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Integrating E2S Power Thermal Energy Storage Solution with Existing Power Plants

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Summary



- E2S Power
- Market Drivers
- Thermal Energy Storage integration with Existing Power Plant Infrastructure
- Technology Key Differentiators
- Integration with combined cycles in a hybrid scenario
- Comparison with other energy storage technologies
- Current Development Status – Approach to Market

E2S Power: Swiss Company Focused on Thermal Energy Storage Solutions



A joint venture between SS&A Power Development (60%) and WIKAI (40%)
a Germany company, global leader in pressure and temperature
measurements.

Addressing the Need for Energy Storage and Conversion of Legacy Fossil Fueled Power Plants



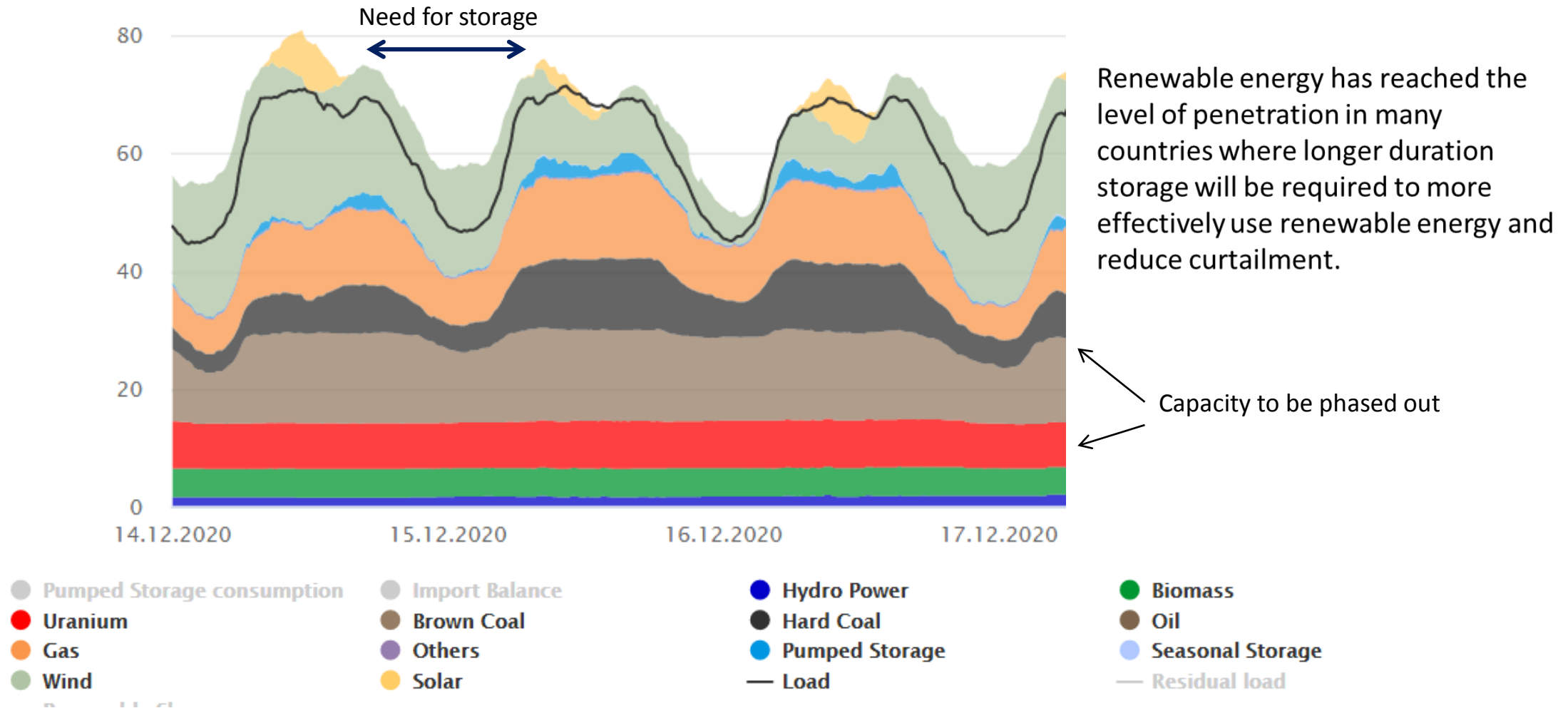
1. Need for Energy Storage

- Renewable energy represented over 40% of the share of power generation in 2020 in key countries such as UK and Germany and is set to increase in Europe and the US.
- This will drive the need to address intermittency, dependable capacity and grid stability.

