere

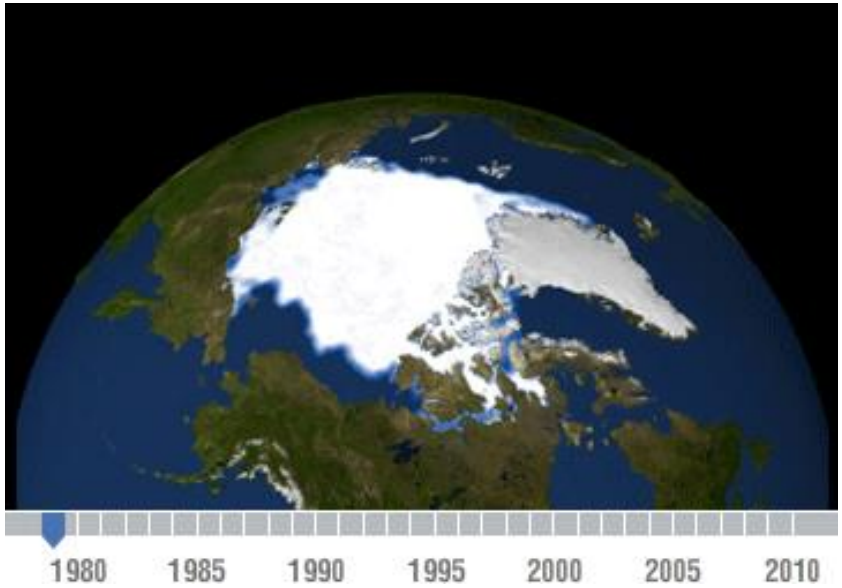
Ice loss in **Arctic**:

- 30 Gt/yr 1992–2001
- 147 Gt/yr 2002 to 2011

Area covered in ice decreased from 11 mio km² to about 6 mio km²

Ice loss per year in Antarctic and Greenland: 500 km³





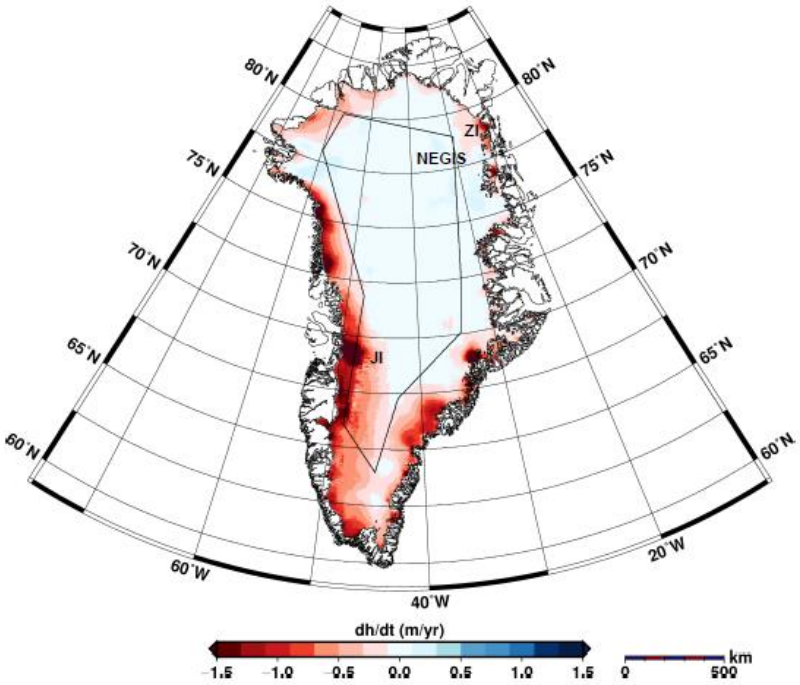
Source: IPCC. *Climate Change 2013: The Physical Science Basis.*
Wikipedia. *Folgen der globalen Erwärmung in der Arktis*

Impact – Cryosphere

Greenland

- Evidence for mass loss of glaciers: the island is “raising” 4cm/a (2000: 0,5 cm/a)
- Covered with ice by 85%
- 7,4 m potential increase in sea levels

Elevation change map

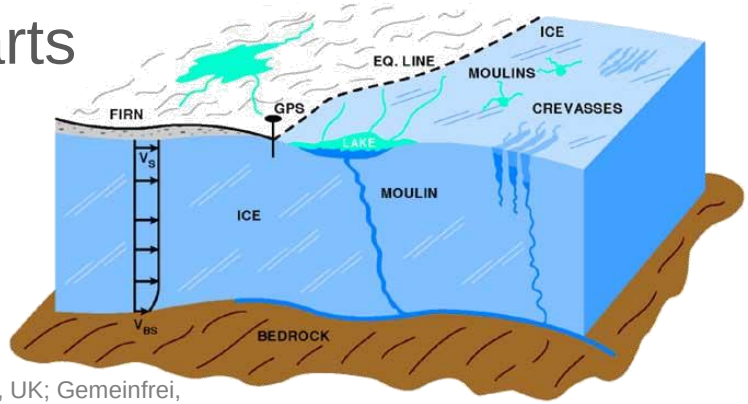


Source: Steffen/Huff (www.heise.de); Helm et al., The Cryoshpere, 2014

Impact – Cryosphere

Greenland

- Meltwater stream flows into a large moulin
- Very common in Greenland
- Ice cannot “release” water – water “presses” ice in two parts

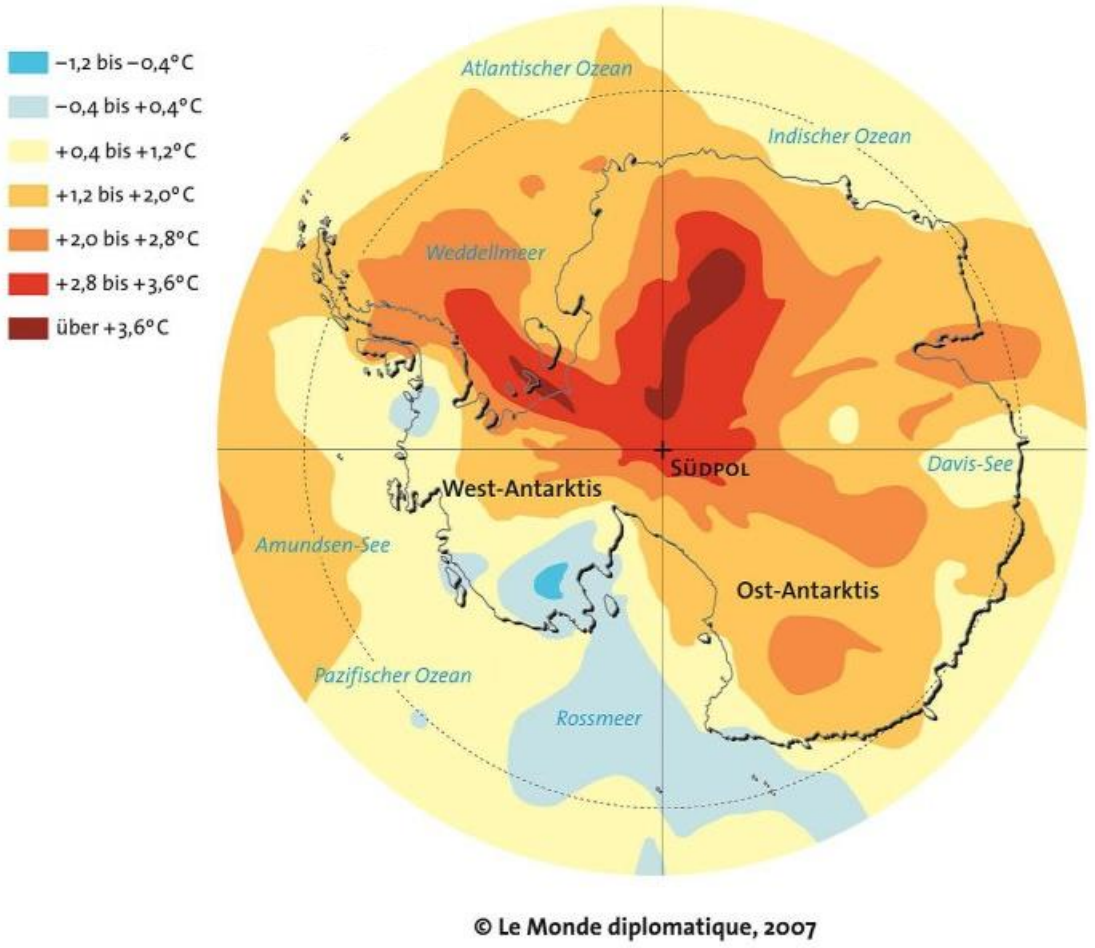


Source: Roger J. Braithwaite, University of Manchester, UK; Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=665512

