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COUPLED AGENT-BASED TECHNOLOGY ADOPTION AND ENERGY SYSTEM MODEL

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Motivation

Energy system models (ESM)

+ … guarantee optimality

+ … allow to quantify future scenarios

- … neglects human behavior

Agent-based models (ABM)

+ … enable modelling (social) networks

+ … allow representation of non-deterministic behaviour

- … neglect system level effects

Need for behavioral realism[1]

Need for system level feedback

1. Pfenninger, S., Hawkes, A., & Keirstead, J. (2014). Energy systems modeling for twenty-first century energy challenges. In Renewable and Sustainable Energy Reviews (Vol. 33, pp. 74–86). Elsevier BV. https://doi.org/10.1016/j.rser.2014.02.003

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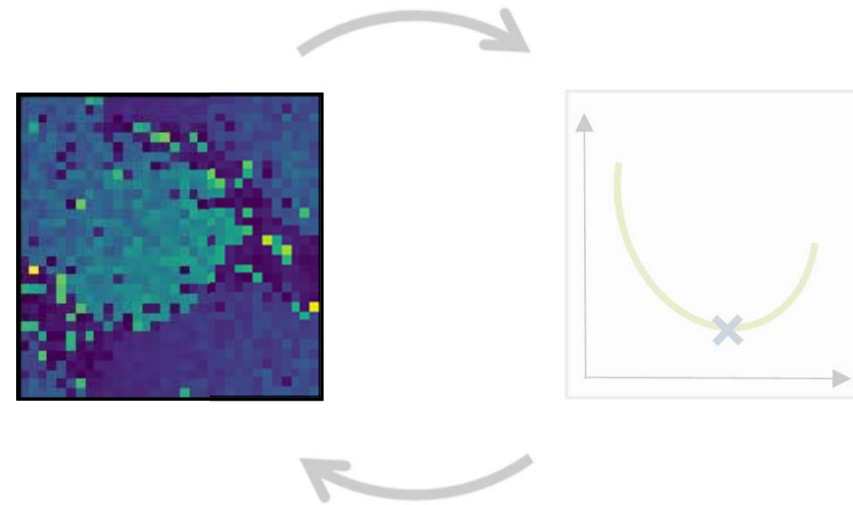
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Motivation

A coupled model

- enhances the ESM with behavioral realism,

- can model downstream effects of the ABM results and

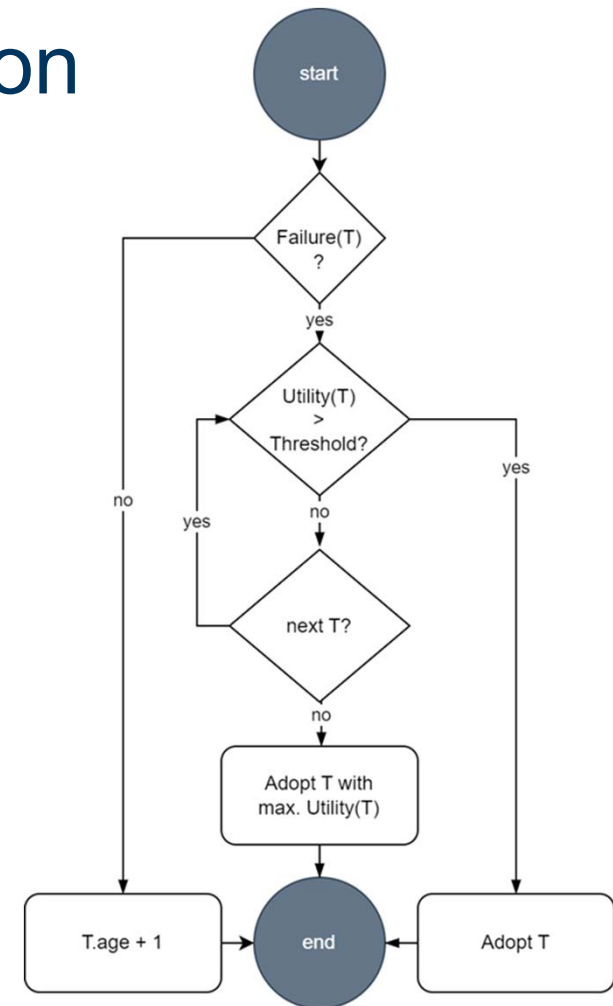- thereby **combines the strengths of both approaches.**
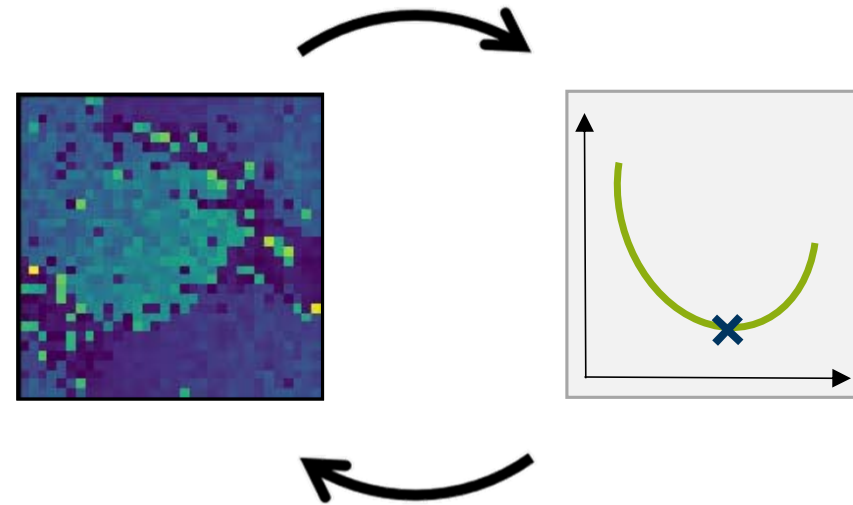
Content

