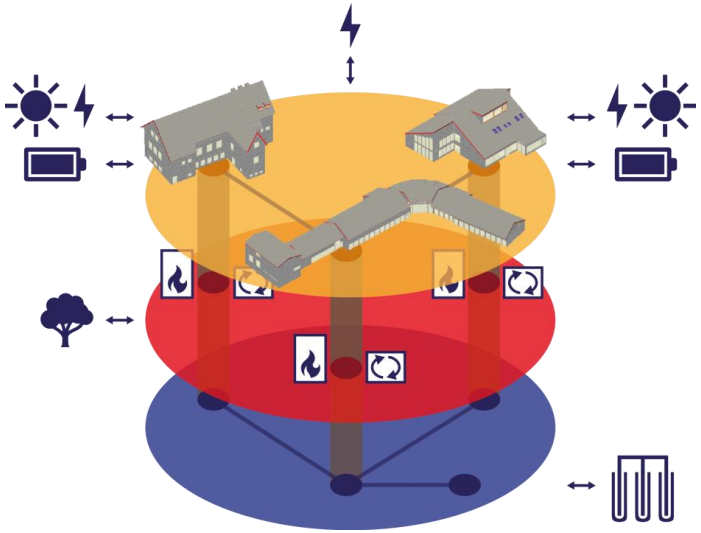

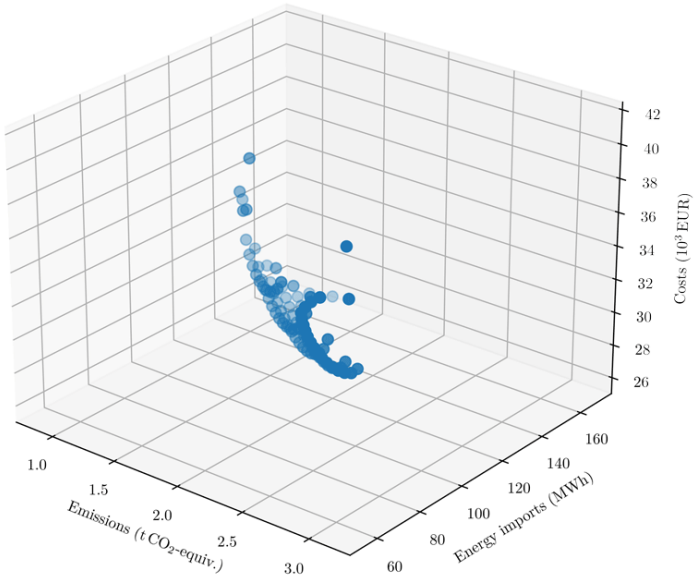

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A HIGHLY ADAPTABLE MULTI-OBJECTIVE ENERGY SYSTEM OPTIMISATION FRAMEWORK

IMPLEMENTATION AND CASE STUDIES

Chair of Energy Systems & Energy Economics

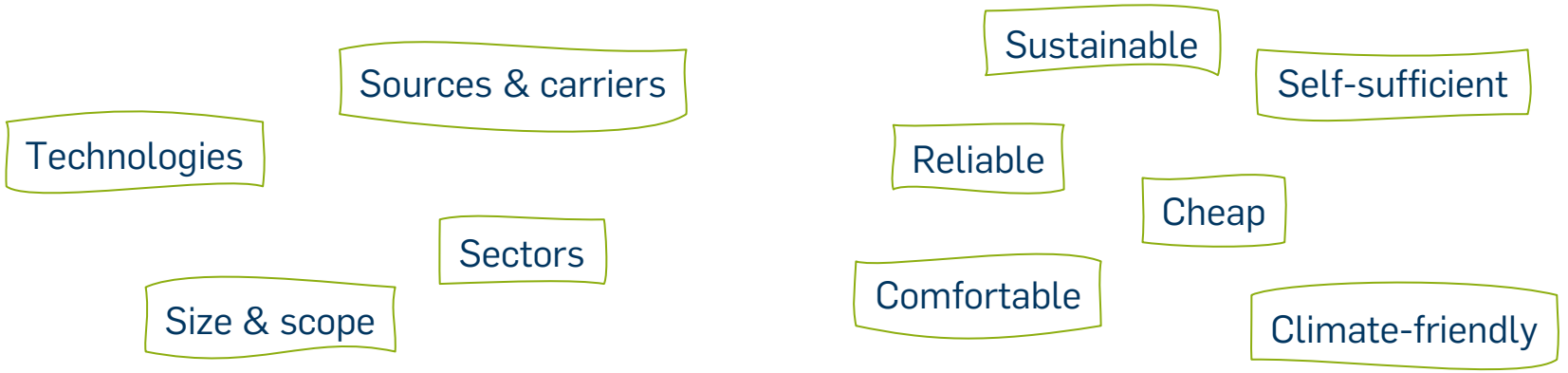
Jonas Finke, Valentin Bertsch # 07.09.2022 # OR 2022 Karlsruhe # jonas.finke@rub.de

