# LCA-based environmental impacts of transformation strategies for the German energy system

## Methodological approach and main findings

**Tobias Junne (DLR) and the InNOSys Team**

InNOSys Final Workshop
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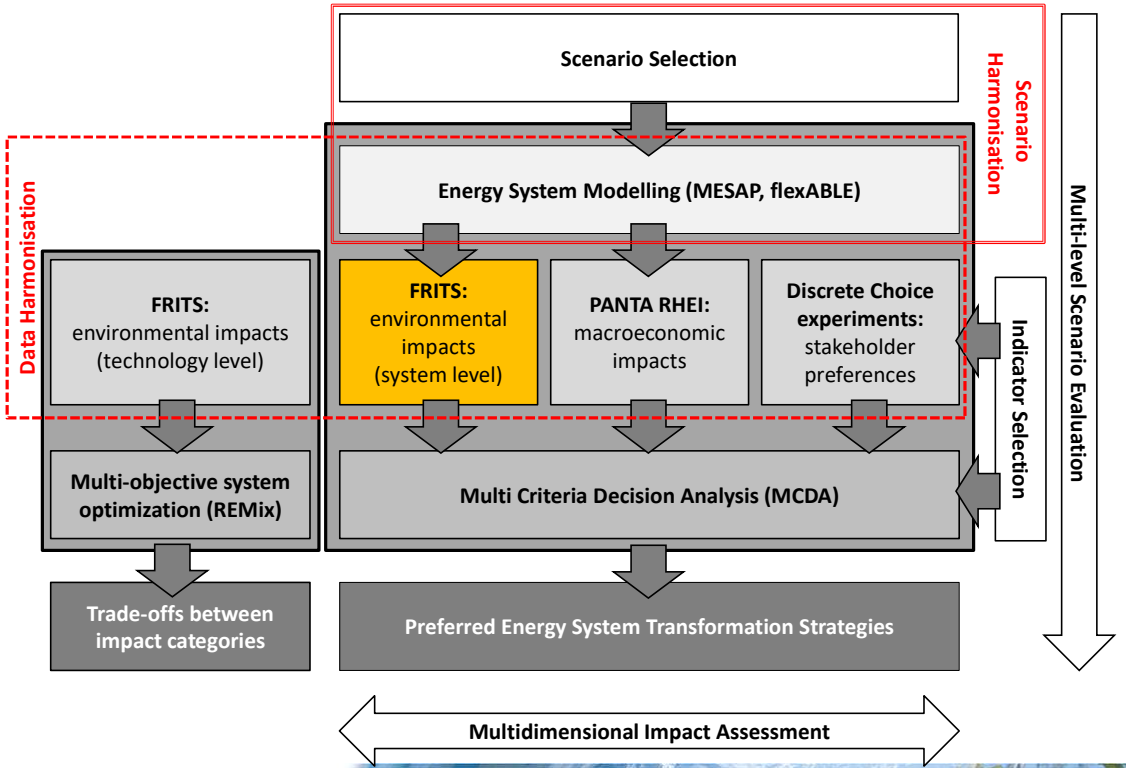
Supported by:

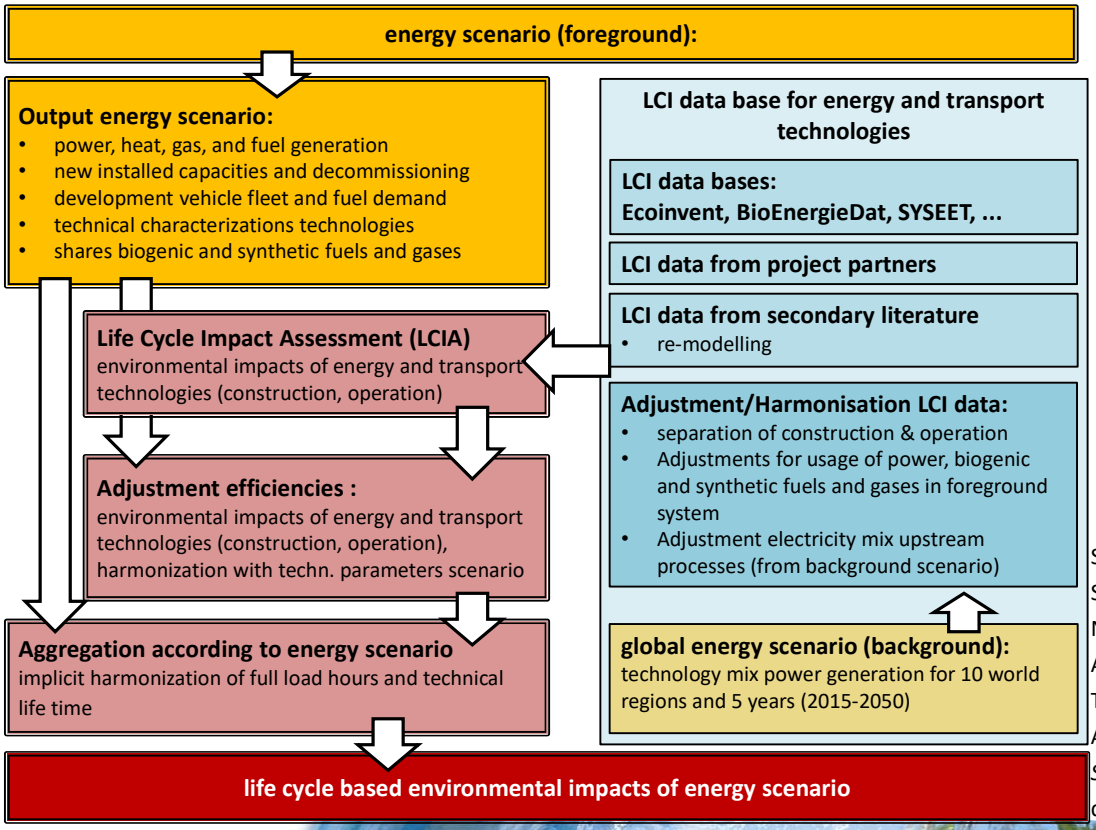
Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

# Impact assessment of the harmonized scenarios



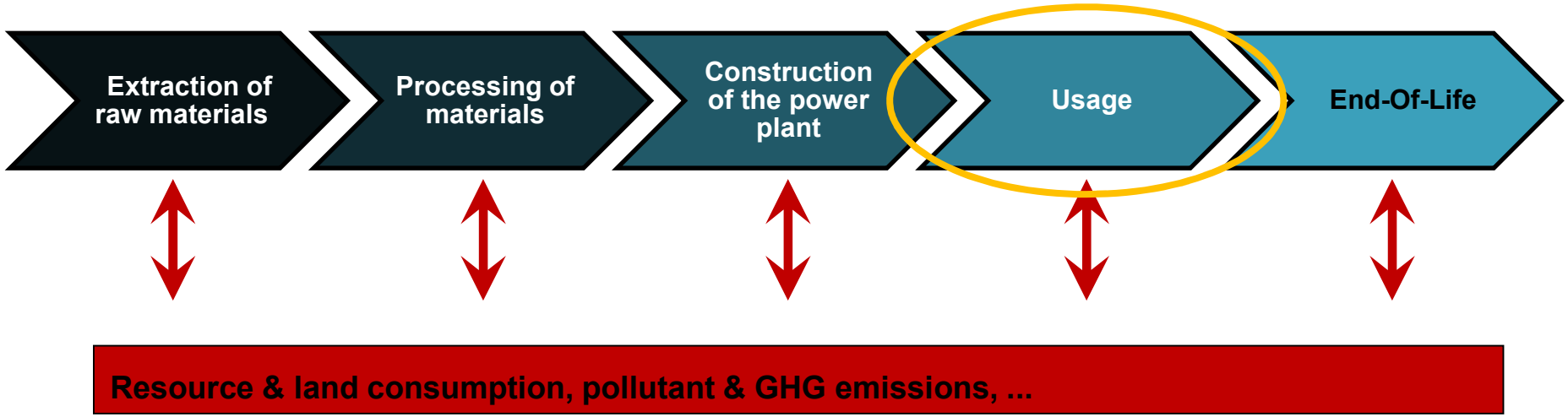

# Introducing FRITS




Source: Junne, T.; Simon, S.; Buchgeister, J.; Saiger, M.; Baumann, M.; Haase, M.; Wulf, C.; Naegler, T. Environmental Sustainability Assessment of Multi-Sectoral Energy Transformation Pathways: Methodological Approach and Case Study for Germany. *Sustain.* 2020, *12*, 8225, doi:10.3390/su12198225.