Impact – Cryosphere

Antarctic

Predicted change in temperature until 2050



Impact – Cryosphere

Antarctic

Ice's thickness up to 5 km

Collapse of the West-Antarctic ice sheet

- Similar size like France
- Min. 1m sea level rise

Elevation change map

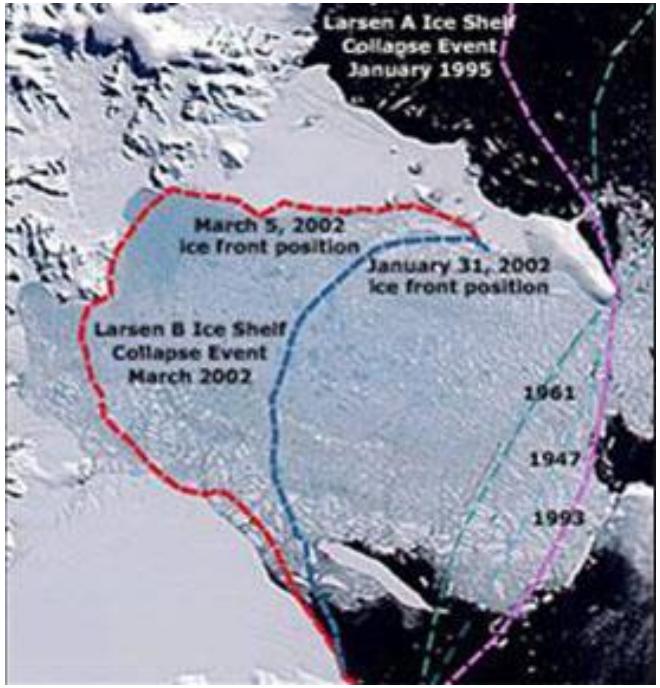
Source: Helm et al., The Cryoshpere, 2014; www.universetoday.com

Impact – Cryosphere

Larsen B ice shelf collapse in Spring 2002

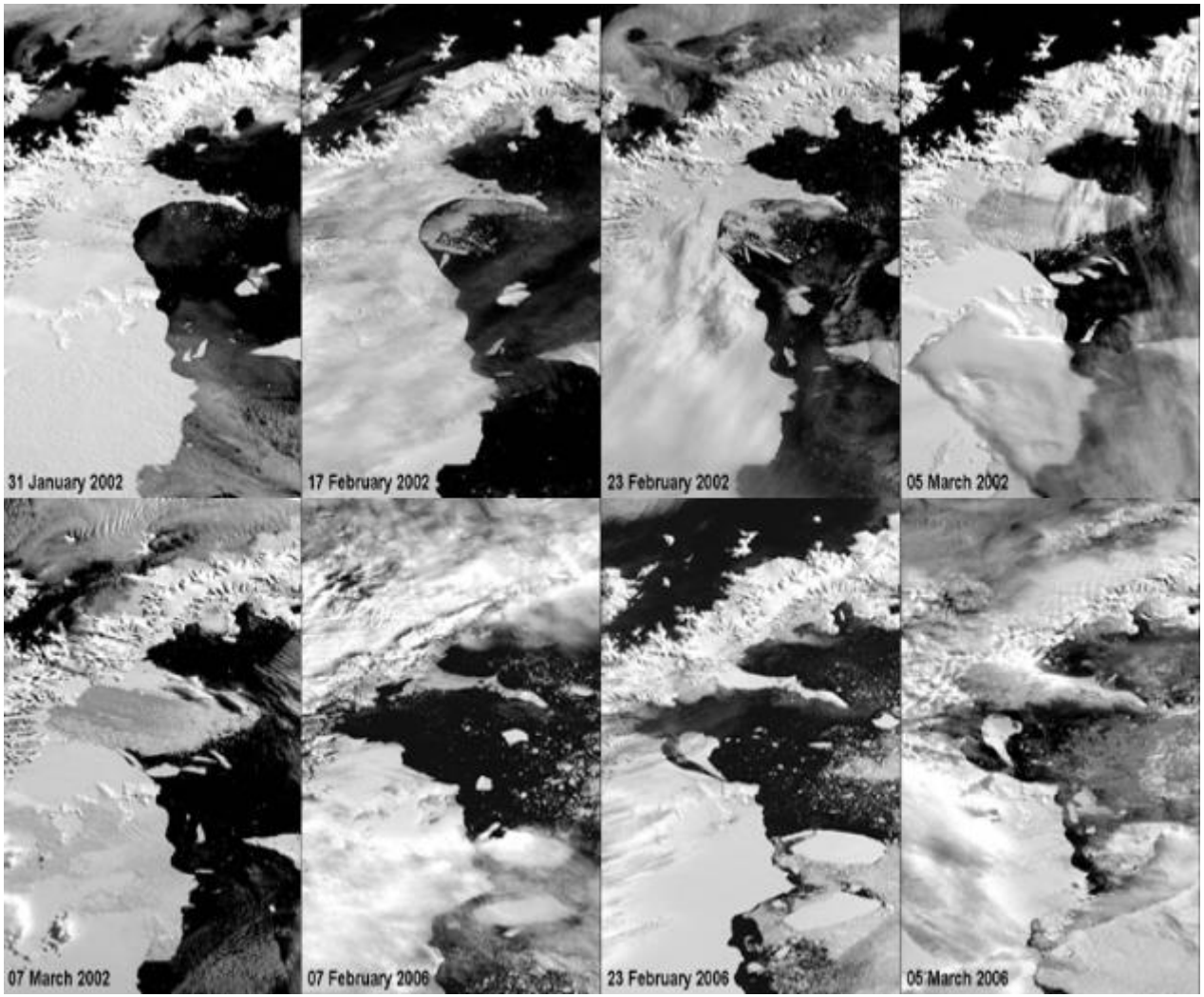
Affected area: 48.600 km²

Ice thickness: ~ 200 m



Source: Ted Scambos, NSIDC;

Impact – Cryosphere: Larson Ice Shelf

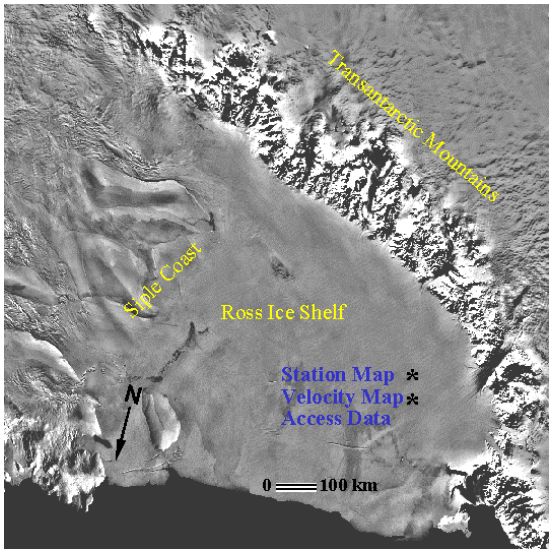


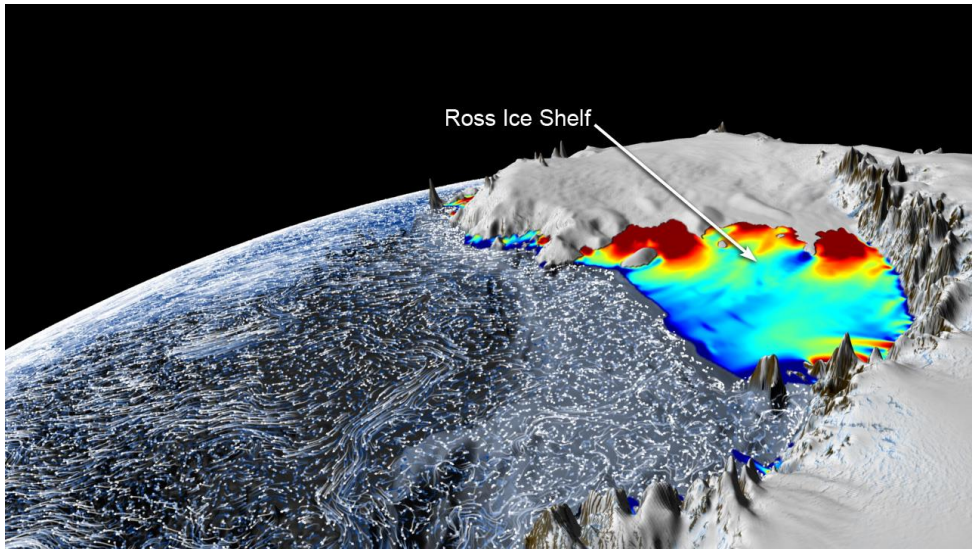
Source: UNEP/GRID Sioux Falls, from NASA MODIS data

Impact – Cryosphere

Antarctic: Ross Ice Shelf

Largest ice shelf in Antarcitc (487.000 km²)



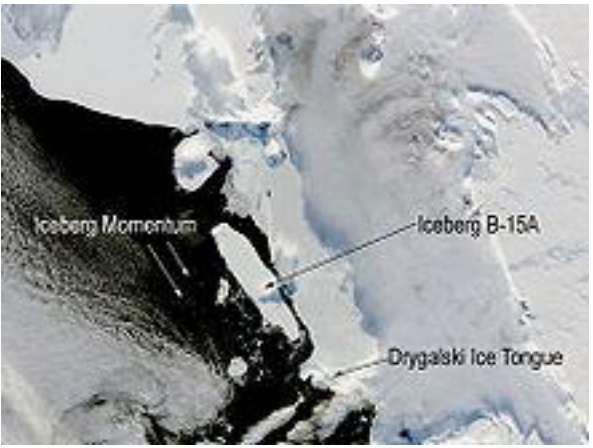


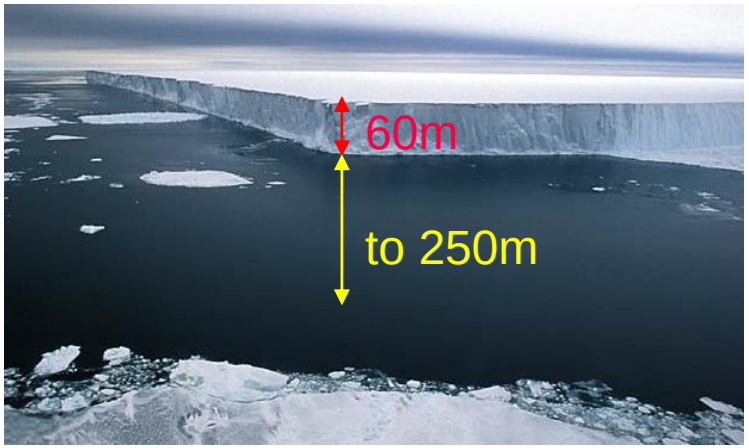
Source: https://nsidc.org/data/velmap/ross_shelf/riggs/riggs.html; http://sites.coloradocollege.edu/csiddoway/rosetta-ice-ross-ice-shelf-project/

