POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Towards net zero energy systems: Decarbonization bottlenecks and new opportunities in a rapidly changing world

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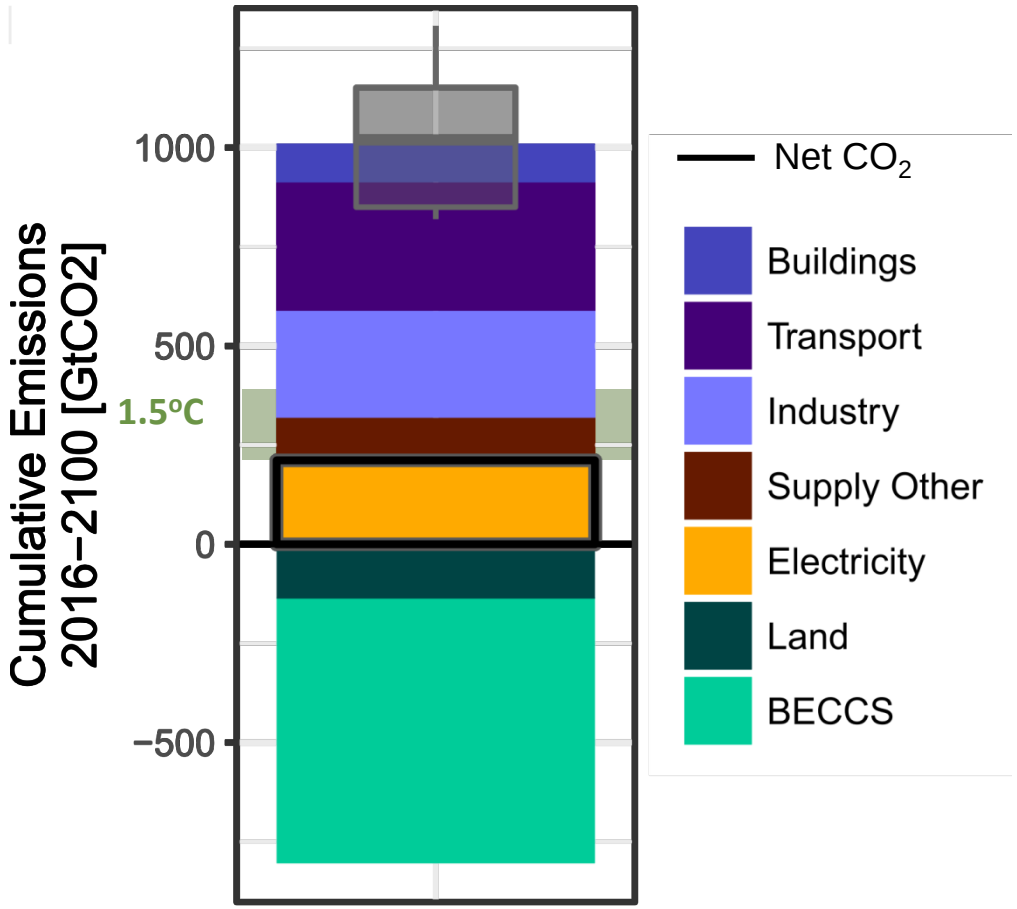
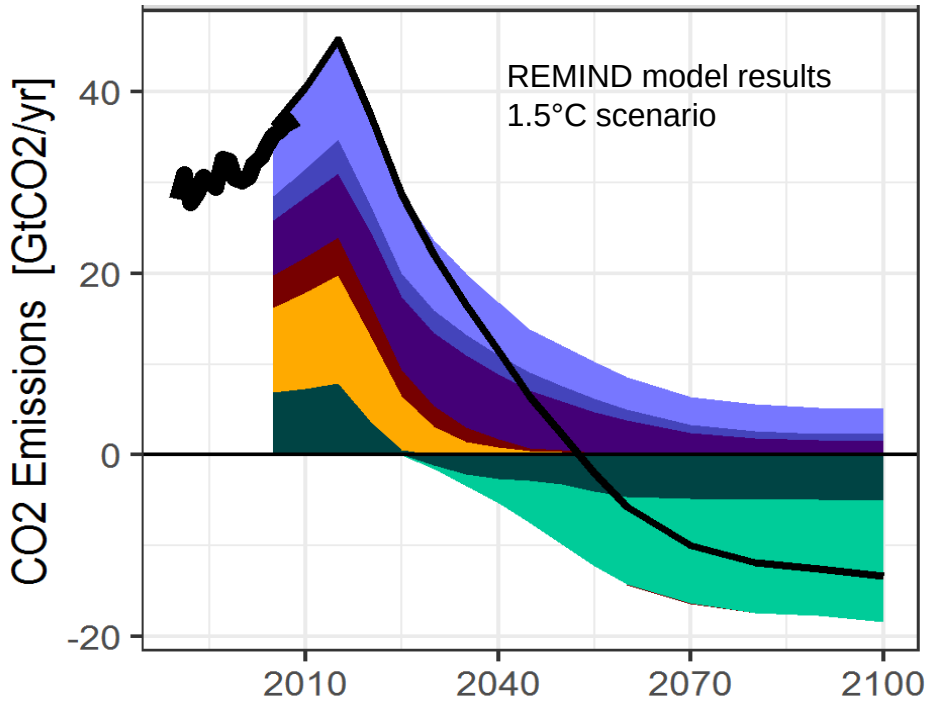
The transition to CO_2-neutral energy systems



1.5°C decarbonization scenarios



Feasibility of Paris targets and scale of carbon dioxide removal (CDR) ultimately determined by residual fossil emissions

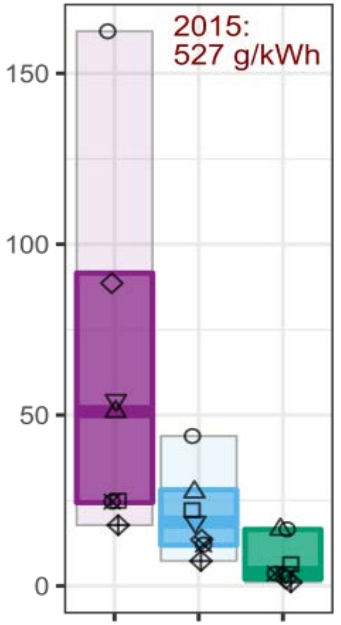
Based on
Luderer et al. (2018), *Nature Clim. Chnage*
Bertram et al. (2018), ERL

