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# Wind powered Thermal Energy Systems – Opportunities from a holistic system's perspective and comparison of concepts for room heating

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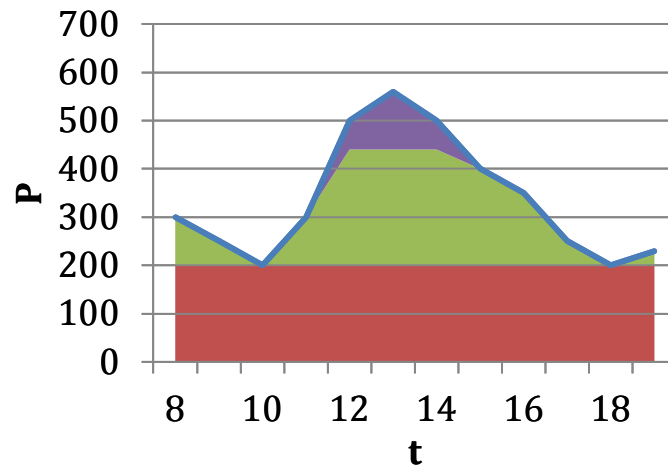
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# Motivation: Challenges in RE-dominated Systems

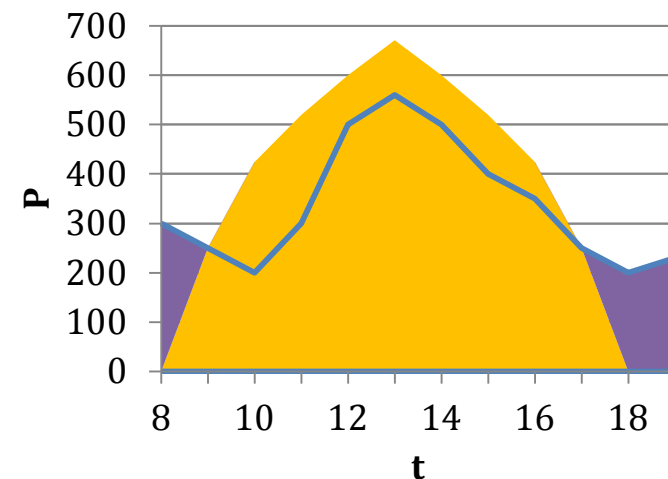
## Past

- Aim: load covering
- Measure: adapting power generation



## Future Trend

- Aim: residual load covering
- Measure:
  - adapting power generation
  - adapting power consumption



