

PATHFINDER project  
**SecMOD**  
*ETH Zürich & RWTH*



**ETH** zürich



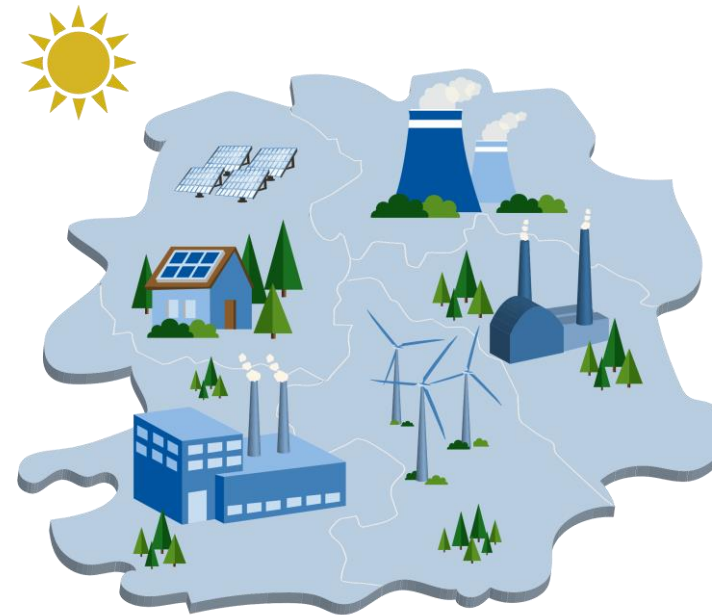
HOCHSCHULE  
LUZERN



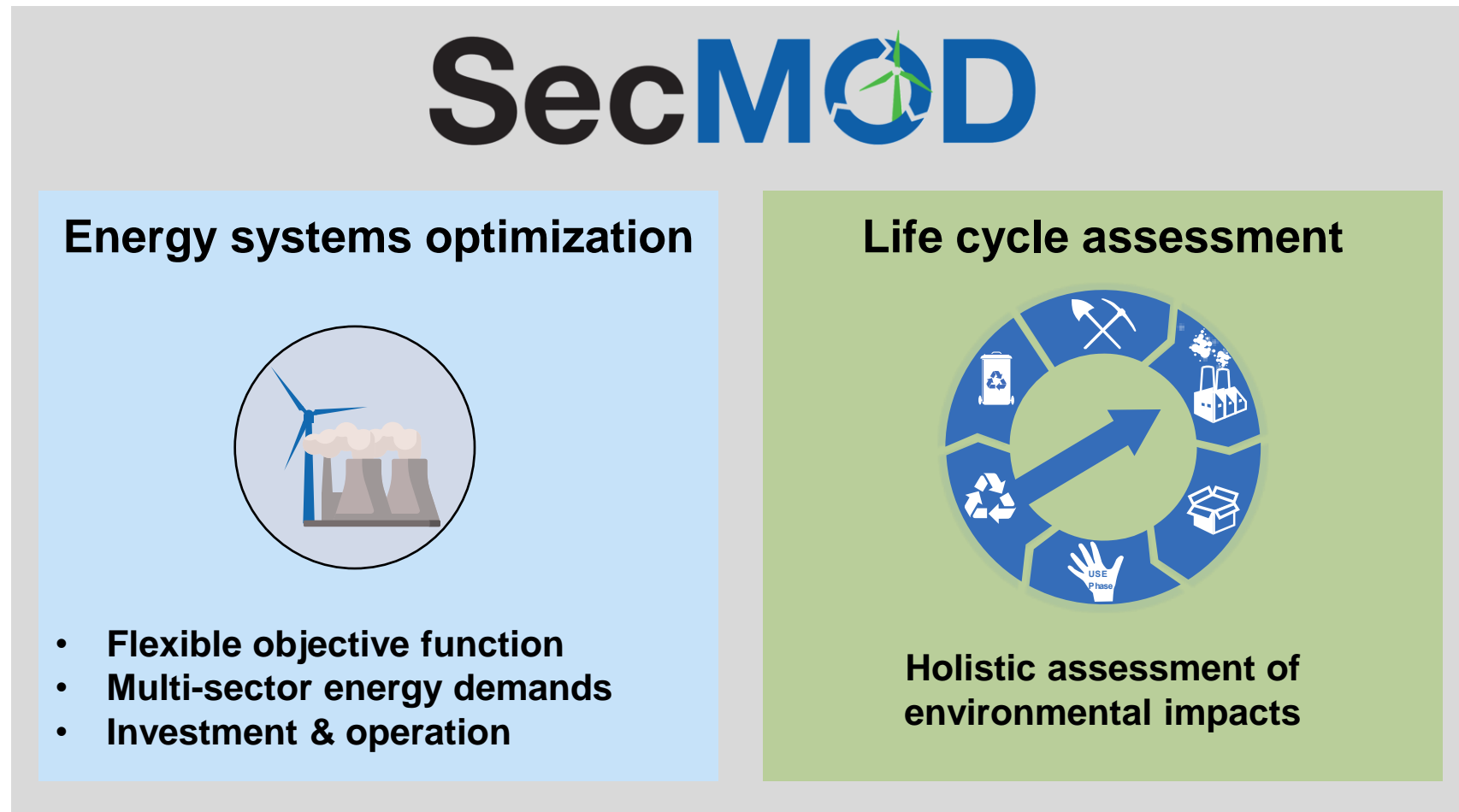
UNIVERSITÉ  
DE GENÈVE

**EPFL**

- 1 Purpose & main features
- 2 Case study
- 3 Technical details
- 4 Integration into PATHFINDER



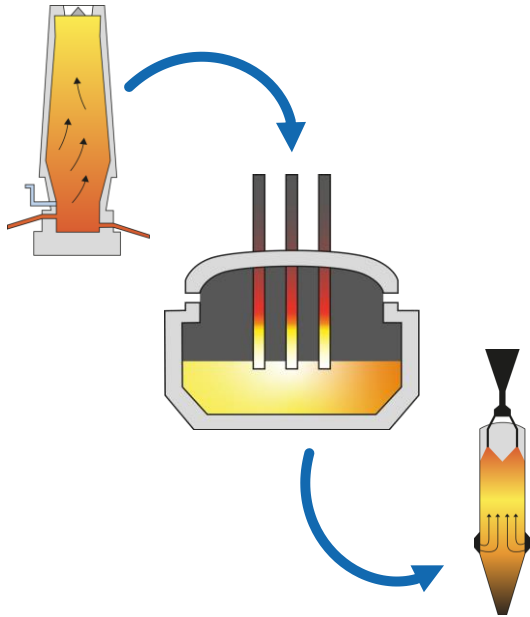
# An open-source framework for optimization & life cycle assessment of sector-coupled energy systems



