e think
ENERGY RESEARCH

GEOTHERMAL DHC
Towards Decarbonized Heating and Cooling!

Costs, Benefits and Potential of (U)TES in DHC

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e-think energy research

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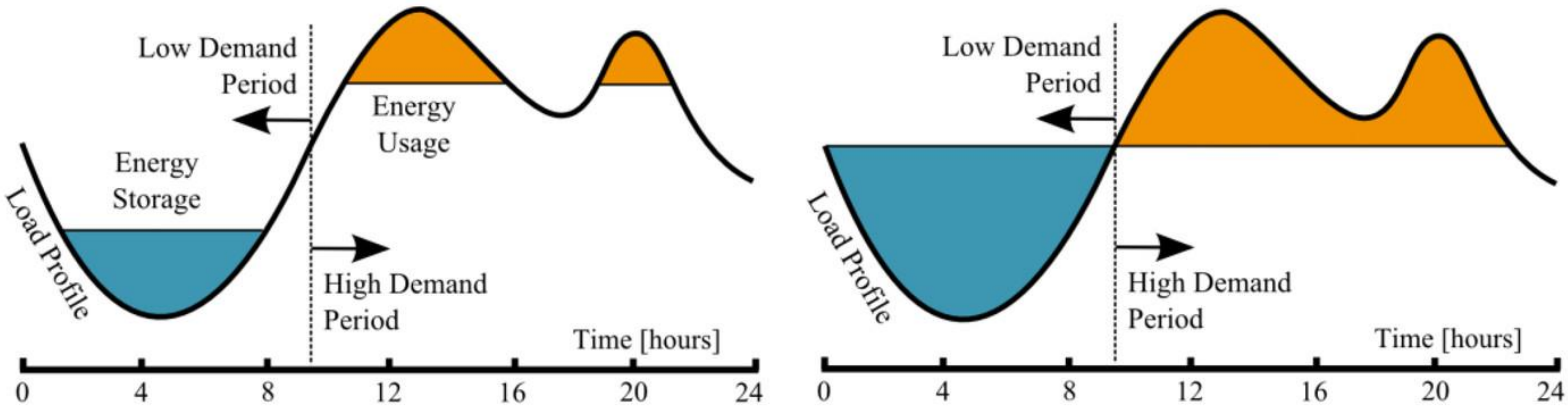
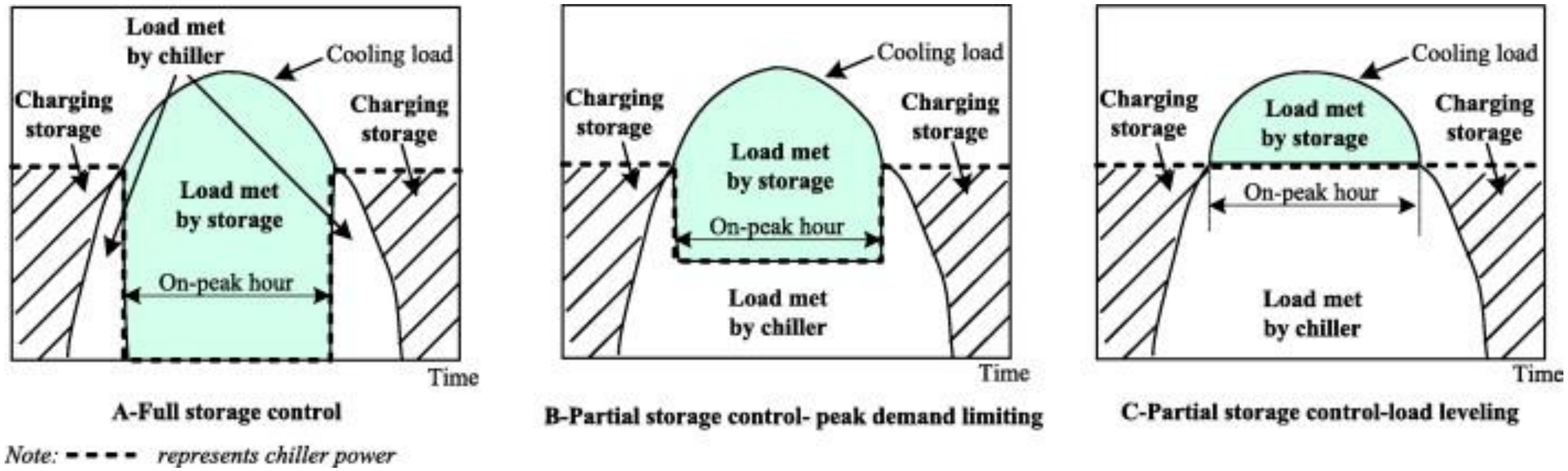
Table of Contents

- Thermal energy storage (TES): **Flattening the curve**
- More **Benefits** and **Drawbacks** of TES in DHC systems
- (U)TES **Classification**, **Market Readiness, Size**, **Costs, Diffusion** and **Features**
- Results of a simulation with the **Hotmaps Dispatch Model**
- Conclusions: **challenges and potential**
- Q&A

Flattening the load profile

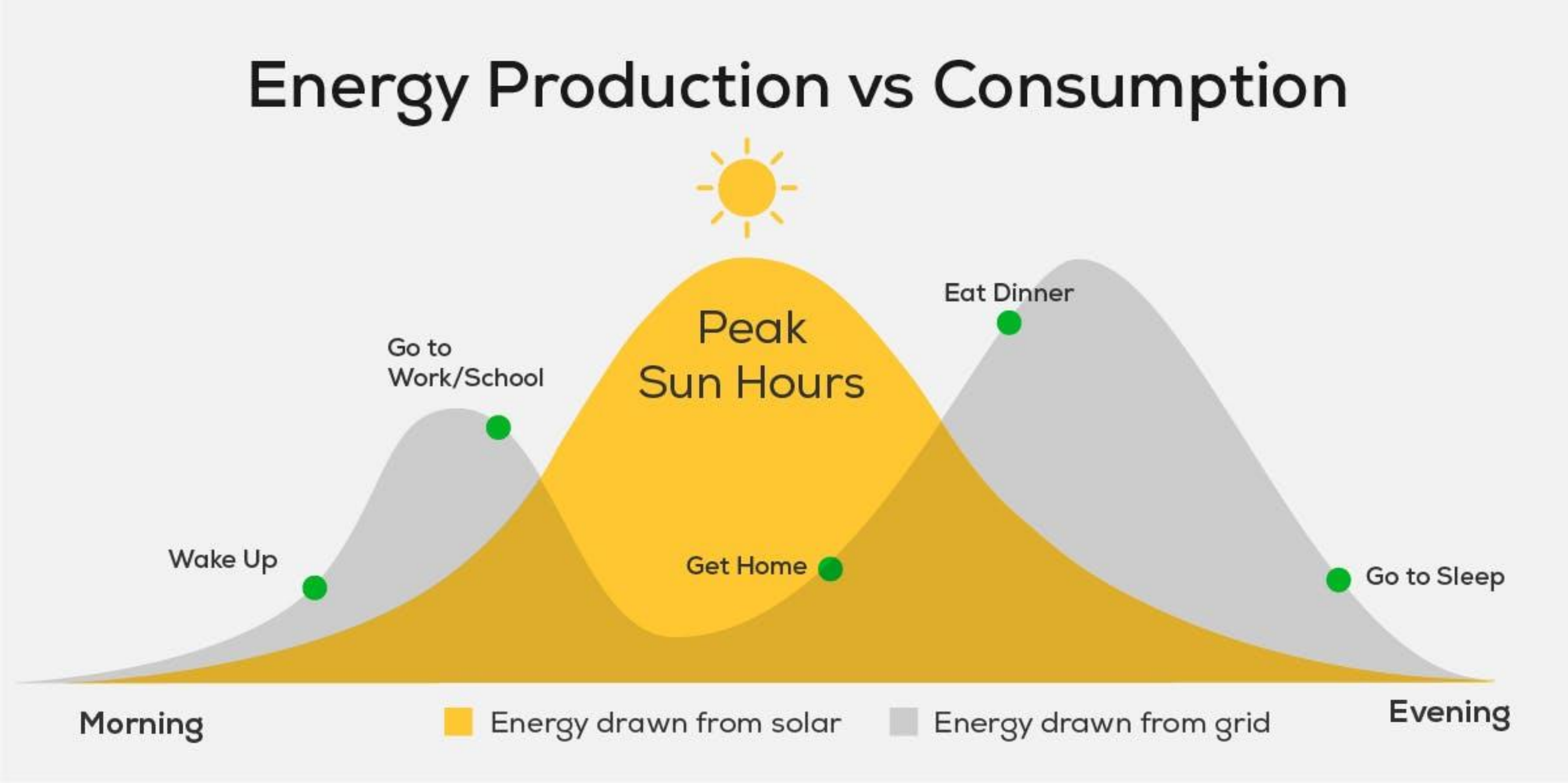


Source: Sabihuddin, S. et al. "A Numerical and Graphical Review of Energy Storage Technologies. Energies.", 2015