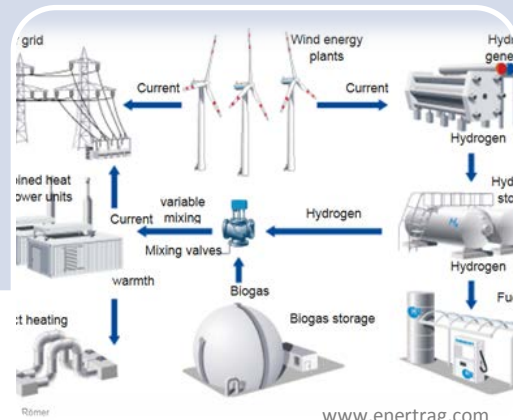
# State-of-the-art concepts



Dispatchable renewables



Cross-sectoral energy supply



Hybrid power plants



**Wind powered thermal energy systems**



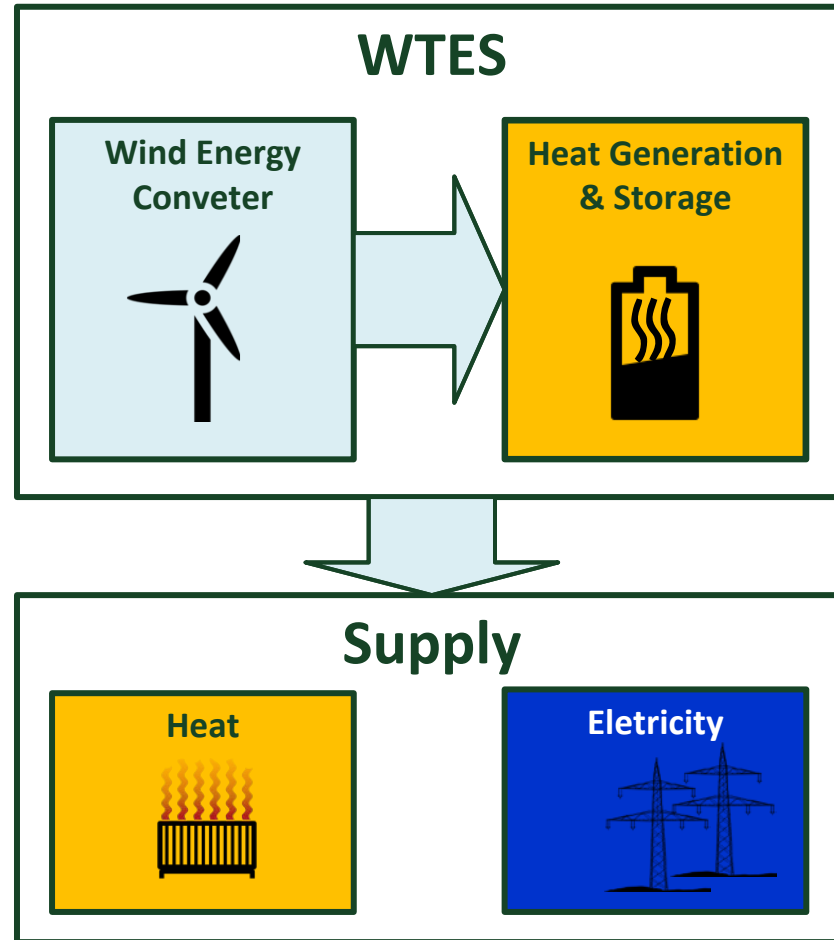
# Theoretical Concept of WTES

## An Overview

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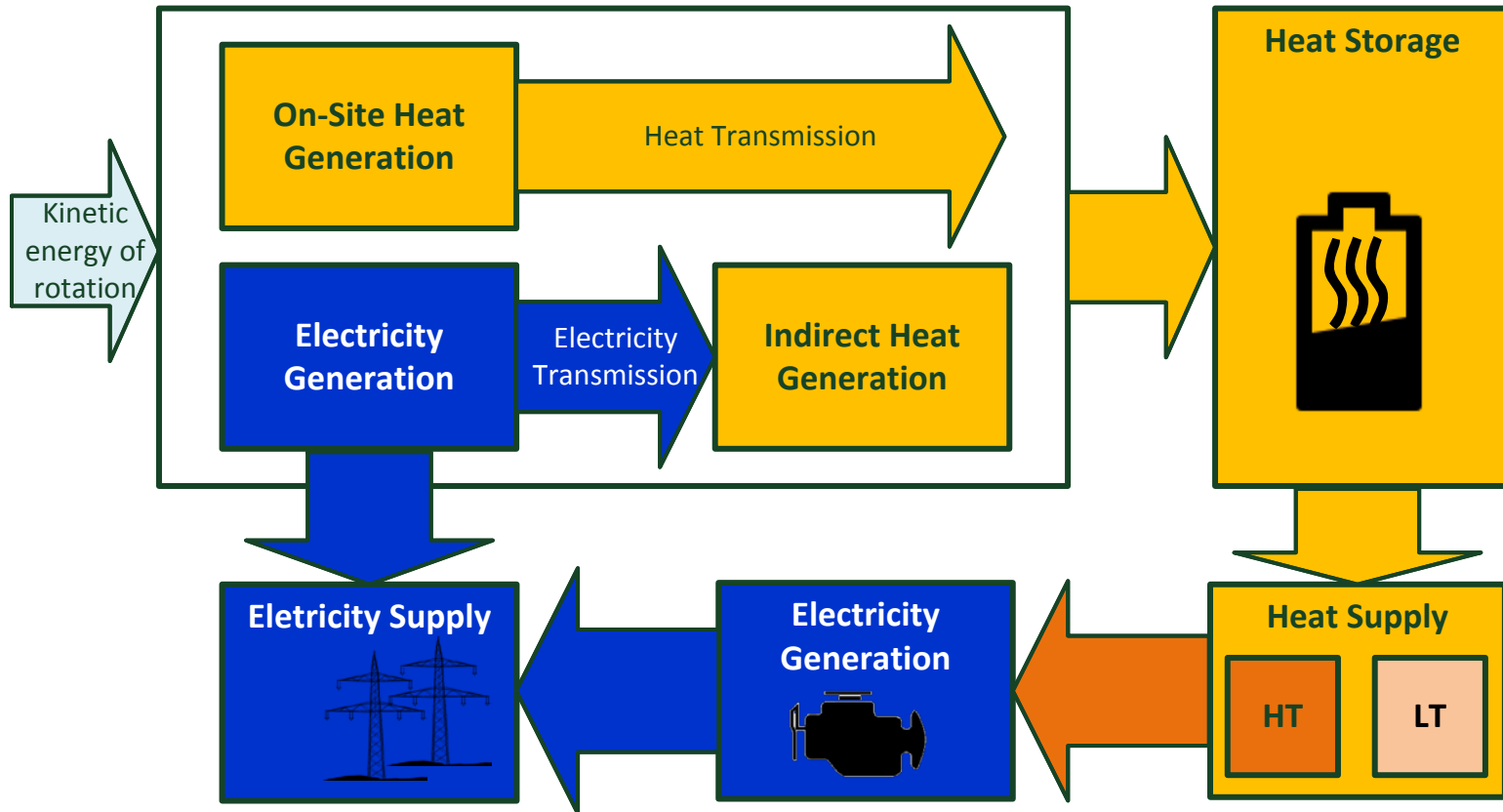


