Design of renewable and system-beneficial district heating systems using dynamic emission factors for grid-sourced electricity in optimization models

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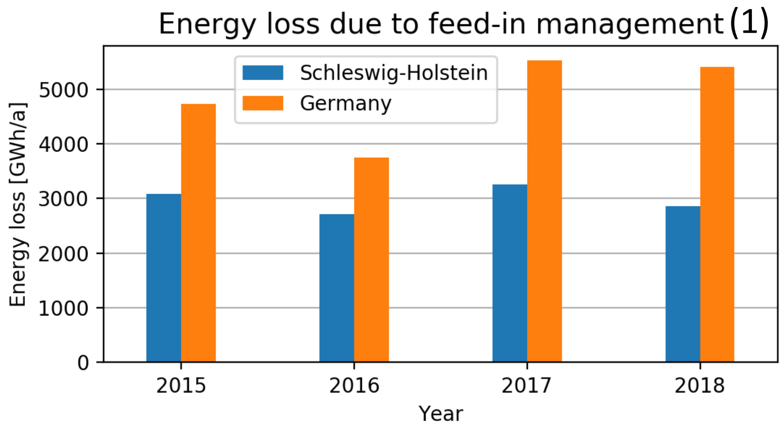
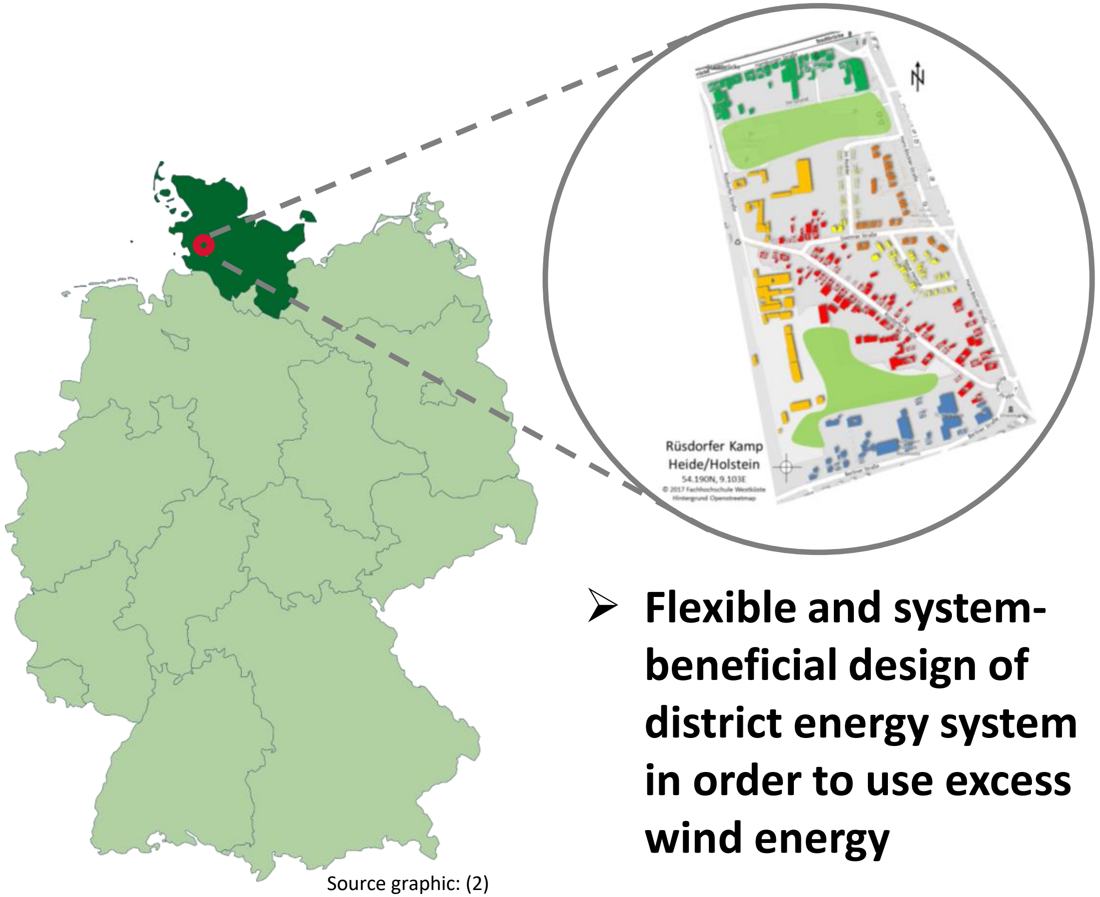
Background



