LOW-CARBON SOLAR-DRIVEN DISTRICT HEATING SOLUTIONS WITH SEASONAL STORAGE

PARABOLIC TROUGH VS. PV WITH AIR SOURCE HEAT PUMP

Matthias Loevenich, Dirk Krüger, Navina Konz, Tobias Hirsch

DLR Institute of Solar Research, Linder Höhe, 51147 Köln, *matthias.loevenich@dlr.de

This research was funded by the German Federal Ministry for Economic Affairs and Energy (BMWE) under the 8th Energy Research Programme, project “URBAN ARENA FW100” (grant no. 03ENM6027) and under the DLR internal project “Defossilization of the Industry”.

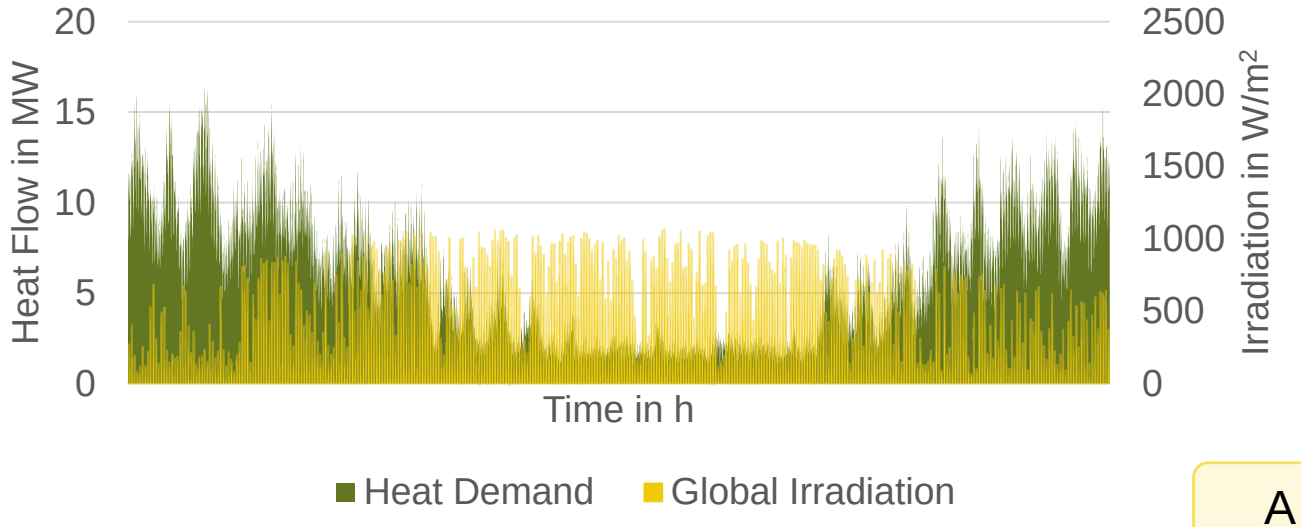
DLR



MOTIVATION

DLR (CC BY-NC-ND 3.0)

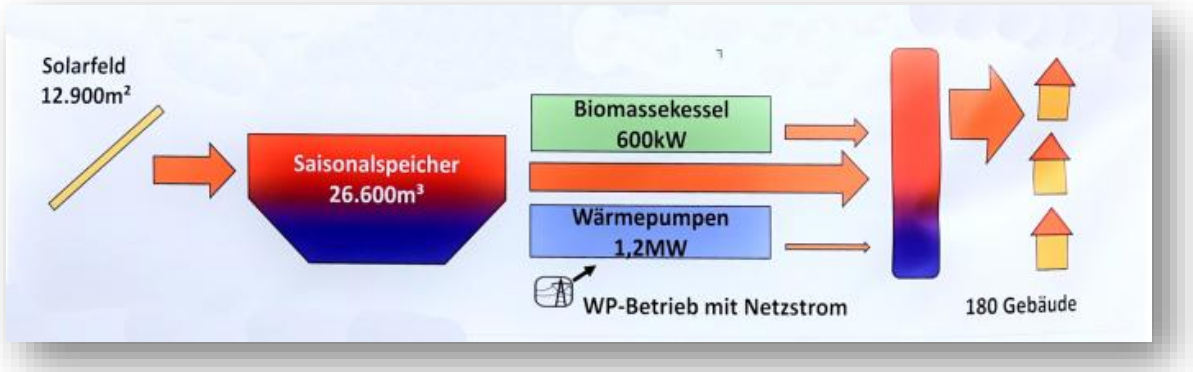
Motivation
Low-Carbon Solar-Driven District Heating Solutions



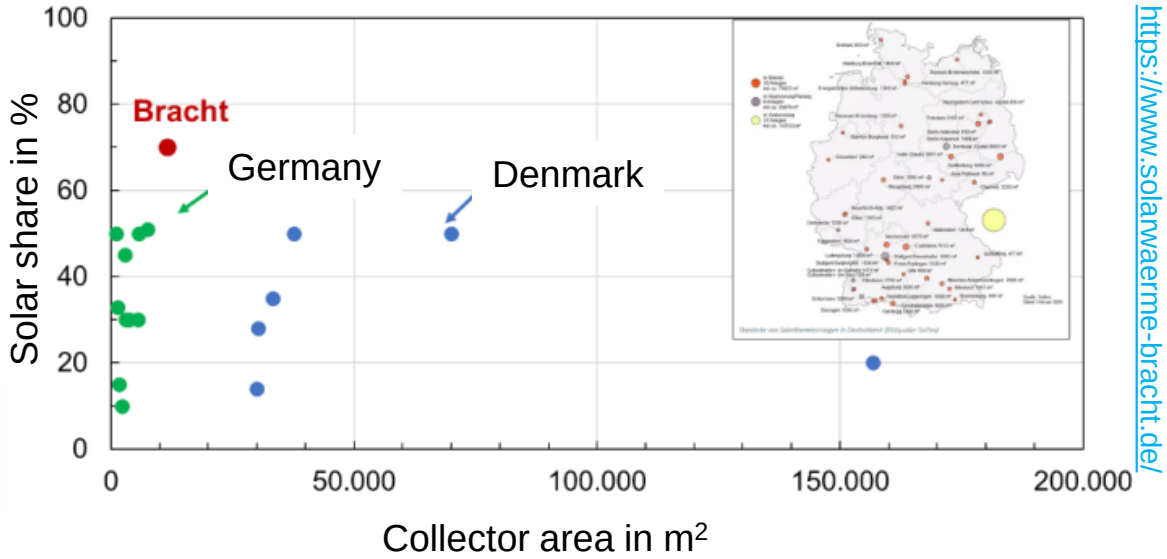
seasonal demand changes are **contrary** to the **available solar irradiation**

Quelle: ProSolNetz

Bracht: Combining flat plate collectors, pit storage, heat pumps, biomass boiler and tank storage



