ENERGY STORAGE PARTNERSHIP (ESP) TECHNOLOGY WEBINAR SERIES

ESMAP
Energy Sector Management Assistance Program

THE WORLD BANK
IBRD • IDA

THERMAL ENERGY STORAGE
A KEY ENABLER OF THE CLEAN ENERGY TRANSITION

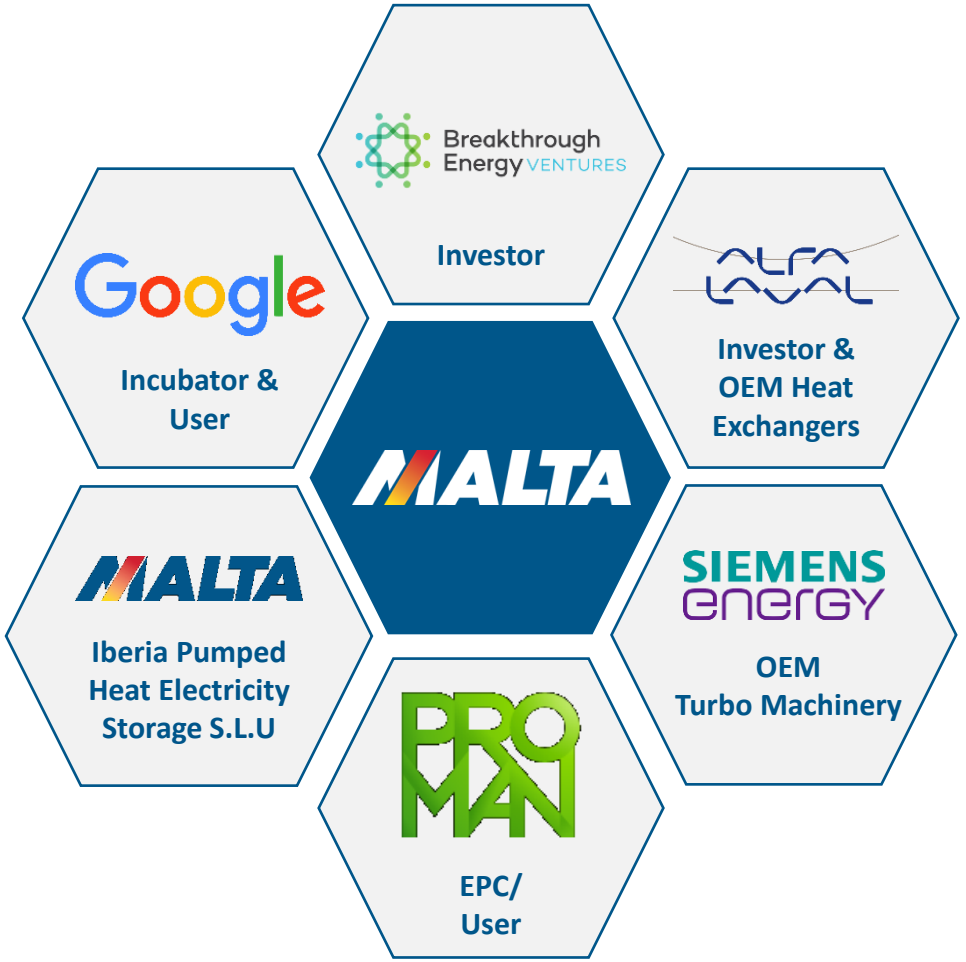
"Utility scale long duration synchronous pumped heat electricity storage for the energy transition"

Michael Geyer, Malta Inc.

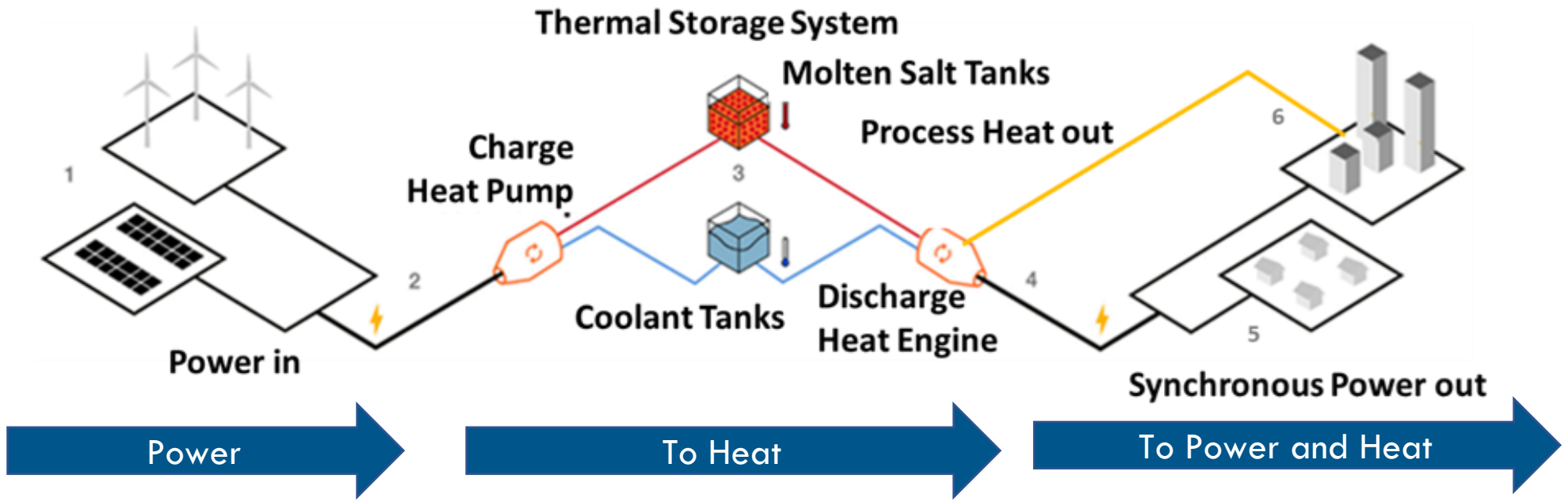
April 28th, 2022

Introduction of Malta Inc.

- Malta's ownership represents a unique balance of **bold visionaries** and **world-class execution experience**
  - Breakthrough Energy Ventures
  - Google
  - Proman
  - Chevron and Piva
- Strong commitment in Europe
  - Malta Iberia Pumped Heat Electricity Storage SLU
  - Malta Hochtemperatur Wärmepumpen Stromspeicher GmbH
- Selected strong Own Equipment Manufacturers
  - Heat Exchanger OEM – Alfa Laval
  - Turbomachinery OEM – Siemens Energy
- Foundig Member of Long Duration Energy Storage Council



Breakthrough Utility Scale Synchronous Power & Heat Storage



Long duration energy storage = from 10+hrs to days and weeks

Utility scale synchronous dispatchable power > 100MWe

Long lifetime > 25 years, no storage medium degradation

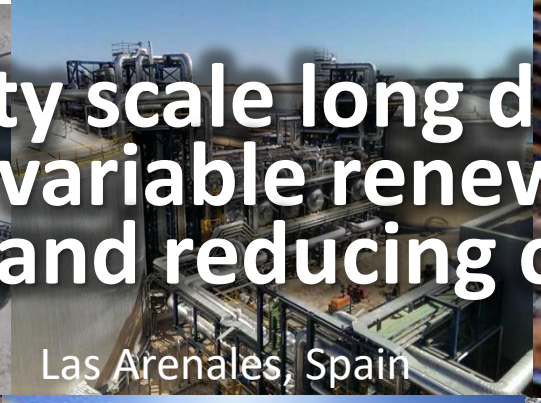
Competitive < 200USD/kWh LDES capacity

Malta makes mature synchronous utility scale long duration molten salt storage competitive for all variable renewables increasing charge/discharge efficiency and reducing cost


