Flexibility provision in 5th gen district heating systems

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Introduction and research question

Research project „CLUE - Concepts, Planning, Demonstration and Replication of Local User-friendly Energy Communities“ investigates technological solutions for local energy communities in the electricity sector in different national subprojects

German subproject lead by Fraunhofer ISE in cooperation with eon and Fakt AG

Case study is Shamrockpark in Herne, a former industrial site from the coal mining company RAG which is now converted into a mixed used area with mostly commercial buildings.

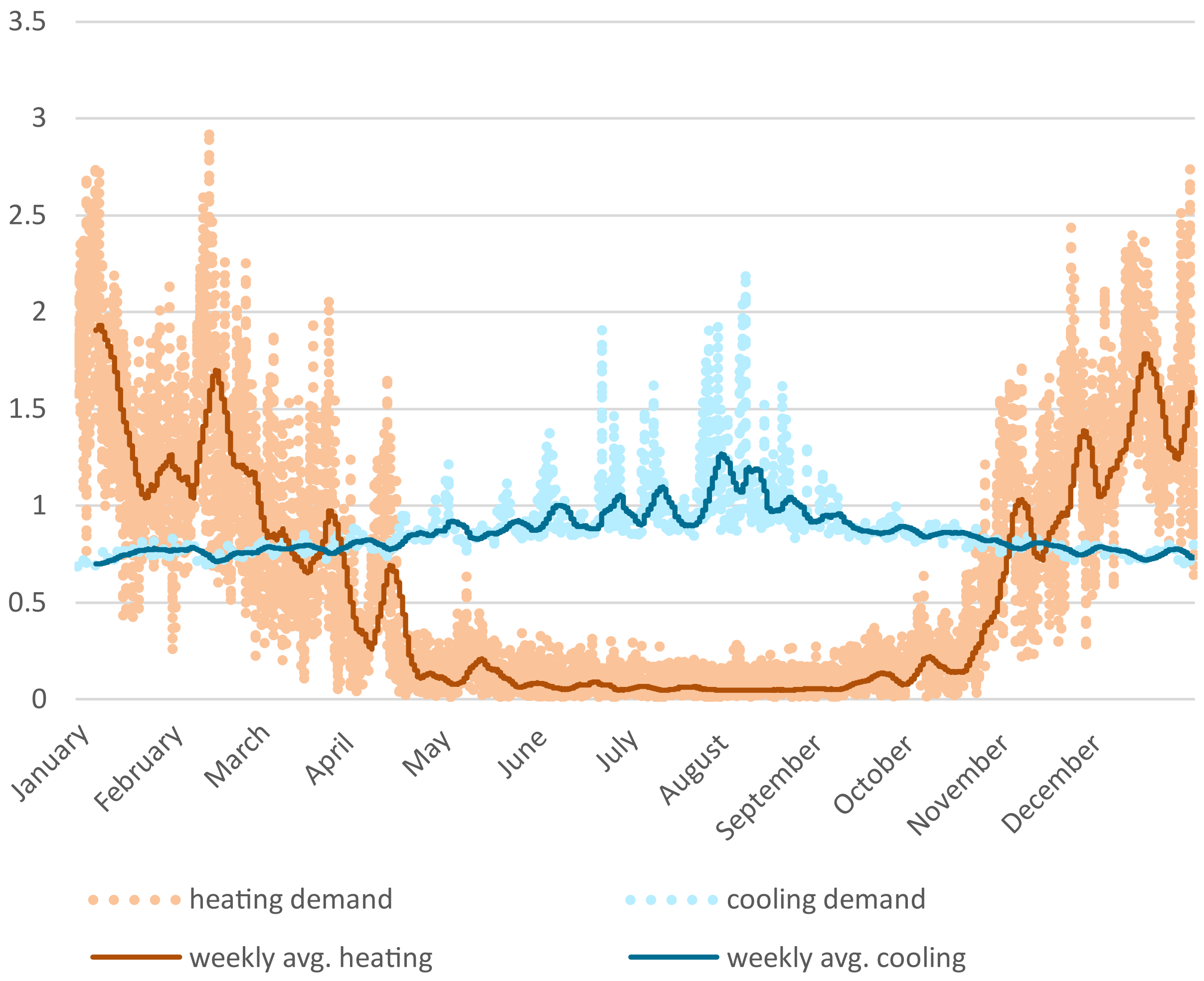
Scope of the project:

