Nuclear power to tackle climate change?

The global climate impacts of the anthropogenic heat flux

The consumption of primary energy from sources such as fossil or nuclear fuels and the consequent **dissipation** to heat induces a direct climate warming, the so called **anthropogenic heat flux (AHF) forcing**. Here, we investigate the potential future **global temperature change** due to this anthropogenic heat flux in climate models, in particular, for a civilisation with the desire for **continued growth** based on **nuclear power**.

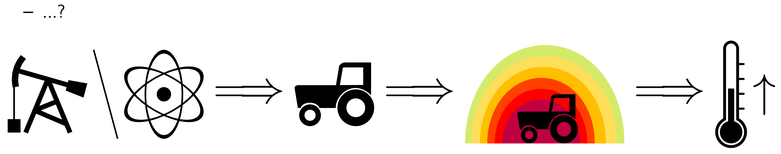
Peter Steiglechner[1,2], Maria A. Martin[1], Georg Feulner[1]

Contact: peter.steiglechner@gmail.com

[1]Potsdam Institute for Climate Impact Research, Potsdam, Germany
[2]Institute of Physics and Astronomy, Potsdam University, Potsdam, Germany

Anthropogenic Heat Flux (AHF) – A Direct Climate Forcing

- Conversion and **consumption** of primary energy by the human civilisation → eventuall, nearly all energy **dissipates to waste heat** (cf. second law of thermodynamics).
- On local scales: Waste Heat → 'Urban Heat Island effect'.
- If primary energy comes from **external sources** → **additional** energy is emitted to the natural balance → **anthropogenic heat flux (AHF)** ≙ **climate forcing**.
- This additional energy can be ...
  - Nuclear Power,
  - Fossil Fuel Energy
  - Geothermal Energy (partially)
  - Solar Energy (partially, e.g. if the solar panels decrease the local albedo)
  - ...?



- Currently relevant on a global scale?

$$\text{AHF} \approx 0.034\,\text{W/m}^2 \quad (\sim 2\%\text{ of the forcing from } CO_2) \quad \Longrightarrow \quad \Delta T \approx 0.01\,\text{K}. \quad \text{Global Mean Temperature Change}$$

- However, an increasing number of studies investigates continental to global impacts of the AHF under certain growth scenarios (e.g. Flanner, 2009, and Chaisson, 2008).

The Problem: Exponential Growth of the AHF

The Past

- **Exponential growth** of worldwide energy production (and AHF): $\sim 2\%/yr$.

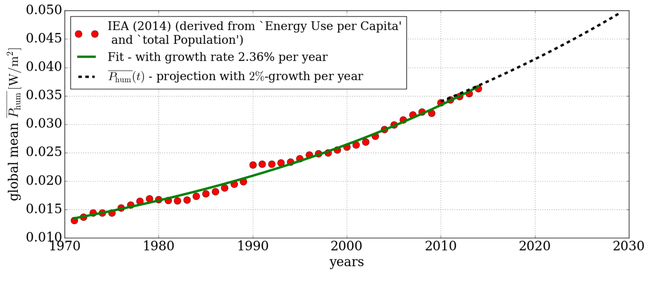


Fig. 1: Global mean energy production and, hence, AHF (given by P_{hum}) over the past decades (IEA, 2014) and a projection with a 2%-growth rate.

Future Projections

- Possible drivers for further **continuation** of the observed growth are:
  - Growth of **population**, **economy/prosperity** and energy-intensive **technology** (e.g. Bitcoin),
  - **Inertia** of the economic system (Garrett, 2014),
  - Possible use of **fusion power** for carbon-neutral electricity generation in the future.