Kathu, South Africa


Xina, South Africa


Gansu Akesai, China


Las Arenales, Spain


La Africana, Spain


Solana, USA


Ashalim, Israel


Solana, USA


Noor 2, Morrocco

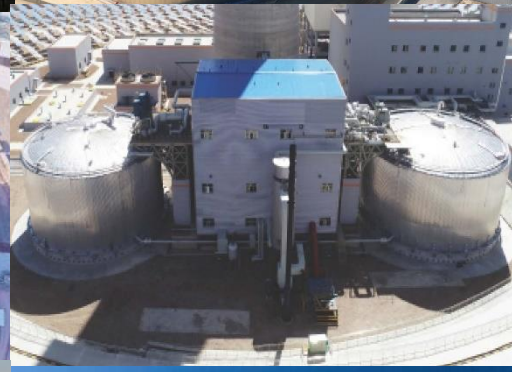

Valle 1, Spain


Bookport, South Africa


Gemasolar, Spain


Noor 3, Morrocco


Cerro Dominador, Chile




Fresnel Shouhang Dunhuang, China


MS Tower Shouhang Dunhuang, China

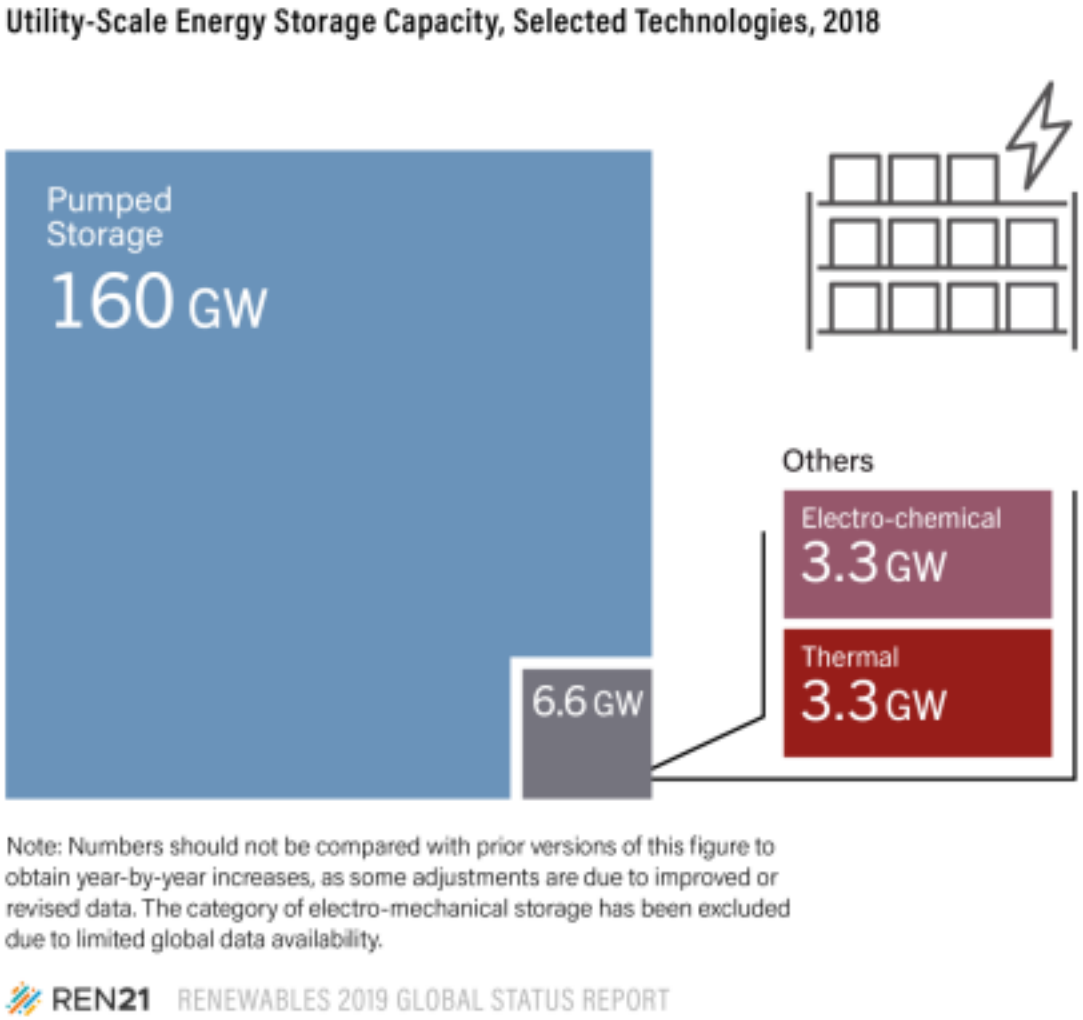

Extresol 2, Spain


Manchasol, Spain


Andasol 3, Spain

Role of Thermal Storage

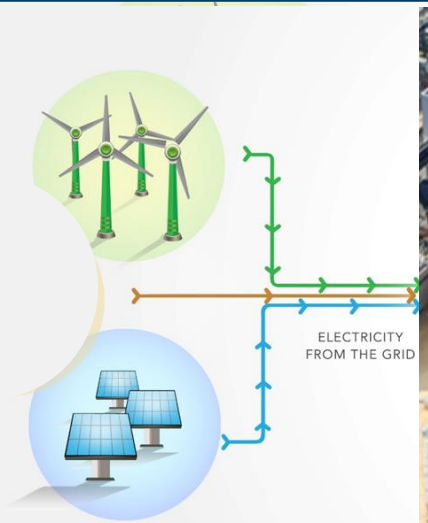
- Global stationary and grid connected energy storage capacity in 2019: 167GWe
- of that 95% is pumped hydro
- of the Non-Pumped Hydro over 40% is molten salt thermal storage

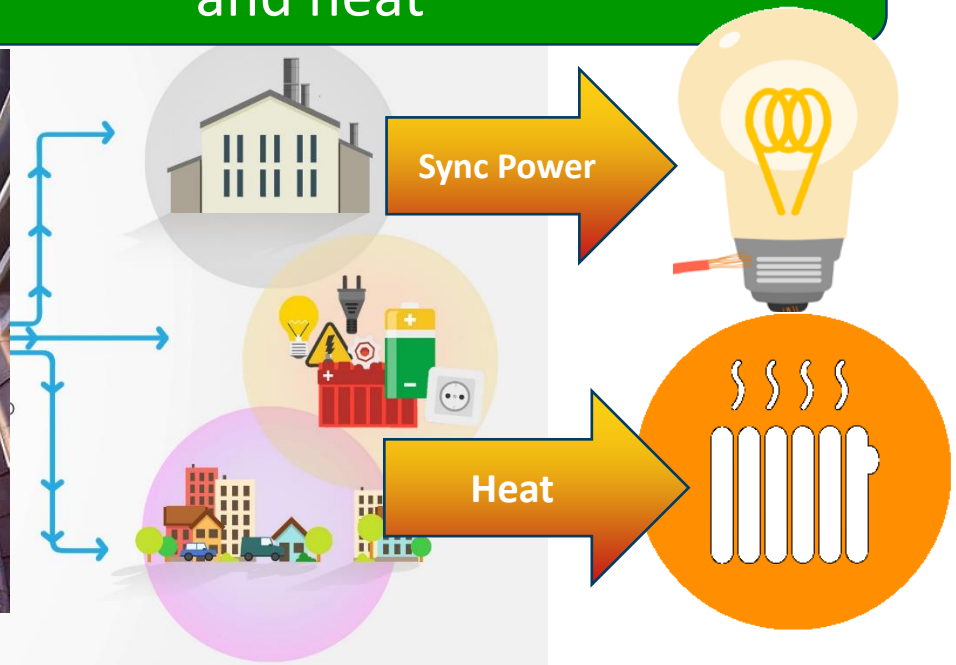


Convert variable renewable into dispatchable sync power

Charge with variable non-sync Renewables

Discharge sync power and heat





Power → to Heat → to Storage → to Power & Heat

Thermal LDES typically offers two major value propositions

Energy shifting

Time horizon	Role of storage	Typical solution
Intraday	Balance variable daily generation with load	**8-24 hours LDES**
Multiday, multiweek	Support multi-day imbalances Absorb surplus generation to avoid grid congestion	**24+ hours LDES**
Seasonal duration	Support during seasonal imbalances Mitigate extreme weather events	**Hydrogen**