Urban district Rüsdorfer Kamp (Heide)



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Research Project QUARREE100

- Resilient, scalable and transferable energy system solutions for built-up urban districts
- High share of renewable energies in all energy sectors
- Integration of urban districts in the overall energy system

➢ **Flexible and system-beneficial design of district energy system in order to use excess wind energy**

Bundesministerium für Bildung und Forschung

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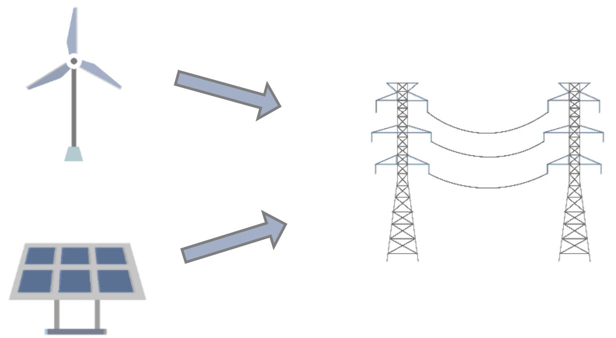
Projektträger Jülich Forschungszentrum Jülich

(1) https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Netz_Systemsicherheit/Netz_Systemsicherheit_node.html
(2) https://de.wikipedia.org/wiki/Datei:Deutschland_Lage_von_Schleswig-Holstein.svg

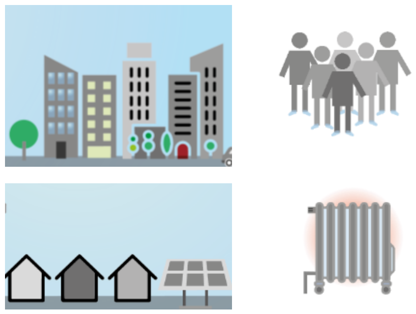
Background

Electrical power system



Exchange of electricity

District-Energy-System



Objectives

- High share of renewable energies
- Support integrating volatile renewable energies
- Low costs

Exogenous model parameter for electricity:

- price [€/kWh]
- emission factor [kg/kWh]

Boundary conditions

Optimization model

min **Costs**

s.t. **Emission ≤ Limit**

- Optimal investment decisions in local energy **conversion** and **storage** technologies
- Optimal unit commitment

Research issue

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Challenges

1. Emission factor of grid-sourced electricity dependents on fluctuating renewable energies.
2. How can a grid supportive design and behavior of the district energy system be achieved?