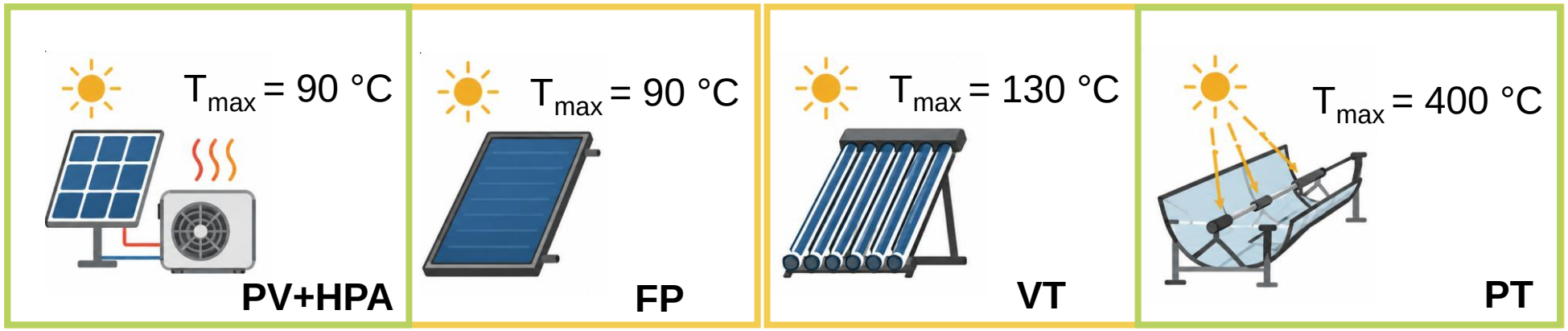
A trend towards **higher solar share**



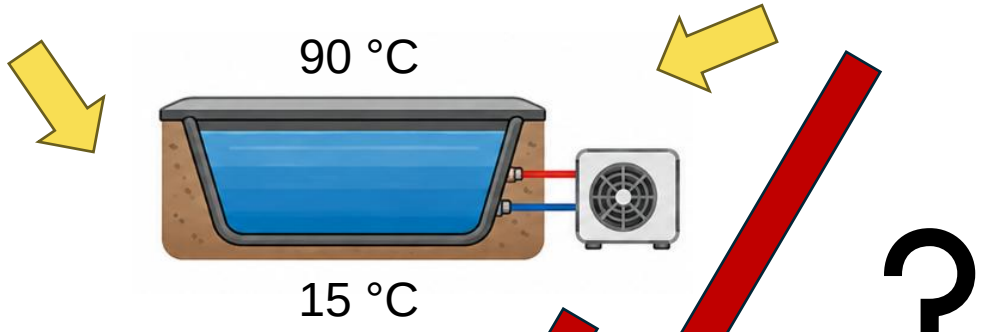
https://www.solawaerme-bracht.de/

Motivation
Is there a Benefit from Solar Heat at higher Temperature?

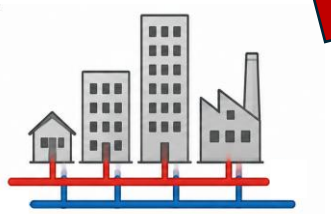
Solar Heat



Seasonal Pit Storage



District Heating Network



?

- **PV+HPA** and **FP** yield **similar LCOH** with **seasonal storage** [1]
- Can **solar heat** from **PT** at **higher temperatures** bring **benefits** for district heat with **seasonal storage**?
- **Compare PT to PV+HPA** for **solar district heat** with **seasonal storage**

[1] Sporleder et al., 2024

Icons created with ChatGPT https://chatgpt.com/

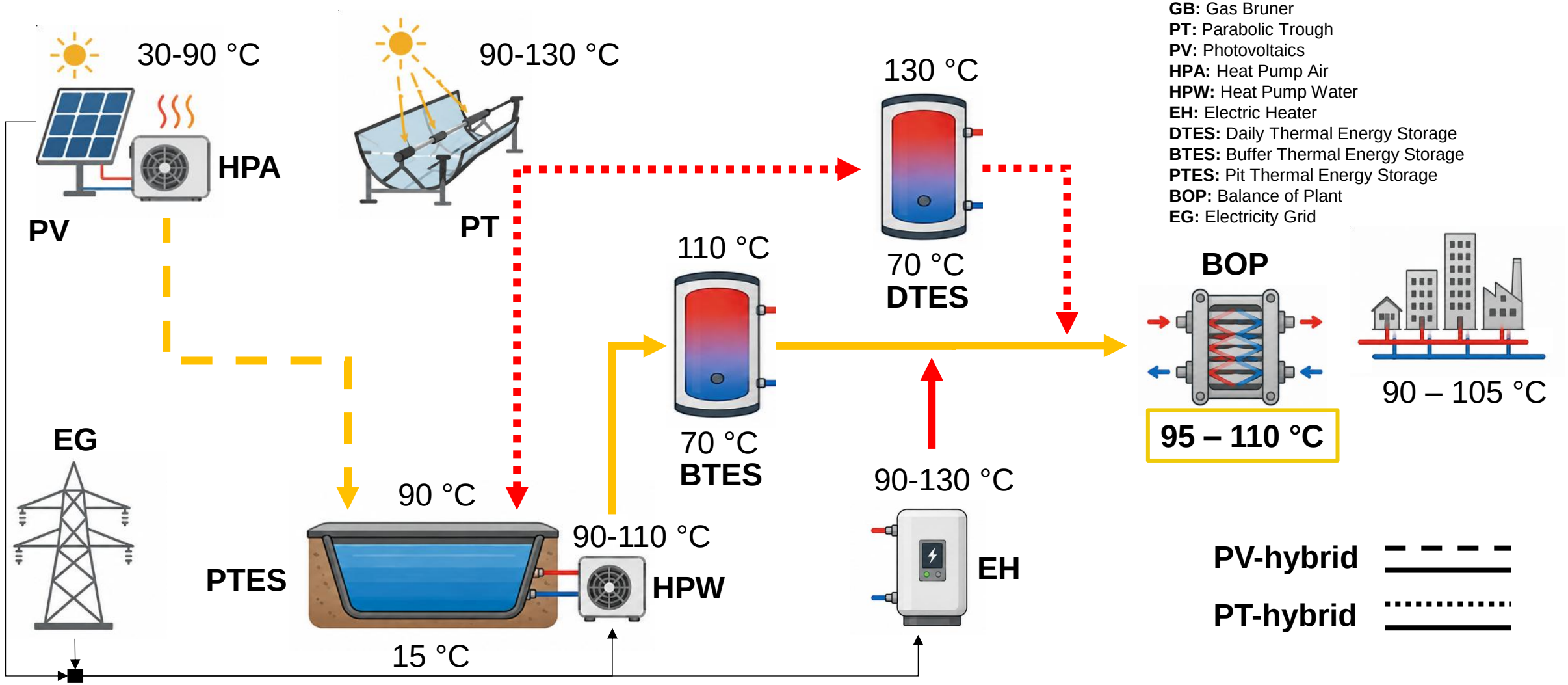


METHODOLOGY

DLR (CC BY-NC-ND 3.0)

Methodology
Defining the Heat Supply Systems

Minimize LCOH for 100 % Demand Coverage



GB: Gas Bruner
PT: Parabolic Trough
PV: Photovoltaics
HPA: Heat Pump Air
HPW: Heat Pump Water
EH: Electric Heater
DTES: Daily Thermal Energy Storage
BTES: Buffer Thermal Energy Storage
PTES: Pit Thermal Energy Storage
BOP: Balance of Plant
EG: Electricity Grid

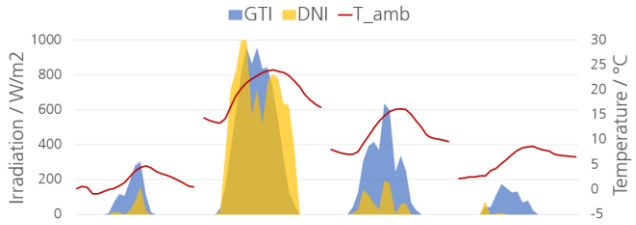
HTF: Pressurized Water

Icons created with ChatGPT https://chatgpt.com/

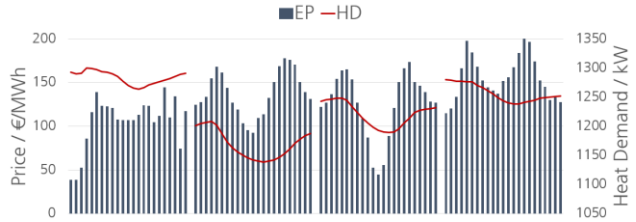
Methodology
Techno-Economic Optimization of Design and Operation