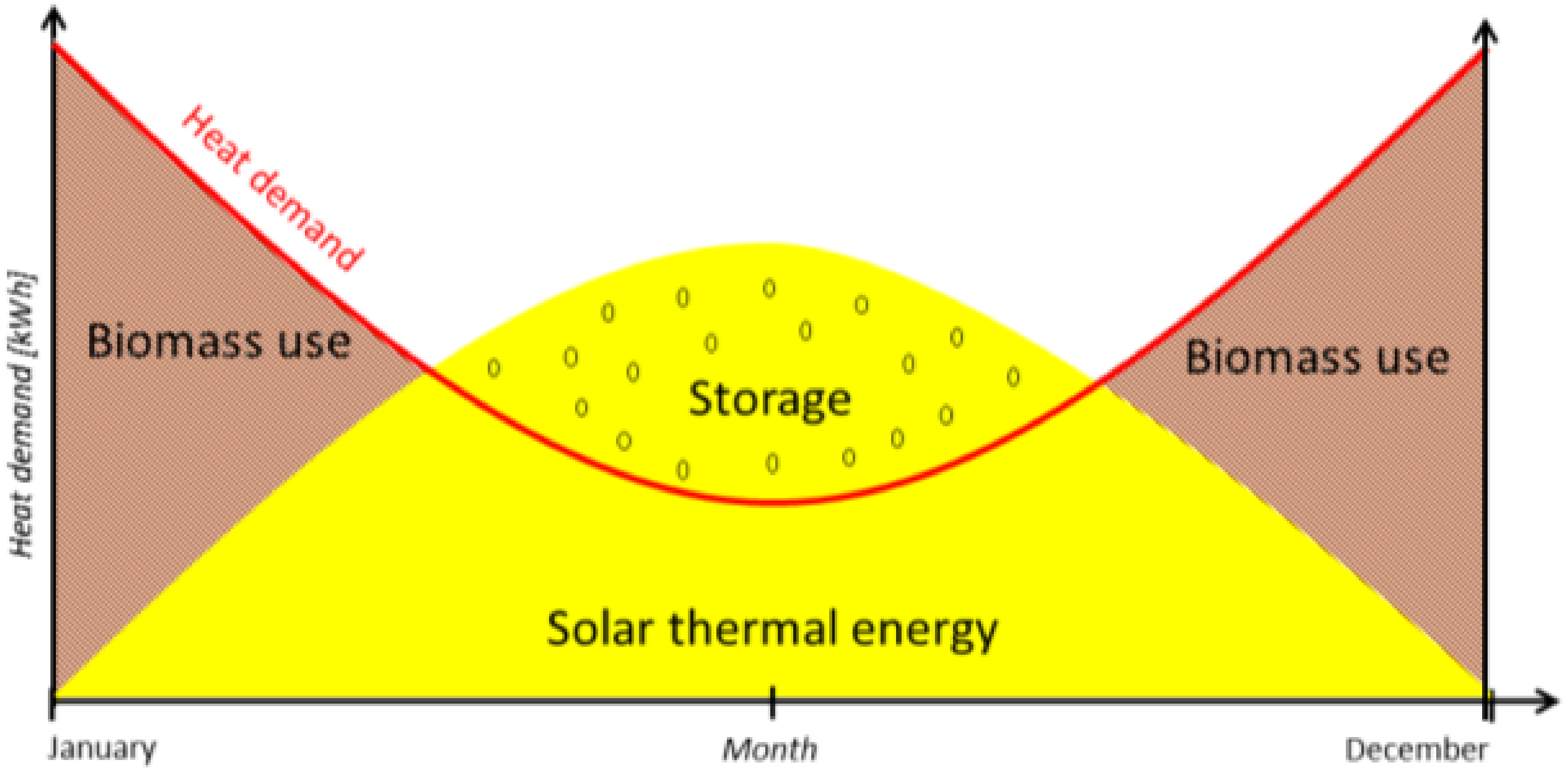
Source:Sun, Y. et al., "Peak load shifting control using different cold thermal energy storage facilities in commercial buildings: A review.", 2013, Energy Conversion and Management.

Demand/Production Profiles: Daily



Source: Hannah Ritchie, Max Roser and Pablo Rosado, Energy Production and Consumption, 2022

Demand/Production Profiles: Seasonal



Source: Rutz, D. et al., "Small, Modular and Renewable District Heating & Cooling Grids for Communities in South-Eastern Europe", 2016

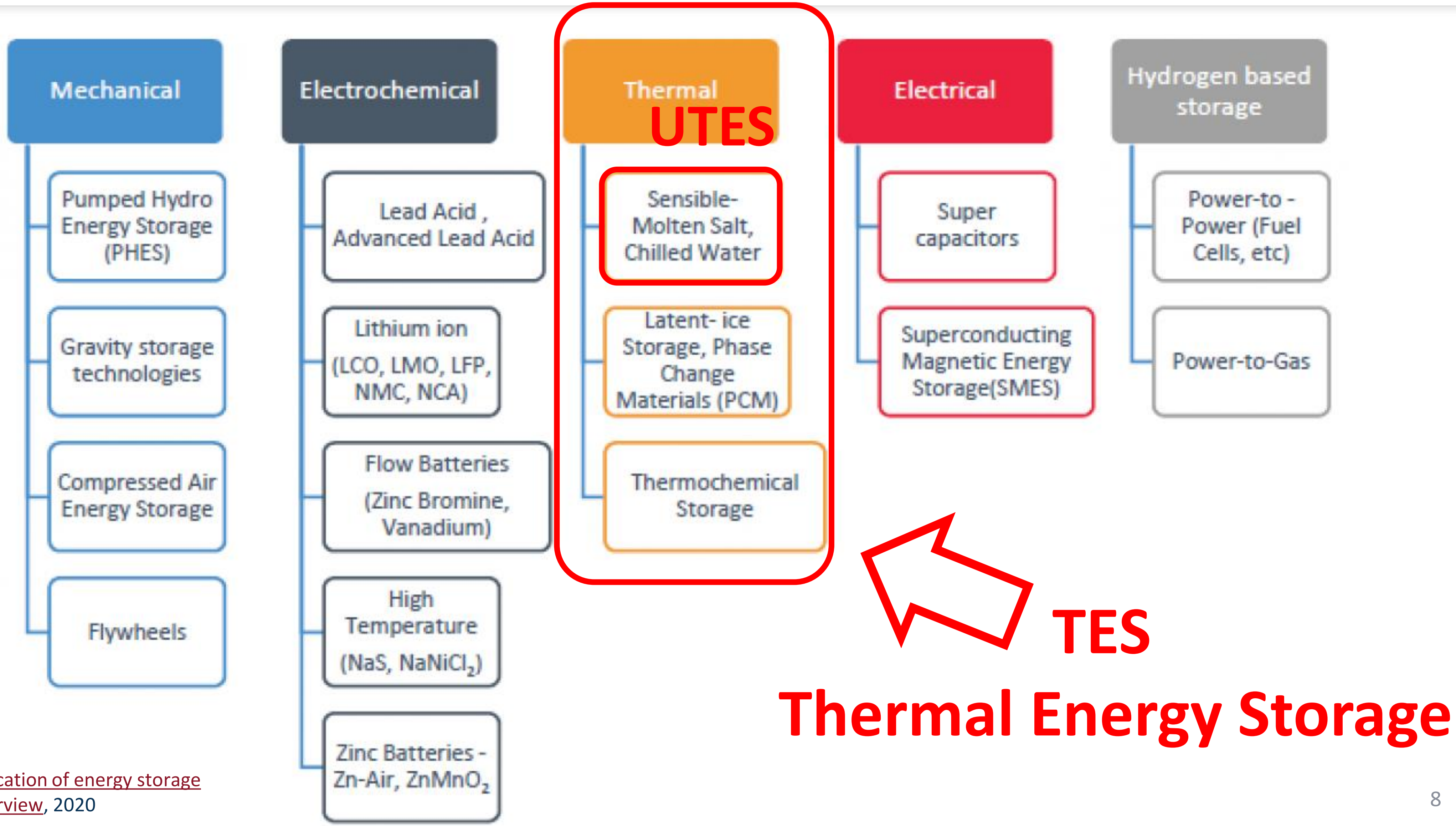
Benefits of (U)TES in DHC systems

- ✓ Increase flexibility, efficiency and feasibility of DHCs (thus reduce CO_2 emissions and heating costs, decoupling from fuel prices, avoid the risk of storing fuel)
- ✓ Reduce investment costs by reducing generation capacity (increasing operating hours), pipe size in DHCs, the need for a pressurized vessel
- ✓ Better management of CHP plants, shifting the production of electricity when unit prices are higher, so maximizing profits
- ✓ Relieve the intermittent nature of renewable energy sources.
- ✓ Reduce operational cost (e.g. use of boilers and chillers, as well as pumping systems, by reducing mass flow rates in some areas during the peak request).
- ✓ Overcome the limitations in circulating mass flow rate and increasing the number of users connected without modifying the network design

Drawbacks of (U)TES in DHC systems

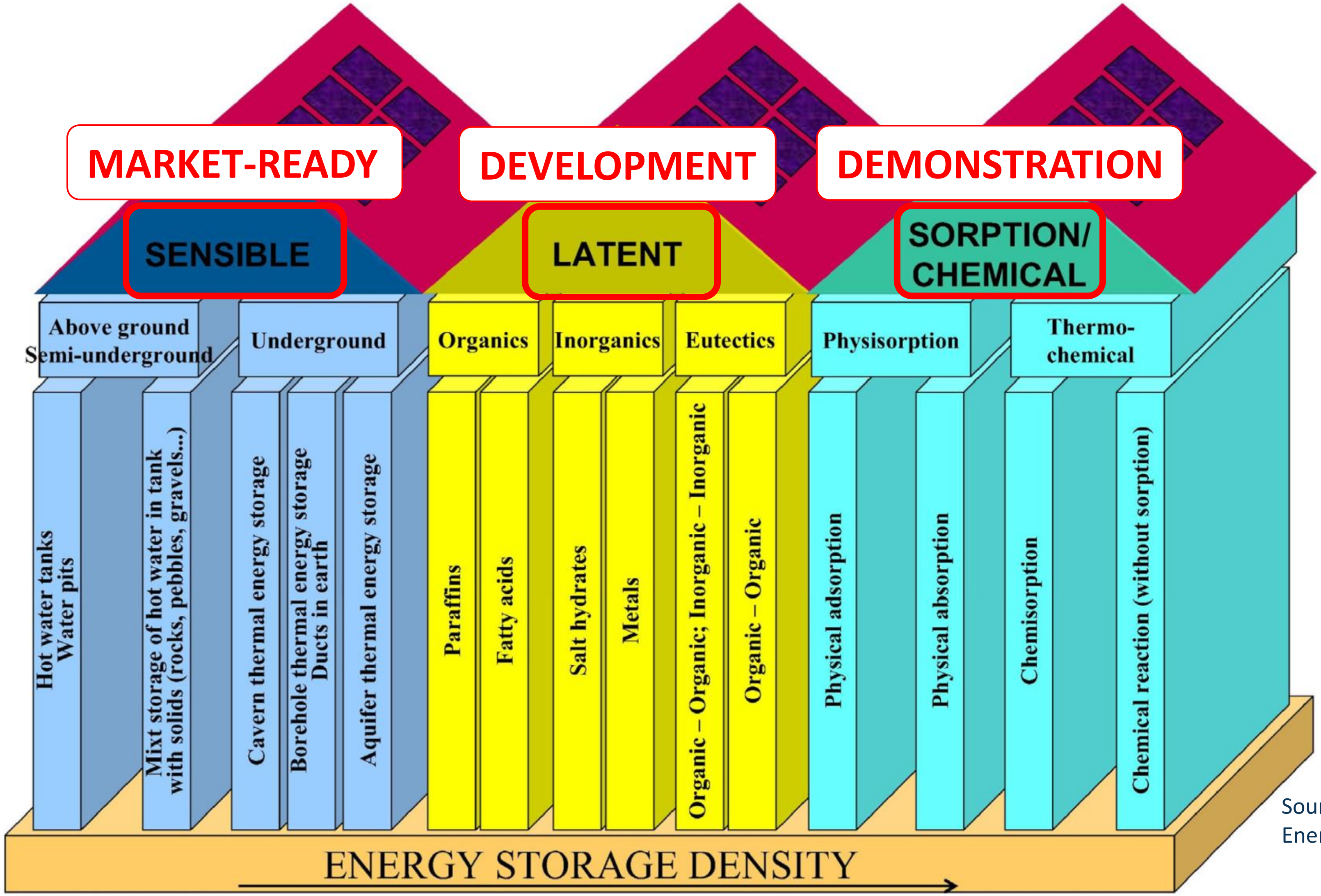
- Investment costs of the installation are non-negligible
- A dedicated space has to be reserved for the installation (less for UTES, but UTES require specific ground conditions)
- Each technology has its specific capacity and temperature limits
- Thermal losses can be significant, particularly for long-term storages
- The design of the system and the connection planning can be challenging.
- The lack of suitable supportive legislation can be problematic