Grid services

Grid services offered by LDES

- **Synchronous Inertia**
- **Fast frequency response (FFR)**
- **Primary/secondary/tertiary reserve**
- **Reactive power/voltage control**
- **Short circuit level improvement**
- **System restoration/ black start**

Note: services are technology-specific

McKinsey & Company

Source: Long Duration Energy Storage Council

700MWe 12-15hour molten salt storage in construction now

- Dubai Electricity Water Authority (DEWA) awarded 950MW CSP/PV project in 2017 at a record-low tariff of 73/MWh for a 35year power purchase agreement
- The $4.4 billion Noor Energy 1 solar thermal project will be the world's largest CSP plant and includes a
- 100 MW CSP tower plant with 15hour molten salt storage
- 3x 200 MW parabolic trough plants with 12hours molten salt storage
- 250 MW of PV capacity

https://www.evwind.es/2020/01/30/worlds-tallest-concentrated-solar-power-tower-completed-in-dubai/73309

Storage molten salt and Li mined together in the Atacama

Lithium Mining in the Atacama

Solar Salt Mining ($NaNO_3$ and KNO_3) in the Atacama

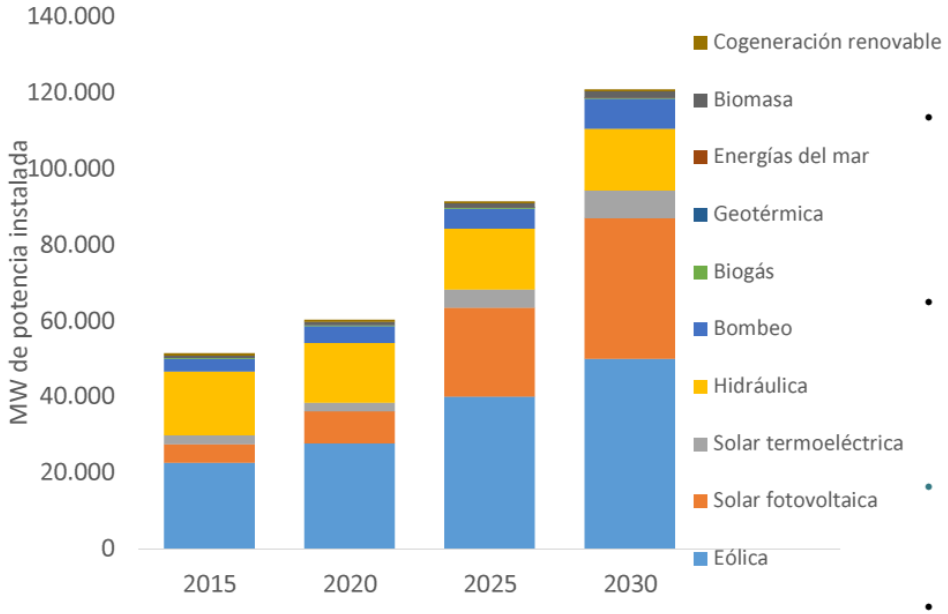
Practical Example: Case of Spain and Iberian Peninsula

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

IDAE Instituto para la Diversificación y Ahorro de la Energía

PNIEC Energía y Clima

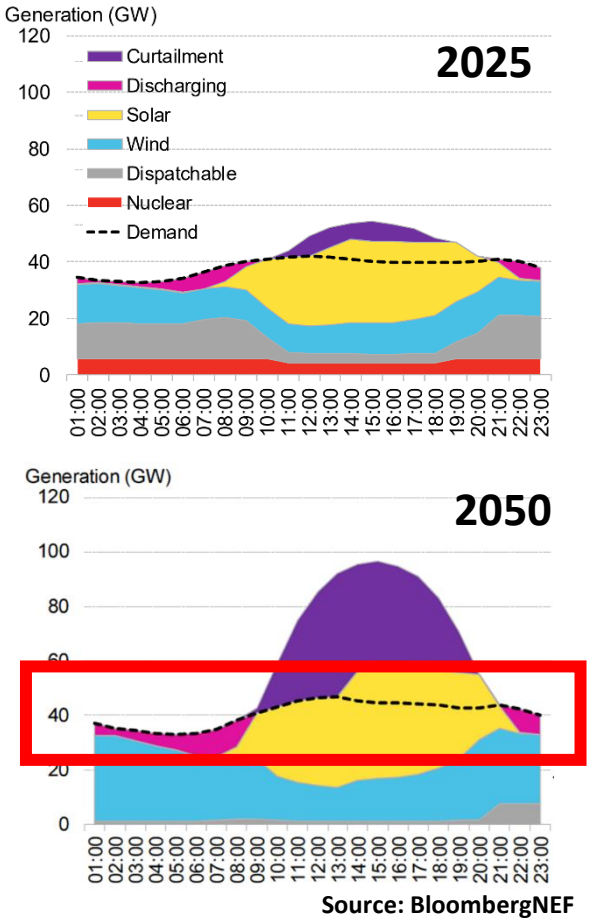
2030 RENEWABLE ELECTRICITY: 74%



Note: the exact breakdown of power generation will depend on the evolution of cost, deployability and performance of each technology (or combination of technologies).

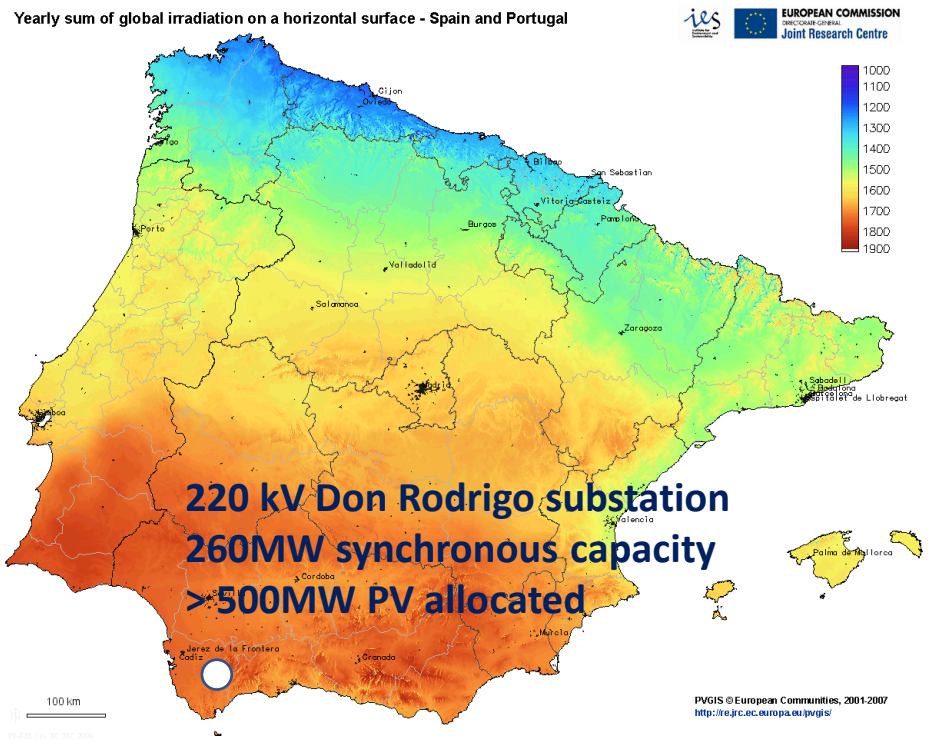
- **57 GW of new RES capacity** (28,5 GW PV, 22,3 GW wind, 5 GW CSP, 0,8 GW biomass, 0,5 GW hydro).
- **6 GW of new storage** (3,5 GW pumped hydro, 2,5 GW batteries) + CSP inherent storage.
- No new fossil capacity needed
- Coal phase-out by market mechanisms 2025-2029