# General Characteristics

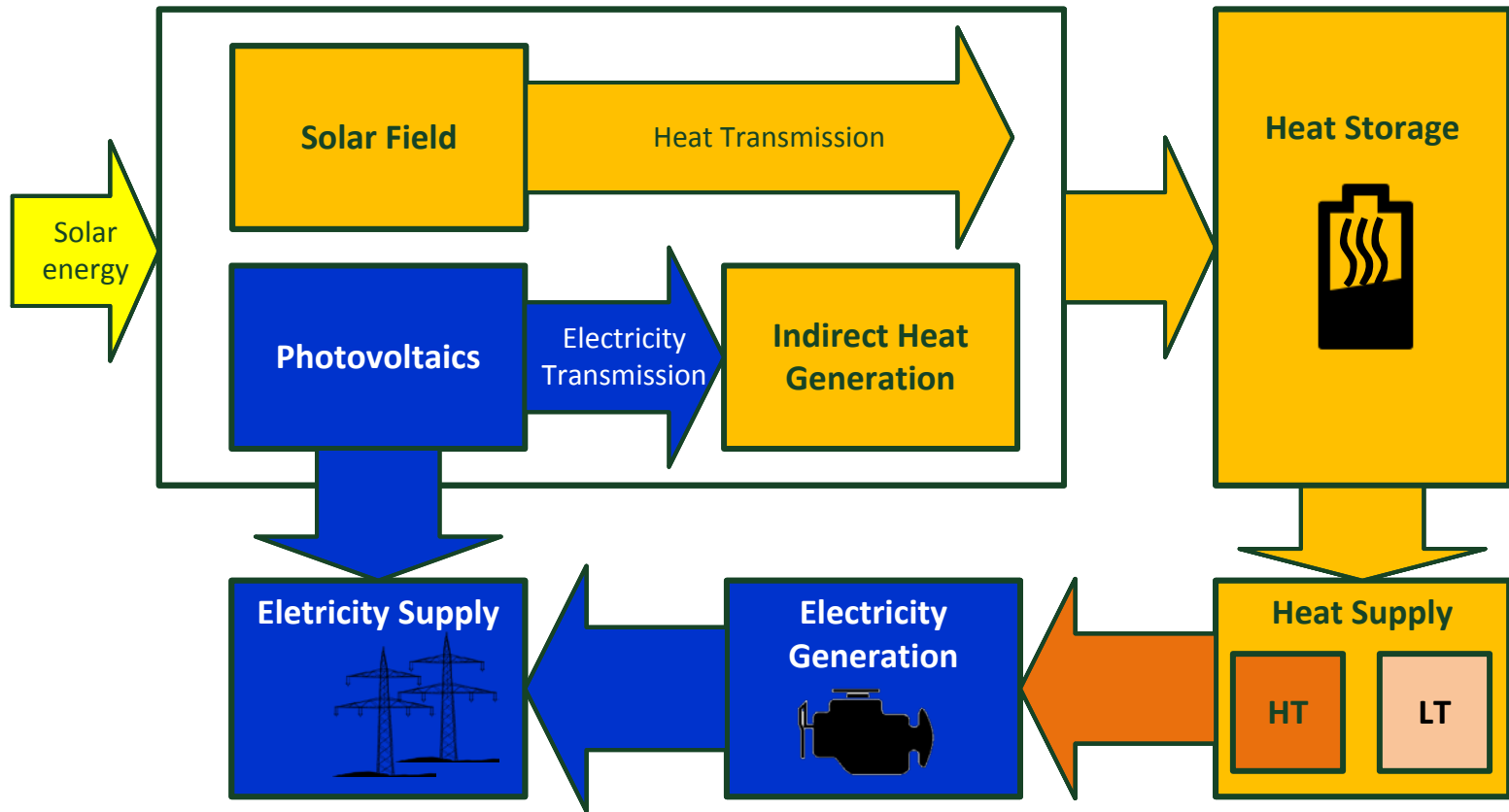




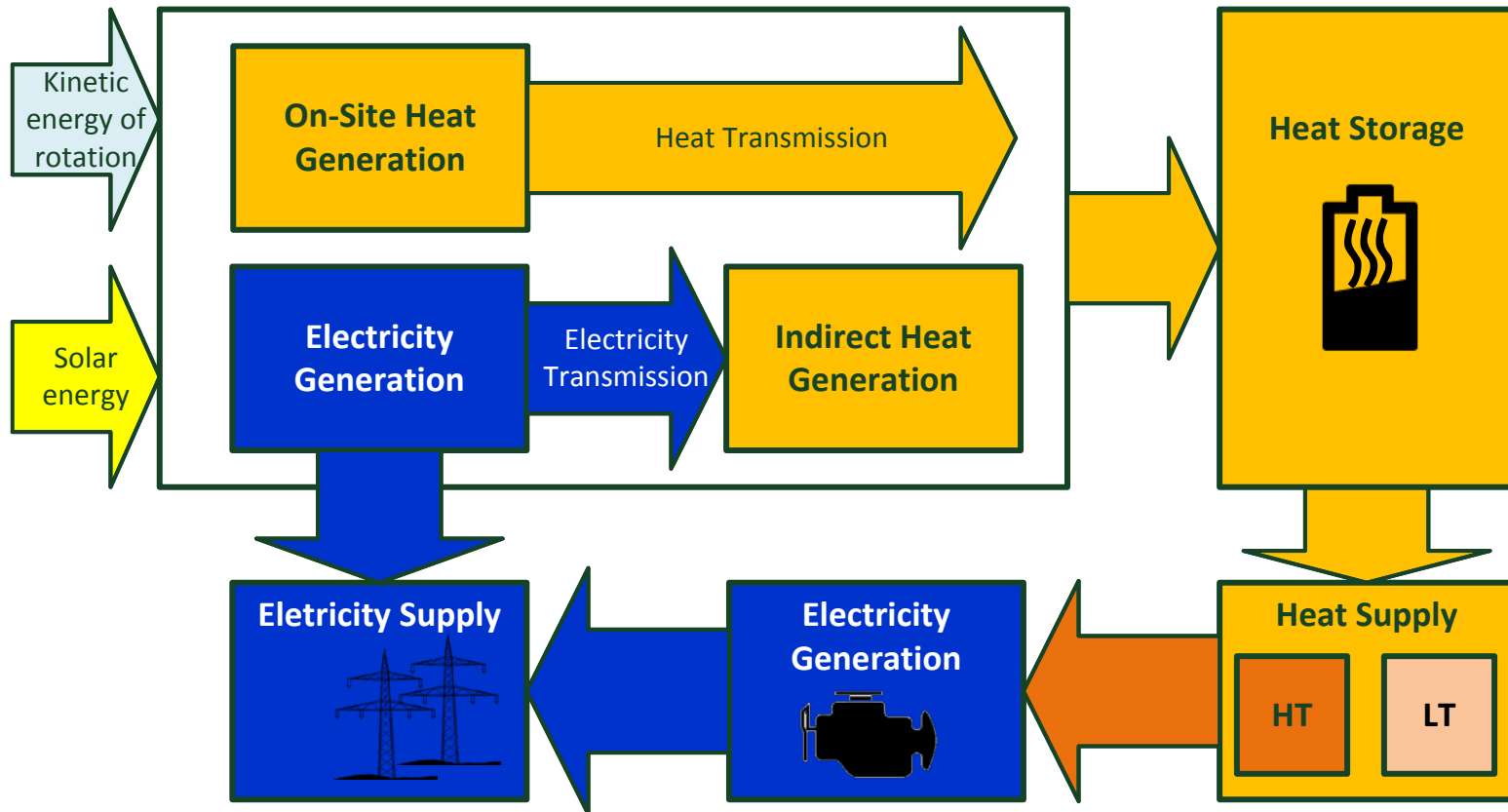
# General Characteristics



# Switching the resource...



