14th sdewes Conference Dubrovnik 2019

Integrating future background scenarios for prospective LCA

Method and case study on the German energy system with a focus on prospective changes of the global electricity supply

Tobias Junne[a], Sonja Simon[a], Jens Buchgeister[a,b], Maximilian Saiger[a,1], Manuel Baumann[b], Tobias Naegler[a]

[a]Department of Energy Systems Analysis, Institute of Engineering Thermodynamics, German Aerospace Center (DLR), Stuttgart, Germany
[b]Institute for Technology Assessment and System Analysis (ITAS), Karlsruhe Institute of Technology, Karlsruhe, Germany

DLR

[1]now at LCS Life Cycle Simulation GmbH, Backnang, Germany

Motivation

Motivation

General challenges

Future energy systems require to consider:

- Access to energy
- Security of supply
- Affordability
- Influence on job allocation
- Acceptance
- Environmental burden shifting

⟹ Existing studies focus on costs + directly emitted CO_2

⟹ There is a need to combine multi-dimensional indicators and energy system models

Motivation

General challenges

Future energy systems require to consider:

- Access to energy
- Security of supply
- Affordability
- Influence on job allocation
- Acceptance
- Environmental burden shifting

} **Life Cycle Assessment (LCA)**

⟹ Existing studies focus on costs + directly emitted CO_2

⟹ There is a need to combine multi-dimensional indicators and energy system models

Methods

Methods

Global energy scenario (foreground):
- Electricity and heat generation
- Newly installed capacities and decommissioning (electricity, heat)
- Vehicle fleet development + fuel consumption
- Technical parameters of technologies

LCI data of today's energy technologies

LCI databases:
Ecoinvent, BioEnergieDat

LCI data from secondary literature
- Remodelling; background processes from Ecoinvent

Adaptation/Dynamization of LCI data:
- Separation of construction and operation
- Modelling of fuel markets
- Full load hours and service life
- Efficiency, power to heat ratio, COP, for energy technologies
- Electricity mix upstream chain (from background scenario)

LCI data (adapted)
Energy technologies
For foreground scenario (construction, operation)

Life Cycle Impact Assessment (LCIA)
Environmental impacts of energy technologies

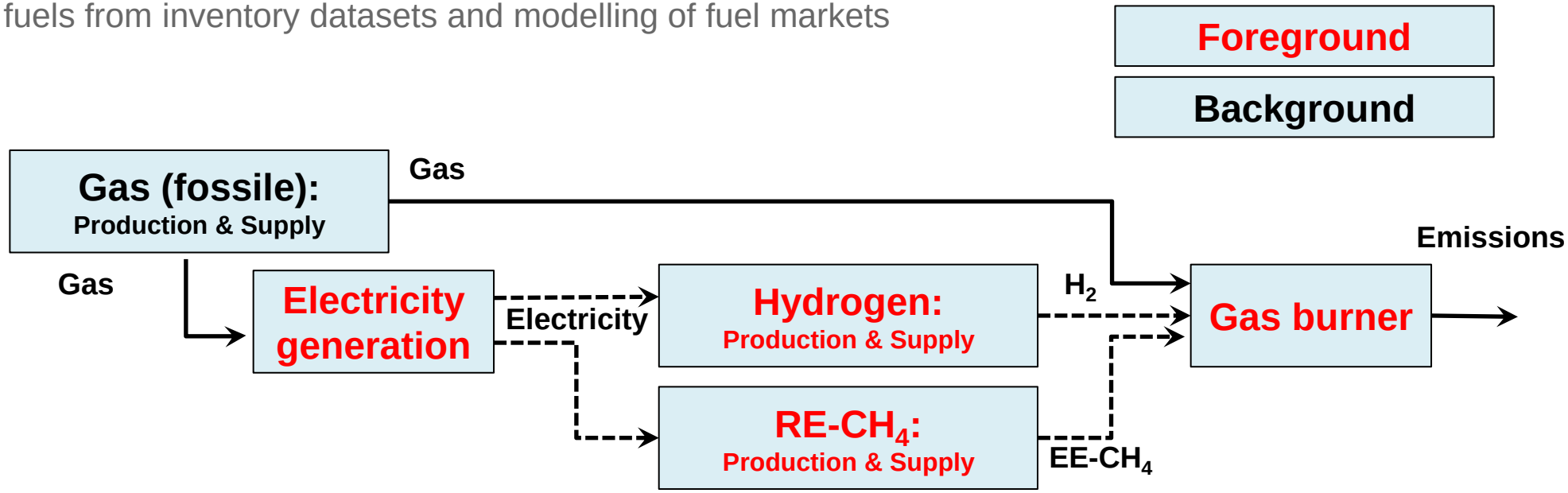
Aggregation according to scenario

Environmental impacts of energy scenario

Global energy scenario (background):
Technology mix for power generation in 10 world regions 2015-2050 for individual support years

Methods

Excluding fuels from inventory datasets and modelling of fuel markets



In the event that energy sources are generated in the foreground system (electricity, district heating, synthetic gases and fuels):

- Separate the input of these energy sources from the (end-) consumption technologies
- Environmental impact separately determined using these energy sources in (end-) consumption technologies by modelling of markets in the LCI-databse

⇨ Adjustment of energy carrier mix to scenario assumptions possible

Methods

Global energy scenario (foreground):
- Electricity and heat generation
- Newly installed capacities and decommissioning (electricity, heat)
- Vehicle fleet development + fuel consumption
- Technical parameters of technologies

LCI data (adapted)
Energy technologies
For foreground scenario (construction, operation)

Life Cycle Impact Assessment (LCIA)
Environmental impacts of energy technologies

Aggregation according to scenario

Environmental impacts of energy scenario

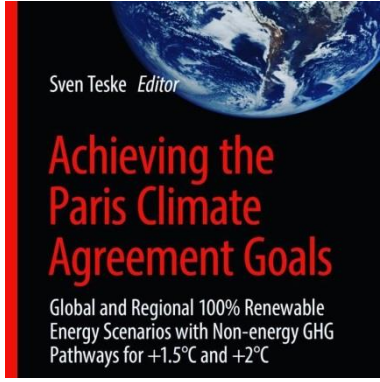
LCI data of today's energy technologies

LCI databases:
Ecoinvent, BioEnergieDat

LCI data from secondary literature
- Remodelling; background processes from Ecoinvent