# Model examples

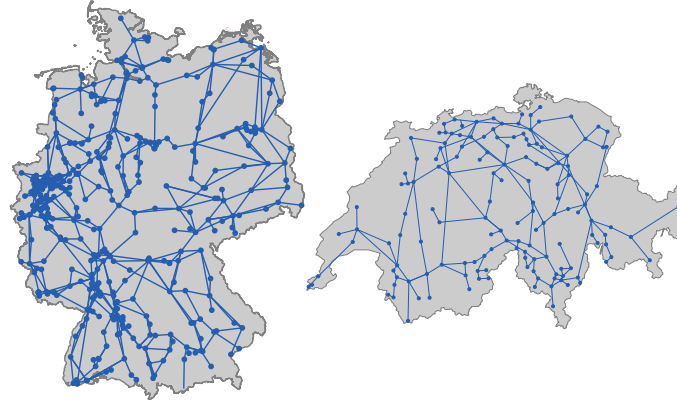
## Framework with flexible resolution

### Industrial sites



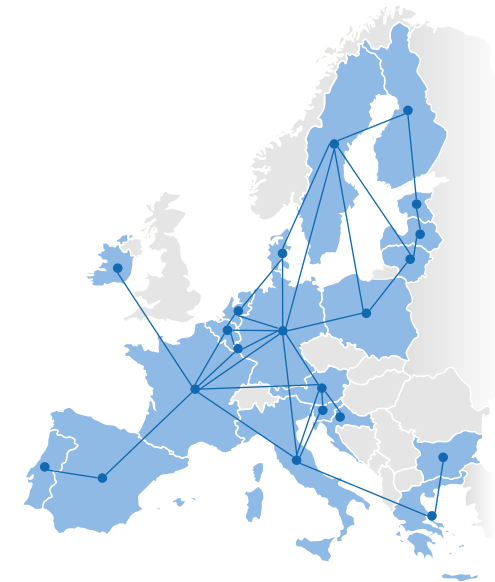
optimal production routes  
in steel plants<sup>1</sup>

### National Energy Systems



optimal transition pathways & LCA  
of national energy systems<sup>2</sup>

### International Energy Systems



transition of the European  
electricity system<sup>3</sup>

<sup>1</sup> Reinert et al. *Ein Open-Source Software-Framework zur Entwicklung emissionsarmer industrieller Energiesystem*. December 9, 2020.

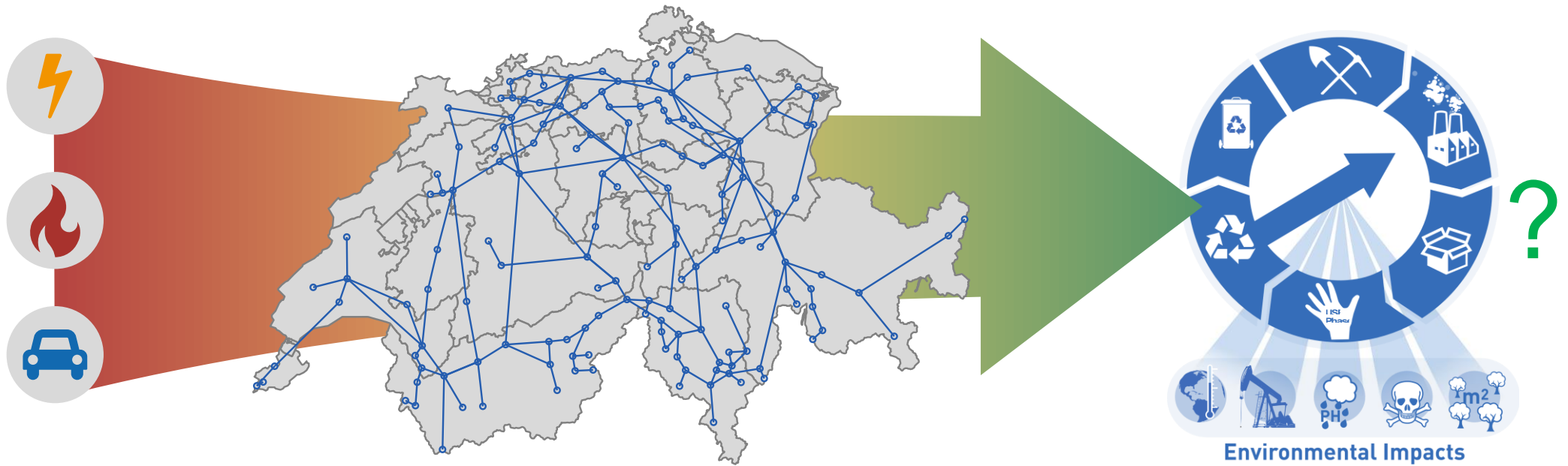
[https://www.in4climate.nrw/fileadmin/Veranstaltungen/2020/20201204\\_Statuskonferenz/Pr%C3%A4sentationen\\_Session\\_2/04122020-statuskonferenz-reinert.pdf](https://www.in4climate.nrw/fileadmin/Veranstaltungen/2020/20201204_Statuskonferenz/Pr%C3%A4sentationen_Session_2/04122020-statuskonferenz-reinert.pdf)

<sup>2</sup> Baumgärtner et al. *Life-Cycle Assessment of Sector-Coupled National Energy Systems: Environmental Impacts of Electricity, Heat, and Transportation in Germany Till 2050*. *Frontiers in Energy Research* 2021;9.

Reinert et al. *Environmental impacts of the future German energy system from integrated energy systems optimization and dynamic life cycle assessment*. In *Computers & Chemical Engineering* 2021;153:107406.

