

# Economic and Environmental Impacts of the Optimal Design of Sector-Coupling Energy Systems in Residential Districts

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# Agenda

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## Background & Motivation

- Sector Coupling in Residential Districts
- Research Project: ODH@Bochum-Weitmar

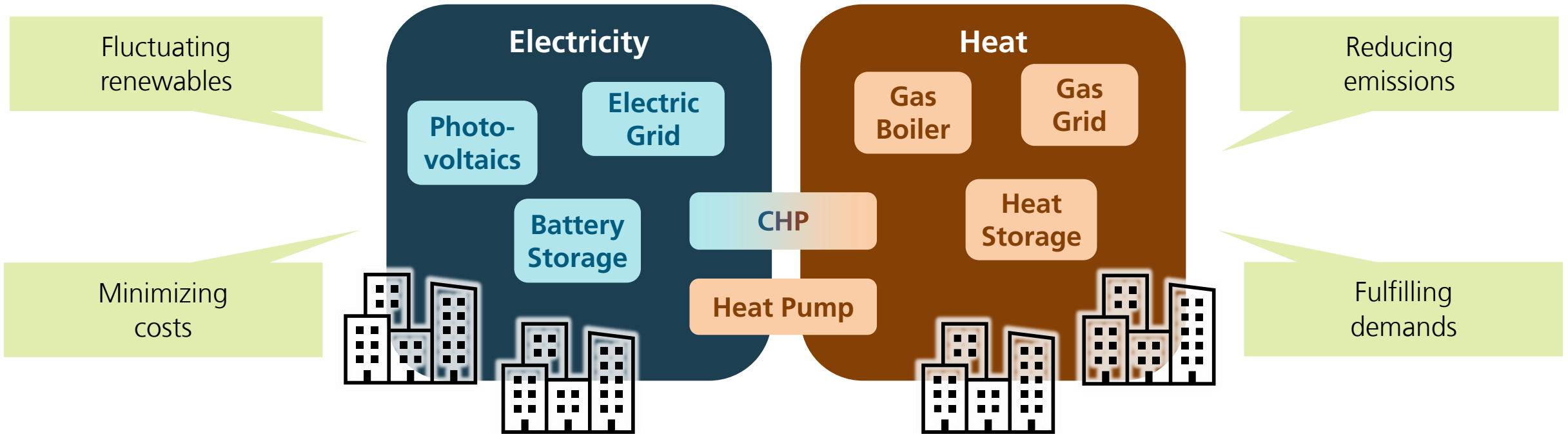
## Methodology

- Model Overview
- Multi-Objective Optimization
- Model Implementation

## Case Study

- Energy Concepts under Analysis
- Overview of Parameters and Input Data
- Optimization Results

# Sector Coupling in Residential Districts



How can the economic and environmental impacts of the design optimization of sector-coupling energy systems be analyzed?

# Research Project: ODH@Bochum-Weitmar

## Overview [1]

### Location

- District of Weitmar in Bochum.
- 232 multi-family houses from 1950s and 1960s.

### Partners

- Vonovia
- **Fh. UMSICHT**
- Fh. FIT
- Fh. IOSB-AST
- Fh. IOSB-INA
- Ampeers Energy

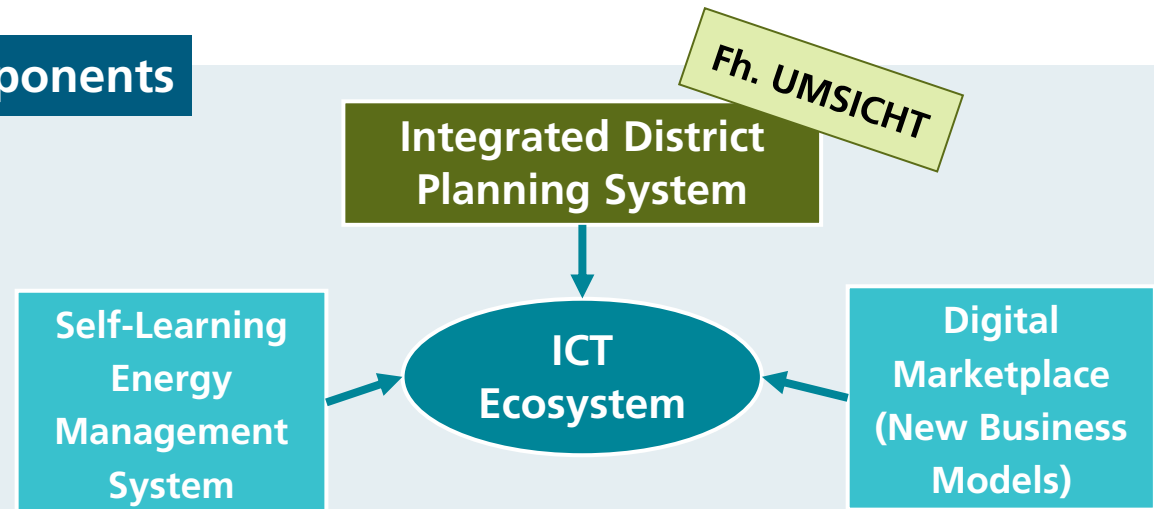
### Funding

- Ministry of Economic Affairs, Industry, Climate Action and Energy of the State of North Rhine-Westphalia