- Motivation
- **The ABM**
- The ESM
- The coupled model
- Discussion & Conclusion

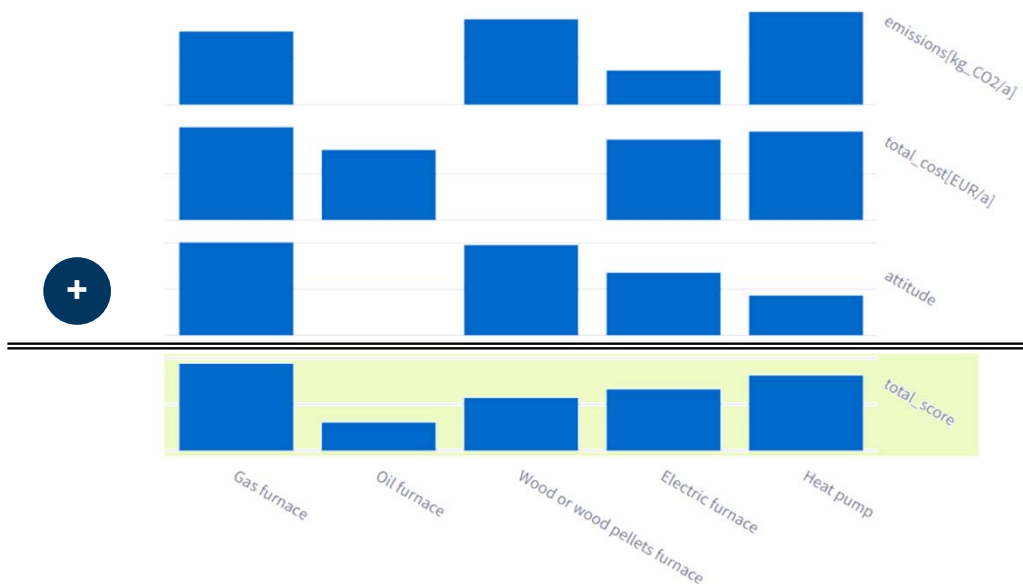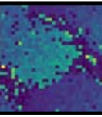# Agent based model – Implementation

Theory of planned behaviour

- Has been widely used to model adoption decisions

- Sometimes enhanced with a "peer-effect"

- No implementation guide*,

- Most implement …

  - … a utility function

  - … a PBC barrier

- Ajzen, I. (1991). The theory of planned behavior. In Organizational Behavior and Human Decision Processes (Vol. 50, Issue 2, pp. 179–211). Elsevier BV. https://doi.org/10.1016/0749-5978(91)90020-t
- Muelder, H., & Filatova, T. (2018). One Theory - Many Formalizations: Testing Different Code Implementations of the Theory of Planned Behaviour in Energy Agent-Based Models. In Journal of Artificial Societies and Social Simulation (Vol. 21, Issue 4). Journal of Artificial Societies and Social Simulation. https://doi.org/10.18564/jasss.3855
- Sopha, B. M., Klöckner, C. A., & Hertwich, E. G. (2013). Adoption and diffusion of heating systems in Norway: Coupling agent-based modeling with empirical research. In Environmental Innovation and Societal Transitions (Vol. 8, pp. 42–61). Elsevier BV. https://doi.org/10.1016/j.eist.2013.06.001

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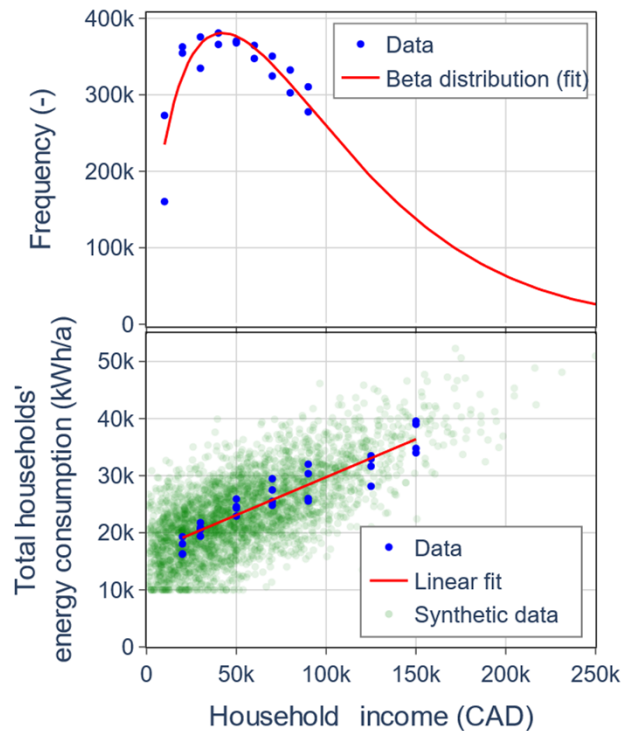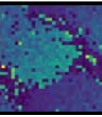BOCHUM