Iberia intraday generation on a spring day



Source: BloombergNEF

First synchronous 100MWe Malta PHES Project in Spain



Solar radiation on Iberia peninsula

- **Synchronous Malta storage opens grid access to 262MW MGES Access capacity of Don Rodrigo substation**
- **Great potential for replication in Southern Europe and MENA**

Energy Storage

EIB grants technical assistance for 100-MW long-duration storage project in Spain

January 20 (Renewables Now) - The European Union and the European Investment Bank (EIB) have granted project development assistance (PDA) to Malta Iberia Pumped Heat Electricity Storage SLU (Malta Iberia), an affiliate of US-based long-duration energy storage developer Malta Inc.

Batteries, CC0 licensed from Pixabay

Malta Inc said that the PDA agreement will enable it to pursue the development of its 100-MW Sun2Store thermal energy storage project in Spain. The company's solution, which it says would be the first of its kind in Europe, combines pumped heat technology with molten salt to provide 1,000 MWh and store energy for ten hours.

Malta has partnered with Sweden's Alfa Laval AB (STO:ALFA) on heat exchangers for this project, and with Germany's Siemens Energy AG (ETR:ENR) on turbomachinery.

The European Innovation Fund, executed by the EIB, selected Malta Iberia's Sun2Store proposal out hundreds of applications, Malta said. Through the PDA support, Malta Iberia secures technical assistance and independent technology assessment, the company added.

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GreenYellow gets USD-25m Proparco investment for decentralised solar in South-

BayWa CEO slams draft EU taxonomy

Jan 25, 2022 15:46 CEST

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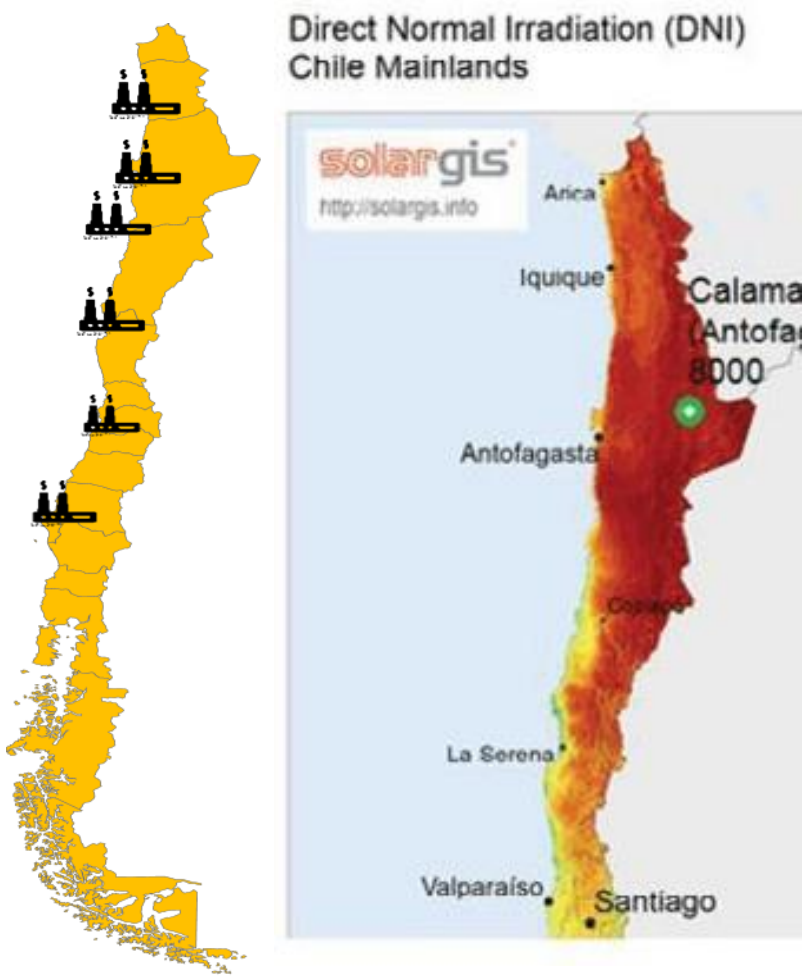
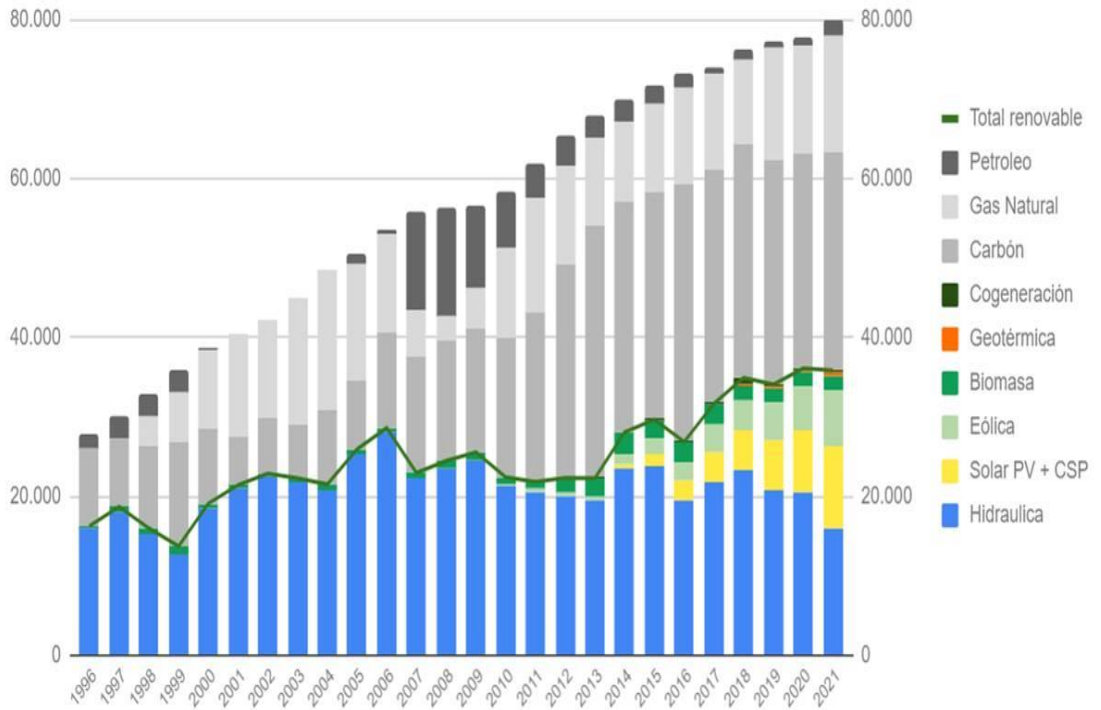
https://renewablesnow.com/news/eib-grants-technical-assistance-for-100-mw-long-duration-storage-project-in-spain-770040/