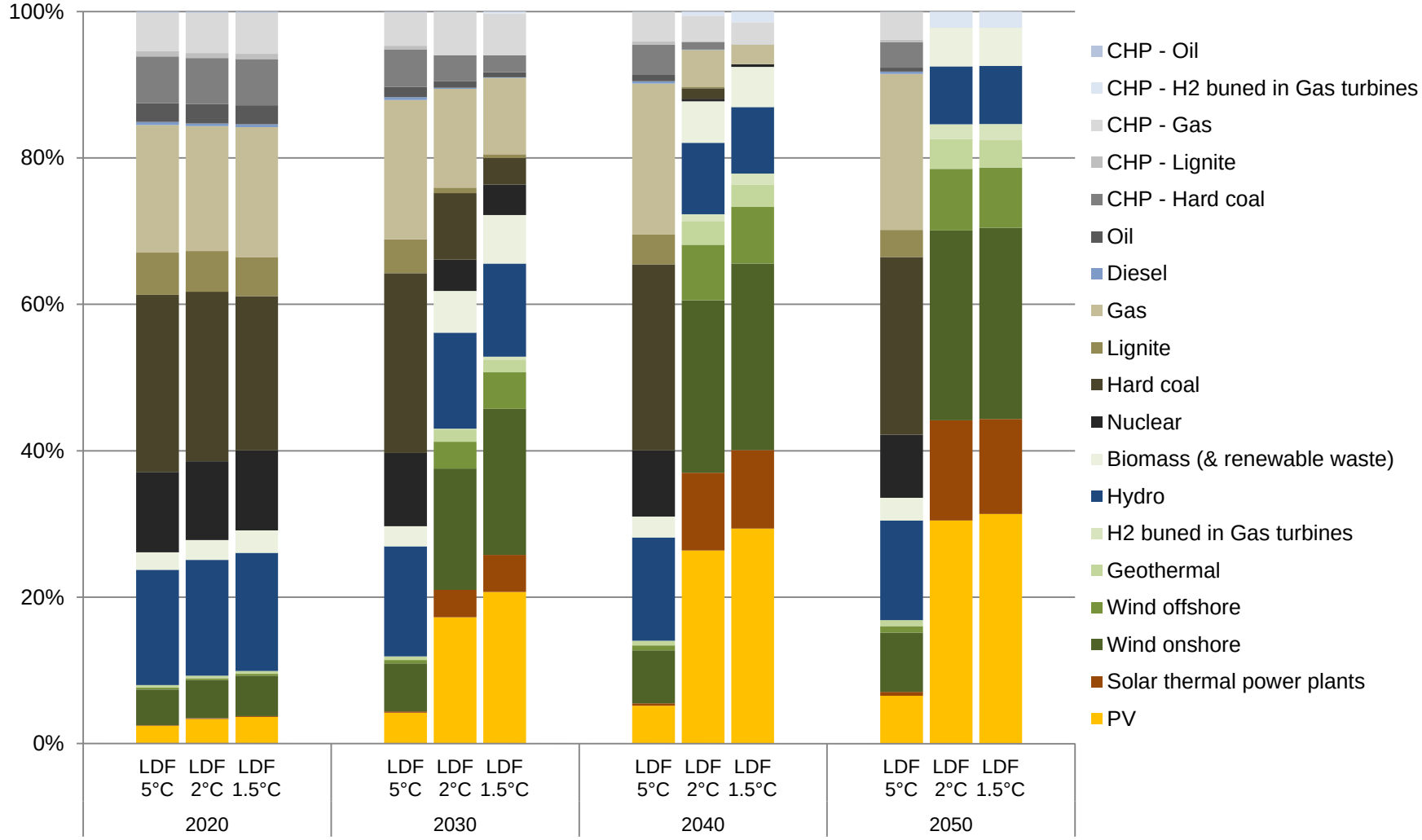
Adaptation/Dynamization of LCI data:
- Separation of construction and operation
- Modelling of fuel markets
- Full load hours and service life
- Efficiency, power to heat ratio, COP, for energy technologies
- Electricity mix upstream chain (from background scenario)

Global energy scenario (background):
Technology mix for power generation in 10 world regions 2015-2050 for individual support years



