

Which energy storage does Switzerland need in the future?

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What do we mean with “need”?

Challenge:

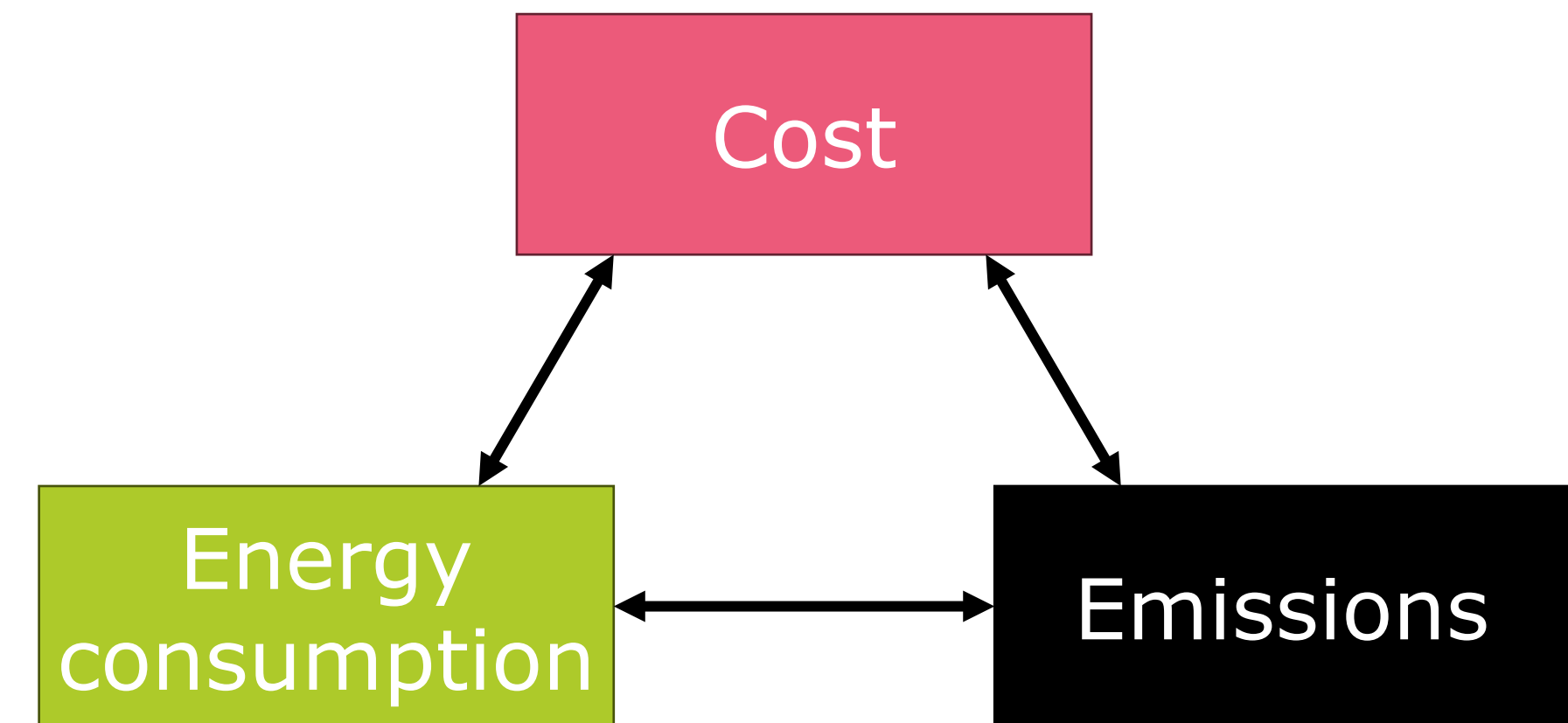
Exploitation of storage depends on storage capacity / power, but also on cost function you optimise.

Potential cost functions:

- System/Operation cost
- Emissions
- Energy consumption

Presented studies:

- Storage demand in Switzerland: Service project for SFOE (<https://lnkd.in/em8nxkzS>)
- Thermal energy storage potential: part of SWEET EDGE (<https://www.sweet-edge.ch>)



How to quantify the storage demand?

Idea: *Dispatch and invest model*

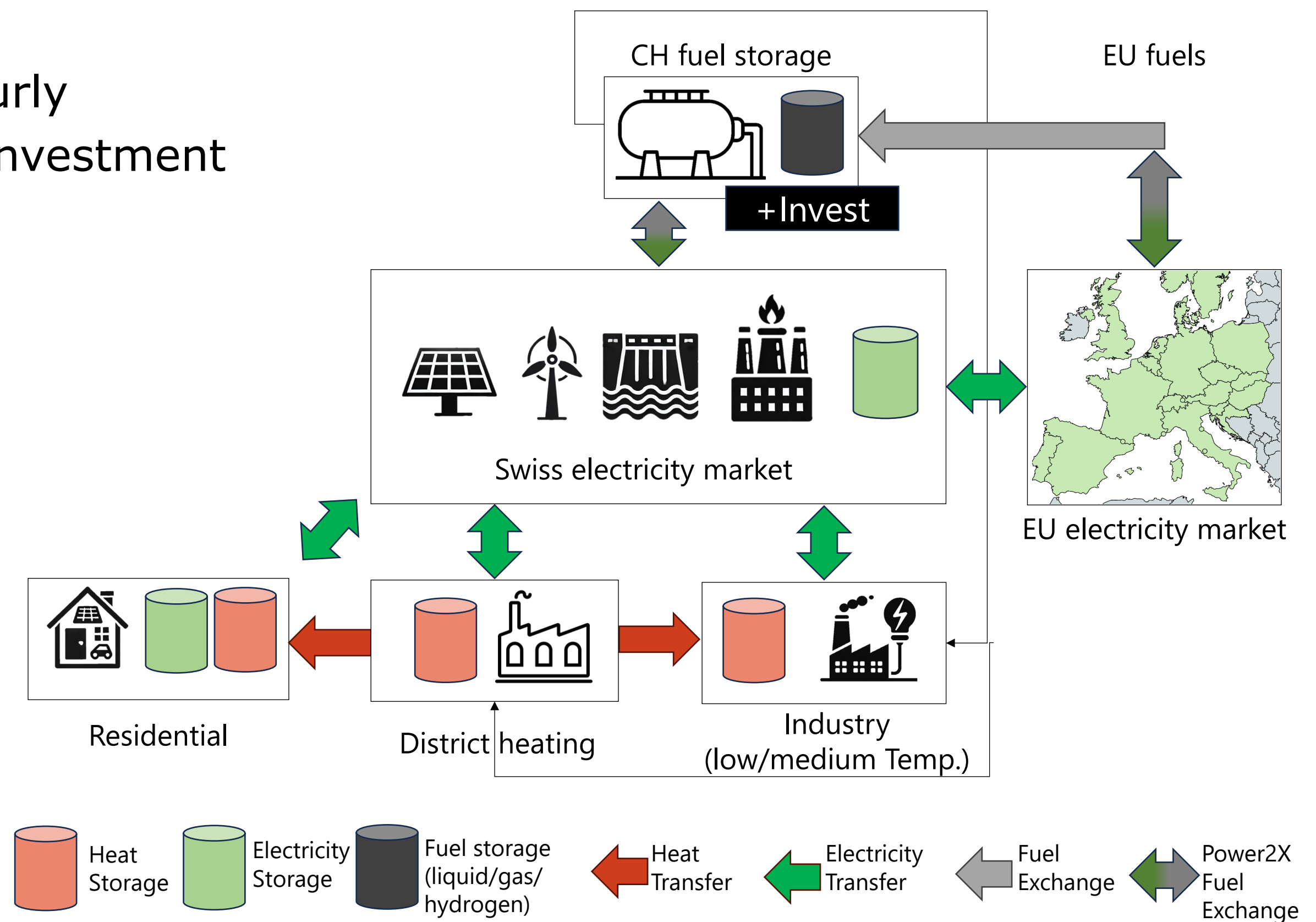
Optimise the energy system operation based on hourly demand / production data and potential additional investment in novel production technologies.

Chosen cost function:

System/Operation cost incl. CO2 compensation

Allowed investments:

- Green-field for district heating systems' sources
- Brown-field for other production plants based on EP2050+ assumptions



Assumptions for thermal storage and flexibility from electromobility

Thermal storage in the model

- *Tank-storage* as proxy for high power storage allowed everywhere (incl. high-temperature industry), but expensive
- *Pit-storage* as proxy for long-term storage only for heating and low temperature industry
- Thermal inertia of buildings
(assuming +/- 0.5 K bandwidth and 50 % participation)

Flexibility from electromobility

- 50 % charging flexibly
- 25 % offer bidirectional operation
- 50 kWh capacity per car, charging at 11 kW