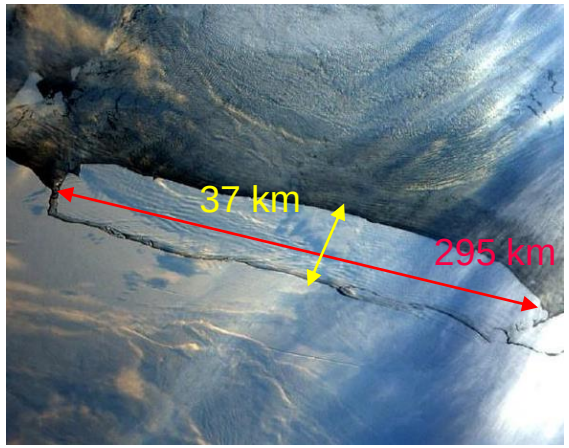
Impact – Cryosphere

Antarctic: Iceberg B 15

- World's largest recorded iceberg (11.000 km²)
- Water content ~ 2.168.250.000.000.000 l (2 billions)
- Could supply Germany 518 years with water
- March 2000







Source: https://nsidc.org/data/velmap/ross_shelf/riggs/riggs.html; http://sites.coloradocollege.edu/csiddoway/rosetta-ice-ross-ice-shelf-project/


B-15A iceberg
in the last years
15/03/2006
13/02/2006
12/29/2005
B-15A fragmentation
04/11/2005
27/10/2005
11/10/2005
16/09/2005
25/07/2005
15/05/2005
15/04/2005
Impact with
Drygalski ice tongue
18/07/2002
15/02/2005
2/02/2004
B-15 iceberg
Victoria land
Ross sea
Ross ice shelf
0
200 Kilometers

Impact – Cryosphere

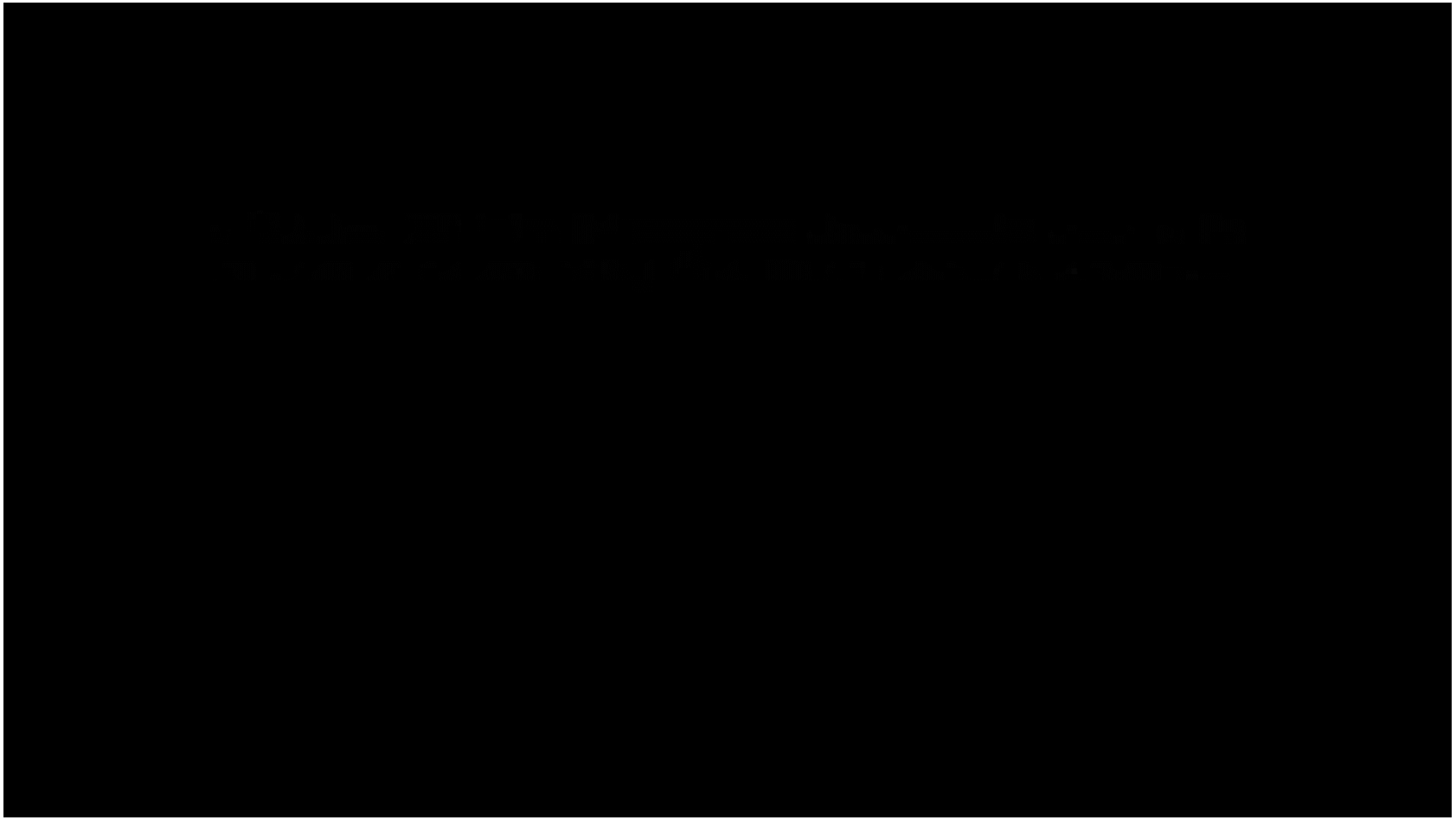
Antarctic: Iceberg B 31

- 660 km²
- Highest elevation: 500m
- Origin: Pine Island Glacier (water loss: 100 bio t/d)
- Crack in the glacier found in October 2011, separated in July 2012