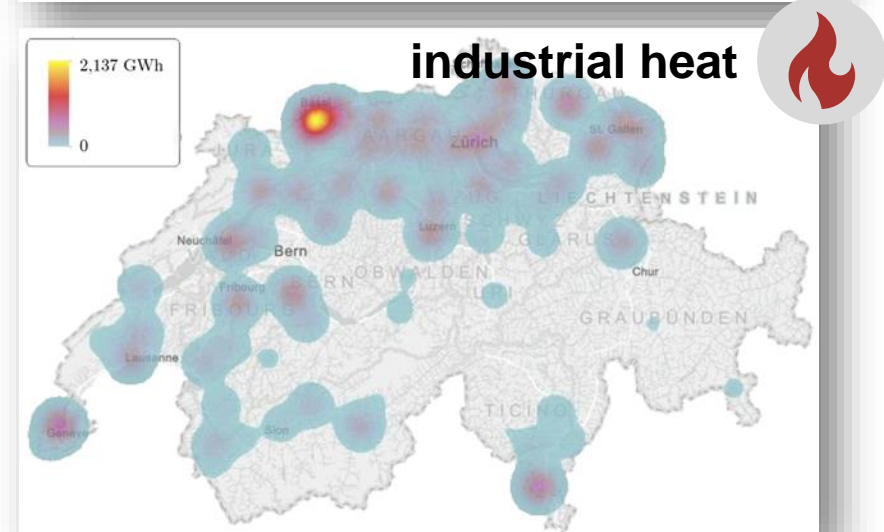
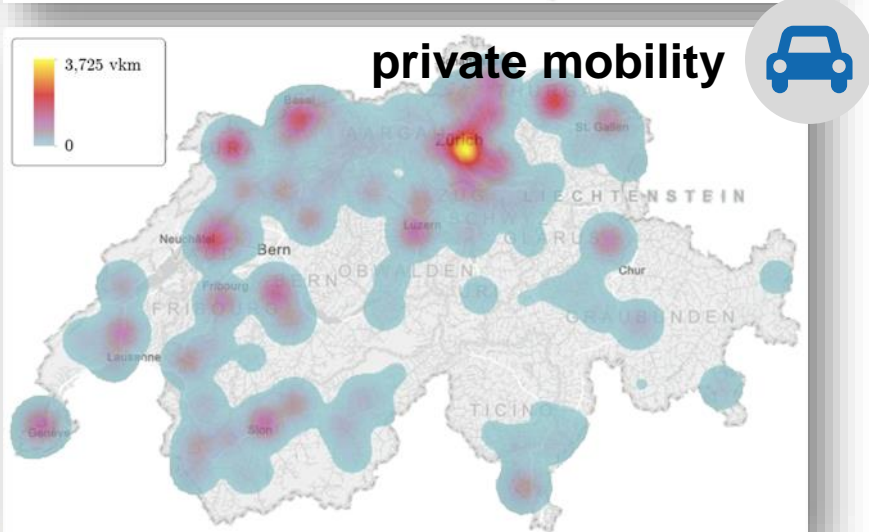
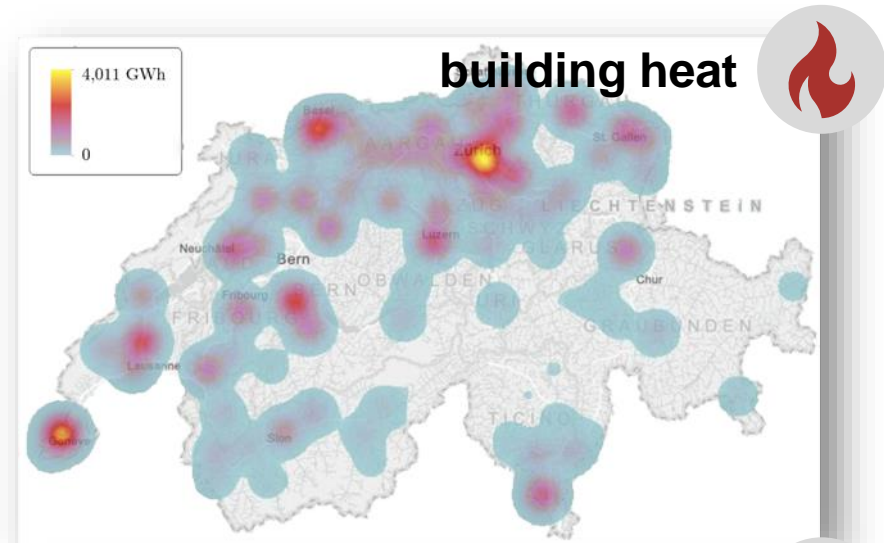
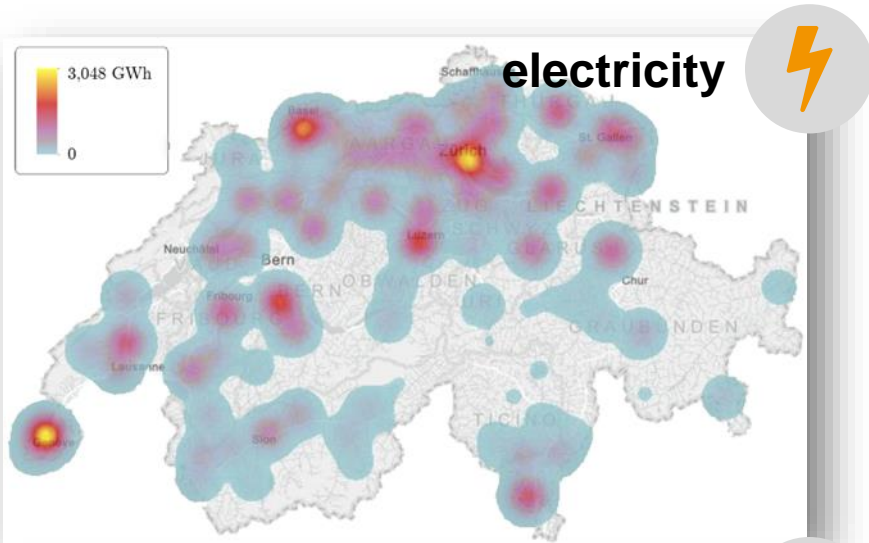
<sup>3</sup> In preparation.