Agenda

- Motivation
- Implementation
- Case studies
- Conclusion & outlook

Motivation

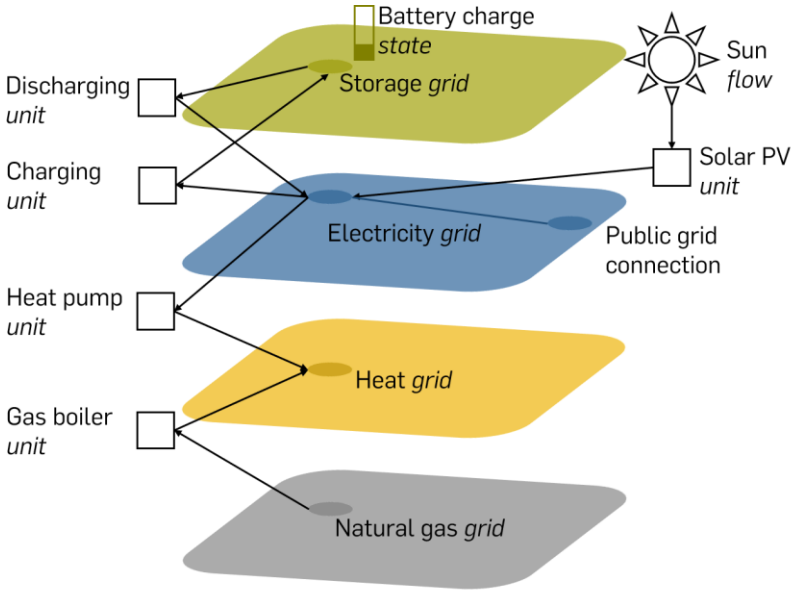
Energy systems are diverse… as are people's interests!



Can we implement a **multi-objective energy system model** suitable for this **diversity** of **systems** and **objectives**?