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Agent based model – Implementation

- **Utility** is defined by a technologies' **score** and **peer effect**
- The **score** S_T is a weighted sum of normalized attributes
- **Peer effect** represents share of neighbours with technology

$$S_T = \sum_a a_T \cdot w_a$$

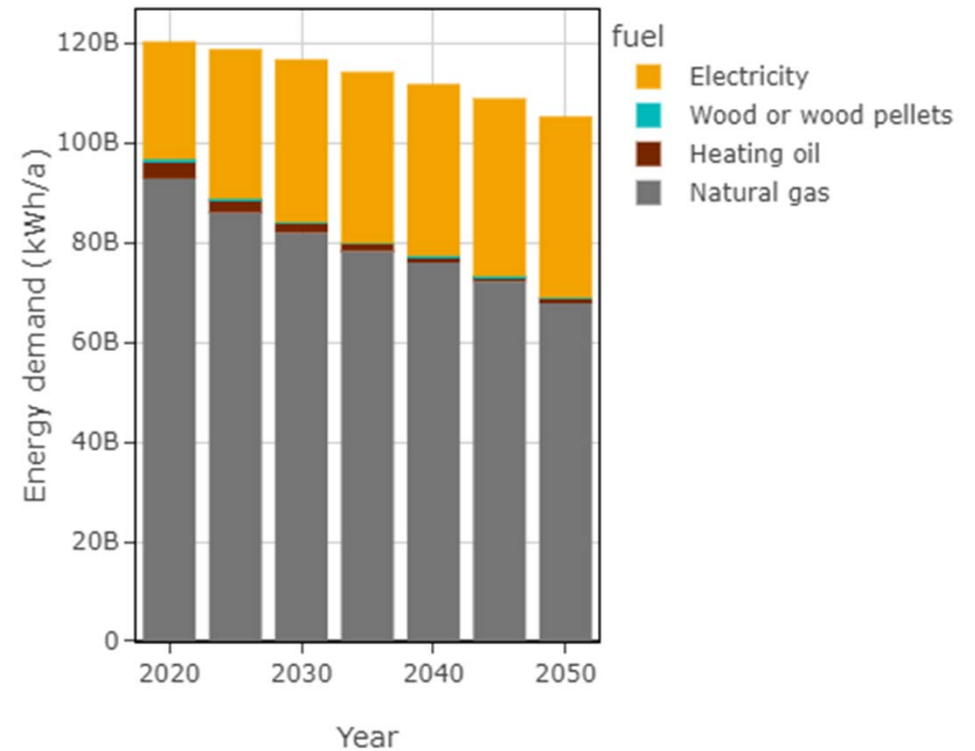$$U_T = \left(S_{T,new} - S_{T,old}\right) \cdot 0.8 + P(T) \cdot 0.2$$

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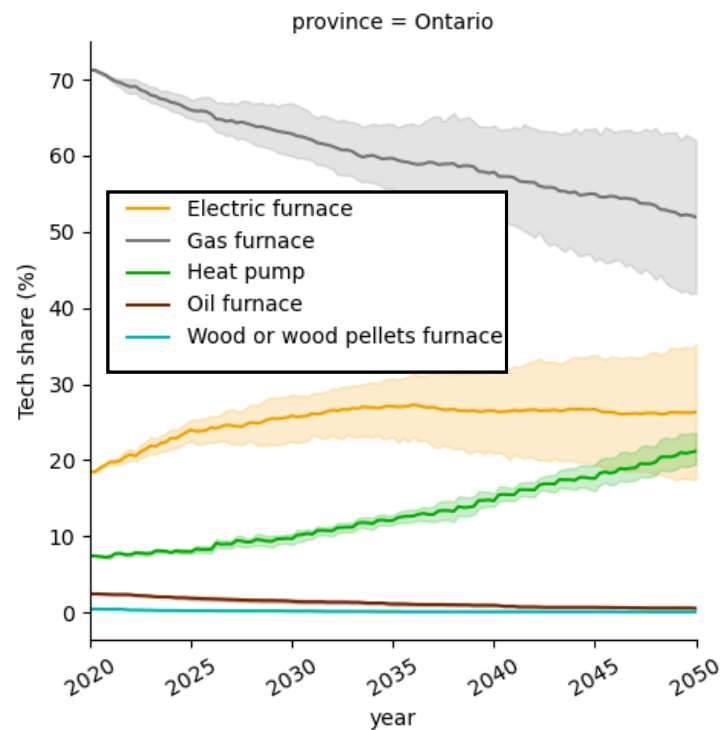**Energy Economics**