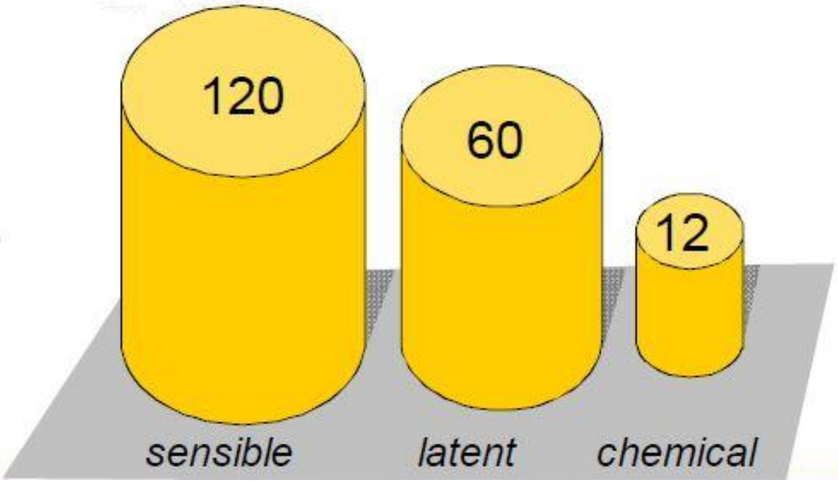
Energy Storage Classification



Source: IESA, Classification of energy storage technologies: an overview, 2020

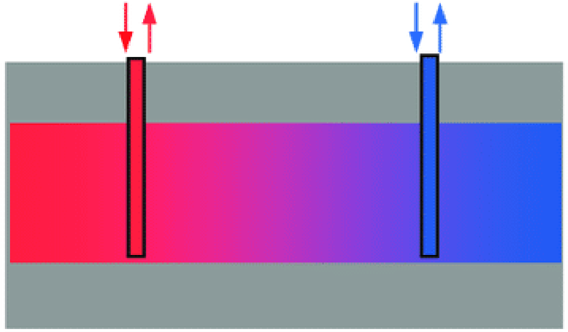
TES Types, Market Readiness, Size



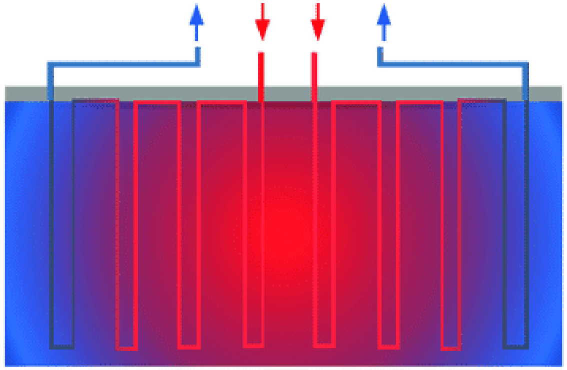


Source: van Helden, W. , Thermische Energiespeicher mit hohen Energiedichten., 2010

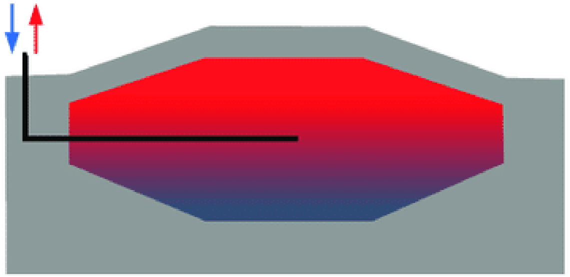
Which Type of Underground Thermal Energy Storage (UTES) is best?



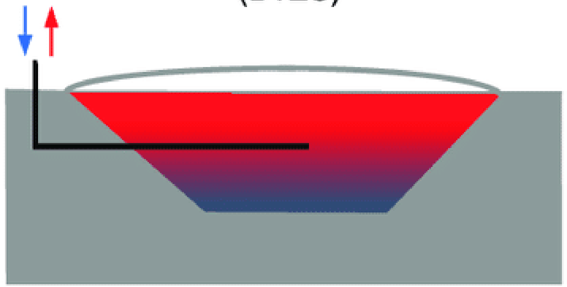
(a) Aquifer Thermal Energy Storage (ATES)



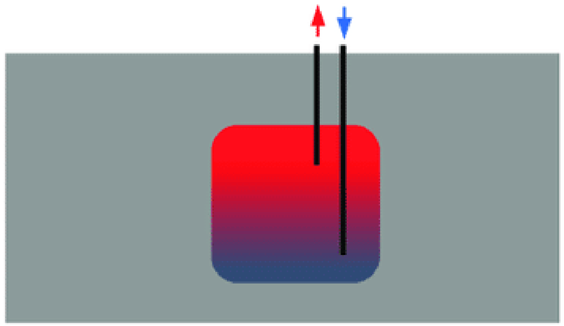
(b) Borehole Thermal Energy Storage (BTES)



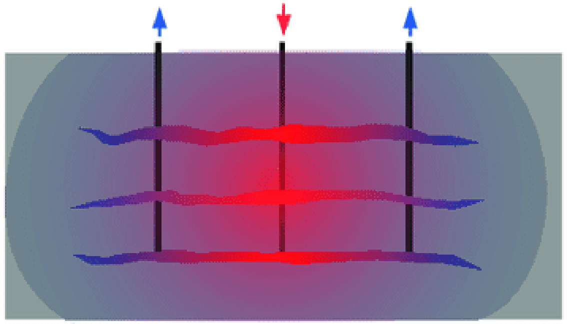
(c) Tank Thermal Energy Storage (TTES)



(d) Pit Thermal Energy Storage (PTES)



(e) Cavern Thermal Energy Storage (CTES)



(f) Fractured Thermal Energy Storage (FTES)

Source: Janiszewski, M., "Techno-economic aspects of seasonal underground storage of solar thermal energy in hard crystalline rocks.", 2019

(U)TES Costs per technology/size (#1)