2. Large number of legacy fossil fueled power plants being decommissioned or repurposed

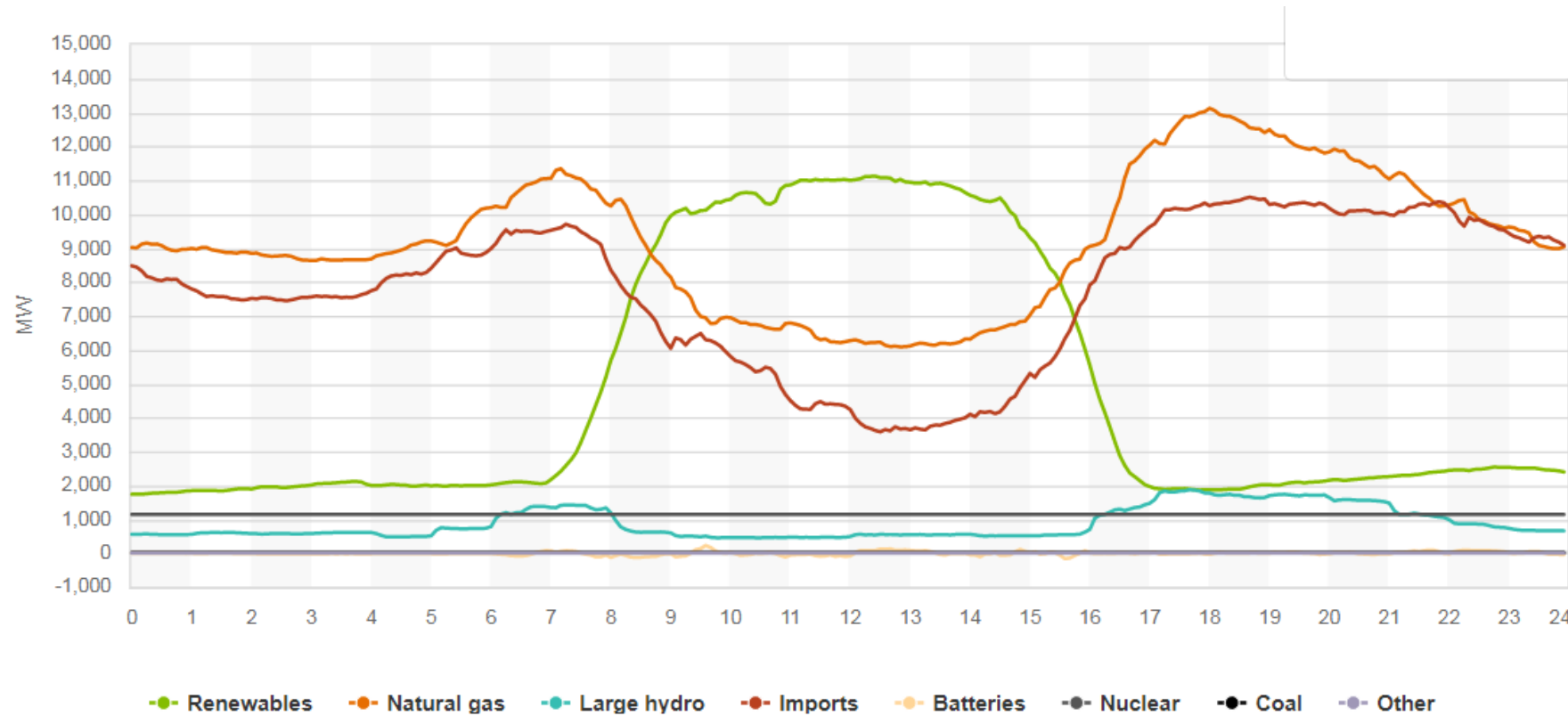
- In the transition to clean energy, utilities have committed to shutting down coal fired power plants in the next few years. This will create a challenge in terms of security of supply and an opportunity to leverage valuable infrastructure.