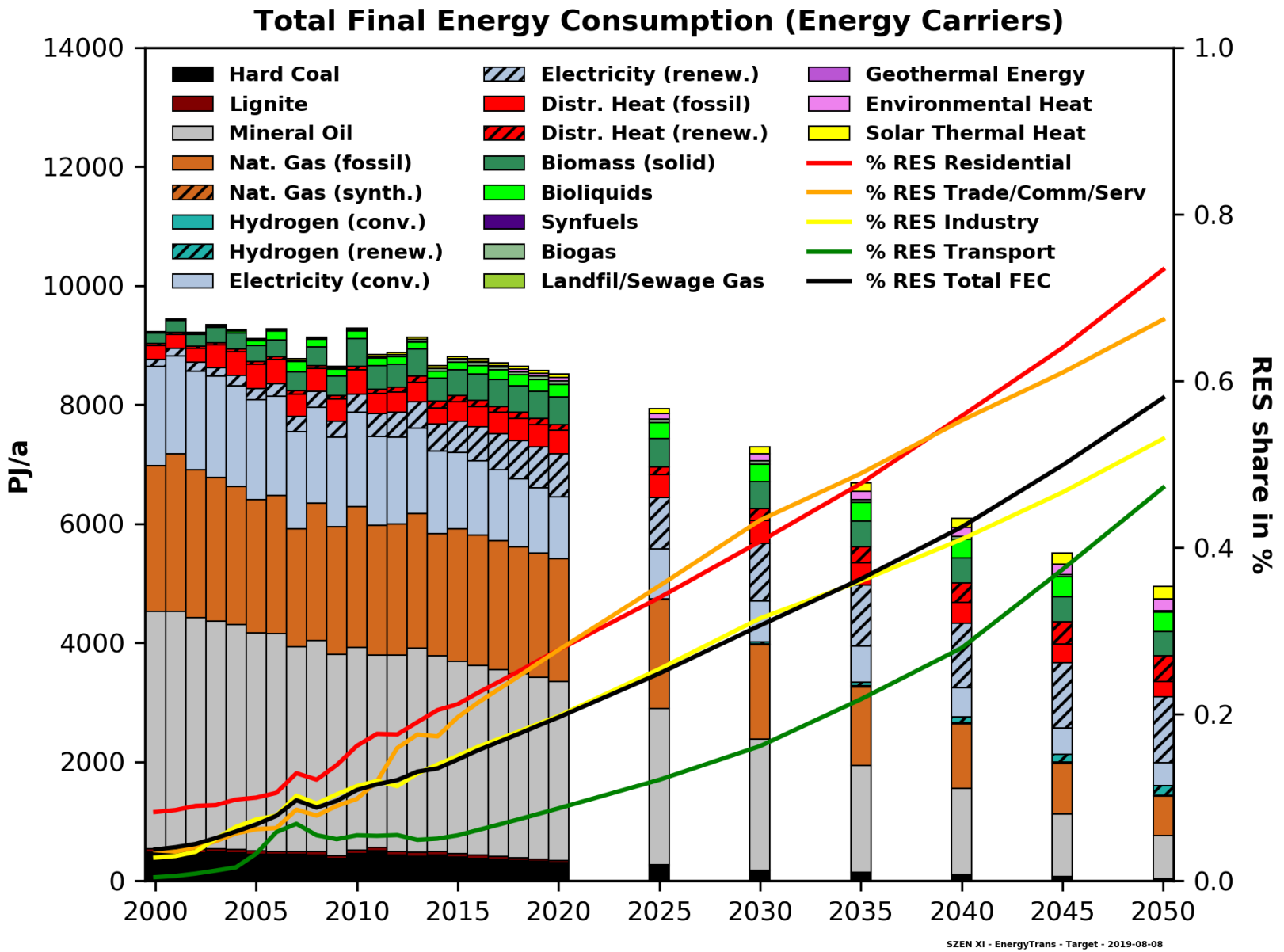
Methods

Adaption of background database – LDF scenarios



Methods

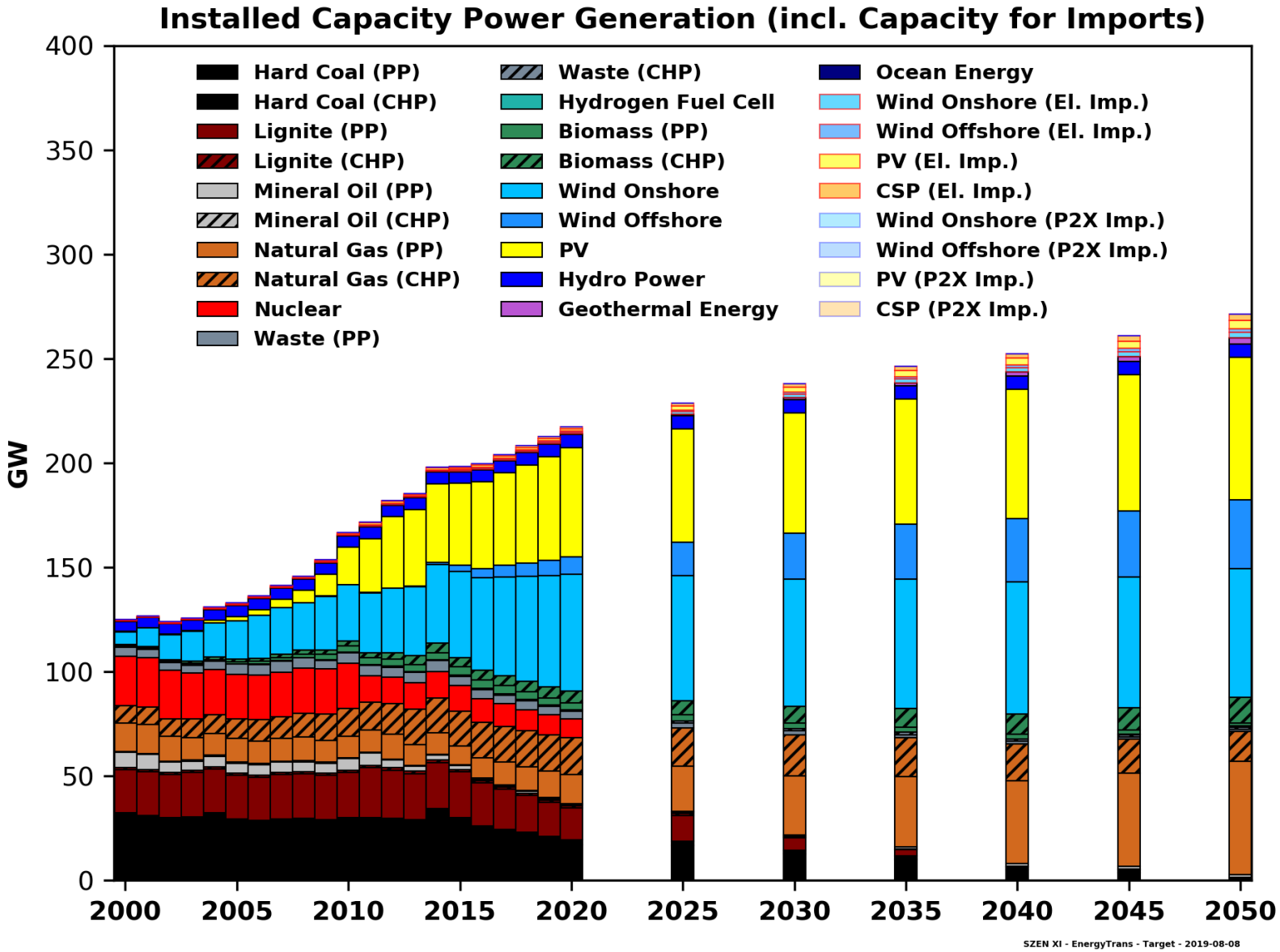
Foreground scenario[1]



[1]T. Pregger, T. Naegler, W. Weimer-Jehle, S. Prehofer, and W. Hauser, "Moving towards socio-technical scenarios of the German energy transition - lessons learned from integrated energy scenario building," *Climatic Change (under review)*, 2019.

Methods

Foreground scenario[1]



[1]T. Pregger, T. Naegler, W. Weimer-Jehle, S. Prehofer, and W. Hauser, "Moving towards socio-technical scenarios of the German energy transition - lessons learned from integrated energy scenario building," *Climatic Change (under review)*, 2019.

Research question

What **influence** do differently ambitious **global background electricity scenarios** have on the **environmental footprint of German energy scenarios**?