Indicators of the system transformation

2050

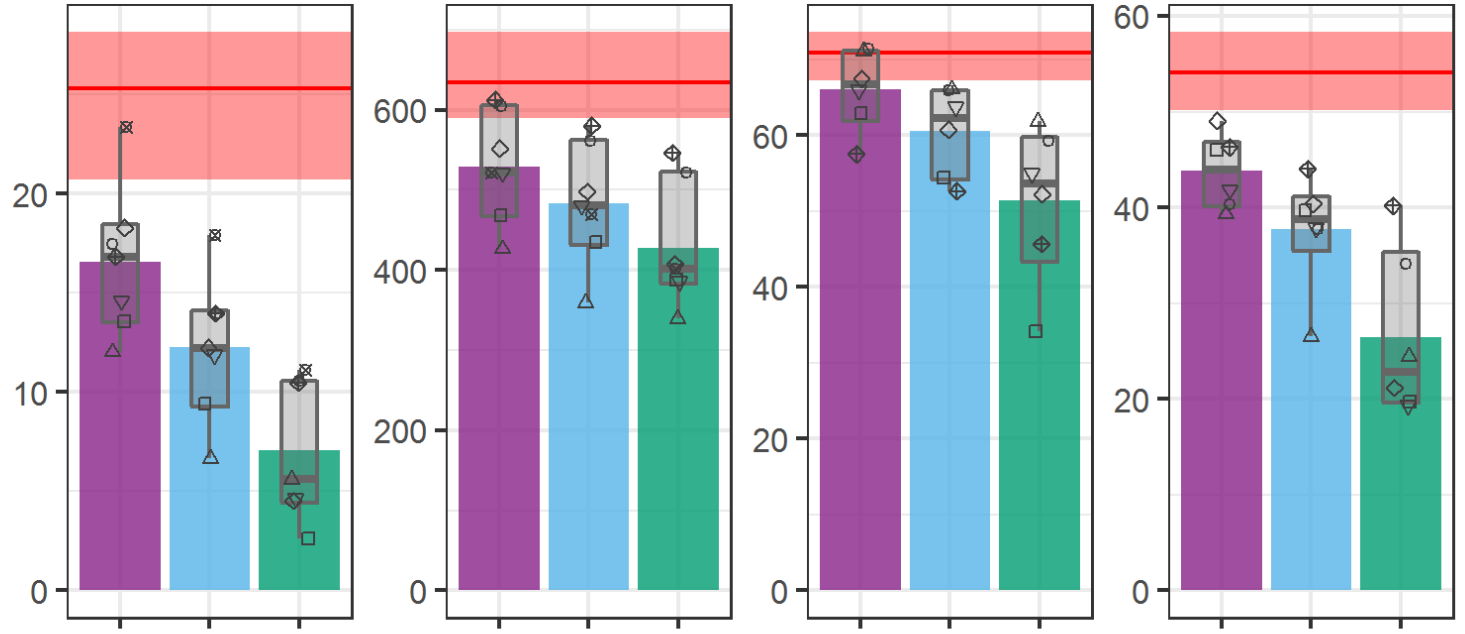
Electricity System

Fossil carbon intensity of electricity [Gt CO2]



Demand side CO2 Emissions

Total demand side emissions [Gt CO2] ~ Final energy consumption [EJ] x Non-electric energy demand [%] x CO2-intensity of fuels [kg/GJ]



Models
max
84th
median
16th
min

Scenario
Med−2C
WB−2C
1.5C−2100

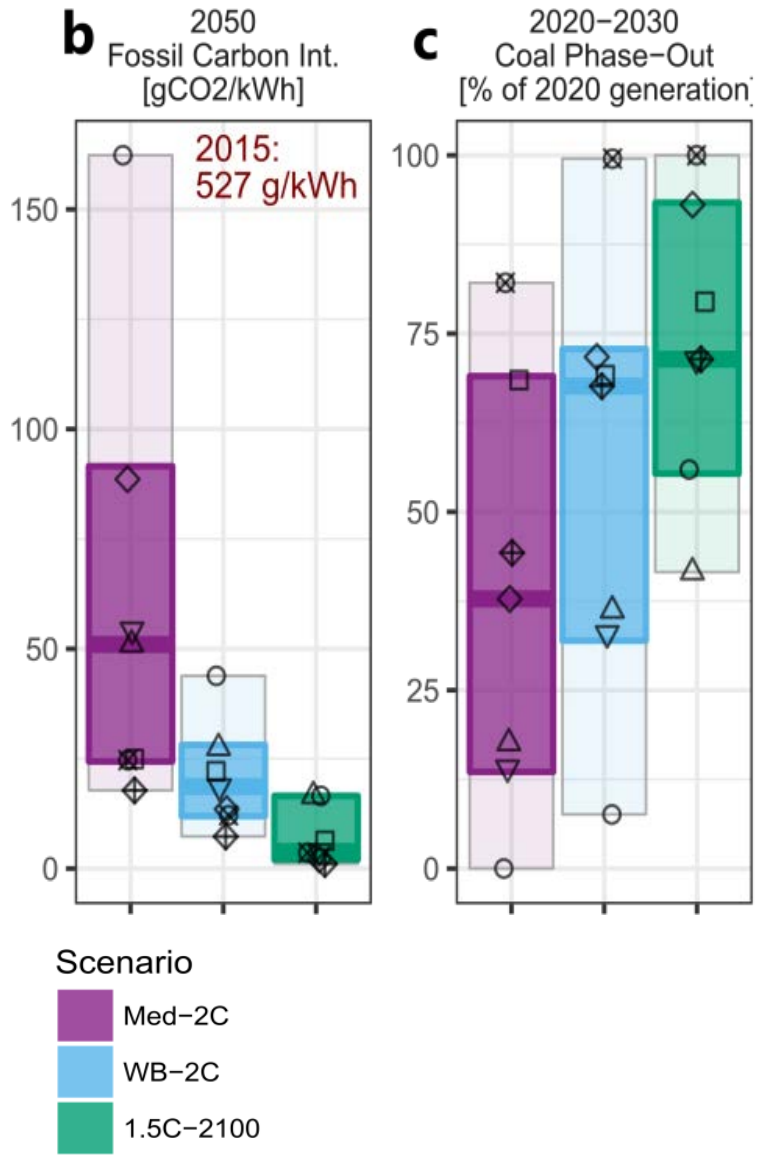
Reference
84th
median
16th

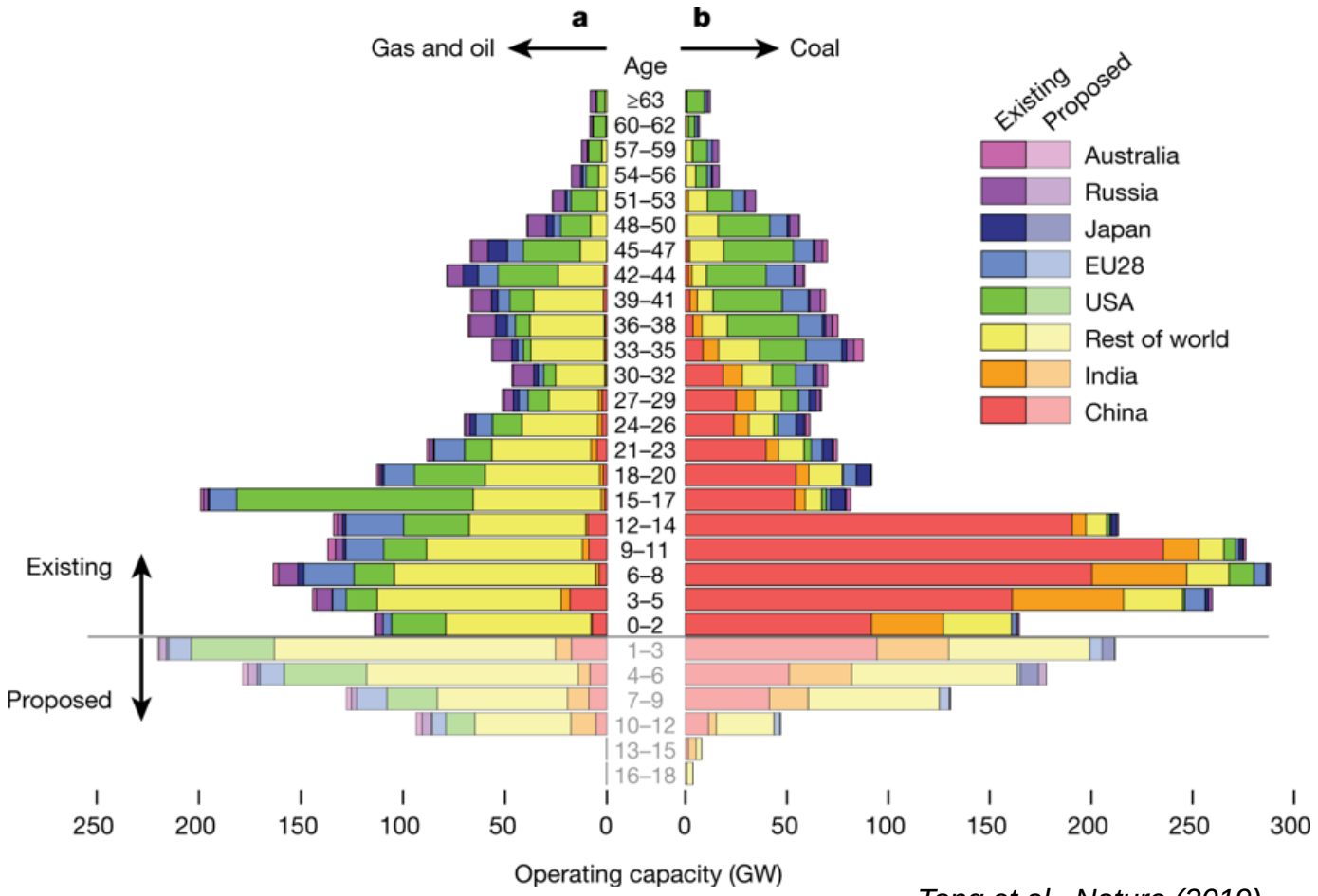
Abatement strategies:

- Energy efficiency & demand reduction
- Reduction of fuel use (Electrification)
- Decarbonization of fuels (Biomass, H2, industry CCS, synthetic fuels)

Luderer et al., Nature Clim. Ch. (2018)

Phasing out fossil electricity

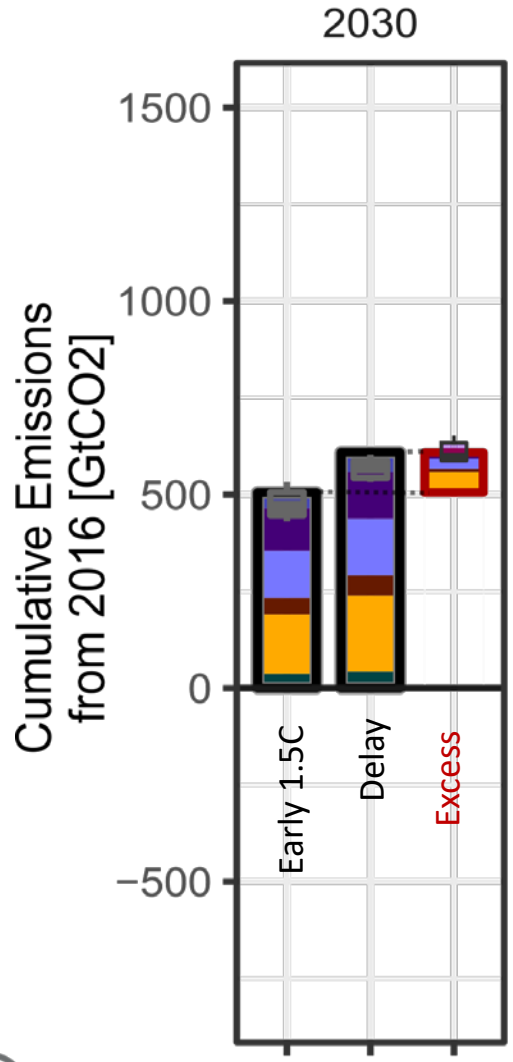




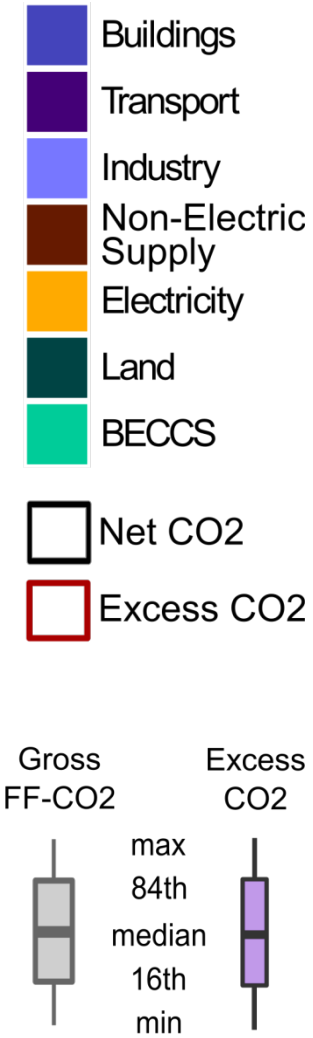
Tong et al., Nature (2019)

How quickly can coal be phased out?

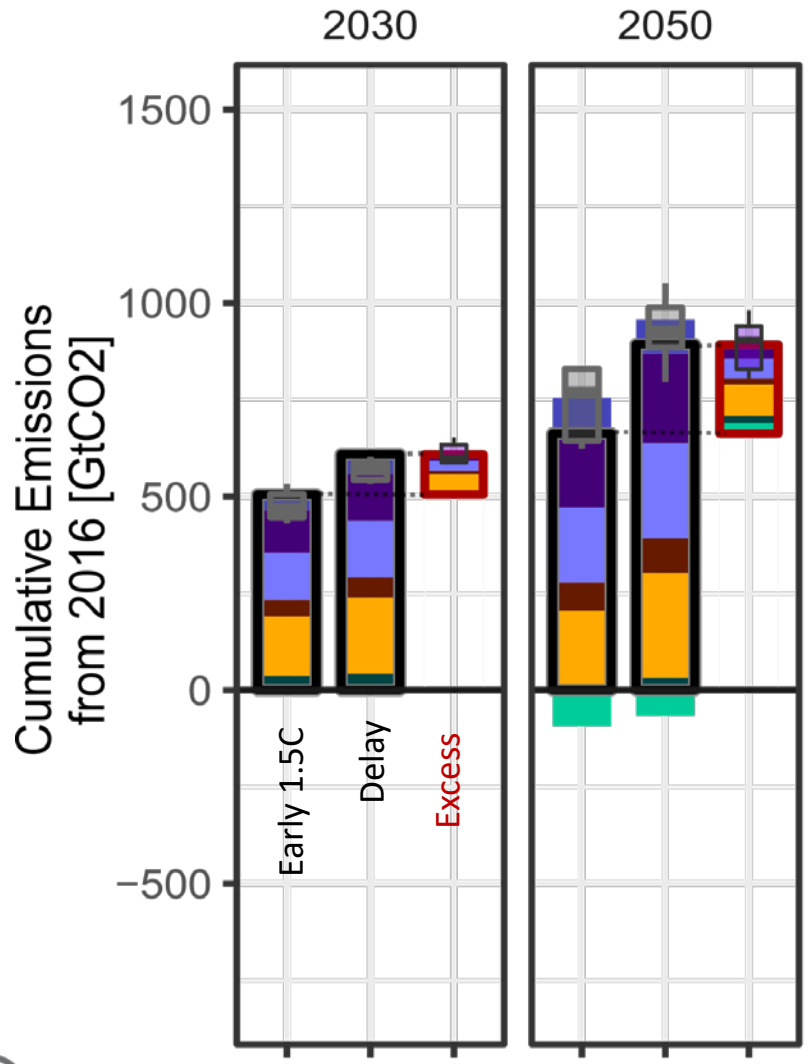
The long legacy of policy choices



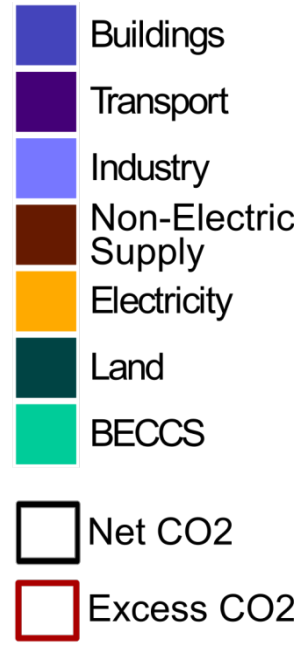
- 80 GtCO2 of excess emissions in NDCs until 2030