### Goals

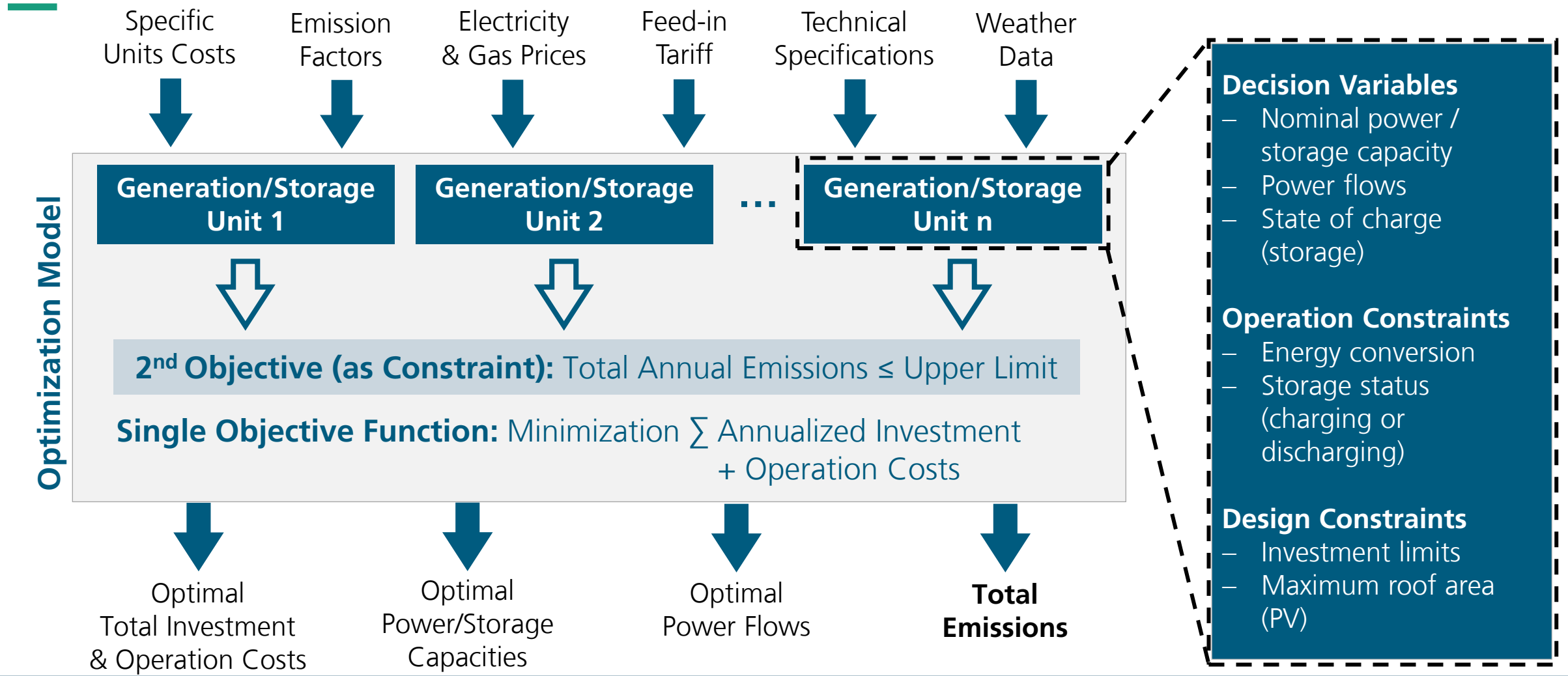
- Development of sustainable energy solutions.
- Optimization of energy efficiency while maintaining rent neutrality.
- Development, evaluation and testing of integrated district solutions.
- Alignment of neighborhood concepts with the needs and user behavior of residents.

### Components



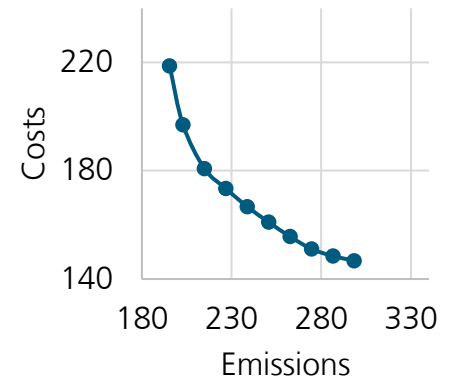
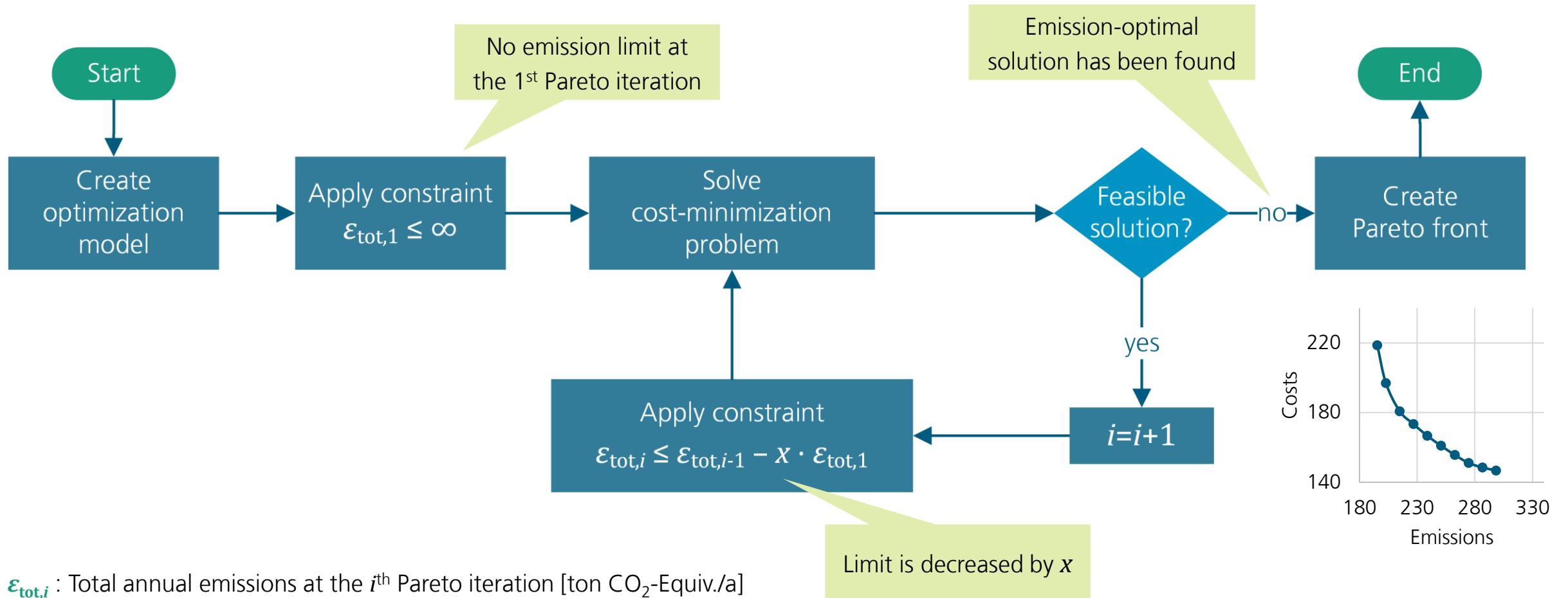
[1] "Bochum-Weitmar - Open District Hub," [Online]. Available: <https://opendistricthub.de/bochum-weitmar/>. [Accessed: 01-Nov-2022].