## Case study: Transition of the **Swiss energy system** to net-zero emissions



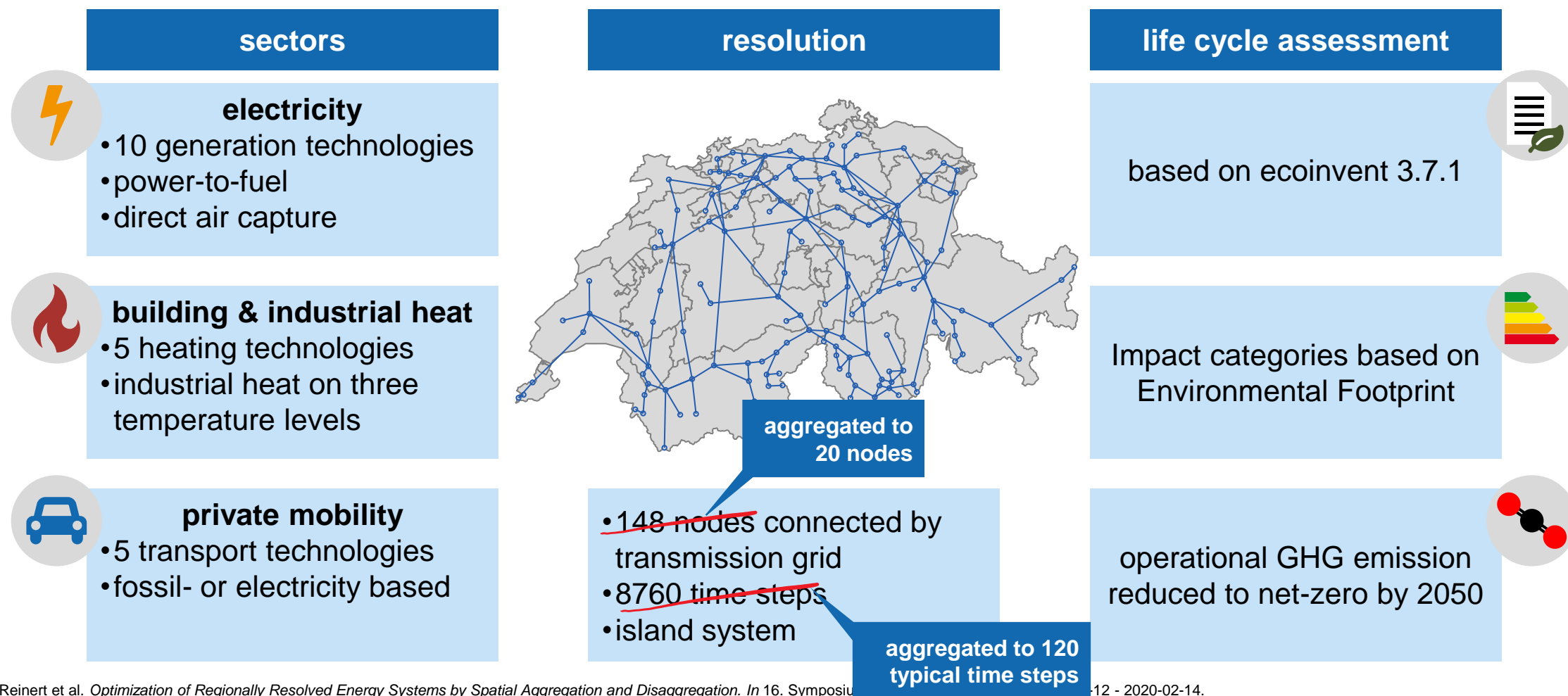
minimize **total annualized costs**  
reduce operational **GHG emissions** to zero by 2050

# Case study: Geographic distribution of energy demand





# Case study: Transition of the Swiss energy system to net-zero emissions



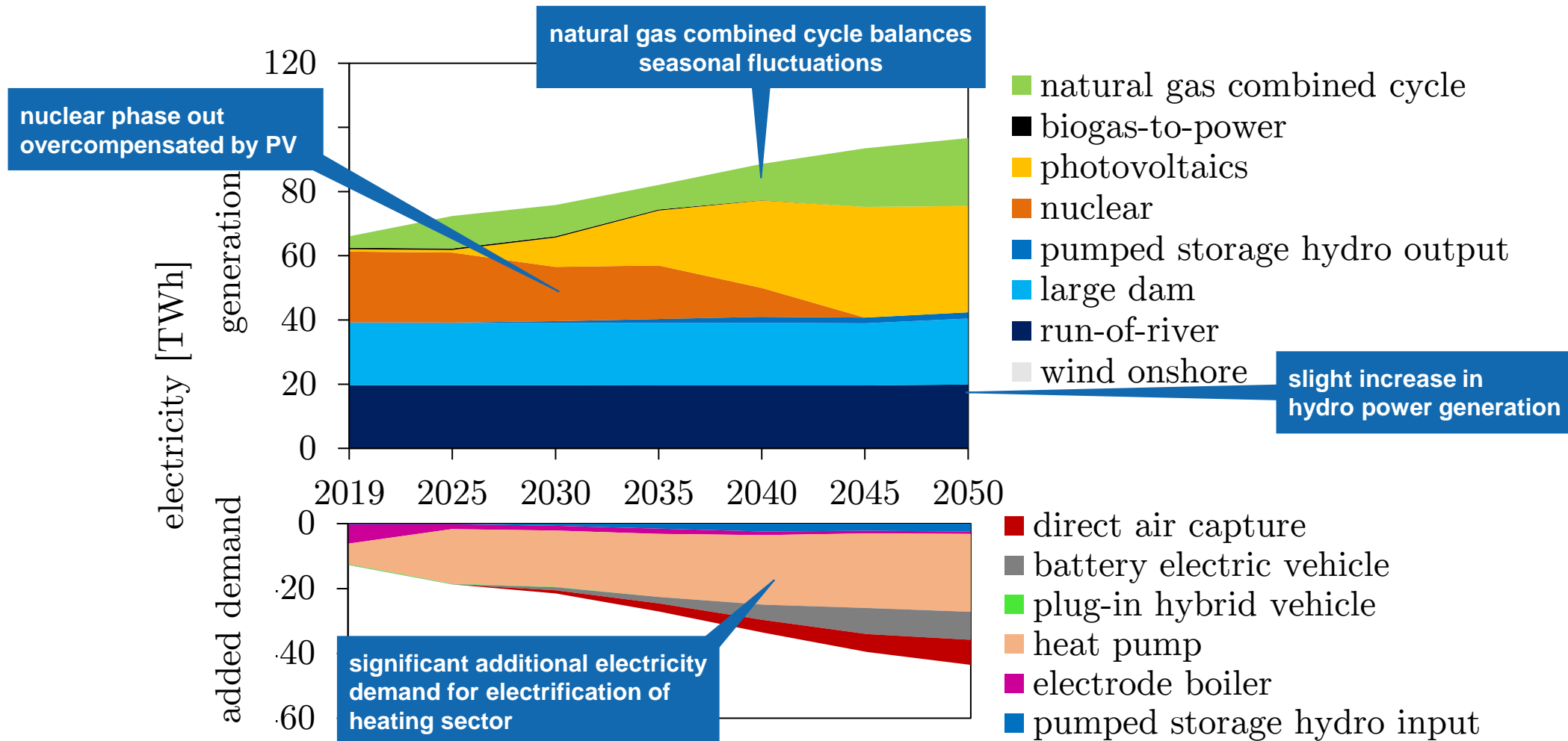
Reinert et al. *Optimization of Regionally Resolved Energy Systems by Spatial Aggregation and Disaggregation*. In 16. Symposium