Icons created with ChatGPT https://chatgpt.com/

Meteo Data

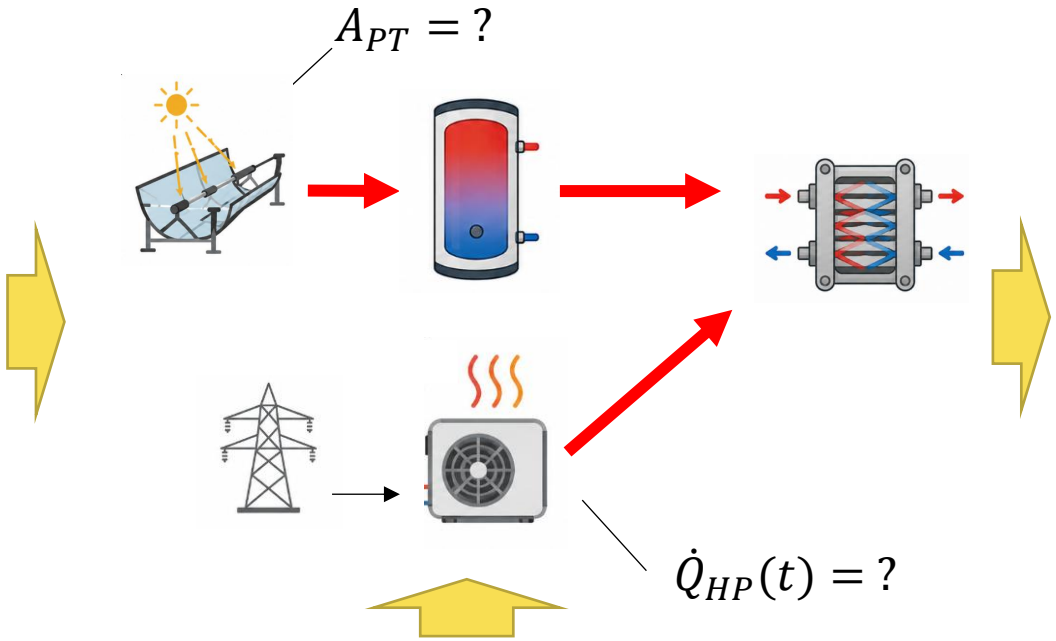


Market and Demand Data

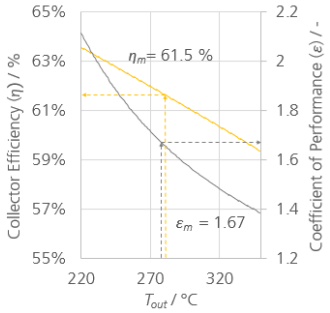


Additional Constraints

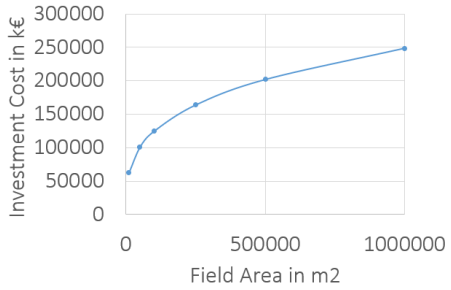
$$A_{land} \leq 20\,000\,m^2$$



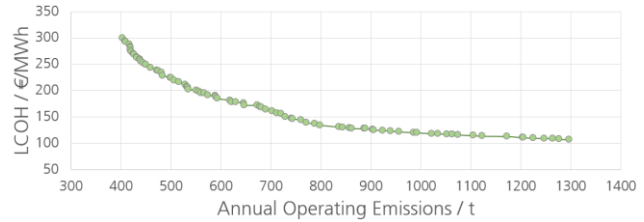
Technical Models



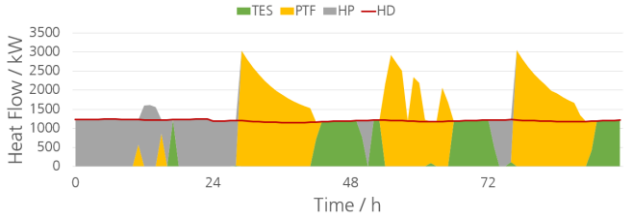
Financial Models



Optimal Designs



Optimal Operations



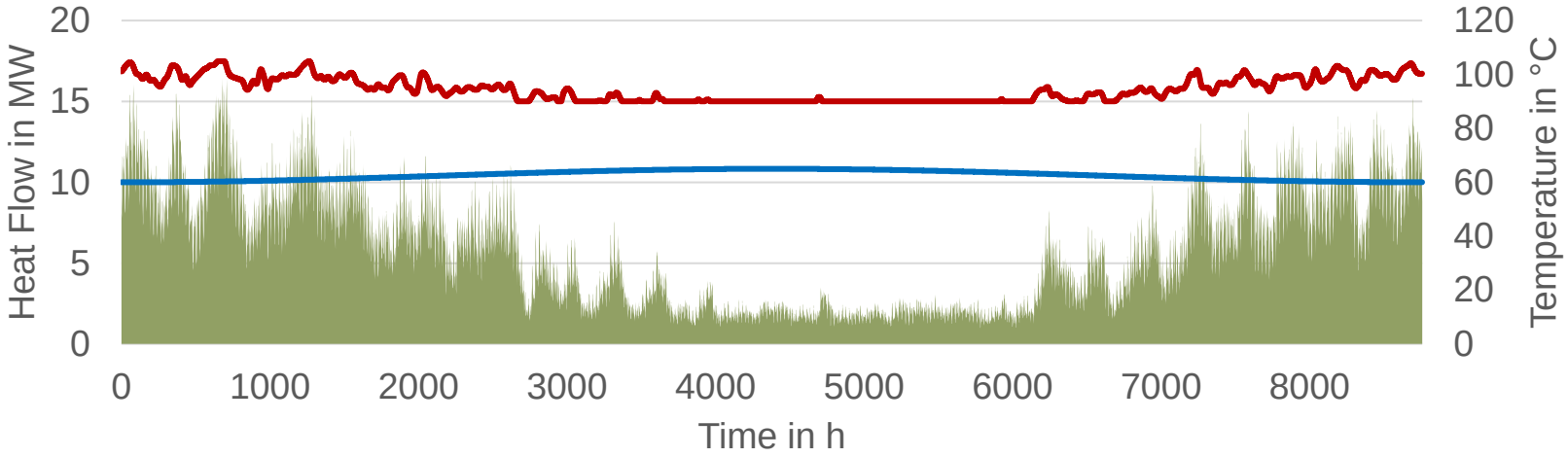
YACOP
Yield Assessment Calculation and Optimization Program

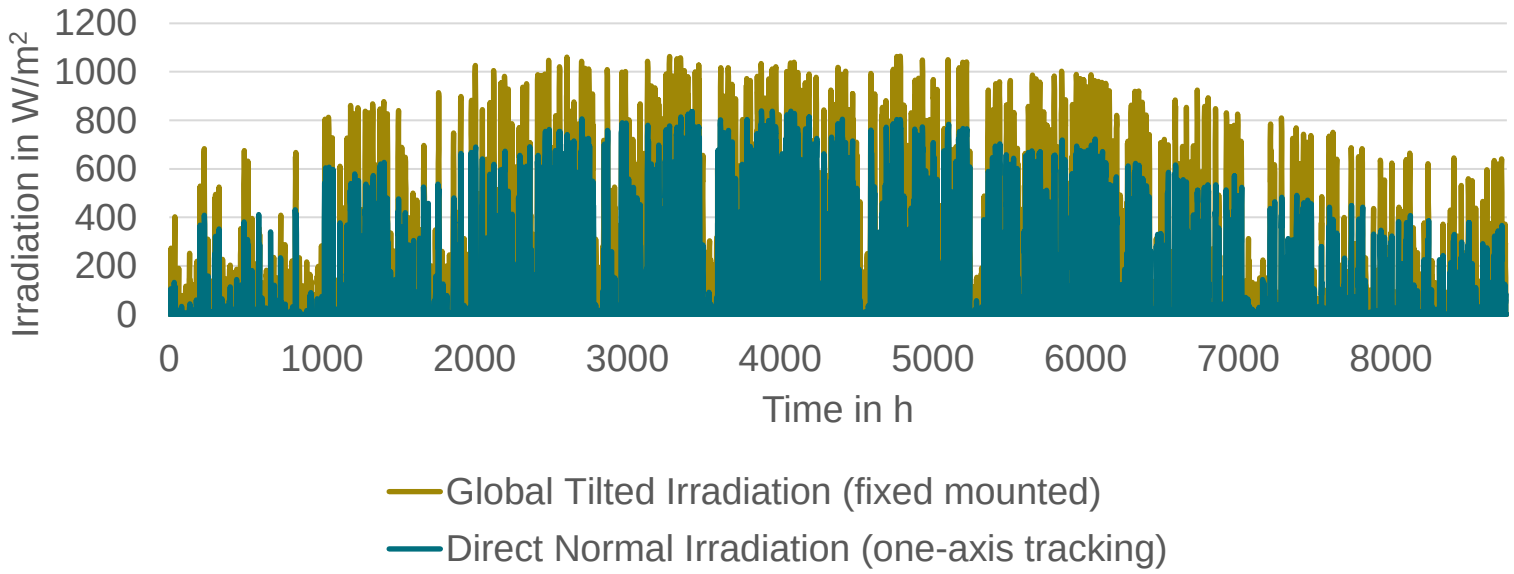
Methodology
Demand Profile and Meteorological Data