- Scientific support of the planning and implementation of the innovative energy concept with a LowEx heating network
- Evaluation of the advantages of the energy concept to gain insights for the optimization of planning and implementation of LowEx heating networks
- Active involvement of the stakeholders
- **Potential of this energy concept for the provision of flexibilities by the Shamrockpark district for the surrounding electricity system**

Source: [1]

Case study Shamrockpark – Specifications of the energy system

- 5GDHC [(1)] system: 22°C warm conductor, 12°C cold conductor
  - supplied by district heating, gas boilers, industrial waste heat, and internal waste heat
  - Building supply at different temperature levels through decentralized heat pumps
- Mulvany Area: small conventional high-temperature network (90°C/50°C) for supplying existing buildings with high temperature demands
- 72 % coverage of heat demand from low-temperature waste heat
- 45 % coverage of cooling demand through passive cooling using the ectogrid and utilization of waste heat



(1) 5th generation district heating and cooling (actually a subtype of 4th gen DH, according to IEA)

The Shamrock Park energy system in the model

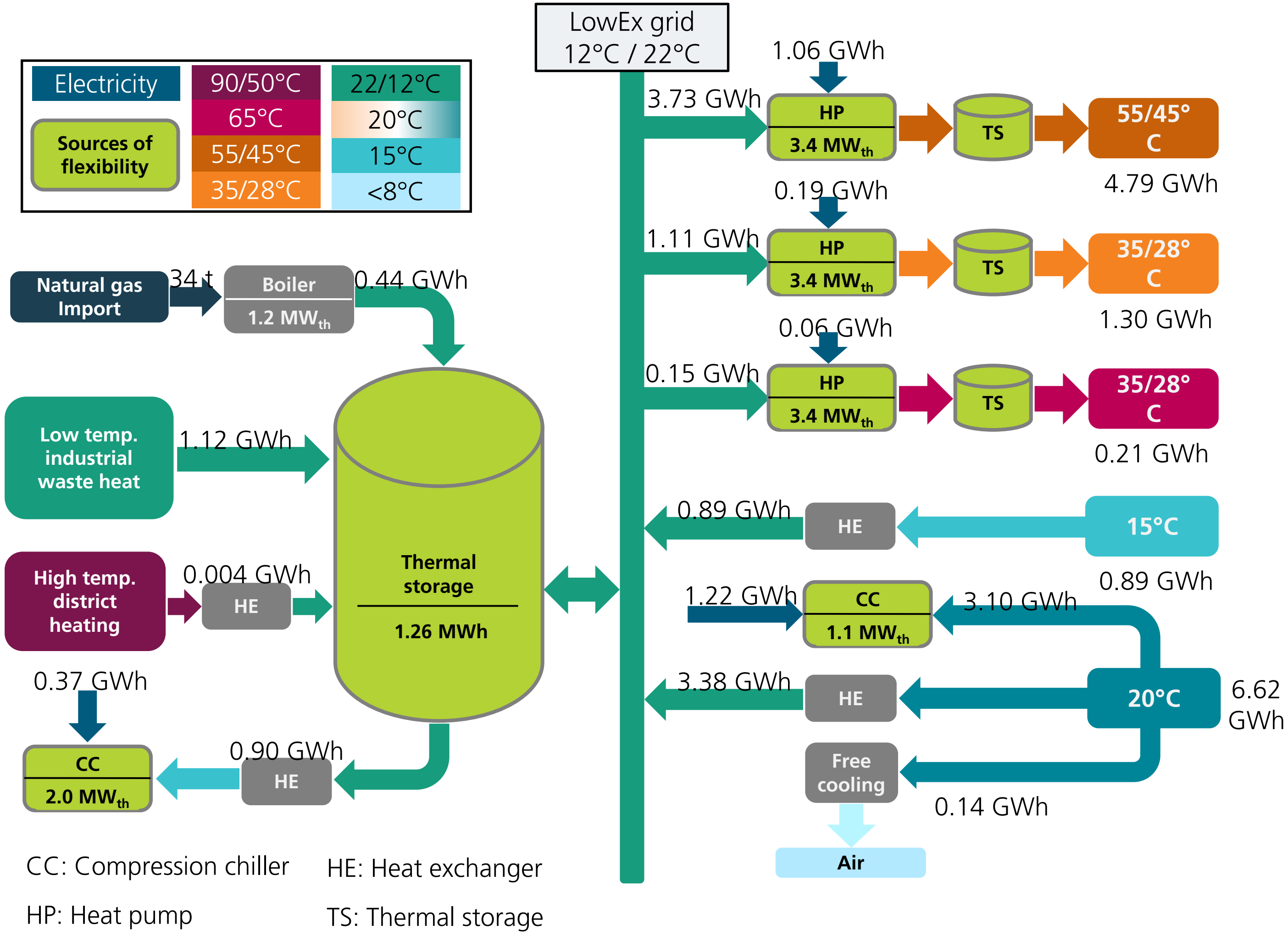
A linear energy system optimization model is used to assess the potential of external flexibilities [2]

Simplifications made in the energy system model

- The demands are aggregated for each temperature level
- Hot water and cold water conductors are combined.