Daily Generation Example - Germany



Daily Generation Scenario - California

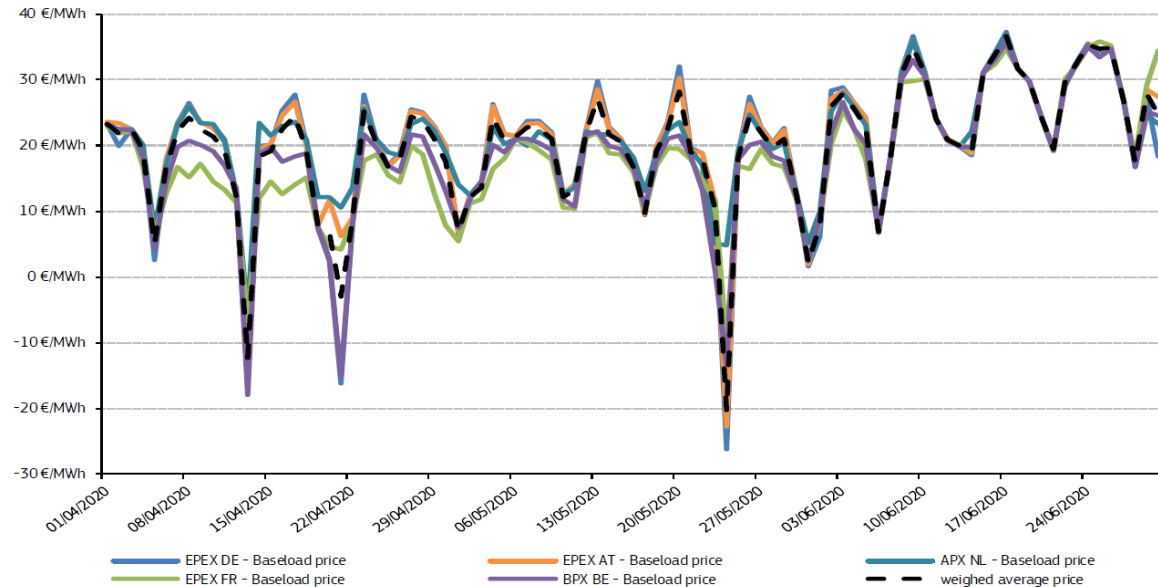
January 2021



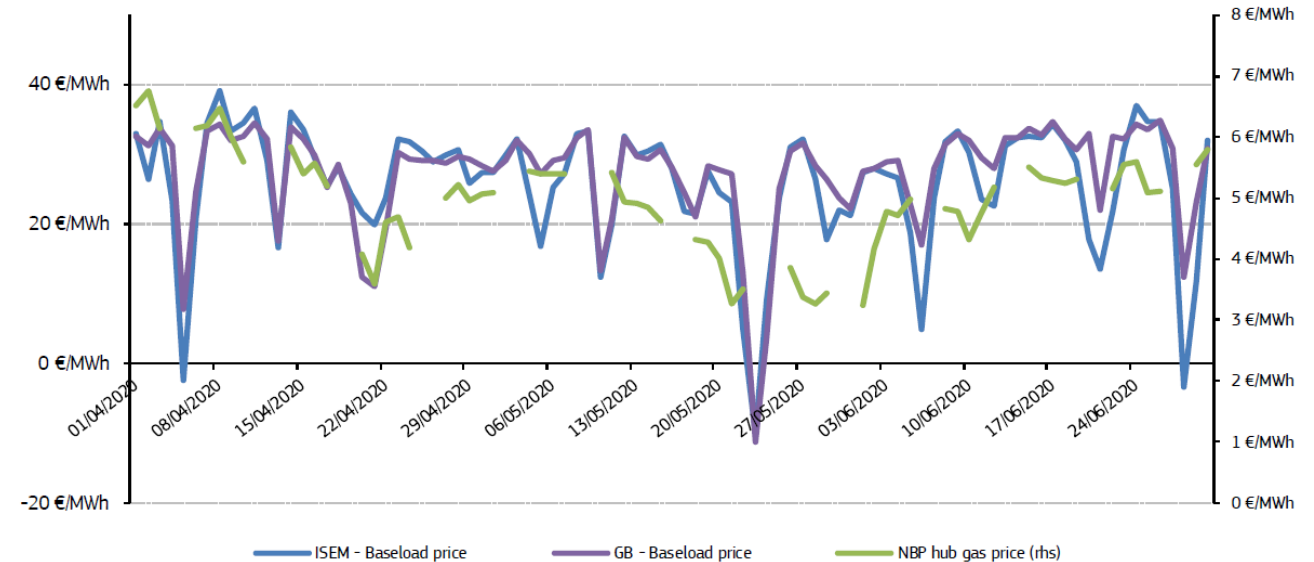
Legacy Gas Fired Power Plants Kept Operating to Ensure Security of Supply

Electricity Markets Increasingly Volatile

Daily average power prices on the day-ahead market in the CWE region

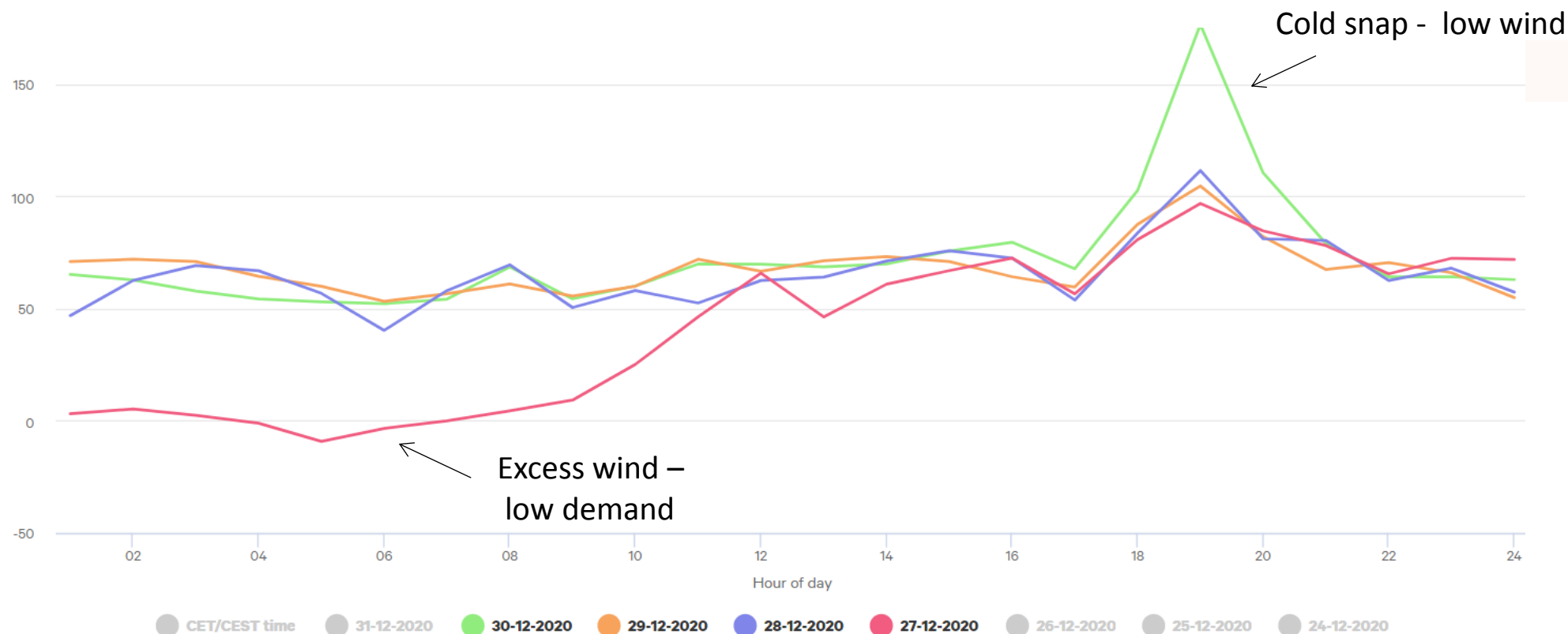


Daily average electricity prices on the day-ahead market in Great Britain and Ireland



Negative prices occurred in Germany and UK/Ireland during periods of low demand and renewable share exceeding 70% and 57% respectively.

UK Market Prices - 4 Days in December 2020



Coal Power Plants Phase out: Repurposing is a Challenge and an Opportunity

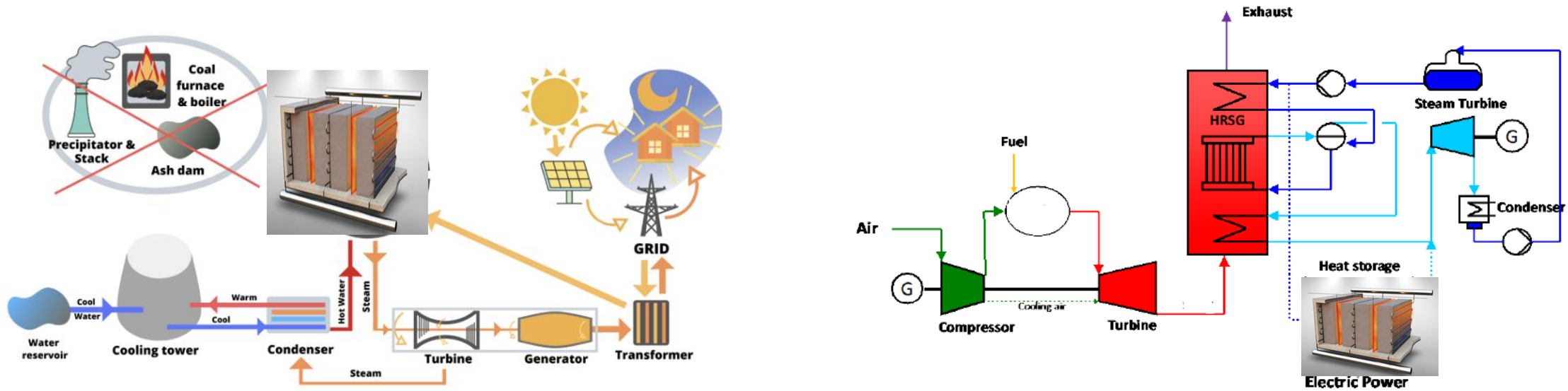
- 30 GW of coal and lignite to be shut down in Germany by 2022 with an additional 20 GW by 2030. All coal to be shut down by 2038 – may be accelerated to 2030.
- Over 4GW of coal have shut down in 2020 in the UK with all unabated coal plants to be shut down by 2024.
- Total of about 200 GW projected to shut down in Europe.
- A substantial portion of the US 236 GW of coal to be shut down by 2030

There is an opportunity to utilize valuable infrastructure, reduce decommissioning costs and preserve jobs

E2S Thermal Energy Storage Solution



Simpler thermal storage solution with better energy density, based on Miscibility Gap Alloys (MGA), aimed at integrating thermal energy storage into existing fossil fuel power stations



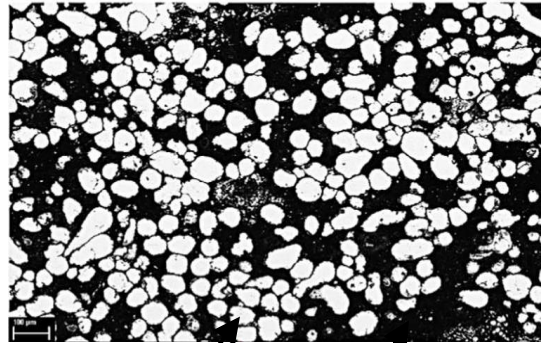
Benefits:

1. Use valuable existing infrastructure
2. Improve efficiency and operational flexibility
3. Reduce emissions and CO2.
4. Preserve jobs and transition local economies

E2S Unique differentiator - MGA Storage Material



Miscibility Gap Alloys (MGA) take advantage of phase change to provide superior energy density:



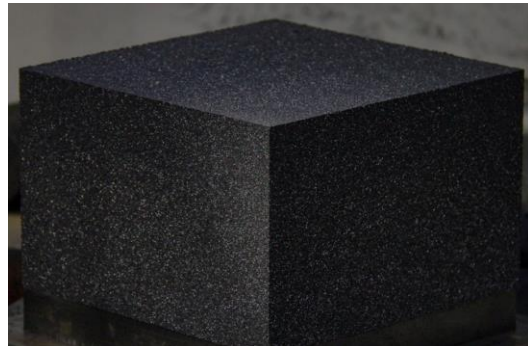
Aluminum

Carbon

Storage media are blocks made of aluminum and graphite, abundant and safe materials

Aluminum melts and stores latent heat

Graphite remains solid and acts as a matrix in a solid block



E2S Power has an exclusive Agreement with Australian company MGA Thermal for utility applications

MGA is the result of 10+ year of research originally developed at the University of Newcastle, Australia

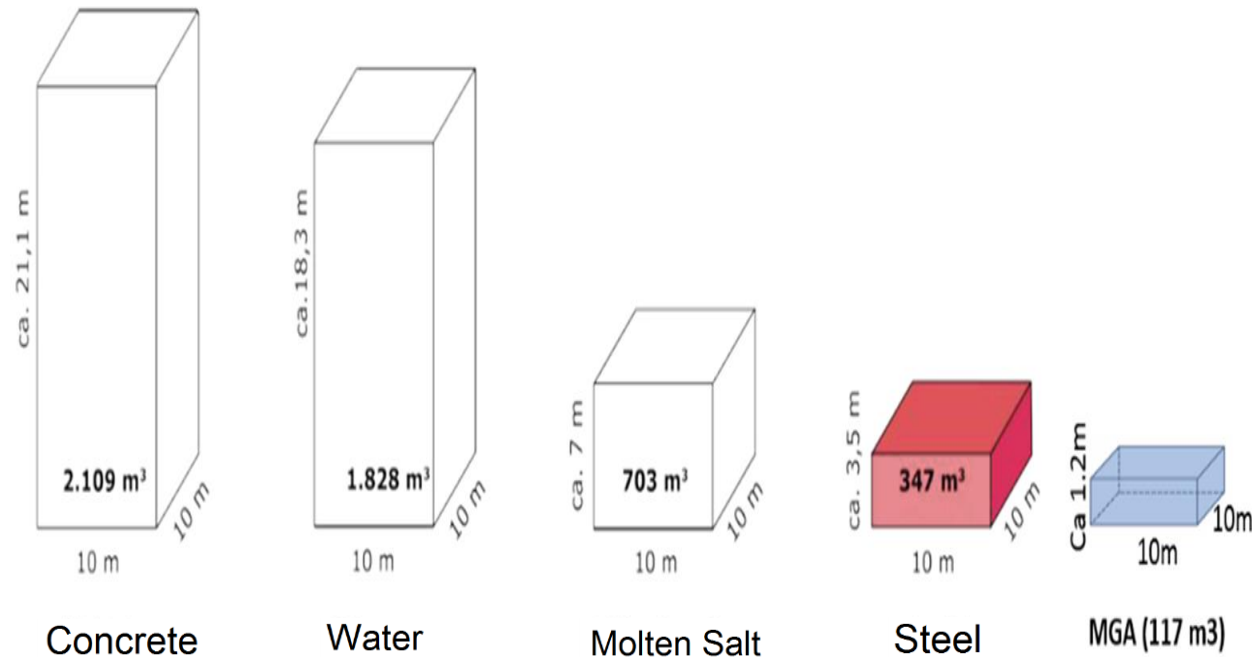
Initially tested on solar thermal applications

Blocks have gone through thousands of cycles of testing

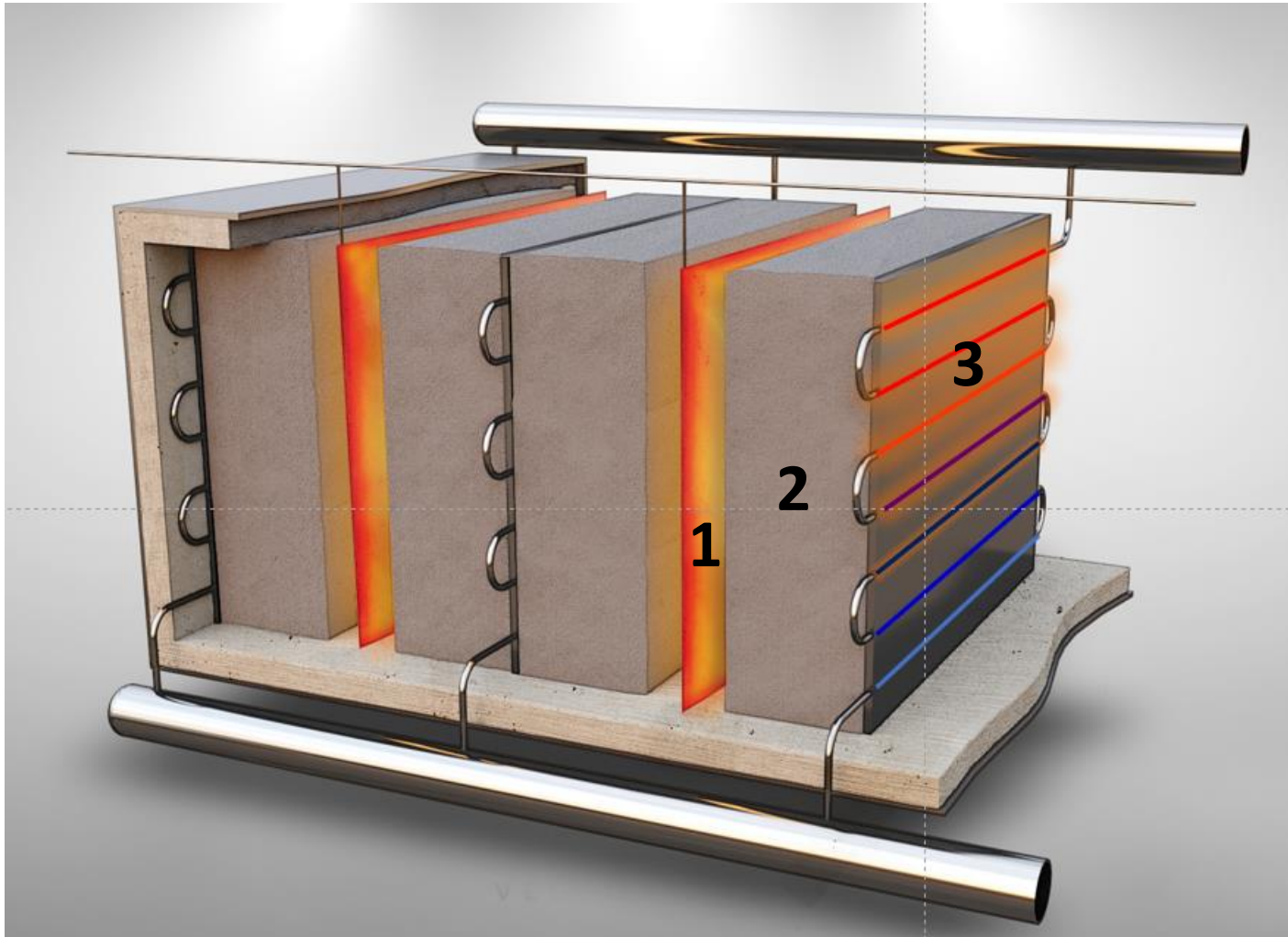
MGA Thermal building large scale manufacturing capability

MGA Energy Storage Solutions

Approximate comparison of Energy Density



E2S Proprietary Technology - TWEST™

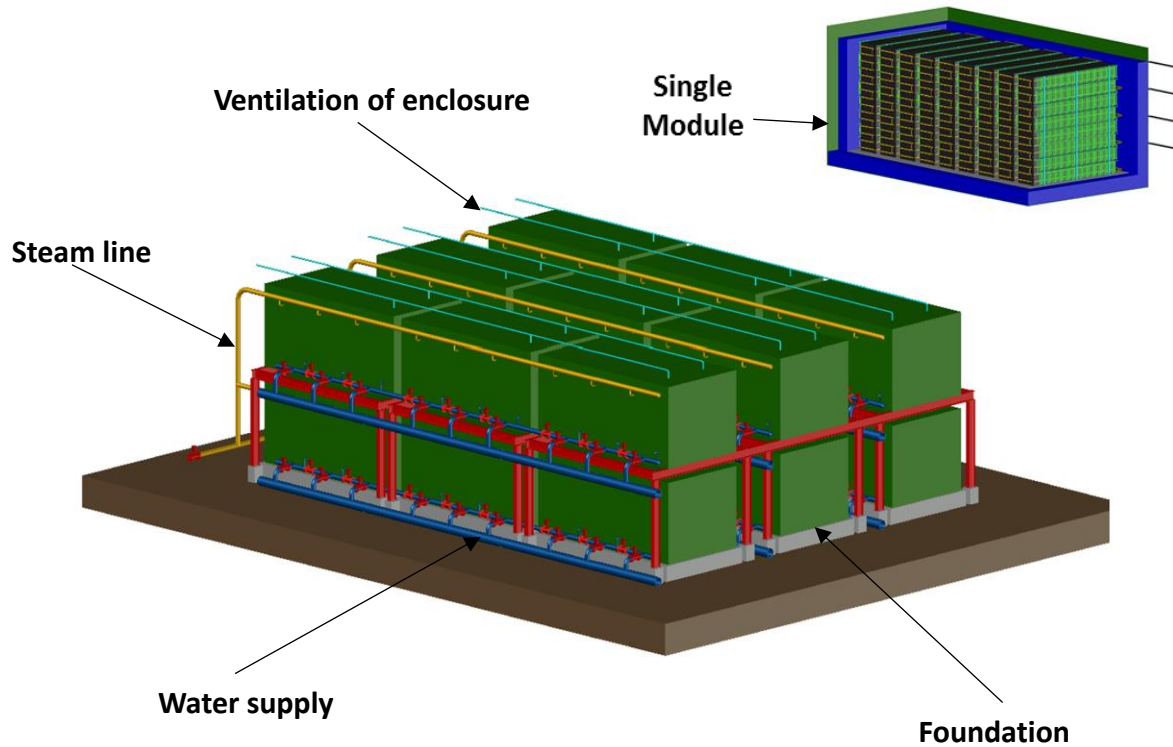


TWEST™ consists:

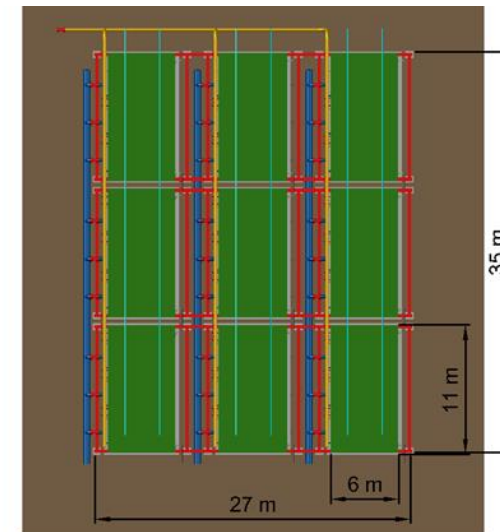
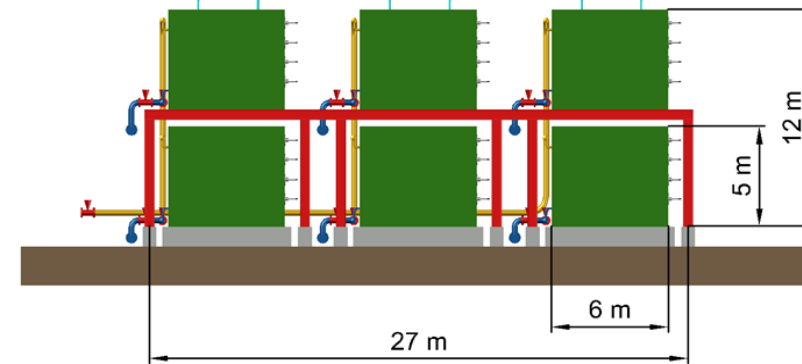
- 1) Electric Radiating Heaters
- 2) MGA storage bricks
- 3) Steam Generator

- Compact design
- Heat transfer via radiation or direct conduction
- No need for additional air blowers or intermediate fluids
- No additional auxiliary consumption
- Maximum efficiency

Example Commercial Scale Plant



50 MWh block Modular Design Can Be Easily Scaled Up and Accommodate Available Footprint



E2S MGA Energy Storage

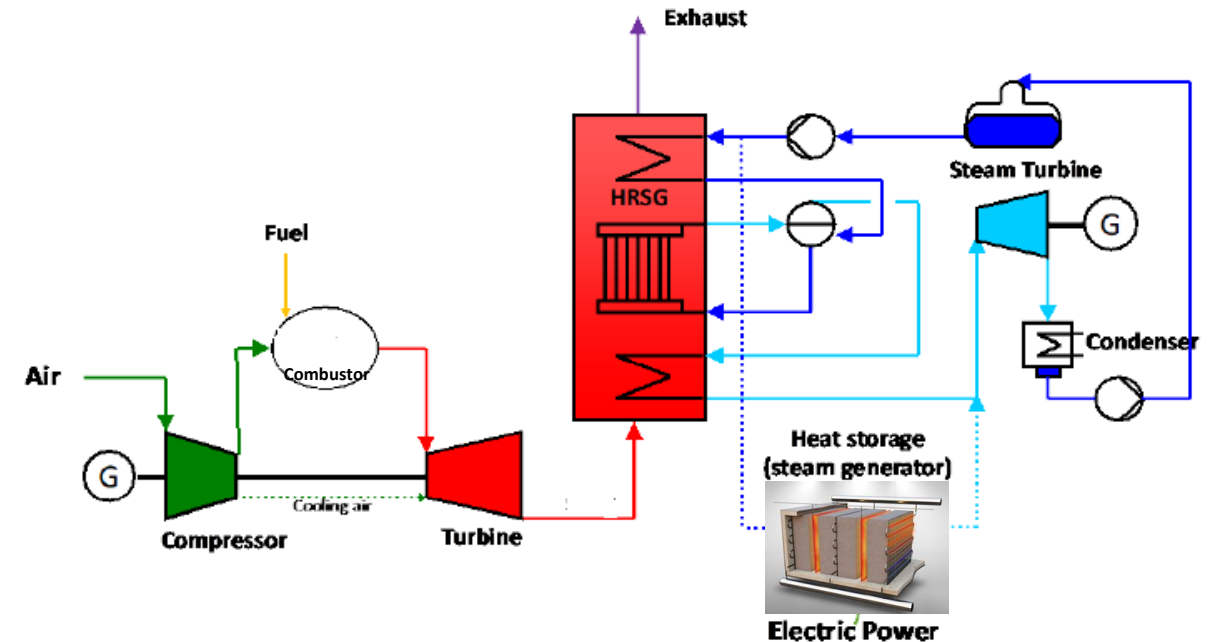
Key Advantages



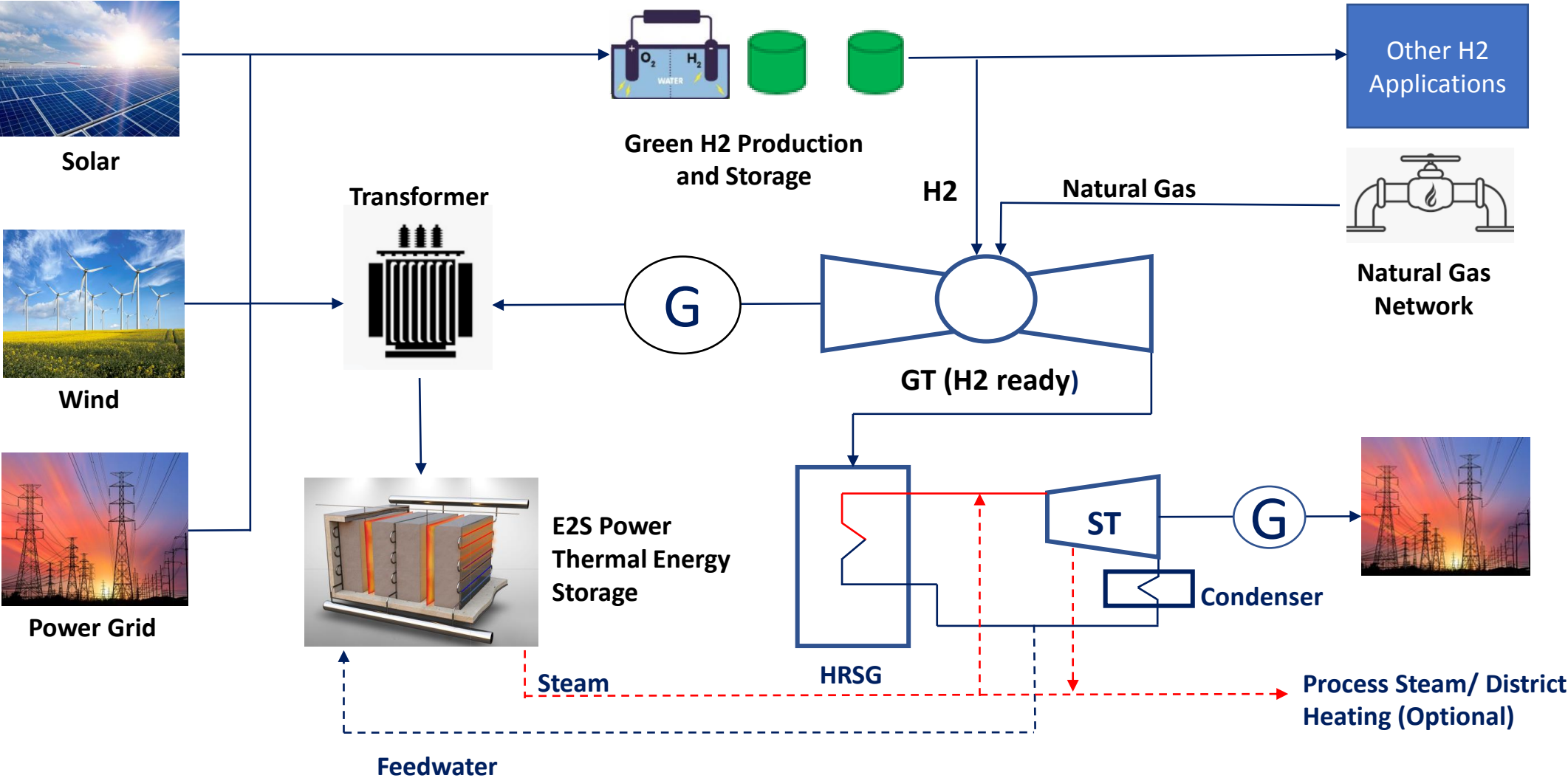
1. Superior energy density compared with other energy storage solutions.
2. Compact and simple system design – easy integration and minimum disruption to existing plant
3. Made of abundant and recyclable material
4. Long life – 30 years
5. MGA storage blocks are safe and remain stable throughout their life cycle.
6. Can be easily scaled up.

Integration with Combined Cycles – Possible Benefits

- Preheat and maintain steam for faster start-up and greater operational flexibility
- Increase maximum peak power (avoiding supplementary firing and peak GT firing) – particularly where extra ST capacity is available
- Improve CCGT efficiency at low load
- Simple integration, minimizing interference with existing plant
- Opportunity for hybrid power plant: renewable, storage, hydrogen to be integrated with CCGT



Hybrid Thermal Energy Storage – Combined Cycle Applications



Comparison with Other Thermal Energy Storage

Molten Salt



- Mainly used as storage technology with solar plants
- Higher energy density than stones but 6 times lower than E2S
- Major disadvantages include complexity, corrosiveness, cost of operation and maintenance.
- Molten salt must be kept above 200 C

Stone, Concrete, Rocks



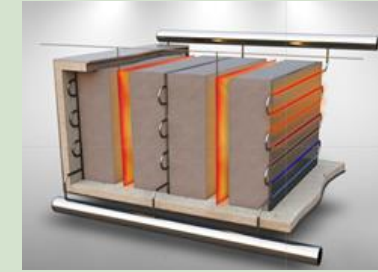
- Relatively low energy density
- Typically uses air blowers or heaters rather than direct steam generation
- Lower efficiency charging/discharging system

Cryogenic



- Temperature required -200°C
- Efficiency is moderate and can be increased by using low grade heat
- Can be built as greenfield or connected to sources of heat
- Main issues are related to complexity - many components to be integrated, tanks, complex operation and maintenance

E2S Power TWEST System



- Energy density 6 times greater than molten salt and 17 times greater than concrete
- Simple, compact, easily scalable
- Once-through direct steam generation in unit
- Flexible operation and easy integration with existing plant
- Environmentally friendly materials.
- Designed for daily cycles, 30 year life

Current Status– Approach to Market



Technology Demonstration

- Successful technology demonstrator tests completed

Pilot Plant – Under Development

- TPP Pljevlja 260 MW in Montenegro –pilot application as an add on to existing boiler as a phased project - Target 2022
- LOI Signed with EP Power Europe for the development of a 50 MWh pilot project – Target 2022



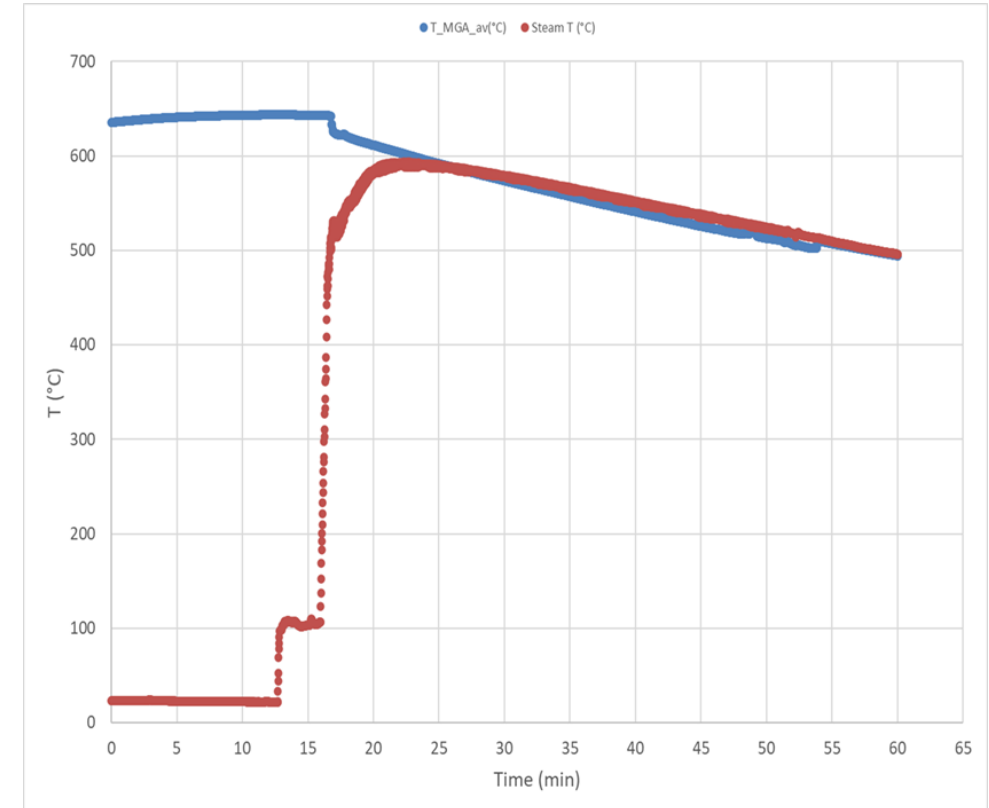
Currently Pursuing Over 4 GW
in Project Opportunities

Commercial Scale Development Pipeline:

- Hybrid CCGT- thermal storage project
- Completed a case study for a decommissioned coal plant in Italy – This would result in a 1,500 MWh commercial scale project.
- MOU with major EPC Contractor for cooperation in North America. Started discussions with utility clients in US and Canada.



E2S Technology Demonstrator



Data acquired utilized in design of utility
scale 50 MWht thermal energy storage plant



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