# Model Overview



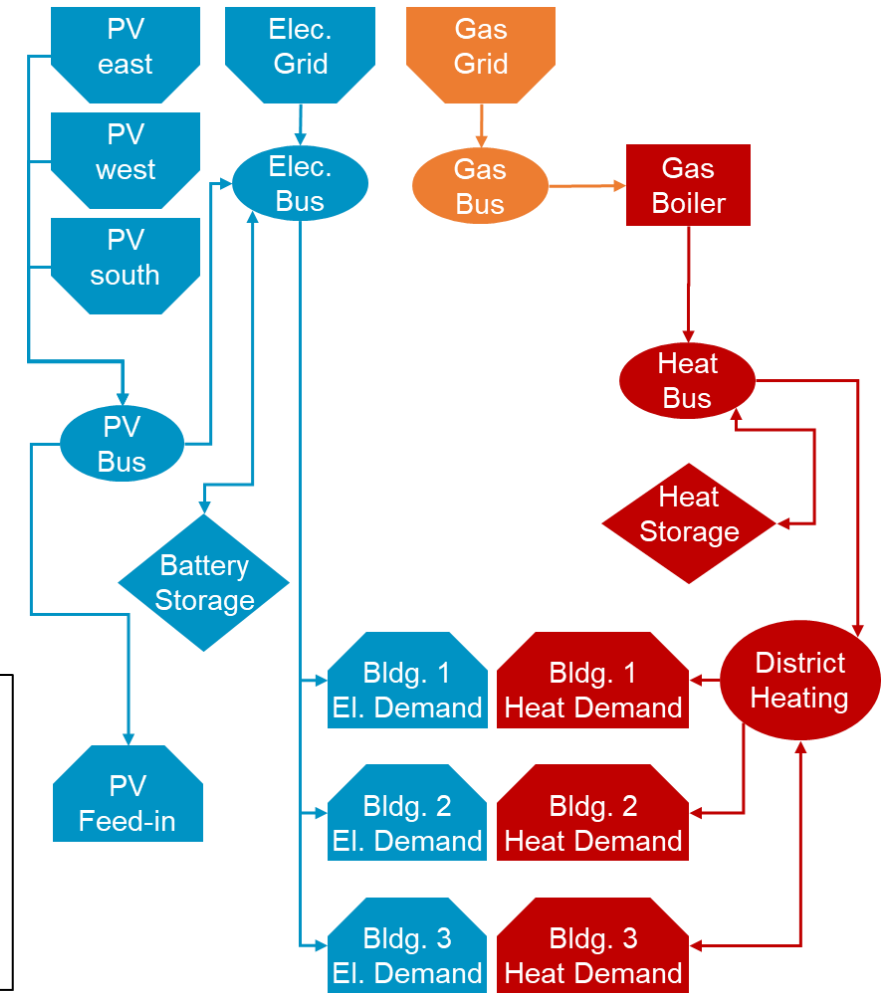
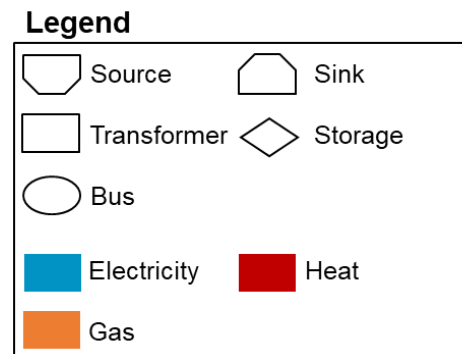
# Multi-Objective Optimization