Source: AFP, NASA

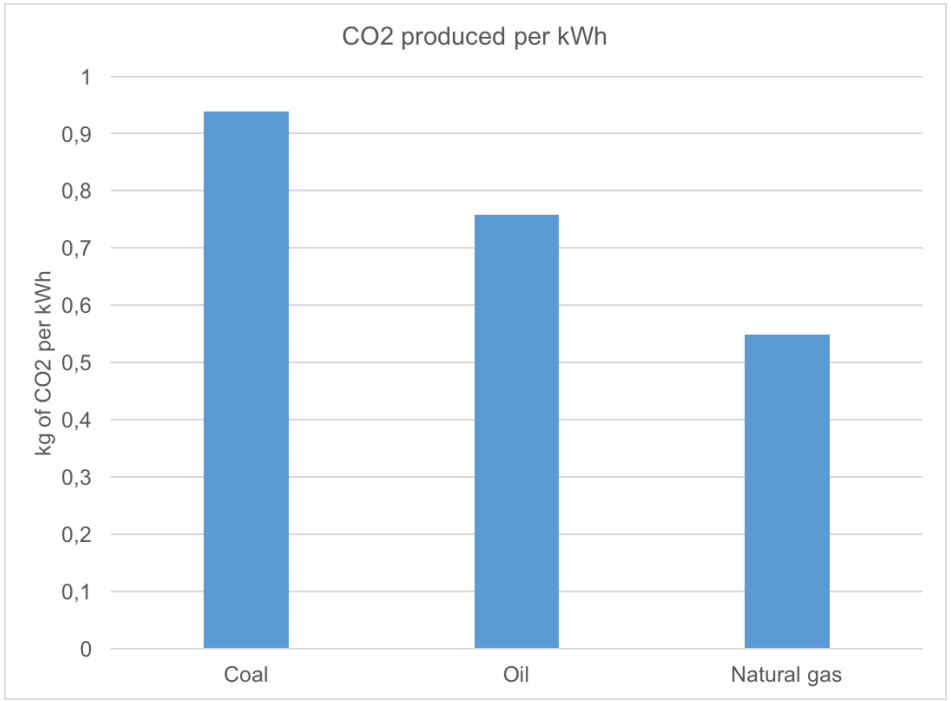
Impact – Cryosphere

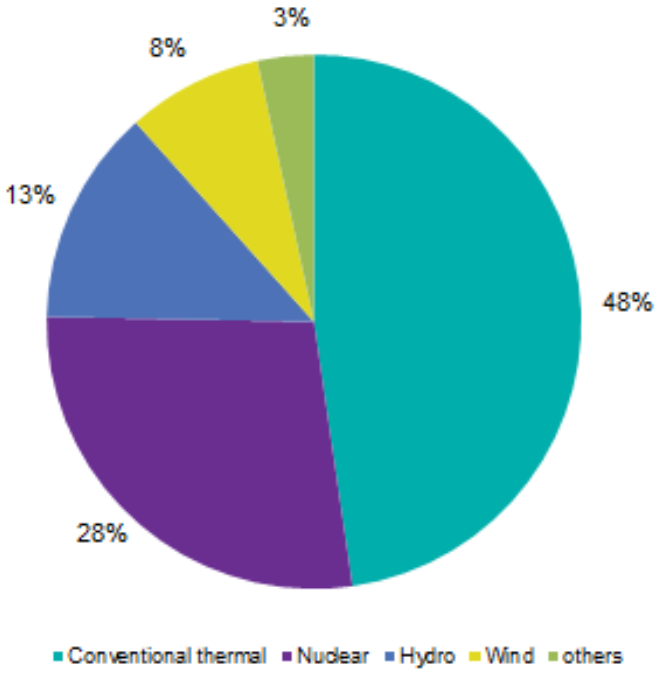
Antarctic: Iceberg B 31



Source: NASA Earth Observatory

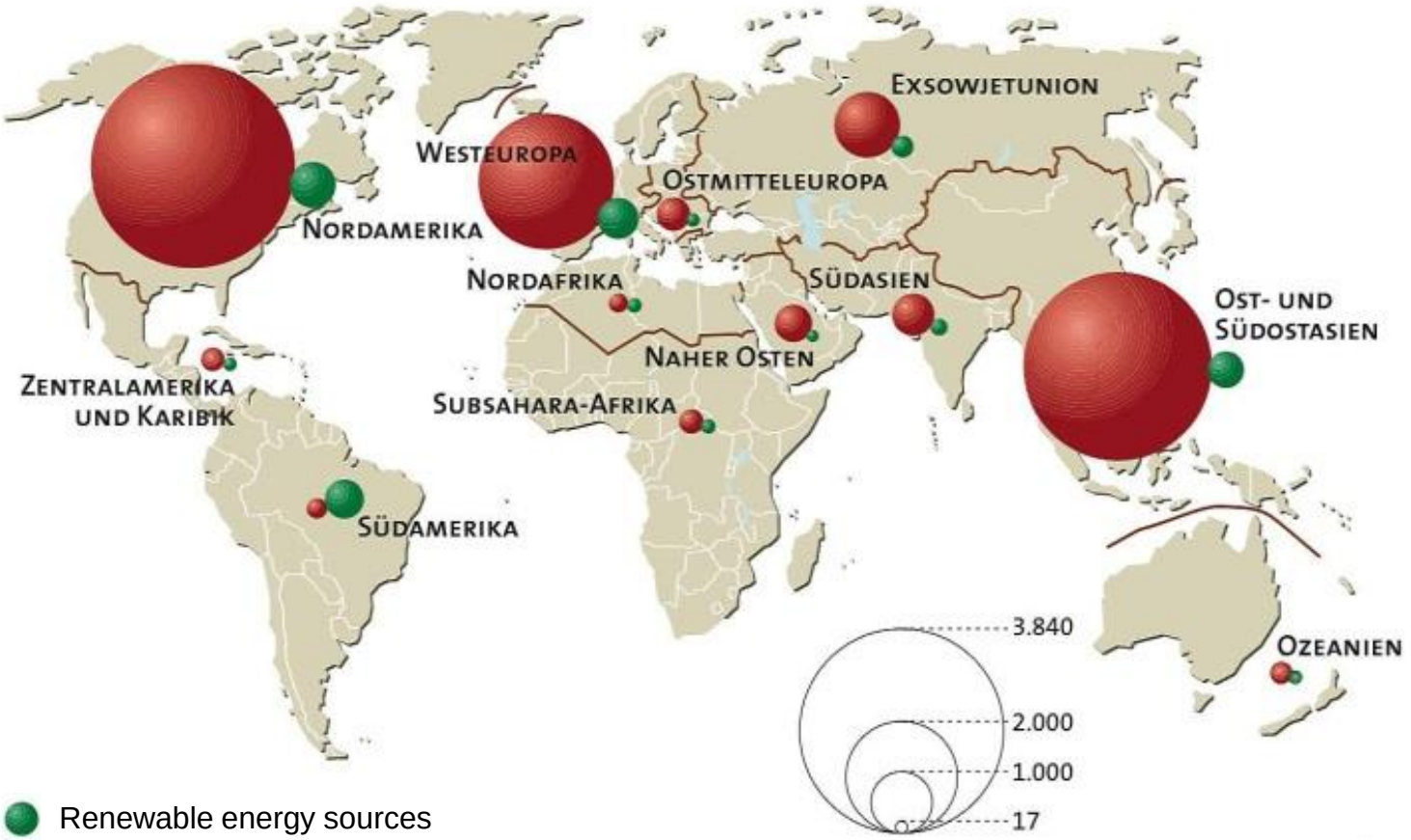
Emissions from the electricity sector





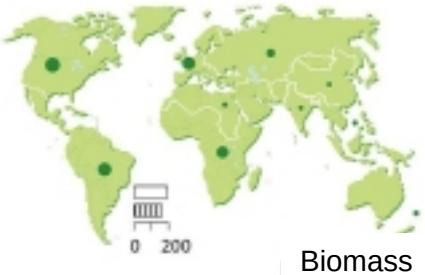
Source: EIA. *How much carbon dioxide is produced per kilowatthour when generating electricity with fossil fuels?*
Eurostat. *Electricity production and supply statistics*