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ABM: Energy demand determination
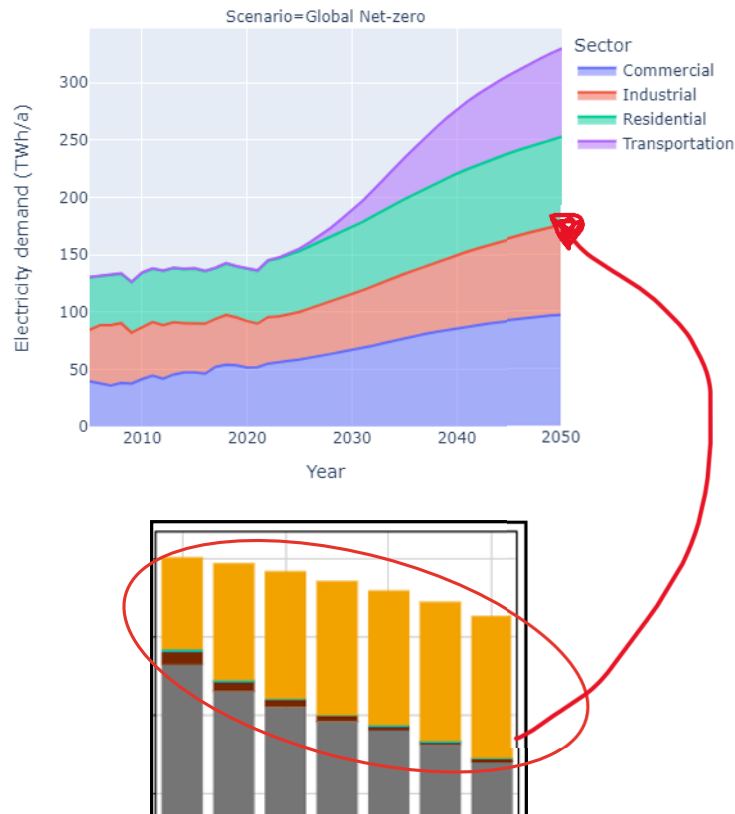

- Income drawn from fitted Beta distribution

- Linear fit of households' total energy consumption by income…

    - $E_{tot,i,p}(I_i) = m \cdot I_i + b$

- … and standard deviation σ per bin used to draw from normal distribution

    - $\mathcal{N}\left(E_{tot,i}(I_i), \sigma^2\right)$

- Annual heat demand is certain share h_p^S [2] of that:

    - $Q_i = \mathcal{N}\left(E_{tot,i}(I_i), \sigma^2\right) \cdot h_p^S$

1. Statistics Canada. Table 25-10-0062-01 Household energy consumption, by household income, Canada and provinces, DOI: https://doi.org/10.25318/2510006201-eng
2. https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&year=2020&rn=2&page=0