## Epsilon-Constraint Method



# Model Implementation

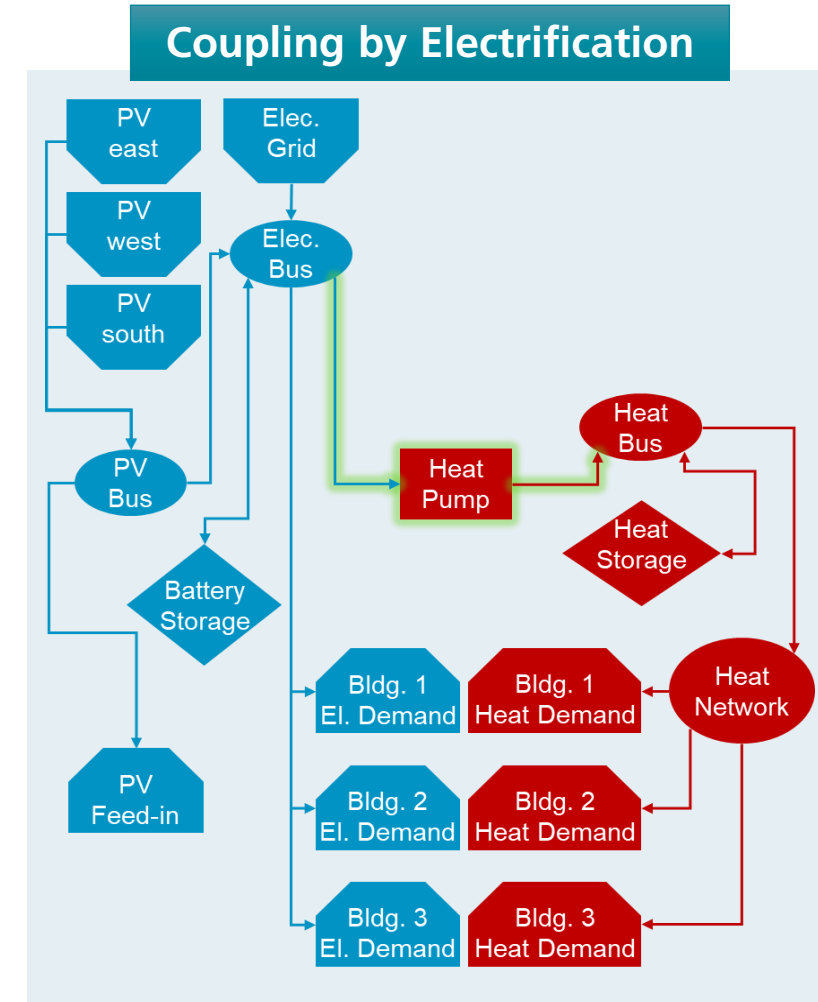
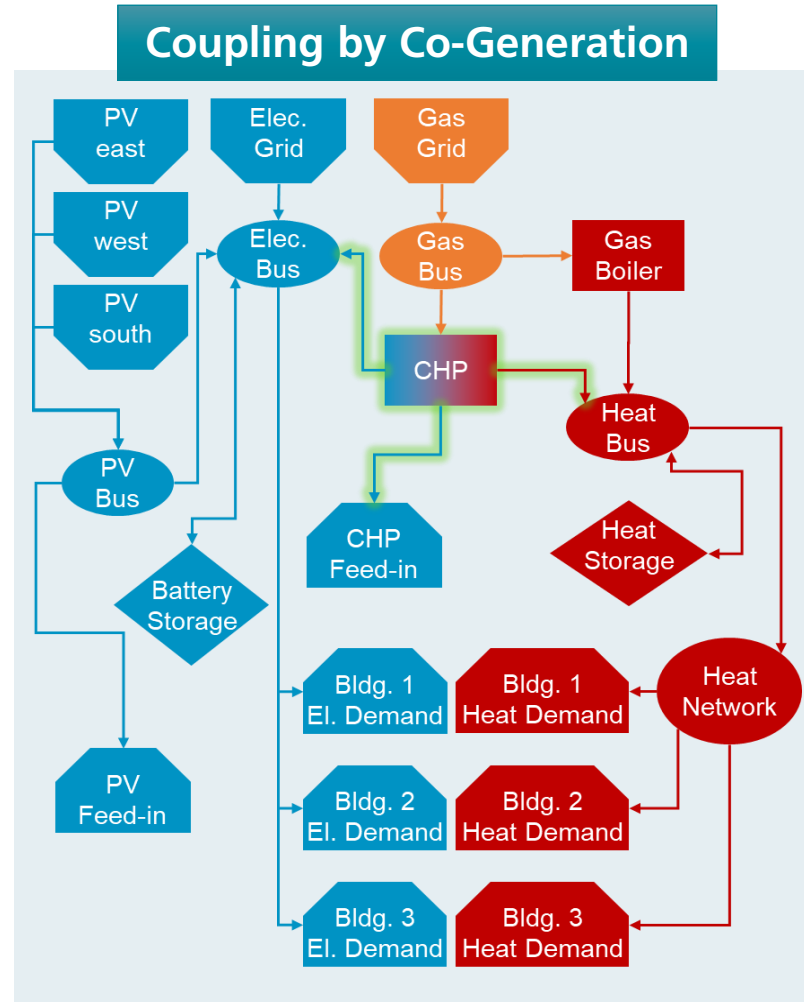
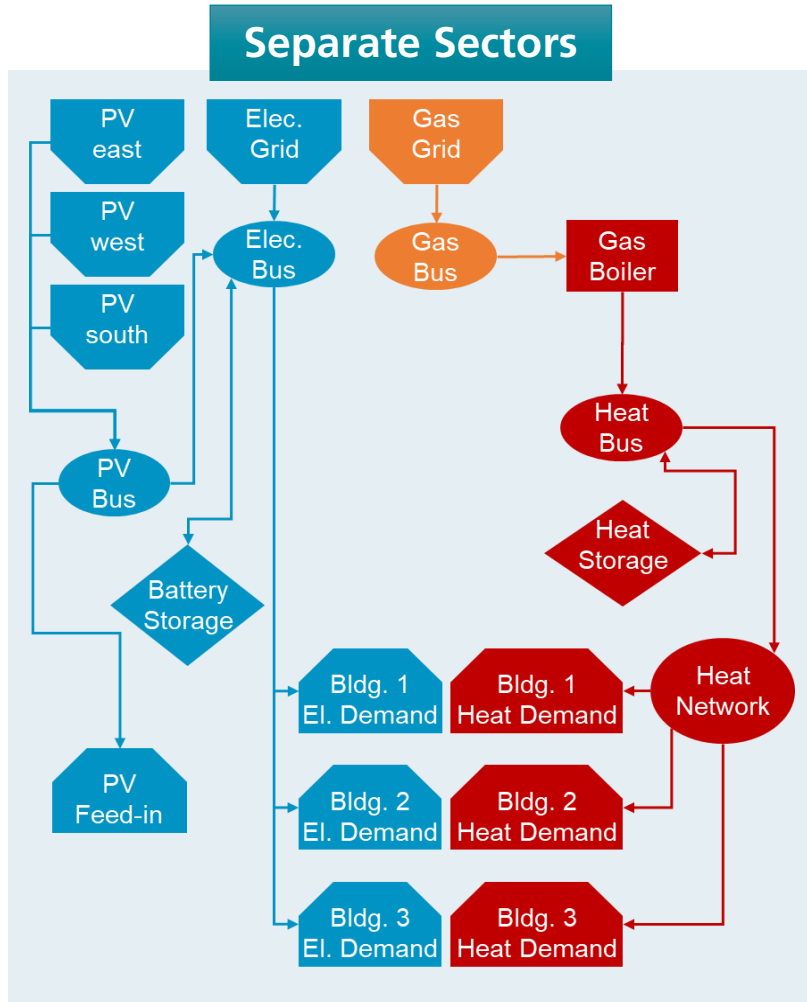
- **Mixed-integer linear programming (MILP)** problem: binary variables for installation decisions.
- Model was implemented using:
  - **Python**
  - **pyomo** (optimization package)
  - **oemof** (framework for modeling energy systems) [2].
- **Modular structure:** units, sources and demands can be structured according to the desired energy system.



[1] "oemof Libraries," [Online]. Available: <https://oemof.org/libraries/>. [Accessed: 01-Oct-2022].