Typical Demand Profile

[1] ProSolNetz
[2] PVGIS

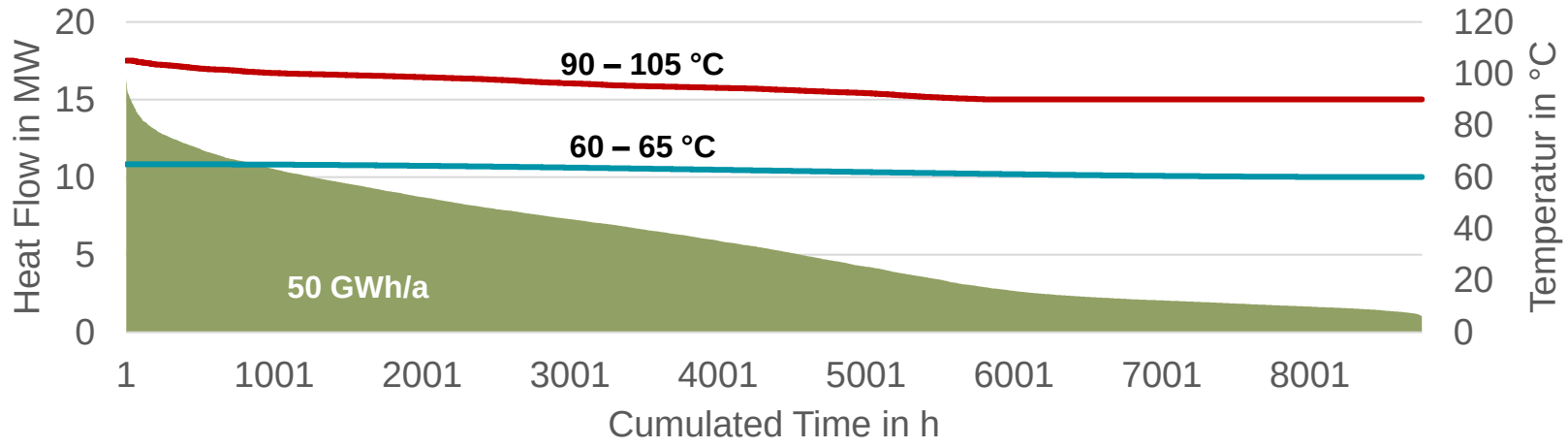
Würzburg, Germany





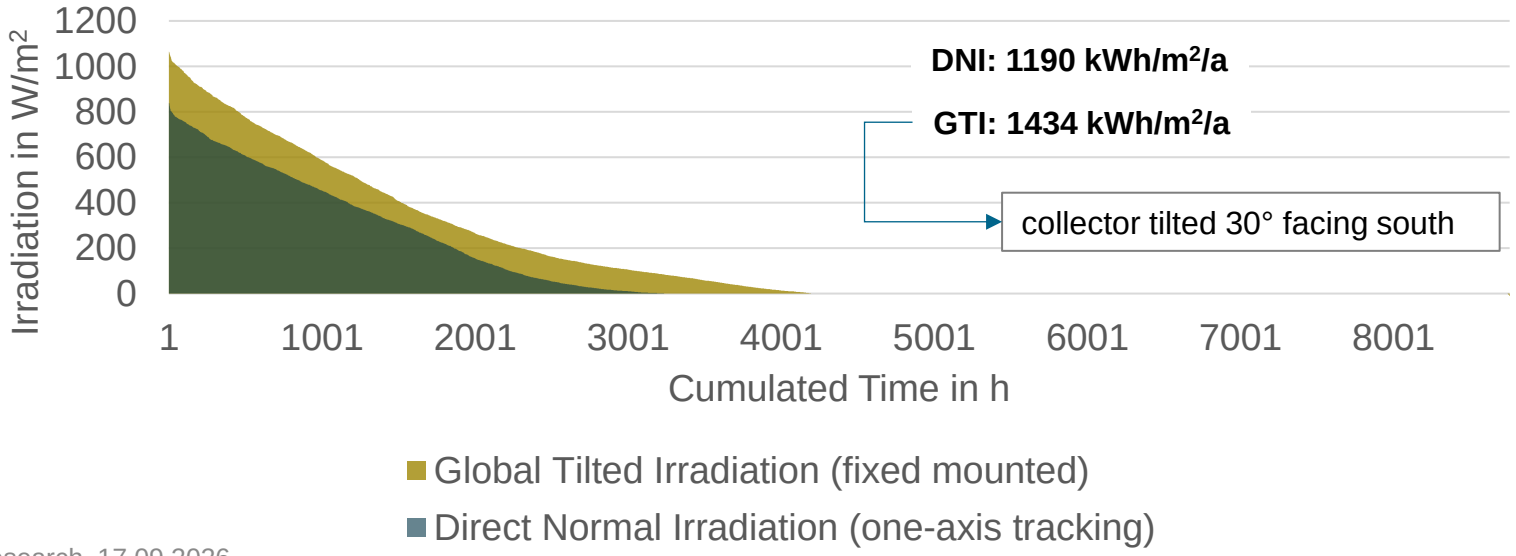
Methodology
Demand Profile and Meteorological Data