Technical specifications

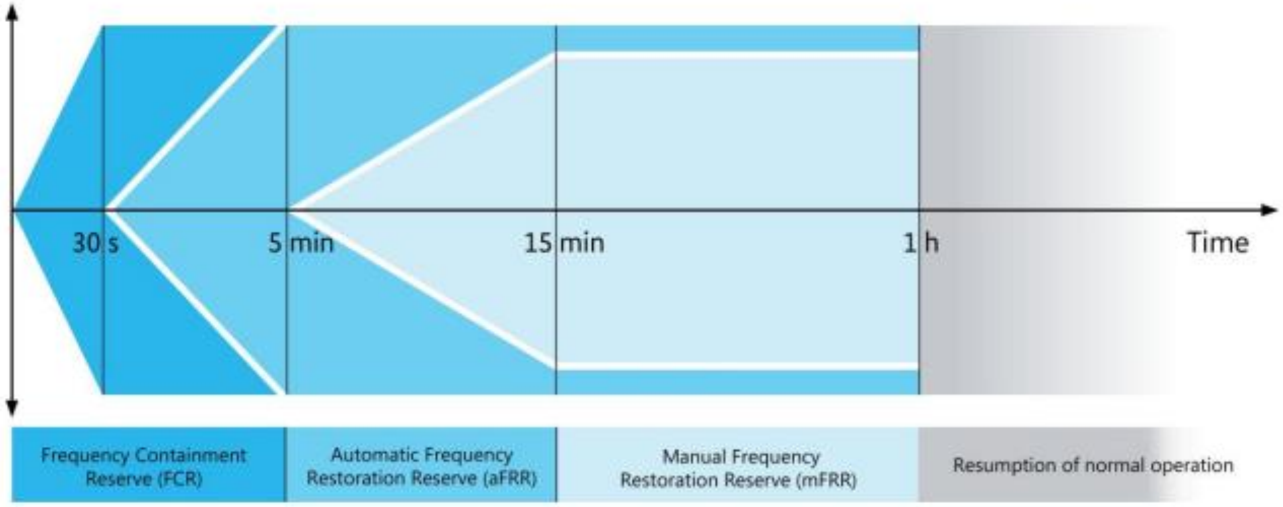
- 1 MW installed capacities of heat pumps
- 1.55 MW installed capacities of compression chillers
- 2 x 60,000l thermal storages (1.26 MWh)
- 0.052 MW installed capacity of CHPS



Control reserve for providing external flexibilities

Control reserve

- Serves to balance generation and consumption and maintaining a stable frequency in the power grid
- aFRR (automatic Frequency Restoration Reserve:
- Positive and negative reserves are traded on separate markets for capacity (RLM) and energy (RAM)



RLM versus RAM

- At RLM the product length is 4 hours, which would lead to low availability in the Shamrockpark energy system
- Depiction of RLM in an energy system model with perfect foresight is difficult. Bids have to be given between one week and one day before where in reality the operation of the energy system is not known.
- In RAM bids are only given on the same day which is closer to the depiction of the energy system in the model

→ RAM is depicted in the model

Source: [3]

Depiction of offering flexibilities in a linear optimization model

Obstacles		Solutions
Flexibility can always be offered but is not always called up	→	Statistic call probabilities
Price for provision of flexibility subject to changes	→	Historic prices are evaluated and different price schemes and their implications are tested in the model
Offered power must be above 1 MW	→	Aggregator is assumed to be in place
Flexibility provision must be separable from „normal“ import and export	→	Two stage modeling: first base scenario, then flexibility scenario

Scenarios

First set of scenarios:
- Fixed price scheme
- Storage capacity optimized depending on aFFR provision
- Call rate of 100 %