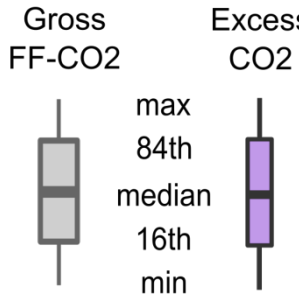


The long legacy of policy choices

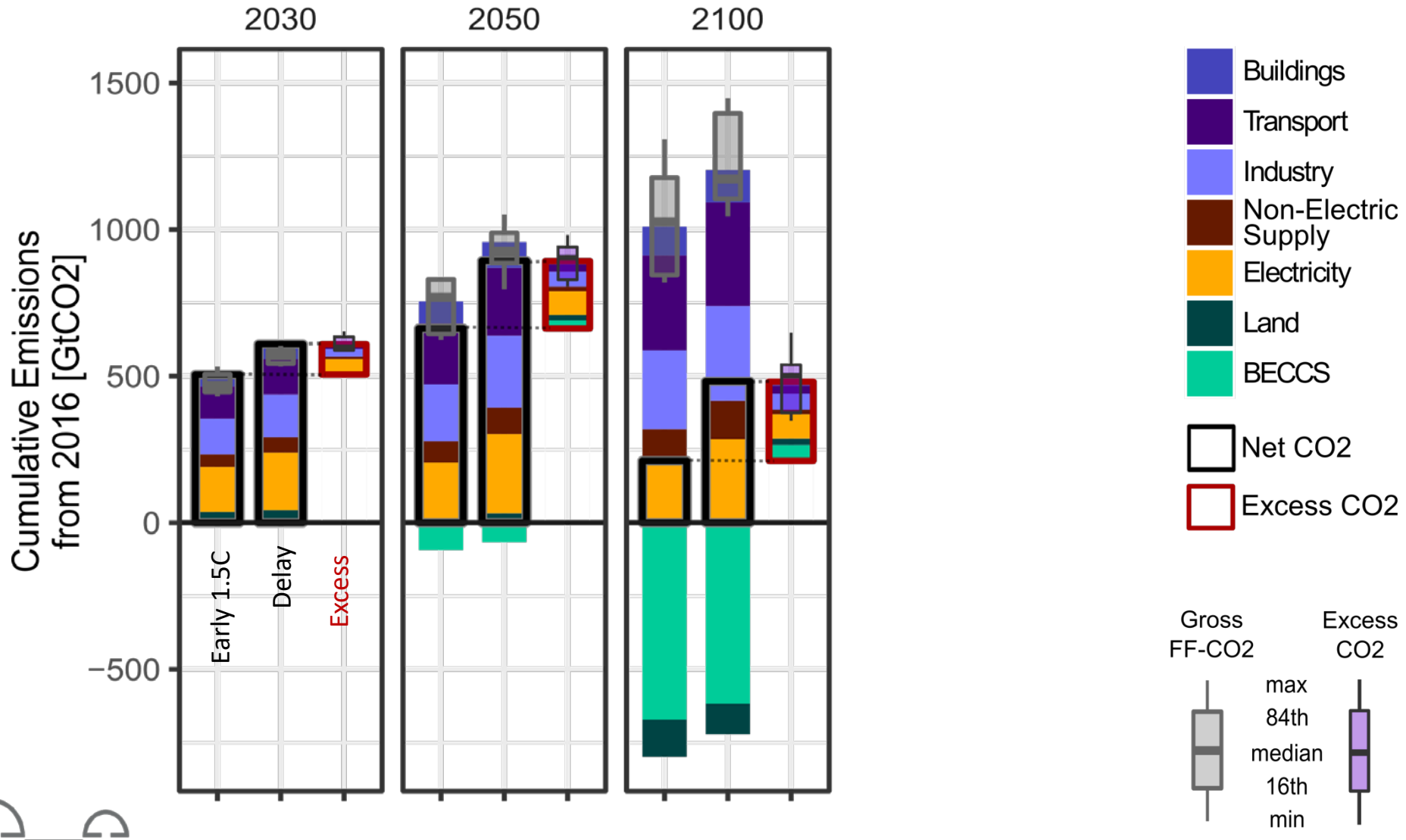


- 80 GtCO2 of excess emissions in INDCs until 2030
- Growing to 250 GtCO2 until 2050 due to carbon lock-in