Approach

1. Using **time-dependent emission factors**

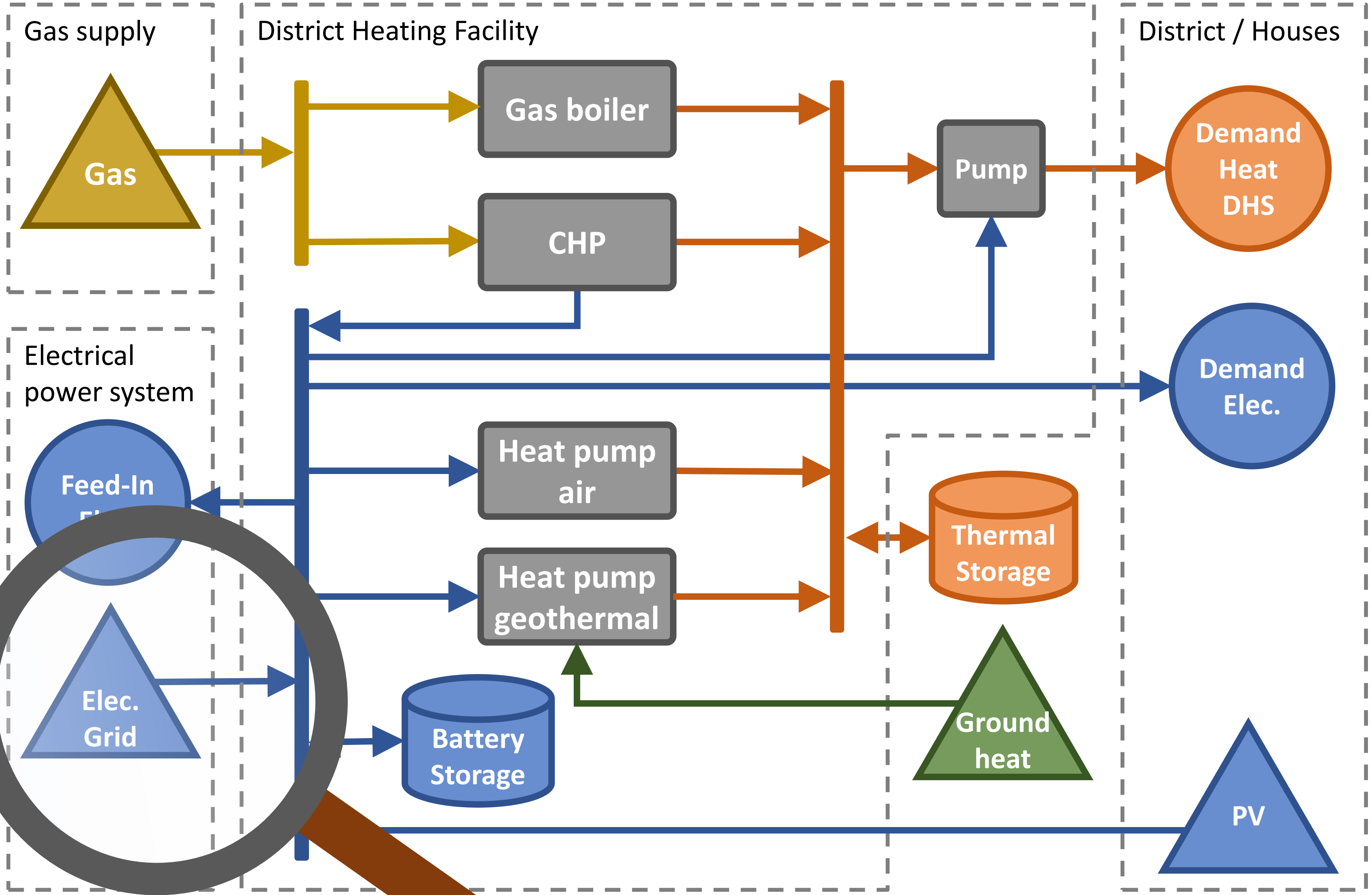
   → How does the energy system design differ?

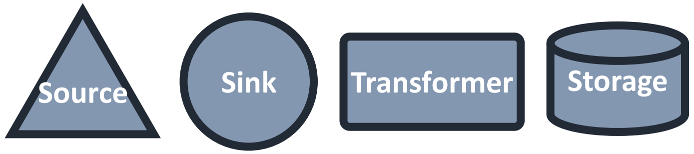
   → When does it matter?