Price variant	Thermal Storage variant	Description	Remuneration aFRR pos. in € / MWh	Remuneration aFRR neg. in € / MWh
0/0	Fixed	No renumeration, just savings	0	0
500/0	Fixed	Little renumeration	500	0
1000/500	Fixed	Lowest level of past three years	1,000	500
0/0	varied	No renumeration, just savings	0	0
500/0	varied	Little renumeration	500	0
1000/500	varied	Lowest level of past three years	1,000	500

Second set of scenarios:
- Price scheme of 2021
- Capacities optimized without provision of aFFR
- Call rate of 10 %

Name of scenario	Description
SC1	Base scenario
SC2	Thermal storage is optimized
SC3	3 MW PV, battery and thermal storage capacity optimized (no battery installed)

Results I

Offering balancing services at fixed price schemes without call rates

- Even with no or low renumeration levels balancing service is offered
- Seasonality: due to all-year cooling demands flexibilities can be offered continuously throughout the year
- Increasing storage capacities seems attractive but depends on call rate of flexibility and available space to build storages

Price variant	Description	Remuneration aFRR pos. in € / MWh	Remuneration aFRR neg. in € / MWh
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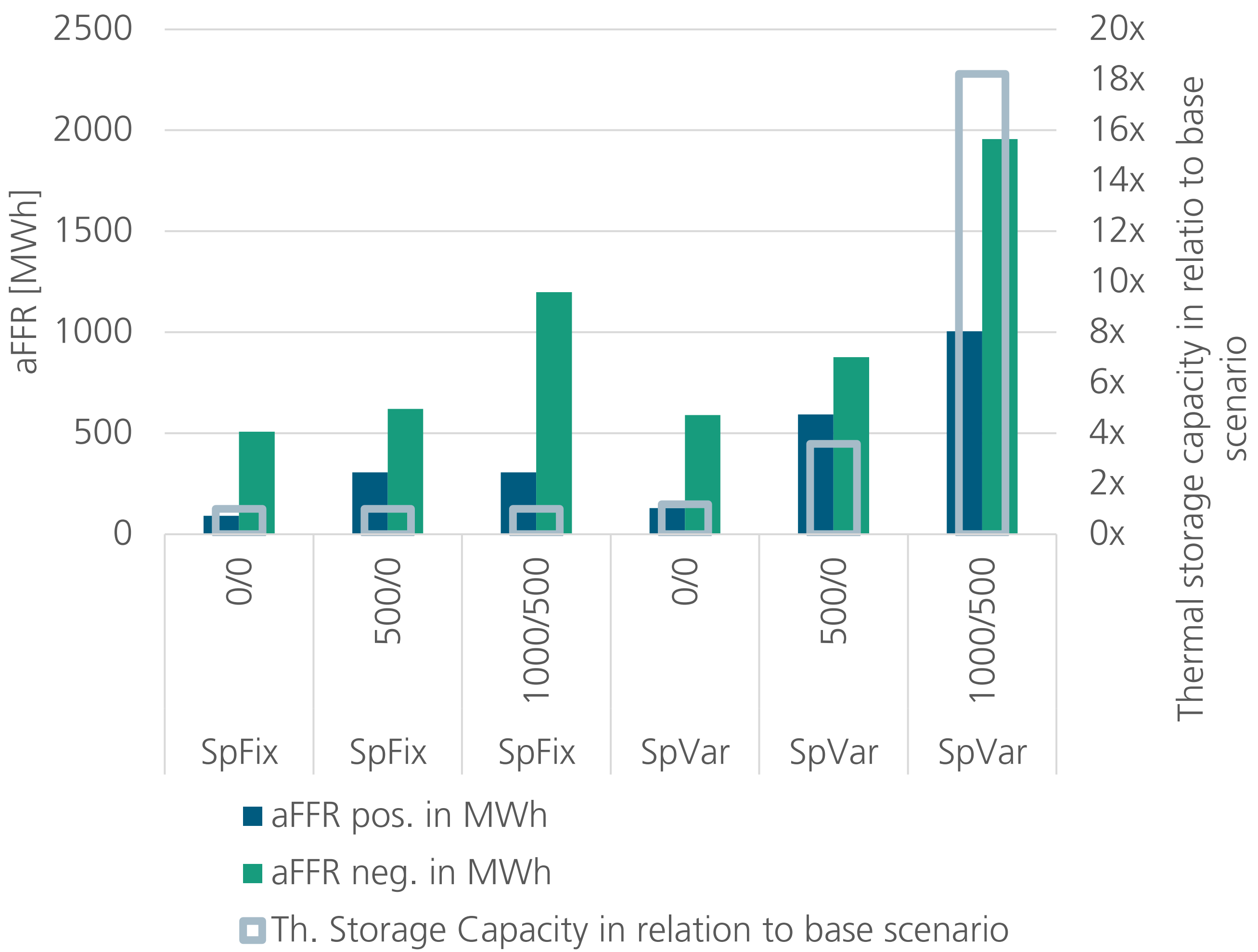
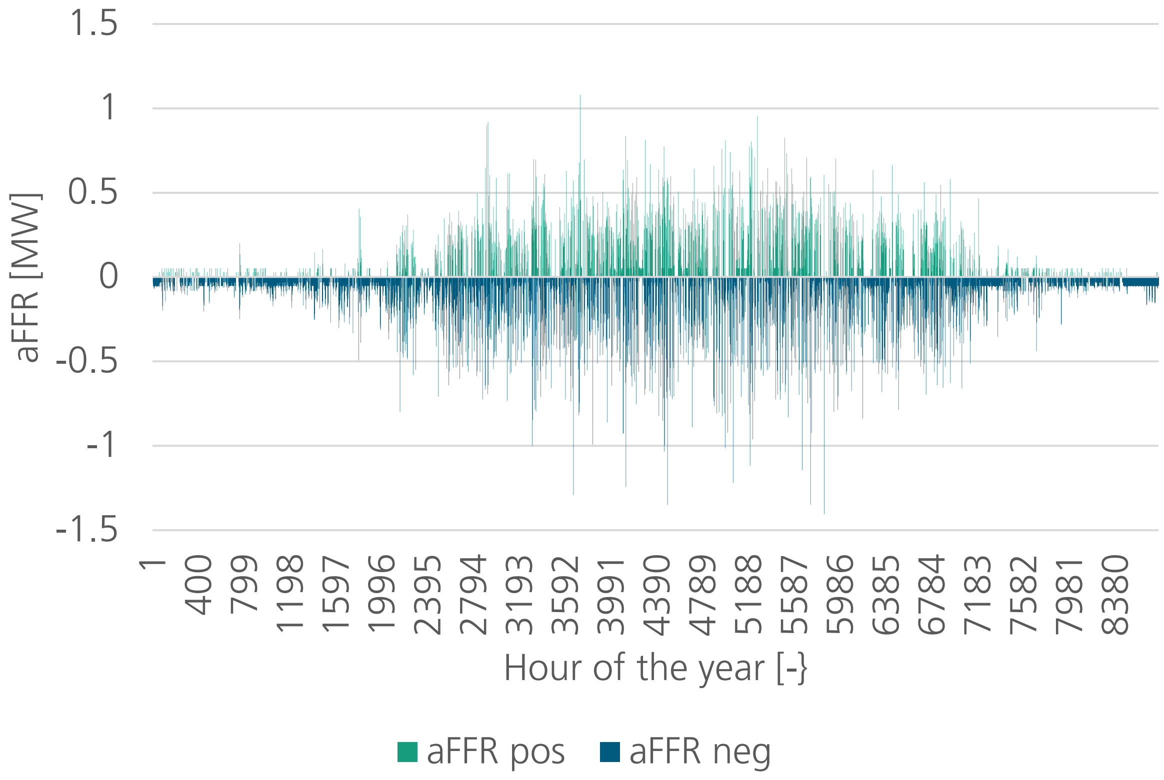