Power generation: Comparison

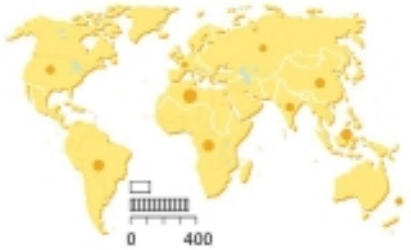


Renewable energy sources in 2020

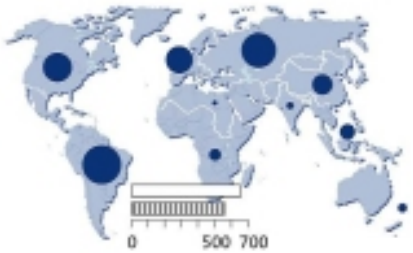
Wind energy



Biomass

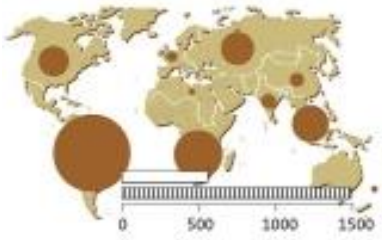


Solar energy

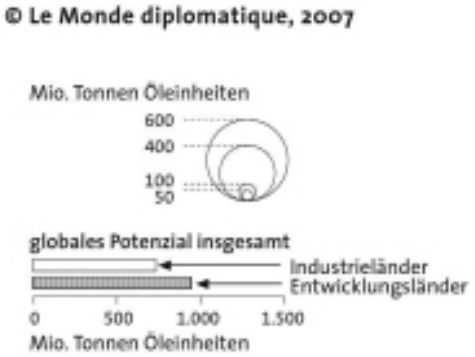


Hydropower

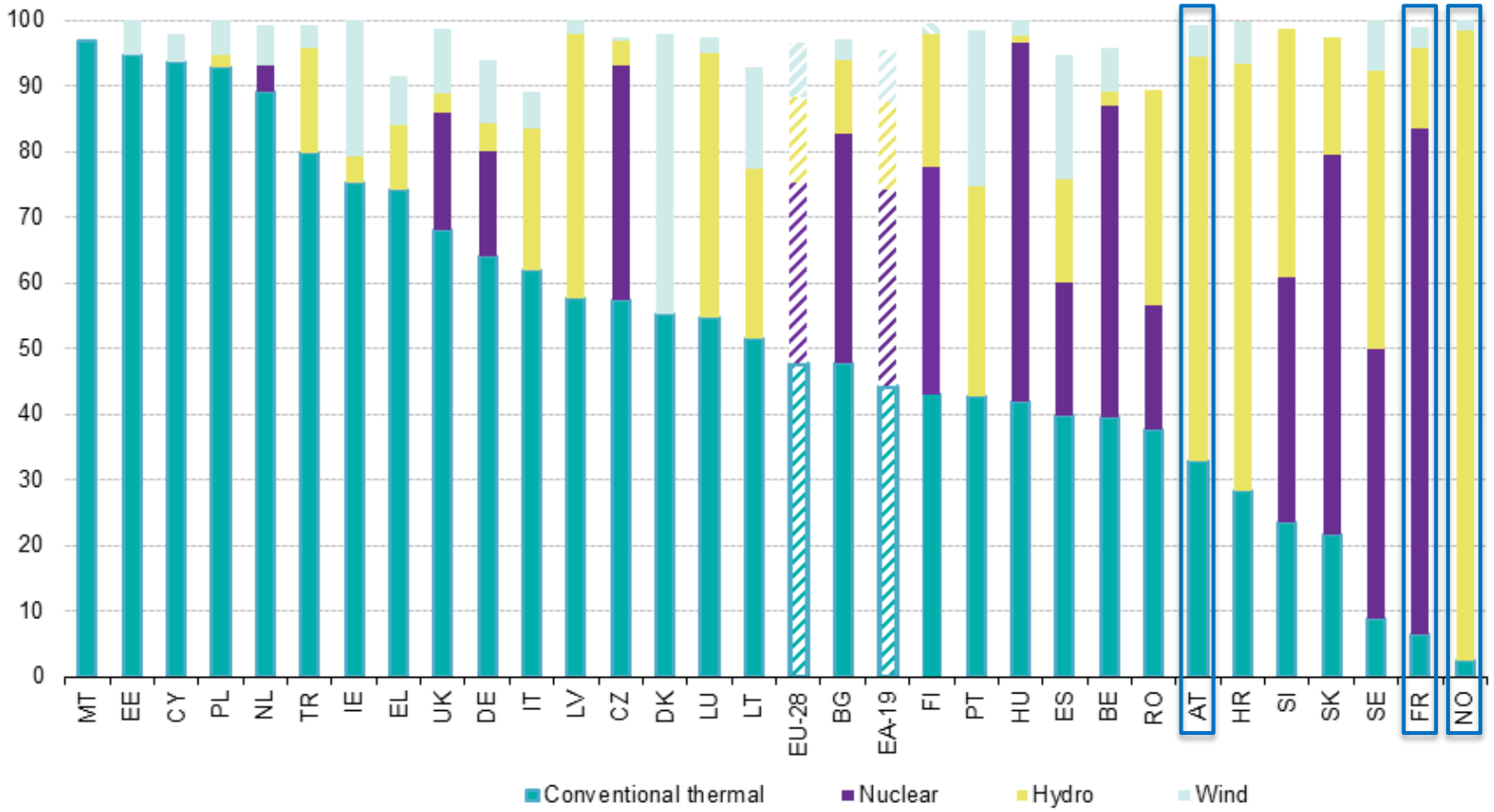
Waste incineration



Wood energy

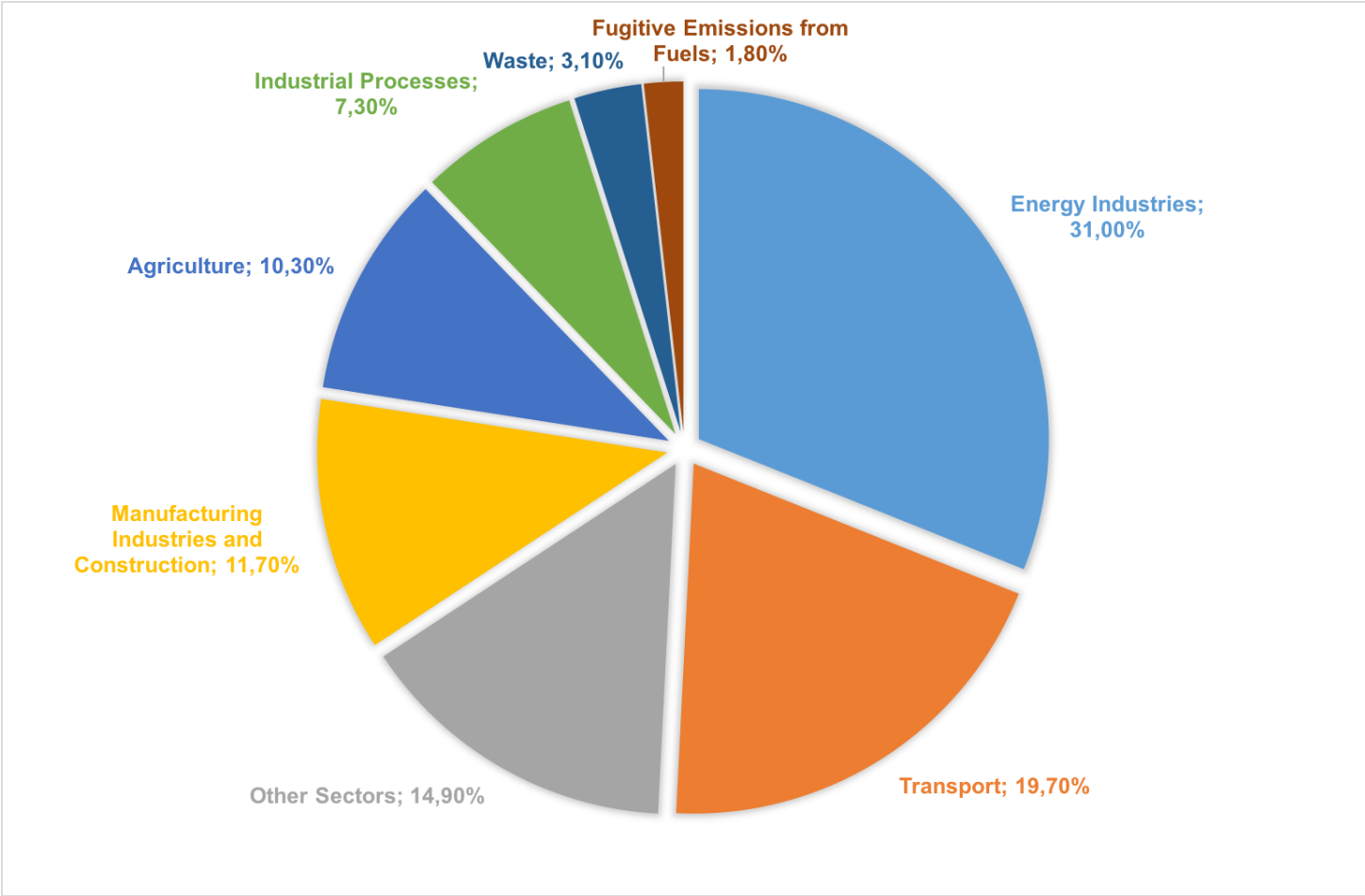


Electricity production



Source: Eurostat. *Electricity production and supply statistics*

GHG emissions



Source: EIA. *Total greenhouse gas (GHG) emission trends and projections*

Climate targets

EU 2020 goals

- lower GHG emissions by 20% compared to 1990
- 20% share of renewable energy, 20% increase in efficiency

EU 2030 goals

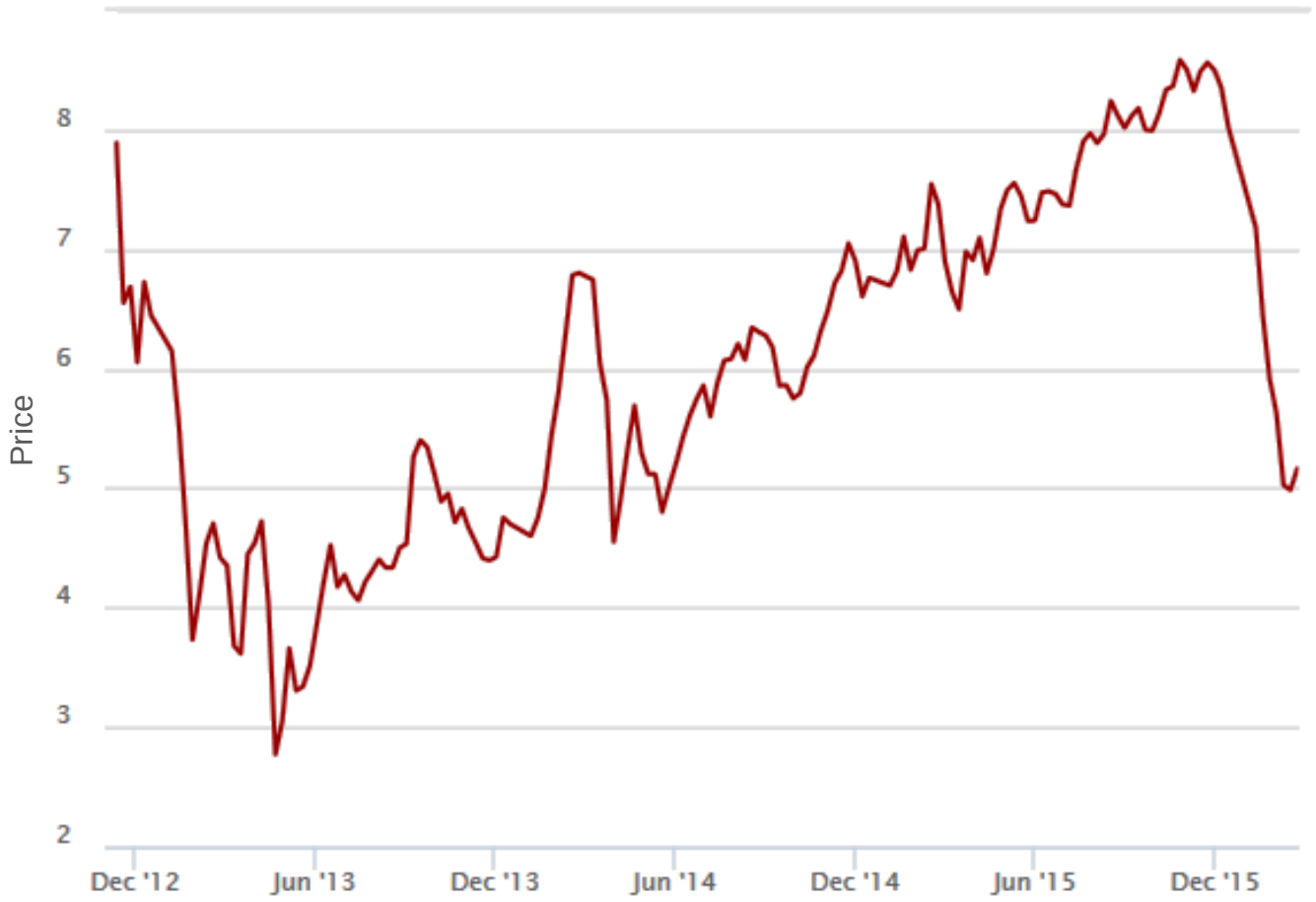
- lower GHG emissions by 40% compared to 1990
- 27% share of renewable energy, 27% increase in efficiency