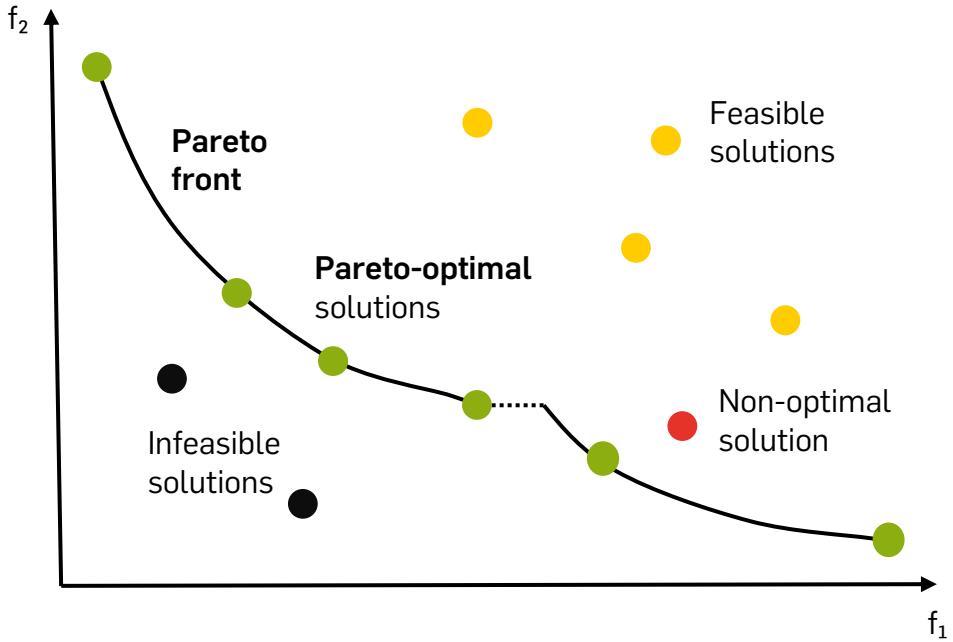
Implementation

Energy system optimisation framework *Backbone*

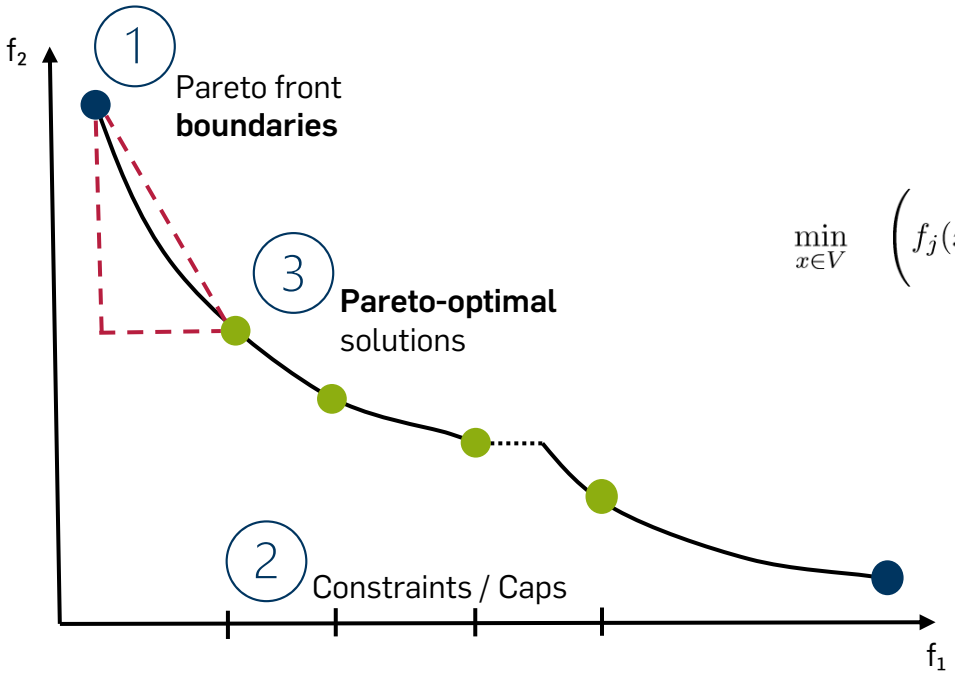


Helistö et al., *Backbone – An Adaptable Energy Systems Modelling Framework*, Energies 2019. See also https://gitlab.vtt.fi/backbone/backbone.

What is Pareto optimality?



Augmented epsilon-constraint method (AUGMECON)



$$\min_{x \in V} \quad \{f_1(x), f_2(x), \ldots, f_k(x)\}$$

$$\downarrow$$

$$\min_{x \in V} \quad \left(f_j(x) + c \sum_{i \in K} s_i \right) \quad \text{s.t.} \quad f_i(x) + s_i = \varepsilon_i \; \forall \; i \in K \setminus \{j\}$$