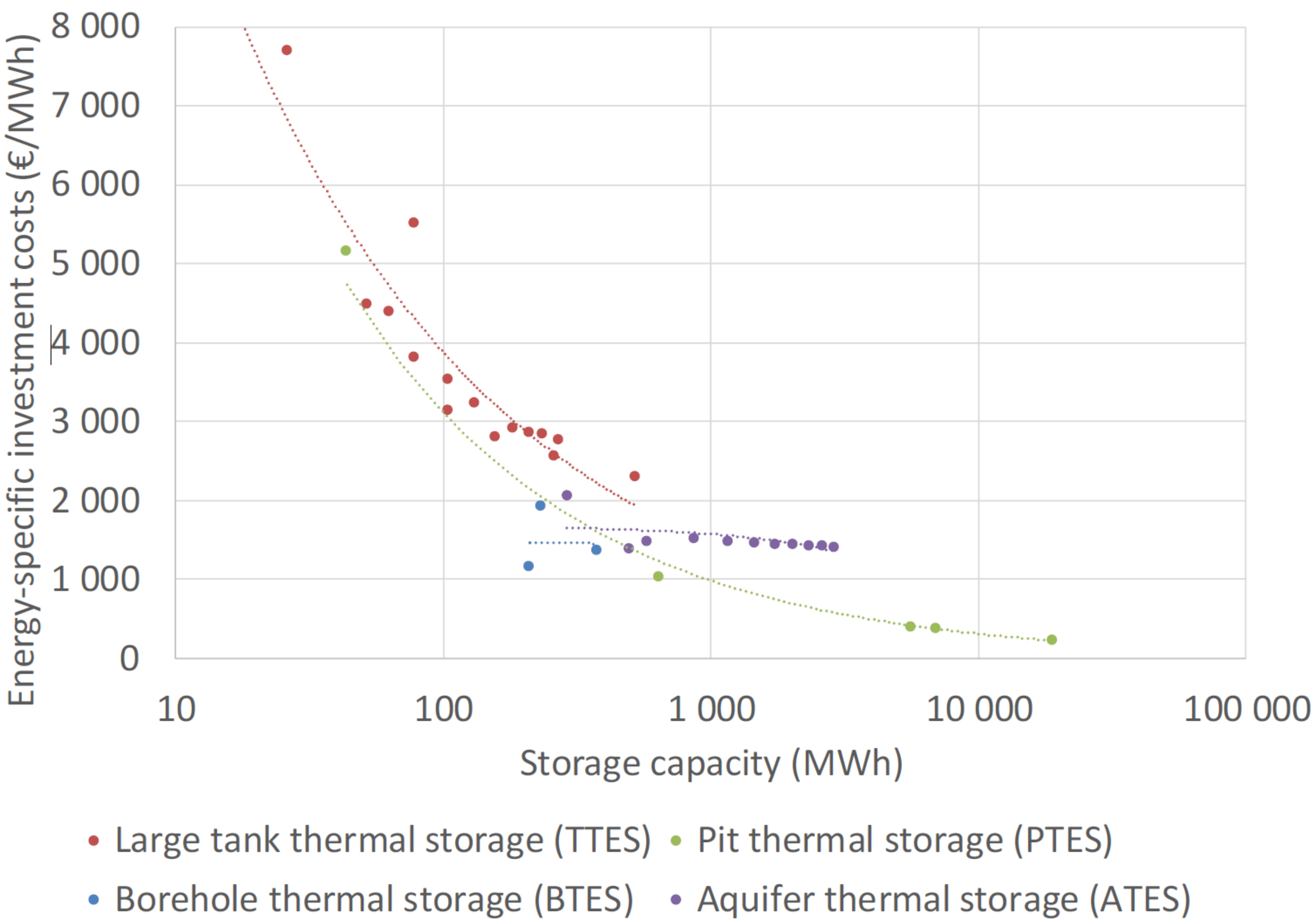
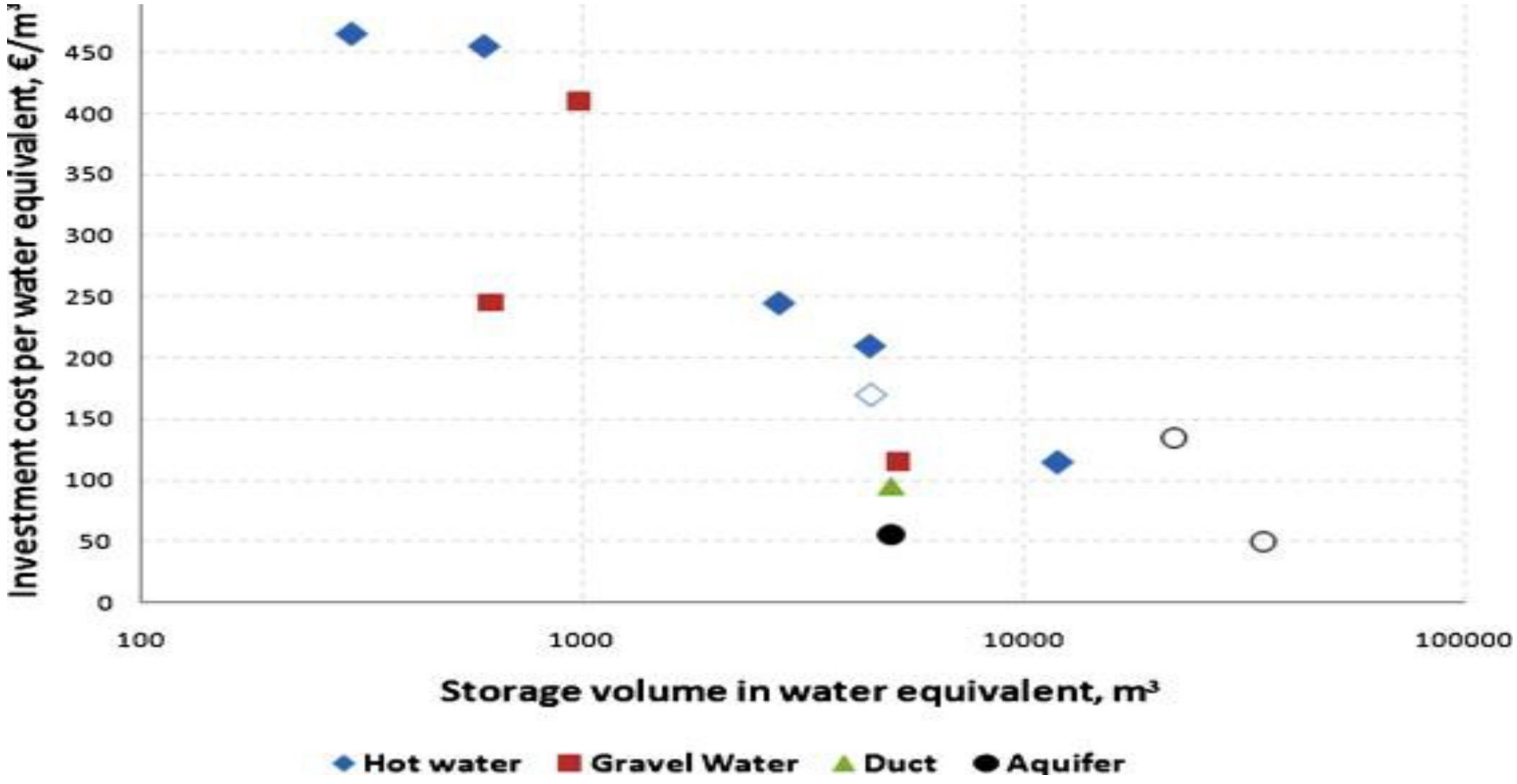


Figure 4: Thermal energy storage investment costs (source: Worm, 2017)

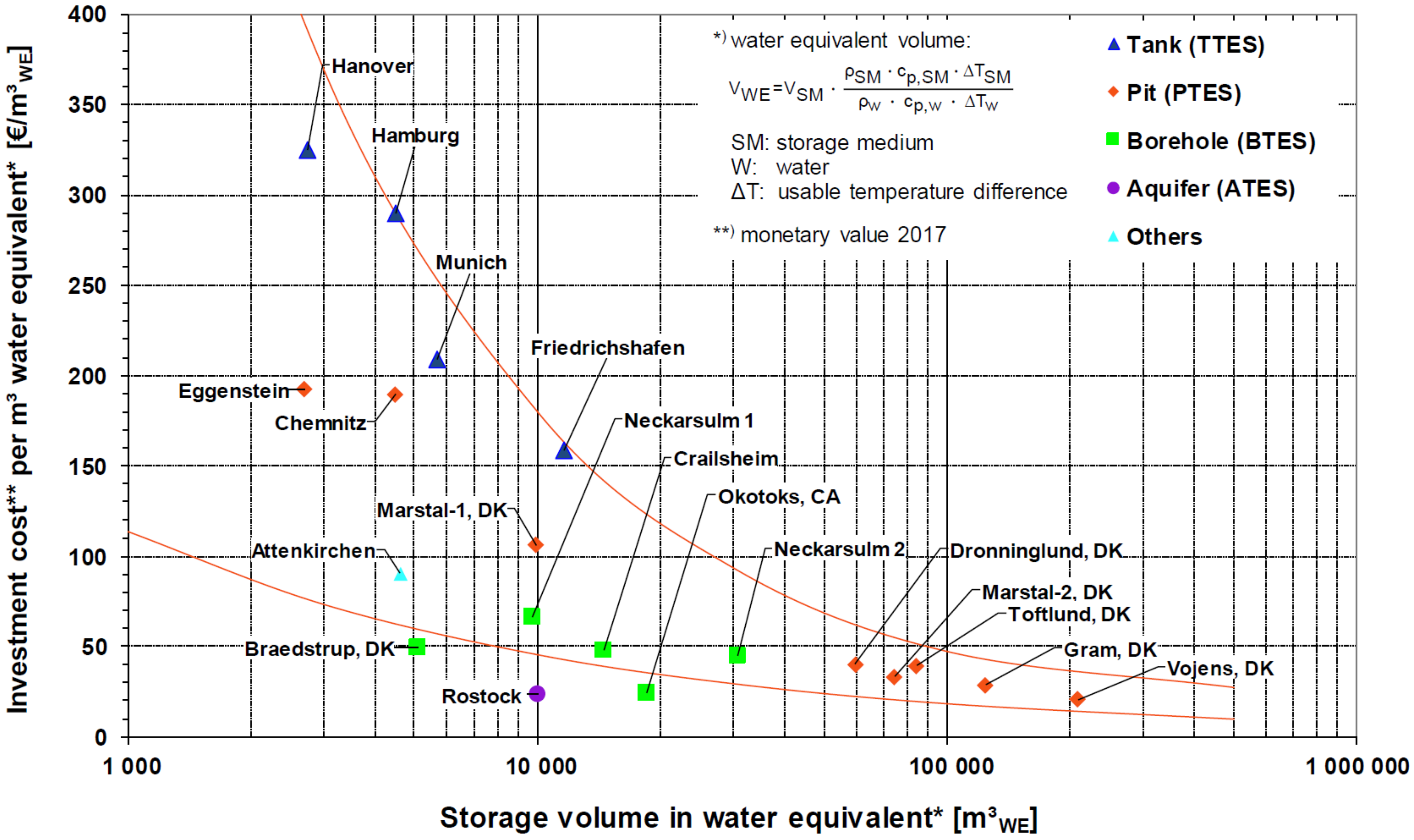
Source: University of Agriculture in Krakow et al., TRACES - Smart strategies for the transition in coal intensive regions - Fact Sheet: Heat Storages., 2022

(U)TES Costs per technology/size (#2)