Practical Example: Case of Chile





Variable renewables rise since 2014

Decline of hydropower since 2015

Coal-exit started in 2019

2005: First gas crisis

2008: Gas crisis peaks

2009: First LNG Terminal built

https://live.invitario.com/en/exit-coal-enter-future/registration/

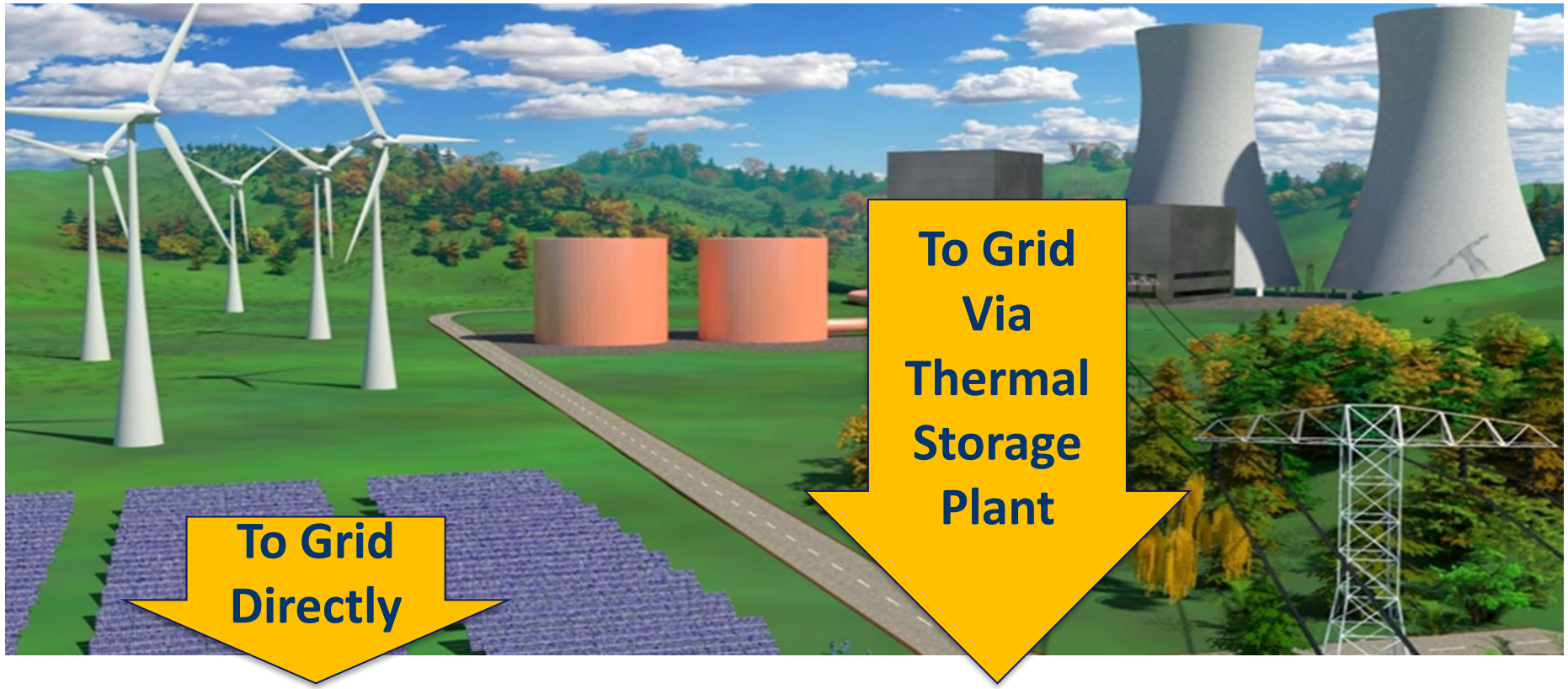
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Why considering repurposing coal plants in Chile?

- Relatively new installations
- Utilizing existing infrastructure:
  - Power generation assets
  - Transmission lines
  - Substations
  - Port facilities
  - Water collection (water rights)
- Maintaining jobs at power plant sites for fair transition
- Power plants are installed in strategically important locations of the existing power system
- Decommissioning is lengthy, costly and has legal uncertainties, etc.

- Case Study: Retrofit the 251MWe Angamos U1 coal plant with molten salt thermal energy storage
- Shut down the coal boiler and substitute it by a molten salt storage system
- Vary discharge time from 5 – 14hours
- Charging with renewable electricity at 20USD/MWhe

24/7 Solar Dispatchable Clean Electricity at 50USD/MWhe



Sunrise to sunset: 20USD/MWhe

Sunset to sunrise: 80USD/MWhe

50USD/MWhe average annual cost for 24/7 dispatchable clean electricity

Malta Teamed Up with Duke Energy to Study Possibility of Converting Coal Units into Clean Energy Storage Facilities

May 19th, 2021: Malta Inc. has teamed up with Duke Energy to study the socioeconomic, environmental and operational benefits of converting retiring coal units into long-duration, zero-emissions energy storage systems by integrating Malta's 100-megawatt, 10-hour pumped heat energy storage system into existing infrastructure at a Duke Energy coal plant in North Carolina with the potential benefits including:

- **Job retention**
- **Local economic impacts**
- **Environmental benefits**
- **Operational benefits**

The goal is to scale technologies that are currently too expensive to compete with fossil-fuel-based incumbent technologies.
A U.S. Department of Energy grant is funding the year-long study of the emerging technology.
https://news.duke-energy.com/releases/malta-teams-up-with-duke-energy-to-study-possibility-of-converting-coal-units-into-clean-energy-storage-facilities

Malta teams up with Duke Energy to study possibility of converting coal units into clean energy storage facilities

Novel approach to turn coal plants into energy storage stations

MAY 24, 2021 TIM SYLVIA

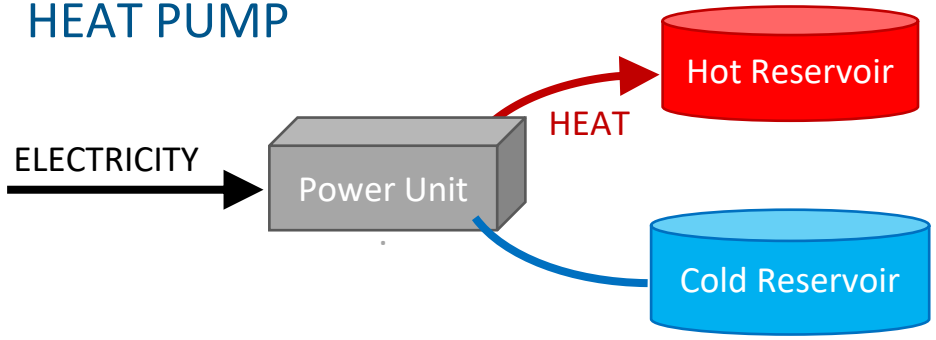
UTILITY SCALE STORAGE UNITED STATES

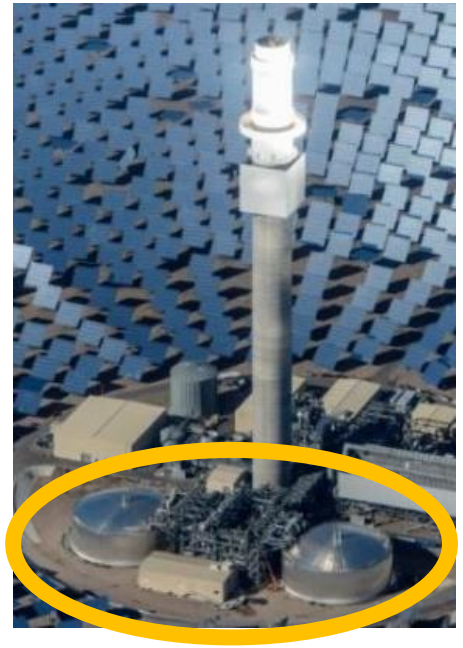
Duke Energy coal-fired power plant

https://www.pv-magazine.com/2021/05/24/novel-approach-to-turn-coal-plants-into-energy-storage-stations/