2. Considering **local and regional excess of renewable energies** due to congestions within the grid

   → **Dynamic** (= time-dependent) **local** emission factor as design parameter

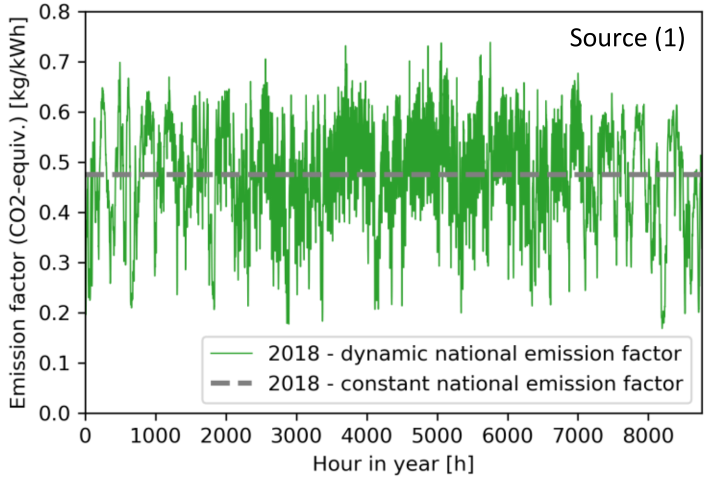
Energy system model

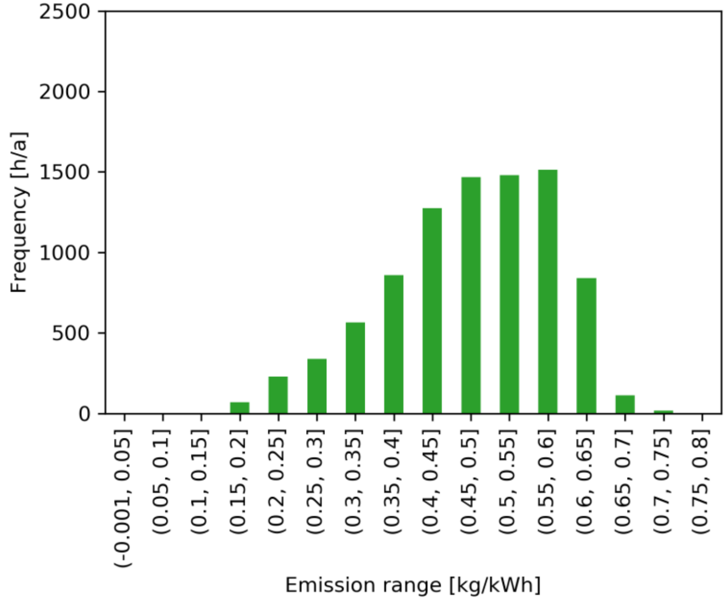




- Linear investment- and unit commitment optimization model (LP)
- 1 year, 1 hour time resolution
- Technology data based on actual market data
- Commodity prices following German prices
- Demand time-series based on real-world case
  - Peak load heat ~2 MW
  - Annual heat demand ~5 GWh
  - Electricity demand ~1.1 GWh
- **Dynamic (time-dependent) emission factor of grid-sourced electricity**

Emission factor of grid-sourced electricity (Germany 2018)





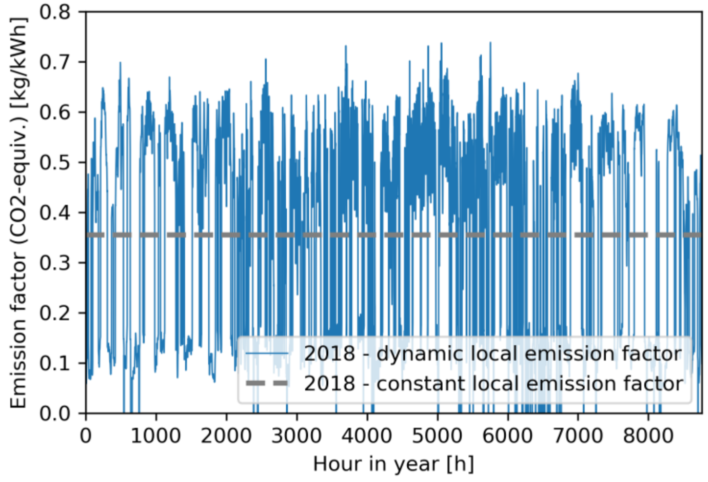
Reduction of emission factor at times of excess

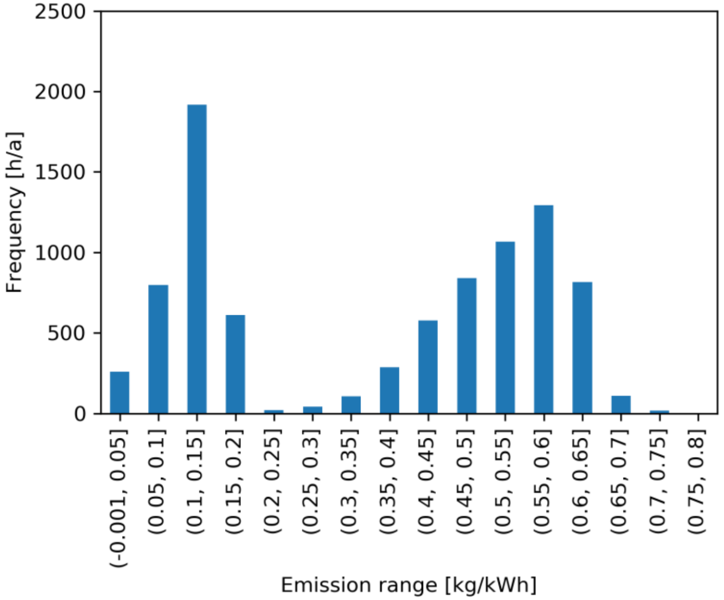
Local and regional cut-off of renewable energy (historical data)

- Feed-in management at next HV/MV transformer station from DSO
- Feed-in management from TSO within region

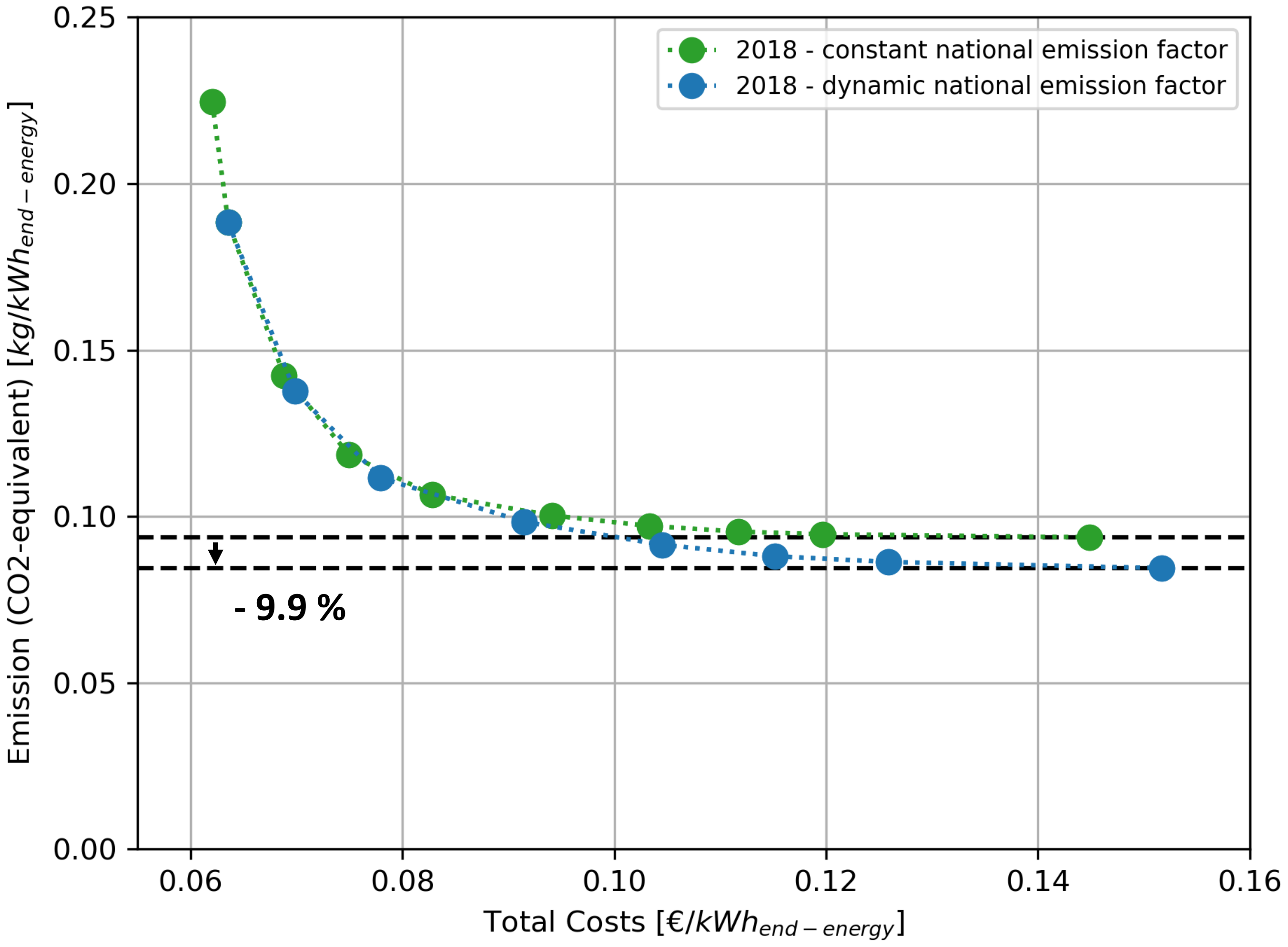
➢ **Periods with low emission factor increase**

(1) Kleiner et.al., Agora Energiewende 2019





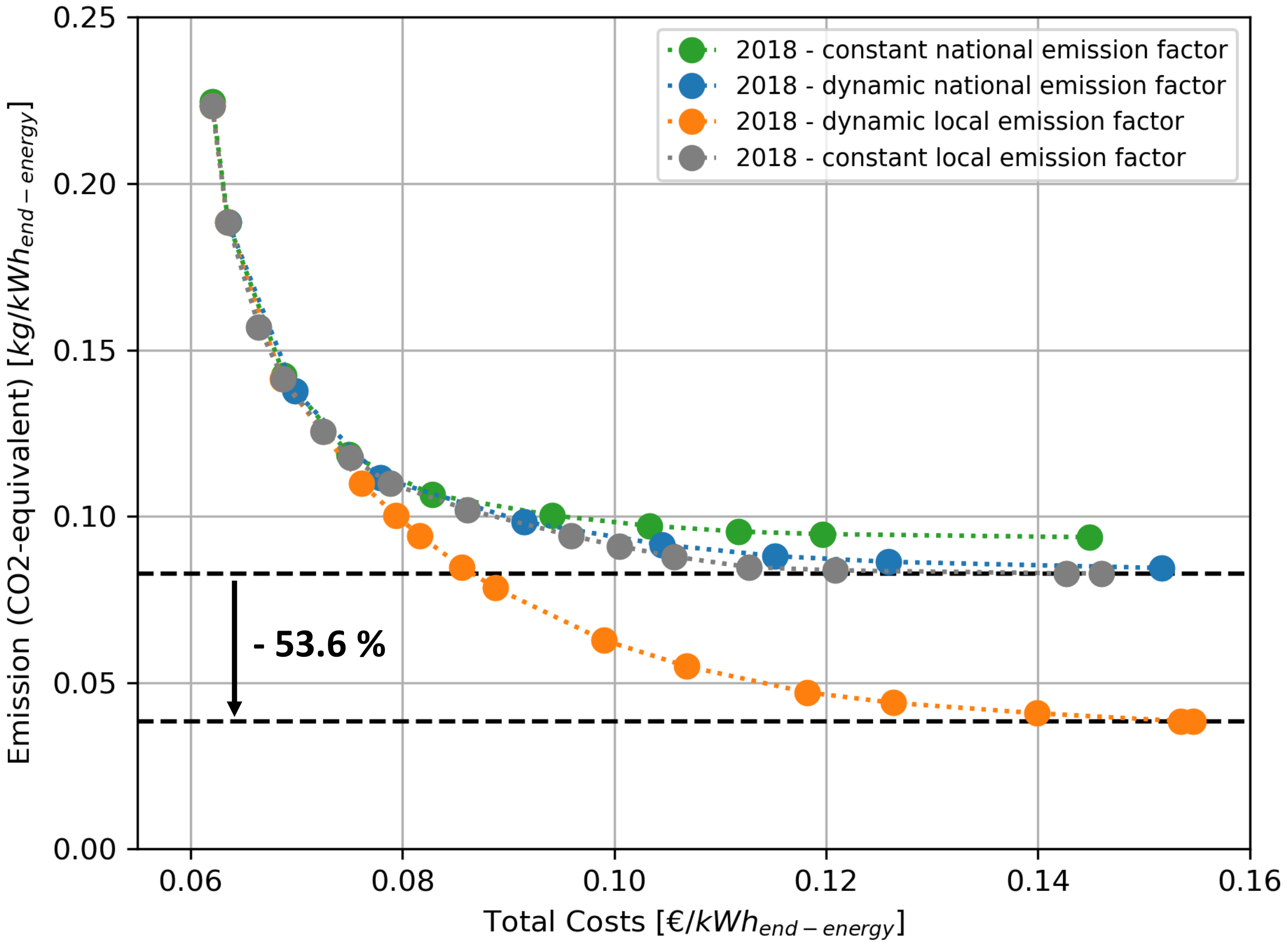
Results – total emission, total costs of energy (Pareto front)



- By using dynamic emission factors for grid-sourced electricity, lower emission at least costs can be achieved

Results – total emission, total costs of energy (Pareto front)

RESILIENTE ENERGIESYSTEME



- By using dynamic emission factors for grid-sourced electricity, lower emission at least costs can be achieved
- Considering renewable cut-off energy, more than 50 % lower emissions can be achieved

Results – total emission, total costs of energy (Pareto front)

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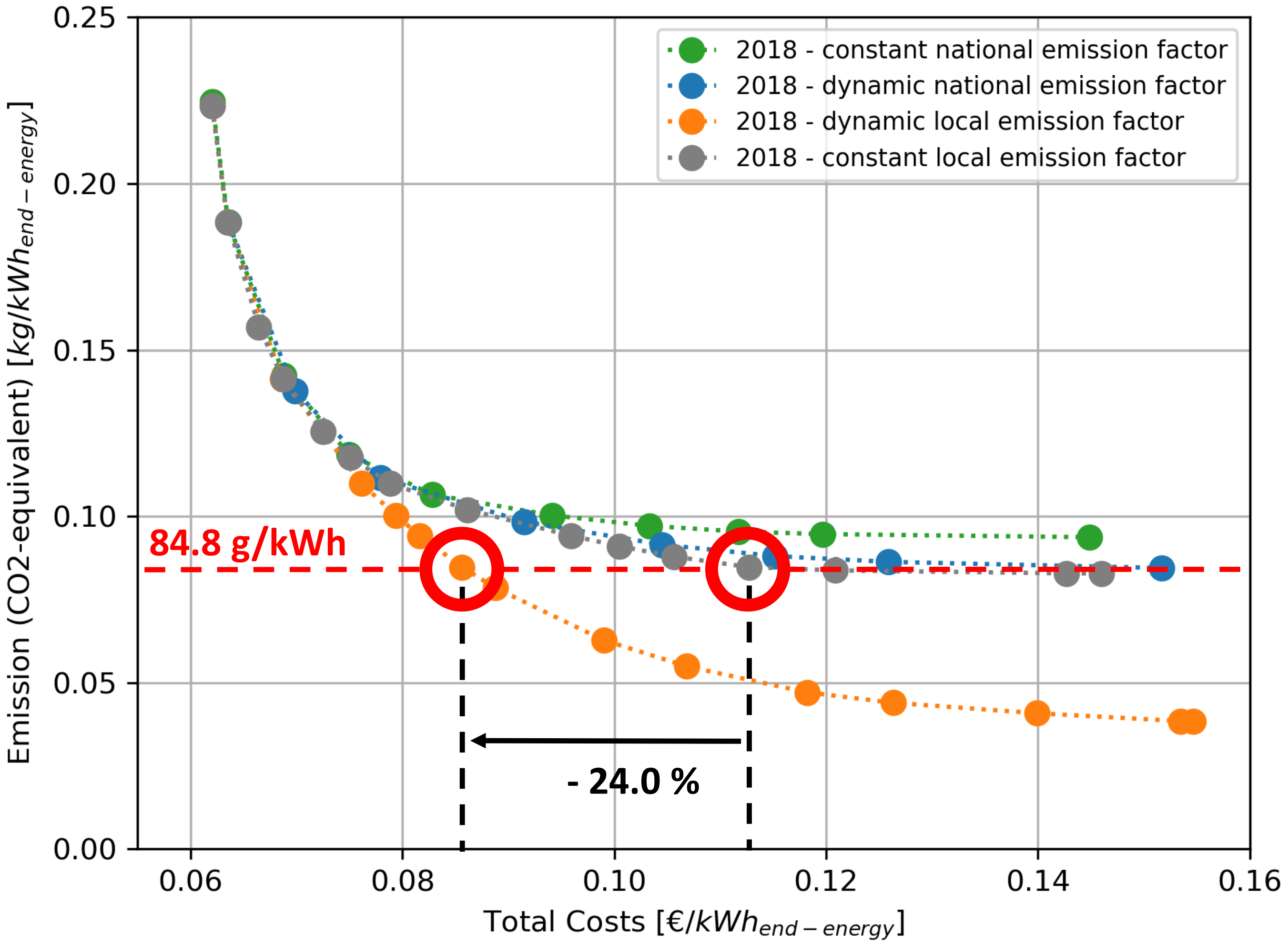

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Results – example of investment decisions and unit commitment

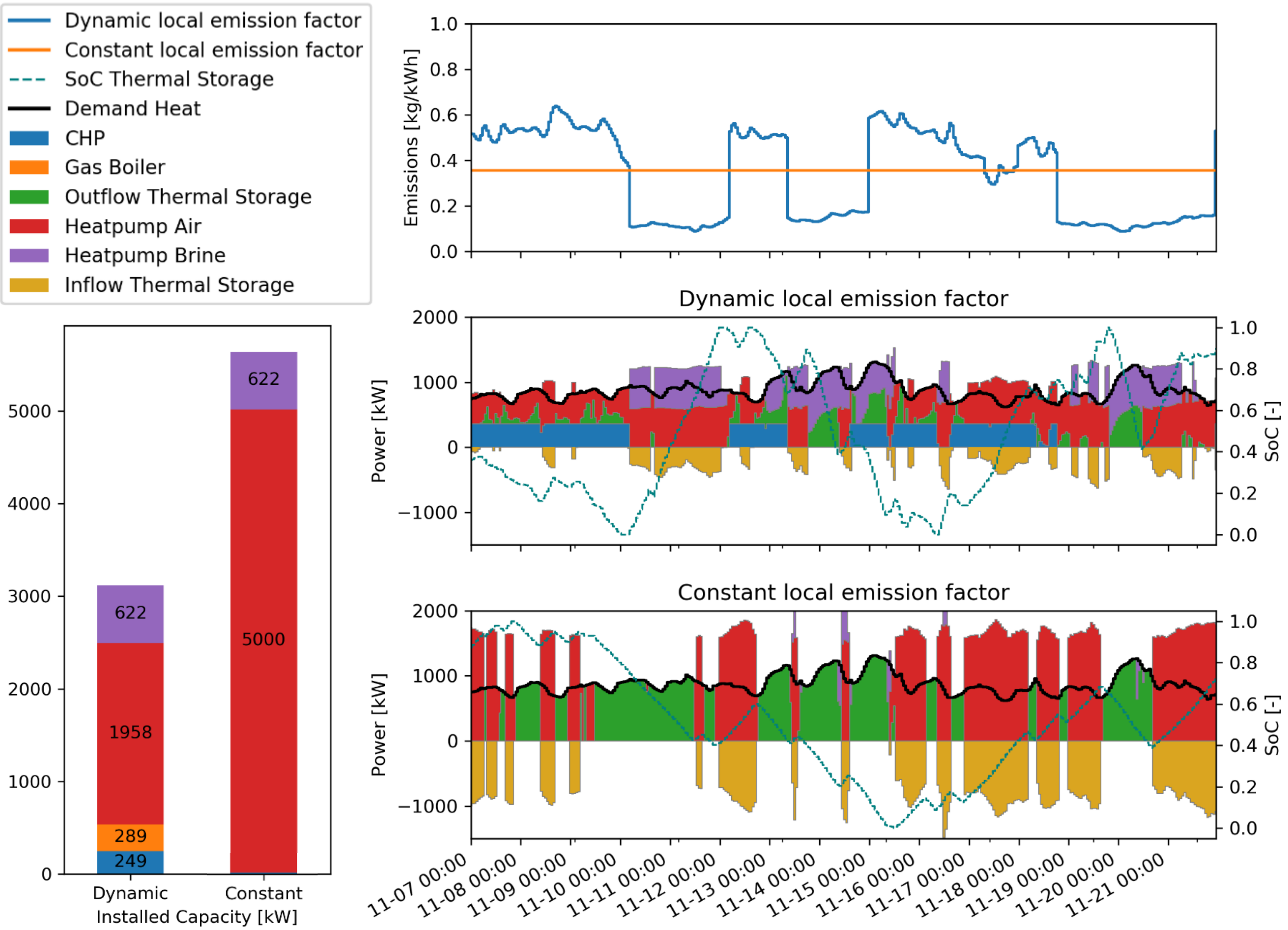
RESILIENTE ENERGIESYSTEME

@Emission_limit = 84.8 g/kWh		Local emission factor: Dynamic	Local emission factor: Constant
Emission Limit	[g/kWh]	84.8	84.8
Total Costs	[ct/kWh]	8.56	11.27
Investment Costs	[ct/kWh]	6.12	8.31
Variable Costs	[ct/kWh]	2.44	2.96
Average EF*	[g/kWh]	113.7	345.2
GSC_{abs} (EF*)[1]**	[-]	0.321	0.973

*EF: Emission factor of grid-sourced electricity

**GSC_{abs}: Grid-Support-Coefficient (absolute) with emission as weighting factor

[1]According Klein et. al. https://doi.org/10.1016/j.apenergy.2015.10.107



Summary

- Dynamic emission factors achieve lower emission at least costs
  → Case study: 53.6 % lower emission possible (local emission factor)
- Variance of the emission factor determines the impact on the design decisions. Thus, dynamic emission factors are important …
  → … during the transformation of the electricity system.
  → … in regions with local congestions due to fluctuating renewable energies.
- Dynamic local emission-factors is a promising concept for designing low-emission and system-beneficial district energy systems.

open source modelling framework oemof

oemof ['ø:mɔf]

open energy modeling framework

https://oemof.org/

https://github.com/oemof/

Thank you for your attention!

QUARREE 100

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Partner Research Project QUARREE100

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