Typical Demand Profile



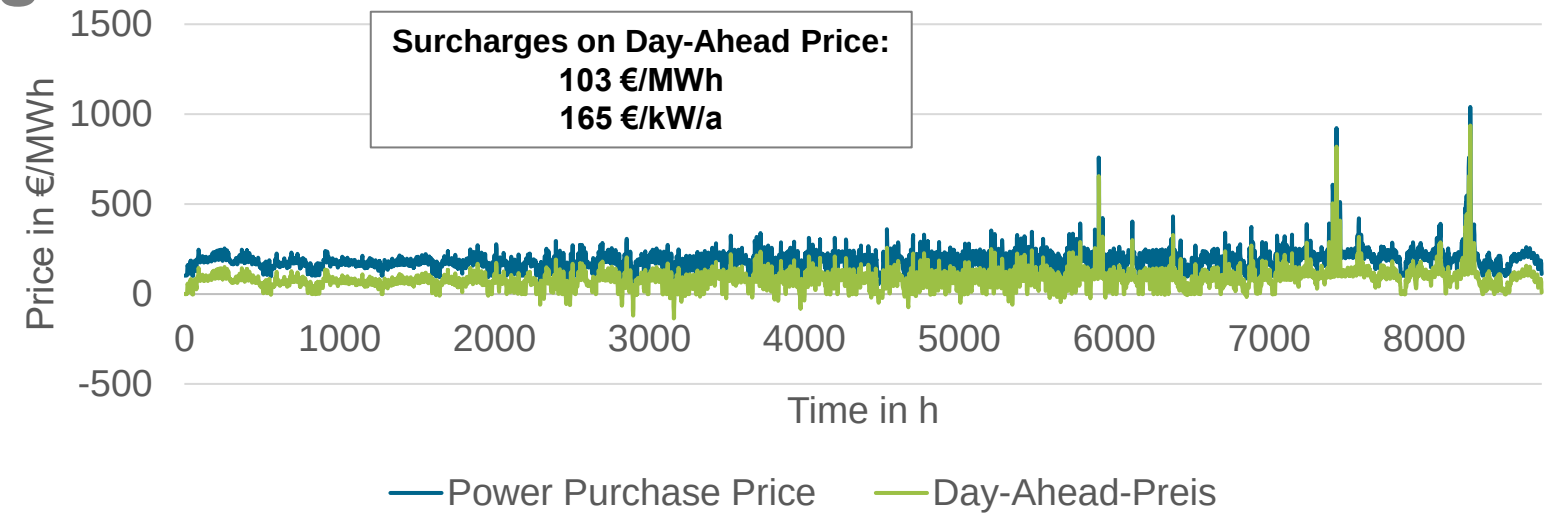
[1] ProSolNetz
[2] PVGIS

Würzburg, Germany



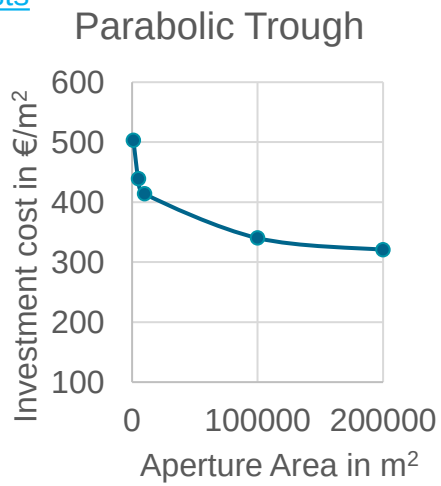
Methodology
Cost Assumptions

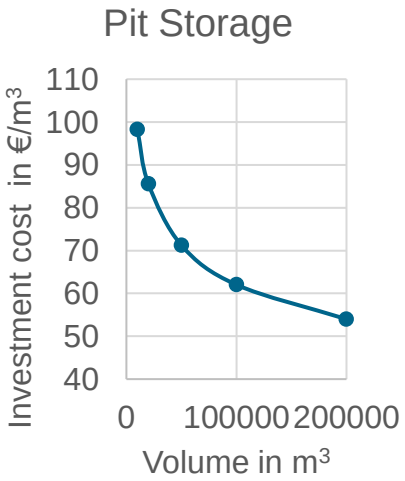
Electricity prices Germany

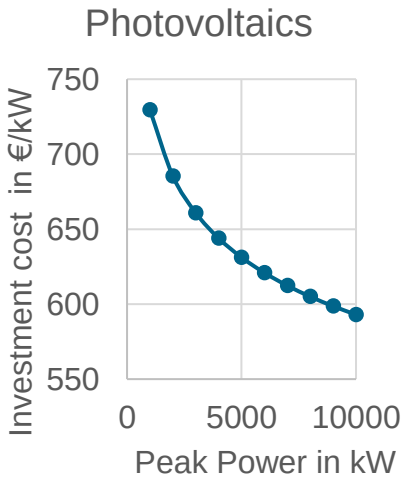


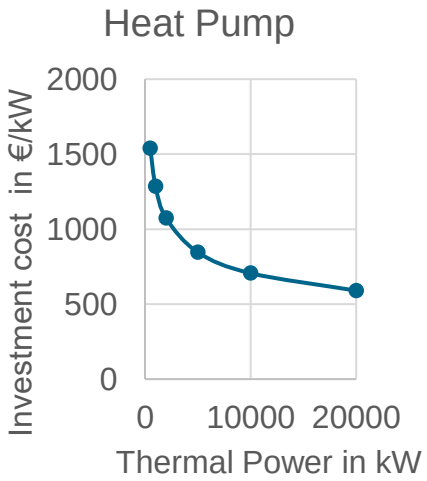
[1] ENTSO-E
[2] Solare Prozesswärme in Deutschland
[3] KWW Technikkatalog
[4] Renewable Power Generation Costs