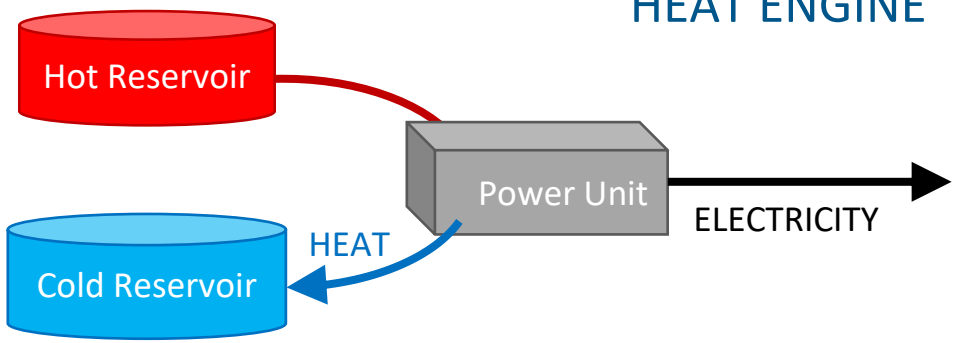
Malta Pumped Heat Electricity Storage - How It Works

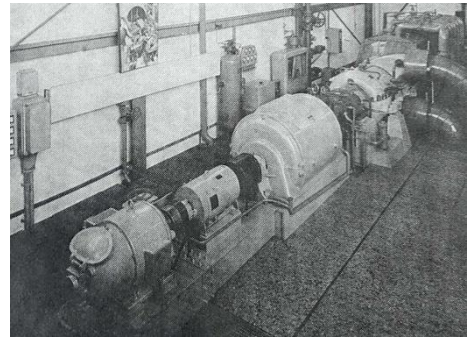
Consumption (Charge): HEAT PUMP



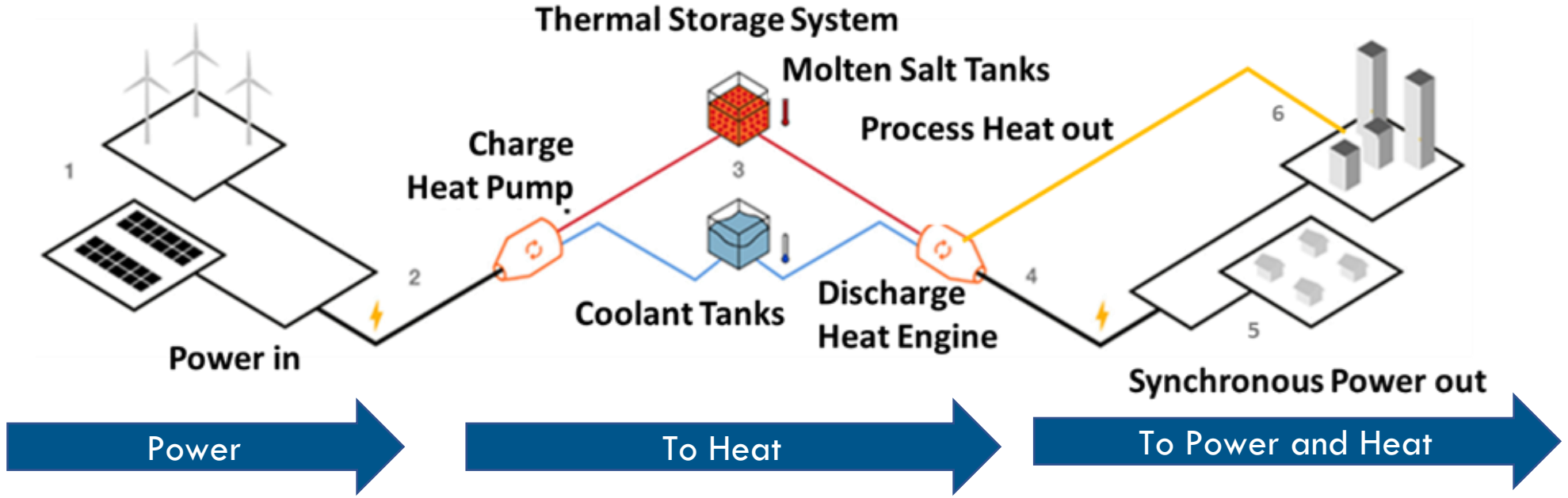


Generation (Discharge): HEAT ENGINE



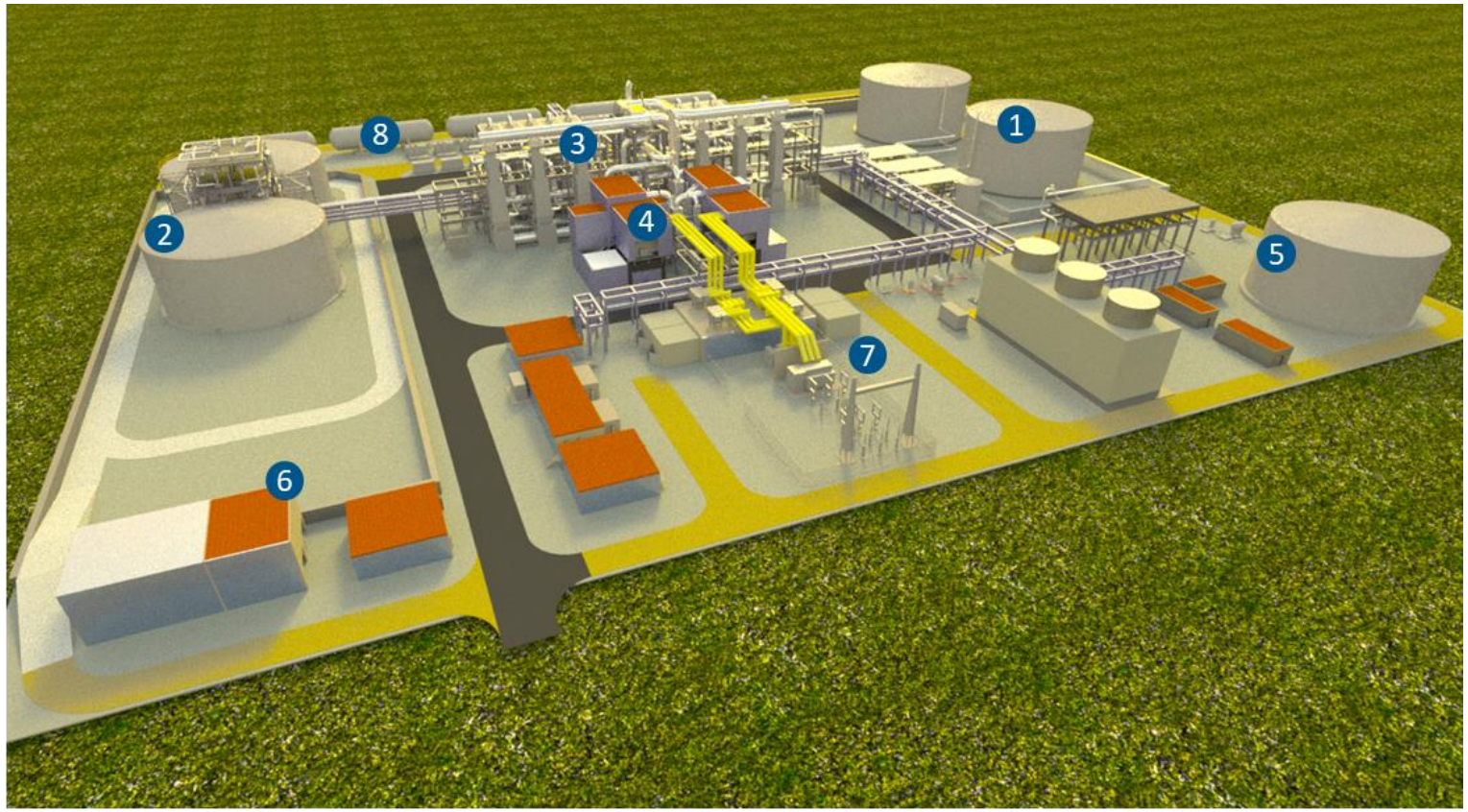


Breakthrough Grid-Scale Synchronous Energy Storage



1. **Collects**. Renewable energy is collected from co-located or grid-connected wind or solar farms—or any other generation source
2. **Converts**. The electrical energy that is collected drives a heat pump, which is a machine that uses electricity to move heat from a colder location to a hotter location, effectively "converting" electricity to stored thermal energy.
3. **Stores**. The heat is stored in hot molten salt and the cold is stored in a cold coolant.
4. **Reconverts**. The heat stored at the large temperature difference between the hot and cold tanks is used to drive the heat engine and reconvert the stored thermal energy back into electrical energy when it is needed. Useful process heat is released by the heat engine