# Another Hybrid Power Plant?





# WTES for room heating

An economic comparison



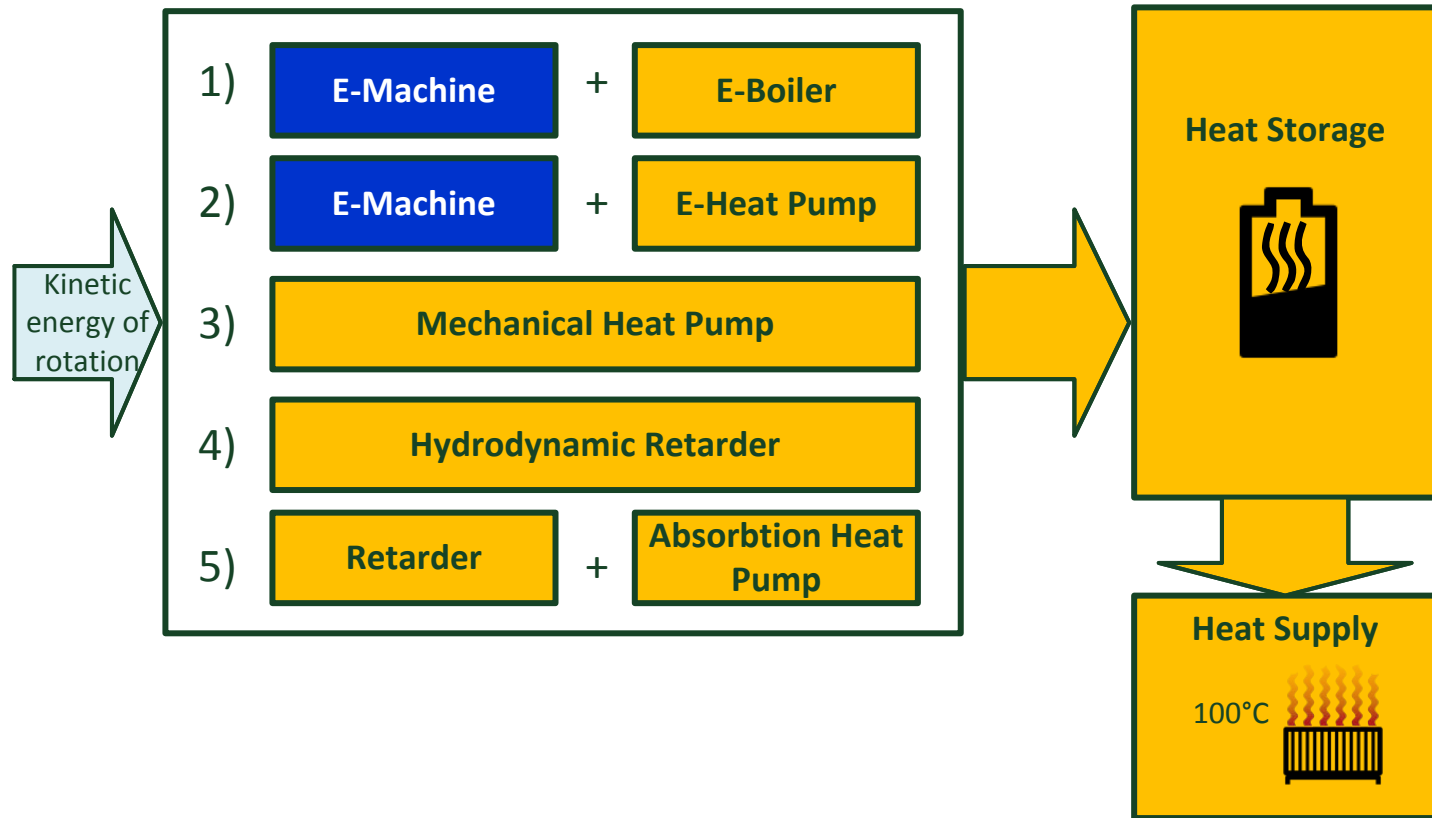
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# Objectives