Assumptions for district heating and heat demand

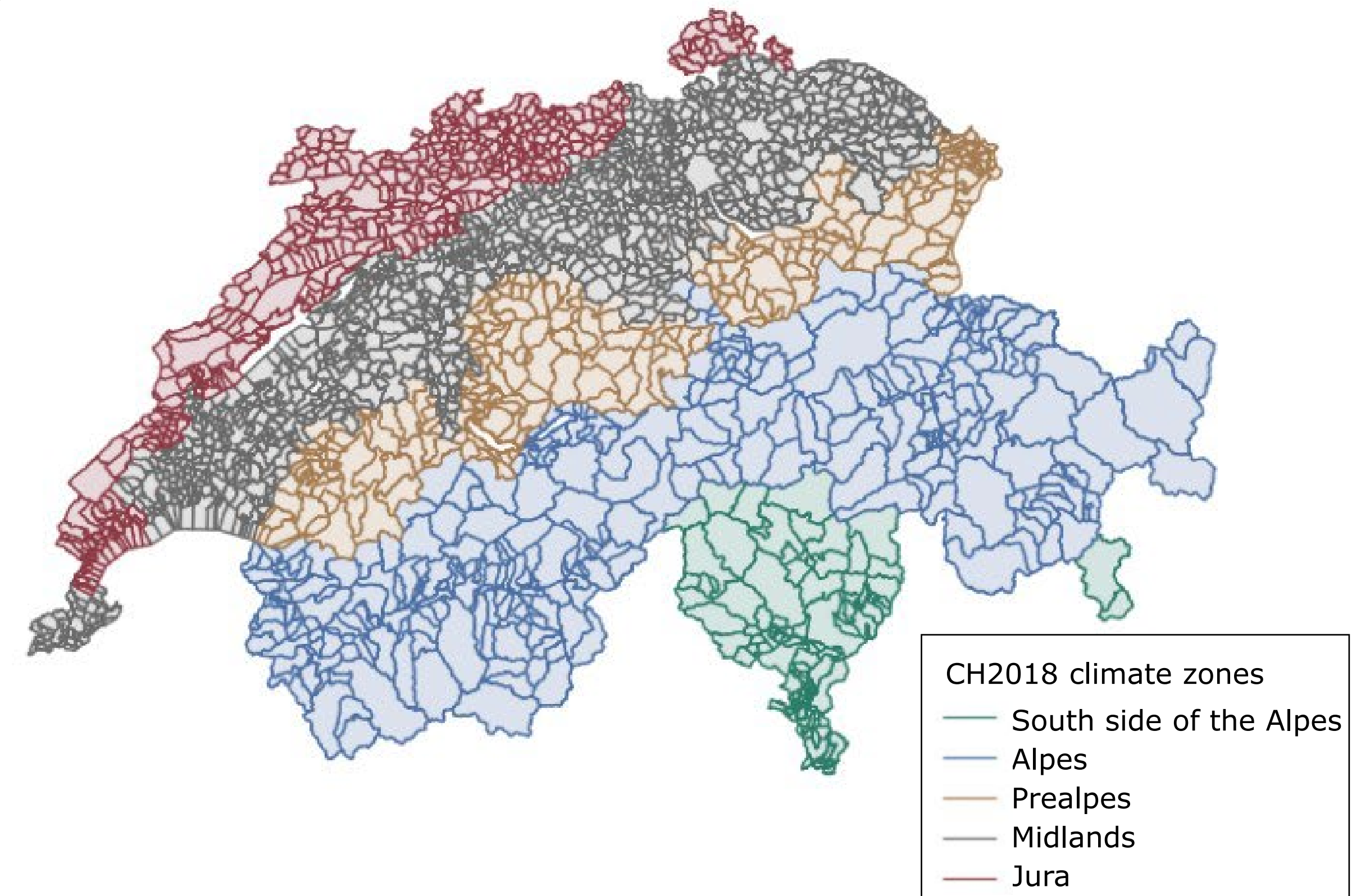
District heating grids

- Industry: temperature levels $<100^{\circ}\text{C}$, $100 - 200^{\circ}\text{C}$, $>200^{\circ}\text{C}$
- Power levels for district heating grids: high (>50 MW), medium ($10 - 50$ MW), low (<10 MW)

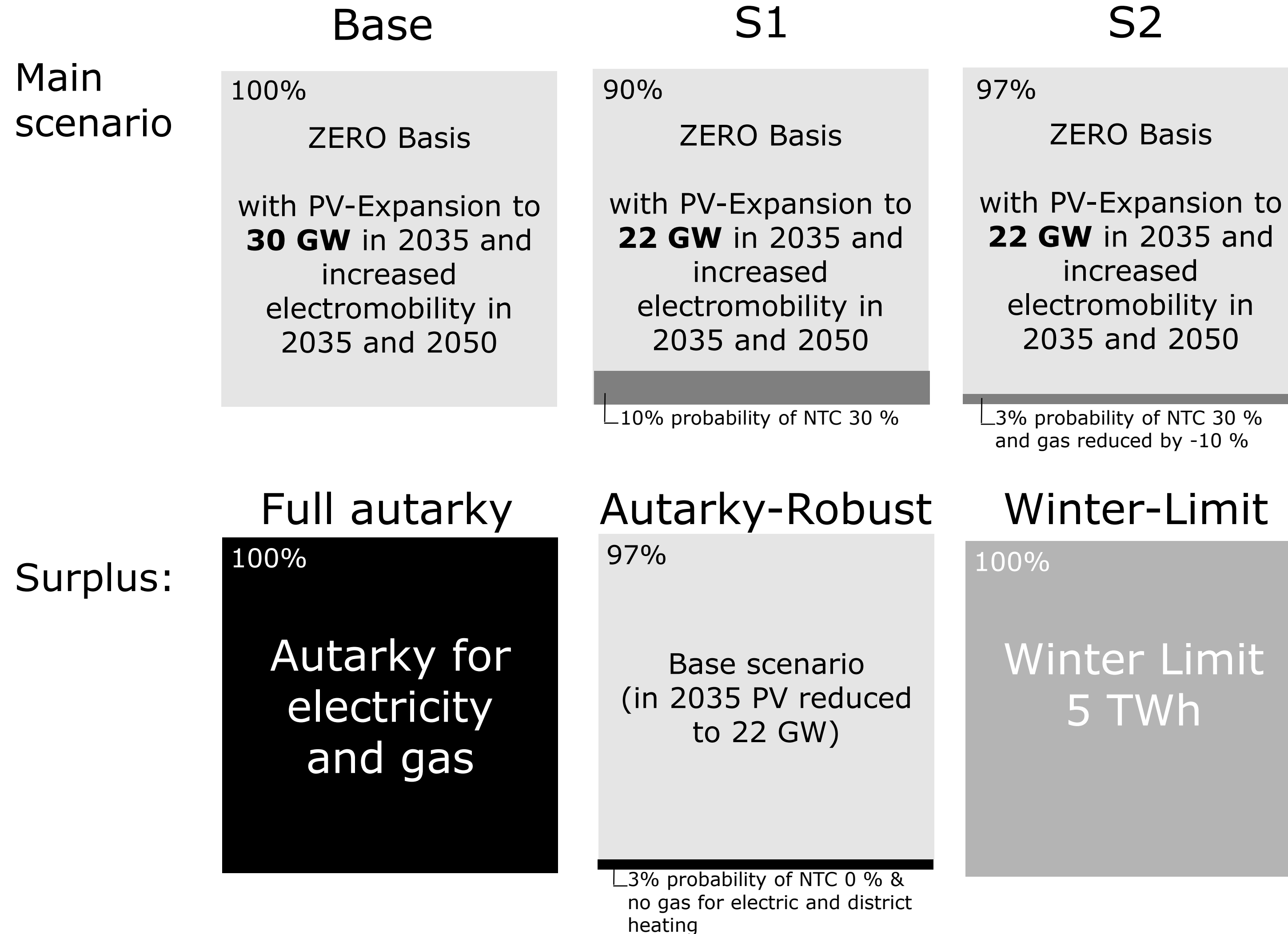
Demand district heating (incl. industry)

- ~ 6 TWh
- (significantly less than in AEE-position paper about TES (AEE: 20 TWh))