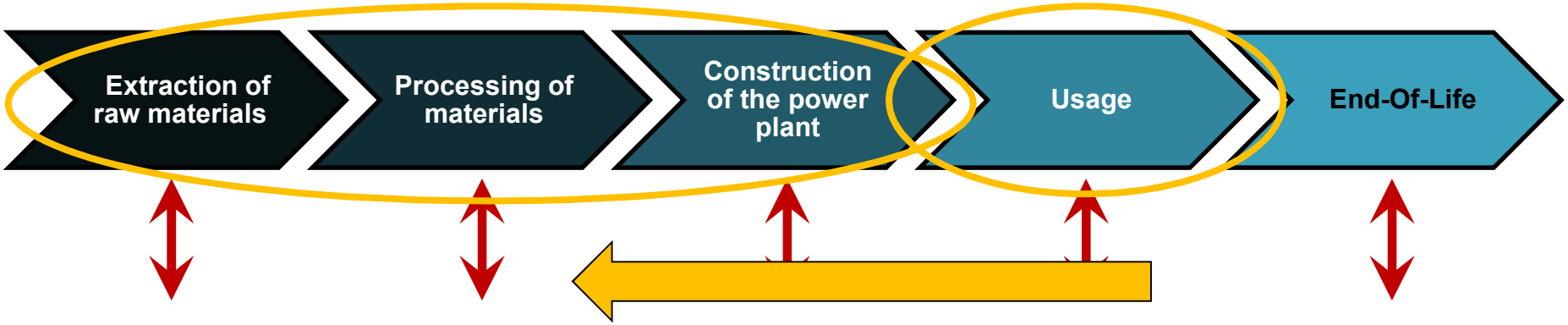
# FRITS – adaption of LCI data

In **energy system models**, the quantification of environmental impacts has so far mostly been limited to **$CO_2$ emissions** during the **use phase** of energy technologies




# FRITS – adaption of LCI data

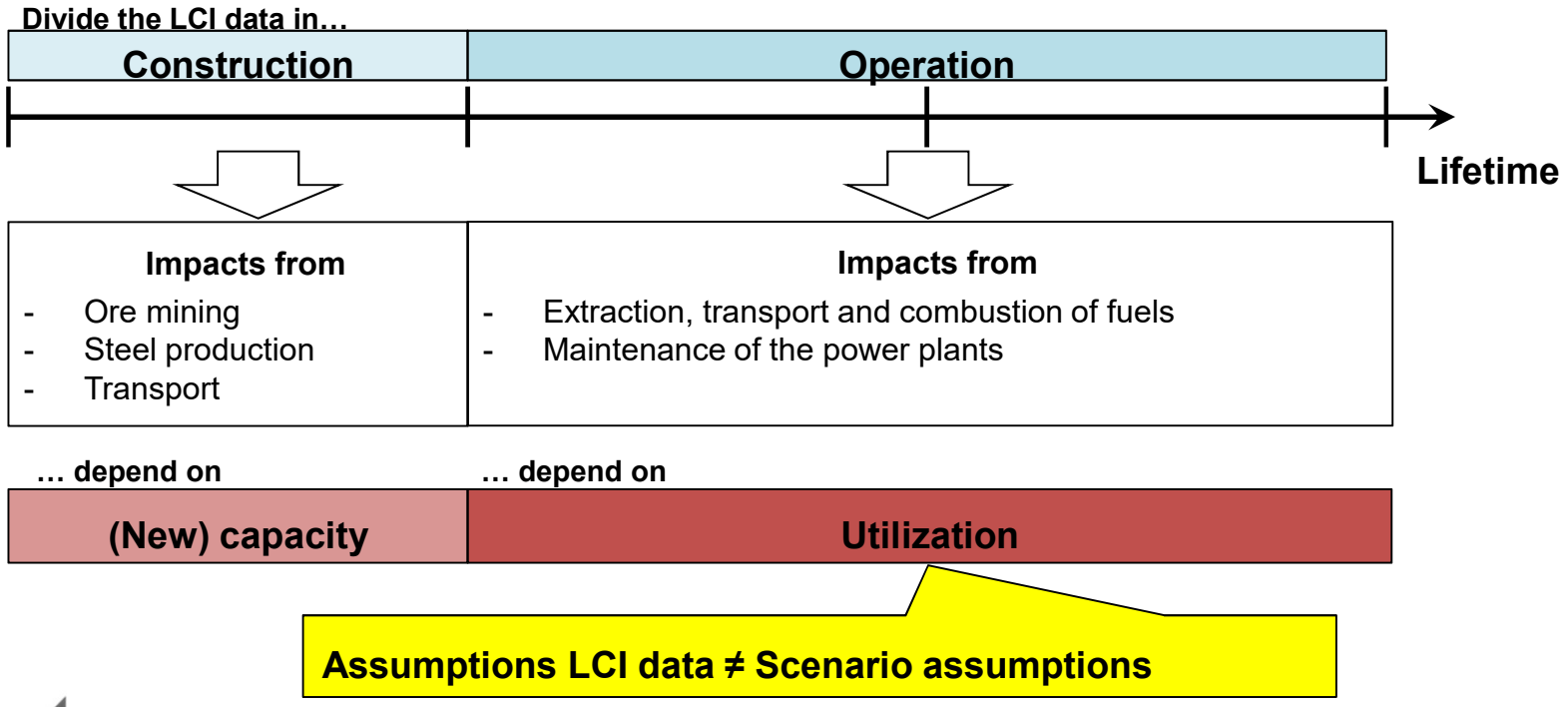
Consideration of environmental impacts from **all** phases of a product's life-cycle including upstream and downstream processes