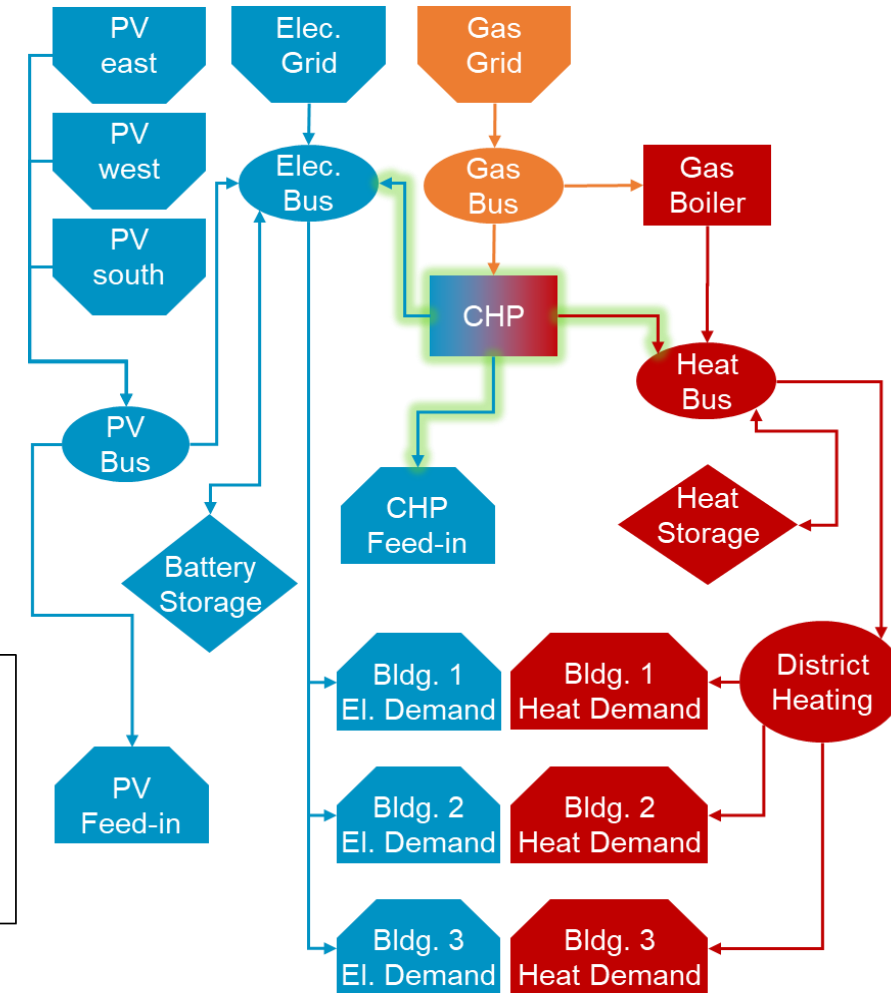
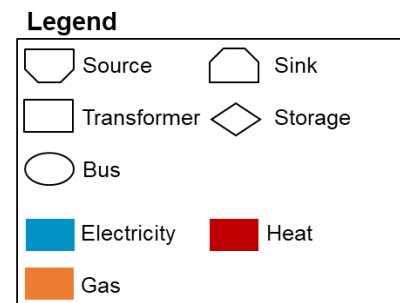
# Energy Concepts under Analysis





