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Chair of Energy Systems & Energy Economics

Modelling to generate near-Pareto-optimal alternatives (MGPA) – A novel multi-criteria optimisation approach for energy planning

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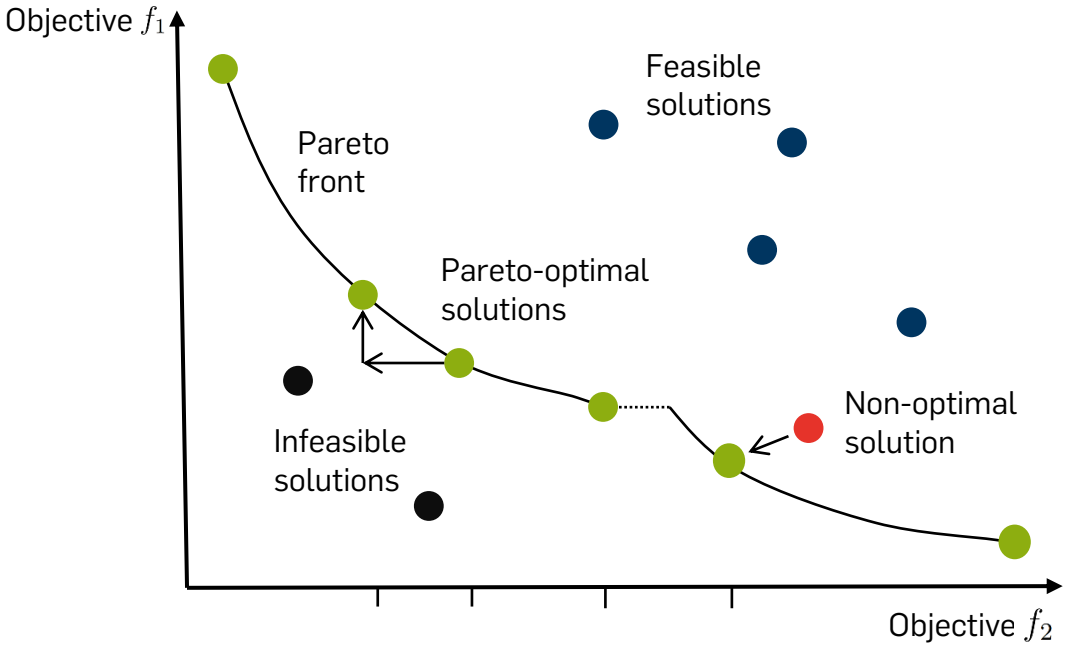
Multi-objective optimisation (MOO) with AUGMECON