Bahl et al. *Rigorous synthesis of energy systems by decomposition via time-series aggregation*. In *Comput Chem Eng* 2018;112:70–81.

12 - 2020-02-14.

# Case study: Electricity sector transformation driven by PV & natural gas

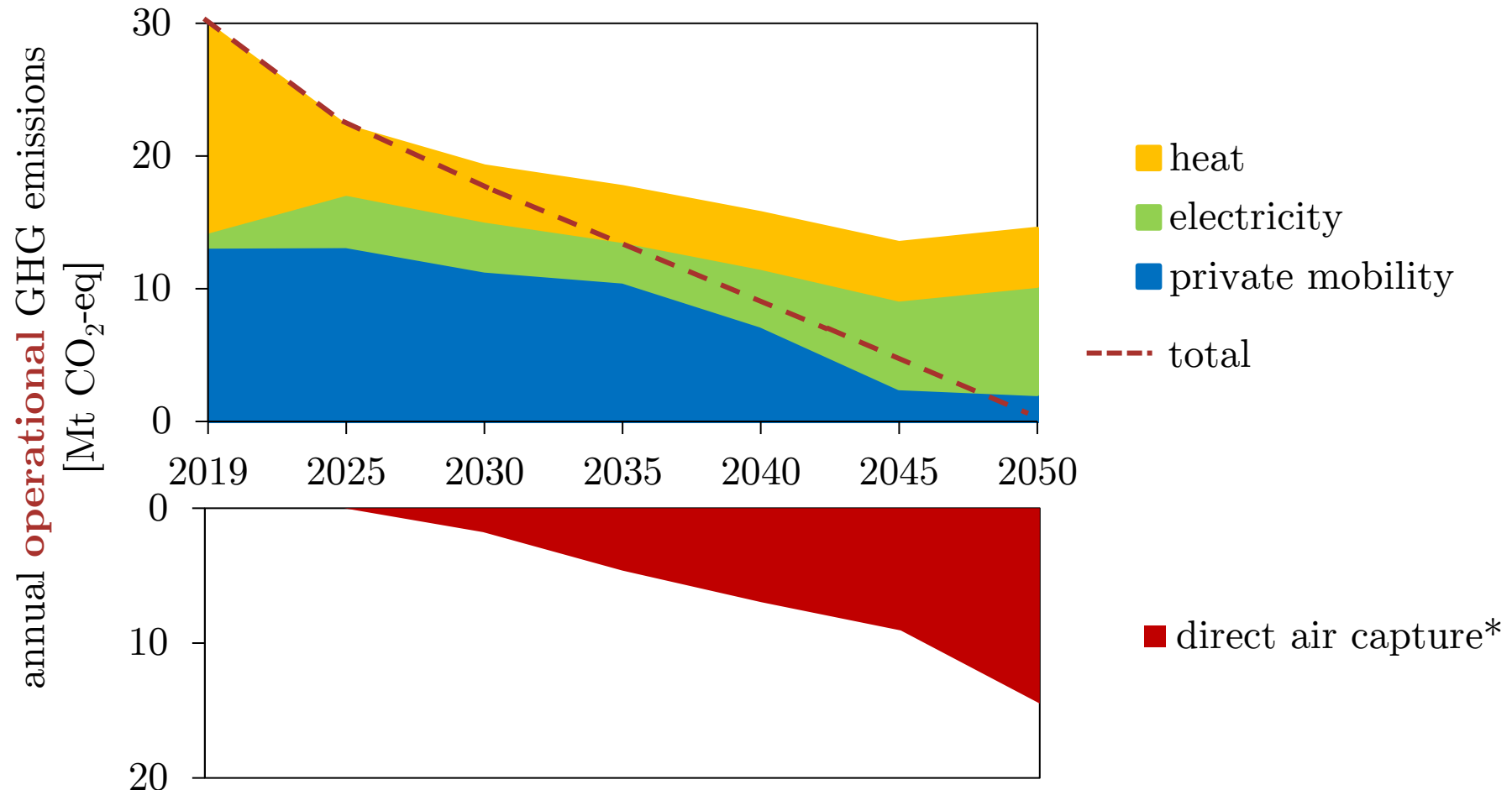
preliminary  
results





# Case study: Net-zero scenario relies on natural gas combined cycle & DAC

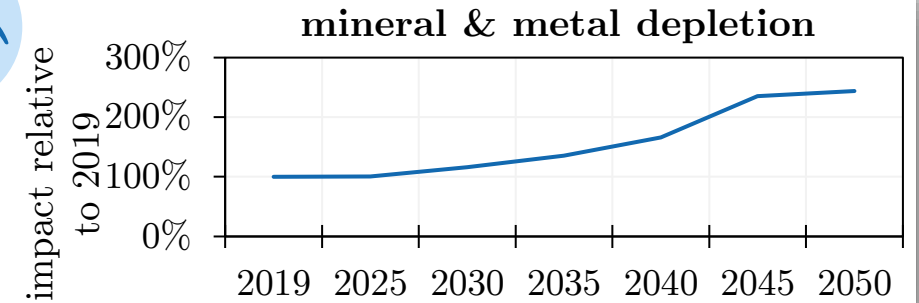