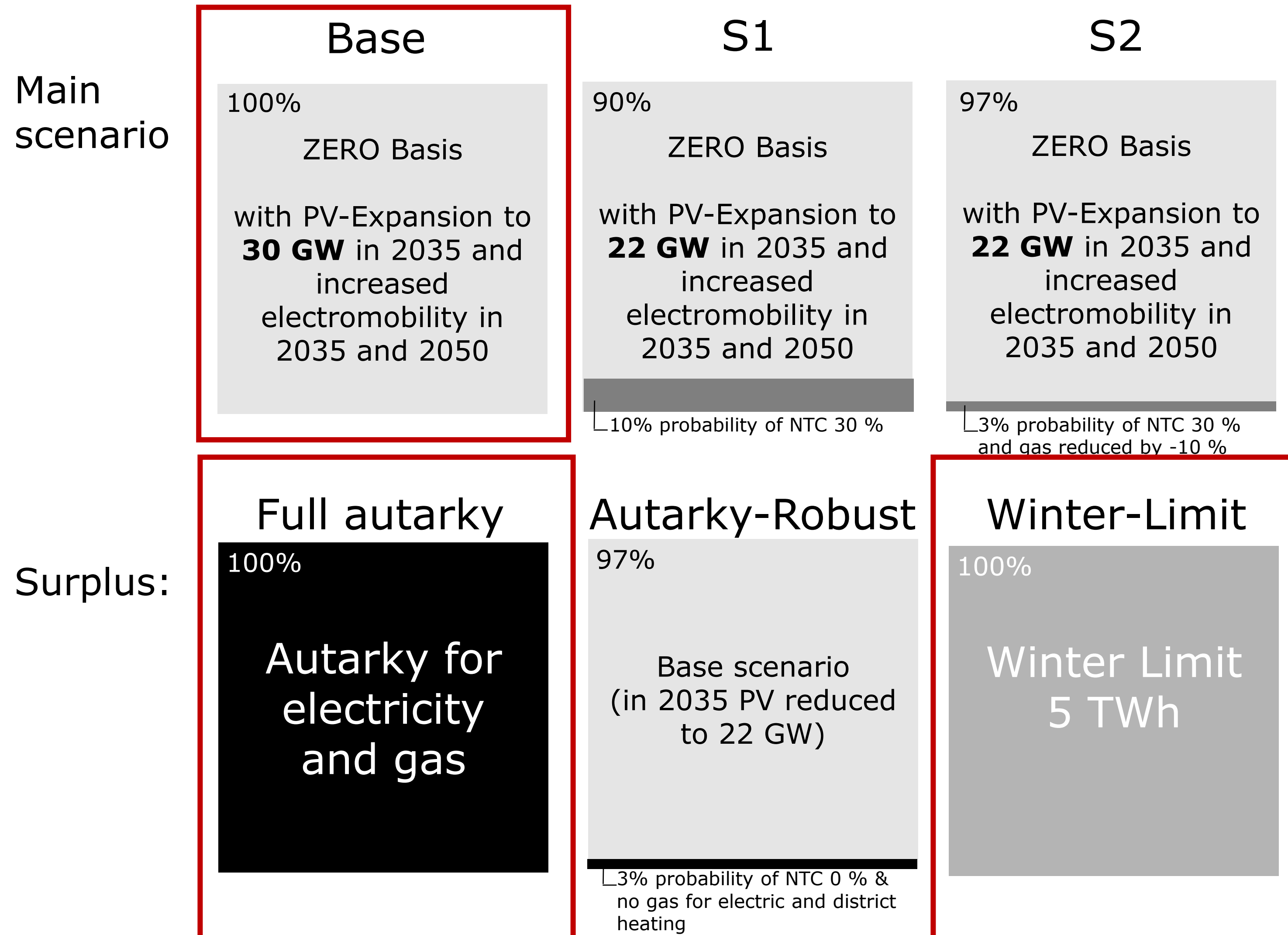
Spatial discretisation



Considered scenarios



Focus scenarios



Investments in 2035: Base case

System with substantial PV (30 GW) and trading

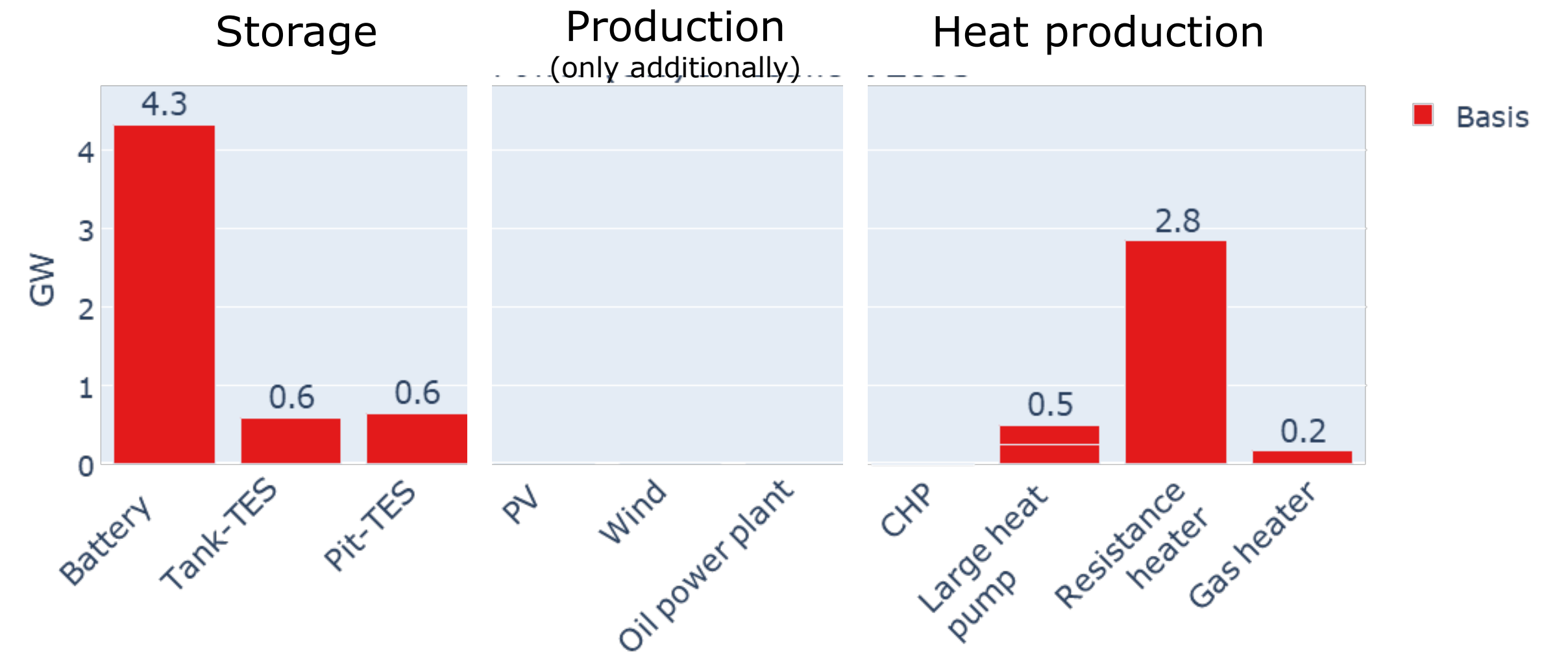
Observations:

- 4.3 GW batteries economically favourable
- Capacity of batteries sufficient for ca. 5 h coverage (22 GWh)
- No additional electricity production investment (Gas, Wind, PV)

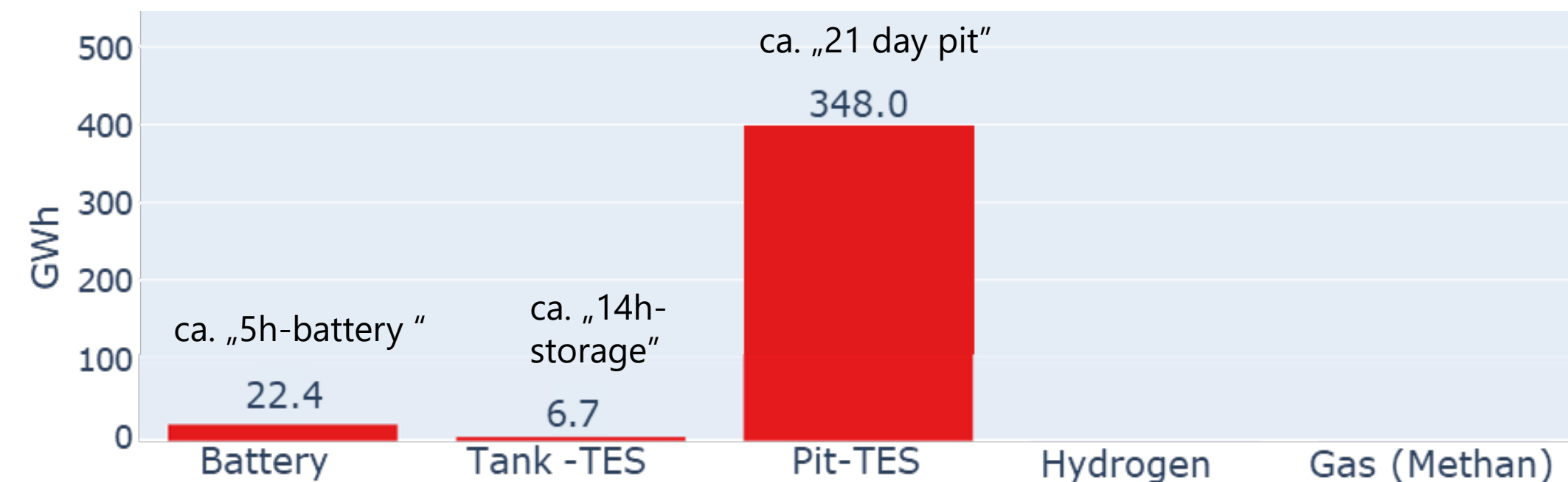
Thermal storage:

- 348 GWh Pit → ca. 9% of accessible district heating
- 6.7 GWh tank as short-term storage
- Power2Heat (resistance heater) for peak loads and excess electricity usage mostly for high temperature industry

Power (GW) Investment



Energy (GWh) Storage capacity



How does 348 GWh pit storage / 7 GWh tank storage look like?

Pit Storage

64 x Dronninglund (60'000 m³, 5.4 GWh, $\Delta T = 75$ K)



Tank storage

5 x Agro Energie Schwyz (28'000 m³, 1.3 GWh, $\Delta T = 40$ K)