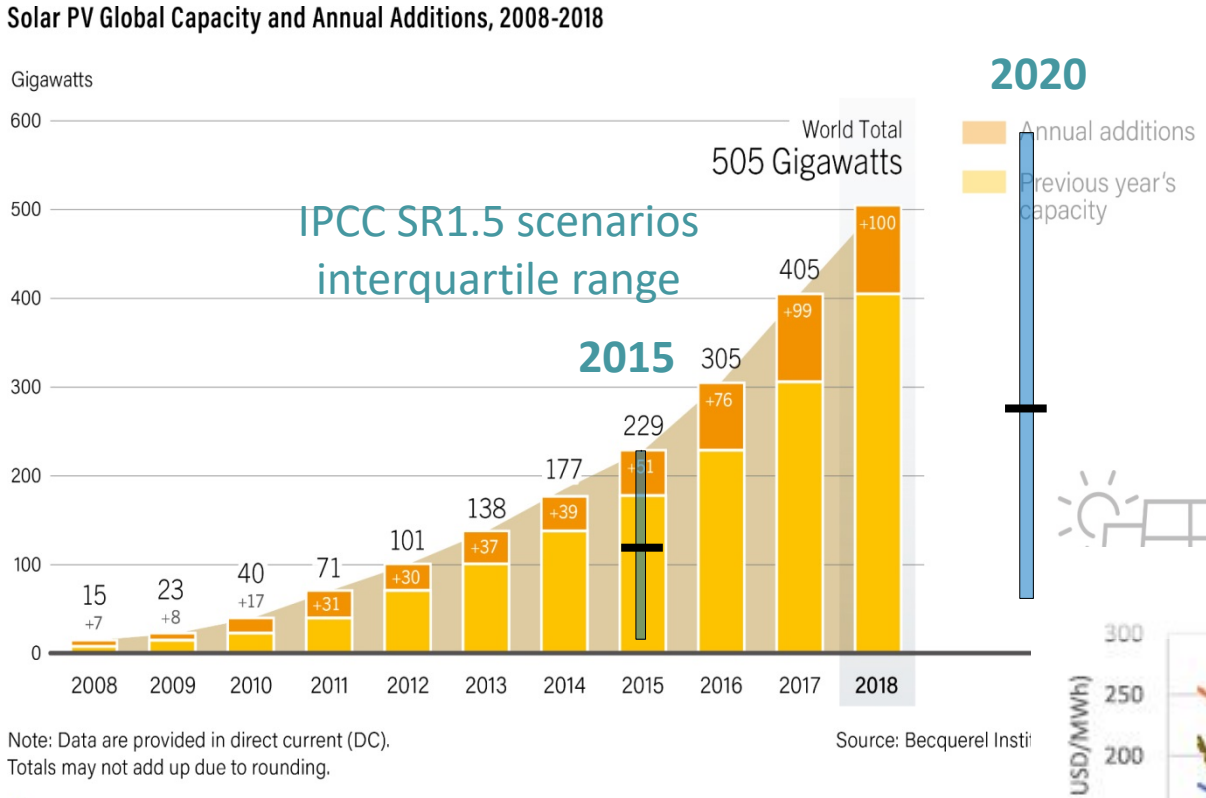


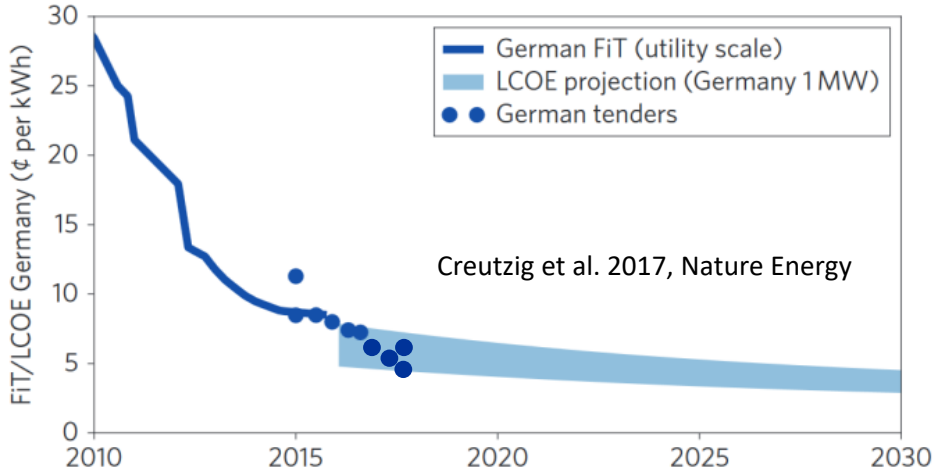


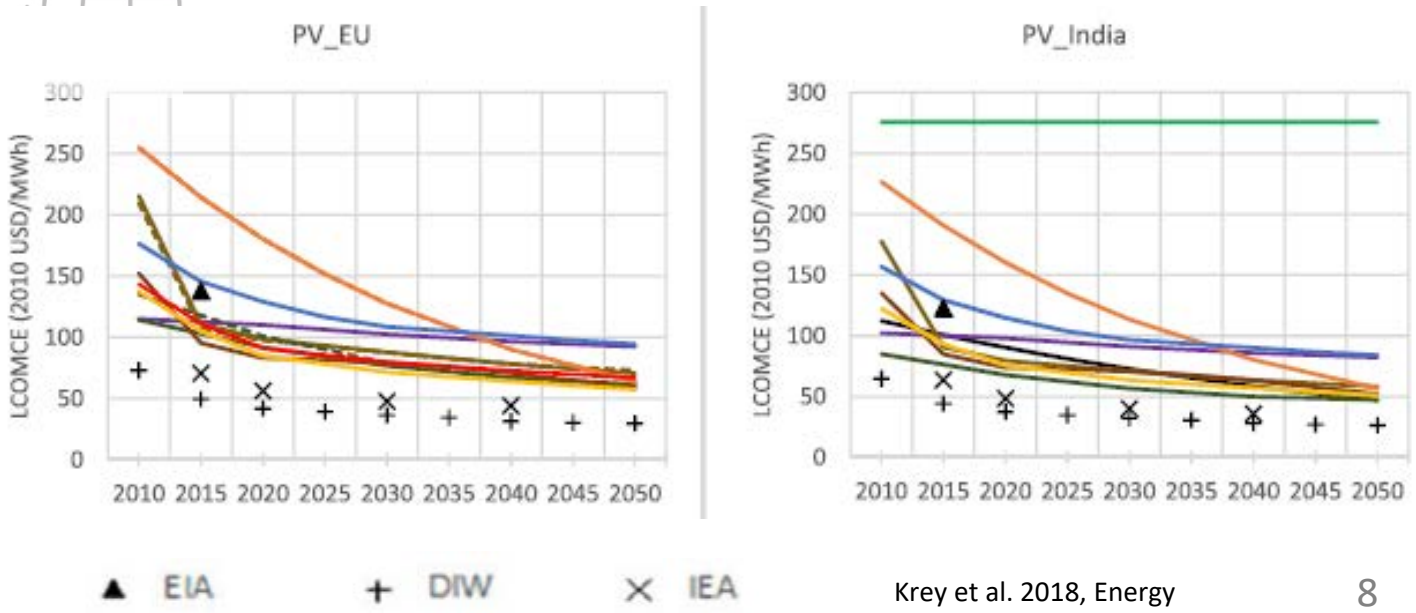
The long legacy of policy choices



Rapid growth of solar PV



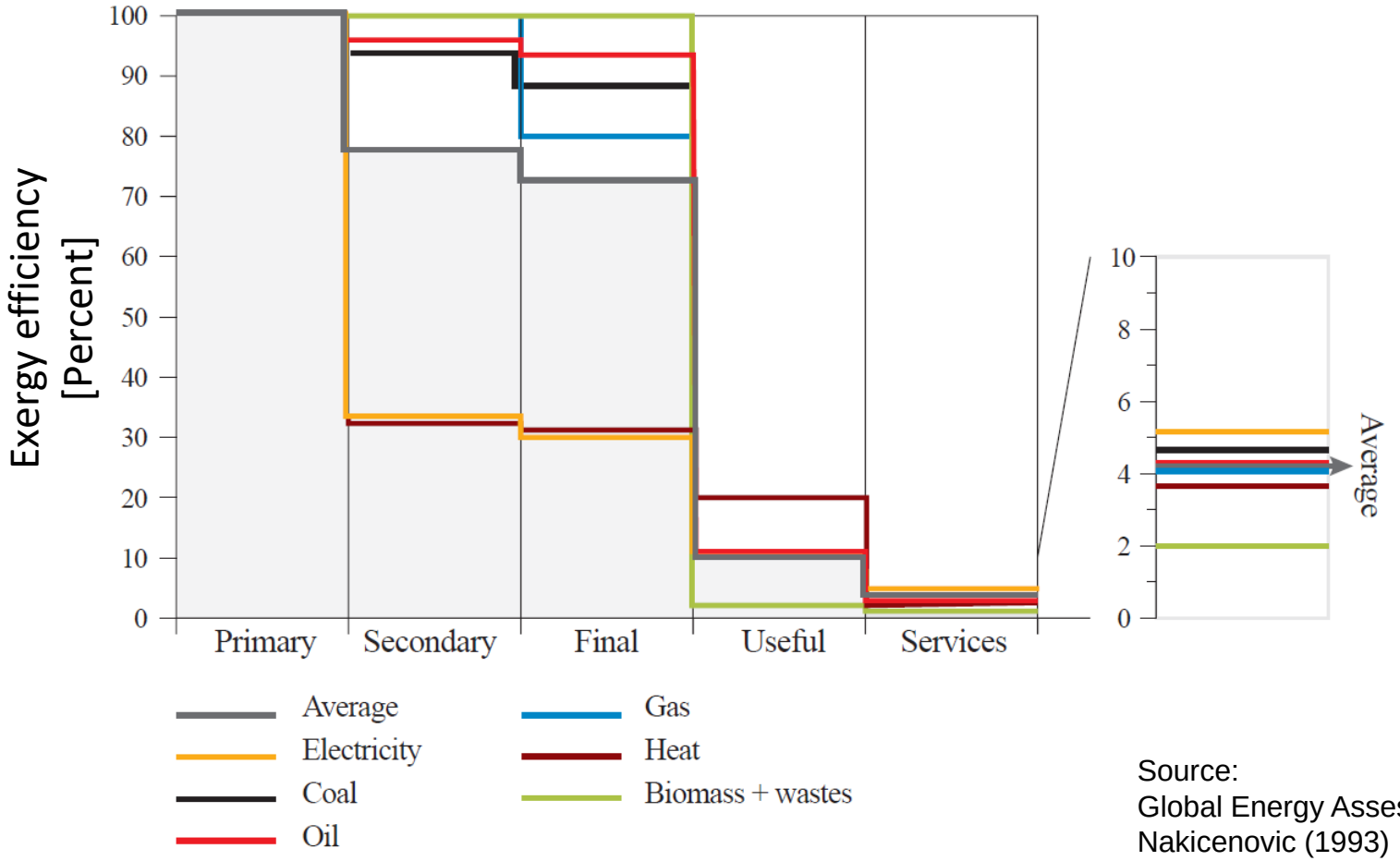




Do IAMs underestimate the mitigation potential of wind and solar energy?