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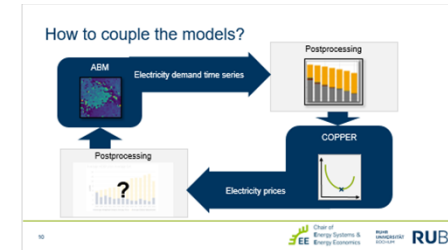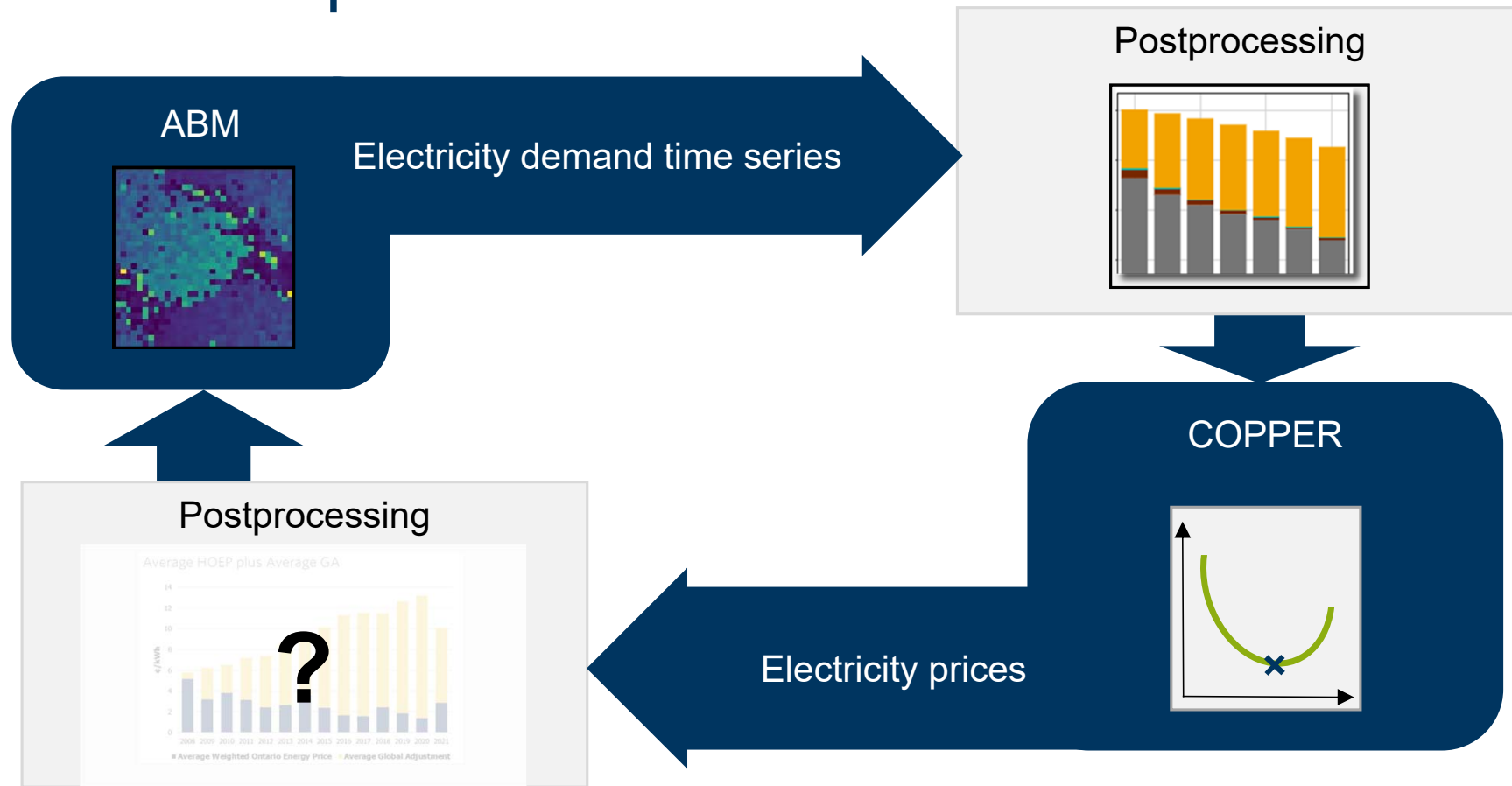**RU**B

ABM: Energy demand results

ABM: Postprocessing

- Demand projections from "Canada's Energy Future"

- "Residential"-Sector demand is replaced with the ABM output

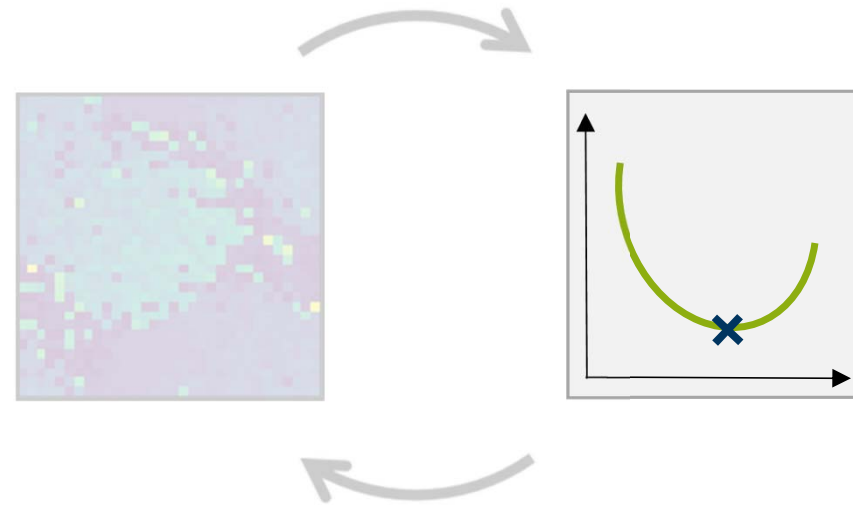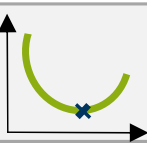- Combined data serves as input to COPPER

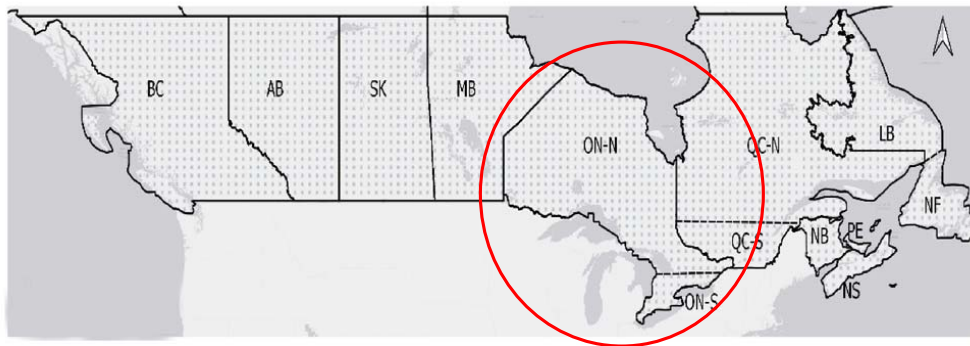Exploring Canada's Energy Future - Canada Energy Regulator (cer-rec.gc.ca)

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How to couple the models?
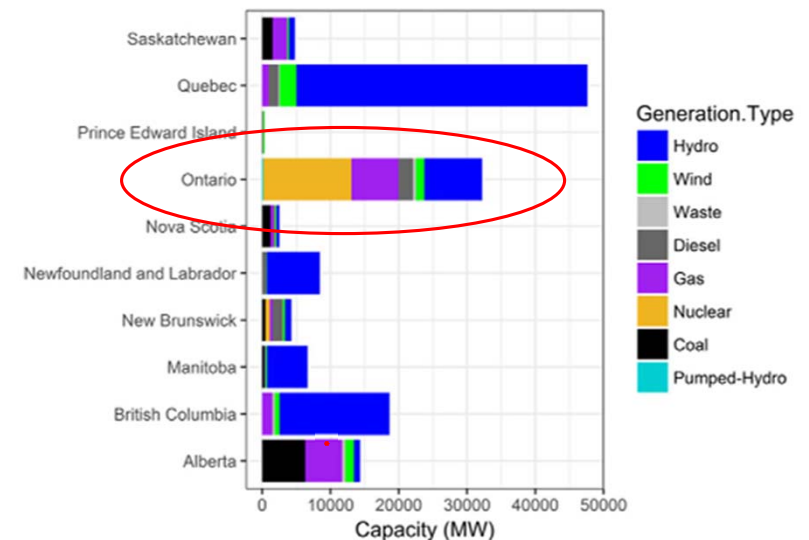
Content

The **C**anadian **O**pportunities for **P**lanning and **P**roduction of **E**lectricity **R**esources framework (COPPER)[1]

- Minimizes cumulative system cost up to 2050
- Resolution:
  - Spatial: Balancing areas (conventional generators) and grid locations (VRE)
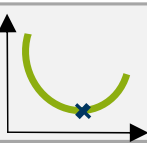 - Temporal: n Typical days with hourly resolution
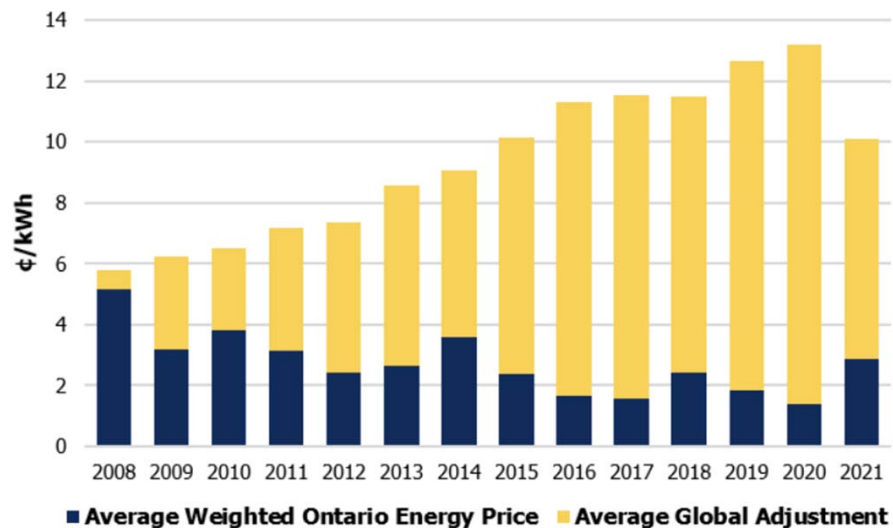
- Generation mix of different provinces (2017)[2]

1) Arjmand, R., & McPherson, M. (2022). Canada's electricity system transition under alternative policy scenarios. In Energy Policy (Vol. 163, p. 112844). Elsevier BV. https://doi.org/10.1016/j.enpol.2022.112844
2) Dolter, B., & Rivers, N. (2018). The cost of decarbonizing the Canadian electricity system. In Energy Policy (Vol. 113, pp. 135–148). Elsevier BV. https://doi.org/10.1016/j.enpol.2017.10.040

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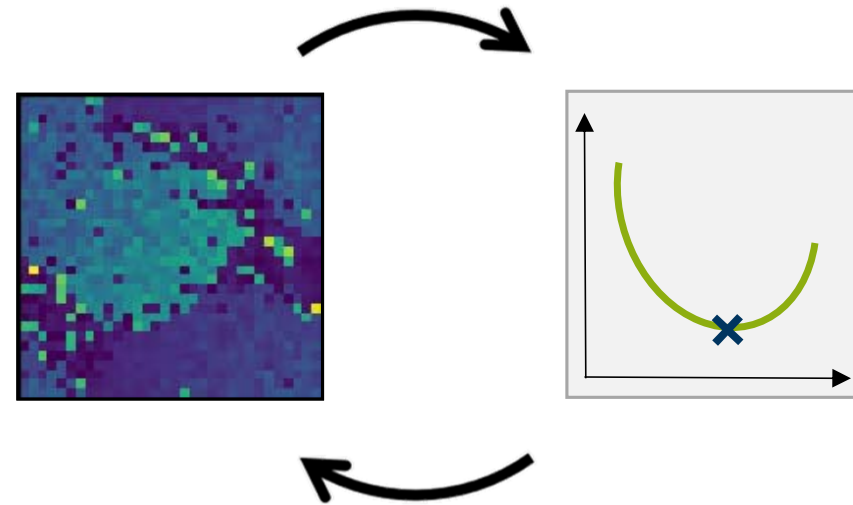RUHR UNIVERSITÄT BOCHUM
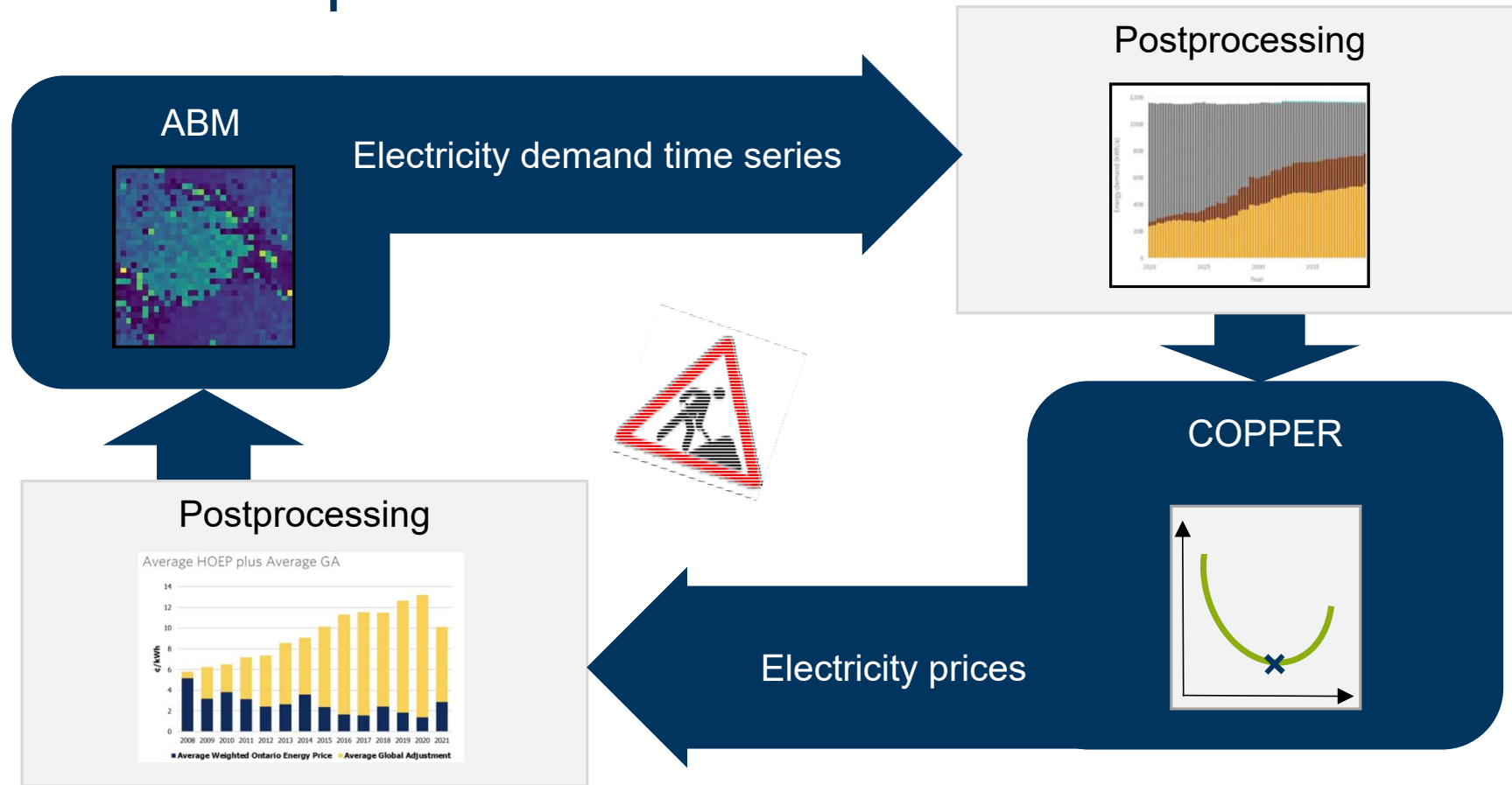
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COPPER: Retail price derivation

Average HOEP plus Average GA

- Retail price =
  wholesale price + "global adjustment"*
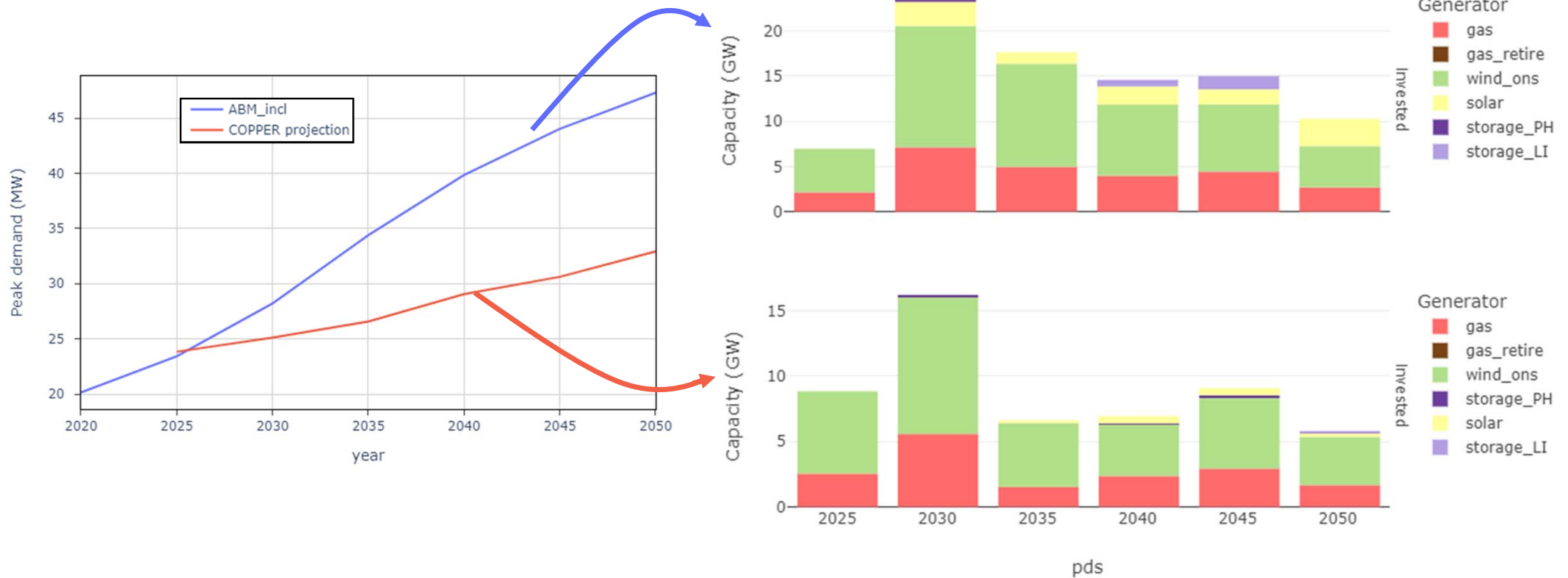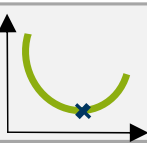- Linear fit for historic global adjustment

Content

How to couple the models?

ABM

Electricity demand time series

Postprocessing

COPPER

Postprocessing

Average HOEP plus Average GA

Electricity prices

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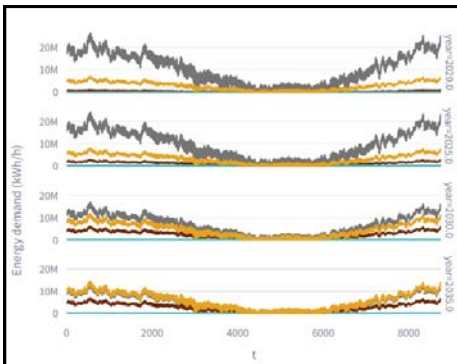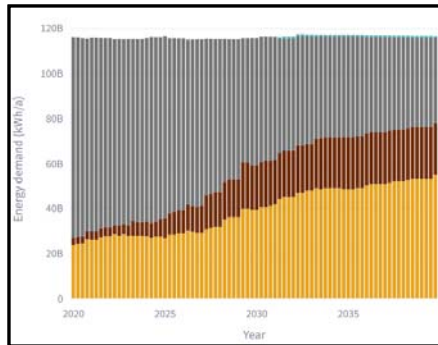
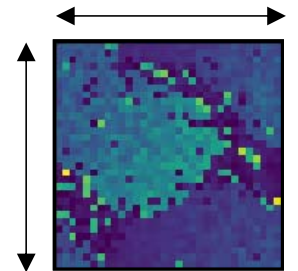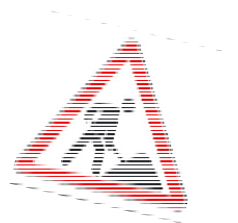# Coupled Model: Results with(out) ABM demand

Discussion/ Limitations / Outlook

- Electricity demand doesn't necessarily increase

- What is the best configuration of the ABM?
  - Topology of model (Grid, Network, …)
  - Neighbours are not necessarily peers

- External influences on attitude neglected

- Refurbishments to be implemented

- How cost-effective do subsidies reduce emissions?

Check out the ABM at: abetam.streamlit.app and shoot me your thoughts at
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