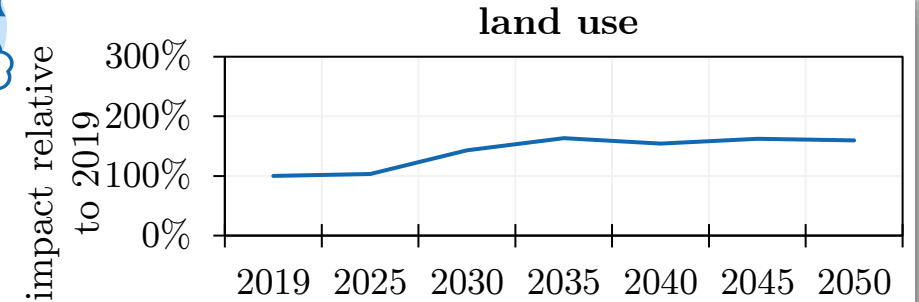
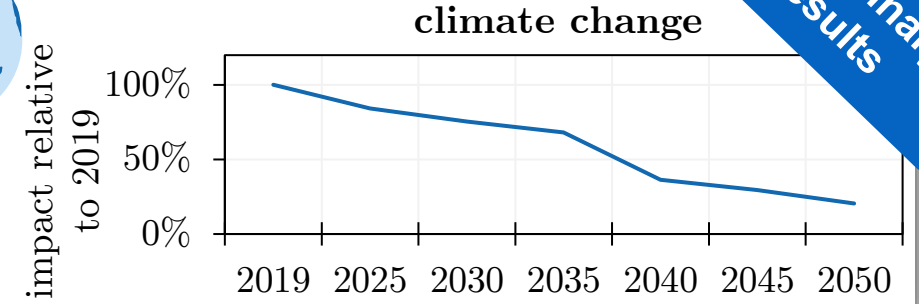
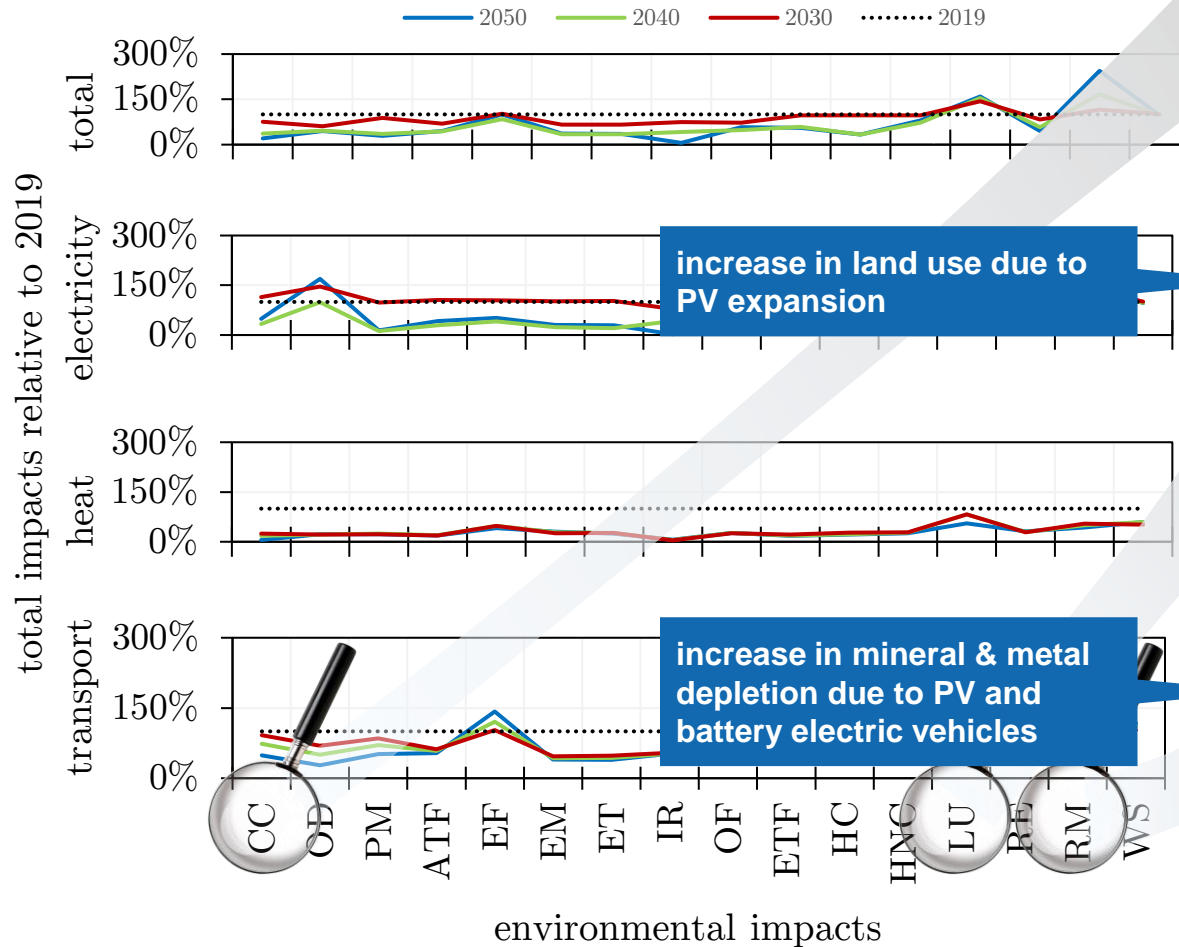
preliminary  
results



\* Deutz and Bardow *Life-cycle assessment of an industrial direct air capture process based on temperature–vacuum swing adsorption*. Nature Energy 2021;6(2):203–13.  
Fasihi et al. *Techno-economic assessment of CO<sub>2</sub> direct air capture plants*. Journal of Cleaner Production 2019;224:957–80.