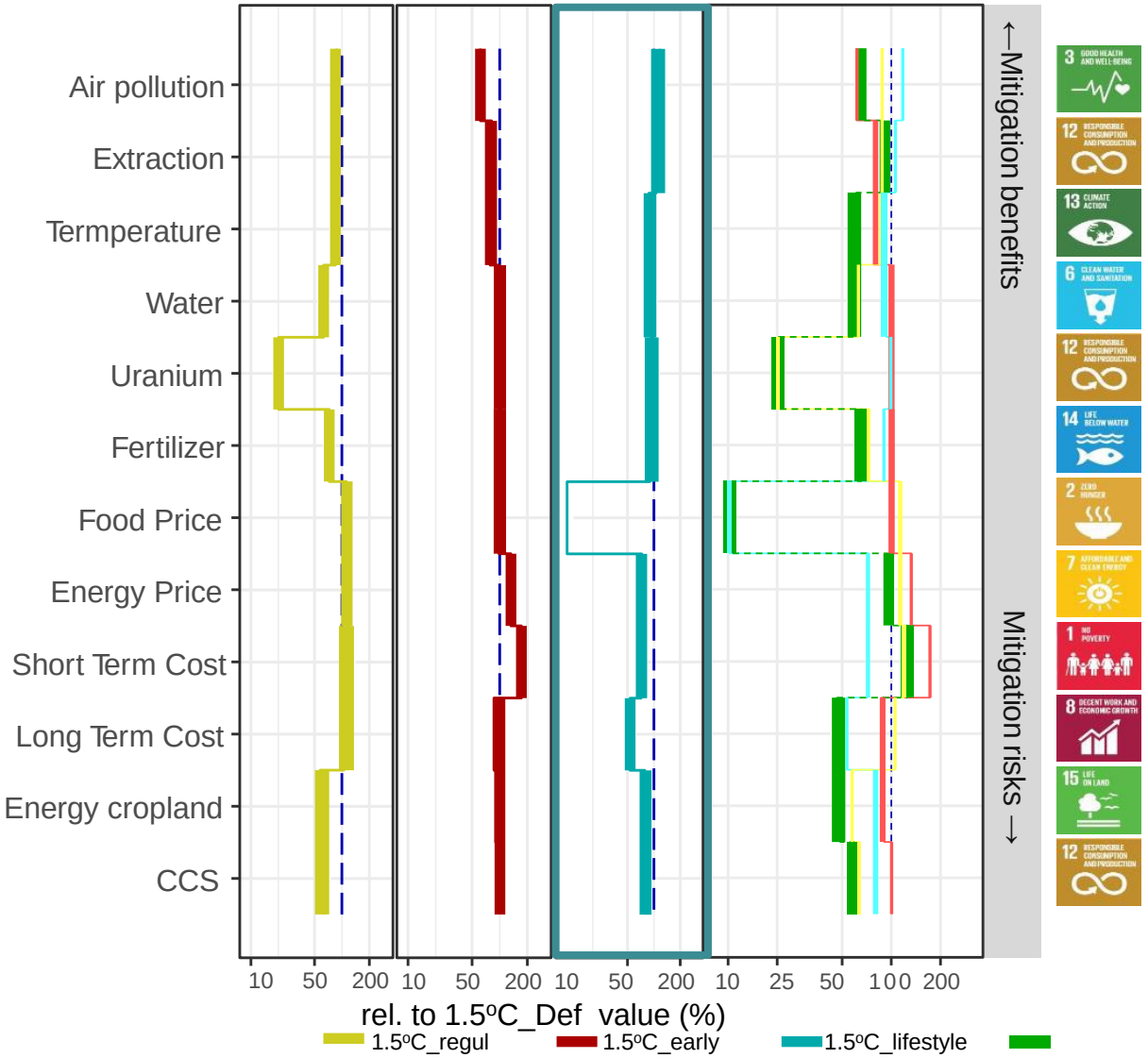
PIK

Energy efficiency: Huge theoretical potential



Source:
Global Energy Assessment (2012)
Nakicenovic (1993)

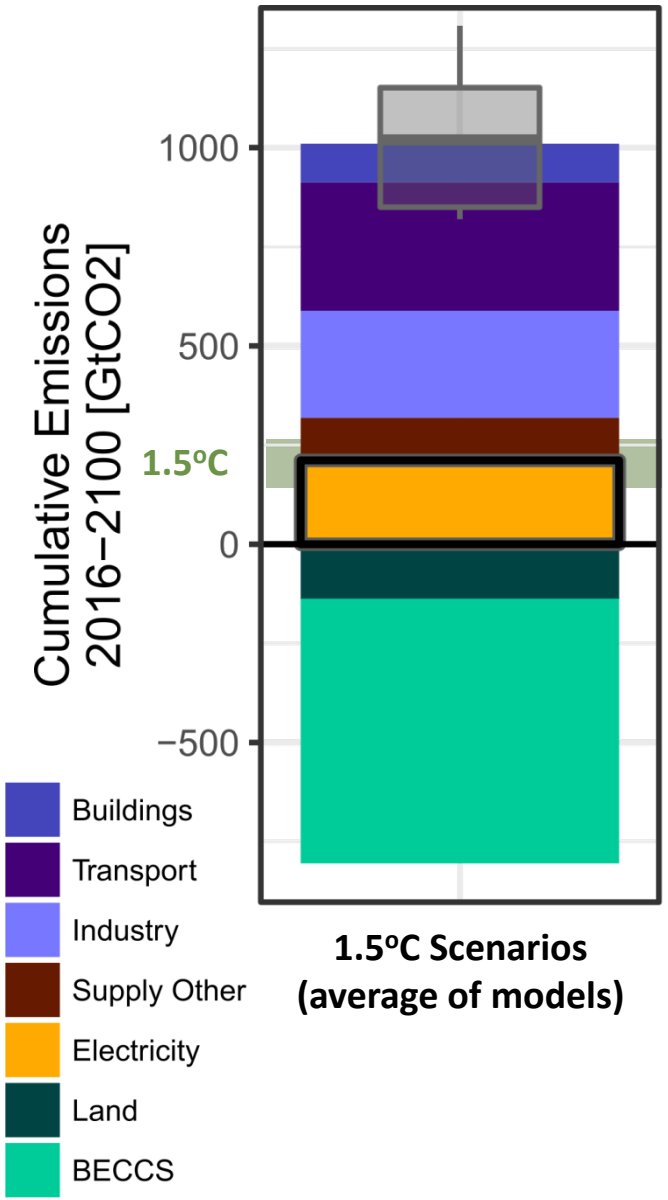
Low energy demand lifestyles: Major benefits



What are policy approaches to achieve transition to low energy demand pathways?

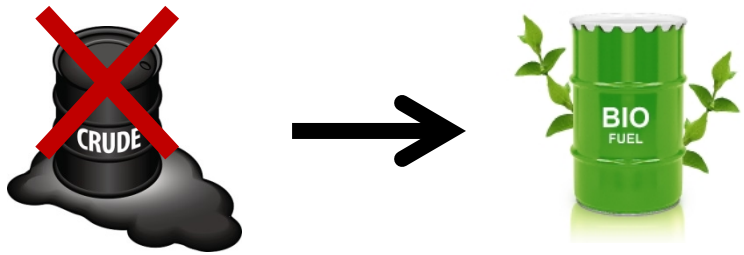
Bertram et al., ERL (2018)

The role of bioenergy…

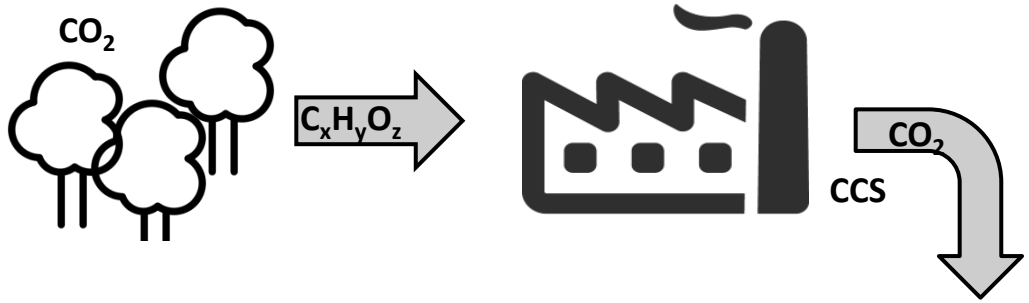


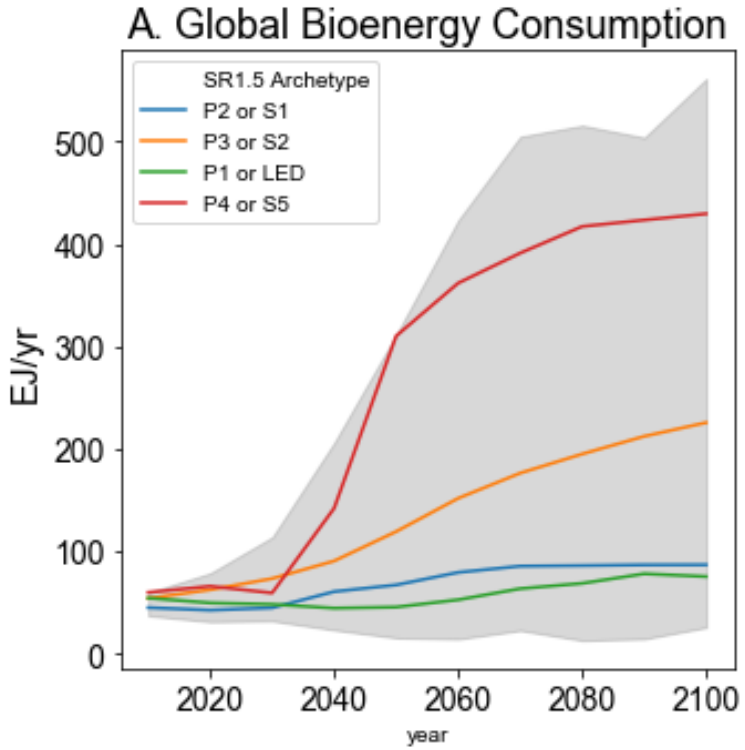
1.5°C Scenarios (average of models)

(1) Substitution of fossil energy



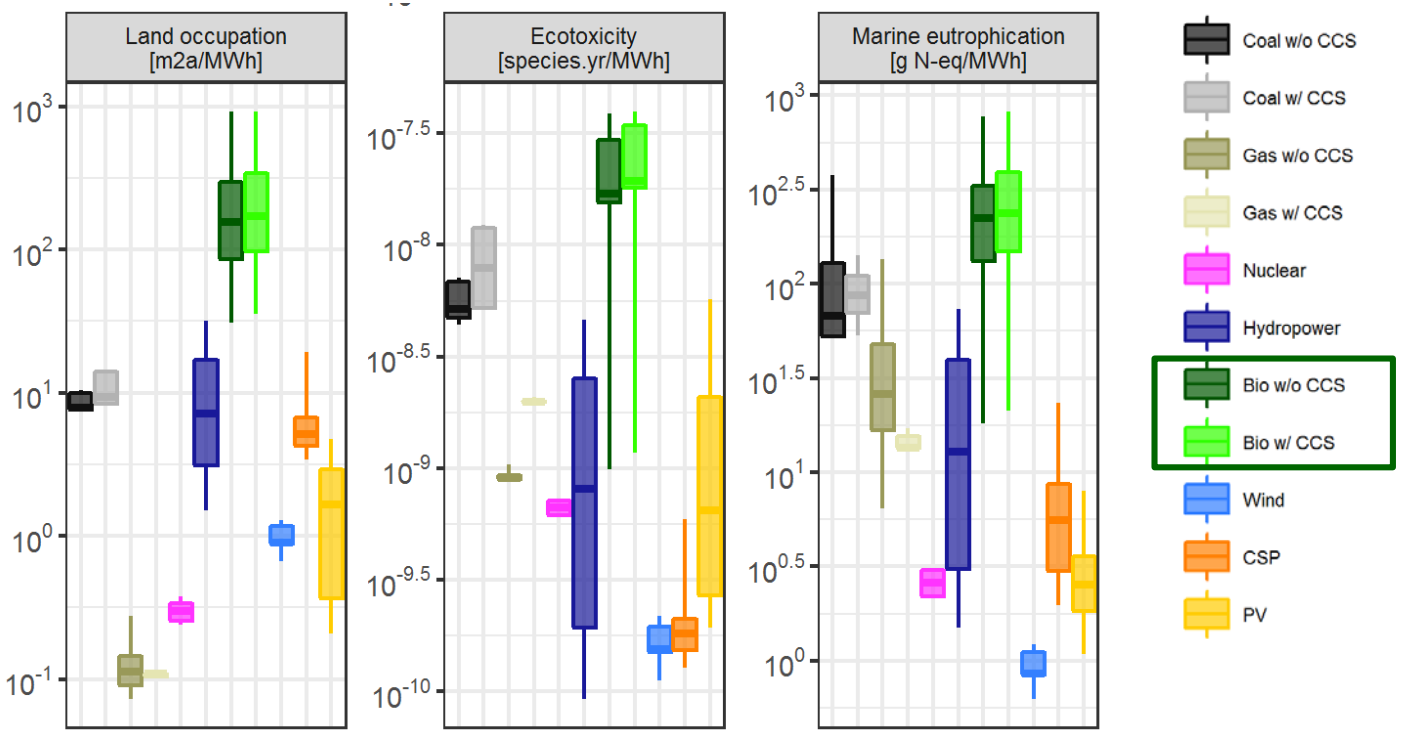
(2) Negative Emissions via combination with CCS (BECCS)





IPCC SRCCL (2019)

…and its environmental impacts

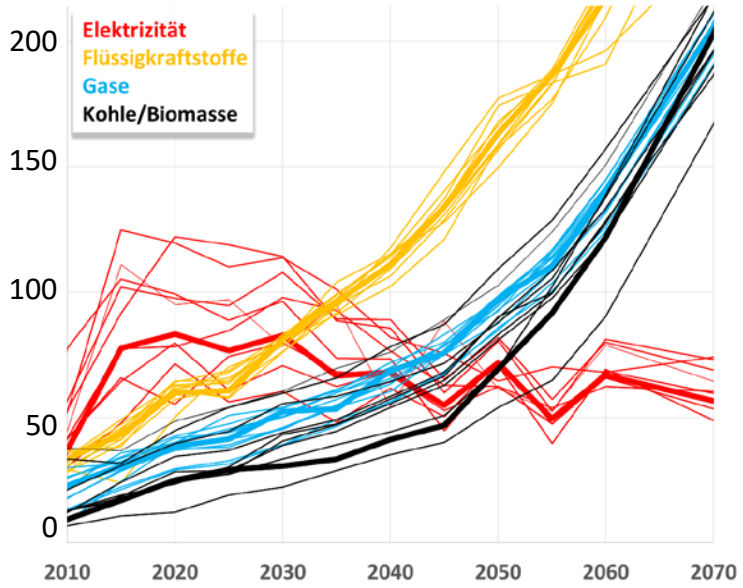


Can we limit the reliance on bioenergy for deep decarbonization?

Coupling Life-Cycle-Assessment with IAM
Luderer et al., in review

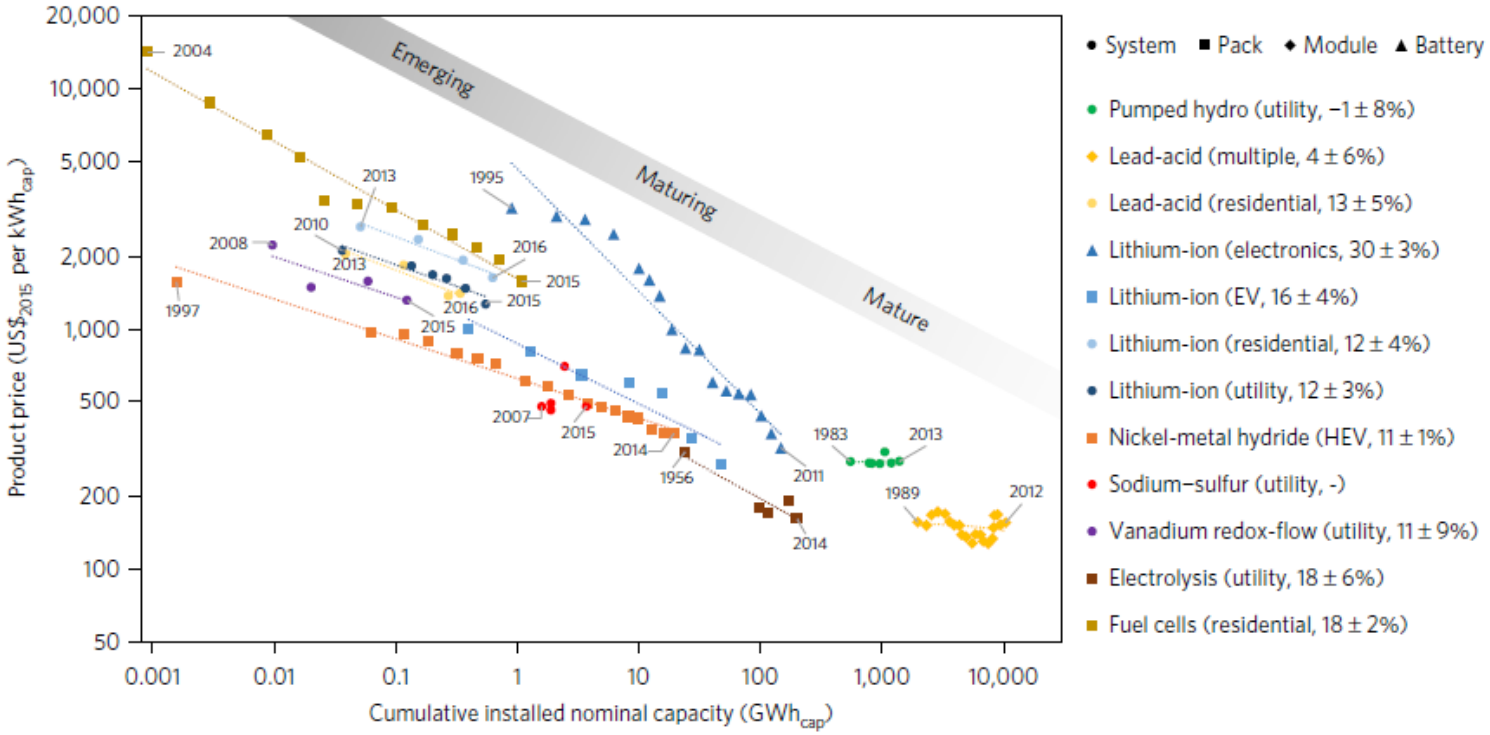
What is the potential for deep electrification?

Energy prices [€/MWh]



REMIND model,
2°C-Scenario with limited
Biomass and CCS

Progress in battery technology



Schmidt et al., 2017, Nat. Energy

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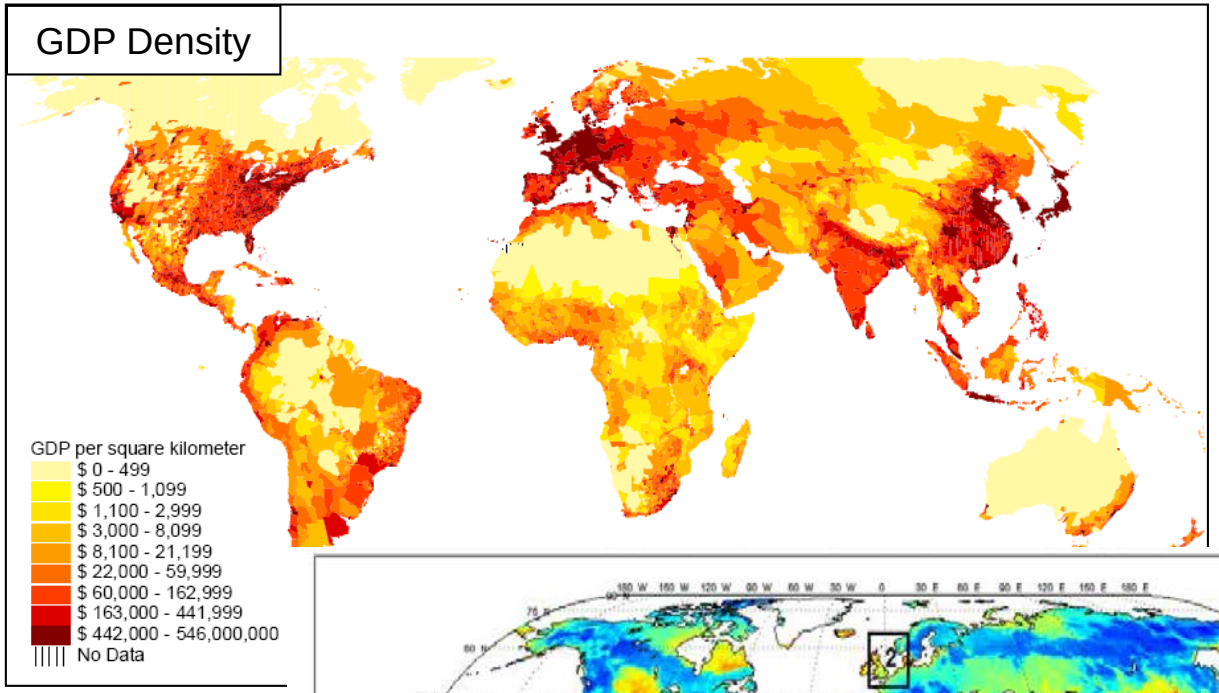
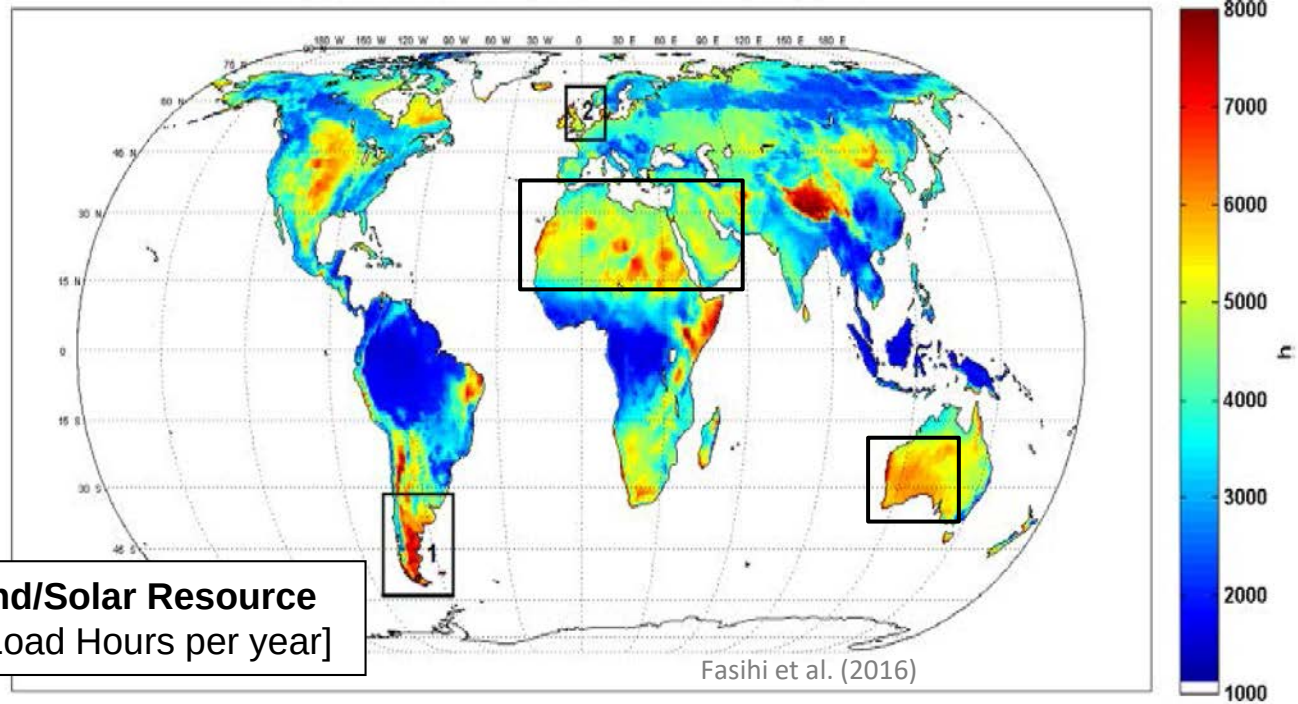
Making renewable energy tradable?





Combined Wind/Solar Resource Potential [Full Load Hours per year]

Fasihi et al. (2016)

- Regional imbalance between highest wind and solar potentials and energy demands
- Trade as
  - **Electricity** via high voltage direct current transmission grid
  - **Synthetic renewable fuels** (H2, methane, methanol,…)
  - **Energy intensive bulk materials** (steel, aluminum, chemicals,…)

Policy implications

- Transformation of industry and transport sector determine bioenergy and CDR requirements
- How do transition speeds differ across sectors and technologies? What are crucial lock-ins and lock-outs, and how can they be avoided?
- Sector coupling: How can electrification of end-uses and e-fuel production facilitate the integration of variable renewable electricity?
- What policies to achieve low energy growth?