2°C target

- Limiting global warming to 2°C above the pre-industrial level
- In 2010 all 194 member states of UNFCCC commit to reach this goal
- To reach the target: Between 2045 and 2060 GHG emissions have to be zero!
- COP 21 (Paris 2015): limit global warming preferably to 1,5°C

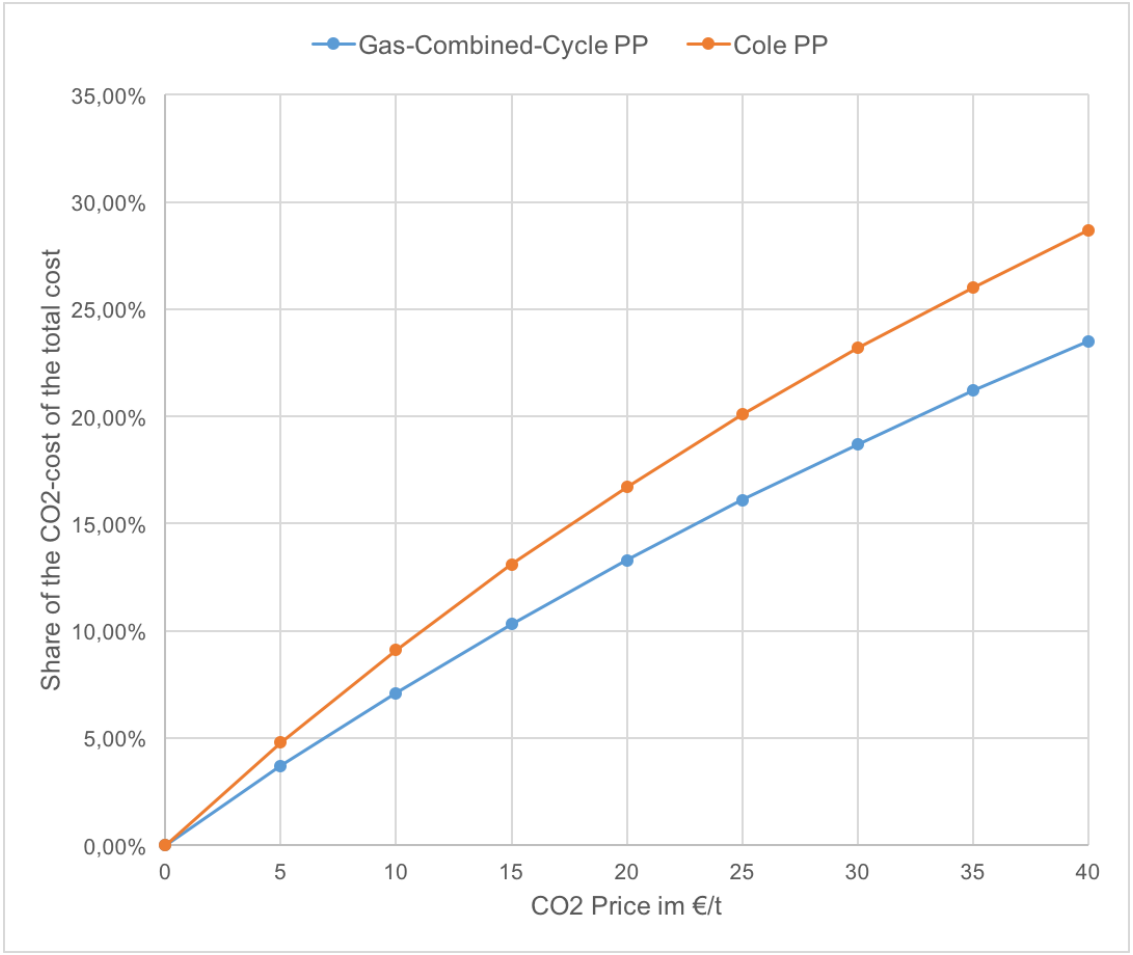
Emission Trading Scheme

23.02.2016
€ 5,14



Source: EEX. *European Emission Allowances Auction (EUA)* https://www.eex.com/de/marktdaten/umweltprodukte/auktionsmarkt/european-emission-allowances-auction--eua---global-environmental-exchange/64312#!/2016/02/23

Emission Trading Scheme

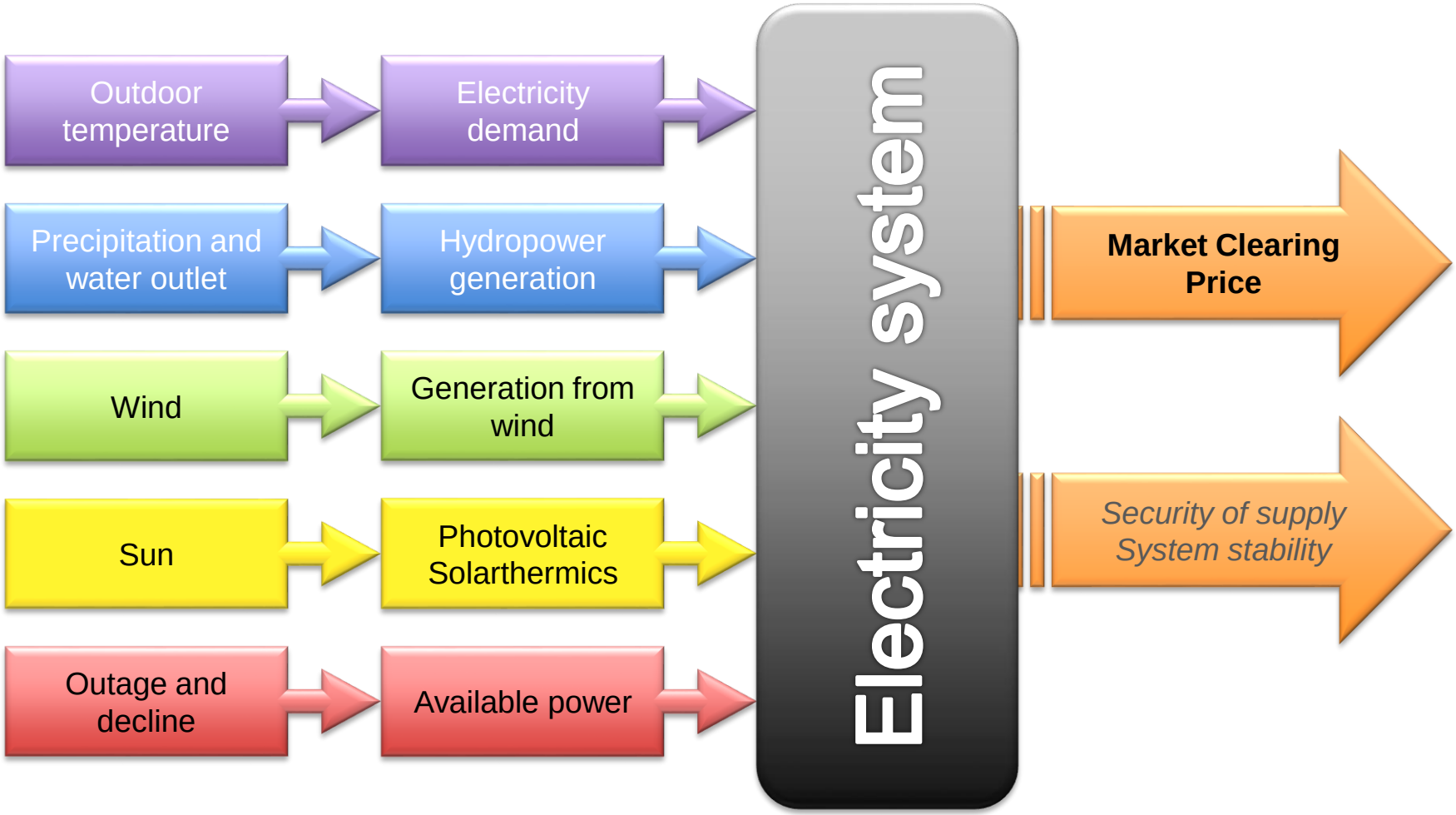


Impact on electricity sector

Is the electricity sector influenced by the weather or the climate?