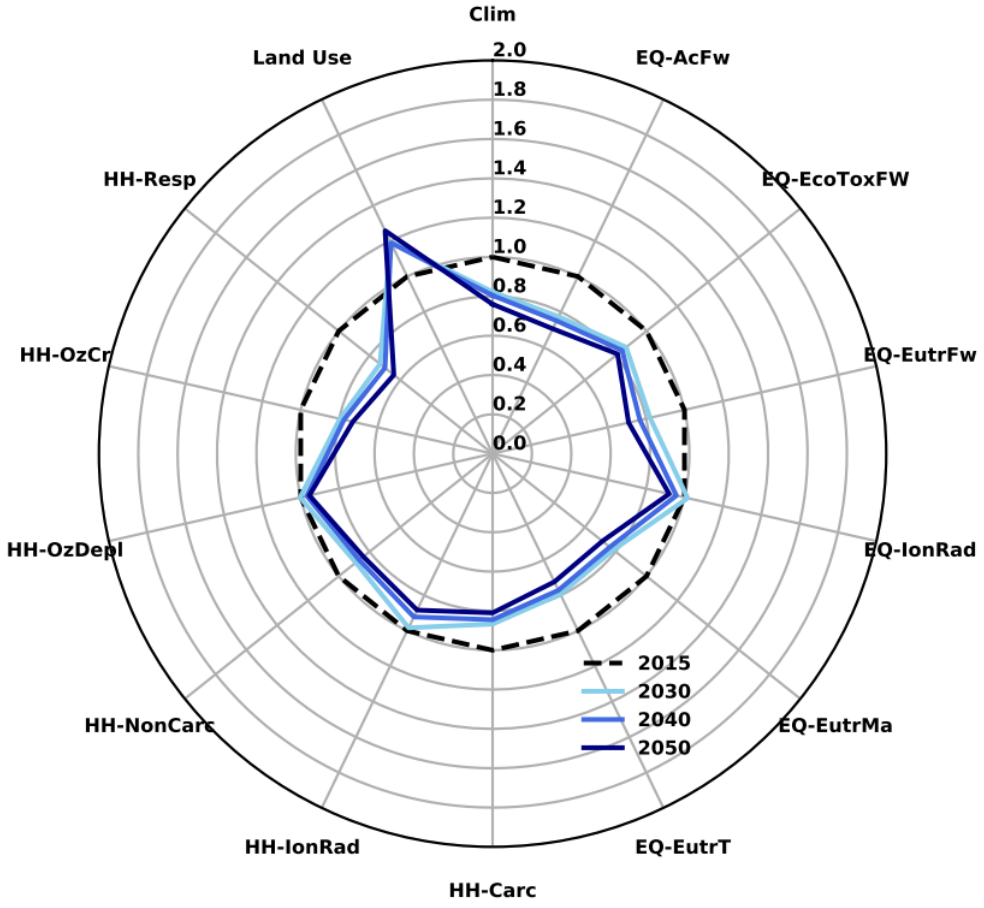
Results

Results

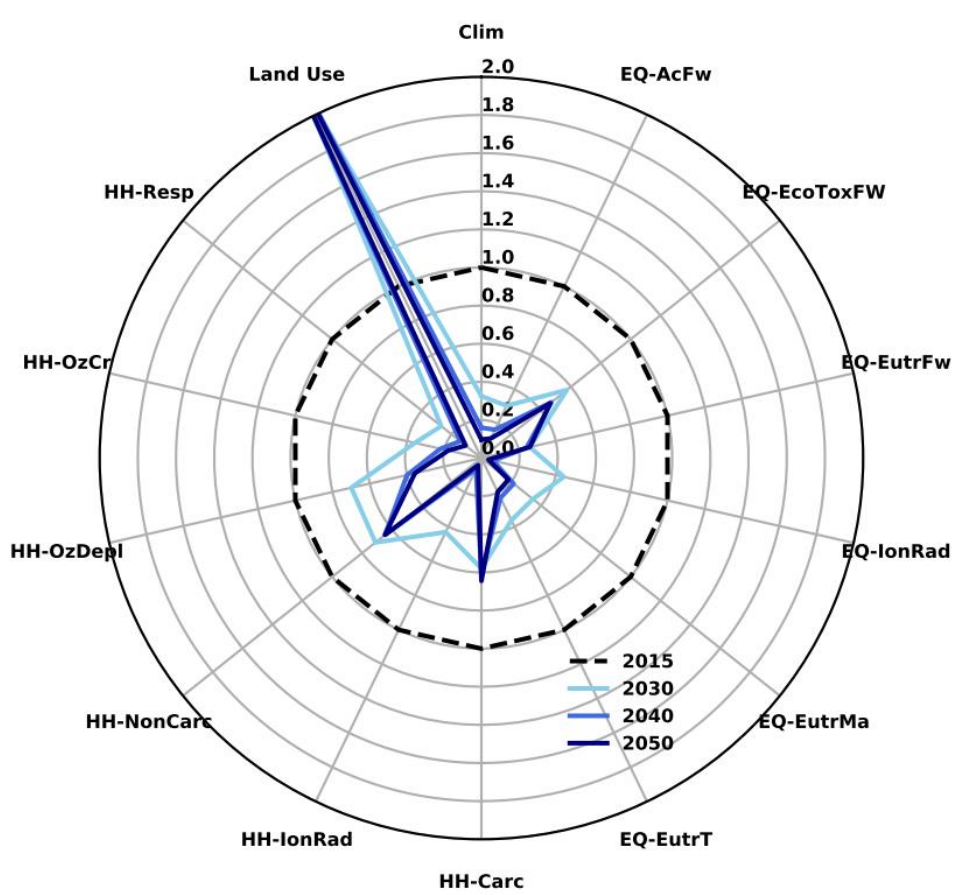
Background database - effects of prospective electricity mix used as input to all processes in the LCI-database

Global market electricity mix - impact/kWh (ILCD midpoint 1.0.8 2016)

LDF 5°C



LDF 1.5°C



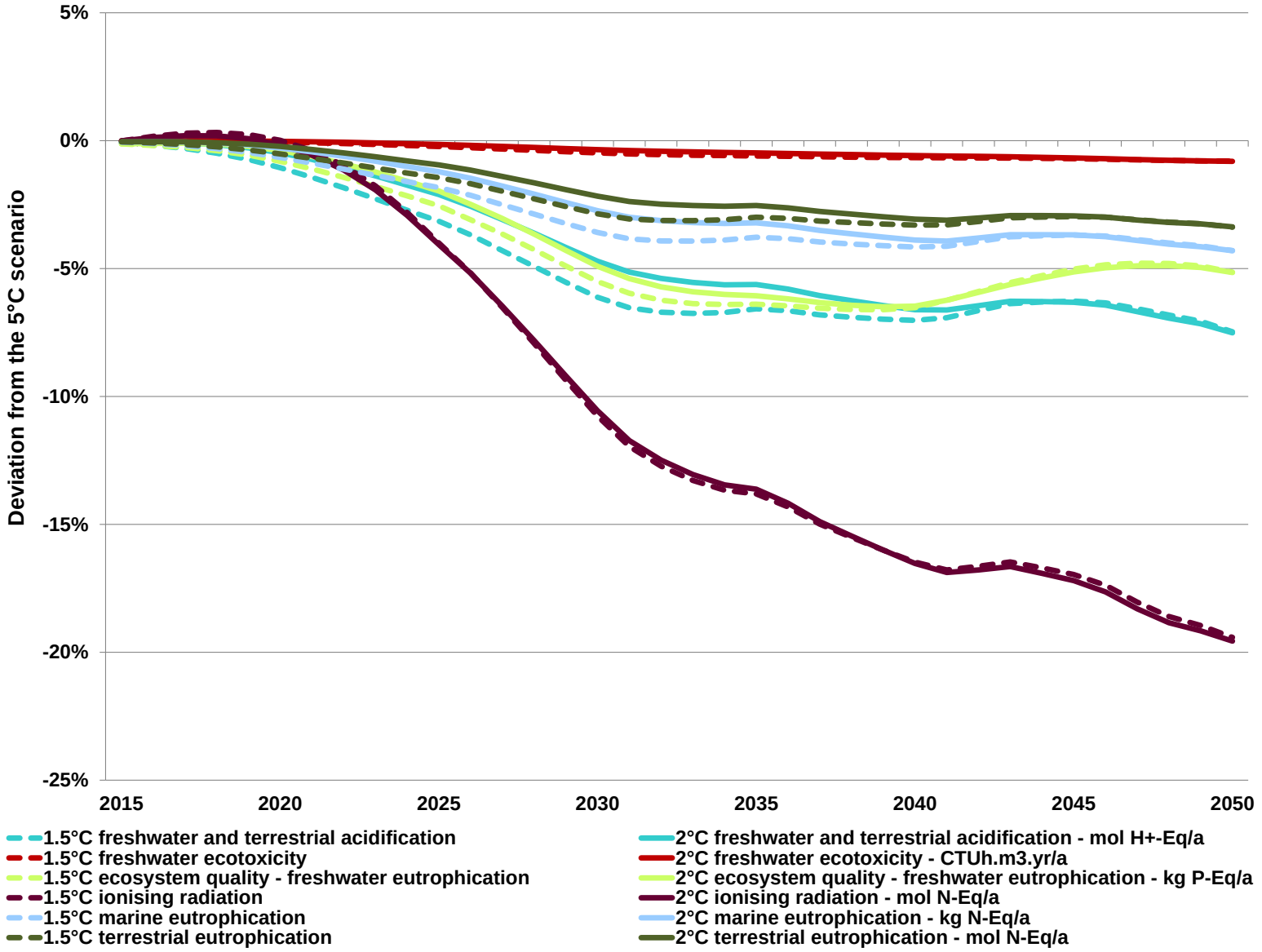
Results

Ecosystem quality

The ambitious background scenarios
…lead to a reduction of **‘ionizing radiation’** of **20%**

