RUHR-UNIVERSITÄT BOCHUM

9TH INTERNATIONAL CONFERENCE ON SMART ENERGY SYSTEMS

Chair of Energy Systems & Energy Economics

Integrated energy system **flexibility** options when using **heat pumps** to reduce **carbon emissions**

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Agenda

- Motivation
- Research Questions
- Methods
  - Optimisation Framework Backbone
  - Setup of Building Models
  - Archetype Buildings
  - Input data
- Results
- Limitations & Outlook

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Motivation

- addressing ongoing **climate change** of immense importance
- shift to **renewable heating technologies** slow
- in **residential stock** major demand but also leverage for decarbonisation

- **heat pumps** in residential buildings
  - primary **renewable-based** technology
  - **topical** in both Ireland and Germany[1,2]
  - still contribute to **carbon emissions**

- **thermal flexibility**
  - to **reduce emissions**

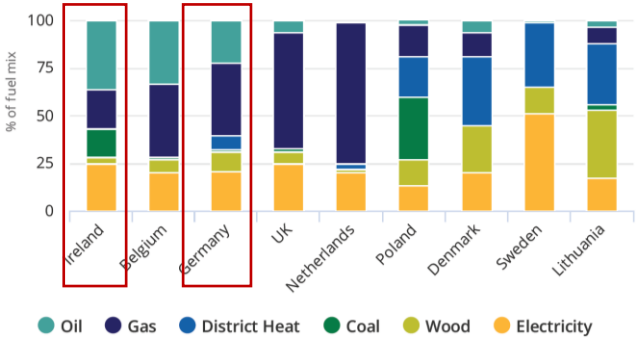

Figure: Household final energy usage (2016)[3]

[1] Sustainable Energy Authority of Ireland (2022). National Heat Study. Net Zero by 2050. Key Insights, Evidence and Actions. *Research Report.* Version V1.0.

[2] Statistisches Bundesamt (2022). Mehr als die Hälfte der im Jahr 2021 gebauten Wohngebäude heizen mit Wärmepumpen. *Press Release No. 226 from 2. June 2022.*

[3] Sustainable Energy Authority of Ireland (2018). *Energy in the Residential Sector. Carbon intensive fuel mix.*

Image sources: heat pump by Tomas Knopp from https://thenounproject.com/browse/icons/term/heat-pump/, heat by Adrien Coquet from https://thenounproject.com/browse/icons/term/heat/

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Research Questions

- How can…
  - energy demand and supply be **decoupled** in the operation of **heat pumps**
  - such as through **passive thermal storage** (mass of buildings)
  - and thereby **reducing emissions**?

- Additionally, what is the impact of **geographical variation** on the potential for emission reduction?
  - i.e. between **Ireland** as one of the northern islands of Europe with a mild climate
  - and **Germany** as a country on the European mainland with a continental climate

Methods – Optimisation Framework Backbone[1]

Network Model:

- highly **adaptable** structure with grids, nodes, lines and units
- various **energy carriers** and **sectors**
- **flexible spatial** and **temporal resolution**

Optimisation:

- **scheduling** and **investment** planning
- **cost** and **emission** minimisation

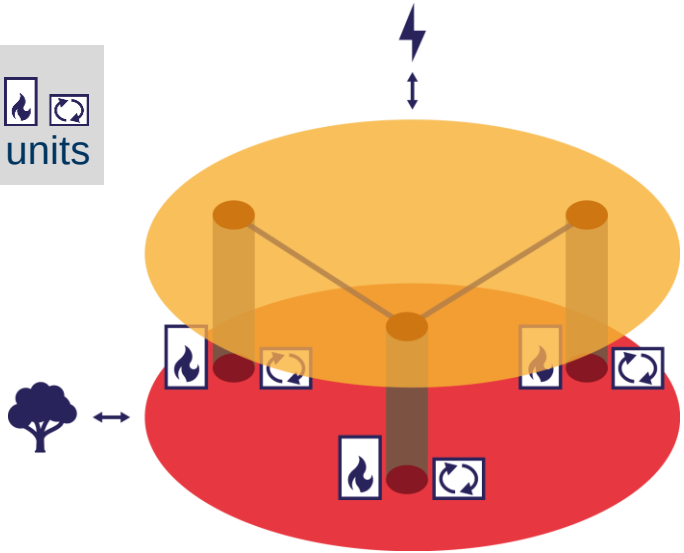

Figure: Backbone model structure

→ this study: development of Backbone models for **residential buildings** in **Germany (GER)** and **Ireland (IRL)** in Backbone

[1] Helistö et al. (2019). Backbone – An Adaptable Energy Systems Modelling Framework, Energies.