- Right answer: **Both!**
  - **Weather** influences day-to-day operations
  - **Climate** influences planning (long and medium term)

Influencing factors and fluctuation

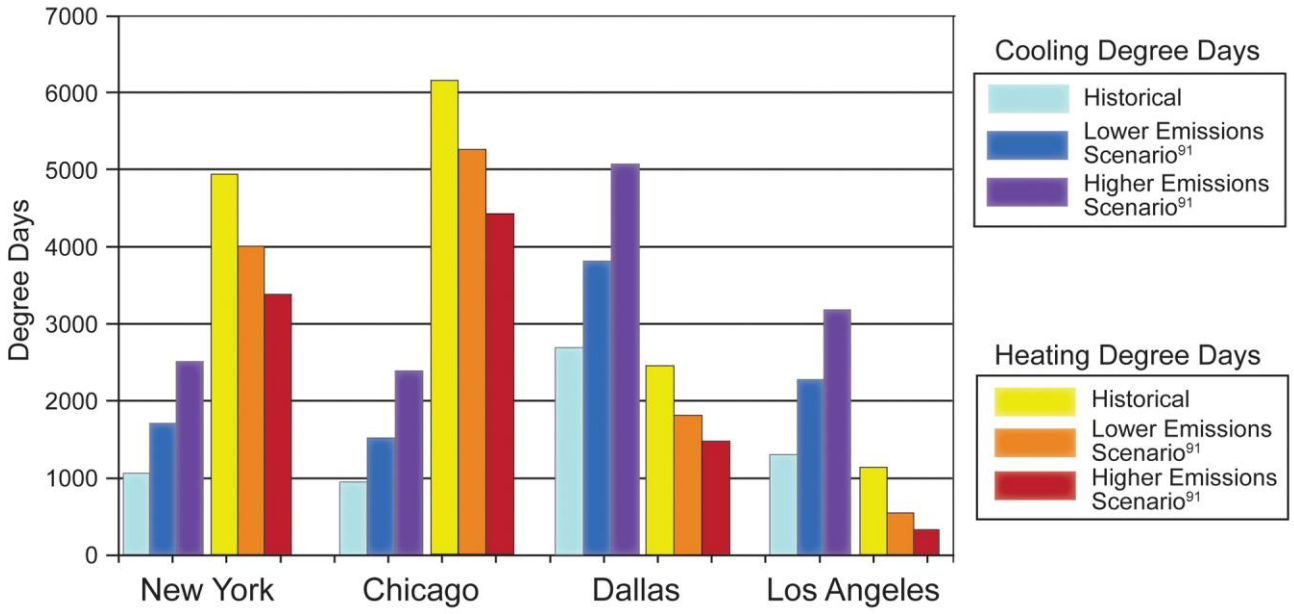


Impact on electricity sector – Energy Demand

- Warmer summers ➔ higher energy demand for cooling
  - Predicted to increase from 300 TWh in 2000 to 4000 TWh in 2050
  - Most growth because of higher income in emerging market countries, only small growth because of Climate Change
  - Summer peak electricity demand increases

- Warmer winters ➔ reduce space heating demand
  - Less wood, oil, gas for heating

Impact on electricity sector – Energy Demand



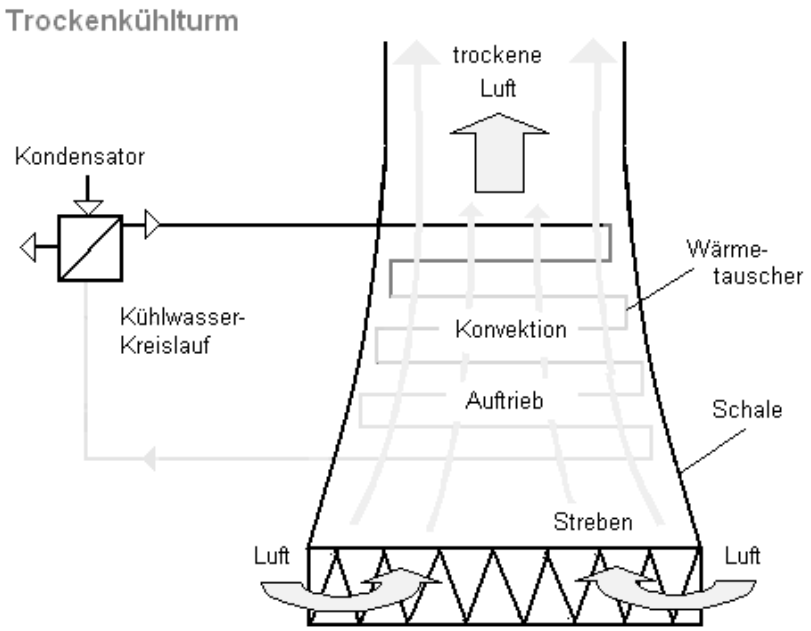
Source: EPA. *Climate Impacts on Energy*

Effects on Electricity Infrastructure

Thermal power plants

- Higher ambient temperatures
  - Efficiency of thermal conversion decreases
  - Cooling towers less effective
- Decreasing volumes of water & higher water temperatures
  - Water cooling less effective

➔ Reduced power output or temporary shutdowns



Source: Wikipedia. *Kühlturm*

Effects on Electricity Infrastructure

Hydro power plants

Problems run-off-river HPP:

- Changing rain patterns
- Higher Temperature ➔ more evaporation

Problems hydro storage PP:

- Fill up during summer from meltwater of glaciers
- What happens if glaciers melt away?

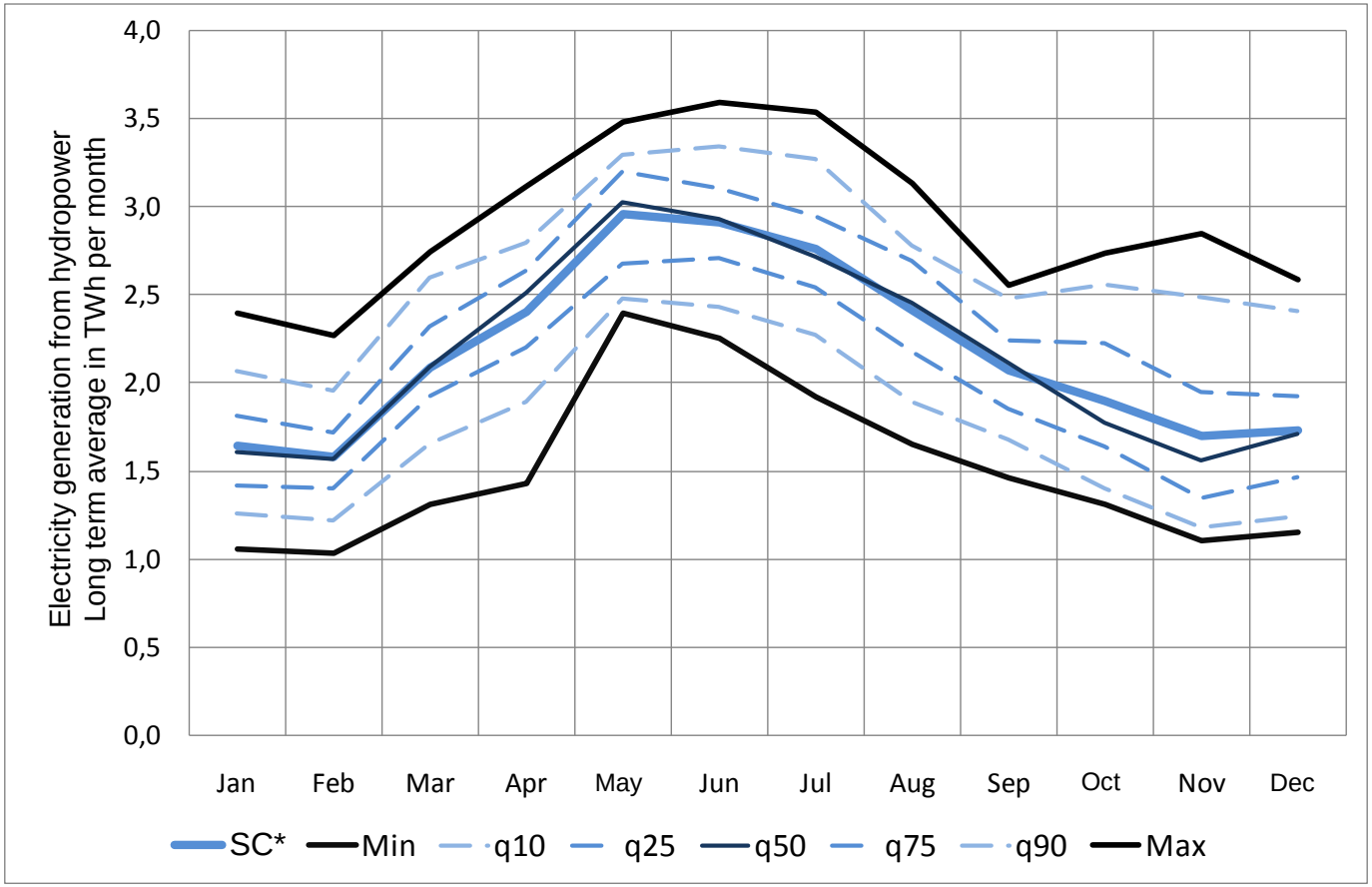
Source: Michael Puttinger. *Exkursion Kaprun*

Effects on Electricity Infrastructure

Run-off-river power plant

Run-off-river power plants in AT

Average electricity generation from run-of-river power plants in Austria (1976-2006)



* = Standard capacity

Source: eHyd (BMLFUW)

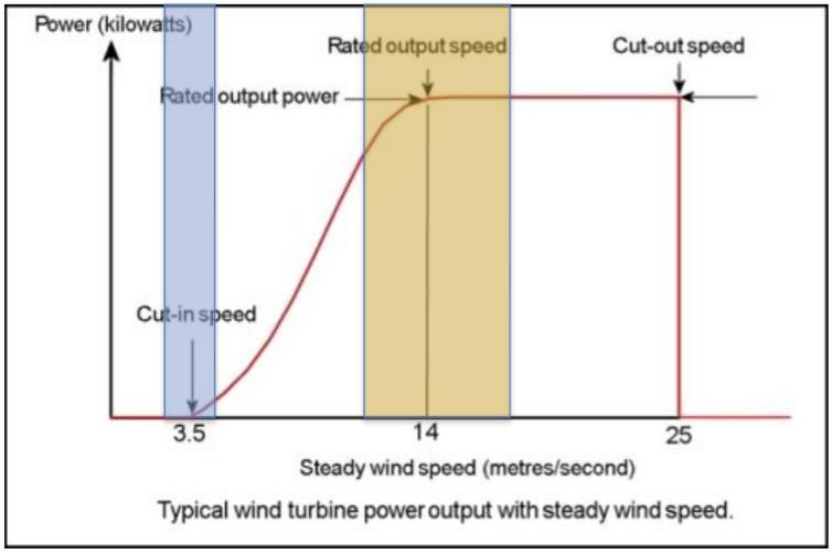
Effects on Electricity Infrastructure – Wind Power Plants

Wind power plants

Increasing number of storms:

- Wind turbines have to be slowed down to prevent damages

- Otherwise…



Typical wind turbine power output with steady wind speed.