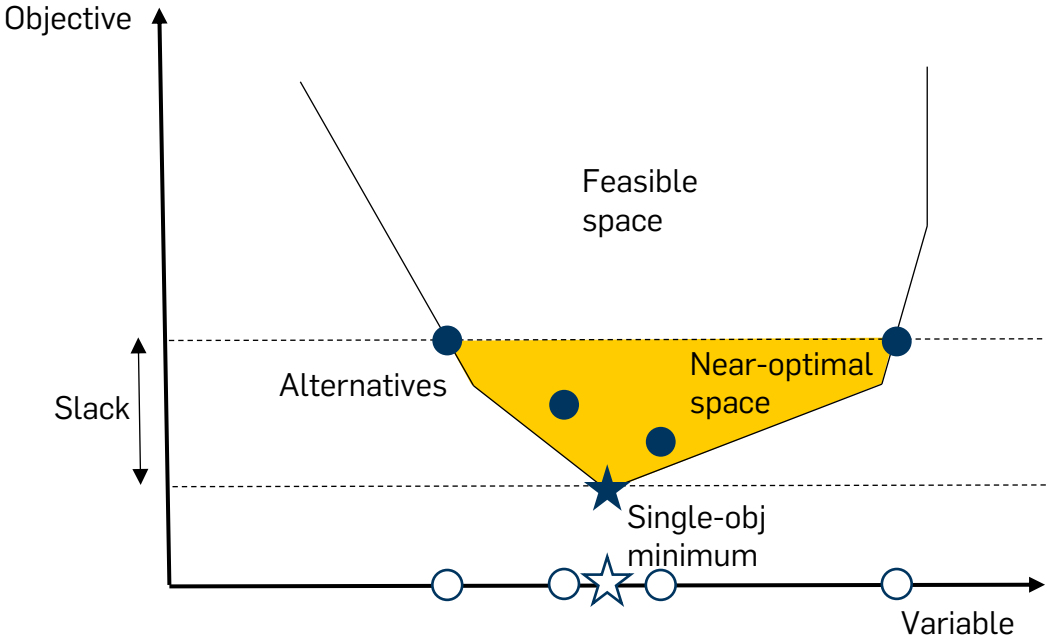
Slack variable

$$\min (f_1 - s) \quad \text{s.t.} \quad f_2 + s = \epsilon$$

Objective 1 Objective 2 Caps

AUGMECON is developed by Mavrotas, *Effective implementation of the epsilon-constraint method in Multi-Objective Mathematical Programming problems*, Applied Mathematics and Computation 2009. https://doi.org/10.1016/j.amc.2009.03.037
The used implementation for energy system modelling is due to Finke and Bertsch, *Implementing a highly adaptable method for the multi-objective optimisation of energy systems*, Applied Energy 2023. https://doi.org/10.1016/j.apenergy.2022.120521

Modelling to generate alternatives (MGA)



Weights

Cap = Minimum + Slack

$$\min_{x \in X} \sum_i w_i x_i \quad \text{s.t.} \quad F(x) \leq \epsilon$$

Variables

Objective

Introduction of MGA to energy system models is due to DeCarolis, *Using modeling to generate alternatives (MGA) to expand our thinking on energy futures*, Energy Economics 2011. https://doi.org/10.1016/j.eneco.2010.05.002

Multi-objective optimisation and modelling to generate alternatives are complementary approaches

	MOO	MGA
Thinking in …	Objective space	Variable space
Criteria are considered…	Explicitly as objectives	Implicitly through diversification (except objective)
Must criteria be known, quantified and modelled explicitly ex-ante?	☑	☒
Are near-optimal solutions considered to address structural uncertainty?	☒	☑
Is model outcome optimal and representative regarding all criteria?	☑	☒

Finke et al. (2024) *Modelling to generate near-Pareto-optimal alternatives (MGPA) for the municipal energy transition*, Applied Energy 376, 124126. https://doi.org/10.1016/j.apenergy.2024.124126

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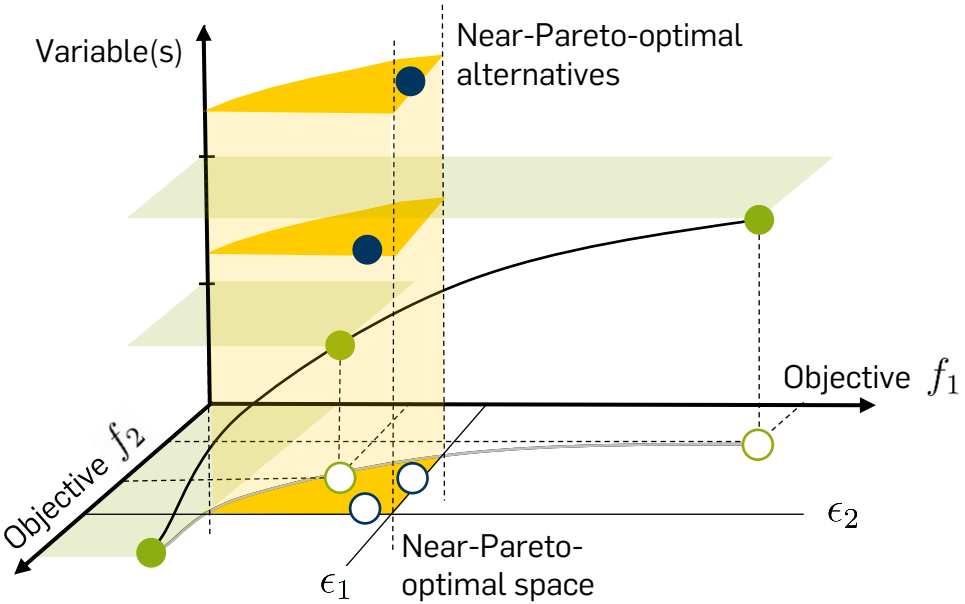

$$\min \left(\sum_i w_i x_i - s_1 - s_2 \right)$$

$$\text{s.t.} \quad f_1 + s_1 = \epsilon_1$$

$$f_2 + s_2 = \epsilon_2$$

1. Decide on objectives and variables
2. Generate Pareto front
3. Decide on near-Pareto-optimal space
4. Generate near-Pareto-optimal alternatives