# Overview of Inputs

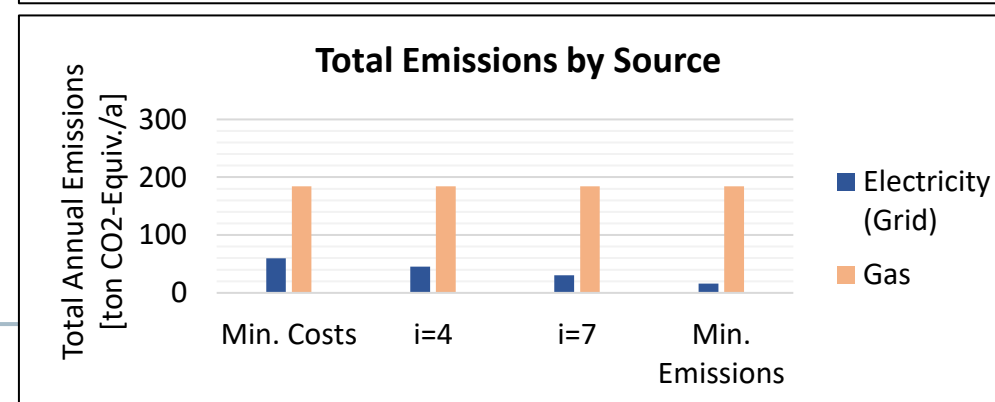
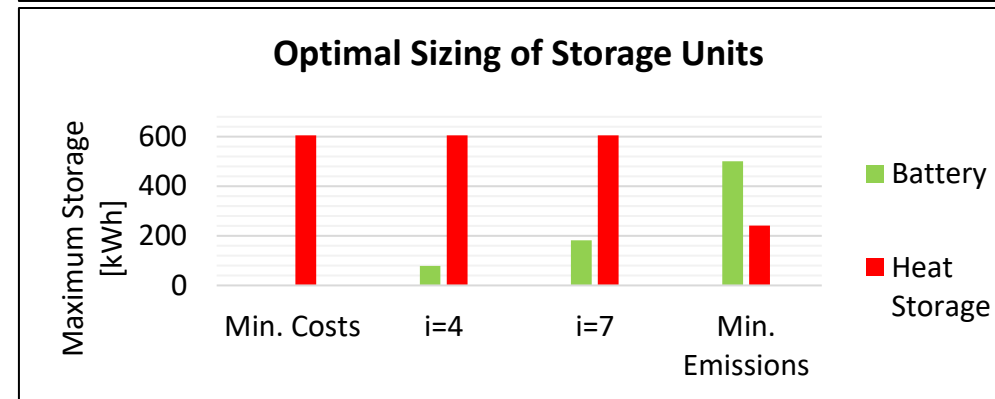
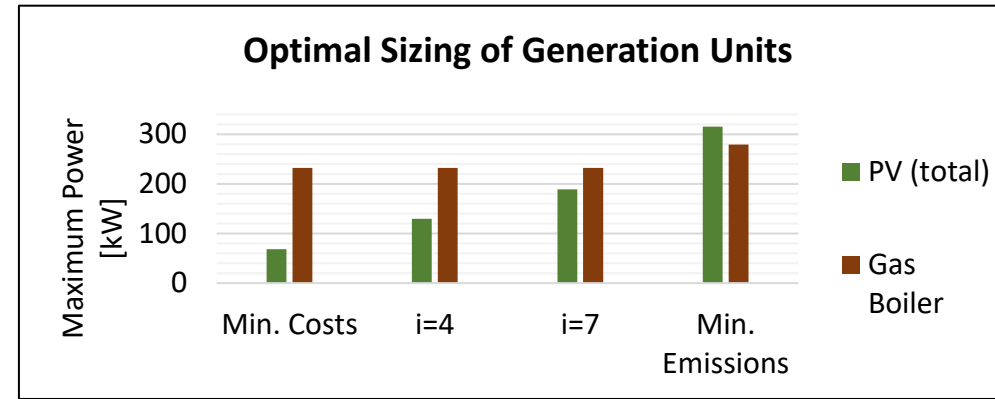
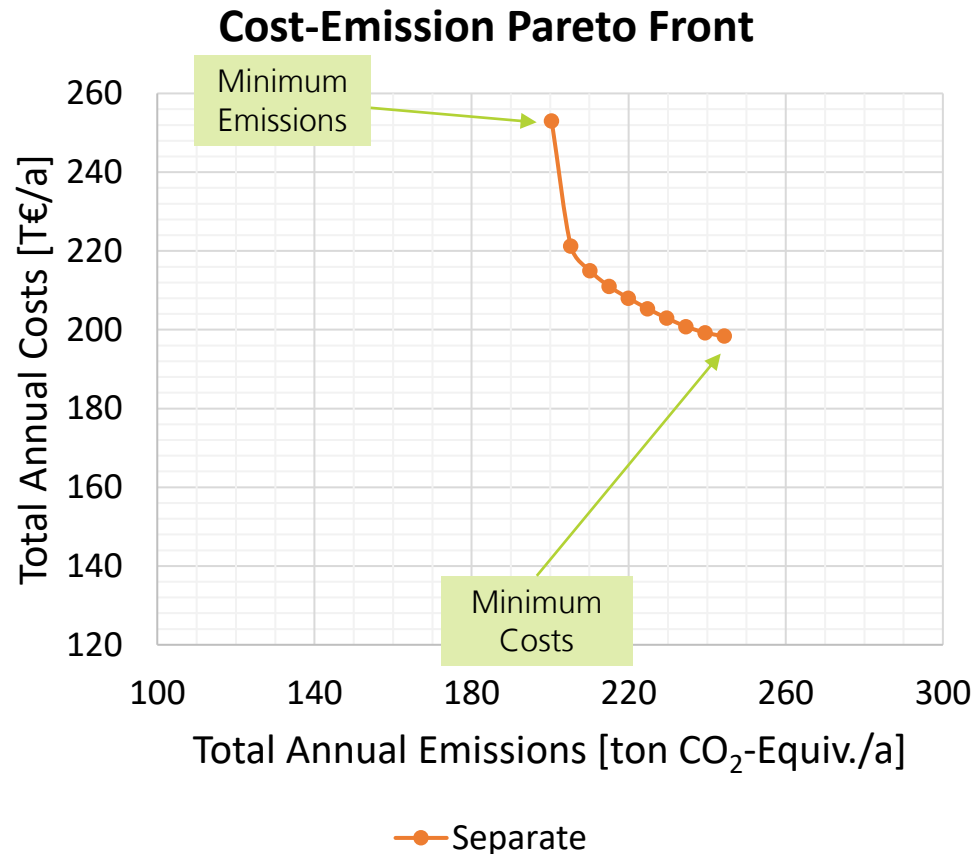
- **13 exemplary buildings**, clustered into 3 groups.
  - Energy demands: generated profiles using the guideline VDI 4655 [3].
- Optimization **horizon** of **one year**, with **hourly** temporal resolution.
- **Investment costs** were given on an **annual basis** using the annuity factor.
- **Emission factors** (in g CO<sub>2</sub>-Equivalent/kWh) were considered for:
  - **Electricity mix** from grid: **485** [4]
  - **Gas imports** from grid: **228** [5]
- **Commodity Prices**:
  - Time-varying **electricity price** (mean = **0.40** €/kWh) [6]
  - Constant **gas price**: **0.16** €/kWh [7]
- **Surcharges/Tariffs**:
  - **PV**: **0.071** €/kWh for **exports** [8]
  - **CHP**: **0.358** €/kWh for **exports**, **0.085** €/kWh for **self-consumption** [9]