# Case study: LCA results

preliminary results



# Matrix notation of SecMOD

## Life cycle assessment notation

$$\underbrace{A}_{\text{technology matrix}} \underbrace{s}_{\text{functional unit}} = \underbrace{f}_{\text{functional unit}}$$

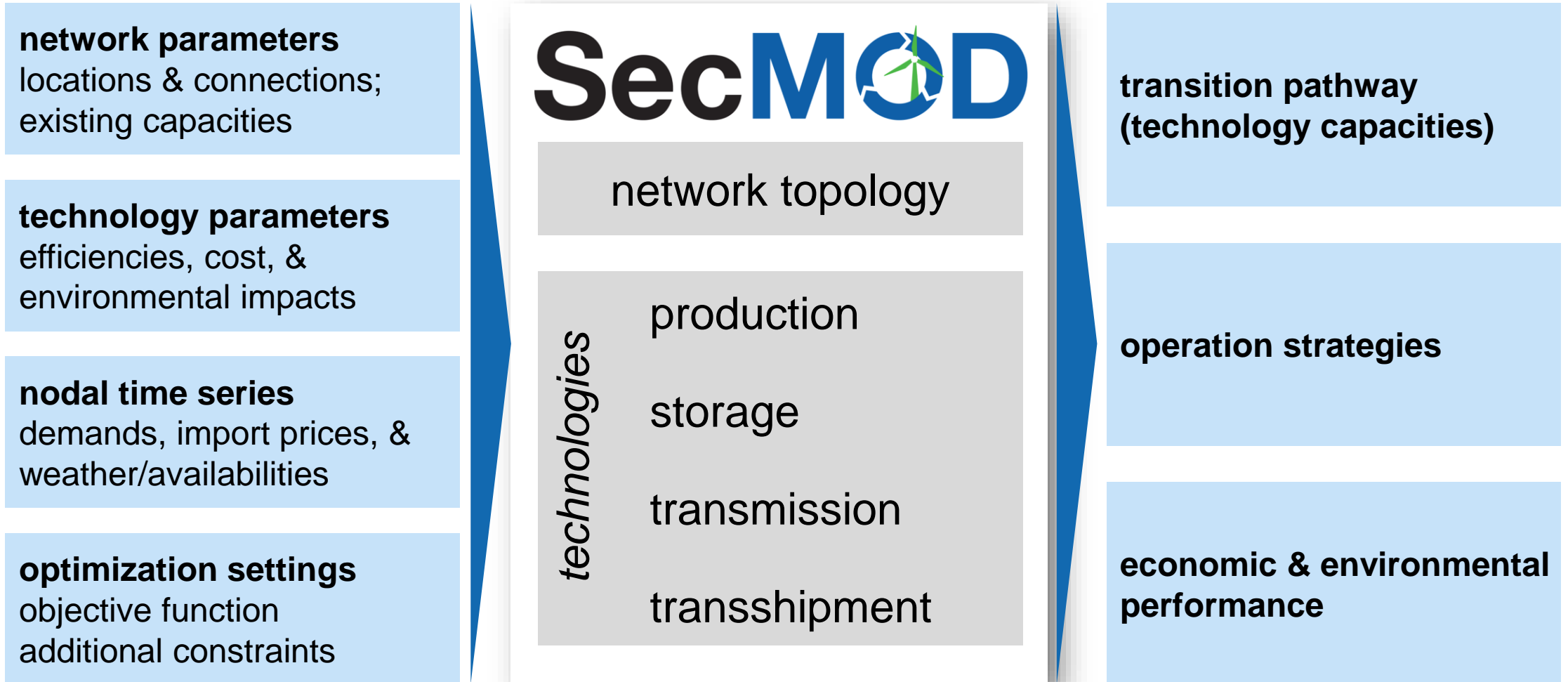
$$\underbrace{Q}_{\text{specific cost}} \underbrace{B}_{\text{specific cost}} \underbrace{s}_{\text{functional unit}} = \underbrace{h}_{\text{environmental \& economic cost}}$$

matrix notation allows direct interface

## Flexible extensibility

$$\begin{array}{c} \text{Process A} \\ \left( \begin{array}{c} \dots \\ \dots \\ \dots \\ \vdots \\ \dots \end{array} \begin{array}{c} -1 \\ -0.5 \\ \vdots \\ 1 \end{array} \right) s = \left( \begin{array}{c} 0 \\ 0 \\ \vdots \\ 1 \end{array} \right) \begin{array}{l} \text{Product 1} \\ \text{Product 2} \\ \\ \text{Product 3} \end{array} \\ A \quad s = f \end{array}$$