Investments in 2035: Full Autarky

Full autarky gas and electricity

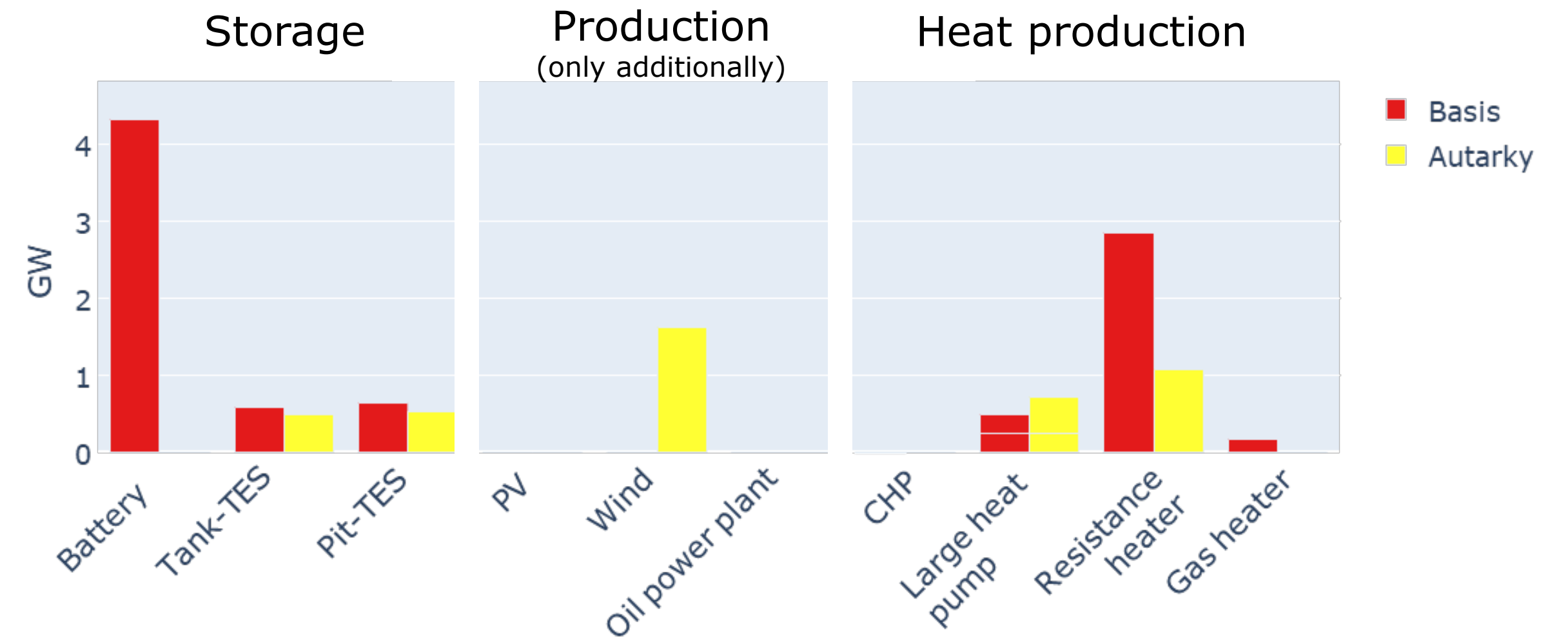
Observations:

- No additional batteries
- Wind as essential technology for autarky
- Higher demand for pit storage (348 → 495 GWh)

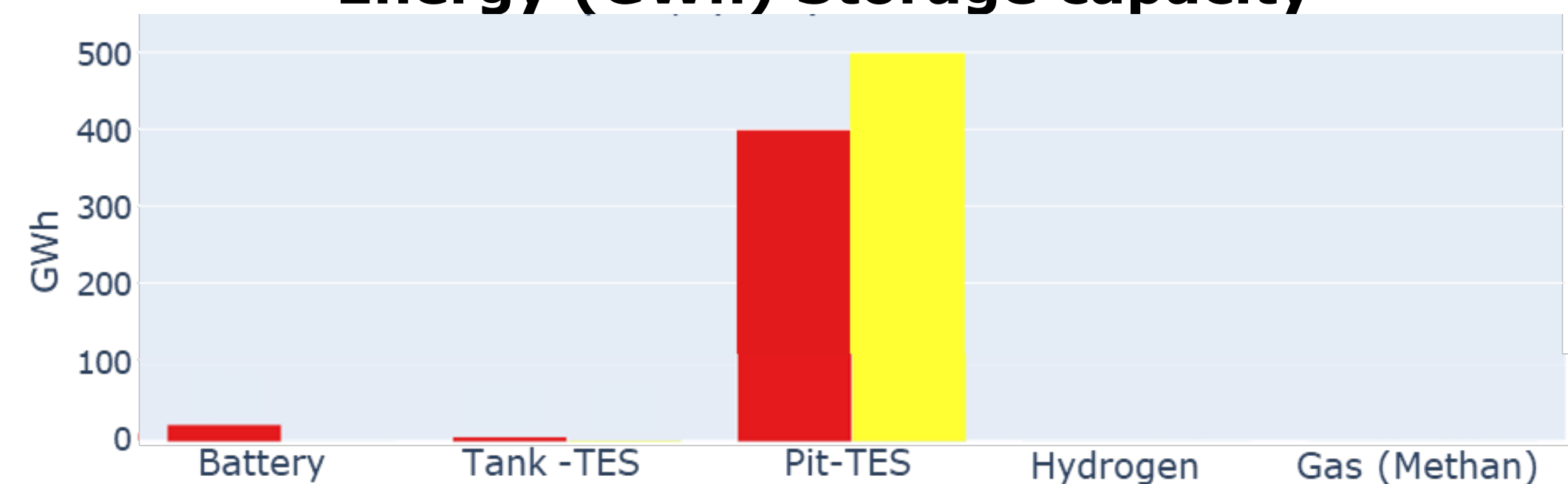
Thermal storage:

- Pit-storage covers around 12% of district heating demand

Power (GW) Investment



Energy (GWh) Storage capacity



Investments in 2050: Winter-Limit

5 TWh net import limit in Winter

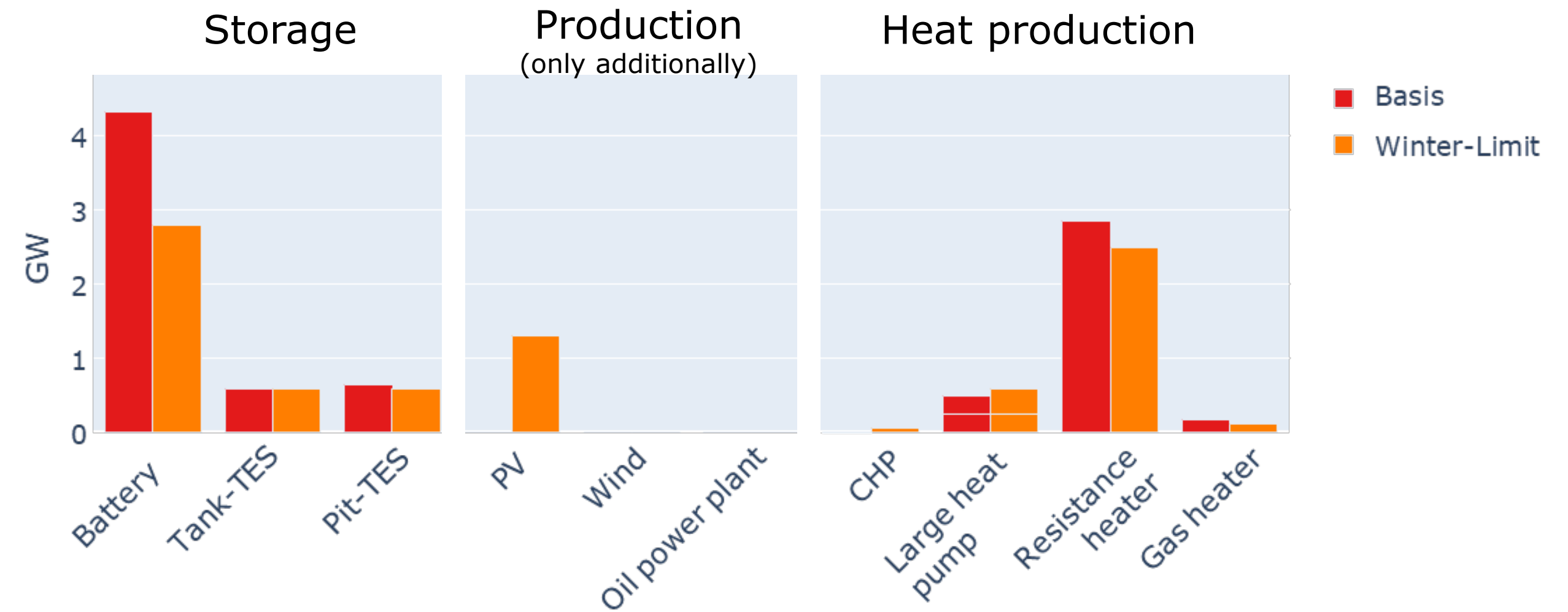
Observations:

- Investment in additional PV
- Reduced battery power / capacity

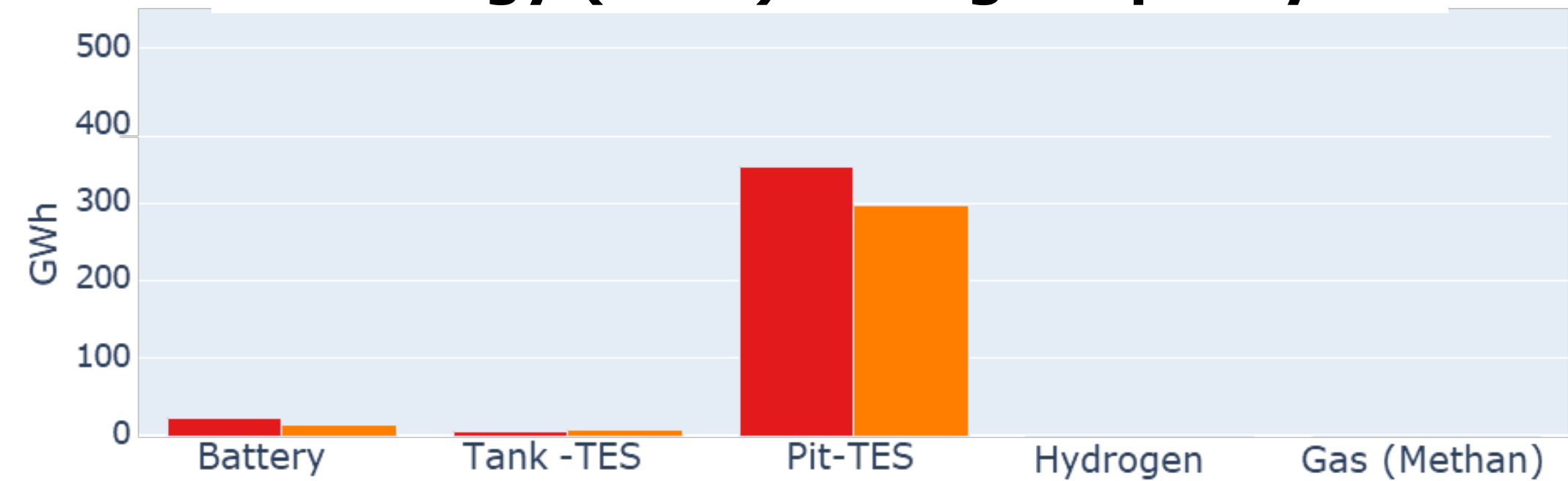
Thermal storage:

- Pit storage reduced due to higher PV contribution in Winter

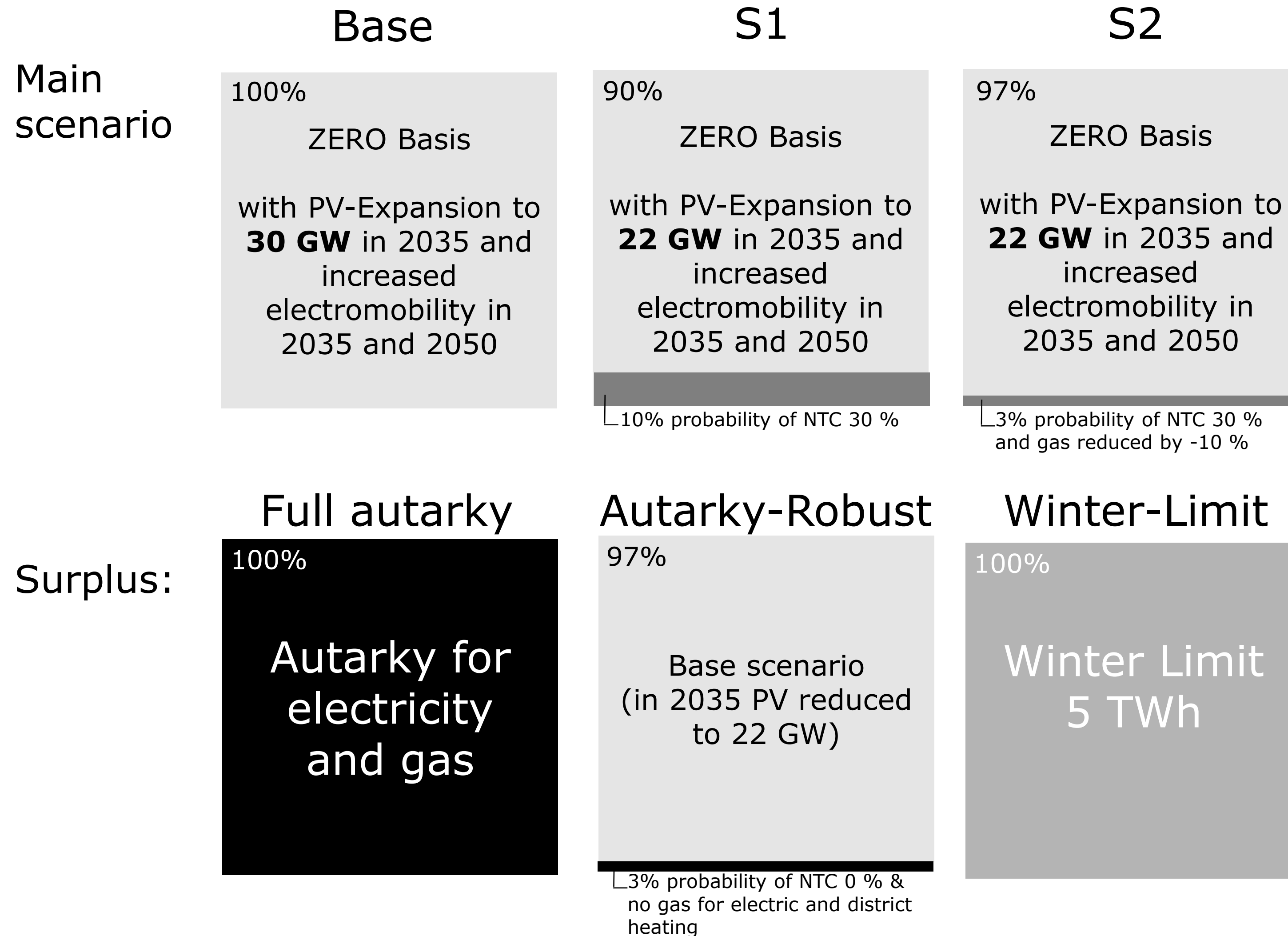
Power (GW) Investment



Energy (GWh) Storage capacity



Reminder: Considered scenarios



Result overview 2035 – part 1

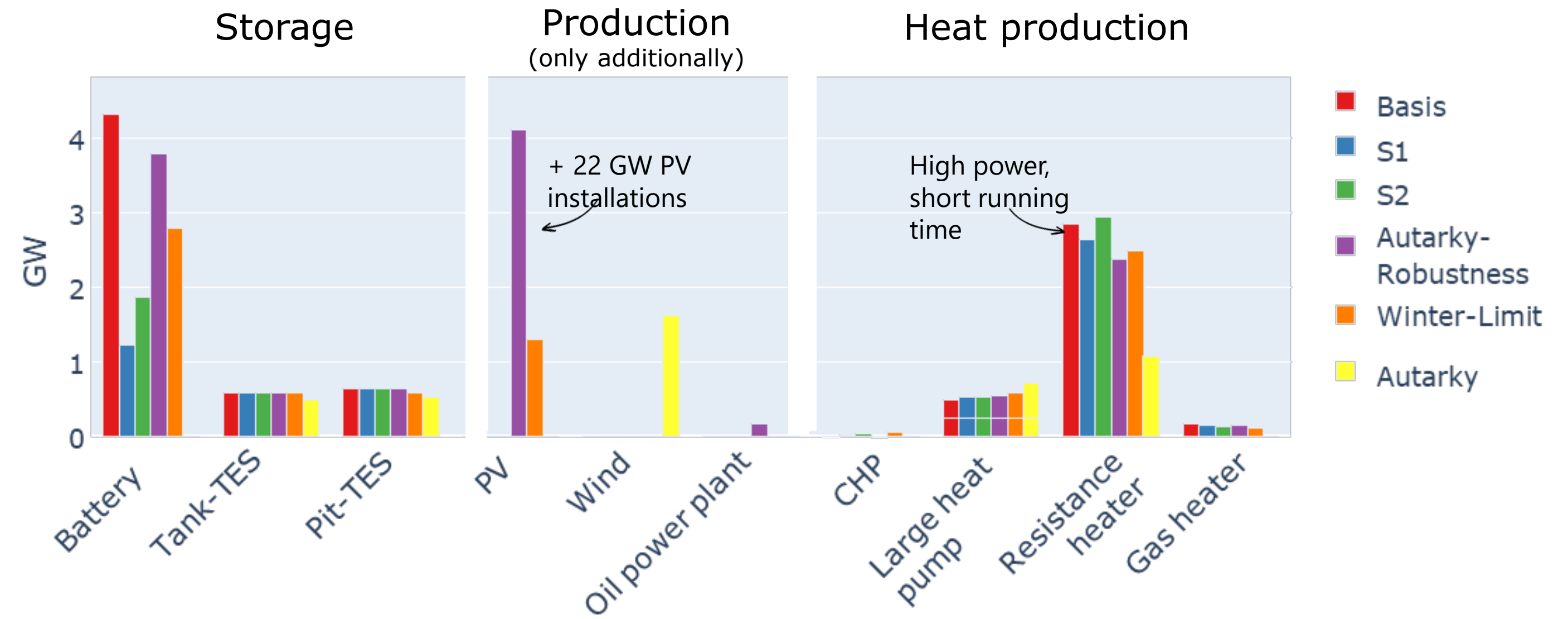
Cost function

Cost for energy provision incl. CO₂ compensation and investments

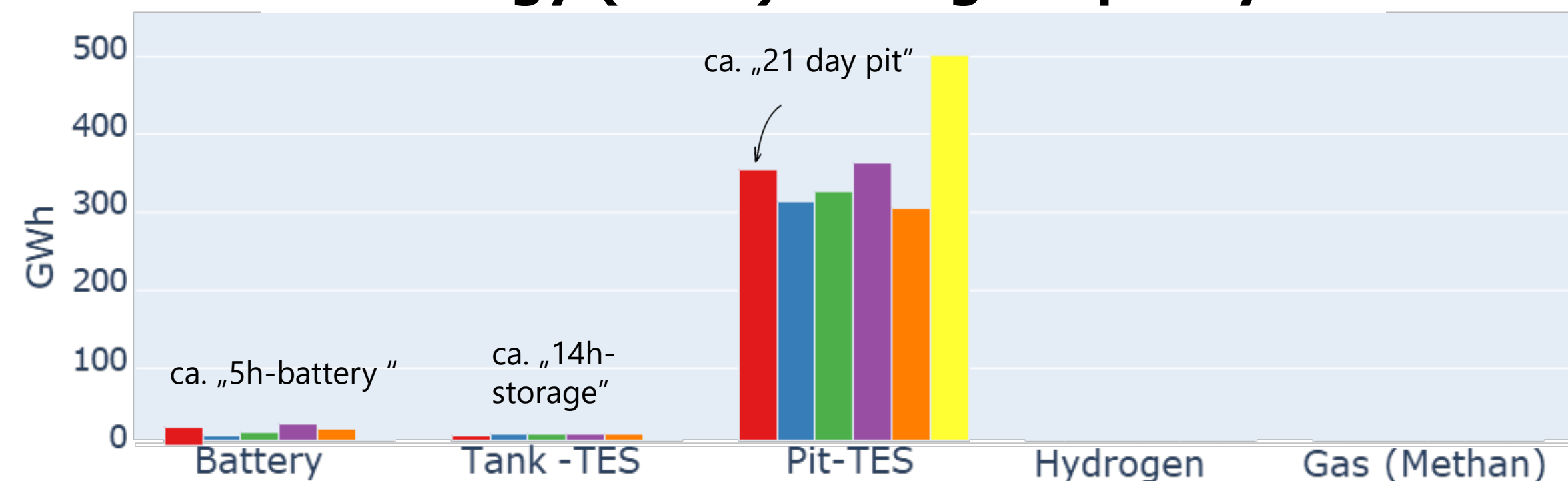
Observations:

- Thermal storages (TES) for high power and high capacity are needed
- Strong demand for high capacity storage (ca. 10 % of accessible district heating demand)
- Thermal storage demand significantly higher if higher demand / other than district heating demand could access TES

Power (GW) Investment



Energy (GWh) Storage capacity

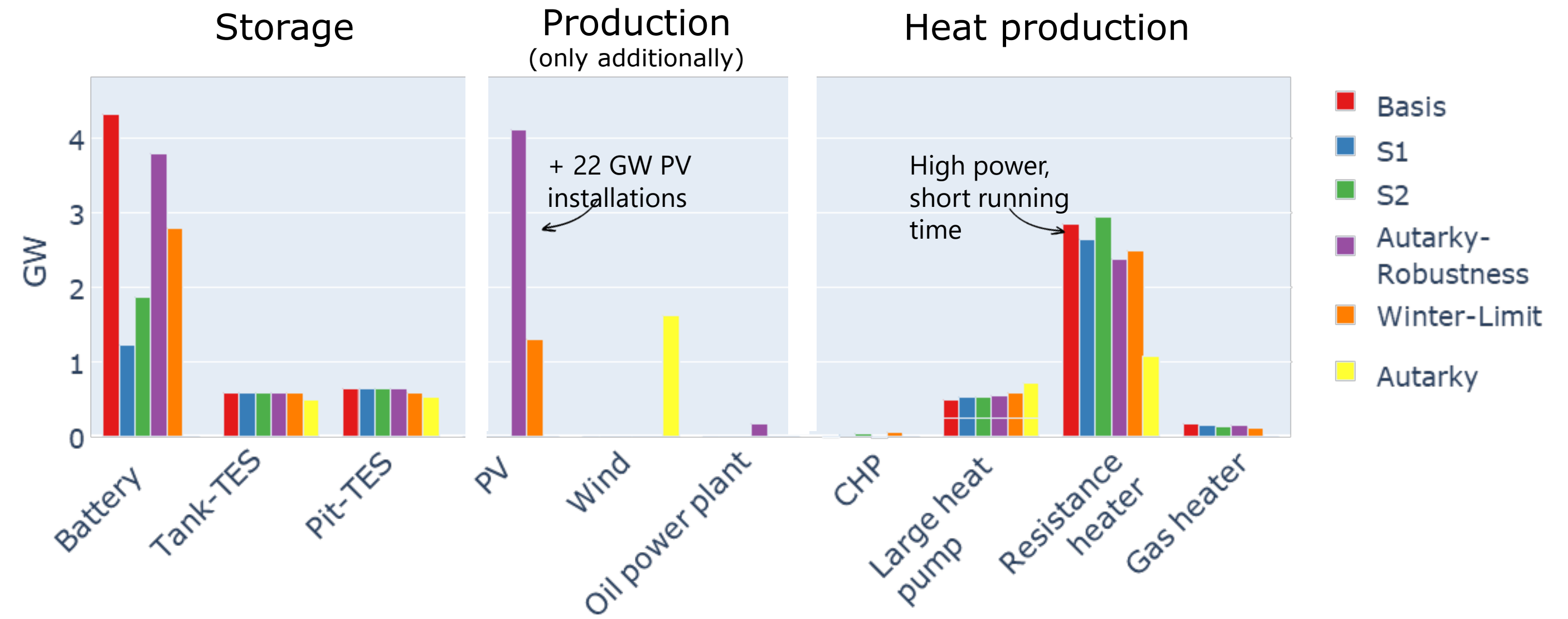


Result overview 2035 – part 2

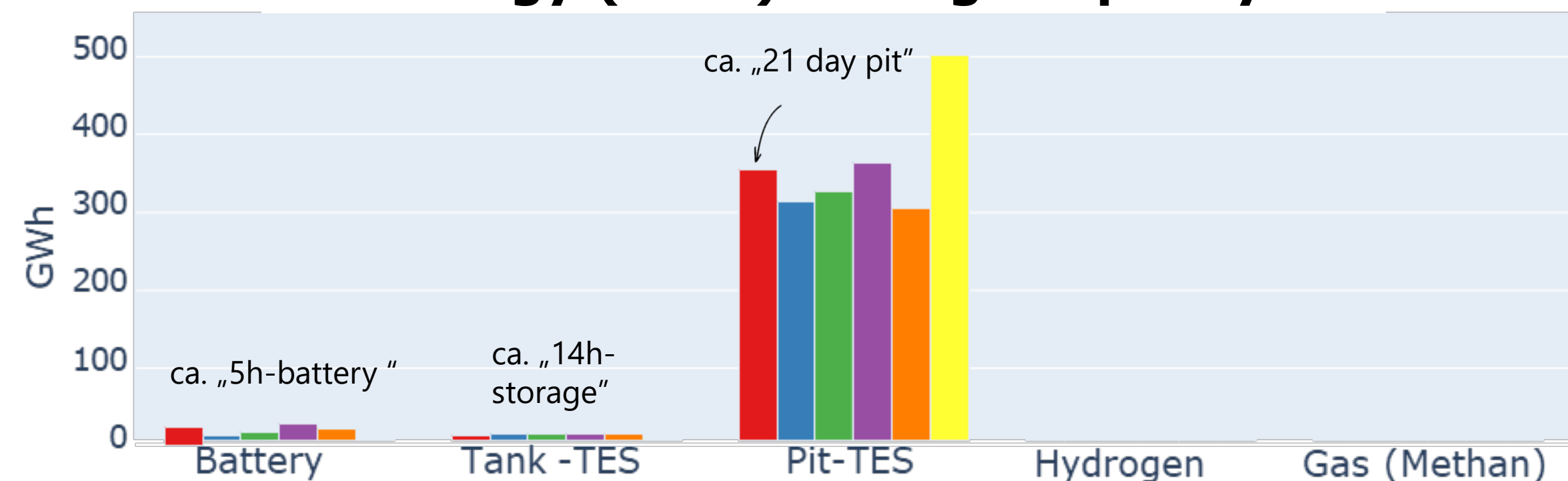
Observation:

- Batteries are economic in base case already due to positive price evolution
- Hydrogen and gas storages are in our model not efficient as additional PV capacity, wind power and oil power plant provide cheaper alternatives in crises
- Autarky cases (→ less trading) necessitate less batteries due to flexibility from hydropower and higher PV exploitation