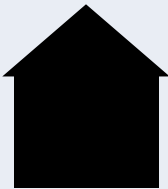
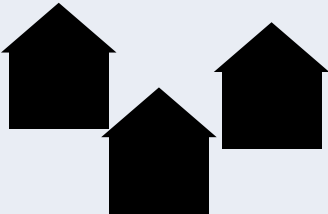




1. Technically feasible WTES for room heating
2. Cost estimation using commercially available components



# 5 Heat Generation Concepts



# 3 System Sizes

Small	Medium	Large
1 House	500 Houses	5.000 Houses
		
 <a href="http://www.windindustrie-in-deutschland.de">www.windindustrie-in-deutschland.de</a>	 <a href="http://www.enercon.de">www.enercon.de</a>	 <a href="http://www.enercon.de">www.enercon.de</a>



# Methodology

## Levelized cost of energy (heat)

$$LCOE = \frac{\sum_{i=1}^n \left( \frac{I_i + M_i + F_i}{(1+r)^i} \right)}{\sum_{i=1}^n \left( \frac{E_i}{(1+r)^i} \right)}$$

- I: Capital expenditures (CAPEX)  
 M: Operational expenditures (OPEX)  
 F: Fuel expenditures = 0  
 E: Annual thermal energy generated  
 r: Discount rate = 0.05  
 n: Lifespan of the project = 20 yr