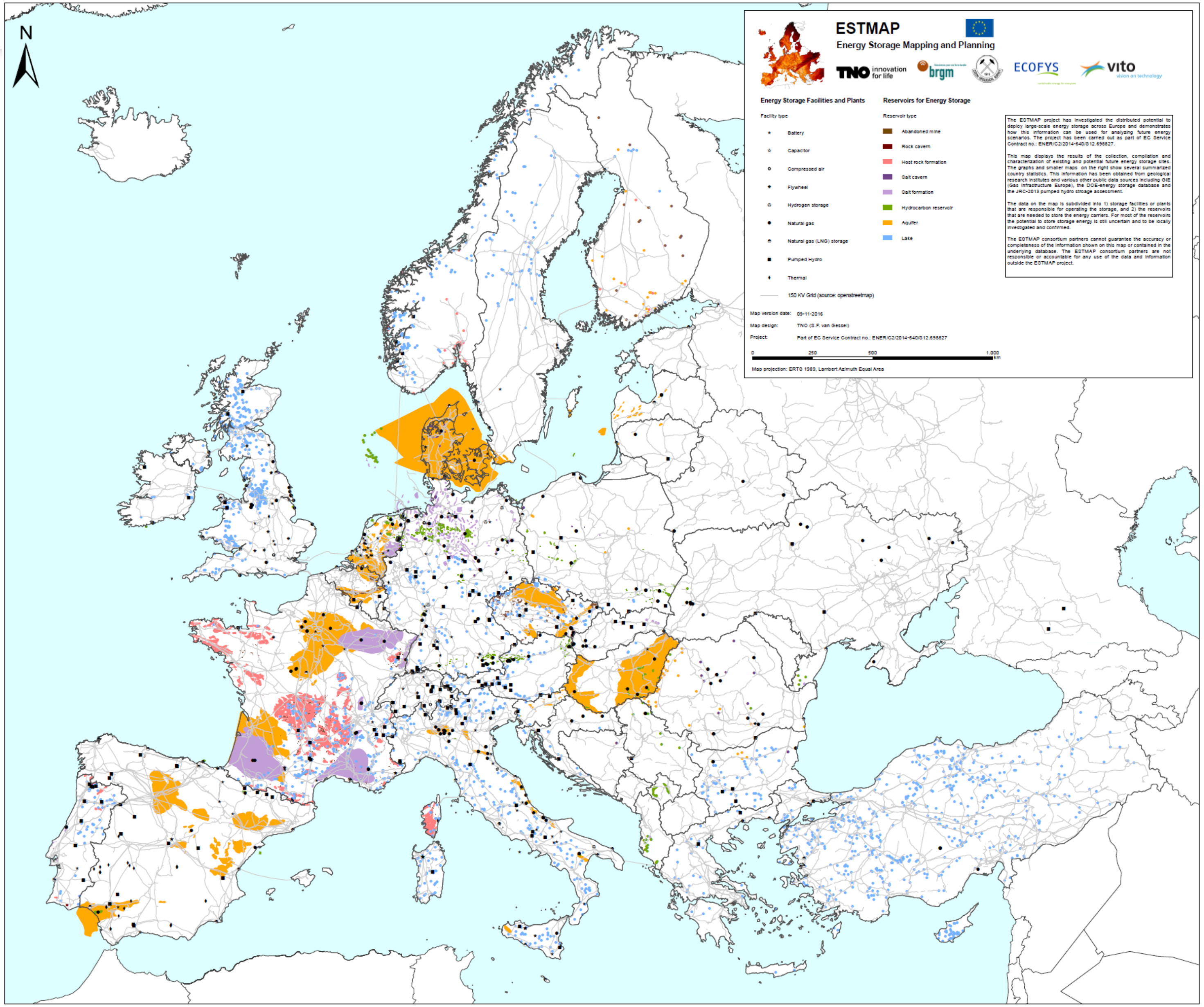
Source: Bryant, S. M., Seasonal Thermal Energy Storage in District Heating Systems., 2013

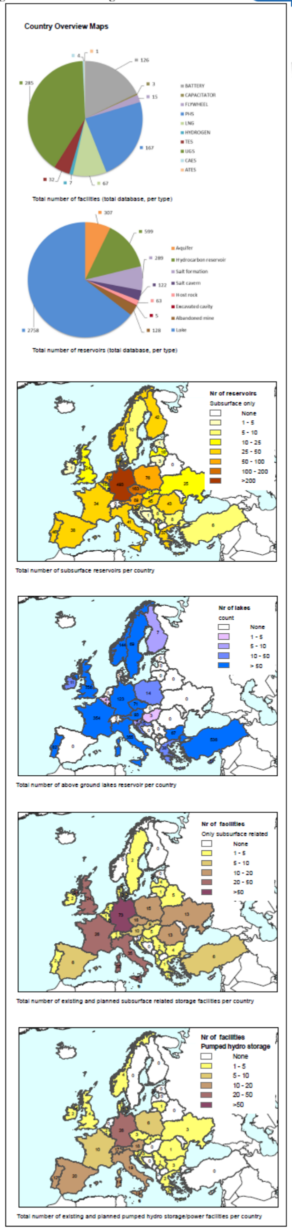
(U)TES Costs per technology/size (#3)



Source: Janiszewski, M., "Techno-economic aspects of seasonal underground storage of solar thermal energy in hard crystalline rocks.", 2019

Energy Storage Mapping in Europe





Source: ESTMAP, "ESTMAP Final Review Meeting", 2016

Acquifer-TES (ATES) in the Netherlands

In 1990 **In 2000** **In 2010**

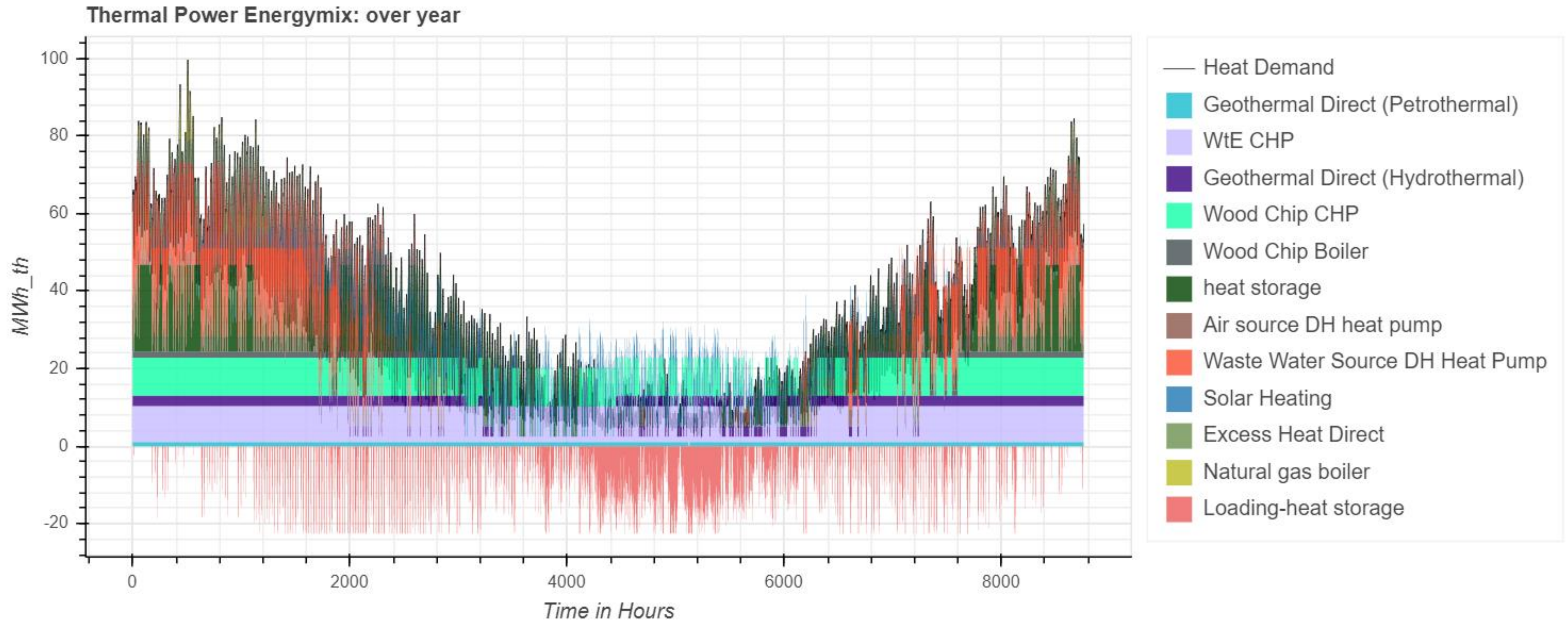
Source: Nordell, B., "Underground thermal energy storage (UTES).", 2012, Innostock

Overview of (U)TES characteristics

TES Type	TTES (Tank)	PTES (Pit)	BTES (Borehole)	ATES (Acquifer)
Storage temp. [°C]	5°-95°	5°-95°	5°-90°	7°-18°
Storage medium	Water	Water (Gravel-water)	Soil surrounding the boreholes	Aquifers’ water
Specific capacity [kWh/m3]	60-80	60-80 (30-50)	15-30	30-40
Geological requirements	stable ground, no groundwater, 5-15m	stable ground, no groundwater, 5-15m	drillable ground, high heat capacity & thermal cond., low hydraulic cond. (k<10-10 m/s), no flow <1m/a, 30-100m	high yield aquifer
Water equiv.	$1m^3=1m^3$	$1m^3=1m^3$	$3\text{-}5m^3=1m^3$	$3\text{-}5m^3=1m^3$
Investment costs [EUR/m3]	110-200€/m^3	20-40€/m^3	20-40€/m^3	50-60€/m^3
Advantages	High charge/dis-charge capacity	High (dis)charge capacity, Low I costs	Most underground properties are suitable	H&C, many suitable sites
Disadvantages	High investment c.	Large area	Low charge/discharge capacity	Low T, Low ΔT
Application	Short-time/diurnal, buffer storage	Long-time >20 GWh, Short-time CHP	Long-time/seasonal for DH plants >20 GWh/year	Long-time /seasonal

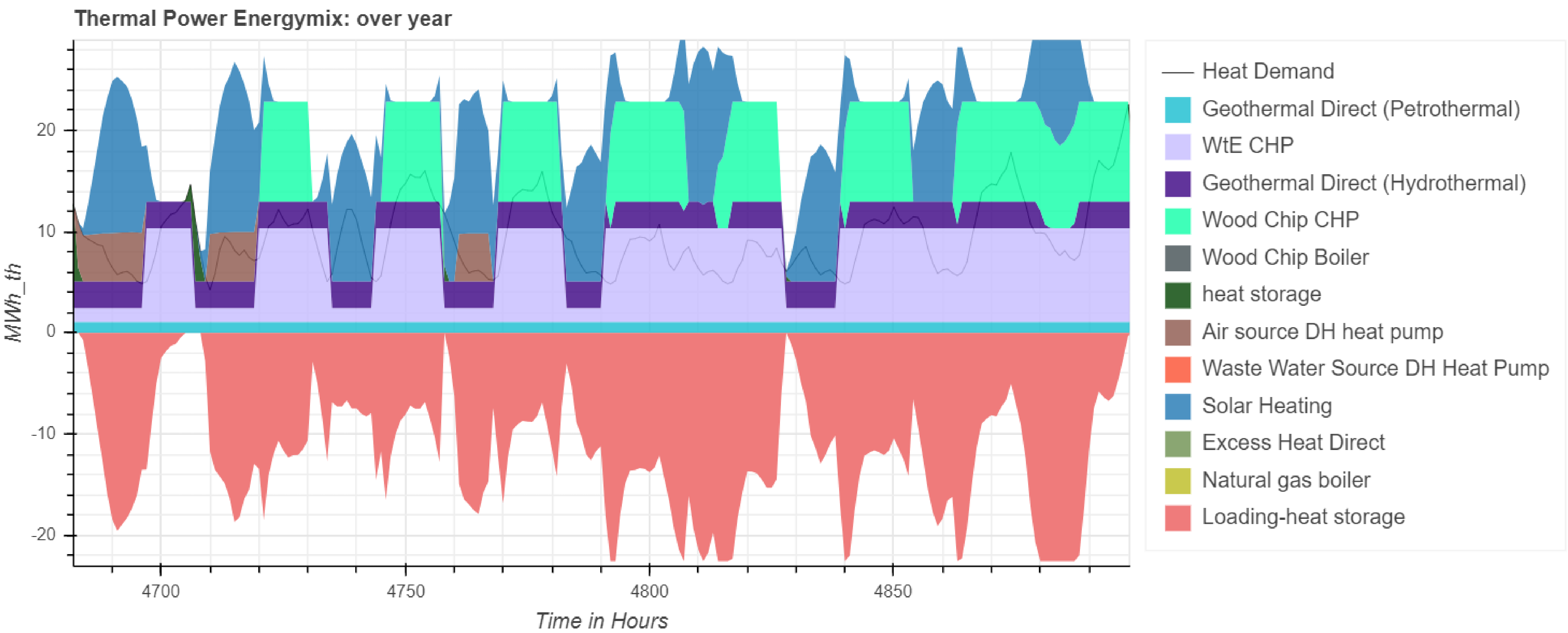
Source: University of Agriculture in Krakow et al. (2022) TRACES - Smart strategies for the transition in coal intensive regions - Fact Sheet: Heat Storages.