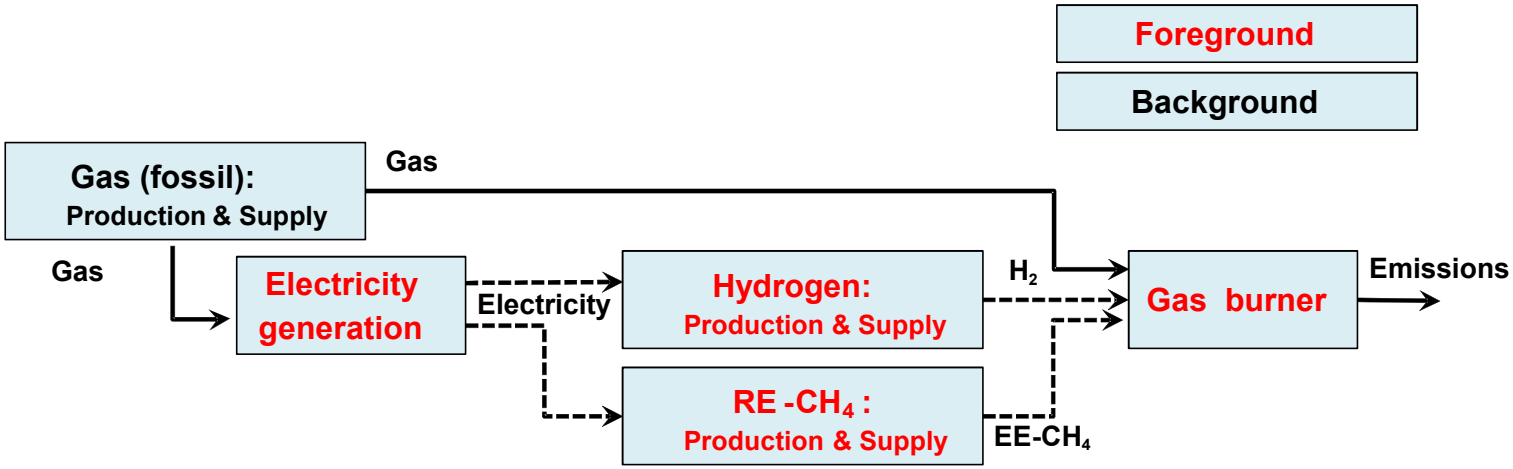

**Shifting the burden of environmental impacts during the transformation of the energy system:**

**Use-phase → Construction (plus upstream supply chain)**

# FRITS – adaption of LCI data




# FRITS – adaption of LCI data

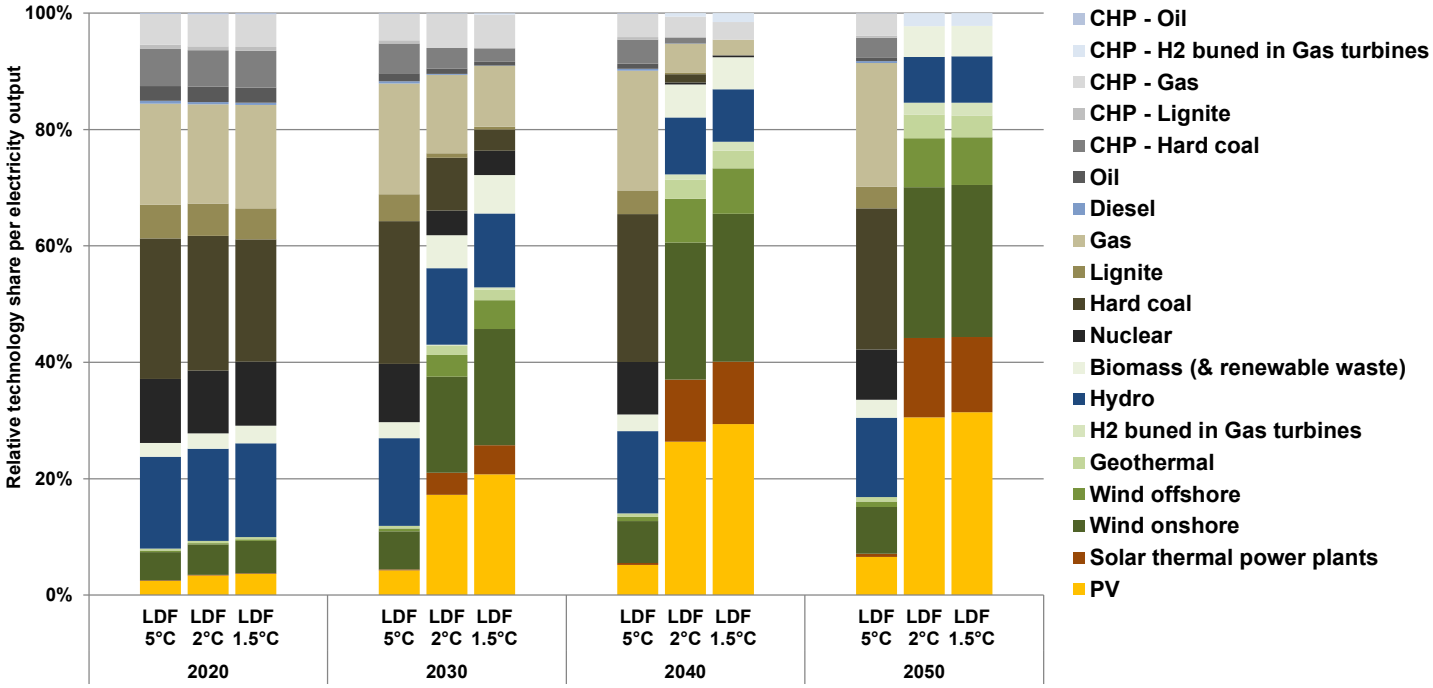


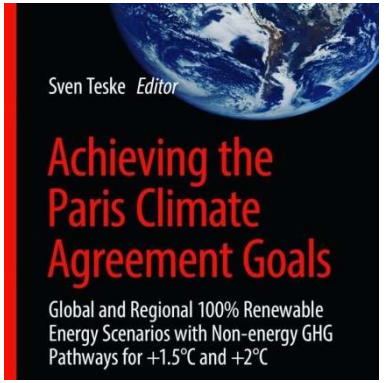

If **energy sources** are **generated in the foreground system** (e.g. electricity and synthetic gases & fuels):

- **Separate the input** of these energy sources **from** the (end-) consumption **technologies**
- **Environmental impact** from these energy sources **separately determined in other sectors** (e.g. conversion sector)

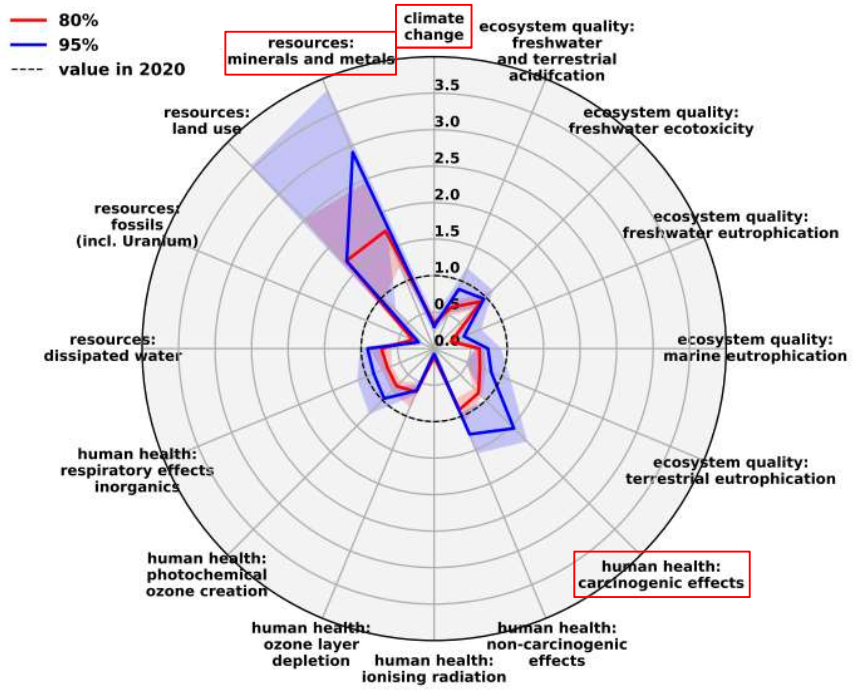
⇨ **Adjustment of energy carrier mix** to scenario assumptions possible