## Cost Breakdown

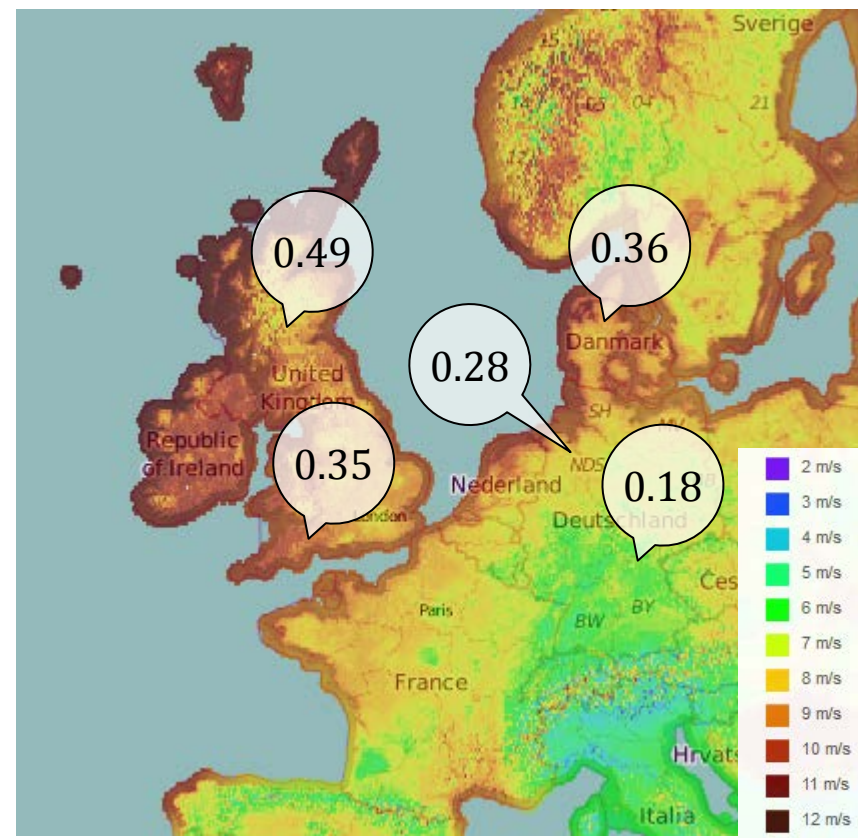
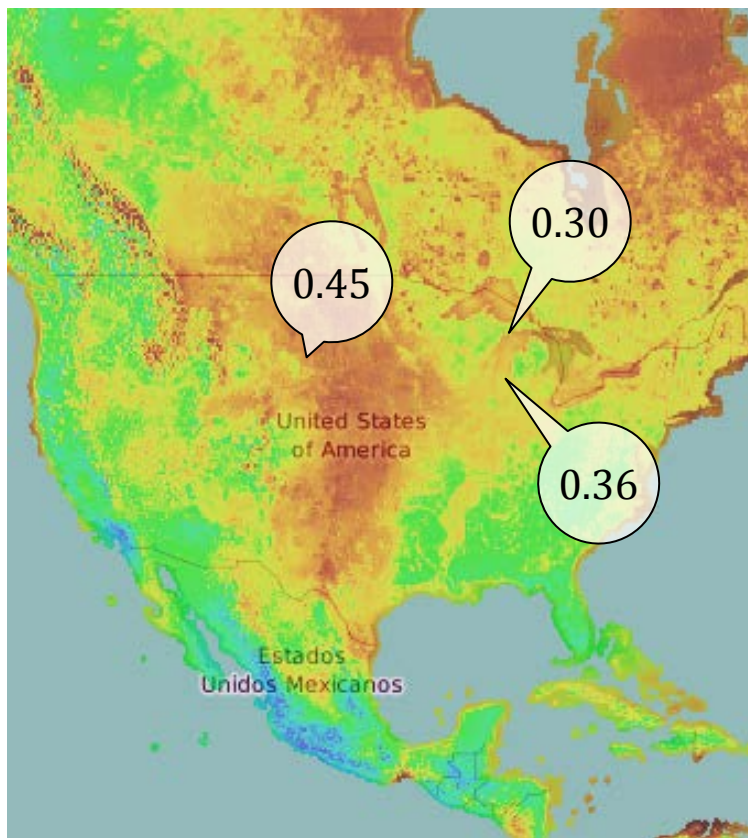
- e.g.: Wind Energy Converters

Component	Share
Engineering and Construction	25%
Tower	22.08%
Rotor	22.42%
Main Frame	2.35%
Gearbox	10.84%
Generator	2.89%
Yaw System	1.05%
Pitch System	2.23%
Power Converter	4.21%
Transformer	3.01%
Break System	1.11%
Nacelle Housing	1.13%
Cables	0.81%
Screws	0.87%





# Typical Capacity Factors

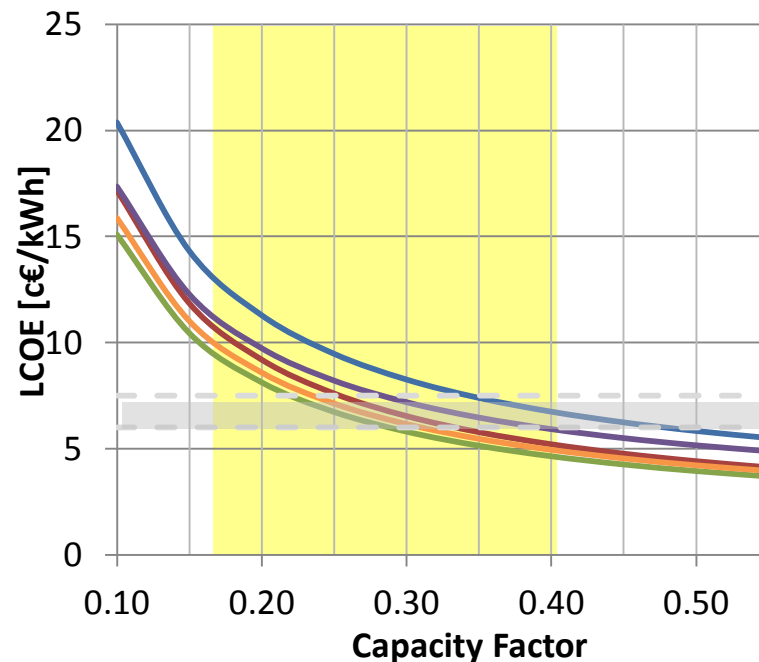
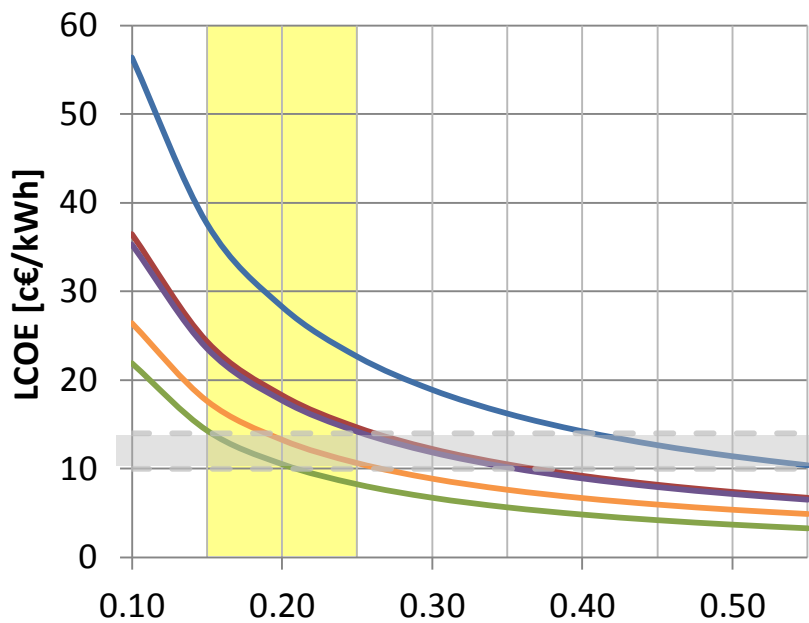