…**’freshwater and terrestrial acidification**’ and **‘freshwater eutrophication’** are reduced by about 8% and 5% respectively

…have a **negative impact** on indicators addressing **‘eutrophication’** and **‘acidification’** from 2039 onwards (e.g. due to the nitrogen oxide emissions during wafer production for PV modules)



Results

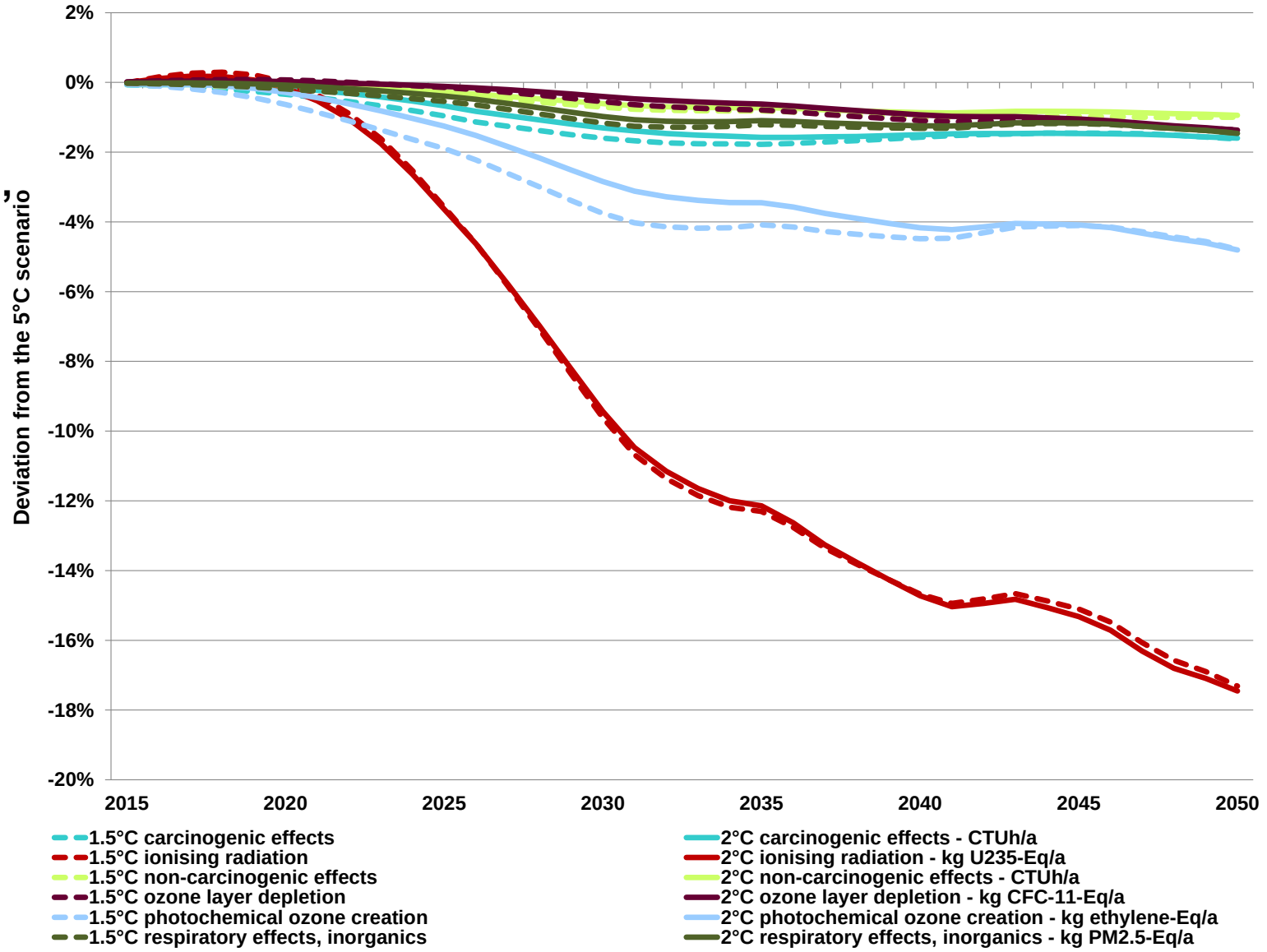
Human health

The ambitious background scenarios

…lead to a reduction of **‘ionizing radiation’** of **~18%**

…**’photochemical ozone creation’** is reduced by **~5%**

…all **other indicators** relating to human health are only **marginally affected**