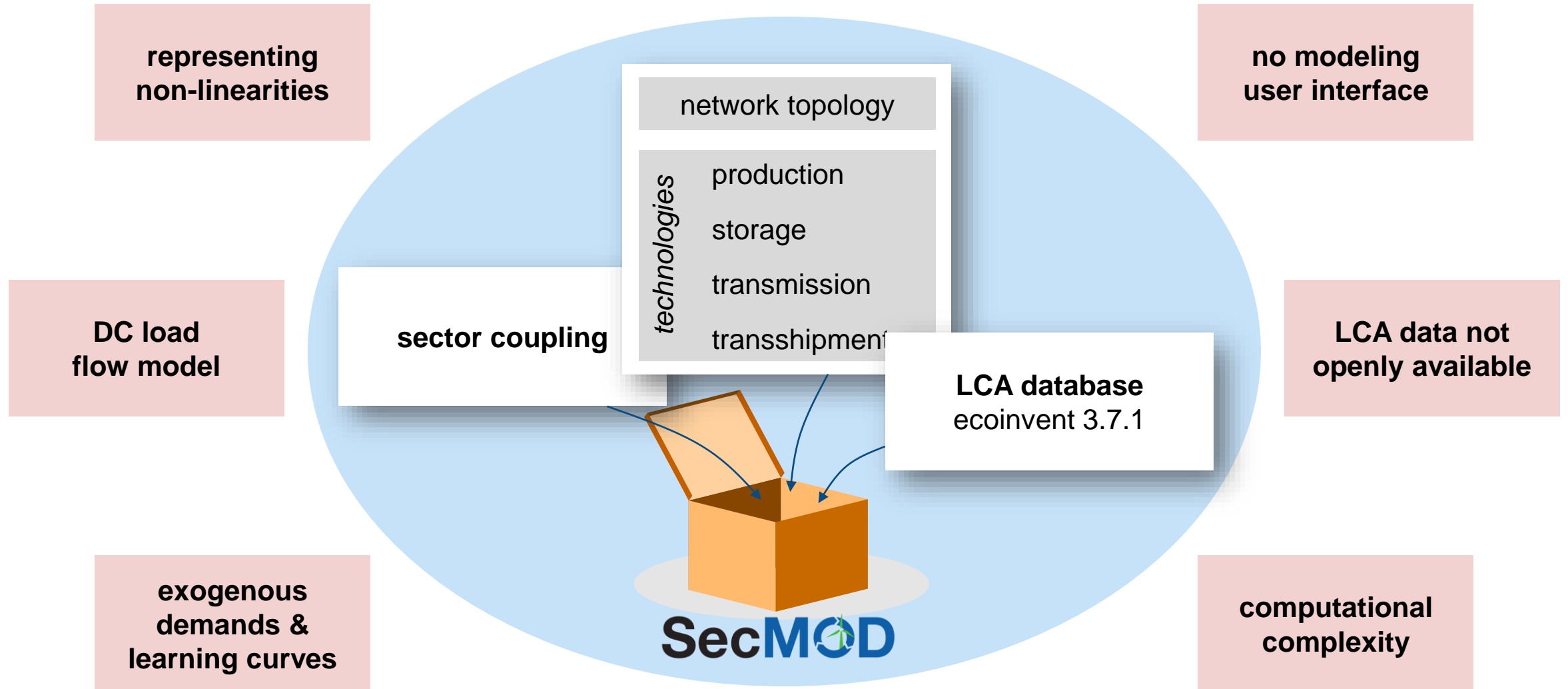
# Main inputs & outputs



Reinert et al. SecMOD: A modular framework combining multi-sector system optimization and life cycle assessment. (in preparation)

Baumgärtner et al. Life-Cycle Assessment of Sector-Coupled National Energy Systems: Environmental Impacts of Electricity, Heat, and Transportation in Germany Till 2050. Frontiers in Energy Research 2021;9.

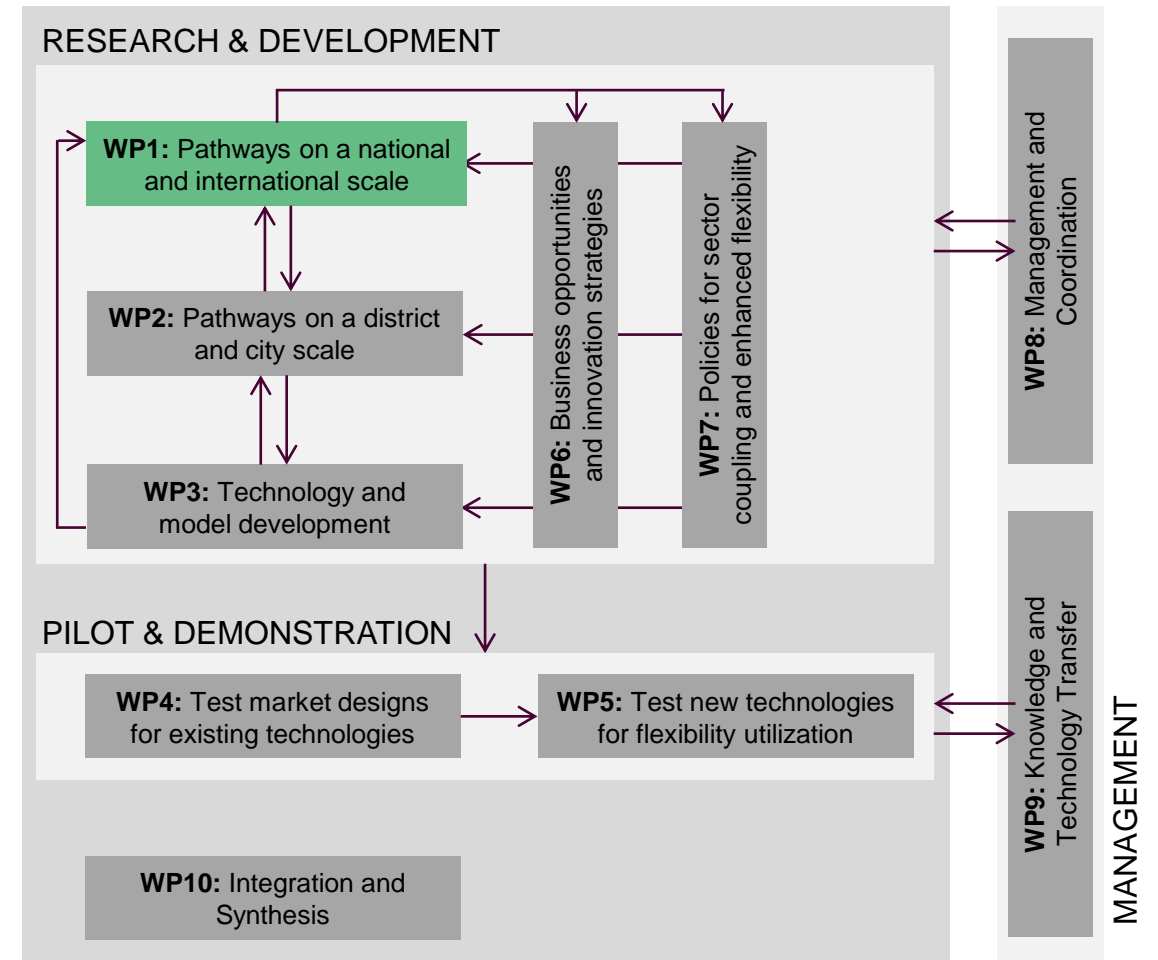
# Limitations - an incomplete todo list



# Future development & linkage to other tools under the PATHFNDR project

detailed modeling of the  
**Swiss industrial & heating sector**

**integration into Nexus-e** to include the  
industrial & heating sector in transition pathways



**Thank you  
for your attention!**



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**ETH zürich**



**Prof.  
André Bardow**  
contact person  
abardow@ethz.ch



**Ludger Leenders**  
Ph.D. student



**Patricia Mayer**  
Ph.D. student



**David Shu**  
Ph.D. student



**Niklas Nolzen**  
Ph.D. student



**Nik Zielonka**  
MSc student

**RWTH AACHEN  
UNIVERSITY**



**Christiane Reinert**  
Ph.D. student



**Benedikt Nilges**  
Ph.D. student



**Sarah Deutz**  
Ph.D. student



**Hannah Minten**  
Ph.D. student



**Nils Klinkenberg**  
graduated Ph.D.

**+ many more  
students**