## Case Study

# Optimization Results

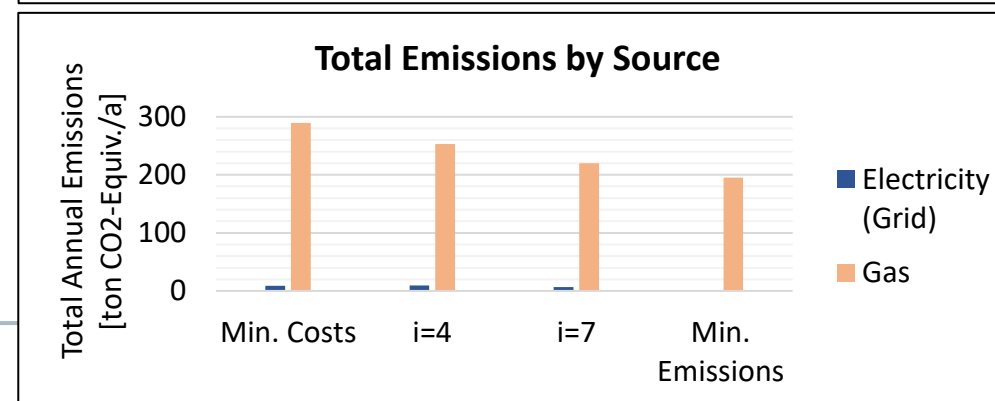
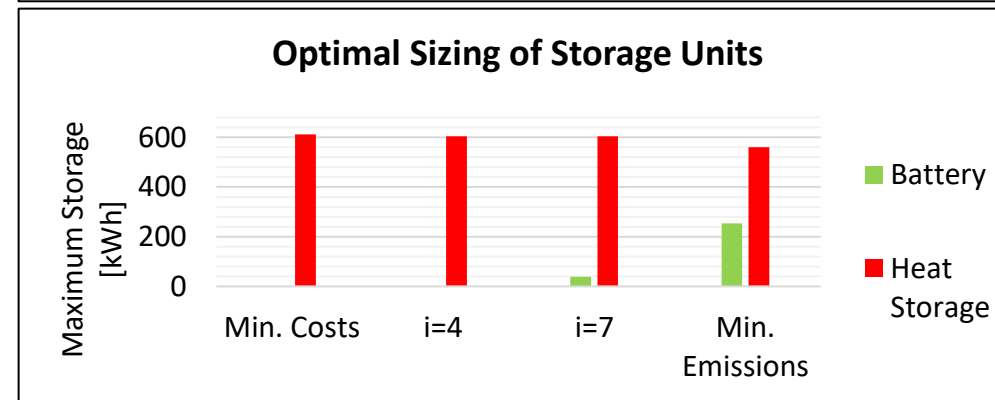
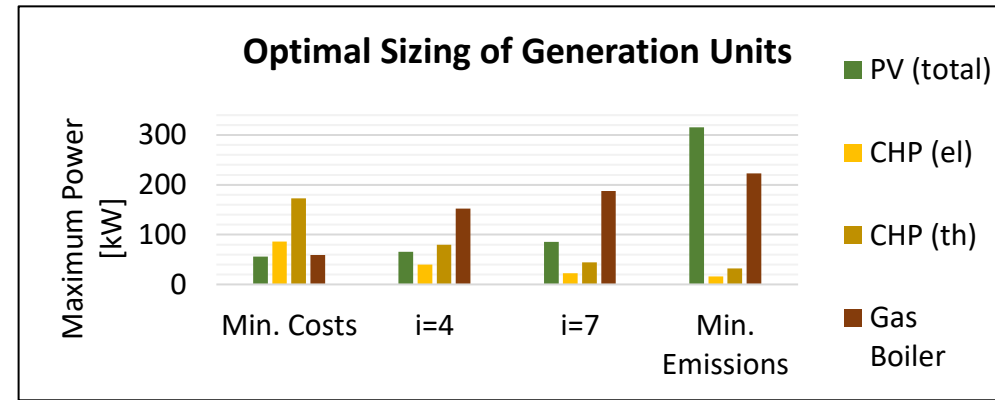
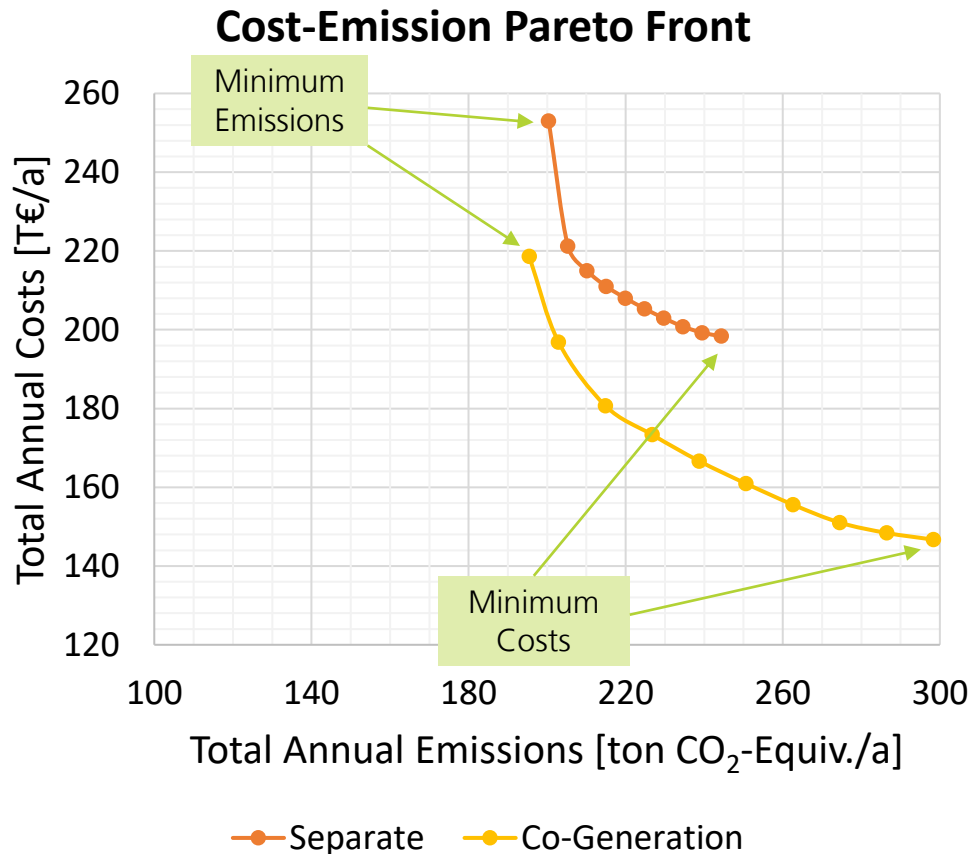
## Concept 1: Separate Sectors



Emission reduction is only possible by reducing imported (grid) electricity **through** increasing PV and battery storage sizing.

# Optimization Results

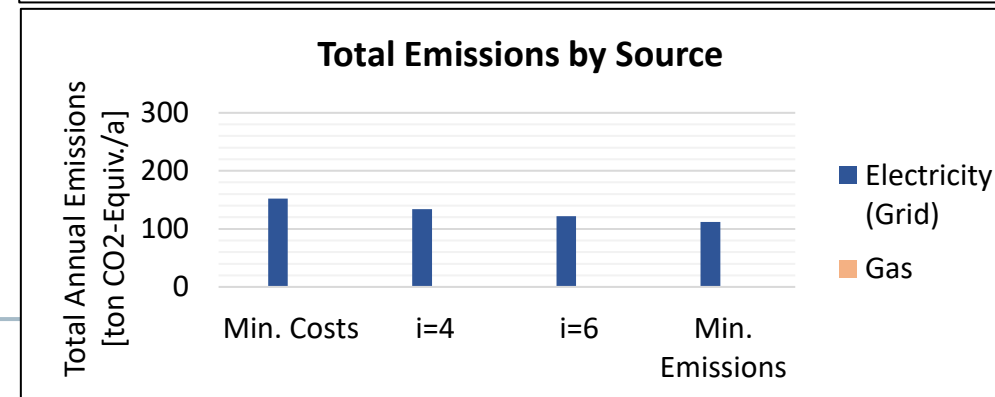
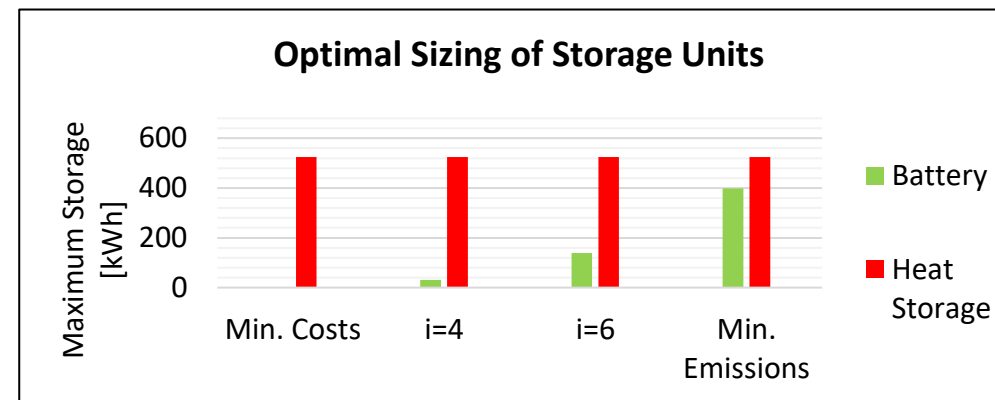
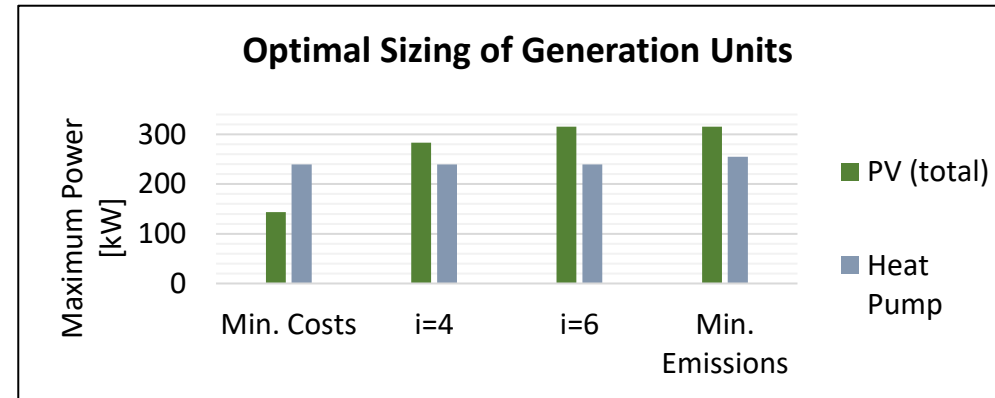
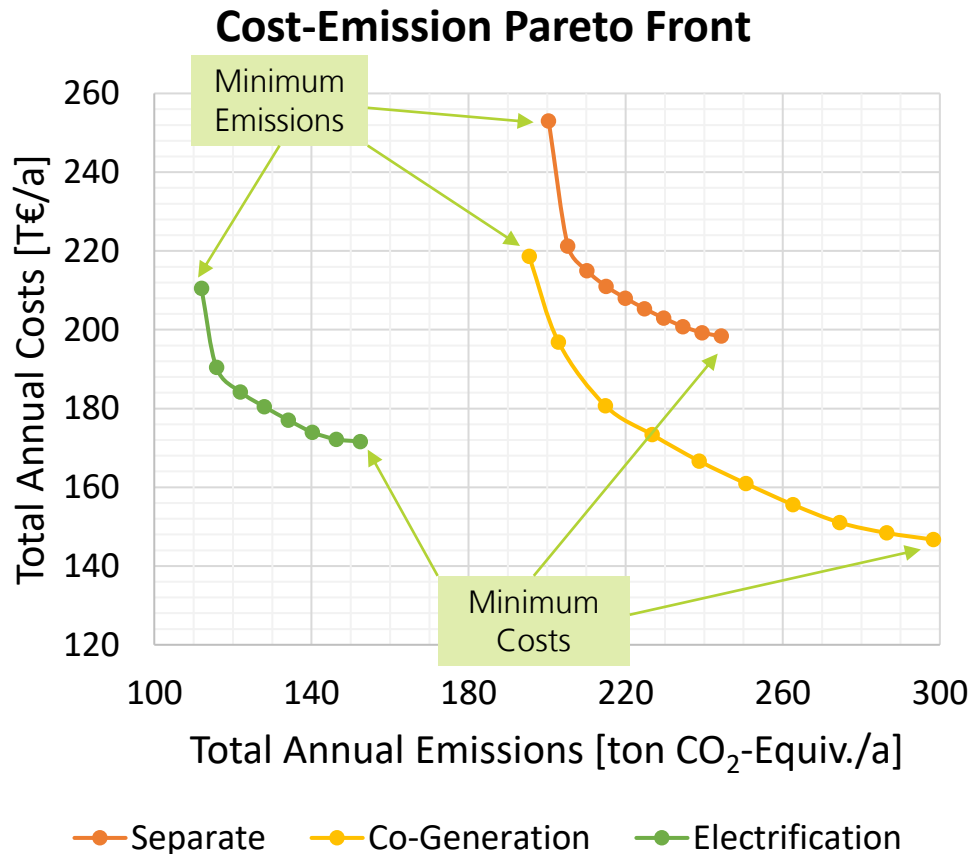
## Concept 2: Coupling by Co-Generation



CHP is economically advantageous due to current surcharges. **However, it leads to high emissions from gas imports!**

# Optimization Results

## Concept 3: Coupling by Electrification



Electrification of heating **causes** remarkable mitigation of emissions.

# Conclusion

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- A multi-objective optimization model has been developed to design energy systems based on economic and environmental goals
  - **Multi-objective optimization is powerful** to identify **cost- and emission-minimization** potentials of energy systems.
- **Gas** is currently playing a **major role in producing emissions** in the residential sector.
- **PV contributes significantly** to the **reduction of emissions** in all concepts.
- Under current CHP-laws (KWKG-Gesetz), **co-generation is cost-efficient but can cause more emissions**.
- Utilizing **heat pumps leads to the highest decrease in emissions**. However, other technical aspects must be taken into consideration.
- Further investigations of environmental impacts can be carried out by also including indirect emissions (scope 3).

# References

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- [2] "oemof Libraries," [Online]. Available: <https://oemof.org/libraries/>. [Accessed: 01-Oct-2022].
- [3] *Referenzlastprofile von Ein- und Mehrfamilien-häusern für den Einsatz von KWK-Anlagen*, VDI 4655 (VDI), 2022.
- [4] el price "Market data," Market Data | EPEX SPOT. <https://www.epexspot.com/en/market-data>.
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# Contact

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