Power (GW) Investment



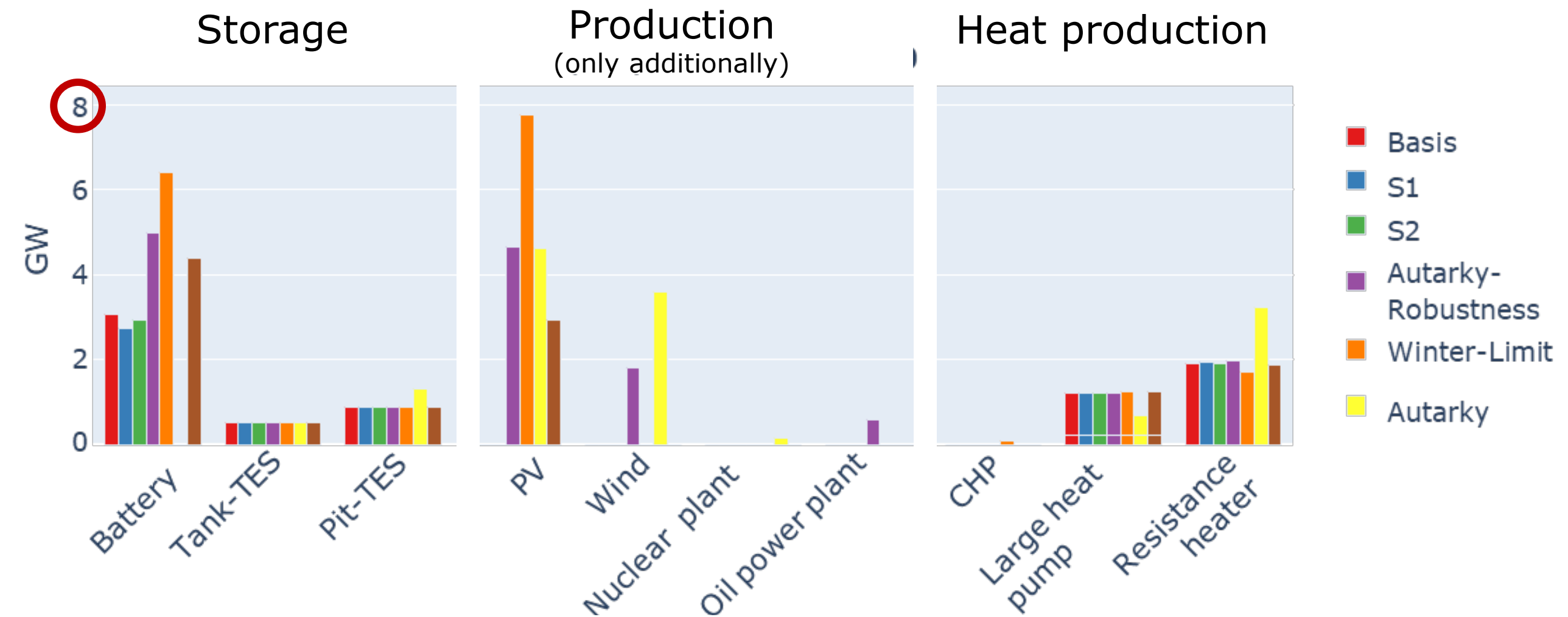
Energy (GWh) Storage capacity



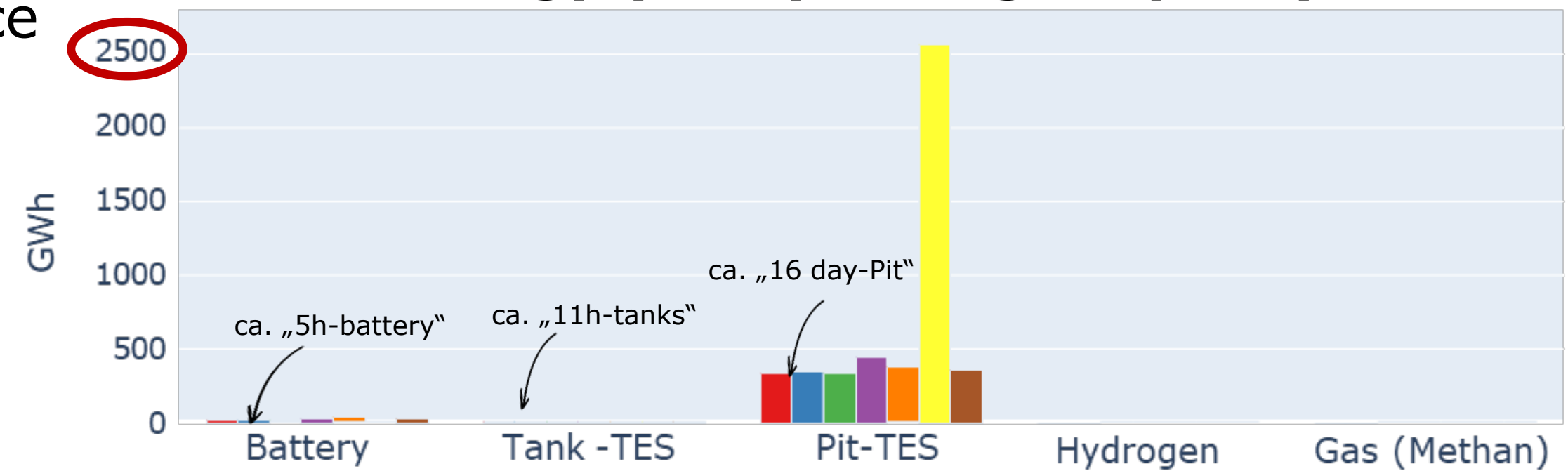
Result overview 2050

- Similar distribution of technologies, power and capacities in "base" and most scenarios.
- In "Winter-Limit" and "Autarky" cases substantially higher batteries, PV, wind and pit-storage.
- Hydrogen and gas storage dominated by hydro-storage, variable renewable production and small dual fuel plant
- Thermal storage contributes to the seasonal balance in Switzerland

Power (GW) Investment



Energy (GWh) Storage capacity



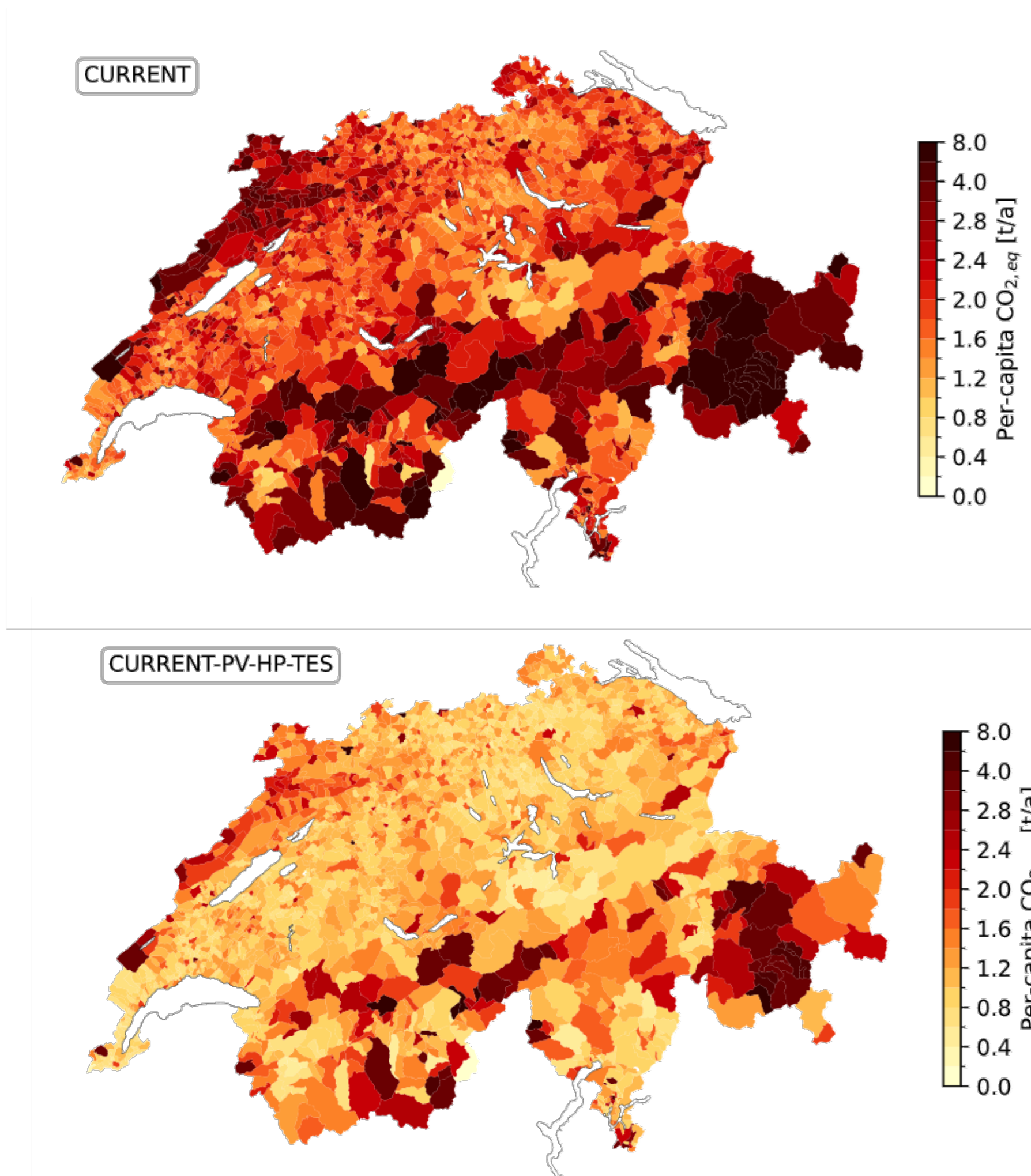
What is missing?

The actual storage demand will be larger and the solutions will be more complex because

we need

- To match storage systems with heat demands and sources
- To ensure that the storage systems are built and integrated
- To make their construction and installation cheaper

Impact of storage in each community



District Energy Model / Recommender tool:

- Framework to study the impact of different (renewable) technologies on (renewable) energy consumption, emissions and costs.
- Automatically parametrised for each community in Switzerland based on public data

Study:

- Effect of thermal energy integration for each community separately on emissions
- Impact strongly depends on the energy source and demand composition

Reference:

U. Schilt et al., SWC 2025, 2026, under review

Take home messages

- Thermal energy storage is a key element in a resilient future energy system
- A demand share of 8 -12 % for long-term thermal storage capacity is economically favourable
- Potential of thermal energy storage limited by district heating expansion
- A small share of short-term tank storage is favourable for high-temperature applications
- More research/work for the optimum position of the thermal energy storage is required

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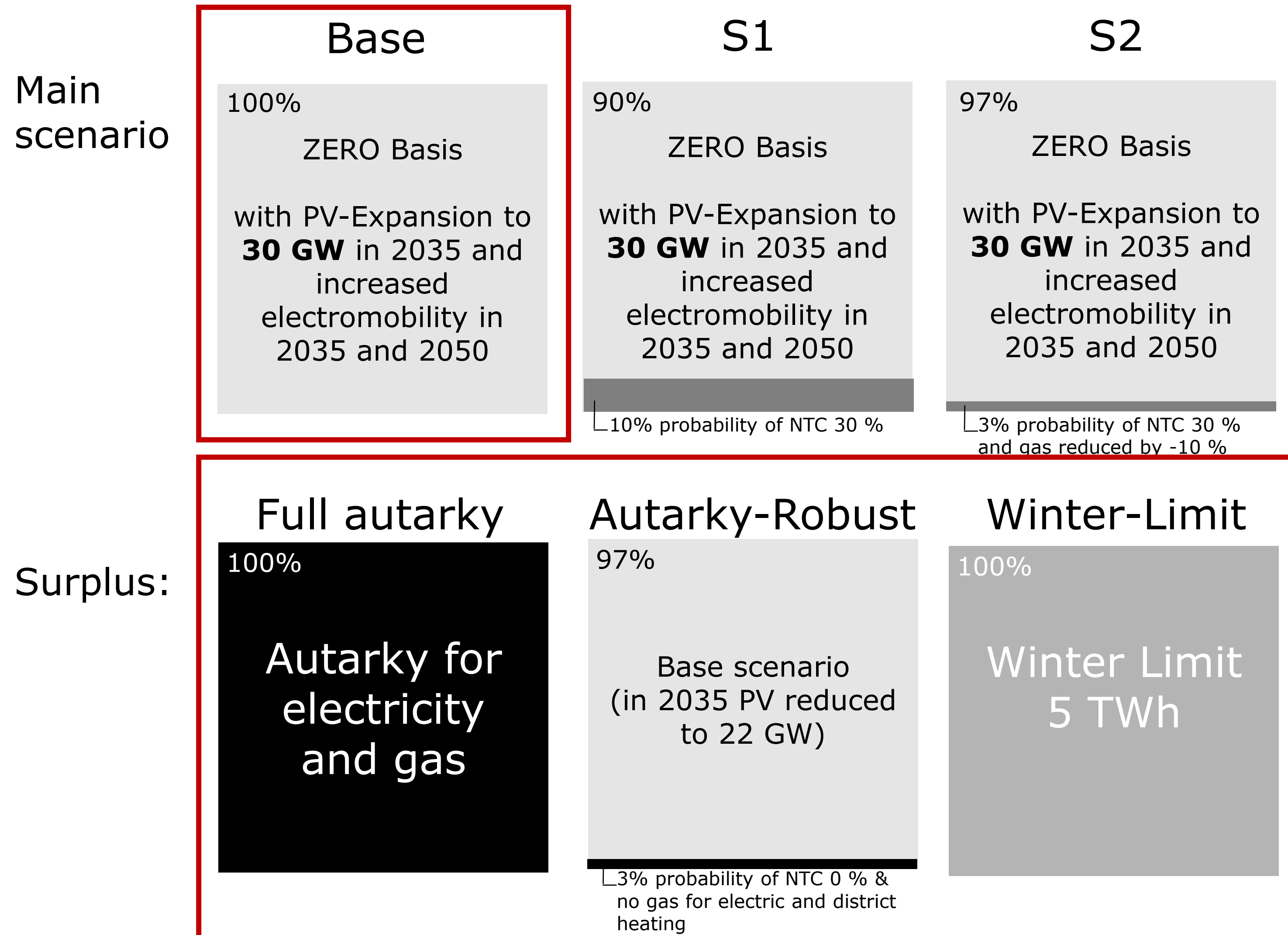
Power plant investment costs for 2050

	Investitionskosten pro Leistung (CHF/kW)	Quelle
Gaskombikraftwerk (CCGT)	855	NEXUS-E (ETH ESC, 2022)
Offene Gasturbine (OCGT)	700	NEXUS-E (ETH ESC, 2022)
Gaskombikraftwerk mit CO ₂ -Abscheidung (CCGT CCS)	1500	NEXUS-E (ETH ESC, 2022)
Heizöl-Kraftwerk	700	NEXUS-E (ETH ESC, 2022)
Wind	2050: 1778 (2035: 1997)	NEXUS-E – unveröffentlicht
Solar – Freifläche	2050: 615 (2035: 697)	NEXUS-E – unveröffentlicht
Kernkraftwerk	8637	Lazard (2024)

Power plant investment costs for 2050

	Investitionskosten (CHF/kW)	Wirkungsgrad / COP	Lebensdauer (Jahre)	Quelle
Widerstandsheizung	47.5	1	15	<u>Mellot et al. (2024)</u>
Gross-Wärmepumpen	781	4.26	20	<u>Mellot et al. (2024)</u>
Industrie Methan-Kessel	191	0.927	20	<u>Mellot et al. (2024)</u>
KWK CCGT mit CCS	1537	Strom-zu-Wärme-Verhältnis 0.61	25	<u>NEXUS-E (ETH ESC, 2022)</u>

Focus scenarios



Investments in 2035: Autarky-Robust

3% probability: Autarky gas and electricity

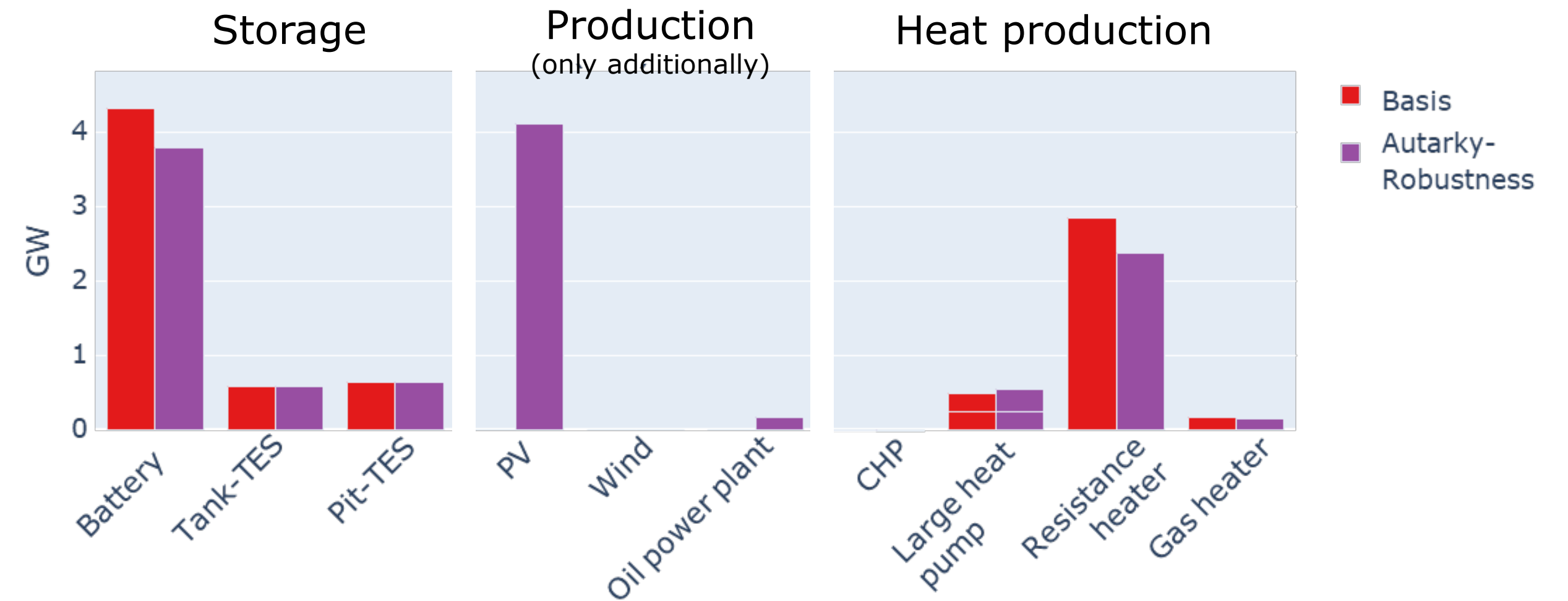
Observations:

- Robustness against crises from PV expansion, batteries and a small oil power plant
- Expansion PV ~4 GW
- Batteries ~4 GW – as a consequence of PV expansion
- Oil power plant 0.2 GW

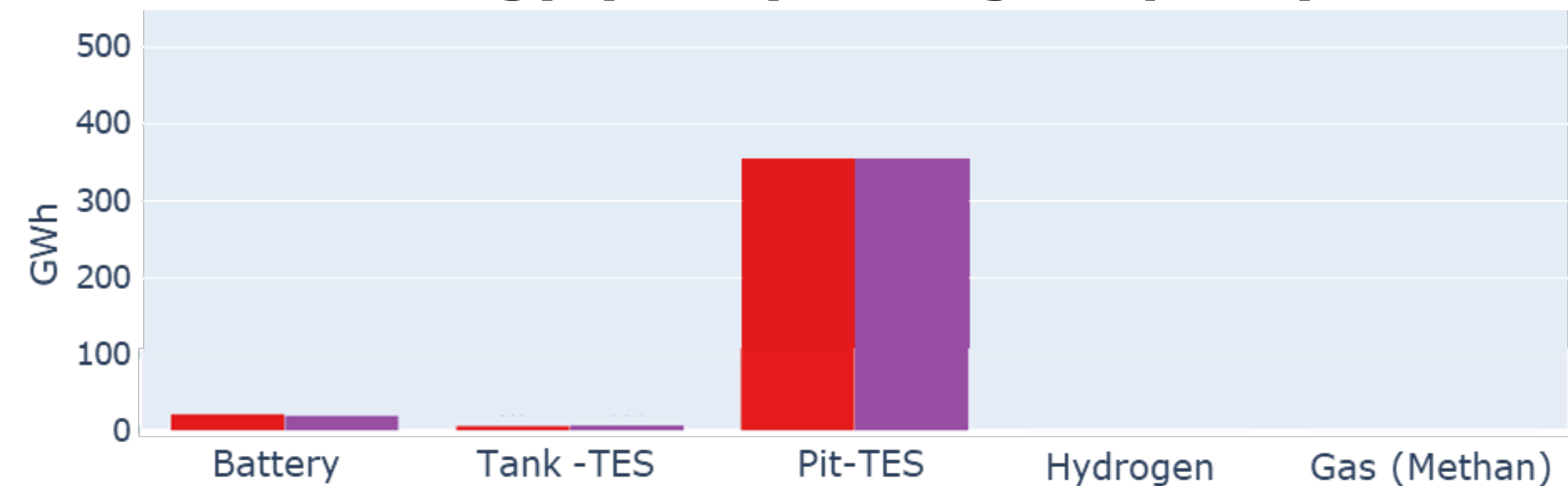
Thermal storage:

- Similar capacity and power

Power (GW) Investment



Energy (GWh) Storage capacity



Result overview (both 2035 and 2025)

- Thermal storage for 10 % of heating demand economically efficient even in base scenario.
- Optimum size in other scenarios varies between 9 – 12 %
- Absolute capacity lower than in other studies due to conservative assumptions of evolution of district heating systems (only 8 % of total space heating demand)
→ large unused potential
- Pits (high capacity) storages are dominant thermal storage technology, but tanks are required for high power and medium/high temperature applications.
- The essential question on optimal placement has not been considered.