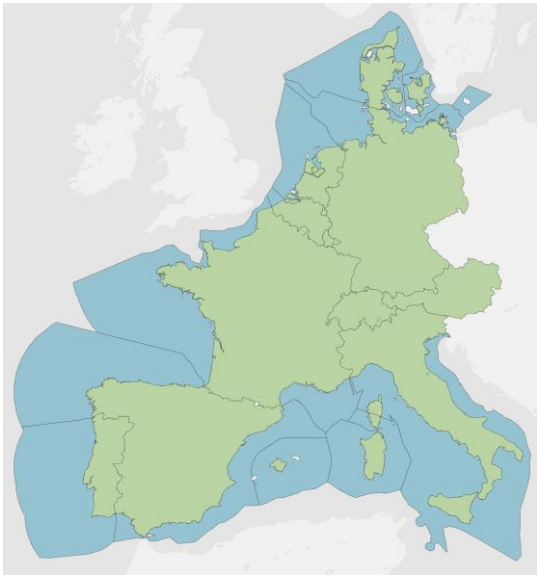
Parallelisation in Step 3!

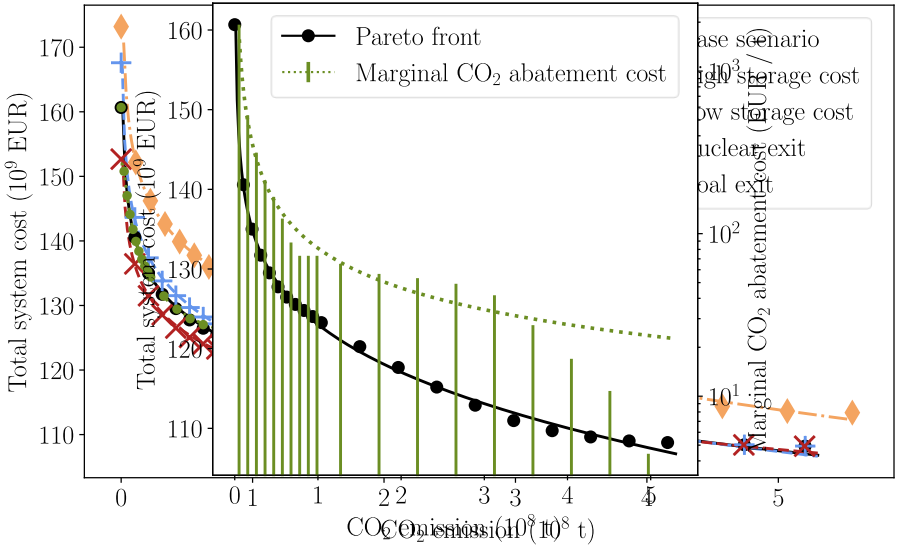
Implementation openly available at:
https://gitlab.vtt.fi/backbone/backbone and
https://gitlab.ruhr-uni-bochum.de/ee/backbone-tools

Mavrotas, *Effective implementation of the epsilon-constraint method in Multi-Objective Mathematical Programming problems*, Applied Mathematics and Computation 2009.

Case studies

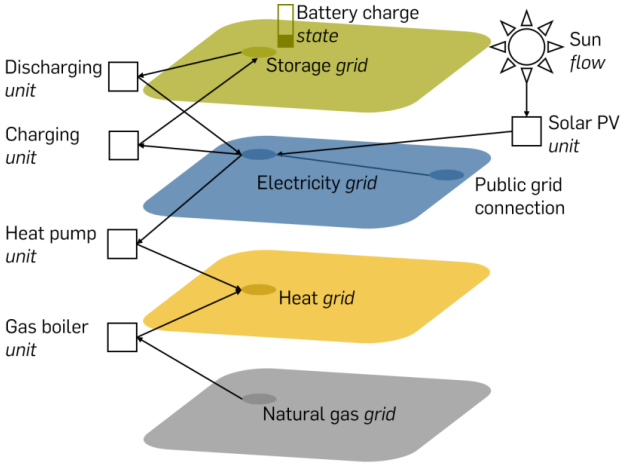
1. Multi-national power system

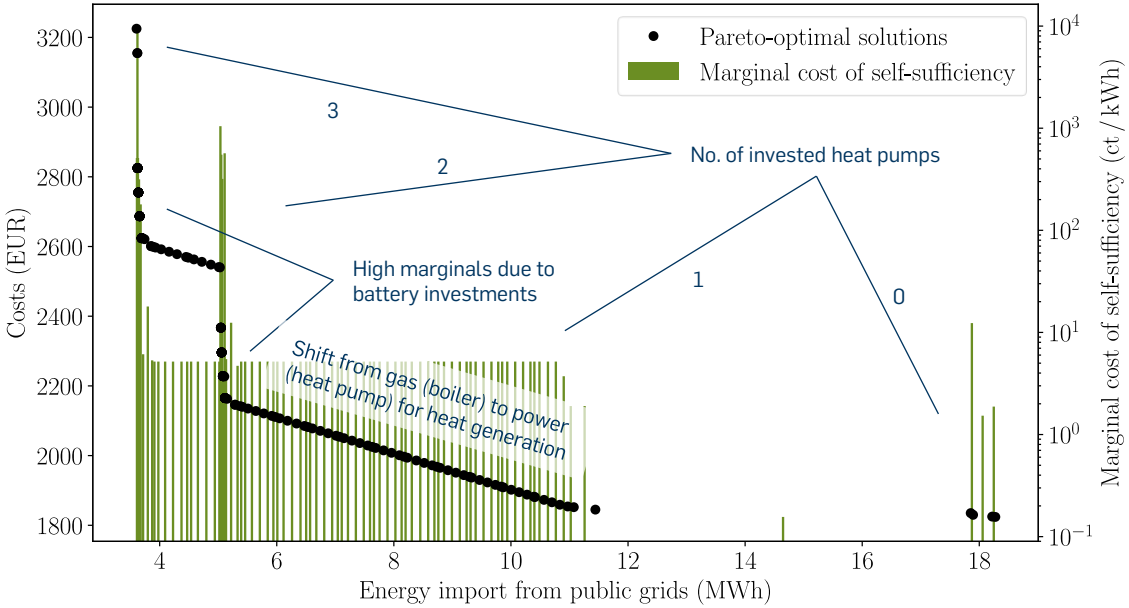




Finke and Bertsch, *Implementing a highly adaptable method for the multi-objective optimisation of energy systems*, Submitted to Applied Energy.

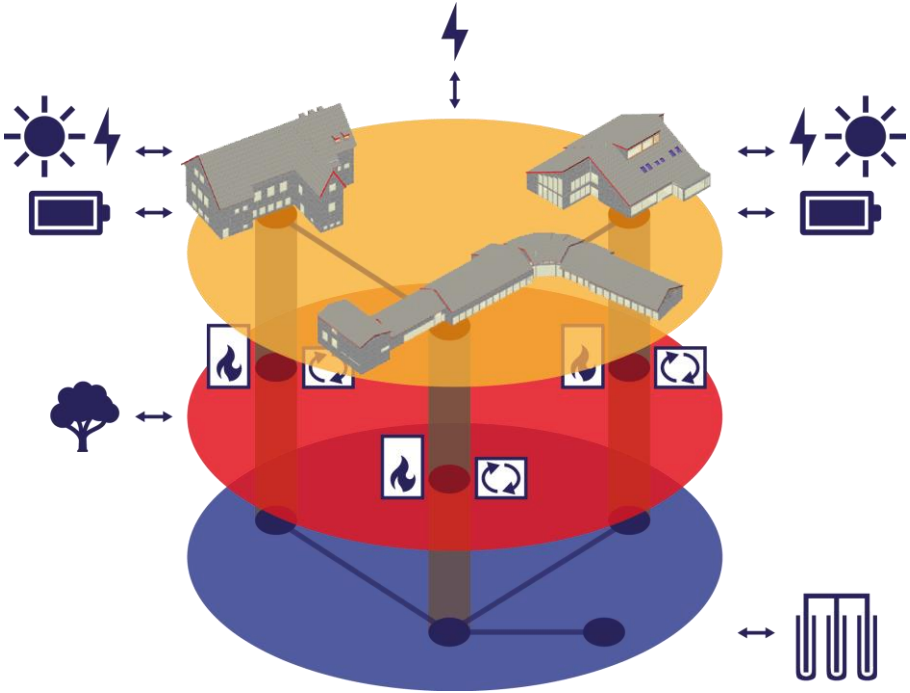
2. Sector-coupled single building (with integers)

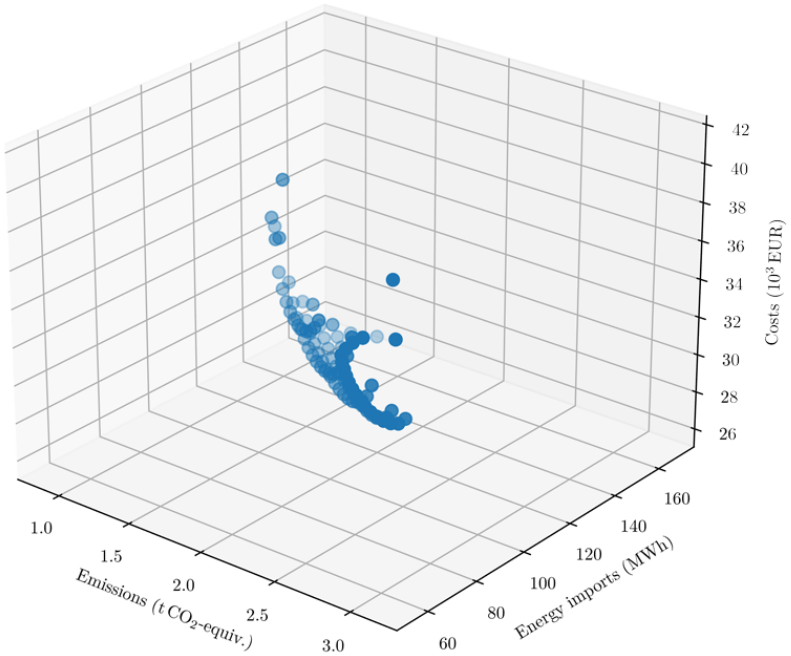




Finke and Bertsch, *Implementing a highly adaptable method for the multi-objective optimisation of energy systems*, Submitted to Applied Energy.

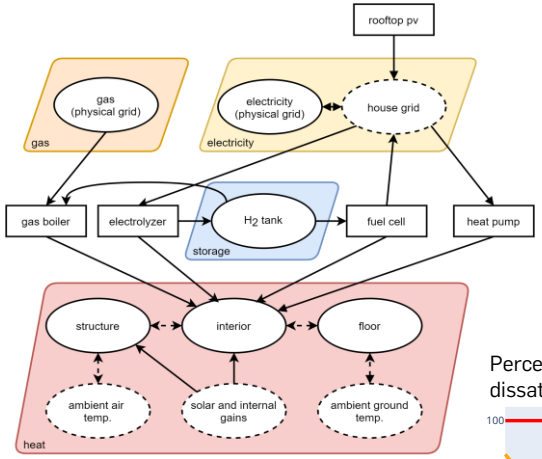
3. Commercial buildings with heating network

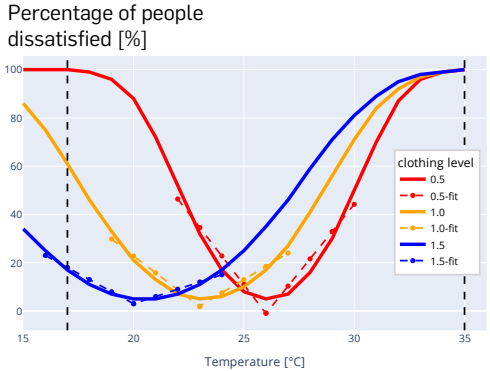


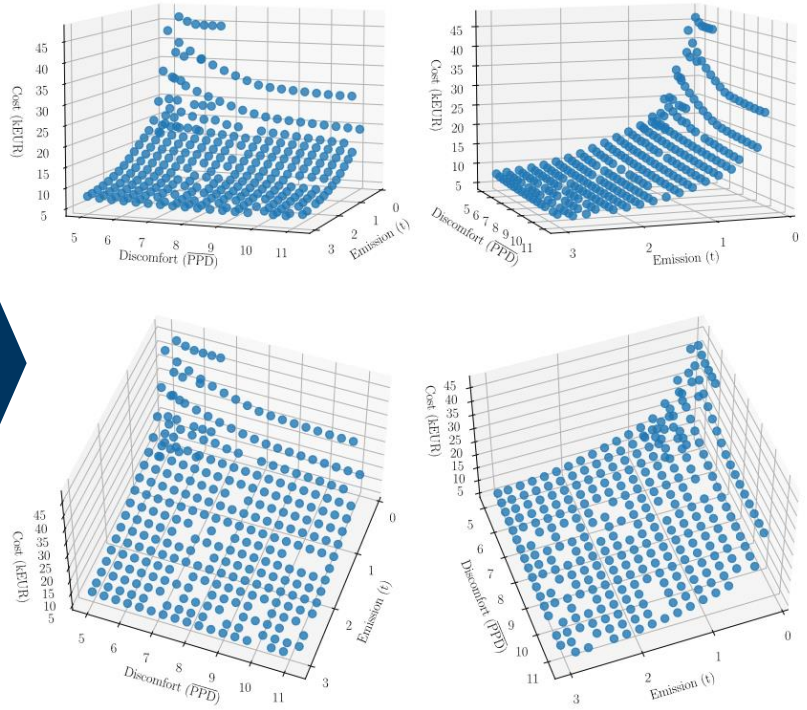


Data on commercial buldings based on Lehrstuhl für Energiesyteme und Energiewirtschaft, *Machbarkeitsstudie: Wärmeversorgung mehrerer Bestandsliegenschaften in der Gemeinde Gödenroth mit "Kalter Nahwärme"*, September 2021.
Nowak, Finke and Bertsch, *Multi-objective energy system modelling to defossilise the existing commercial building stock of a municipality*, Work in progress.

4. Endogenous temperature and thermal comfort







Building model and leftmost figure based on Huckebrink and Bertsch, *Decarbonising the residential heating sector: A techno-economic assessment of selected technologies*, Energy 2022.

Huckebrink, Finke and Bertsch, Optimisation of costs, carbon emissions and thermal comfort in a building-level energy system model, Work in progress.

Conclusion & outlook

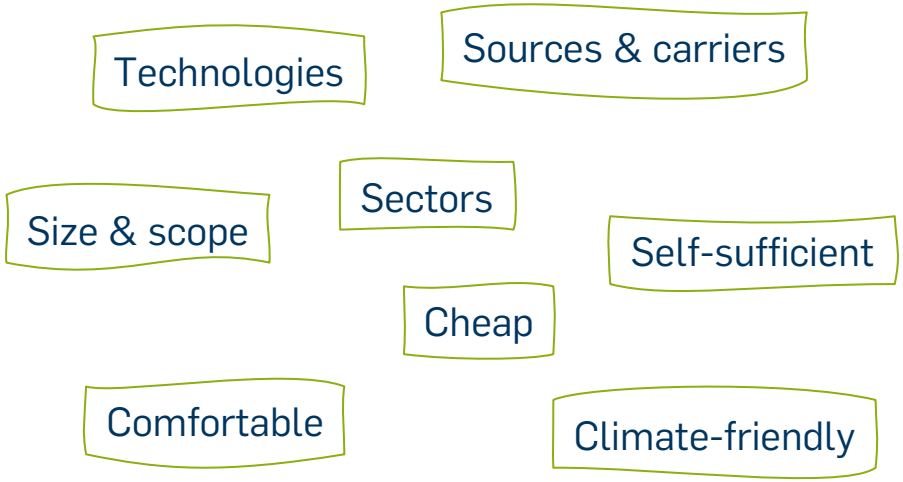
Backbone + AUGMECON =

Multi-objective energy system model

suitable for **diversity** of

systems and

objectives.



Objectives are **too many**, cannot be **modelled** or are **unknown**?

Modelling to Generate Alternatives (MGA)

Thank you for your attention!