Investment Cost Curves



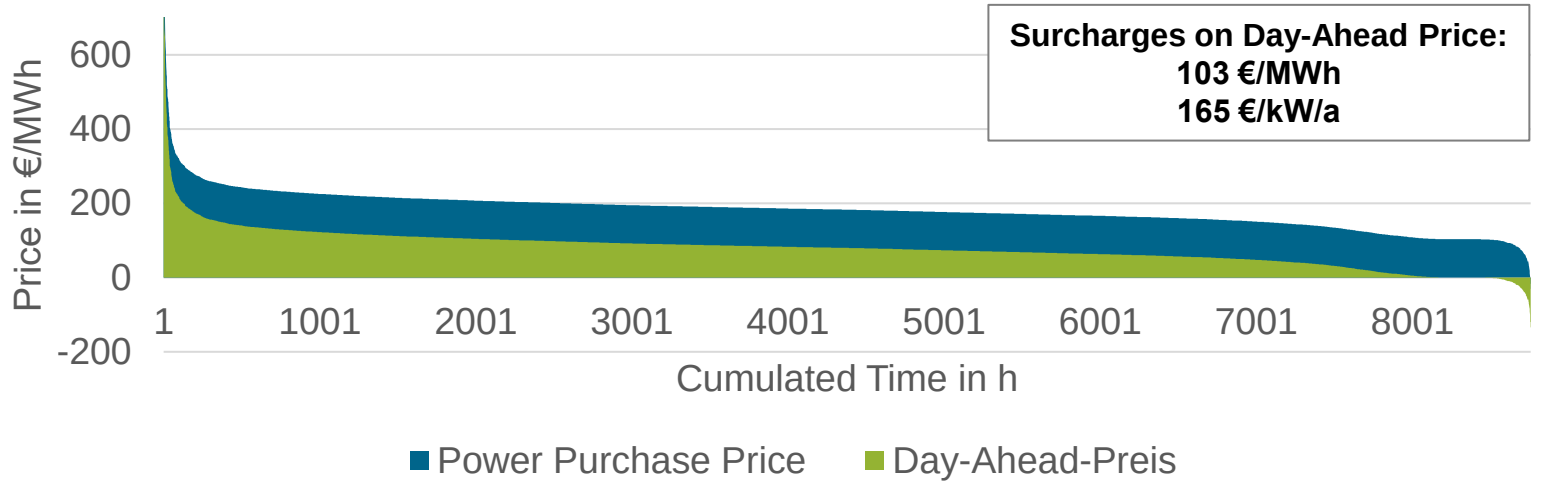






Methodology
Cost Assumptions

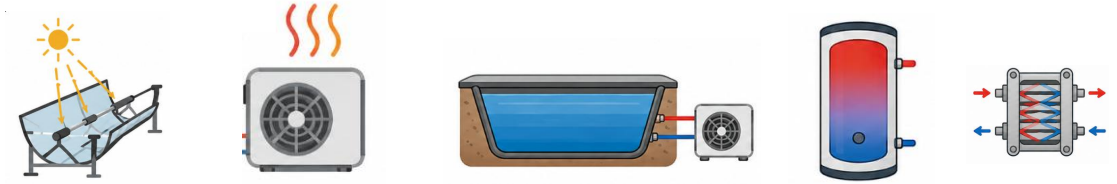
Electricity prices Germany



[1] ENTSO-E
[2] BEW

German Federal Funding

Investment:
40 %



Operation:
variable



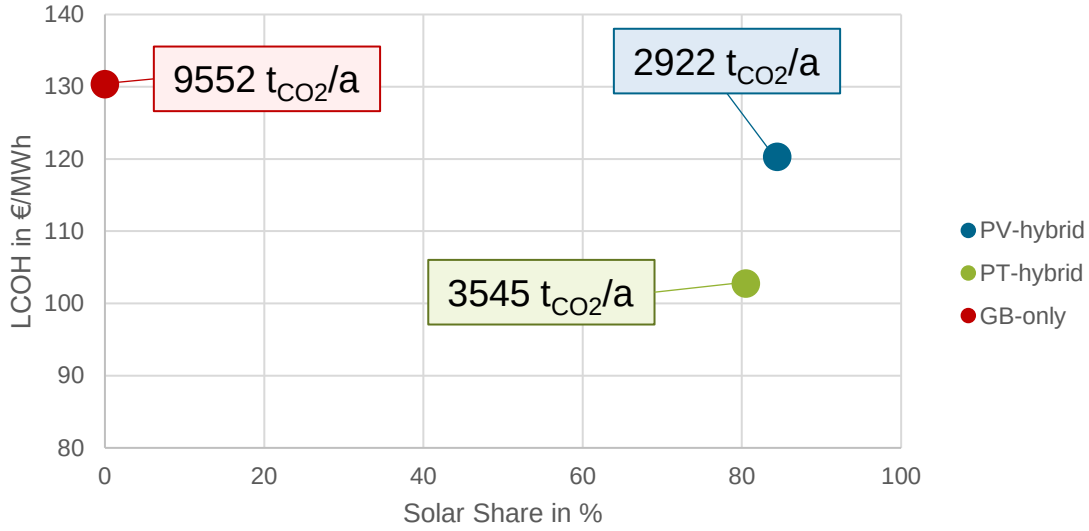
Icons created with ChatGPT https://chatgpt.com/

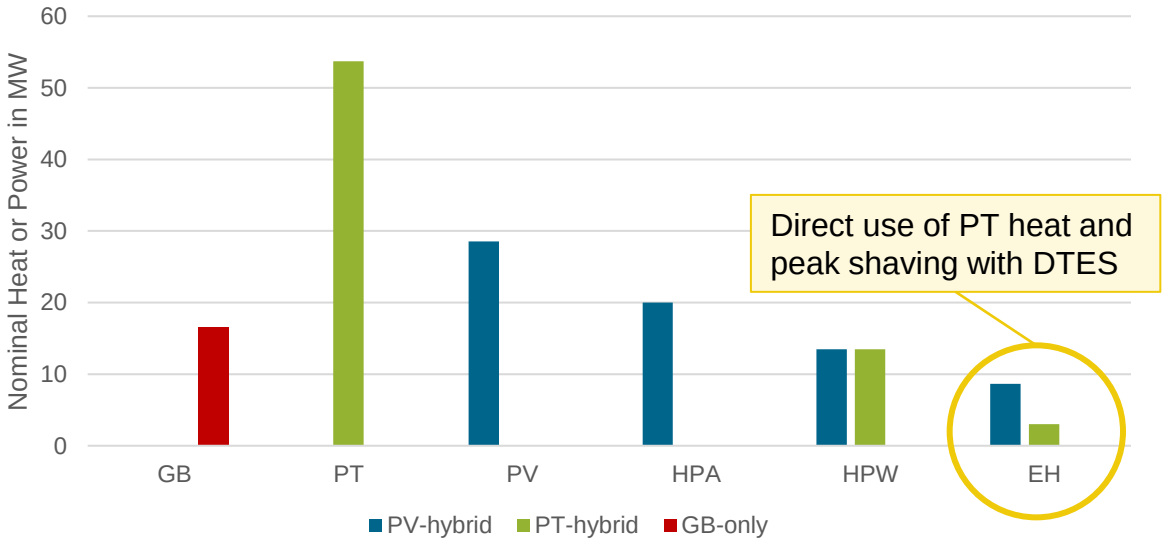


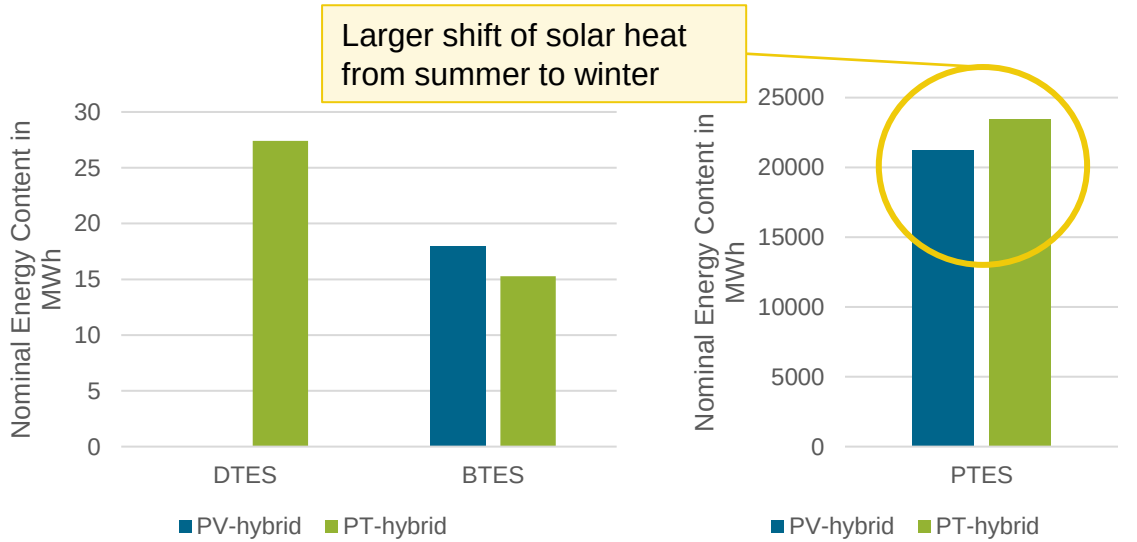
RESULTS & DISCUSSION

DLR (CC BY-NC-ND 3.0)