IRENA Global Atlas, Wind Speed





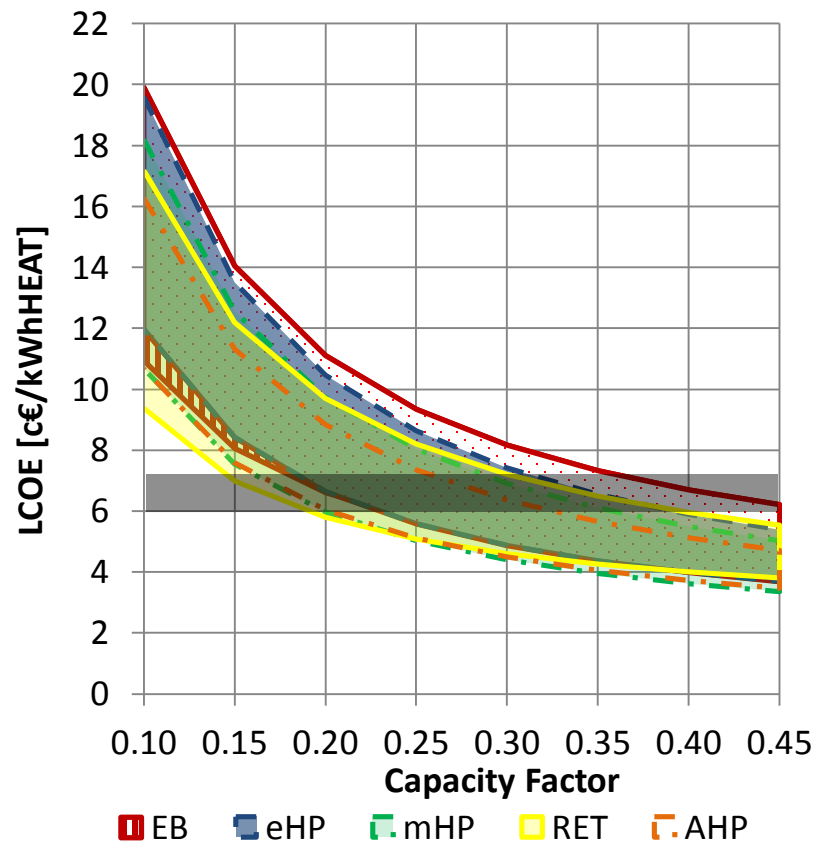
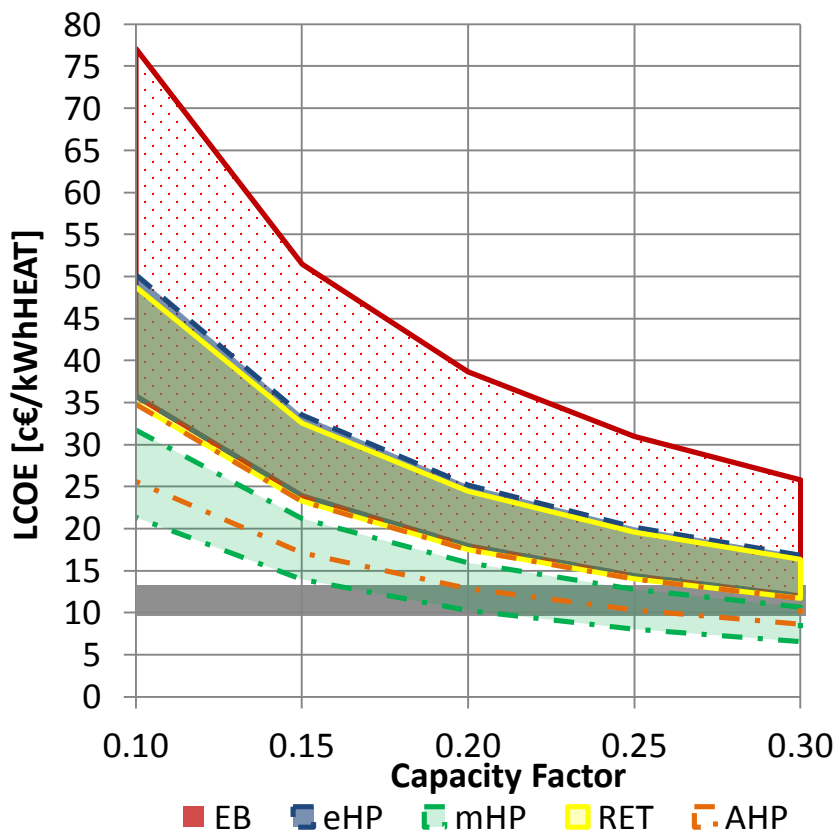
# Results I: Average LCOE<sub>Heat</sub>