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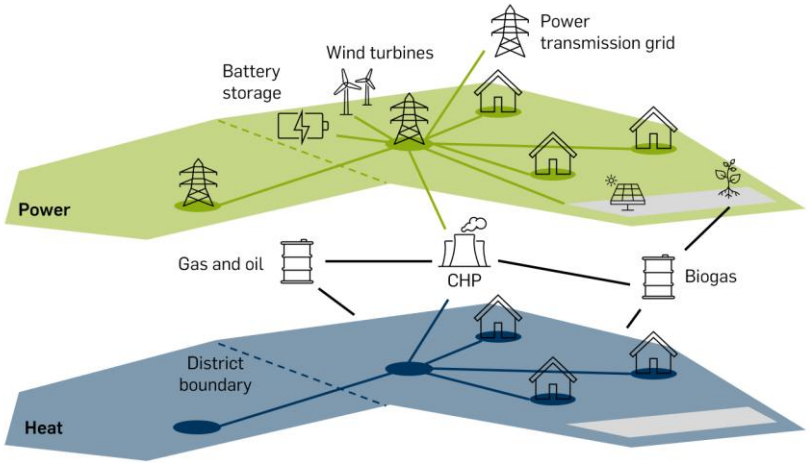
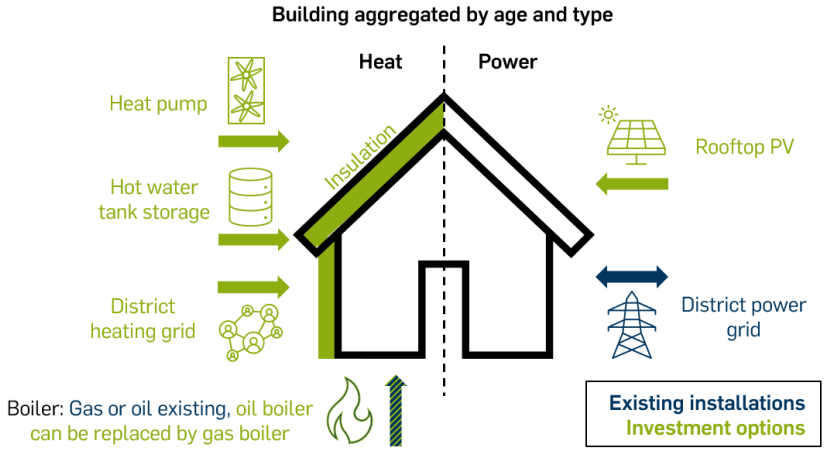
Municipal model of residential power and heat supply





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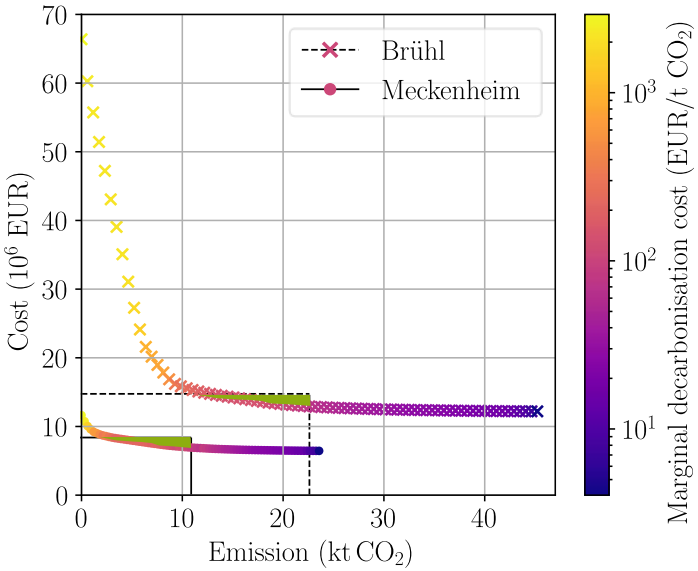
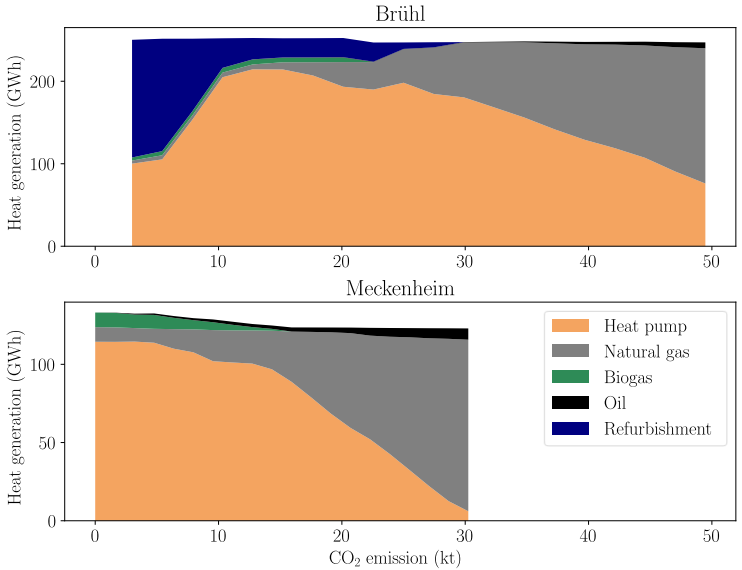
The model data is largely based on RE3ASON, see e.g. McKenna et al. *Combining local preferences with multi-criteria decision analysis and linear optimization to develop feasible energy concepts in small communities.* European Journal of Operational Research 2018. https://doi.org/10.1016/j.ejor.2018.01.036

Pareto fronts between costs and emissions inform choice of decarbonisation target





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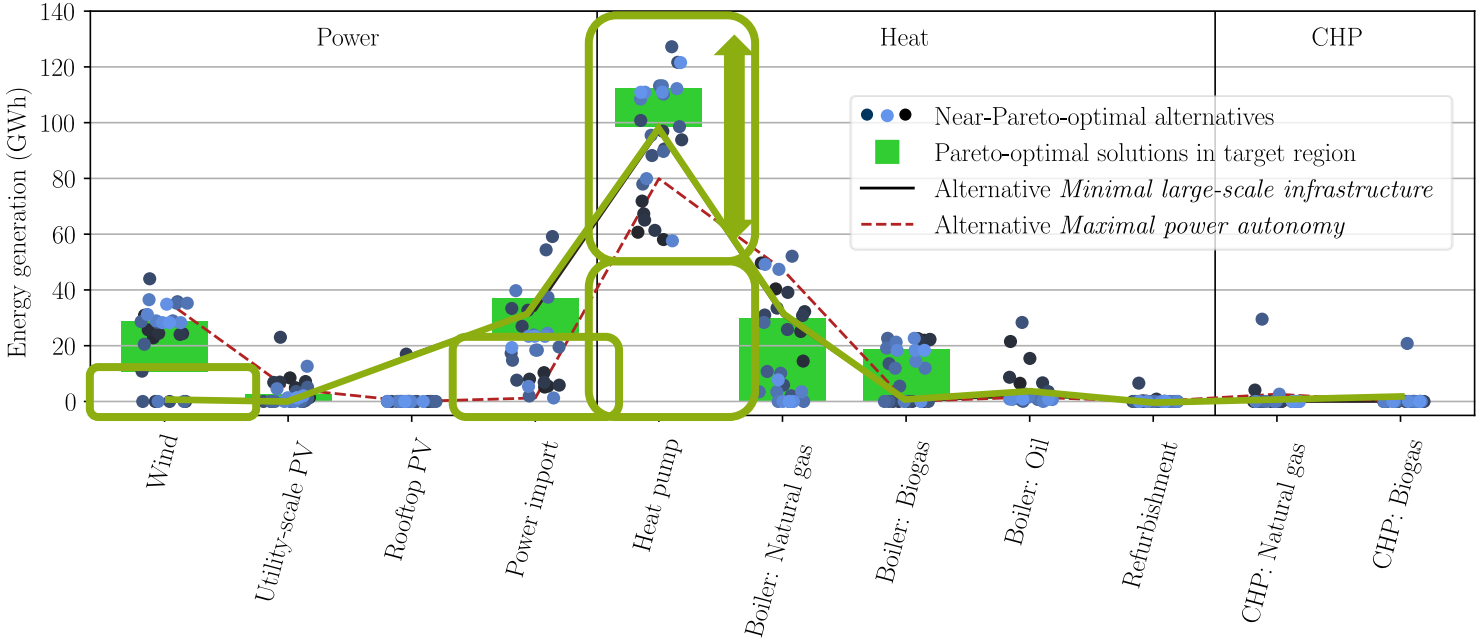
Near-Pareto-optimal alternatives expand diversity of decarbonisation options



The figure only shows results for the municipality Meckenheim.

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Conclusions

Conclusions

- MGA and MOO are two approaches for considering multiple criteria in energy system models with complementary strengths and prerequisites
- MGPA is a novel multi-criteria approach combining their strengths
- Warning: MGA, MOO and MGPA increase complexity, which is not always necessary

Future work

- Link modelling to real stakeholders and decision makers

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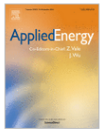

Modelling to generate near-Pareto-optimal alternatives (MGPA) for the municipal energy transition

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Thank you!

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