Source: Erneuerbare Energien in der Praxis (VU). *tut_karthikbhat_Wind_Energy_1.pdf*

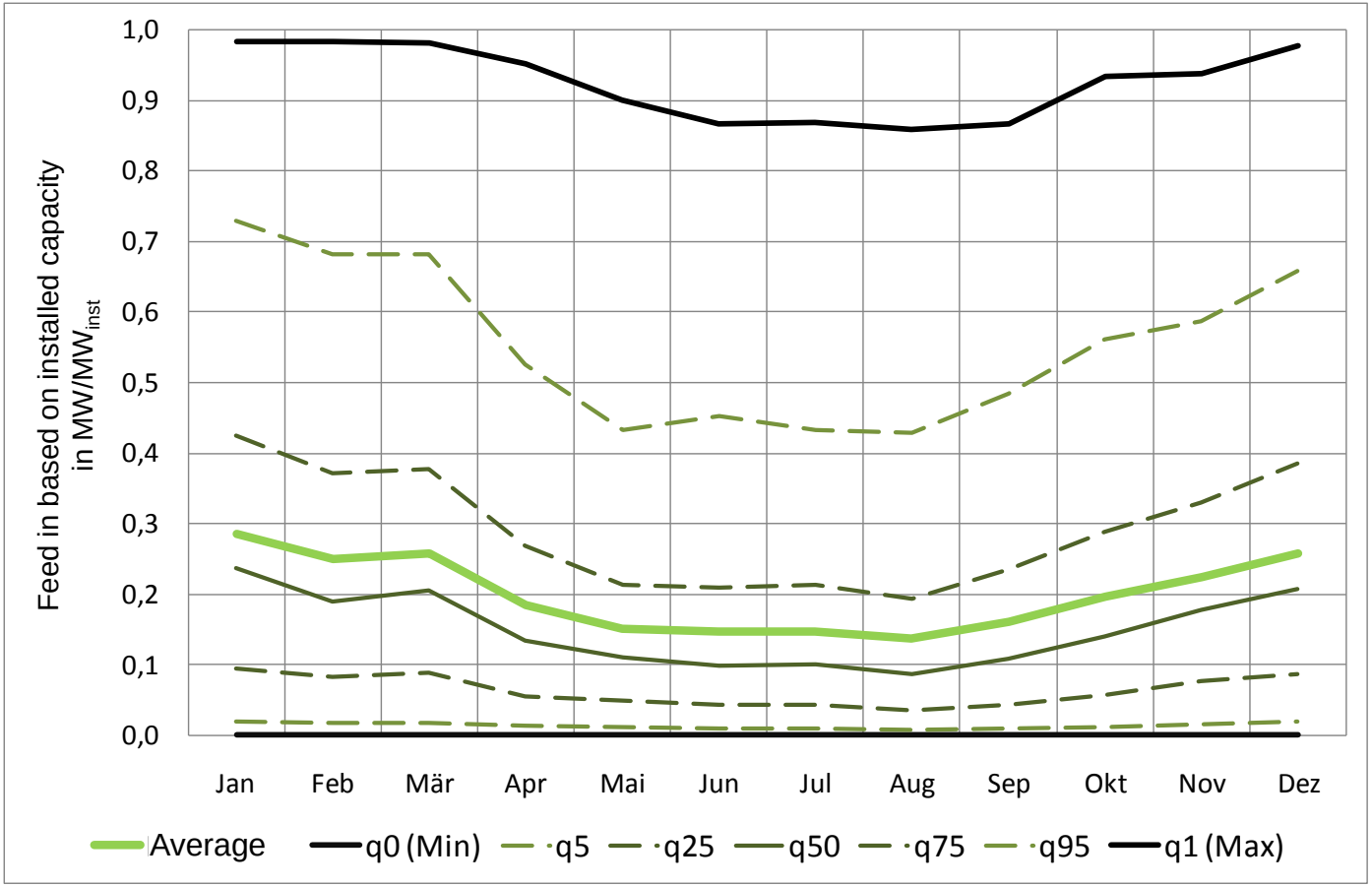
Effects on Electricity Infrastructure

Wind power plants

Source: Youtube

Wind power in Germany

Average wind power generation in Germany (1978-2008)



Source: DWD

Effects on Electricity Infrastructure

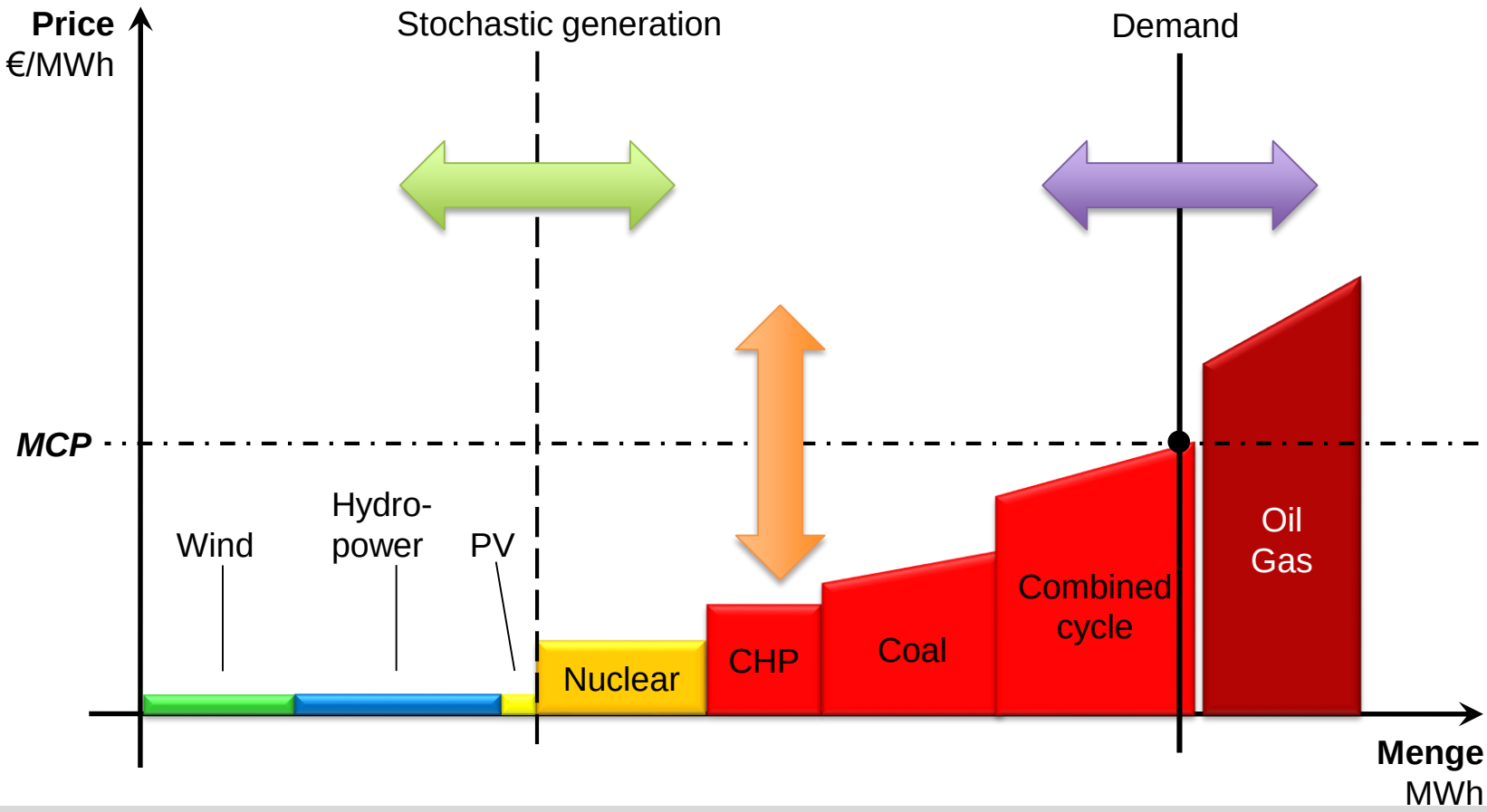
Photovoltaic:

Increase of cloudiness could lead to less electricity production from PV

Nuclear PP:

More extreme weather events (floods) could destroy infrastructure needed to cool down nuclear material (Fukushima)

Influence on MCP



Conclusion

- Energy sector is biggest contributor to GHG emissions
- More energy from RES and CO_2-Capture and Storage Systems (CCS) should be considered
- If Energy sector doesn't change:
  - Climate change will have big impact and it will cost lots of money
- If Energy sector changes:
  - Big investments needed in the near future

Thank you for your attention!

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