Hotmaps Dispatch Model results (#1)



Source: Ali Kök, "Achieving Carbon Neutrality in District Heating: The Impact of Temperature Levels on the Supply Mix of EU-27 in 2050", 2023 (not yet published)

Hotmaps Dispatch Model results (#2)



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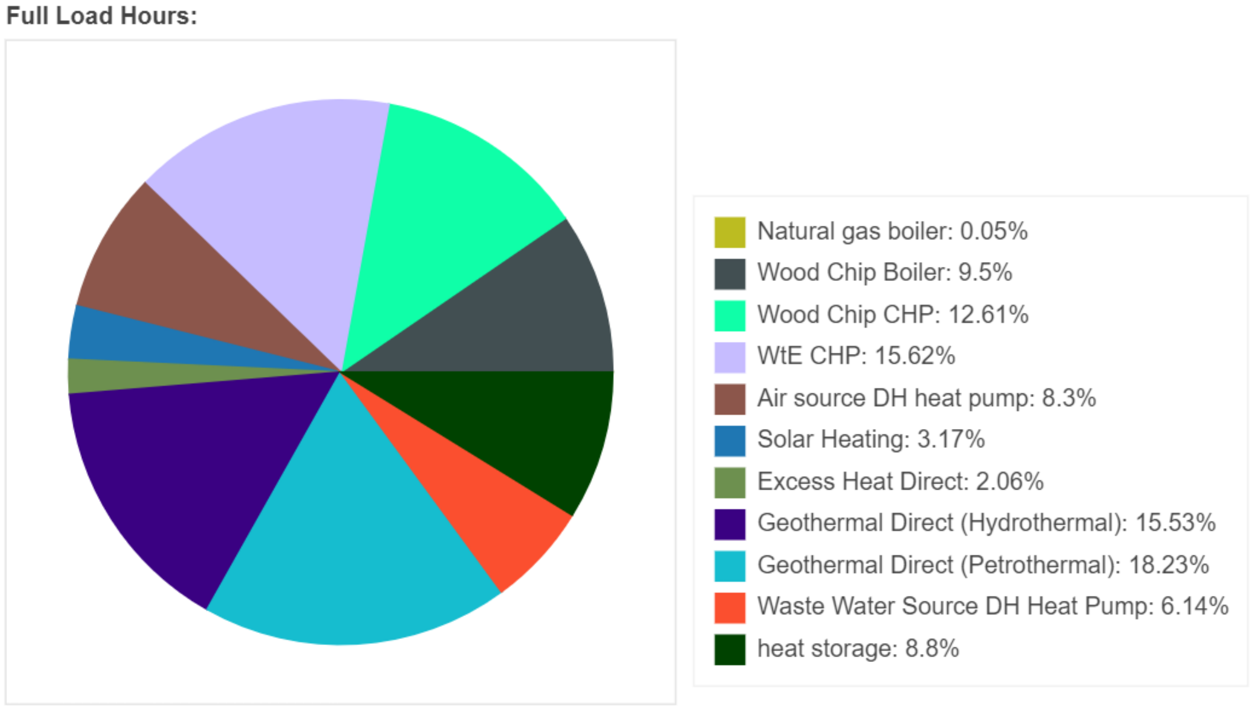
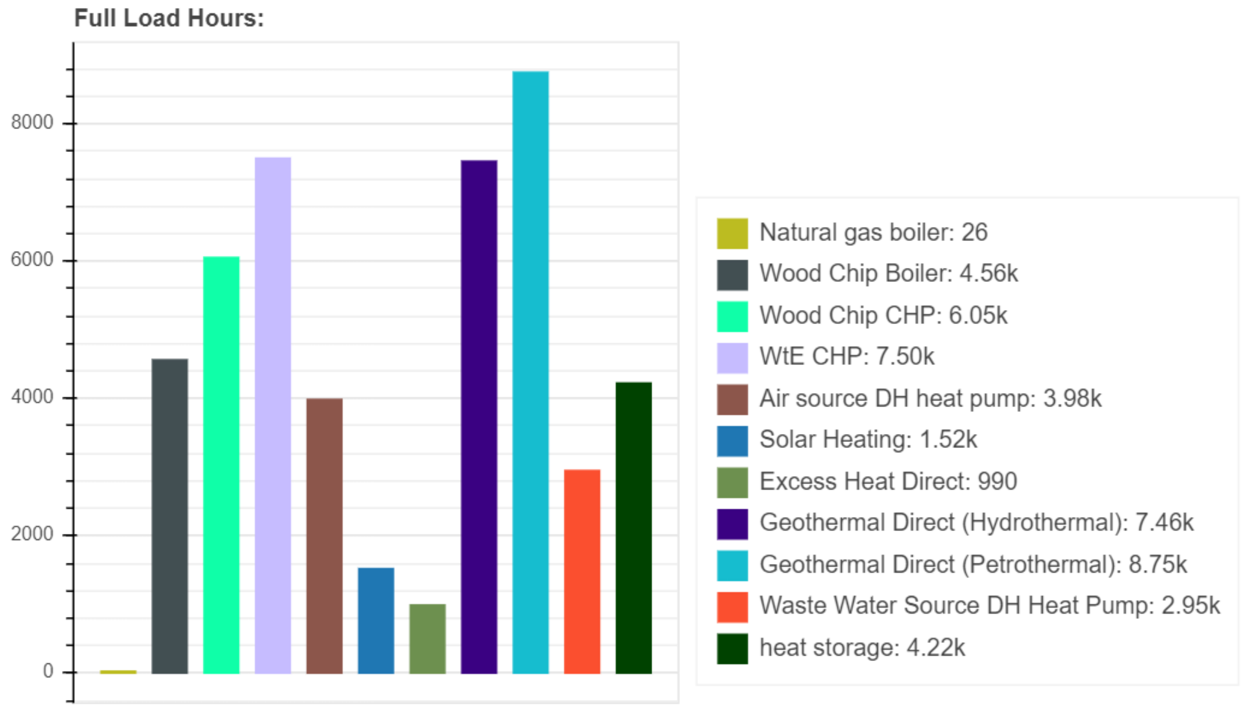
Hotmaps Dispatch Model results (#3)





Source: Ali Kök, “Achieving Carbon Neutrality in District Heating: The Impact of Temperature Levels on the Supply Mix of EU-27 in 2050”, 2023 (not yet published)

Hotmaps Dispatch Model results (#4)

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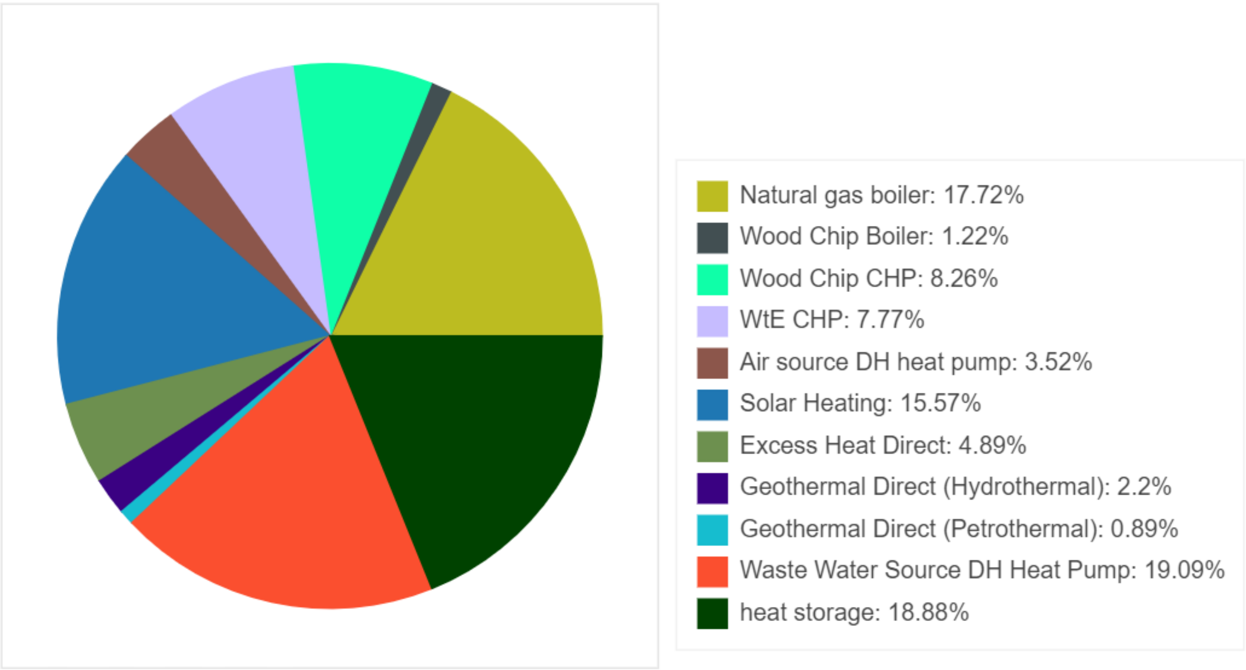
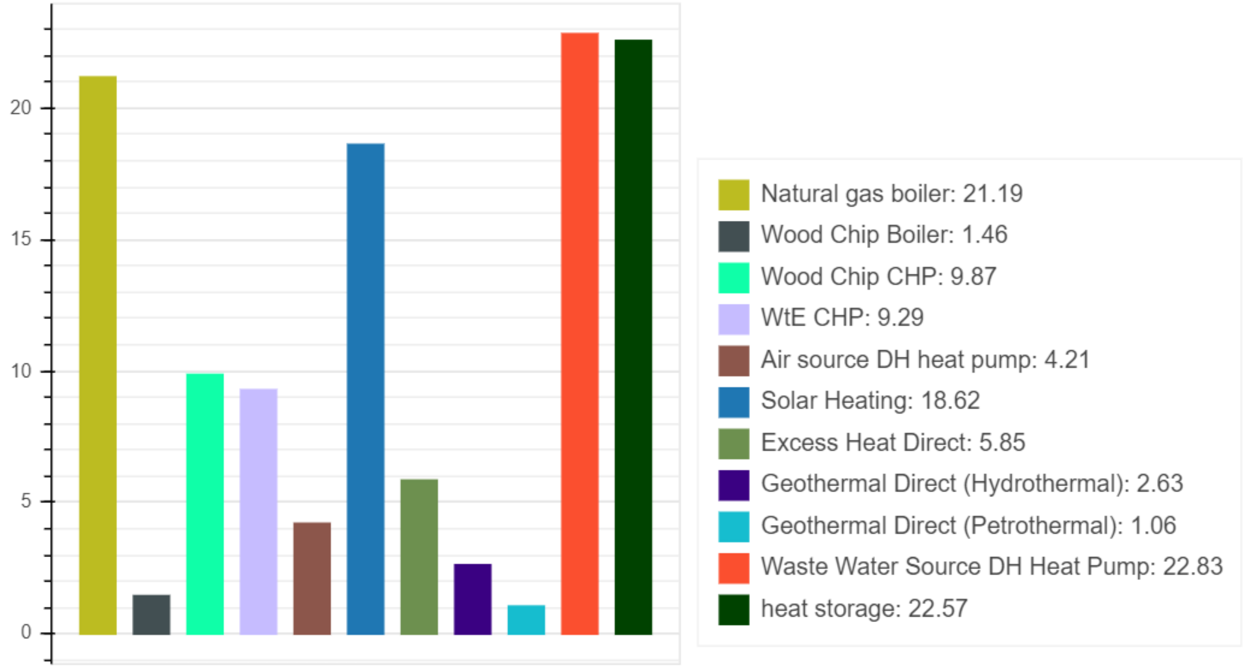
Installed Capacities:



Installed Capacities:



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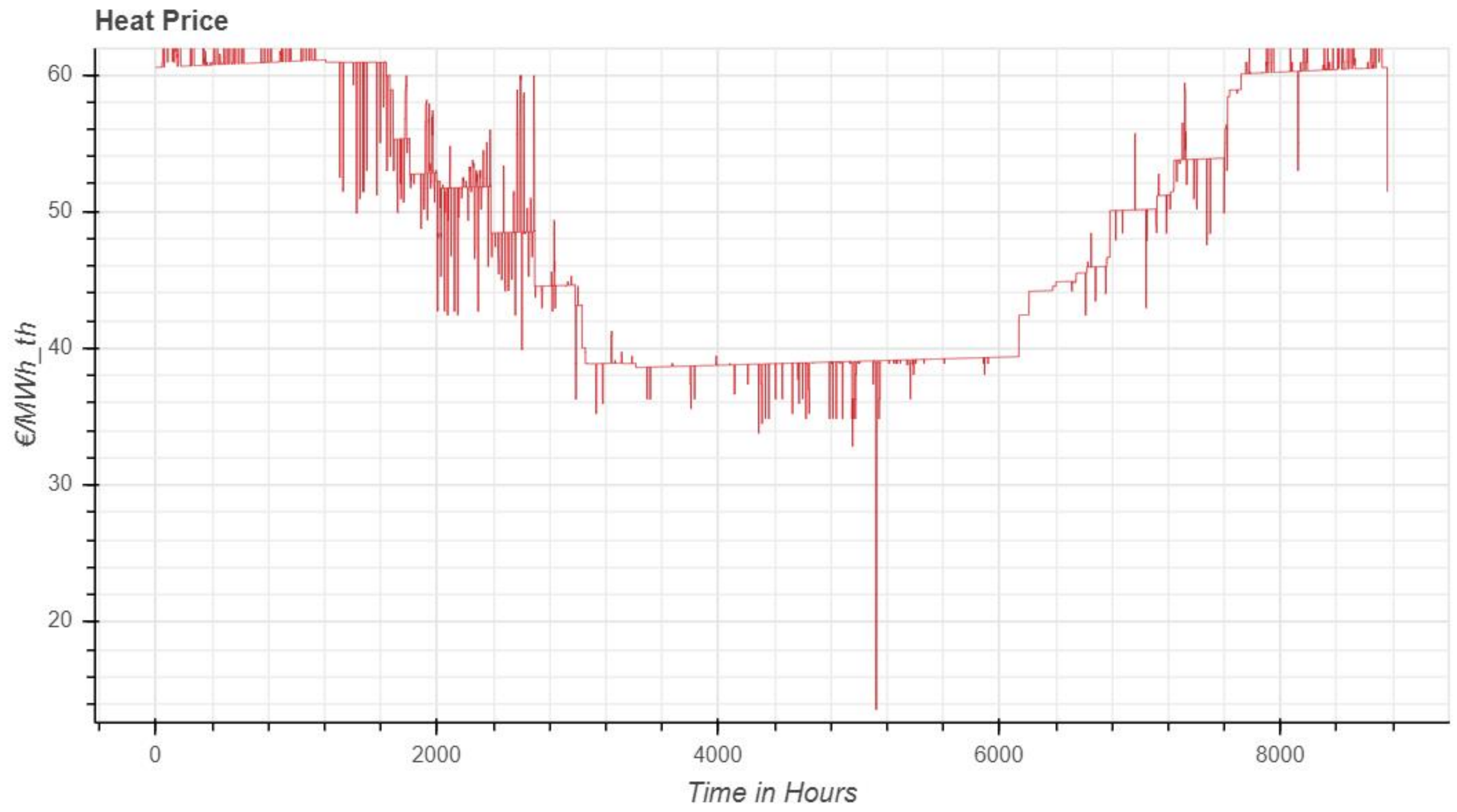
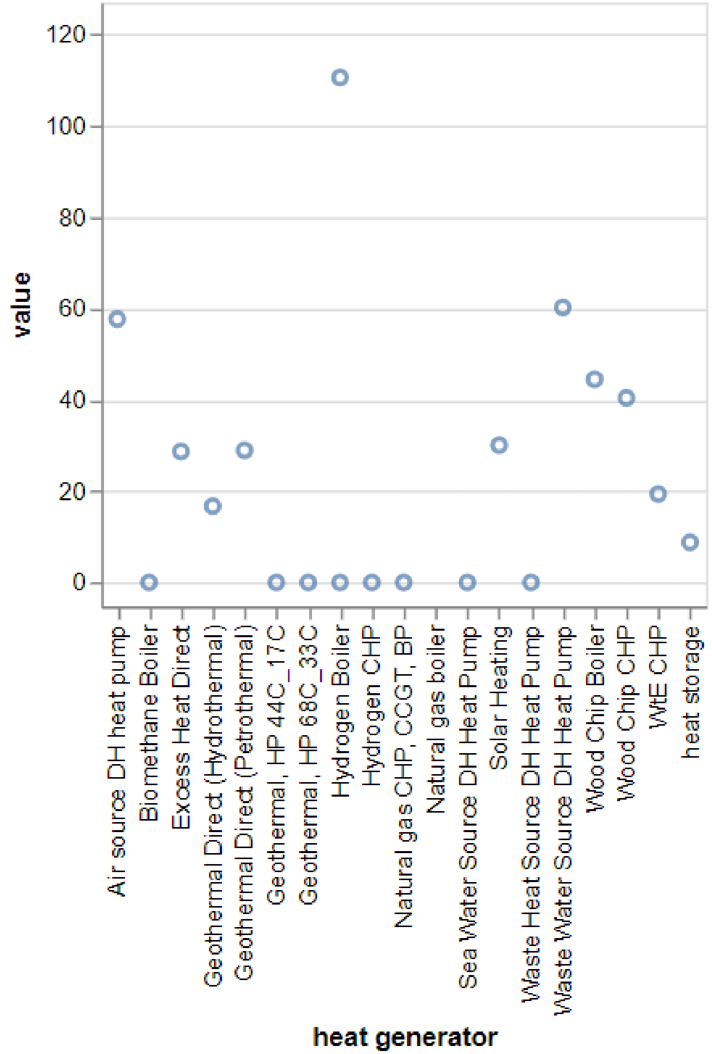
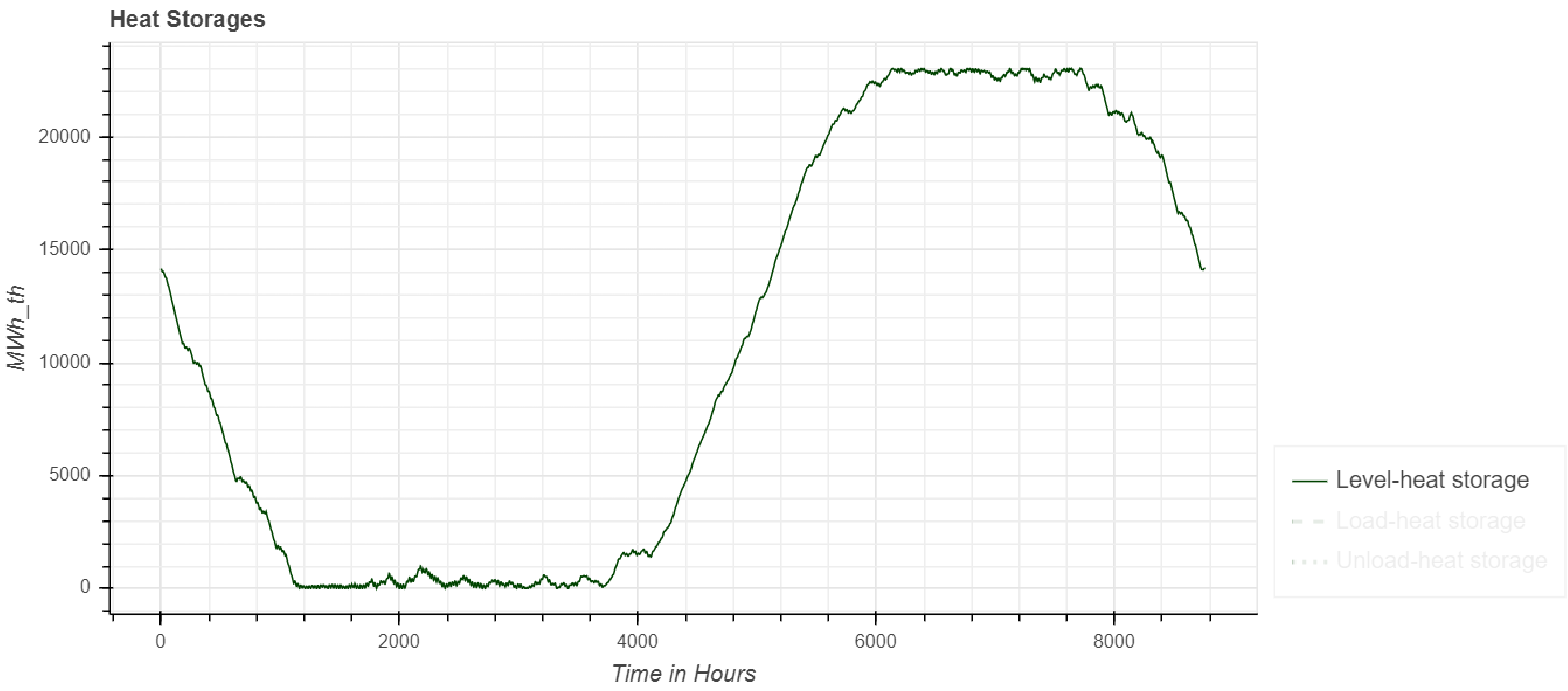
Hotmaps Dispatch Model results (#5)