Results
Levelized Cost, Solar Share and System Designs





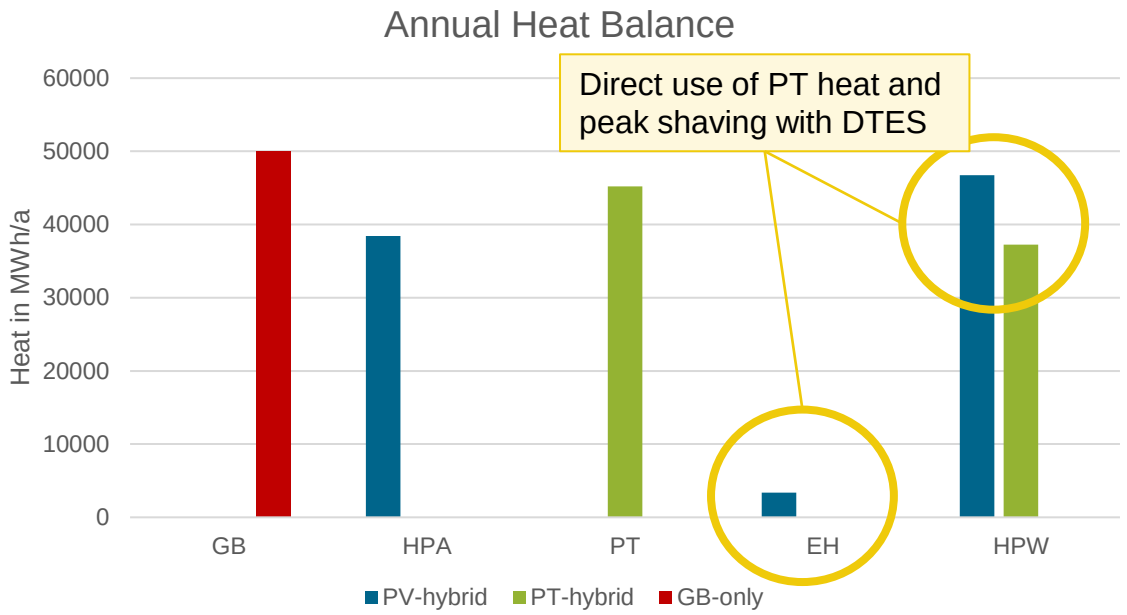


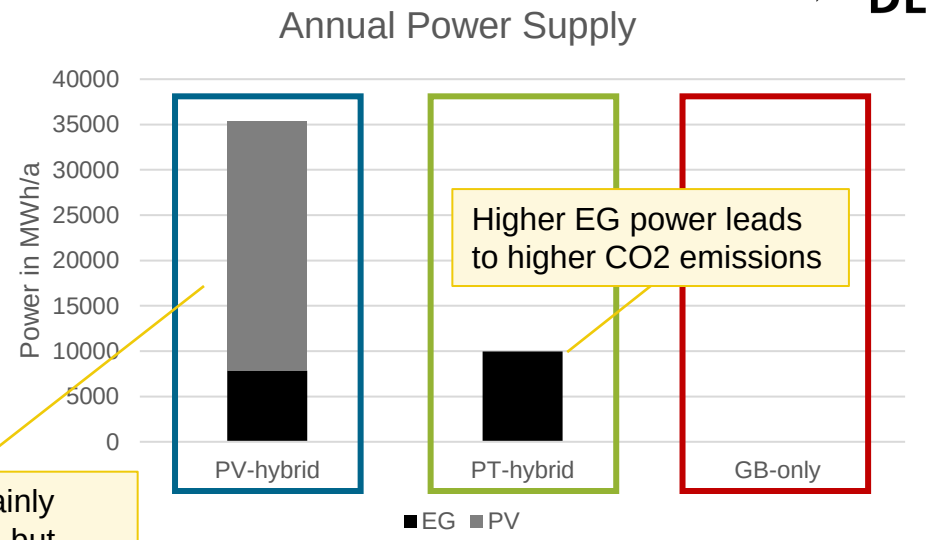
GB: Gas Bruner
PT: Parabolic Trough
PV: Photovoltaics
HPA: Heat Pump Air
HPW: Heat Pump Water
EH: Electric Heater
DTES: Daily Thermal Energy Storage
BTES: Buffer Thermal Energy Storage
PTES: Pit Thermal Energy Storage
BOP: Balance of Plant
EG: Electricity Grid

PV-hybrid
PV
HPA
PTES
HPW
BTES
EH

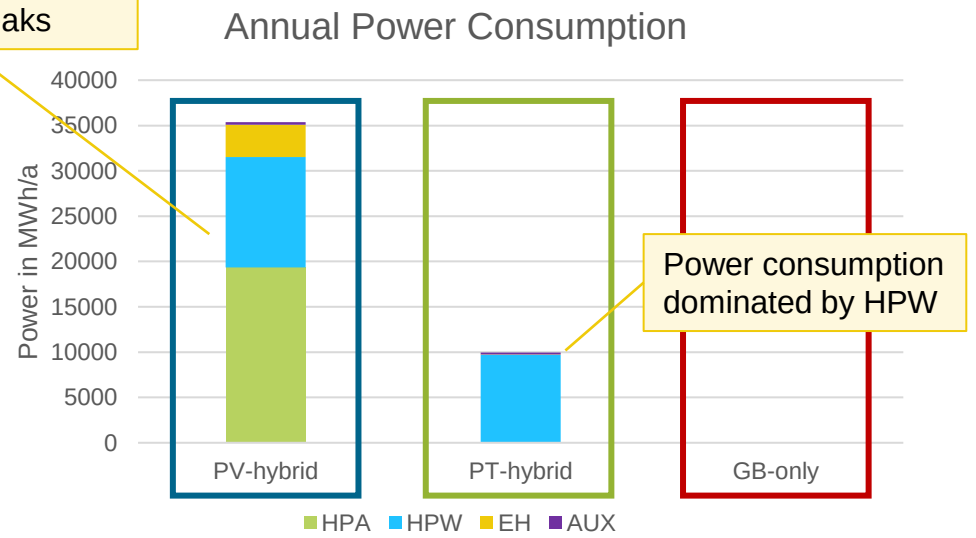
PT-hybrid
PT
DTES
PTES
HPW
BTES
EH

Results
Annual Heat and Power Balance





PV power mainly supplies HPA but also HPW in winter and EH at peaks

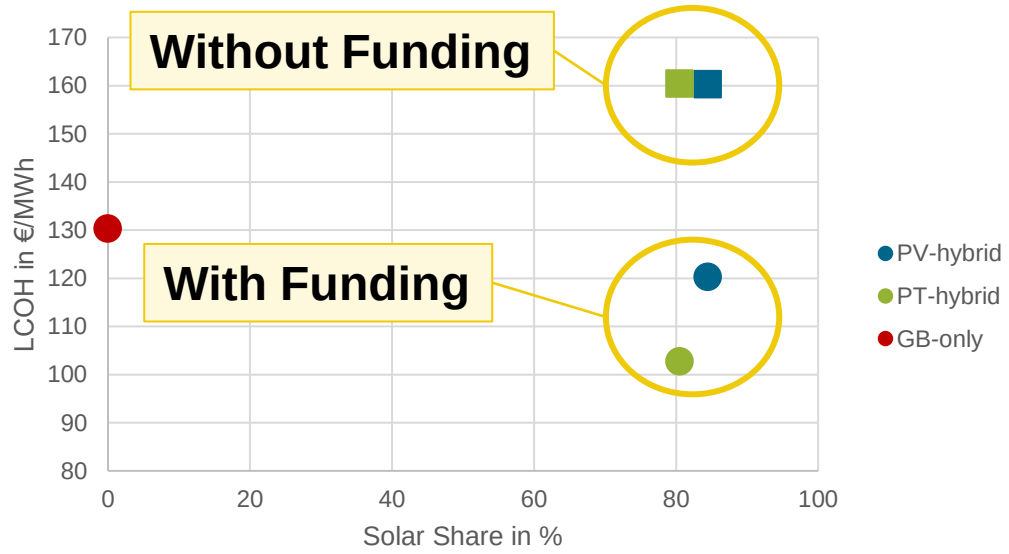


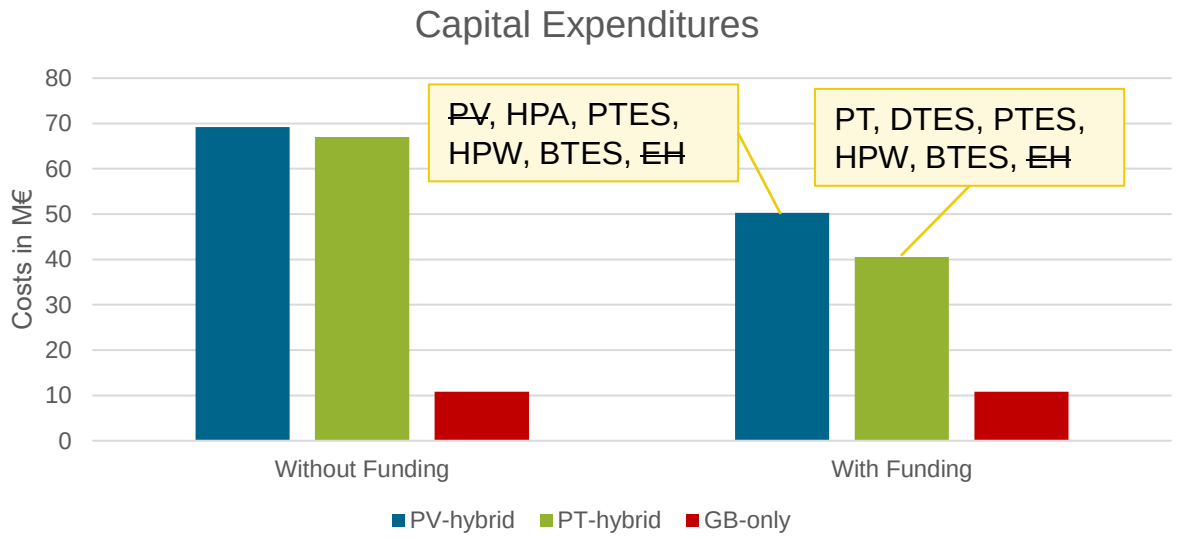
GB: Gas Bruner
PT: Parabolic Trough
PV: Photovoltaics
HPA: Heat Pump Air
HPW: Heat Pump Water
EH: Electric Heater
DTES: Daily Thermal Energy Storage
BTES: Buffer Thermal Energy Storage
PTES: Pit Thermal Energy Storage
BOP: Balance of Plant
EG: Electricity Grid