When is flexibility offered?

Scenario 500/0 Thermal storage fixed

- Overall more negative than positive flexibility is provided
- Provision of flexibilities is higher in summer months than in winter
- The available flexibilities are mainly the result of shifting electrical loads, adapting the operation of the CHP unit and changing the use of free cooling
- When installing more thermal capacity a more even provision of aFFR is possible (not shown)
- The minimum value of 1 MW which is needed to participate directly at the aFFR market is only reached a few times that year



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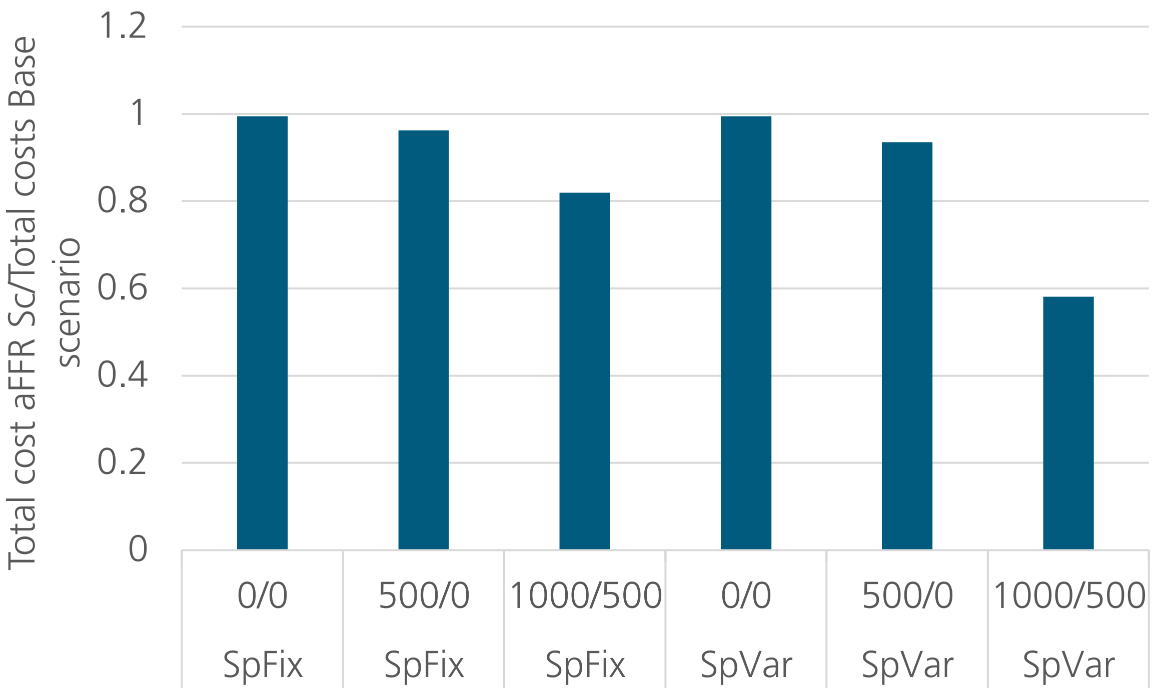
Results II

Offering balancing services at fixed price schemes

- Extending storage cpacity is especially attractive with higher prices
- Offering balancing services is profitable even on low remuneration levels,
  - But the assumption here is that all offered flexibility is provided
  - But: spacewise constraints can make storage expansion impossible

→ Call rates can help to have a more realistic picture on the probability that flexibility can be provided