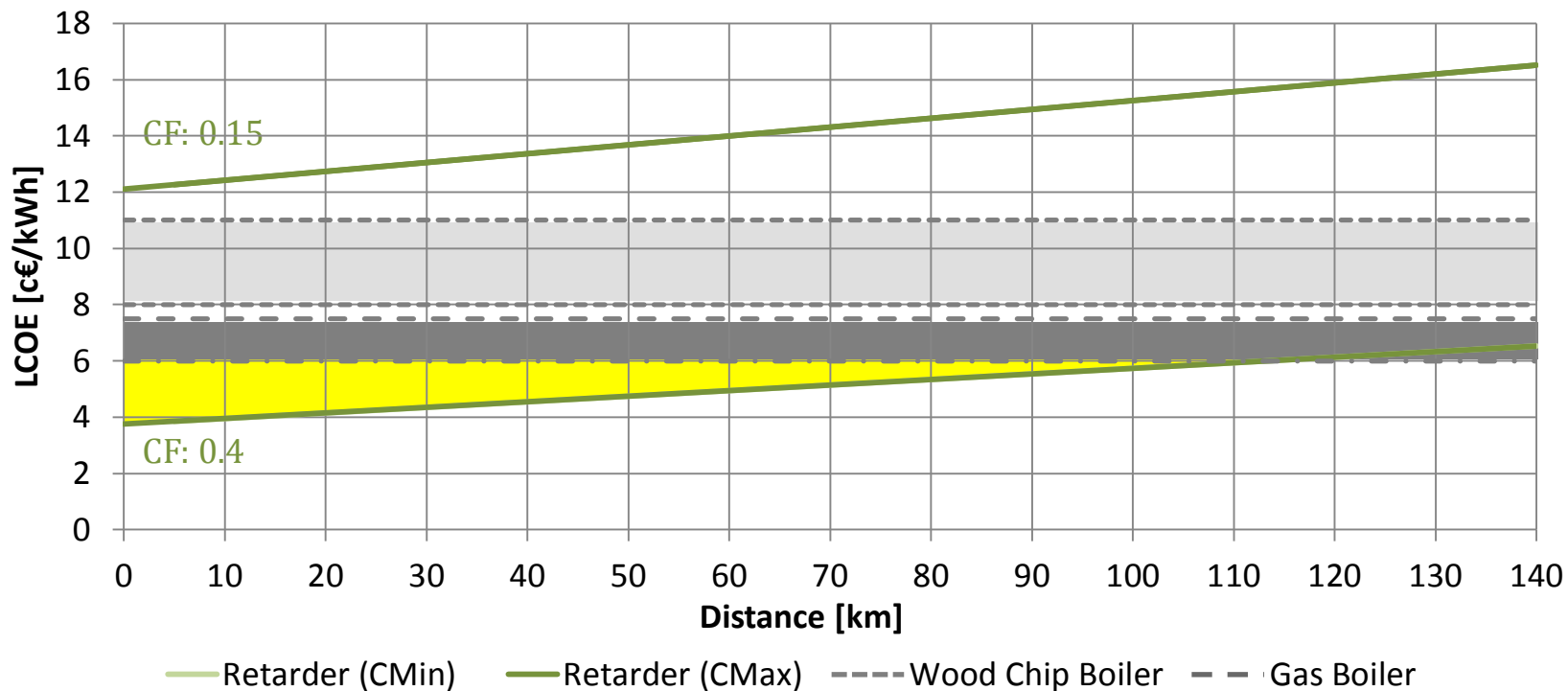
- 1) — WEC+EB
- 2) — WEC+eHP
- 3) — WEC+mHP
- 4) — WEC+RET
- 5) — WEC+RET+AHP
- Gas Boiler



# Results II: Cost sensitivity



# Results III: Large scaled Systems



# Conclusions

WTES...

... are versatile

... can be competitive for room heat supply



# Outlook

1. Hourly analysis

2. Placing and dimensioning of storage



3. Electricity generation and co-generation

4. System integration



**Thank you very much!**

Questions?

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