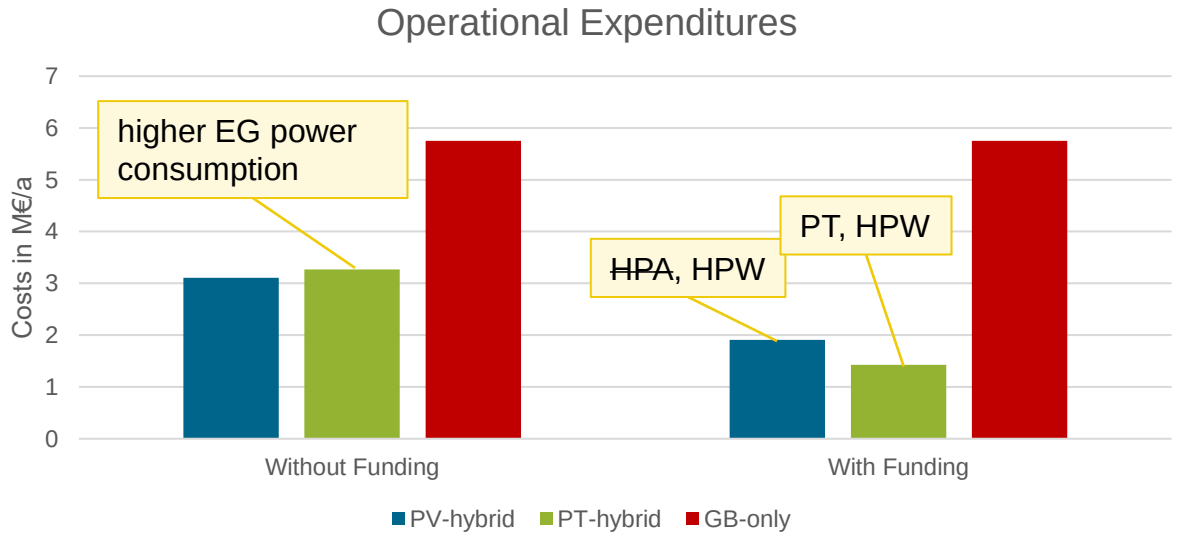
PV-hybrid
PV
HPA
PTES
HPW
BTES
EH

PT-hybrid
PT
DTES
PTES
HPW
BTES
EH

Results
Influence of Funding Mechanisms in Germany





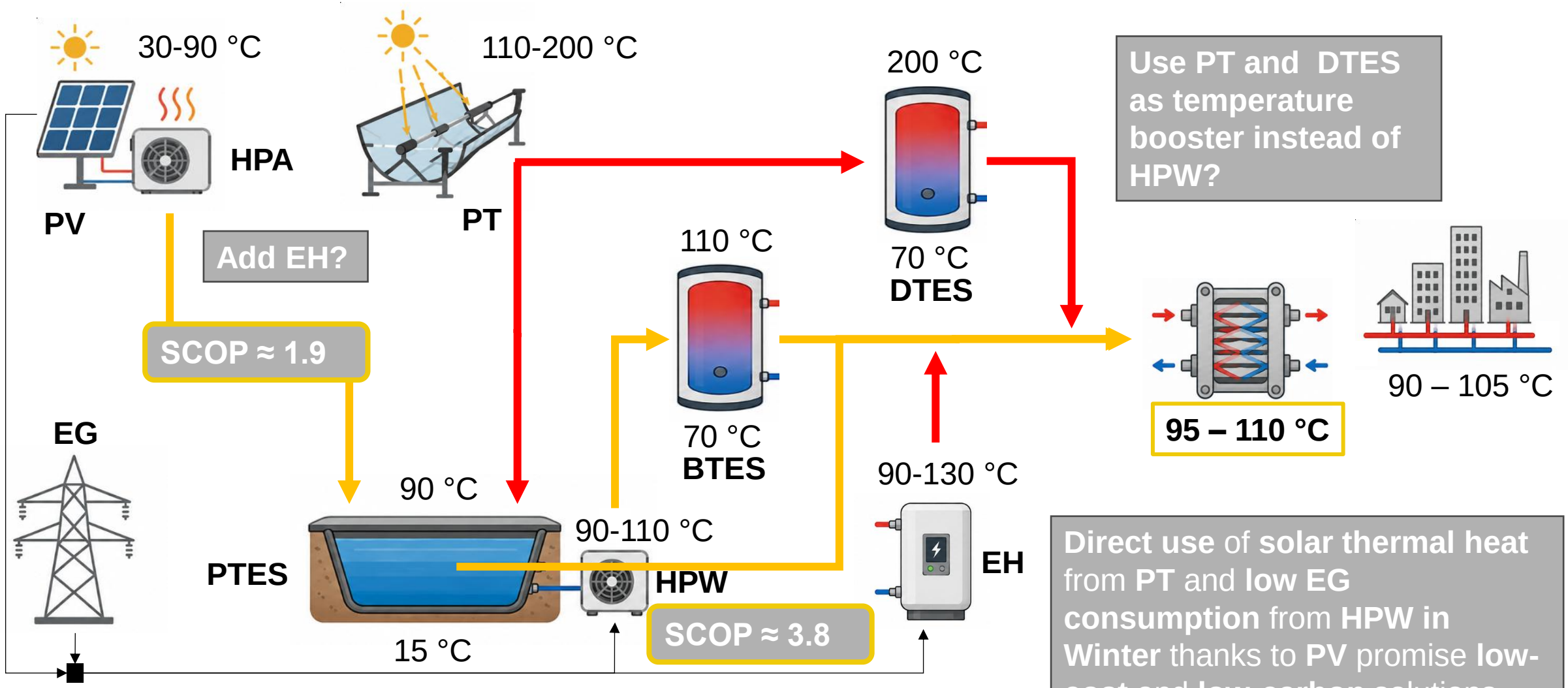


GB: Gas Bruner
PT: Parabolic Trough
PV: Photovoltaics
HPA: Heat Pump Air
HPW: Heat Pump Water
EH: Electric Heater
DTES: Daily Thermal Energy Storage
BTES: Buffer Thermal Energy Storage
PTES: Pit Thermal Energy Storage
BOP: Balance of Plant
EG: Electricity Grid

PV-hybrid	PT-hybrid
PV	PT
HPA	DTES
PTES	PTES
HPW	HPW
BTES	BTES
EH	EH

Discussion
Combine Advantages of PV and PT

Operational Funding starts at 2.5



Direct use of **solar thermal heat** from **PT** and **low EG consumption** from **HPW in Winter** thanks to **PV** promise **low-cost** and **low-carbon** solutions

Icons created with ChatGPT https://chatgpt.com/



CONCLUSIONS

DLR (CC BY-NC-ND 3.0)

Conclusion & Outlook

Solar District Heating can provide **cost comparitive 100% supply** (103-120 €/MWh) at **high solar shares** (>80 %)

Parabolic Trough based solutions can **ensure direct demand supply** in addition to seasonal storage charging even **for district heating networks** with **high supply temperatures**

Parabolic Trough yields **lower LCOH** than **PV + Air Source Heat Pump** in Germany after **federal funding** due to higher outlet temperatures suitable for direct demand supply**,** but also **higher grid penetration** due to storage discharge via heat pump without PV support in winter

A Combination of **Parabolic Trough** and **PV + Air Source Heat Pump** can yield **low cost** with **low grid penetration** and **emissions**



essentially,
all models are wrong,
but some are useful

George E. P. Box

https://freshspectrum.com/simulation

THANK YOU FOR YOUR ATTENTION!

Matthias Loevenich
DLR Institute of Solar Research
matthias.loevenich@dlr.de

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages