Integrated Investment and Dispatch Optimization for District Heating Decarbonization – A Case Study on Dresden, Germany

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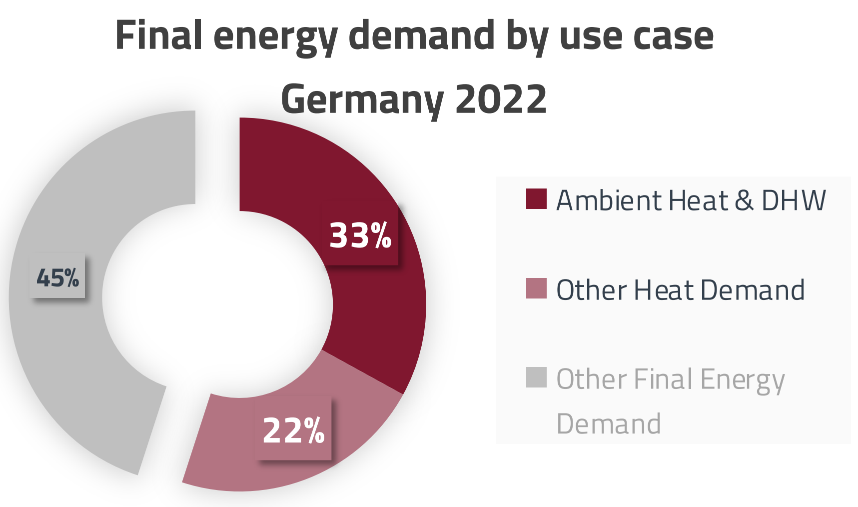
What and Why?

Easy to use and flexible Tool for evaluating investment desicions for decarbonizing district heating

Applied:
Case study of the
district heating system of Dresden



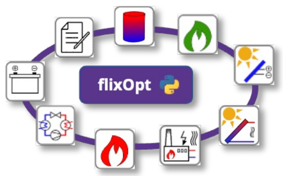
- Heating holds the biggest share in germanys final energy demand
- High hopes for district heating in decarbonizing heating
- Currently: 70 % fossil fuels

→ Huge Investments on the horizon

Methods
Basics

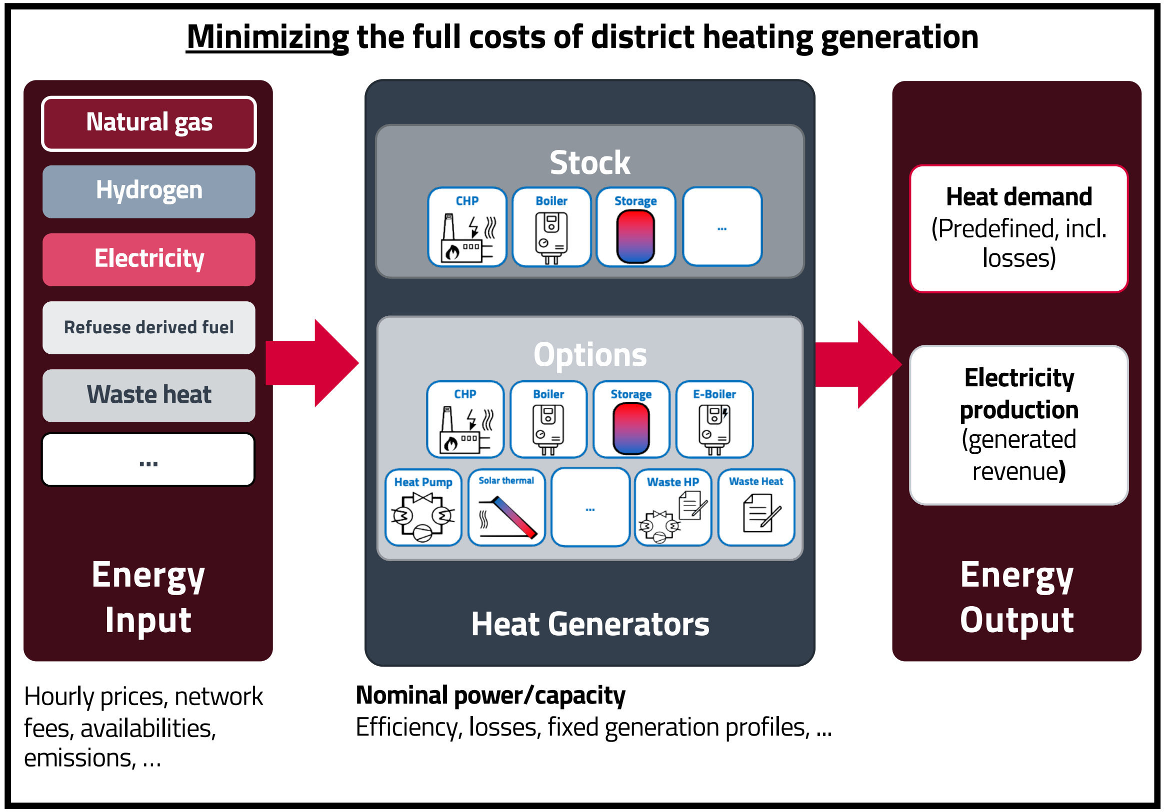
Energy System Optimization Model

Using a Python Framework from TU Dresden



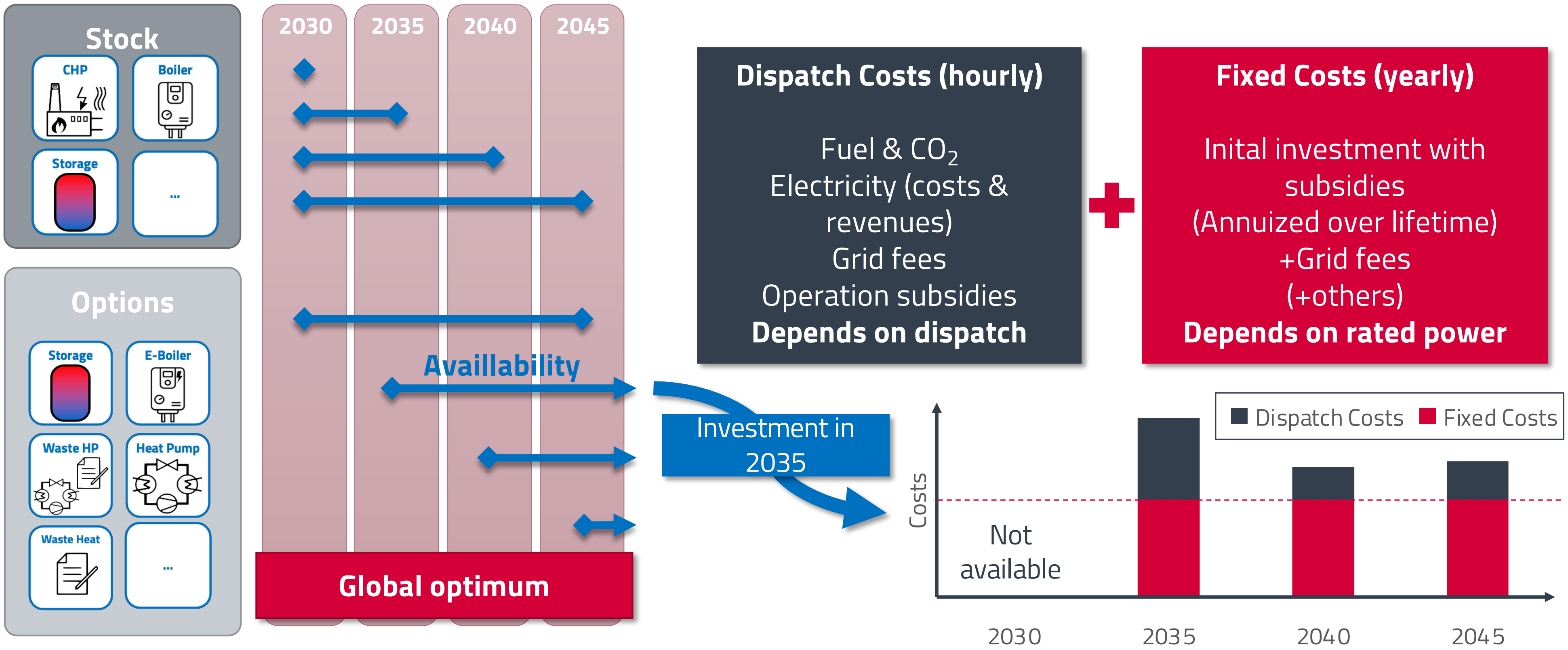
- **Brown field** & **bottom up** analysis
- **Integrated investment and dispatch** with dispatch in **one hour time increments**
- **Minimizing full costs** of heating generation

- **Perfect foresight**
- No spatial resolution
- **M**ixed **I**nteger **L**inear **P**rogramming



Methods

Investments & projecting the transition to 2045



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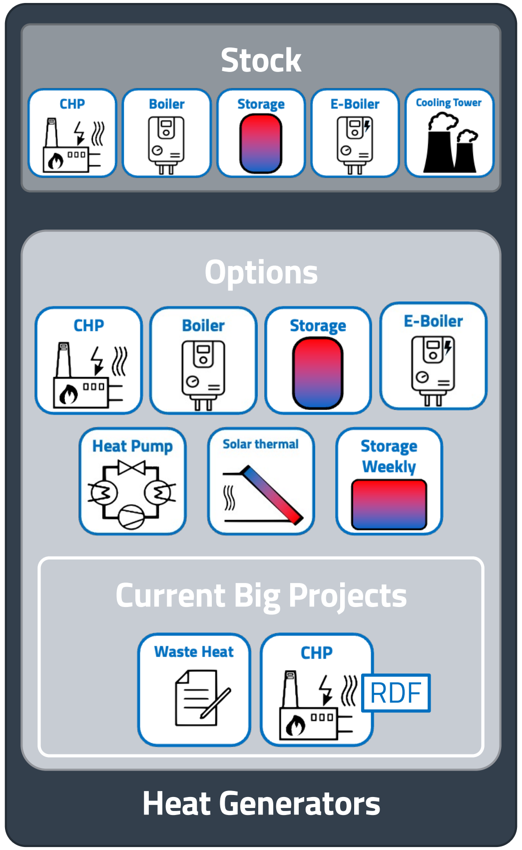
Case Study Dresden - Scenarios



Trend | **Green Germany** | **Dresden Zero** | **Price Driven**

Scenario differences

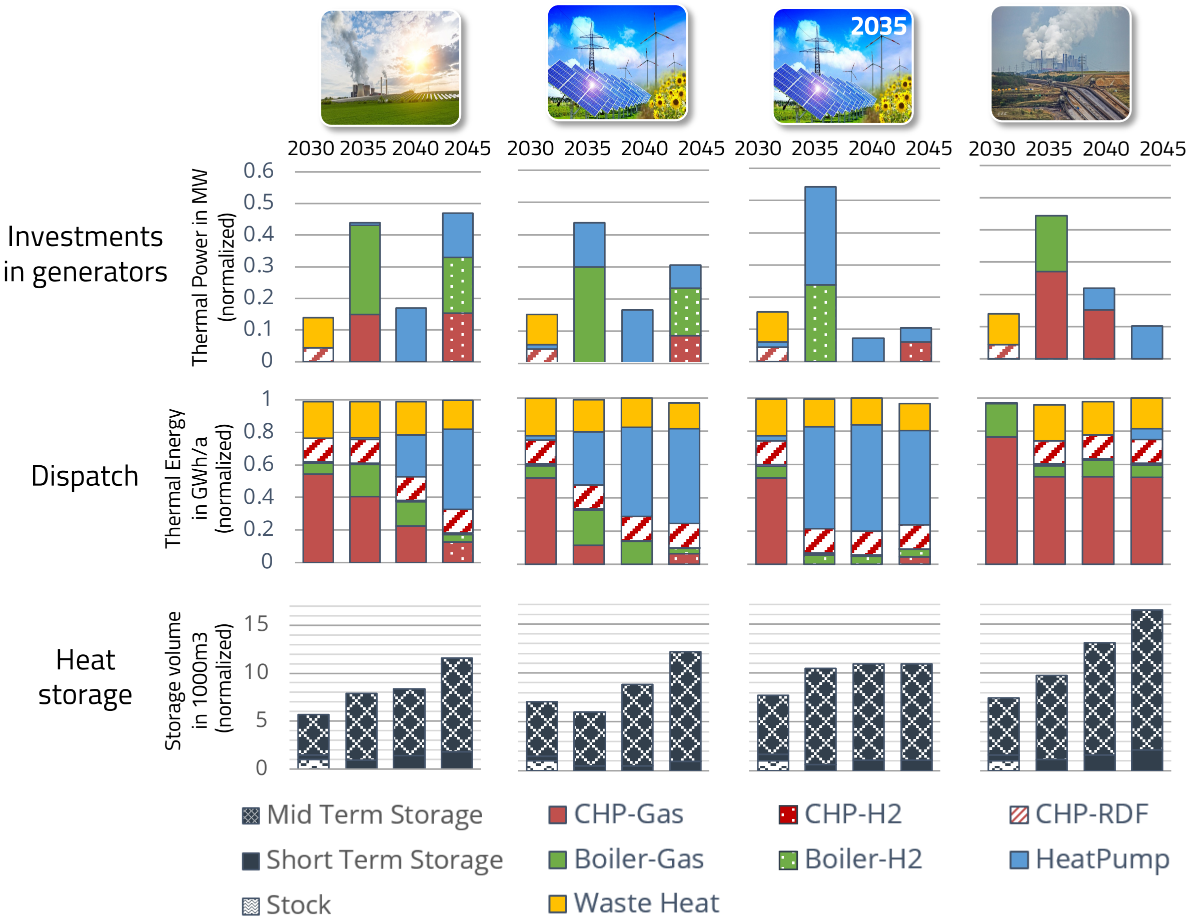
Electricity prices

Decrease of network temperature

Increase in heat demand

Target year for zero emissions

Case Study Dresden - Scenario Results



Results across scenarios

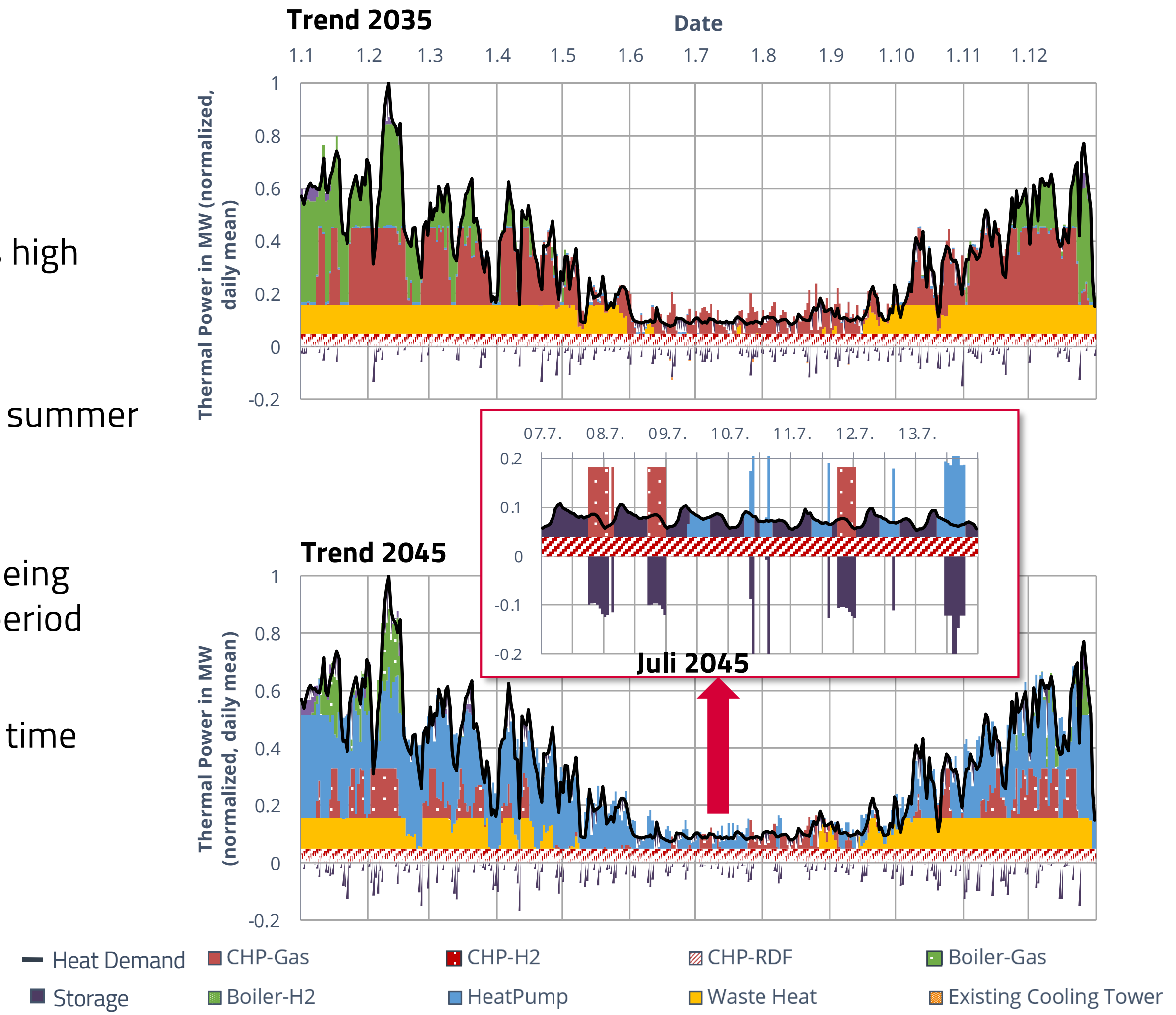
- ✓ RDF CHP & high temperature waste heat
- ✗ Electrode boilers or solar thermal
- ✗ Heat pumps before 2035
- ✗ H_2 CHP before 2045 (including retrofit)

- Natural gas boilers can act as a bridging technology
- **In 2045, Heat Pumps hold biggest share** in heat production if zero emissions are achieved
- Rapidly **increasing storage capacity (11 times by 2045)**
- **Small differences in costs (-5 % to -19 %*)**
- H_2 is the last resort for zero emissions & demand is low

*Compared to the rather expensive year 2021

Case Study Dresden
Techno-economic interactions

- **Future CHP must be highly flexible** & requires high storage capacity in summer
- CHP and heat pumps cannibalise each other in summer due to limited heat demand
- High-temperature waste heat is increasingly being displaced by heat pumps outside the heating period
- Heat pump operation is strongly influenced by time limited operation subsidies (BEW: 10 years)



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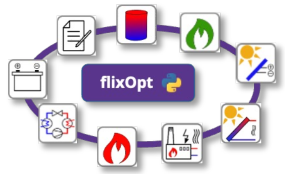
Model capabilities



Empowering district heating operators

- Optimizing the decarbonization based on total costs
- Deeper understanding of techno-economic interactions inside the system
- Identifying no regret options
- Assessing individual projects in context of the system

→ An excellent tool for making decisions about major investments in increasingly complex energy systems.

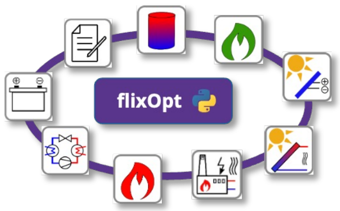
Flexibility and Ease of Use

- General flexibility of the generic flixOpt framework
- Flexible optimization target (multitarget, bounds for CO_2, ...)
- Simple and clear parameterisation (MS Excel)
- Automated evaluation (MS Excel)

→ Experimenting made easy

Modeling the transition - What's next?

- **Spatial Resolution:** Transport limits and pumping power of the district heating network
- **More technologies** like electrolyzers
- Increasing **modeling details**: (for ex. limiting operation of Heat Pumps by source temperature)
- Improving **input data and range of scenarios**
- Model will be published **open source on GitHub**, including automated evaluation and datainput via MS Excel, **extending the existing flixOpt package (collaboration welcome)**



Keen on answering questions

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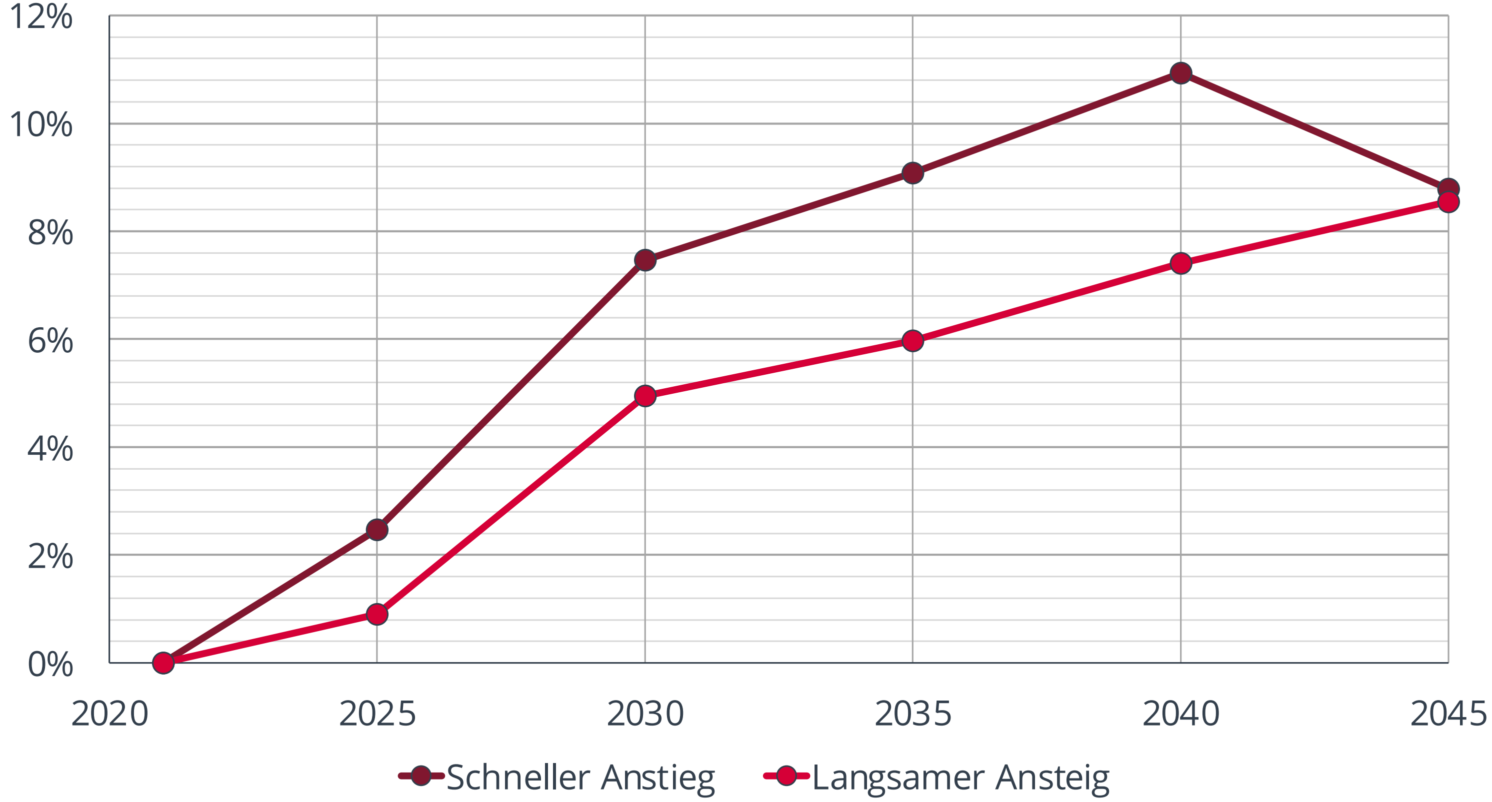
Forecasted Heat Demand



District Heating Network Losses

Loss Coefficient

$$k_{\mathrm{R_{DHN}}} = \frac{Q_{\mathrm{Loss}}}{\sum_{t=1}^{8760}(\vartheta_{\mathrm{m},t} - \vartheta_{\mathrm{amb},t}) * l_{\mathrm{DHN}}}$$

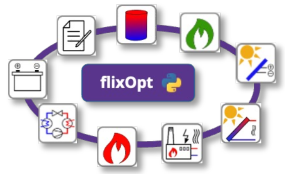
Mean Temperatur difference

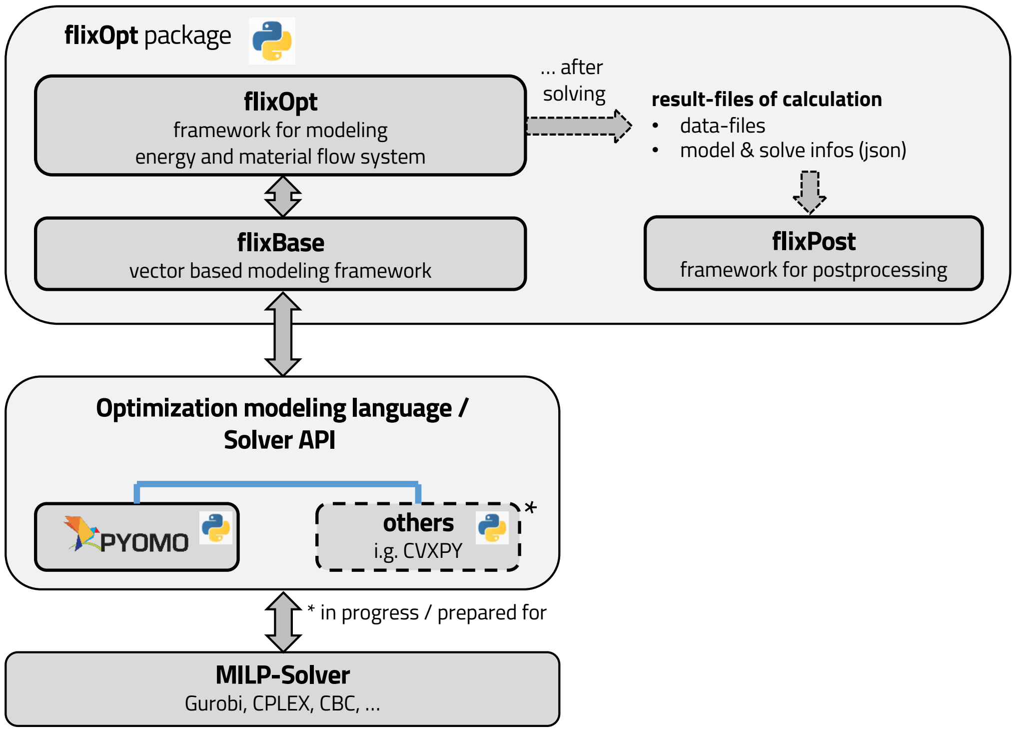
$$\vartheta_{\mathrm{m},t} = \frac{\vartheta_{\mathrm{FF},t} + \vartheta_{\mathrm{R}F,t}}{2}$$

Hourly Heat Loss

$$\boldsymbol{Q_{\mathrm{DHN},t} = k_{R_{\mathrm{DHN}}}\left[\frac{MWh}{K}\right] * \left(\frac{\vartheta_{\mathrm{FF},t} + \vartheta_{\mathrm{RF},t}}{2} - \vartheta_{\mathrm{amb},t}\right)}$$

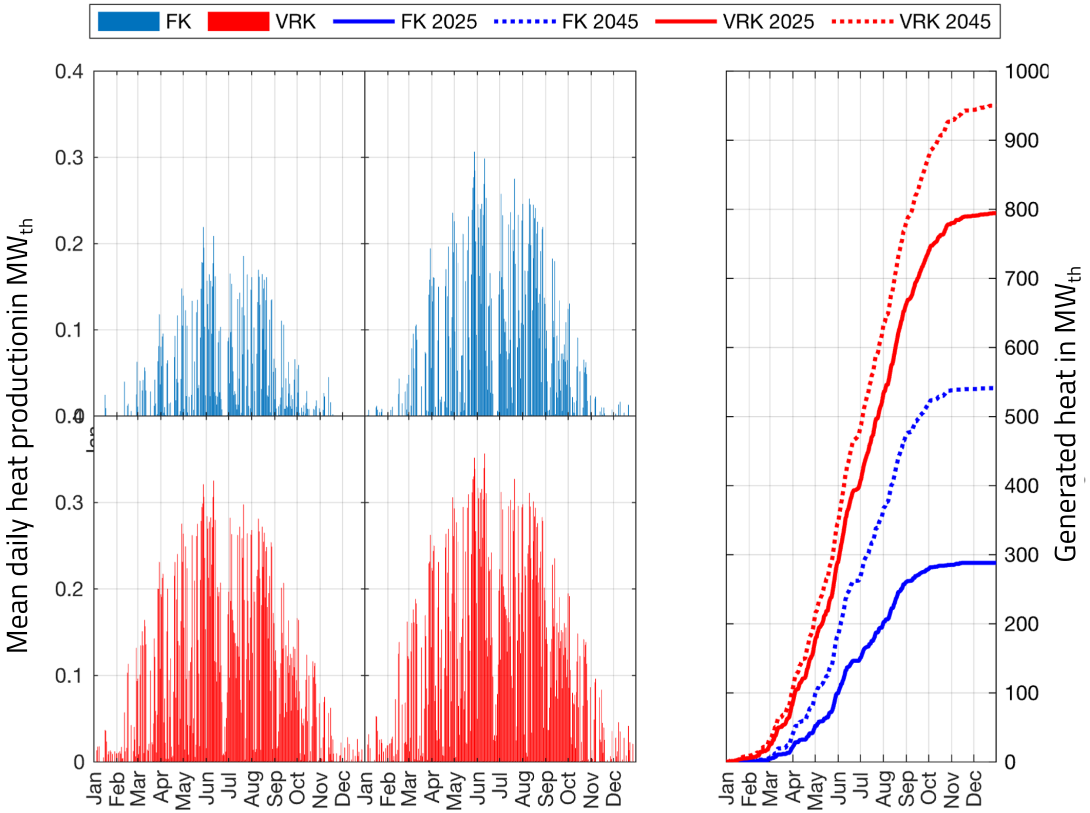
flixOpt architecture



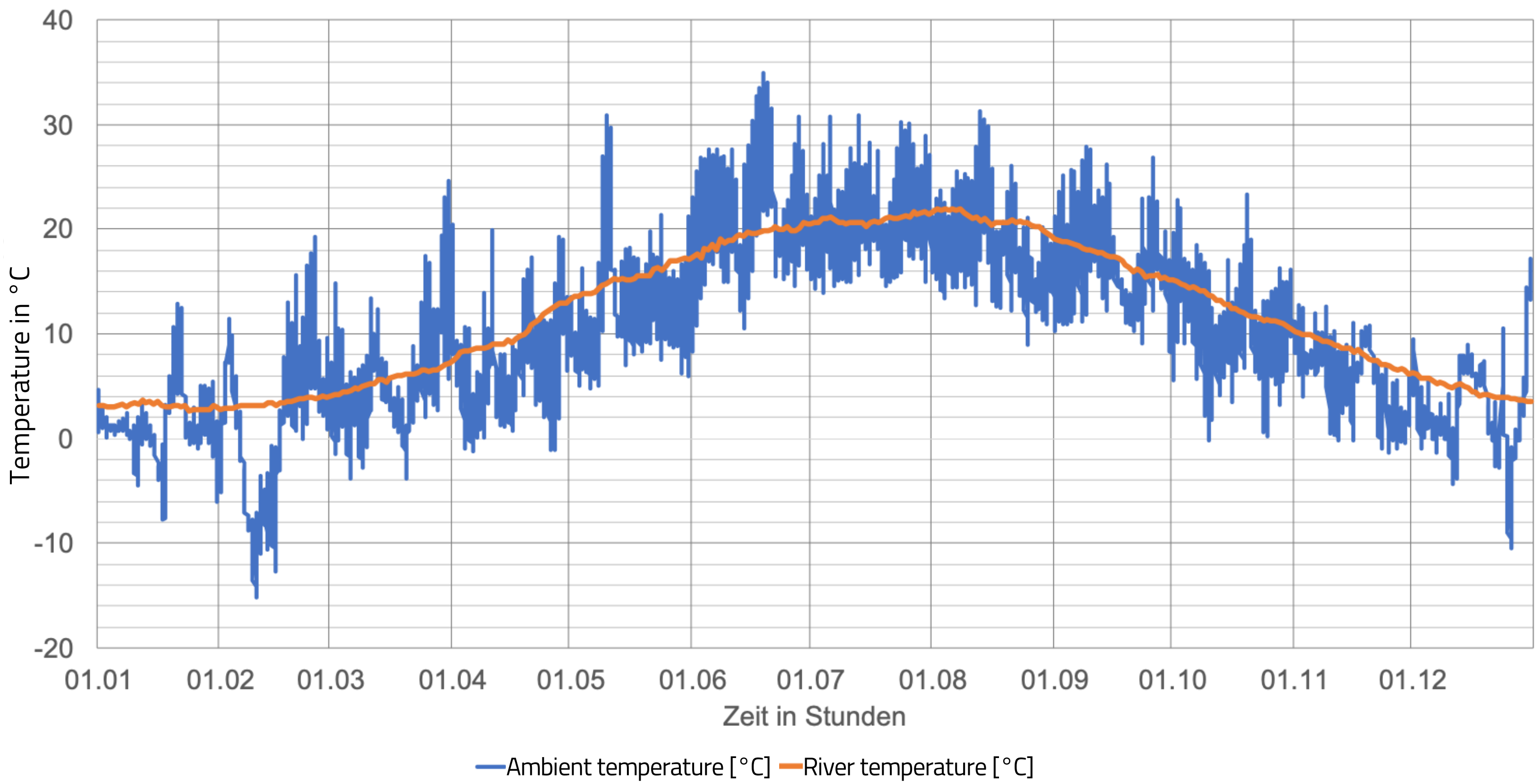


Generation Profile Solarthermal

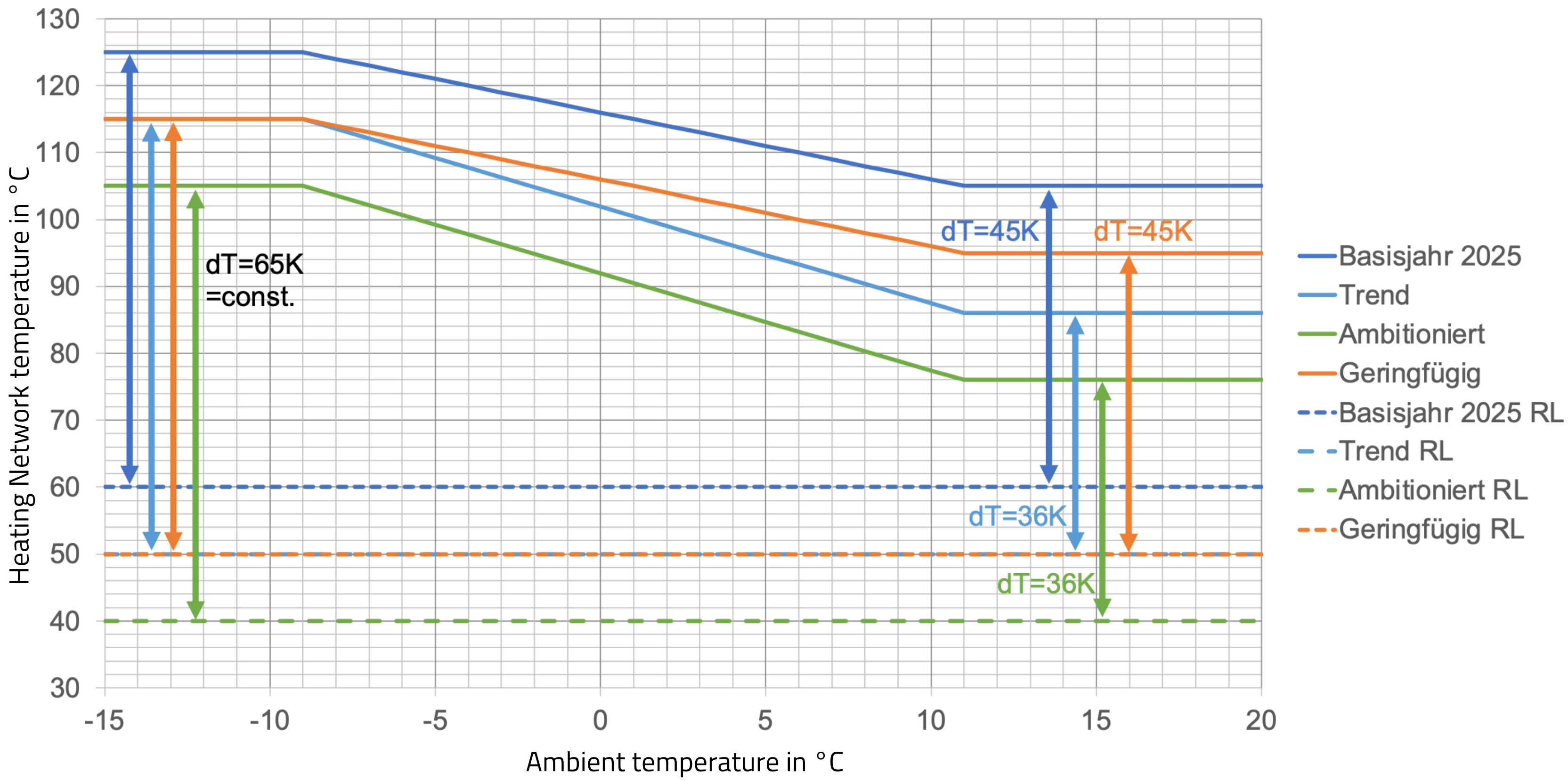
Generation per MW_{th} installed Power



Temperature of heat Sources for Heat Pumps



Heating Network Temperature Reduction



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Energy prices
Grid Fees, taxes and other charges

	Electricity (Electric Boiler)	Electricity (HP)	Natural Gas	Hydrogen
Grid Fee in €/MWh	32,5	20,4	3	3
Taxes in €/MWh	20,5	20,5	5,5*	5,5*
Other Charges in €/MWh	10 (“KWK-Umlage”, “Off-Shore-Netzumlage”, …)	exempted	-	-
Total in €/MWh	63 €/MWh_{el}	40,9 €/MWh_{el}	8,5 €/MWh_{Hu}	8,5 €/MWh_{Hu}
Grid Fee in €/(kW*a)	25,8	56,05	13	13

*CHP is exemptet

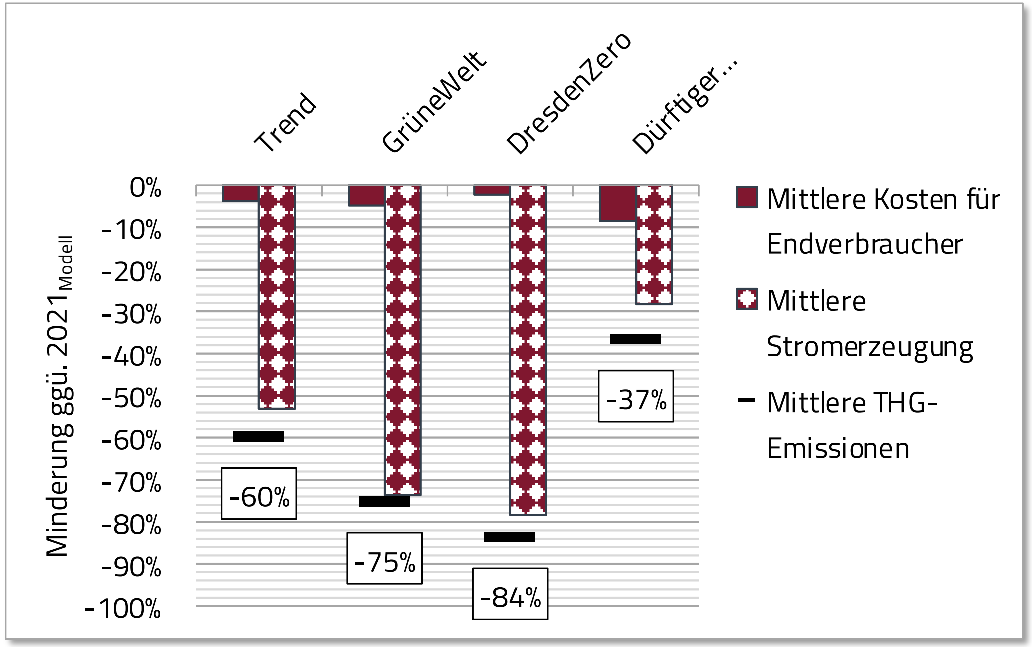
Diskussion
Costs of Heat generation

- Cross-scenario cost reduction of 5 - 19 % compared to 2021
  - Real: individual projects (deviating fixed costs, service life, efficiency, operating concept, ...)
  - Various uncertainties
  - Expensive comparison year 2021

→ **Limited informative value**

- Significantly lower GHG emissions at cost of significantly less electricity generation and slightly higher costs

→ Weighting of electricity generation?



Szenarienübersicht

	Trend	GrüneWelt	DresdenZero	DürftigerKlimaschutz
Strompreisentwicklung	Aktueller Trend	Politische Ziele 2045	Politische Ziele 2045	Aktueller Trend
Wärmebedarf	Langsamer Anstieg	Schneller Anstieg	Schneller Anstieg	Langsamer Anstieg
Netztemperaturabsenkung	Trend	Ambitioniert	Ambitioniert	Geringfügig
Klimaneutralitätsvorgabe	2045	2045	2035	-

Übersicht Energiesystem