Image source Map: https://en.wikipedia.org/wiki/Germany%E2%80%93Ireland_relations#/media/File:Germany_Ireland_Locator.png

Methods – Setup of Building Models

- based on Backbone **building model method** developed by Rasku & Kiviluoma (2019)[1] and Huckebrink & Bertsch (2022)[2]
- **reduced order model** (3R3C)
- **building parameters** (U-values, areas, heat capacities) implemented
- generates **heating demand endogenously**
- **flexibility** originating from the controllable indoor temperature
  → building masses act as a **passive thermal storage**

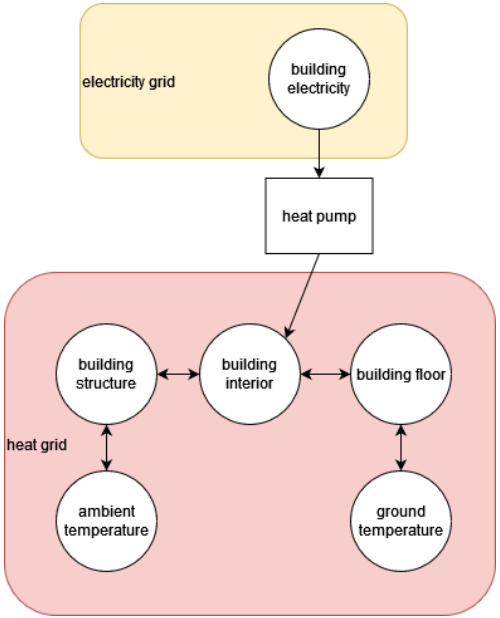

Figure: Own model structure of the building model in Backbone

Huckebrink D. & Bertsch V. (2022). Decarbonising the residential heating sector: A techno-economic assessment of selected technologies. Energy. https://doi.org/10.1016/j.energy.2022.124605.
Rasku T. & Kiviluoma J. (2019). A comparison of widespread flexible residential electric heating and energy efficiency in a future nordic power system. Energies;12. https://doi.org/10.3390/en12010005.

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Methods – Archetype Buildings

- building model used for **residential archetype buildings** for GER and IRL
- **building parameters**
  - for **Ireland** by Ali et al. (2019):
    - **EnergyPlus small-scale models** developed for typical Irish building archetypes
    - Detached houses, accounts for 40% of Irish building stock
  - for **Germany** by Sperber et al. (2020):
    - **TRNSYS model** as well as **reduced-order small-scale models** for typical single-family houses in Germany
    - Single-family houses, accounts for 66% of German building stock

Figure: Detached house by Ali et al. (2019) used in IRL model

Figure: Single-family house by TABULA (2014) used by Sperber et a. (2020) and in GER model

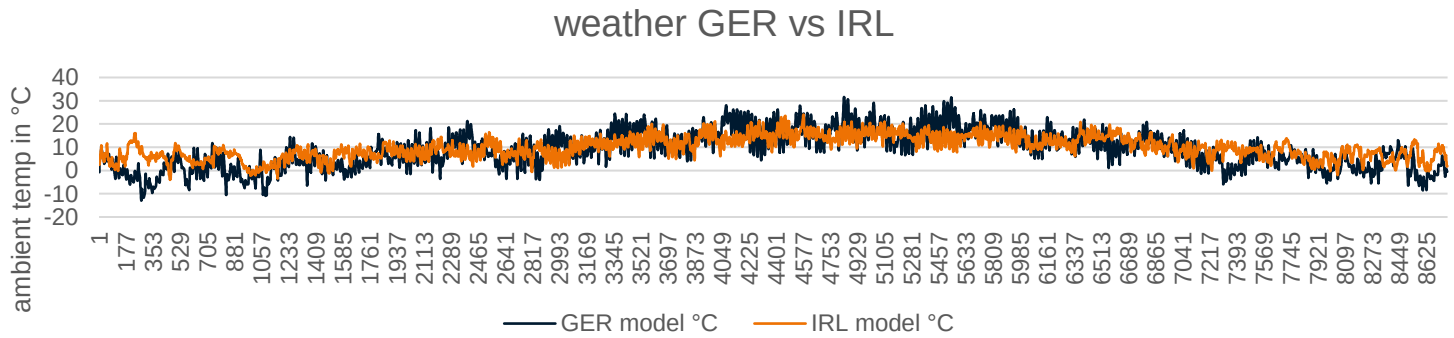
Sperber E., Frey U., Bertsch V. (2020): Reduced-order models for assessing demand response with heat pumps – Insights from the German energy system. In ENERGY AND BUILDINGS 223, p. 110144. DOI: 10.1016/j.enbuild.2020.110144.

Ali U., Shamsi M. H., Hoare C., Mangina E., O'Donnell J., A data-driven approach for multi-scale building archetypes development, Energy and Buildings, Volume 202, 2019, 109364, https://doi.org/10.1016/j.enbuild.2019.109364.

TABULA: I. Ballarini, S.P. Corgnati, V. Corrado, Use of reference buildings to assess the energy saving potentials of the residential building stock: The experience of TABULA project, EnergyPolicy. 68 (2014) 273–284. https://doi.org/https://doi.org/10.1016/j.enpol.2014.01.027.

Methods – Input data

- **construction periods**
  - for GER: 1958-1968, accounts for 14% of single-family houses in GER
  - for IRL: 1991-2000, accounts for 5.2% of all buildings in IRL
- **upscaled** by enlarging building areas by the amount of single-family houses in GER & IRL
- data for **2019** for weather (Berlin & Dublin), fuel and electricity costs and emissions



→ GER buildings better insulated, but heating demand higher because of harsher winters

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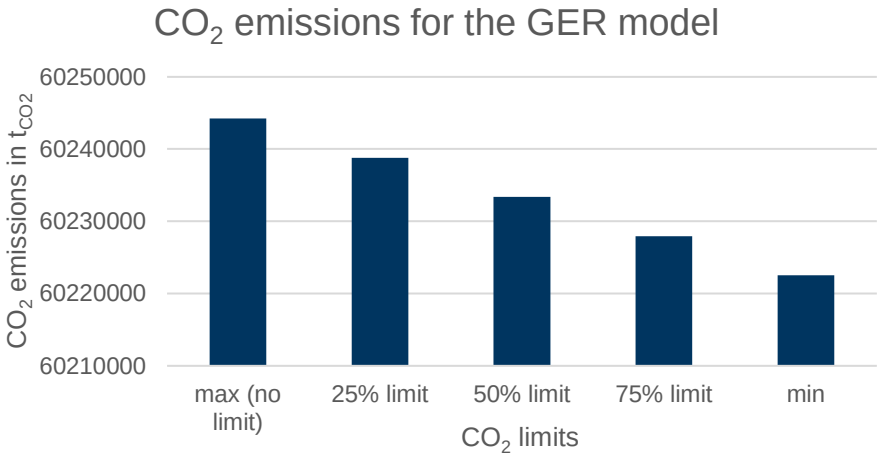
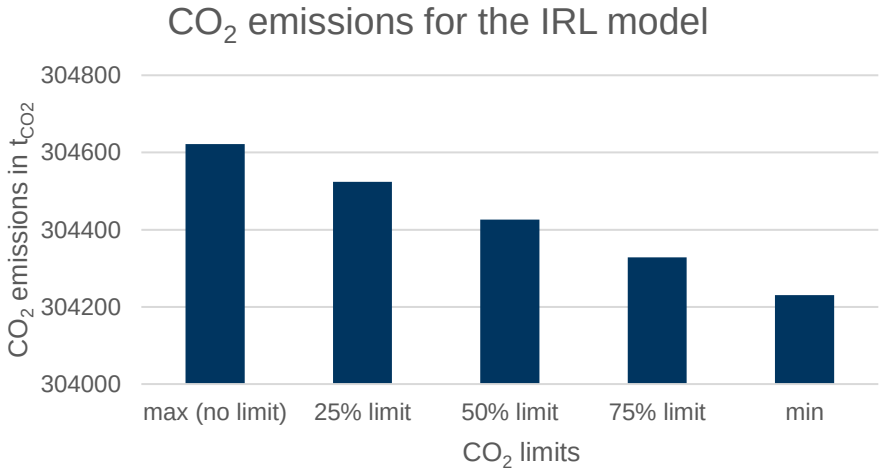
Results

preliminary results

- goal: assessing the **emission-reduction potential** of the **thermal flexibility measures**
- indoor temperature band of 20 °C – 25 °C
- reduction of CO_2 limits





heat	100%	99.99%	99.98%	99.97%	99.96%
costs B€	52.768	52.769	52.772	52.797	52.867

100%	99.97%	99.94%	99.90%	99.87%
0.2575	0.2575	0.2576	0.2577	0.2583

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Limitations and Outlook

- inclusion of all archetype buildings for GER and IRL
- verification of upscaled system ongoing
- spatial diversion of weather data for each country
- inclusion of variable emission factors for electricity

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thank you

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