Results

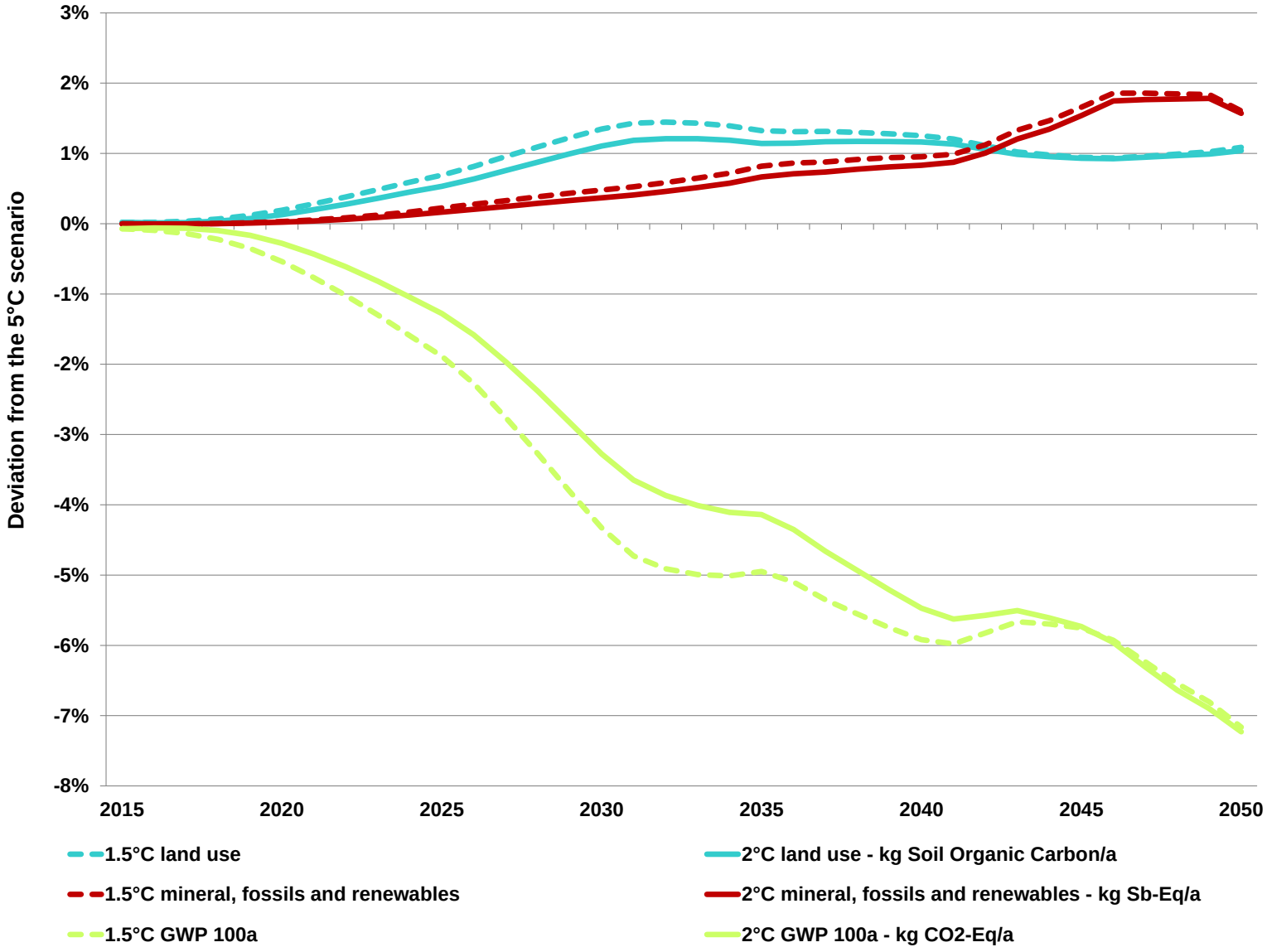
Resources and climate change

The ambitious background scenarios

…lead to a reduction of **‘GWP100a’** of **~7%**

…adverse side effects are found for the impacts **‘land use’** and **‘mineral, fossils and renewables’** which increase by **~1%** and **~2%** respectively due to increased land transformation, land occupation and higher demand of raw materials

For all indicators, **slight differences** in the influence **between the 1.5°C and the 2°C** background scenario for all indicators can be seen especially in the years **2015 to 2040**



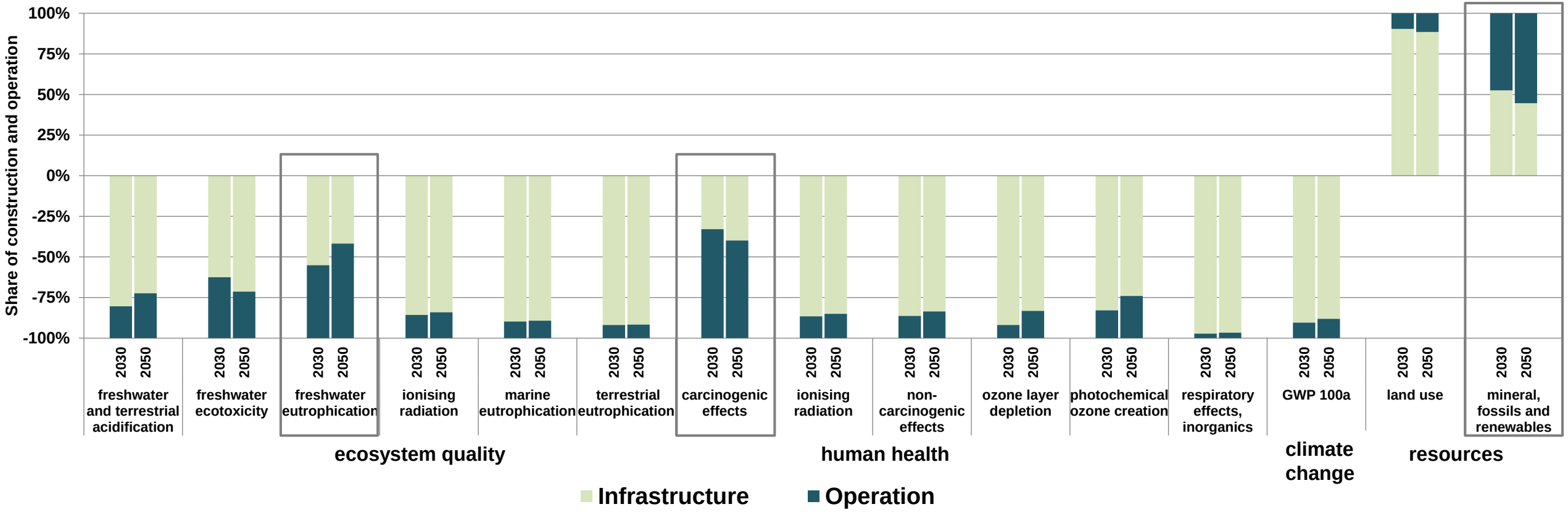
Results

Affected components of the model

The ambitious background scenarios

…mainly affect infrastructure build in the model

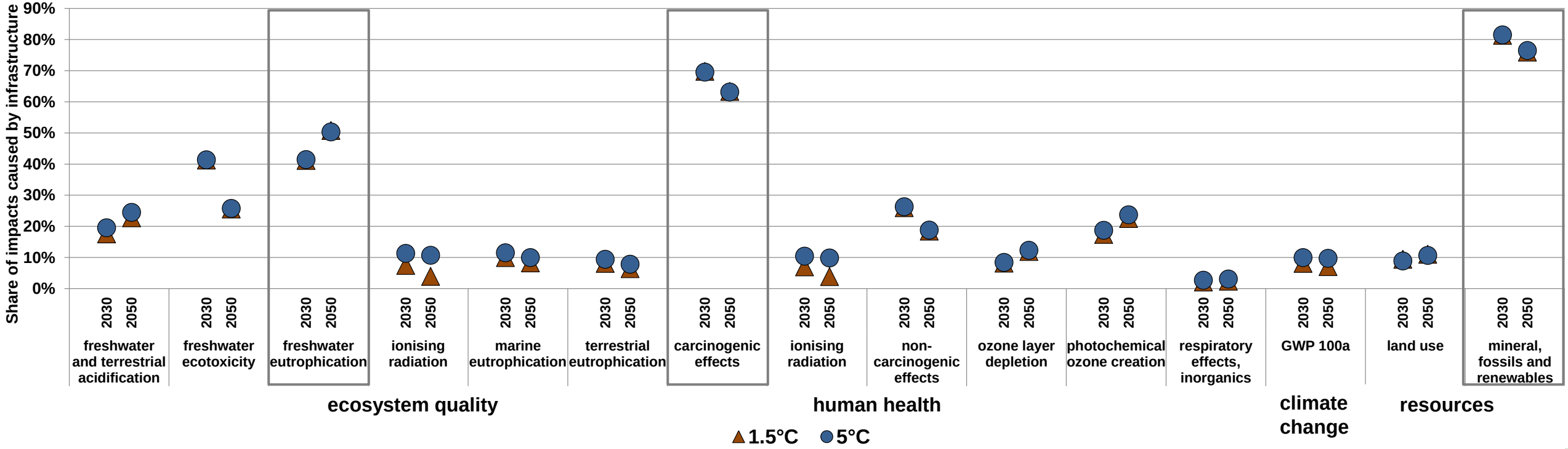
…exceptions are **‘freshwater eutrophication’, ‘carcinogenic effects’** and **‘minerals, fossils and renewables’**



Results

Share of infrastructure in total environmental impacts

- For the categories **‘freshwater eutrophication’, ‘carcinogenic effects’** and **‘mineral, fossils and renewables’** infrastructure accounts for between **~40% and ~81%** of all impacts
- For **other indicators**, **infrastructure** accounts for only a **small proportion** of the total environmental impacts
- The **5°C** scenario increases the **share of the infrastructure** in the total environmental impacts for almost all categories, but the **overall negative impacts are relatively small**



Take away

We can quantitatively show that

- **Changes in the global electricity mix**

... have a significant **positive effect** on the environmental footprint of German energy scenarios for **some impact categories**

Especially for **‘ionizing radiation’, ’freshwater and terrestrial acidification’** and **‘GWP100’**

... mainly affects the **construction of the infrastructure** in the model, which, however, accounts for only a **small proportion** of the total environmental impacts of the cross-sectoral scenario

Note that indicators dependent on the **operation** also integrate e.g. the entire **infrastructure of fuel provision**

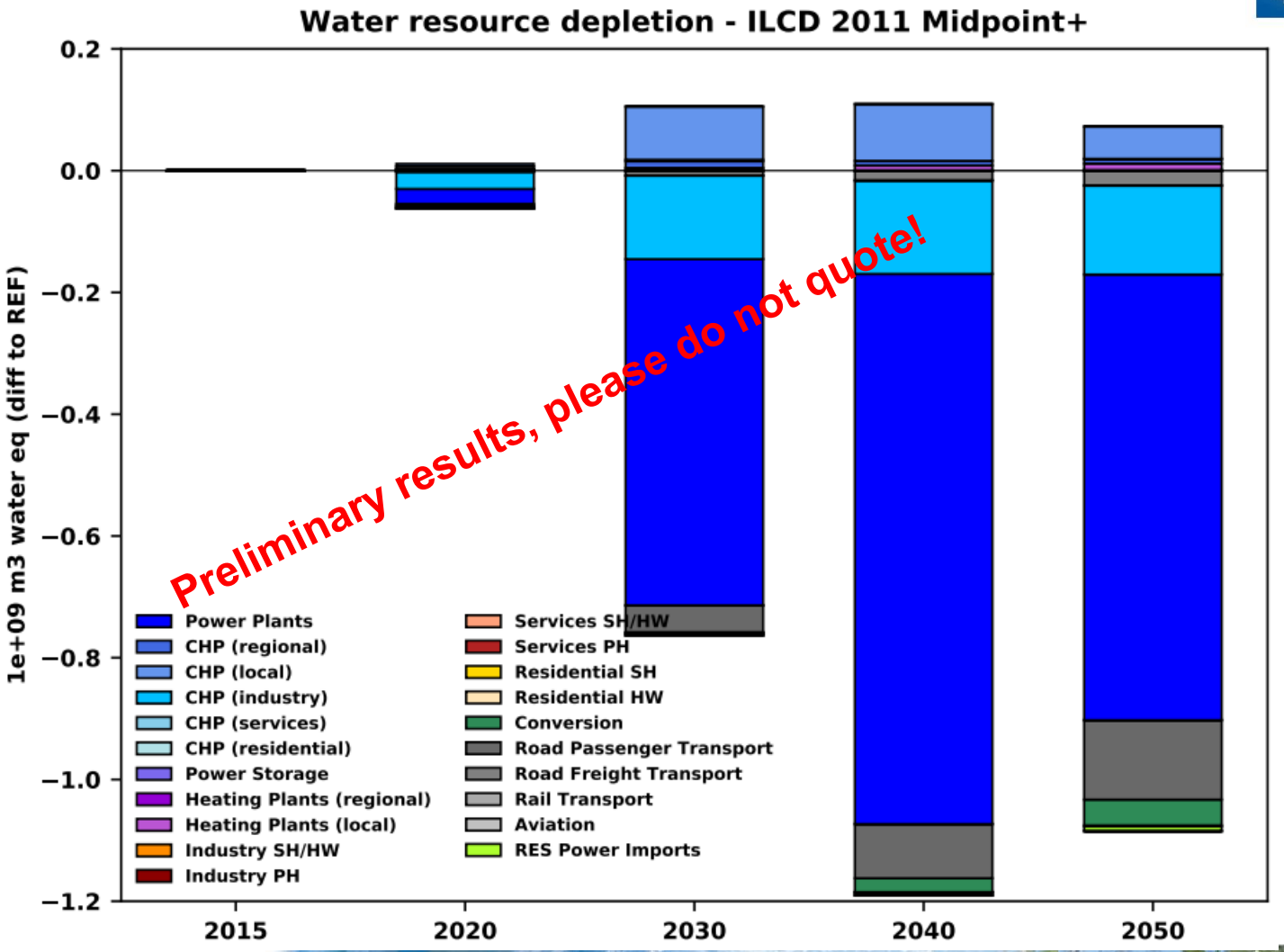
The limitations and challenges in assessing the impact of background changes on the foreground system include that

...only scenarios for the global electricity mix were integrated, but **heat, transport and material extraction processes** are **kept unchanged**

…the results depend very much on the model and **scenario (and the respective technologies)** assessed and the **LCI database and data from literature** used

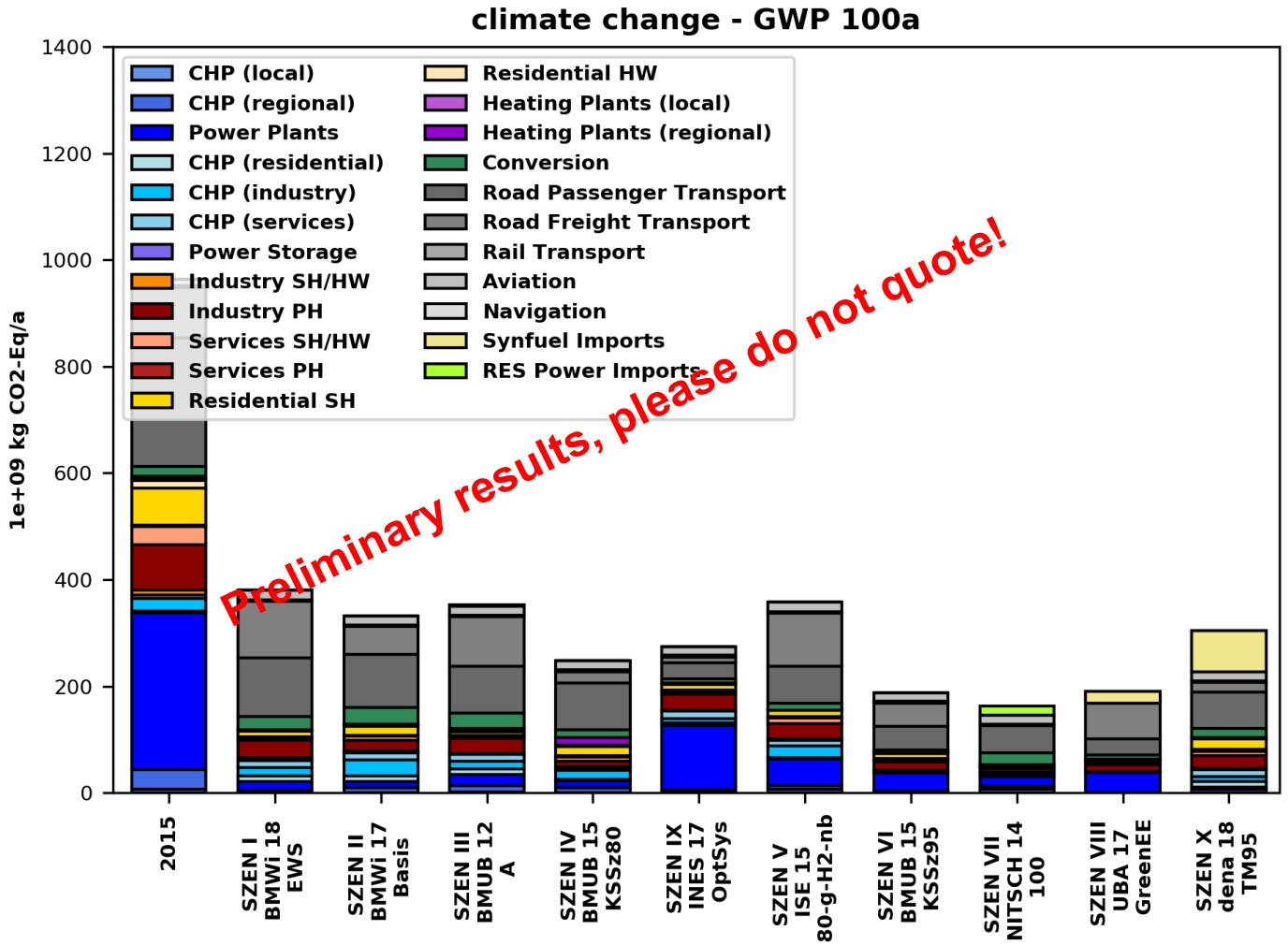
Outlook

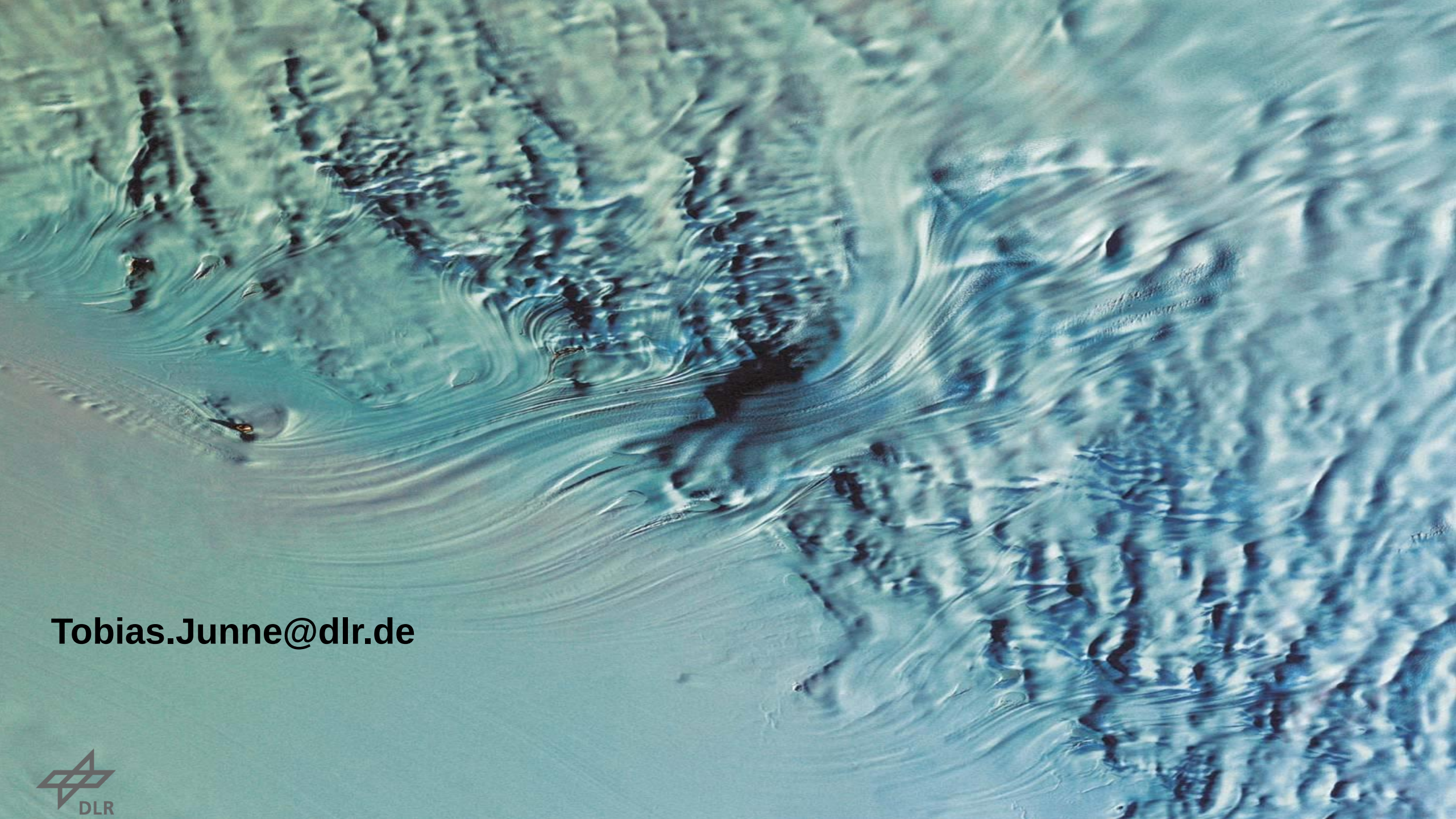
Comparison with reference scenarios (REF)



Outlook

Comparison of various ambitious scenarios





Tobias.Junne@dlr.de