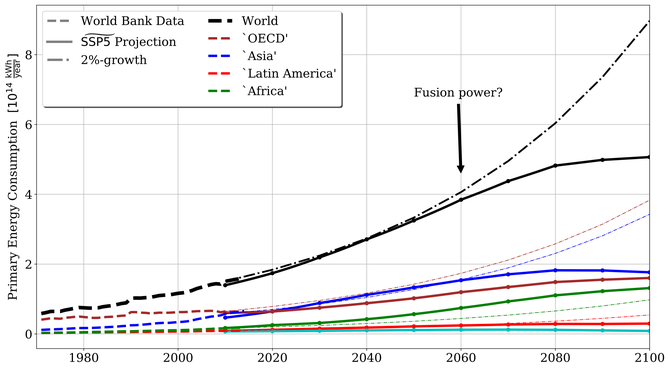


Fig. 2: Primary Energy Production over time for different world regions. Future projections are (1) a simple 2%-growth per year in all regions (dotted) and (2) the energy production data from the SSP5-baseline scenario (solid) (Kriegler et al., 2017) from the Shared Socio-economic Pathway framework.

The Resulting Forcing

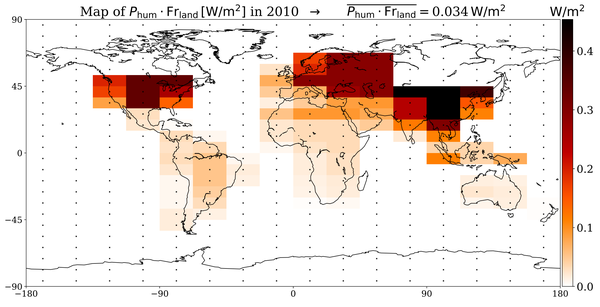


Fig. 3: Heterogeneous AHF forcing P_{hum} in W/m^2 at the surface layer of the atmosphere according to the energy production data from IEA (2014) weighted by the land fraction Fr_{land} of each cell.
Assumption: All Primary Energy Production contributes to the AHF.

The AHF in an Earth System Model of Intermediate Complexity

CLIMBER-3α: Earth System model that combines a general circulation ocean model with a dynamic sea-ice module and a statistical-dynamical atmosphere (Montoya et al., 2005).

- **Temperature Change:** Strongly **localised temperature responses**. But, significantly **amplified ΔT in the Arctic**.
- **Relevant Feedbacks:** Positive **Ice-Albedo Feedback** and negative **Ocean Heat Uptake**. → roughly cancel each other.

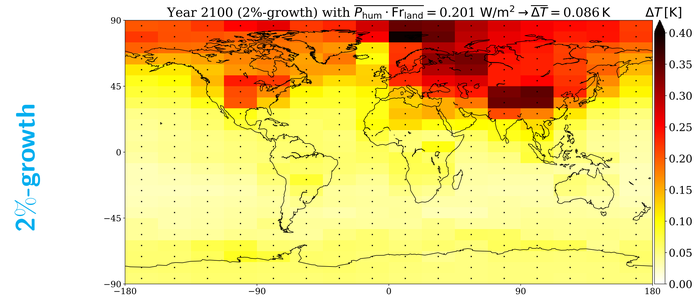


Fig. 4: Corresponding temperature change in 2100 (with constant 2%-growth per year).

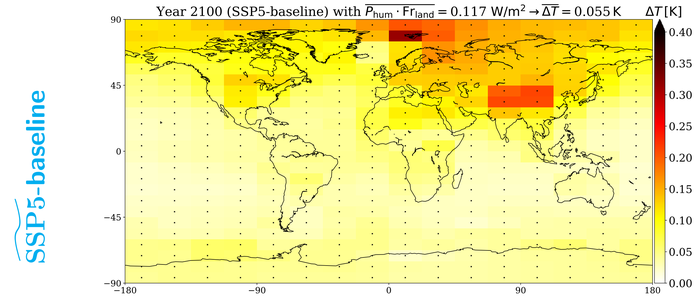


Fig. 5: Corresponding temperature change in 2100 (with AHF growth according to the SSP5-baseline projection).

Further Details:

- **Location Dependency:** Both feedbacks (ocean heat uptake as well as ice-albedo) depend on the location of the heat emission, in particular, on the **latitude** and some features of the surrounding cells like **ocean fraction** and **circulation patterns**.
- **Tipping Elements:** Areas surrounding the North Atlantic (e.g. Spitzbergen) are strongly impacted, which indicates changes in the **ocean circulation**. How might this affect tipping elements such as the Atlantic Meridional Overturning Circulation?

References

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