# Integration of future electricity supply in the background LCI database




# Development of the environmental impacts between the scenario groups between 2050 and 2020

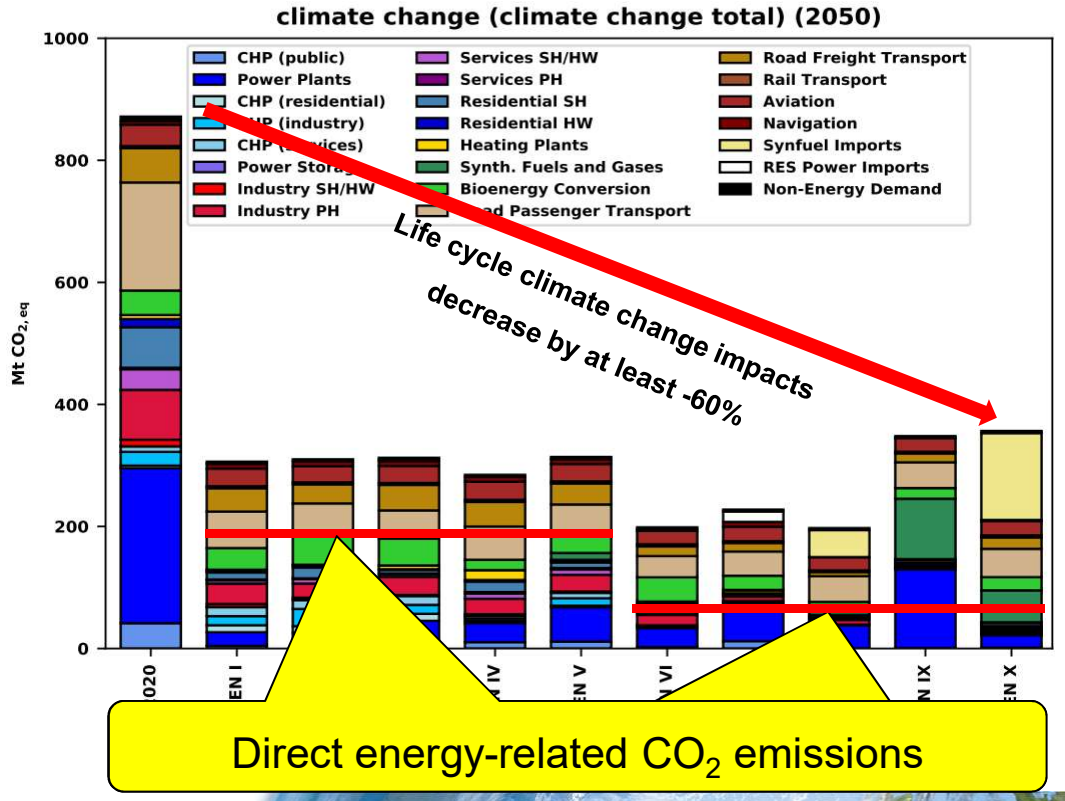



**Motivation:**

- Which **co-benefits and adverse side effects** could occur during the **transformation** towards a climate friendly **energy system**?
- What are the **sectoral drivers** of environmental impacts compared to today?
- Which **technologies** are responsible for the environmental impacts?
- Which **end-use applications**, as the **ultimate polluter**, are driving the environmental impacts?

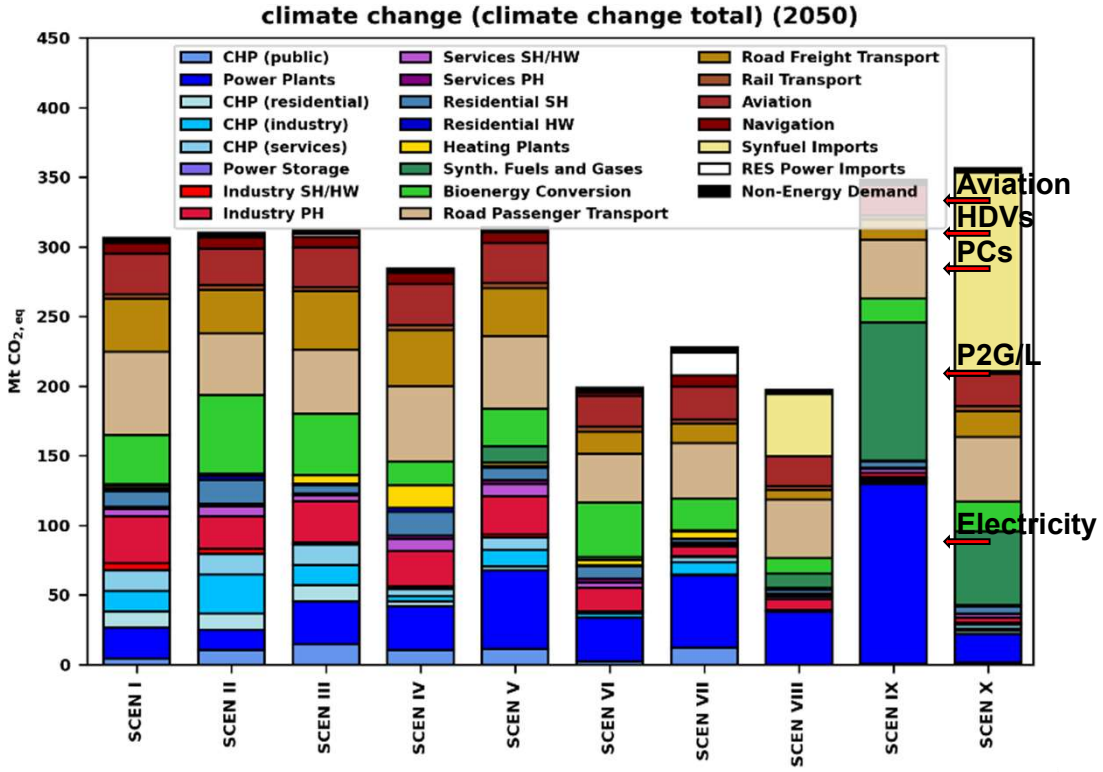
# Climate change impacts

## Sector perspective



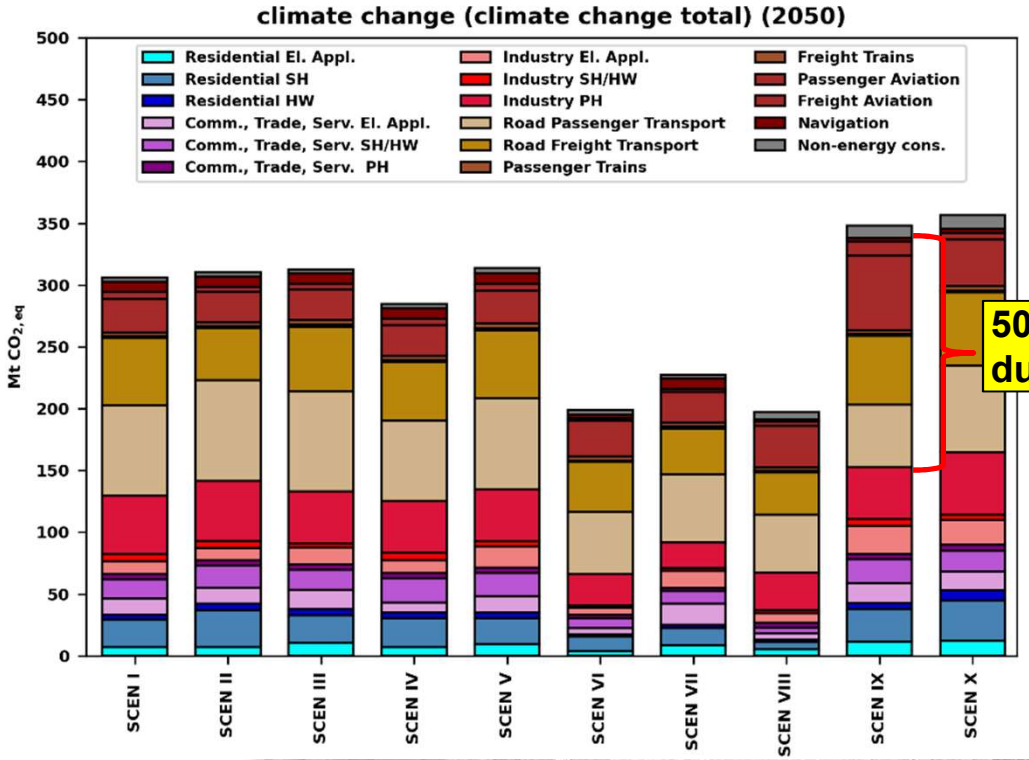

# Climate change impacts

## Sector perspective



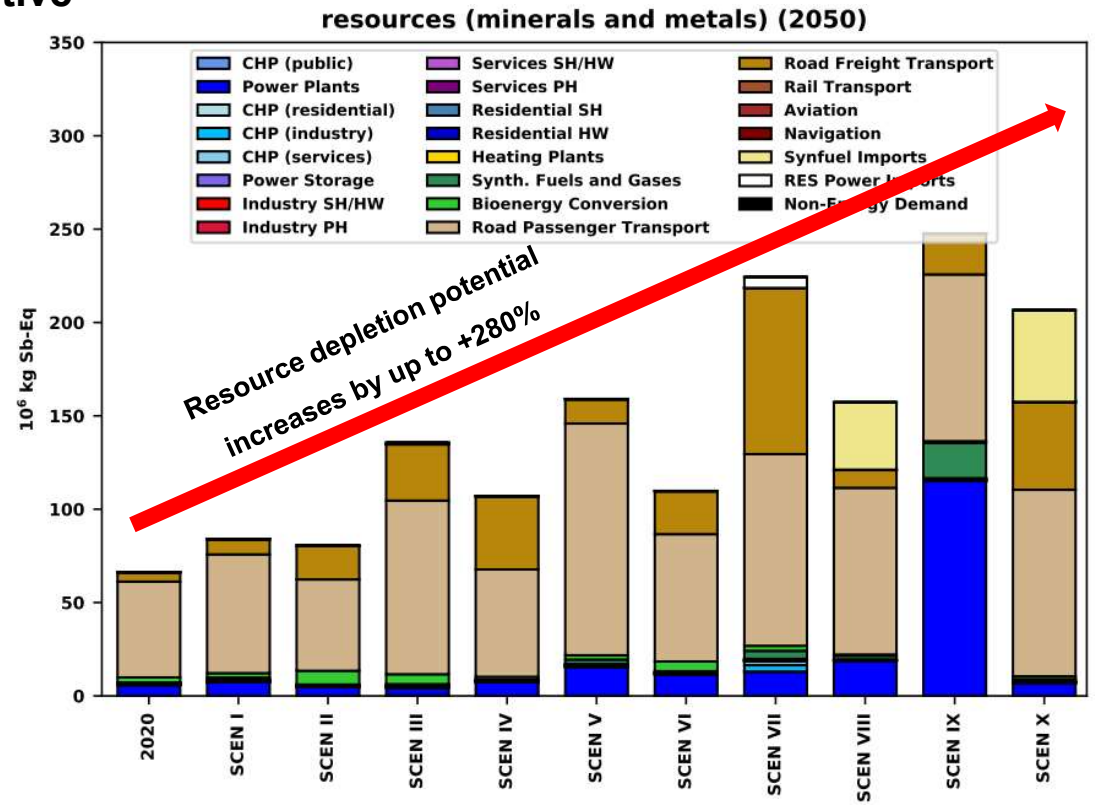

# Climate change impacts

## End-use application perspective



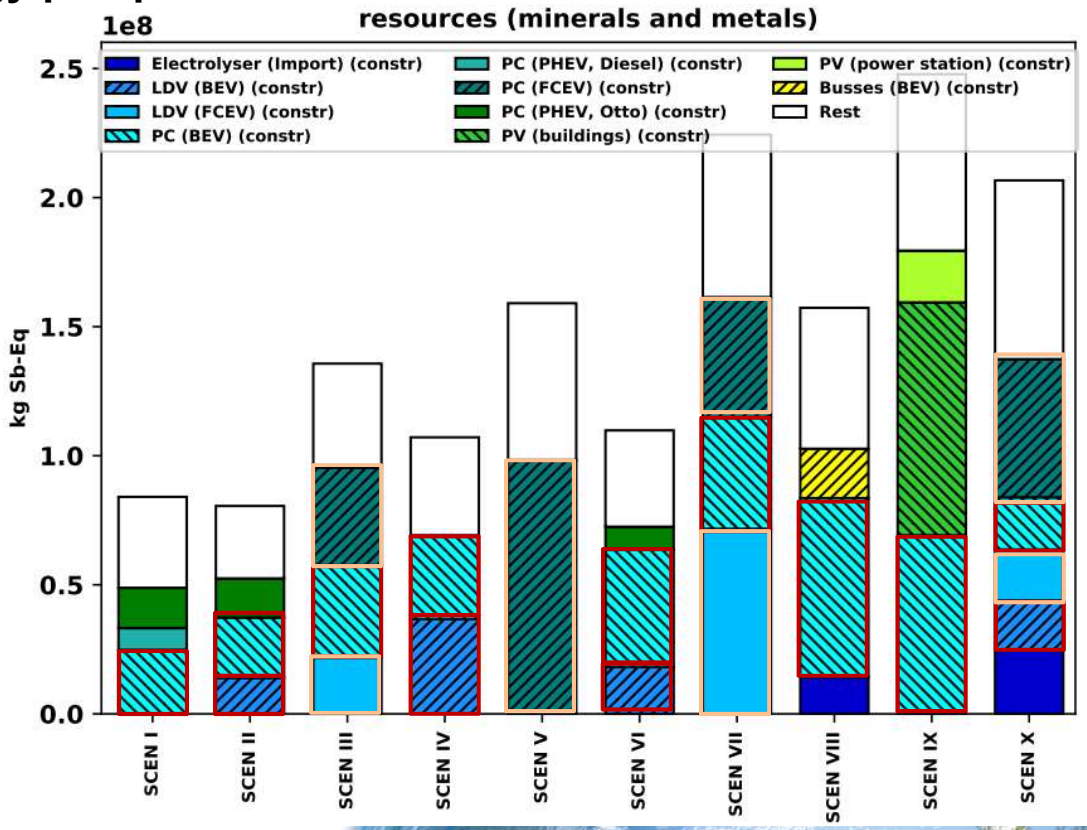

# Resource depletion potential

## Sector perspective




# Resource depletion potential

## Technology perspective



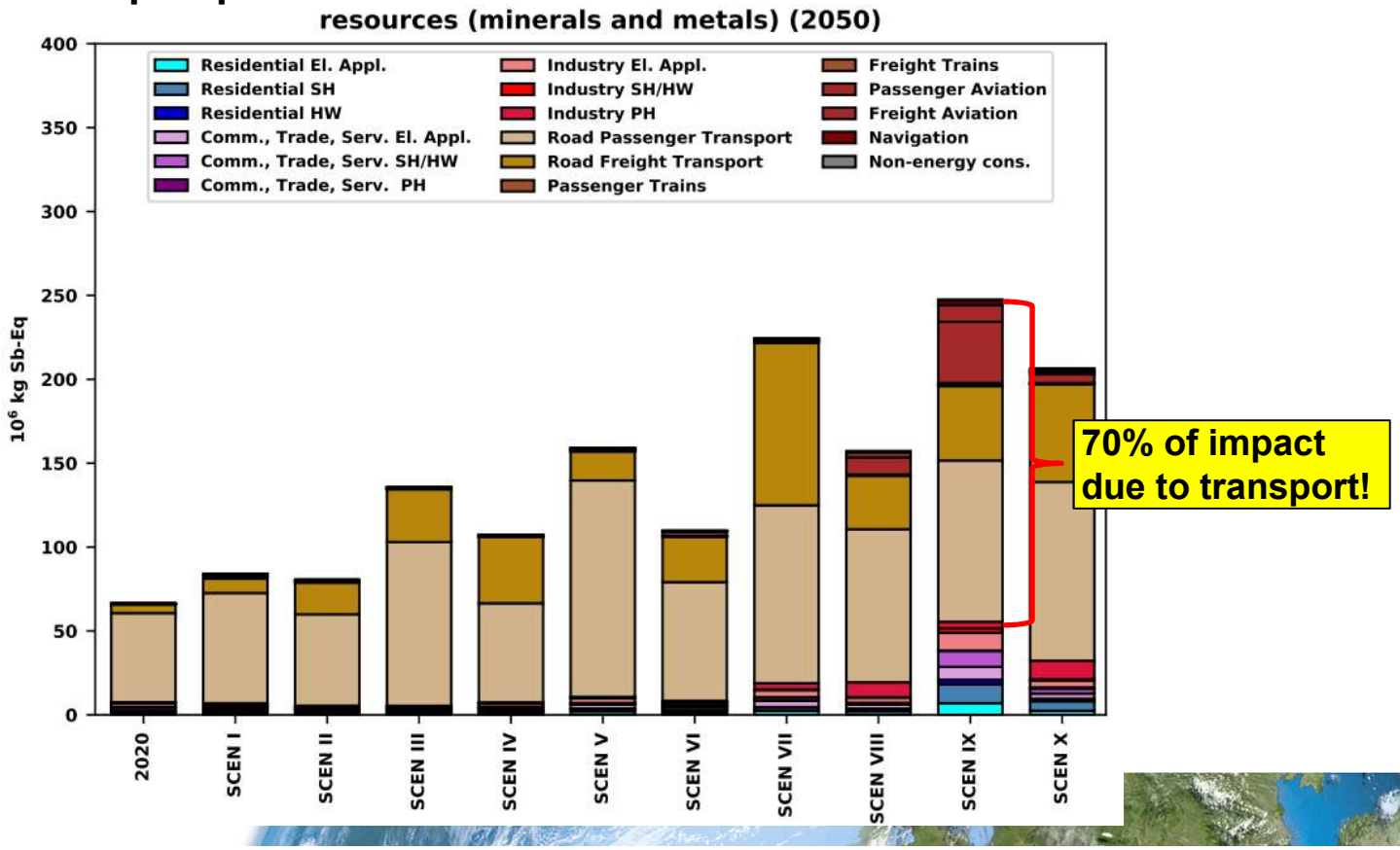

**The impact is mainy driven by the construction phase of …**

… BEVs (PC, HDVs)

… FCEVs (PC, HDVs)

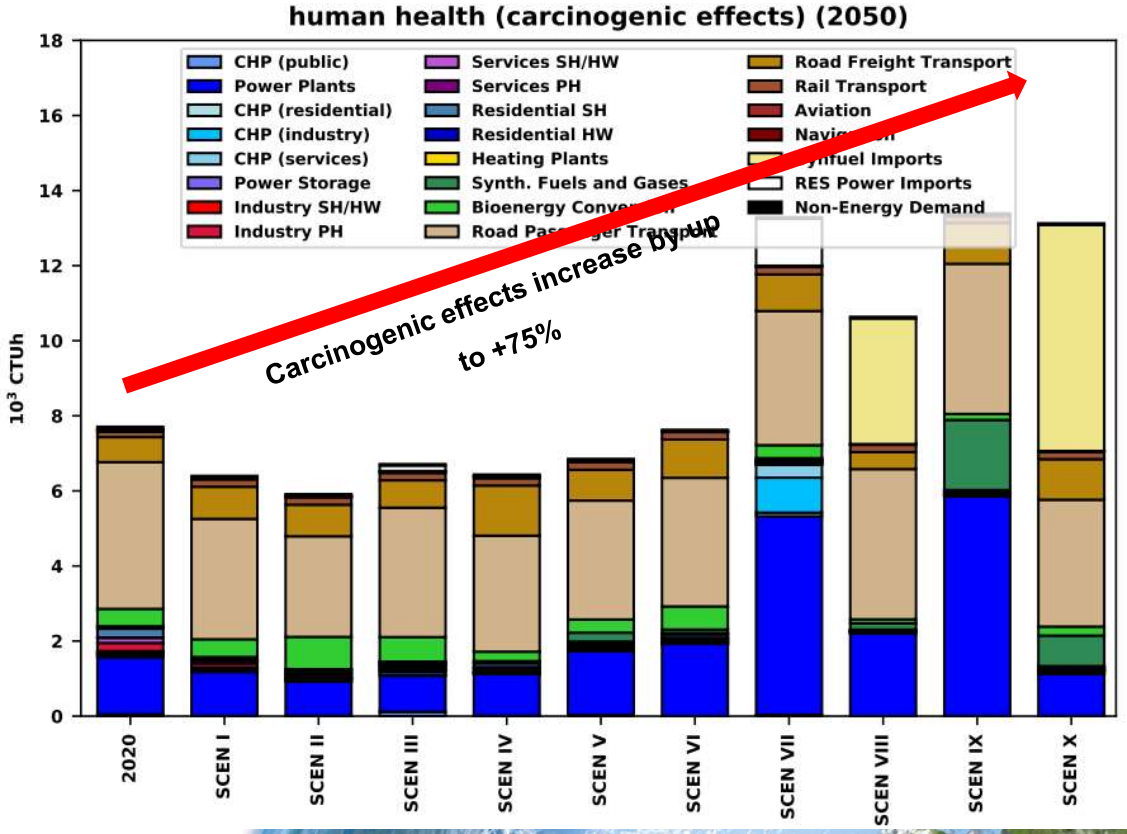
# Resource depletion potential

## End-use application perspective



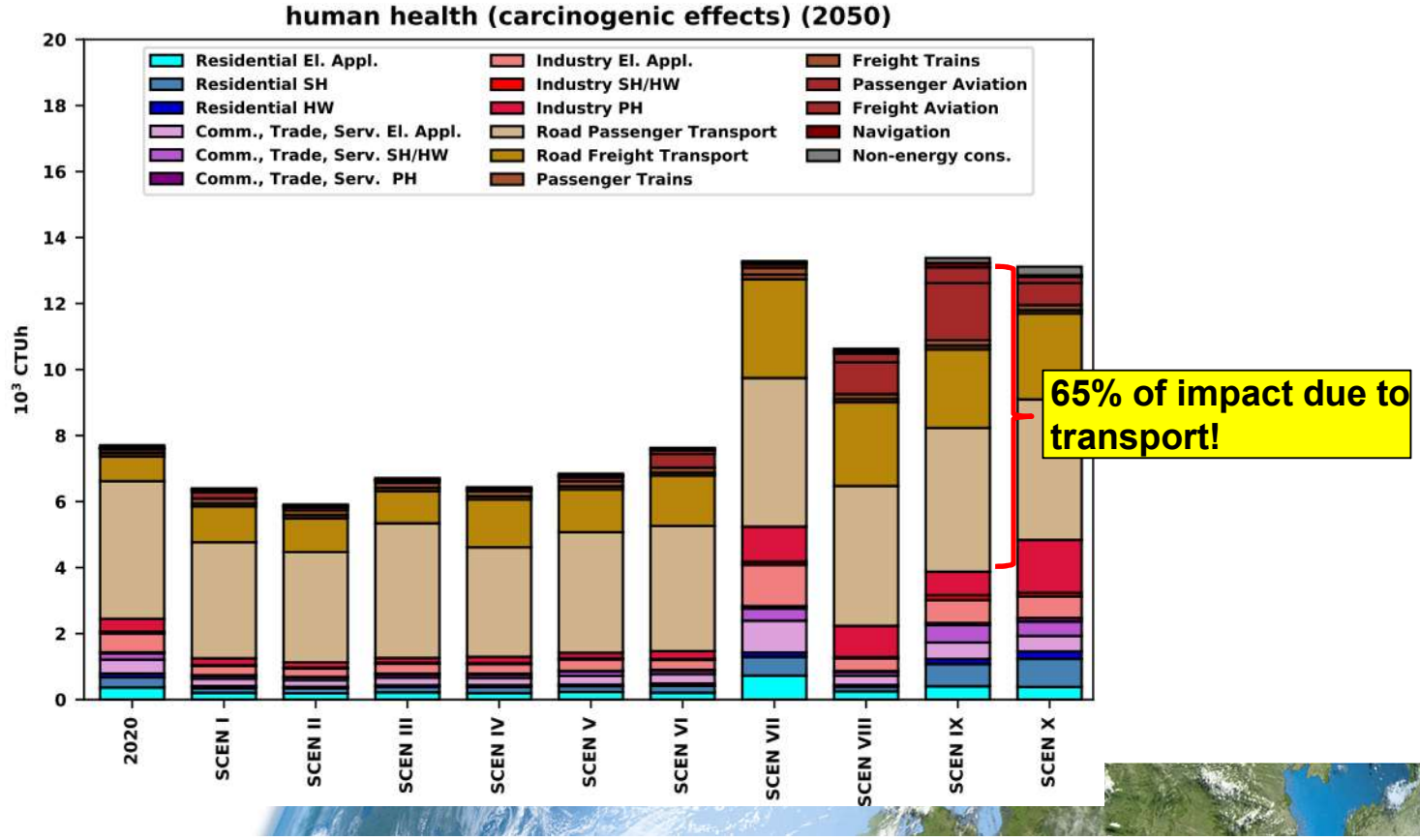
# Carcinogenic effects

## Sector perspective



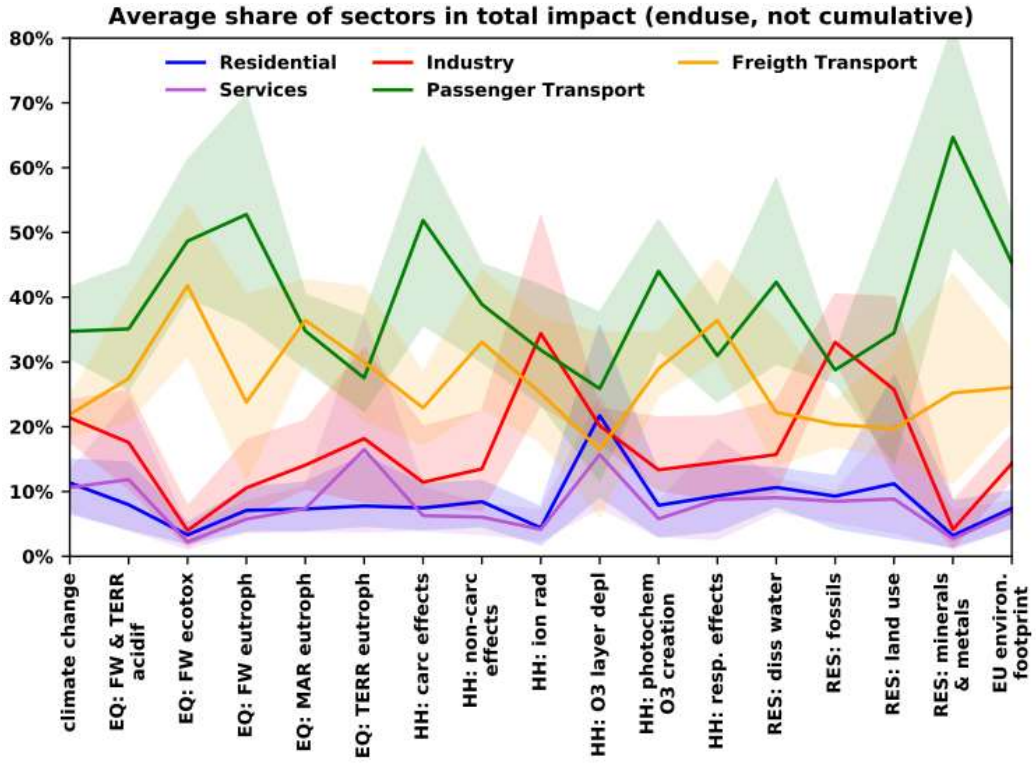
# Carcinogenic effects

## End-use application perspective

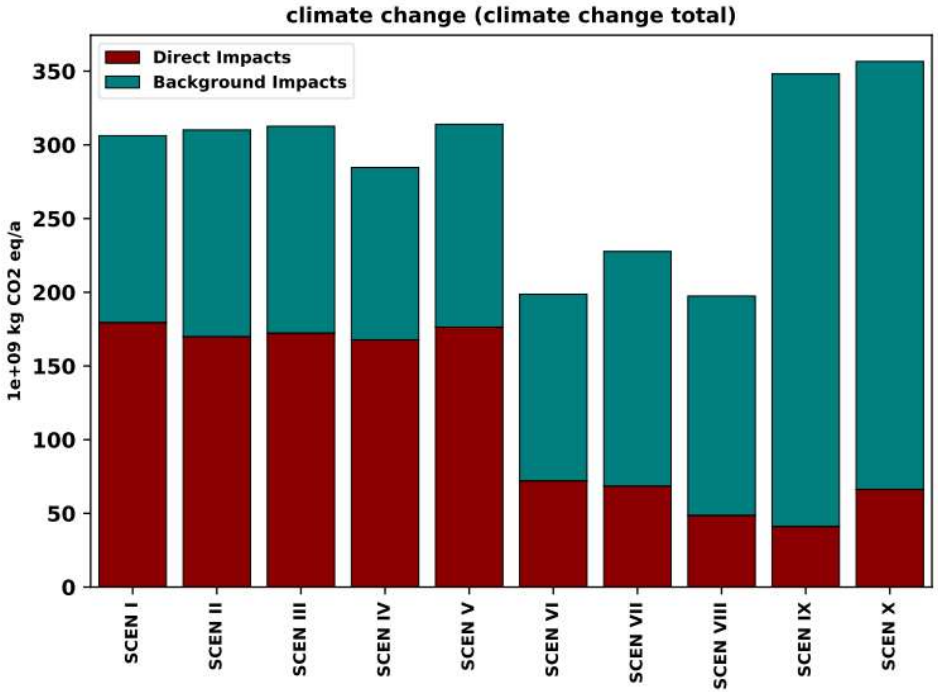


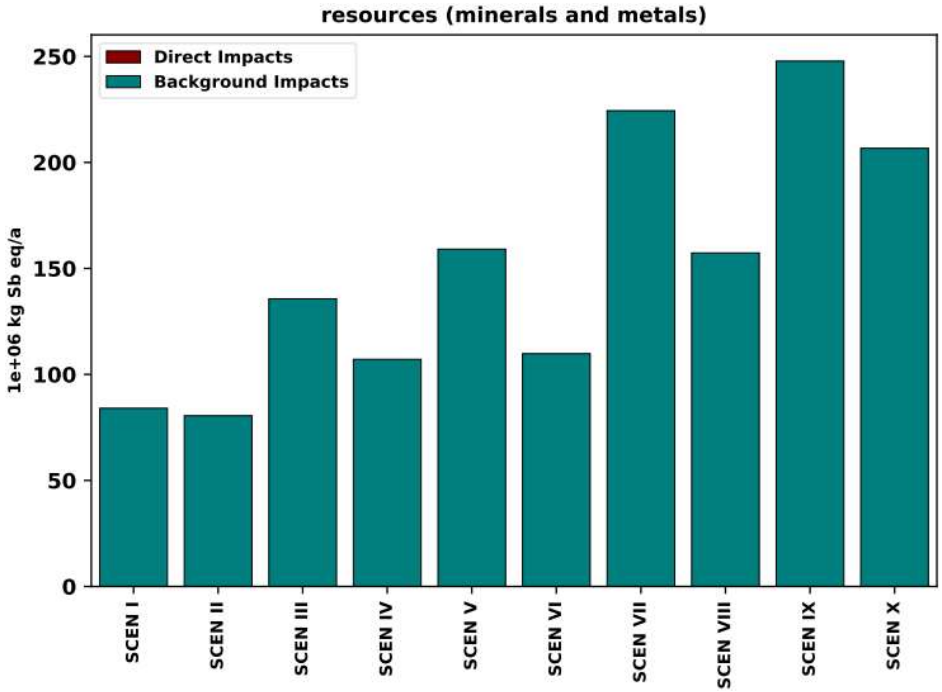
# Breakdown of environmental impacts

## End-use application perspective

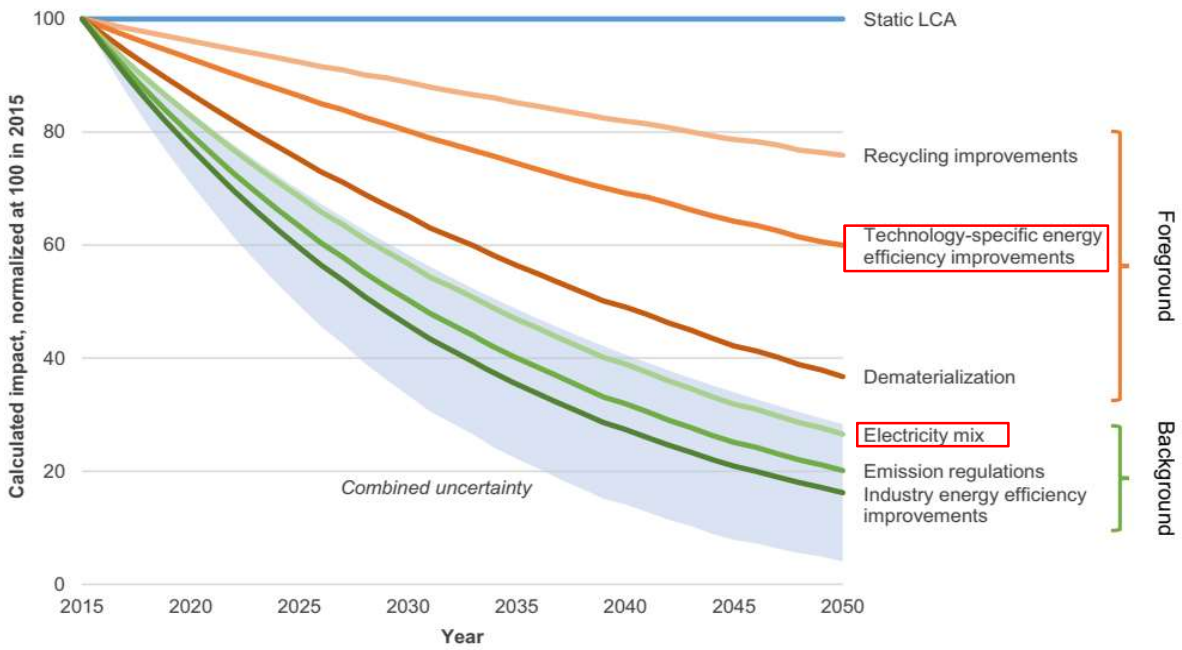



# The life-cycle perspective matters




# Outlook for further work on FRITS




- Better align foreground LCI data with technologies in the ESM
  - Matching the data on which the techno-economic assumptions are based with the LCI data or vice versa
- Integrate further features from scenarios for prospective LCA
  - Adaption of resource extraction and processing, heat and transport supply

Source of figure: L. Vandepaer, L. Gibon, T. The integration of energy scenarios into LCA: LCM2017 Conference Workshop, Luxembourg, September 5, 2017, The International Journal of Life Cycle Assessment, vol. 23, no. 4, pp. 970–977, 2018.

# Take-away

- **Climate-friendly transformation strategies** also result in a decrease of most environmental impacts but may be accompanied by a **significant increase in environmental impacts compared to today,** particularly **mineral resource depletion potential and land use, but – depending on the scenario – also others**
- The **transport sector** is responsible for the largest share of environmental impacts with respect to almost all indicators and across all scenarios
- The **environmental impacts from the upstream chain** increasingly dominate the overall environmental impacts. Considering the life-cycle perspective is therefore **crucial in future scenario assessments**
- **Future assessments** should attempt to **reduce the uncertainties** associated with coupling energy system models (ESMs) with LCIs. This concerns in particular the **data quality and prospectivity** of the LCI data used and better harmonization with the techno-economic data used in the ESMs

# Thank you very much for your attention!

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

INATECH DEPARTMENT OF SUSTAINABLE SYSTEMS ENGINEERING

Supported by:

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INEC INSTITUTE FOR INDUSTRIAL ECOLOGY PFORZHEIM

ITAS Institute for Technology Assessment and Systems Analysis

zirius Center for Interdisciplinary Risk and Innovation Studies

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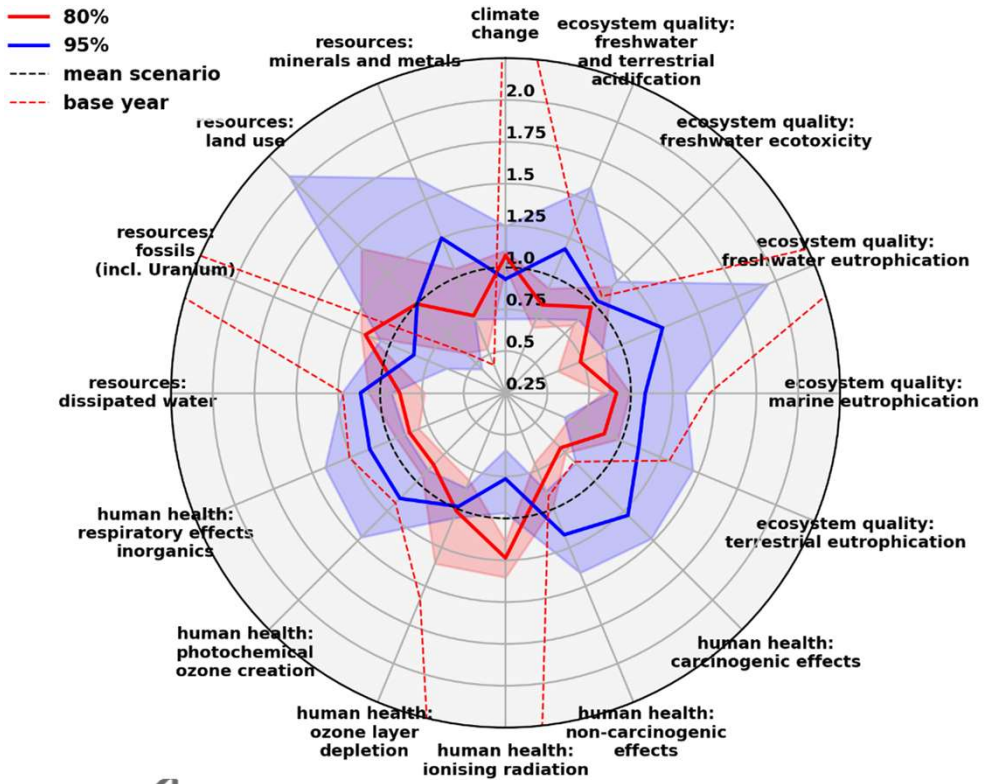
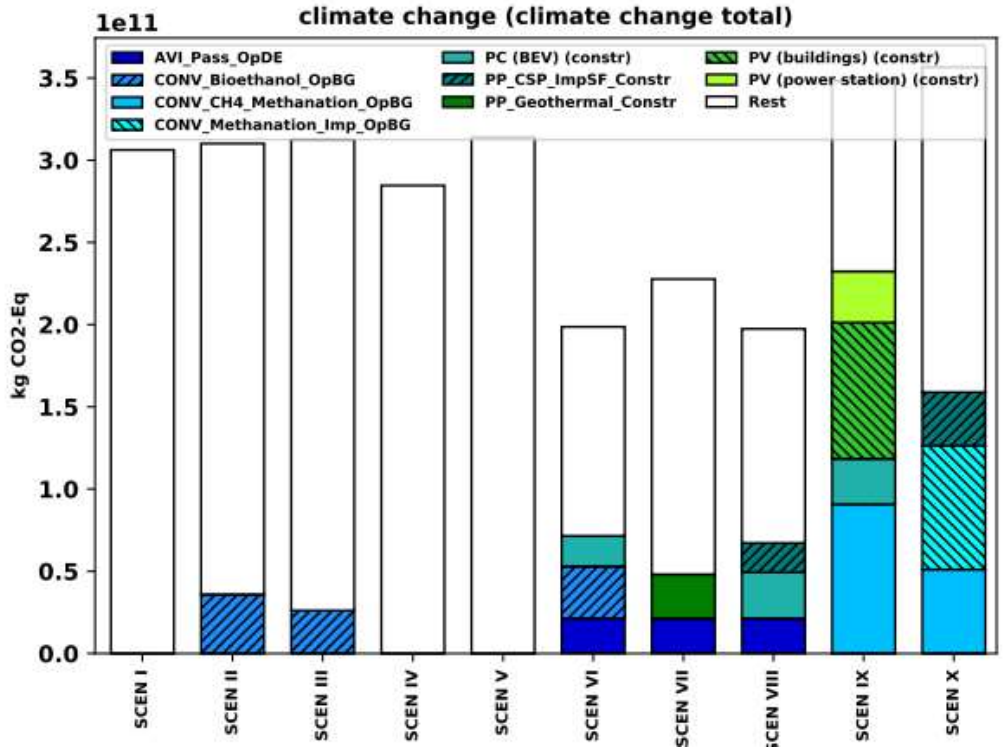
# Upcoming activities




**Motivation:**

What are the key **sectoral and technological drivers** for the increased environmental impacts of the scenarios targeting **95% $CO_2$ avoidance** compared to the scenarios targeting **80% $CO_2$ avoidance**?

# Climate change
## Technology perspective




# Carcinogenic effects

## Technology perspective