Source: Ali Kök, "Achieving Carbon Neutrality in District Heating: The Impact of Temperature Levels on the Supply Mix of EU-27 in 2050", 2023 (not yet published)

Hotmaps Dispatch Model results (#6)



Source: Ali Kök, “Achieving Carbon Neutrality in District Heating: The Impact of Temperature Levels on the Supply Mix of EU-27 in 2050”, 2023 (not yet published)

Conclusions: challenges and potential

- UTES compared to other TES technologies show lower investment costs per water equivalent
- However, LCOH is not the only driver to integrate (U)TES: obligations to reduce emissions might force to move from boiler and chillers to waste-heat and renewable-based DHC
- Integrating TES improves the feasibility and flexibility of DHCs
- A single winner: different UTES technologies are suitable for different purposes and locations

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Thank you for your attention!

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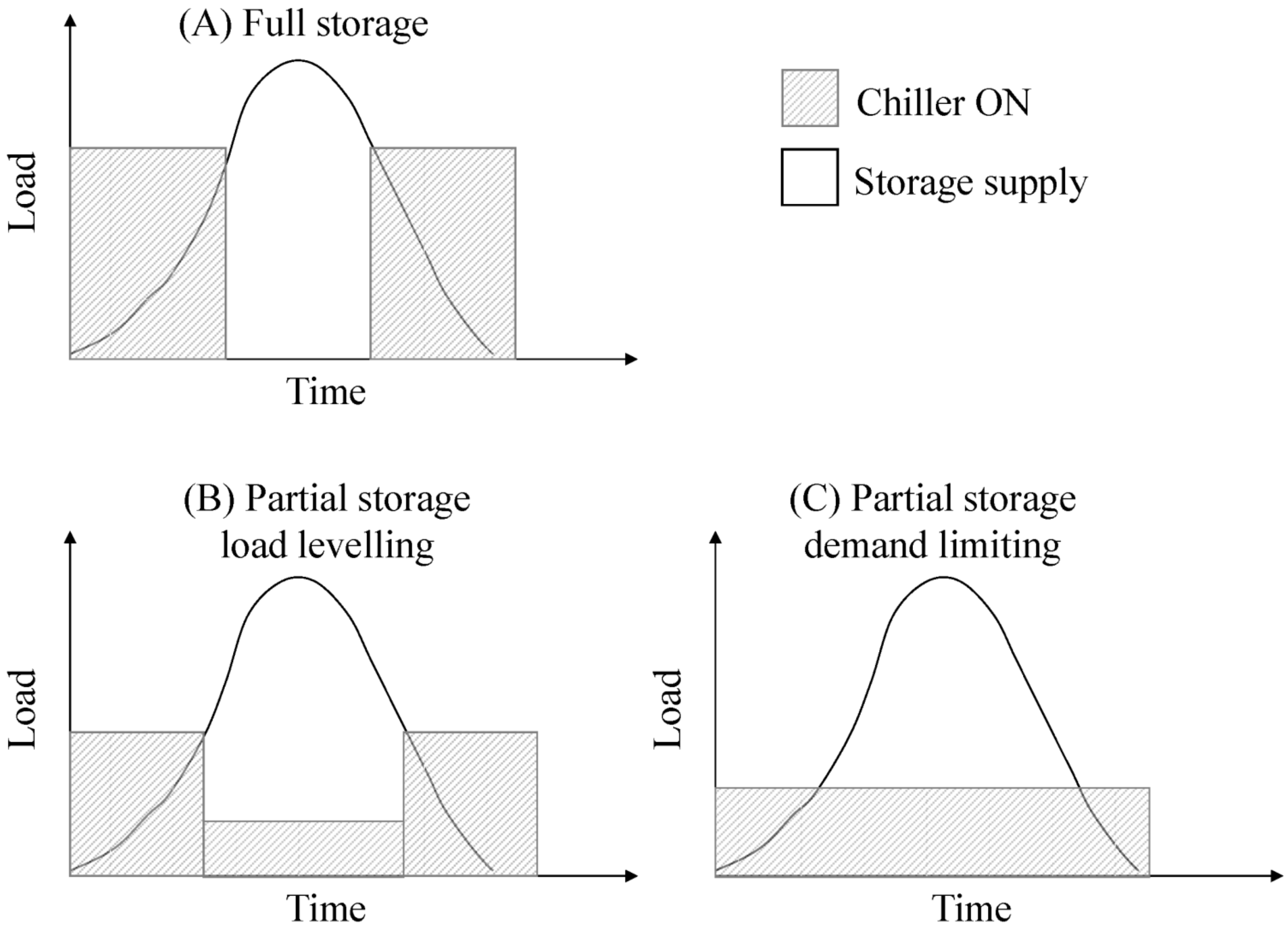
TES Sizing



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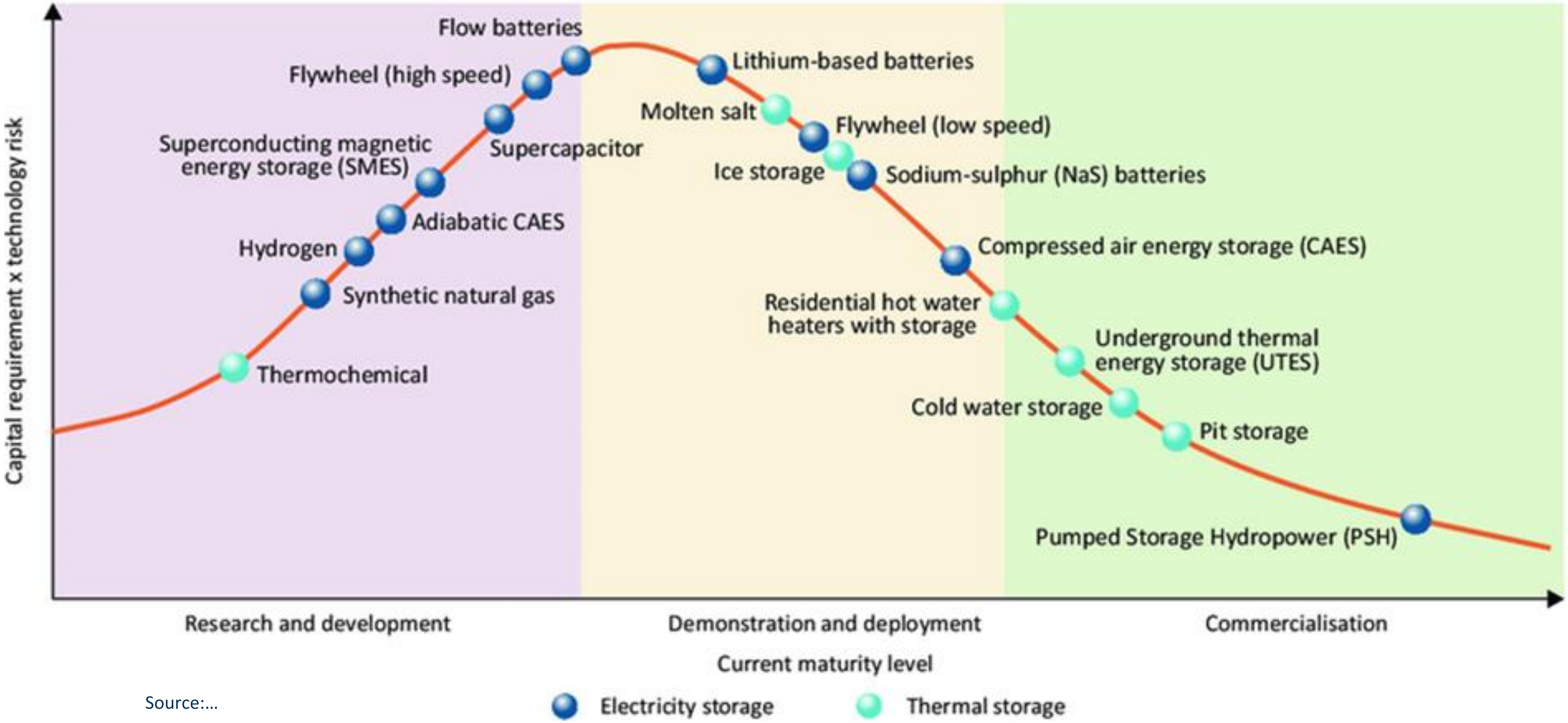
TES Market Readiness (#2)



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