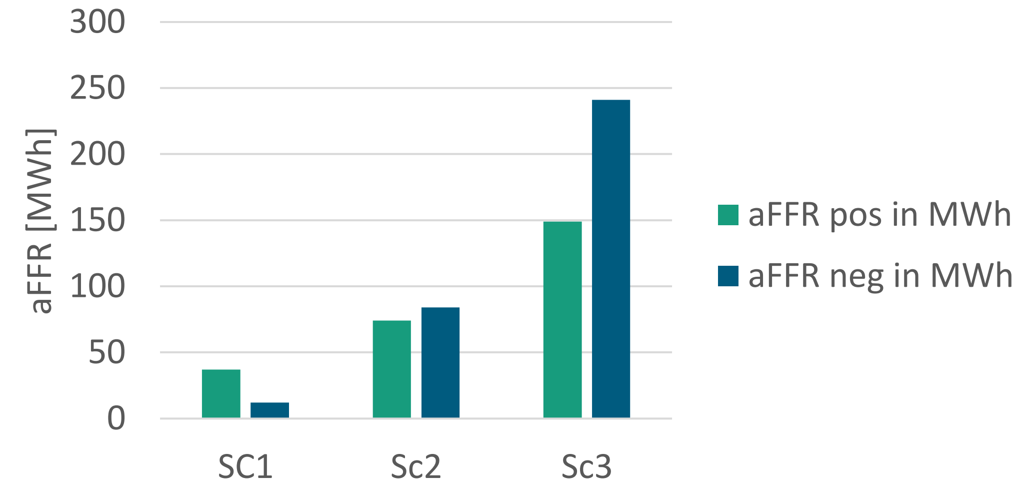


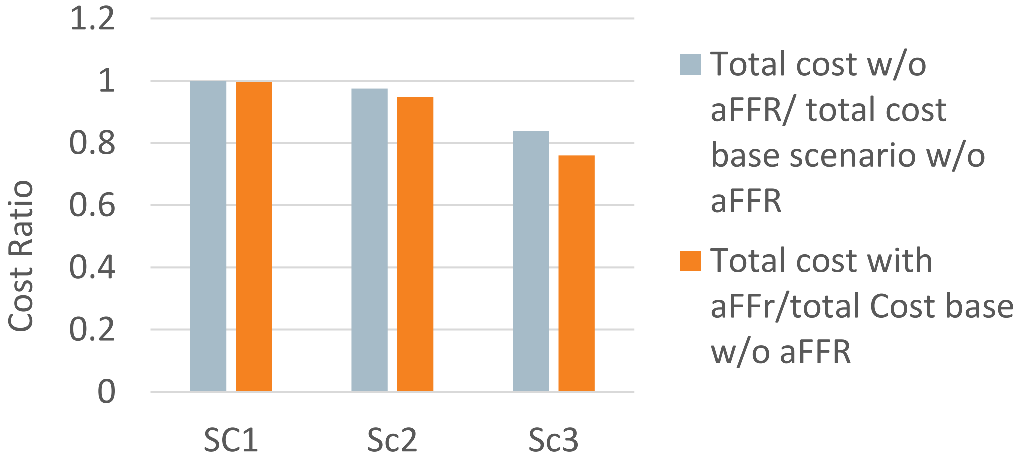
Results III

Offering balancing services at 2021 price scheme and a call rate of 10 %

- The energy system is optimized in the case without providing aFFR, then the aFFR scenario is calculated with fixed capacities
- Especially more electrical supply by PV in combination with higher storage capacities leads to provision of more flexibility and decreased costs, batteries are not installed
- Even without the provision of flexibility these measurements lead to lower overall system costs; providing aFFR could be an additional benefit

Name of scenario	Description
SC1	Base scenario
SC2	Thermal storage is optimized
SC3	3 MW PV, battery and thermal storage capacity optimized (no battery installed)





Conclusion

The **provision of balancing services** can be used to **reduce operating costs** of 5GDHC network

With **all-year heating and cooling demands** balancing services can be offered continuously throughout the year

Quantifying the profits achievable through control power offerings is **difficult**

- Varying market prices, uncertainty of future developments, with small systems only indirect participation on markets possible
- Representation of market environment in optimization tool difficult, also limited representation of energy system w.r.t to dynamic behaviour

The next steps are:

- Harmonisation of the two approaches for a better comparability
- Modeling two other case studies

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Thank you very much for your attention

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References

[1] Gerhard Stryi-Hipp, Erik Fröhlich, Annette Steingrube, Philipp Fleischmann, Johanna Kucknat, Sebastian Gölz, Christoph Rademacher, Florian Bruskolini, Matthias Trockels, CLUE - MONITORING UND OPTIMIERUNG EINES ECTOGRID-ENERGIESYSTEMS MIT ERWEITERUNG EINES PLANUNGSTOOLS Abschlussbericht, Fraunhofer ISE, 2023.

[2] Jan-Bleicke Eggers, Das kommunale Energiesystemmodell KomMod, Dissertation, 2018.

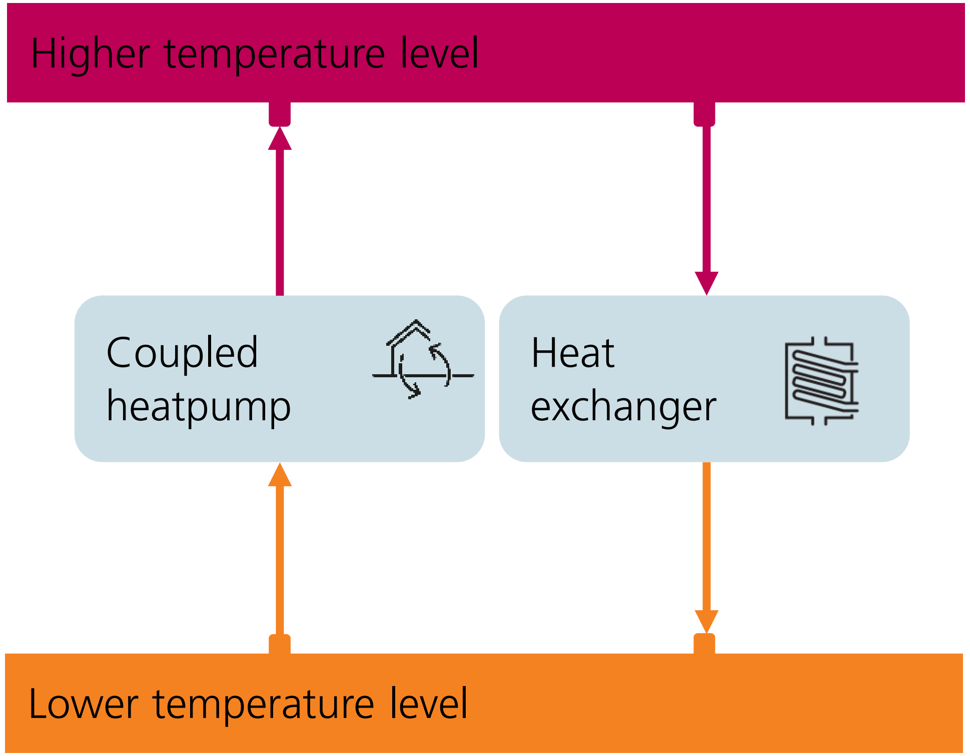
[3] Bundesnetzagentur: This is how the electricity market works. Available from: https://www.smard.de/page/en/wiki-article/5884/5840.

Appendix

KomMod - extension

Adjustment of the model for representation of 5GDHC networks grids

- The KomMod model is a **single-node model**, but it is possible to form energy balances at different temperature levels.
- **Problem**: The temperature levels could not be coupled so far.
- **Extension**:
  - Calculations still based on energy differences (good performance)
  - Implementing a grid-coupling heat pump (including source balances)
  - Implementing a heat exchanger / temperature level coupler (simplified representation of heat exchanger + sign adjustment for coupling heat and cold nodes).



aFRR+/aFRR- Prices between 2021 and 2023
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
€/kWh
Jan 21
Mrz 21
Mai 21
Jul 21
Sep 21
Nov 21
Jan 22
Mrz 22
Mai 22
Jul 22
Sep 22
Nov 22
Jan 23
Mrz 23
Mai 23
Jul 23
Sep 23
Nov 23
Time
Positive
Negative

What amount of control reserve can be delivered for how many hours of the year?

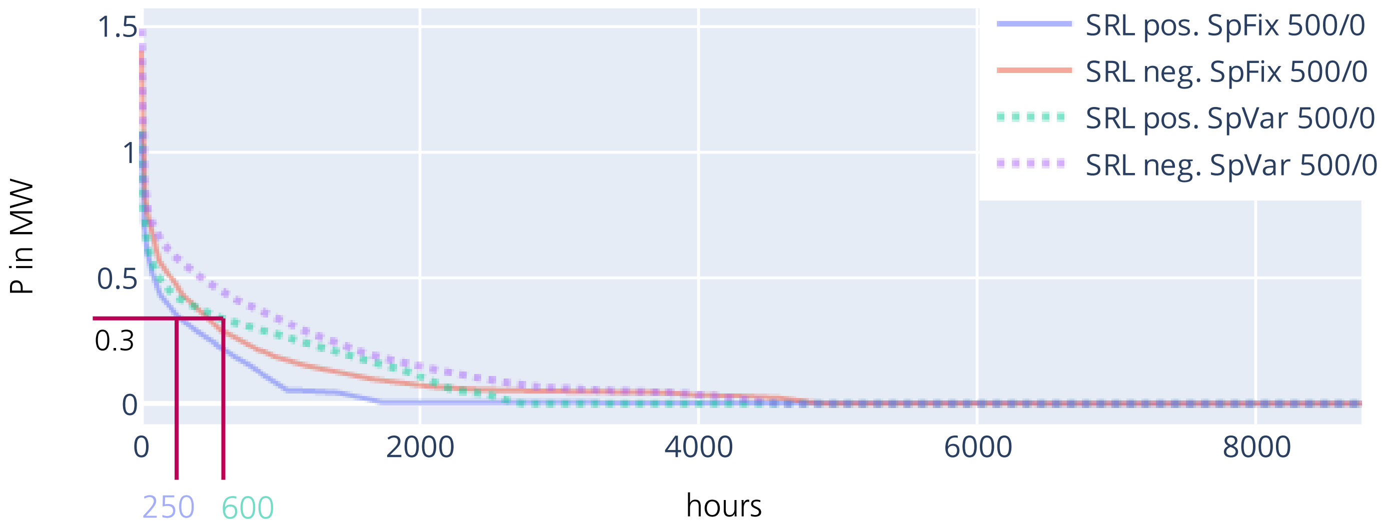


Figure 2: Results showing two different calculation variants for the provision of control reserve. At comparably low revenue levels of control reserve of 500€/MWh pos. and 0€/MWh neg. it is economically attractive to increase thermal storage capacities (+300%) to double the offered flexibility (SpFix: fixed thermal storages, SpVar: optimized storage capacities)

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