5. **Dispatches**. On demand synchronous electrical power is sent back to the grid or end – the heat engine is a turbomachinery train with rotating inertia
6. **Heats**. Useful process heat for industry and/or district heating/cooling is released by heat engine at discharge

Malta M100 3D Layout

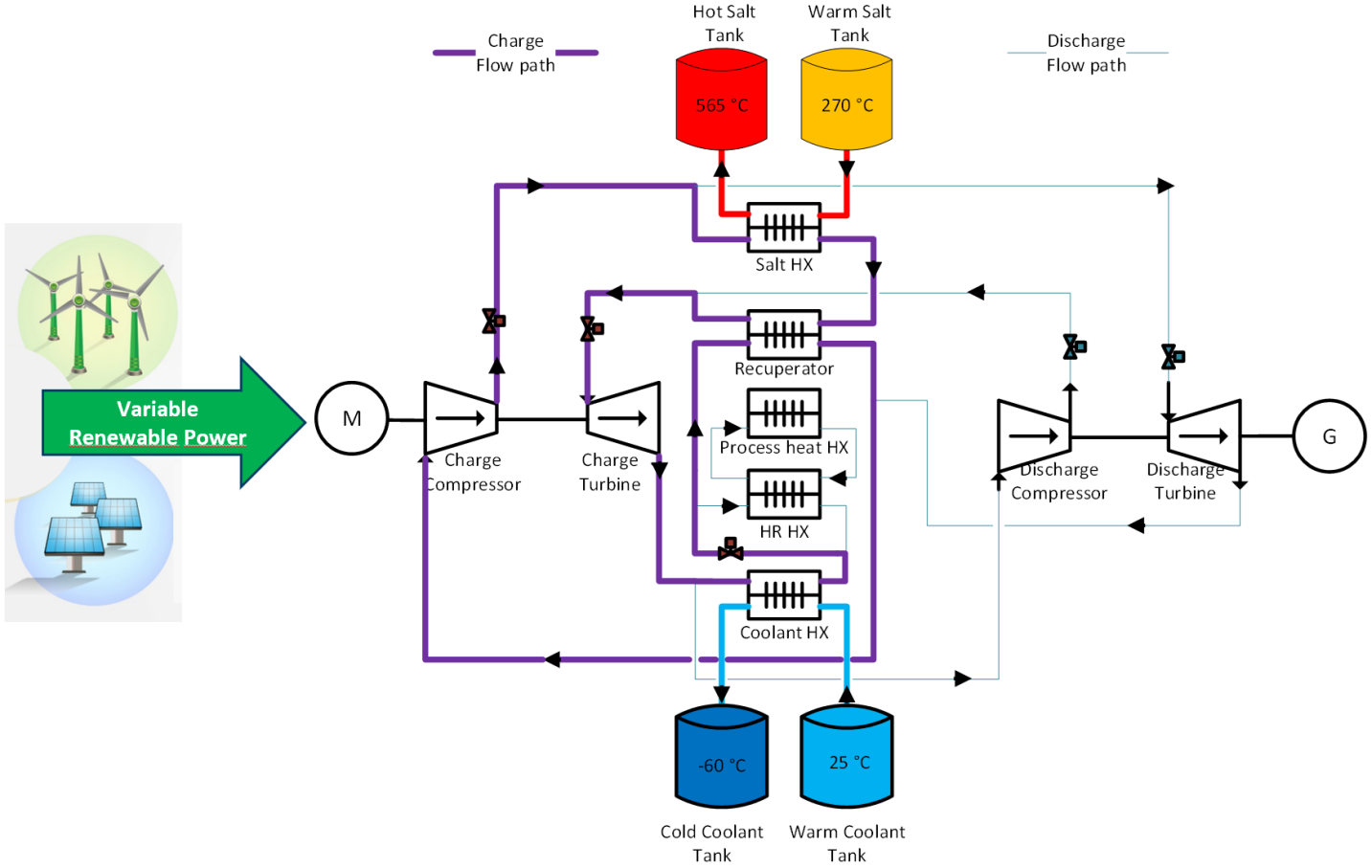


1 Coolant tanks
2 Molten salt tanks
3 Heat Exchangers
4 Turbomachinery
5 Fire Control
6 Controls
7 Switchyard
8 Inventory Control System

Malta Electricity Charge Cycle

During the charge cycle, the system works as a heat pump, using the charge power to pump heat from the cold reservoir (coolant tanks) to the hot reservoir (molten salt tanks), achieving a Coefficient of Performance (COP) of around 1.4.

<u>The process:</u>
The working fluid, air, is compressed and heated up in the compressor and then transfers its heat to the molten salt. The air is then cooled down in the recuperator, expands in the charge turbine and then picks up heat again from the coolant, decreasing the coolant´s temperature. It gets heated up further in the recuperator and then enters the compressor again.

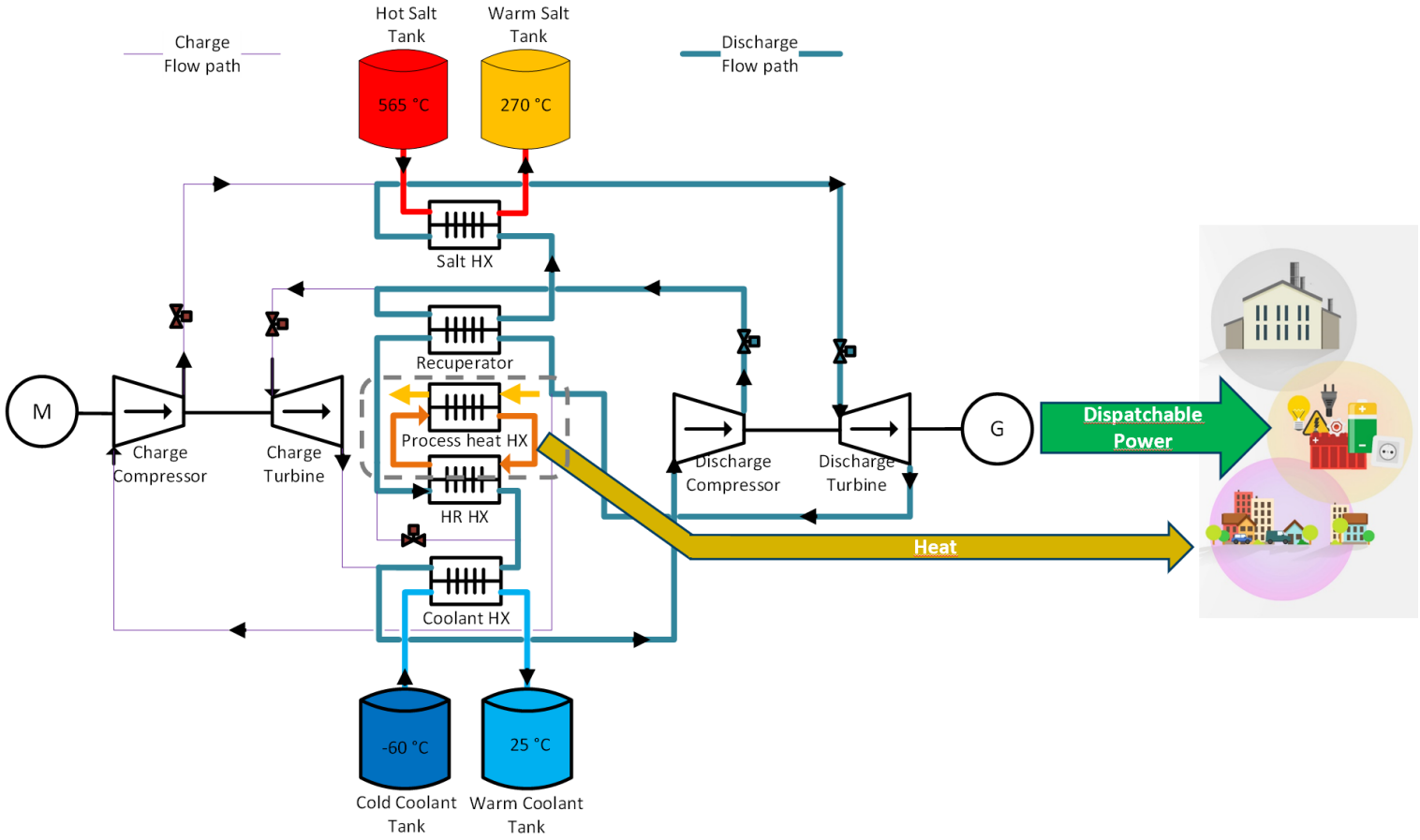


Malta Electricity Discharge Cycle

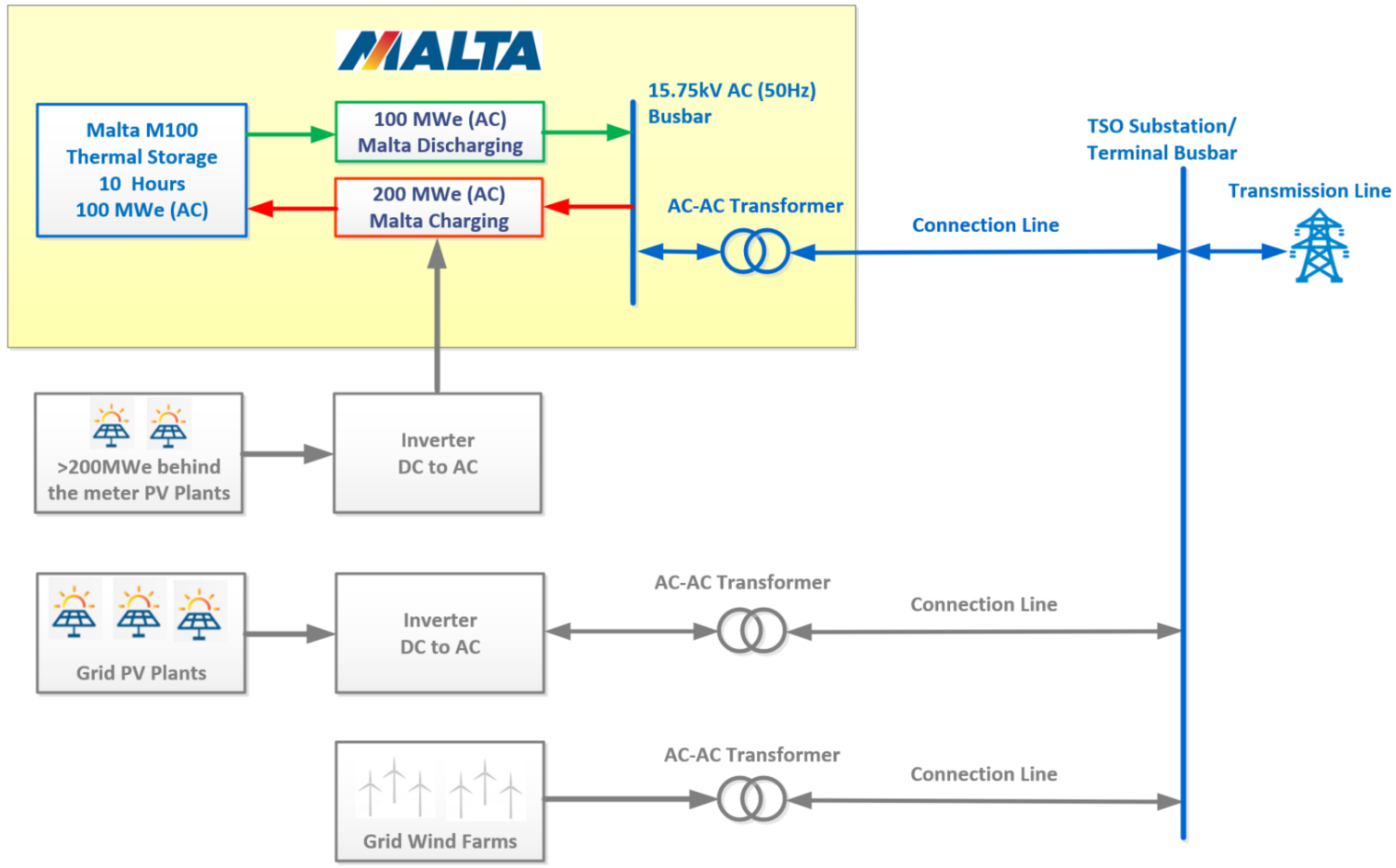
During the discharge cycle, the heat stored in the hot reservoir (molten salt tanks) is converted back into electricity at high efficiency in a closed gas turbine cycle. The residual heat flows back into the cold reservoir (coolant tanks).

<u>The process:</u>

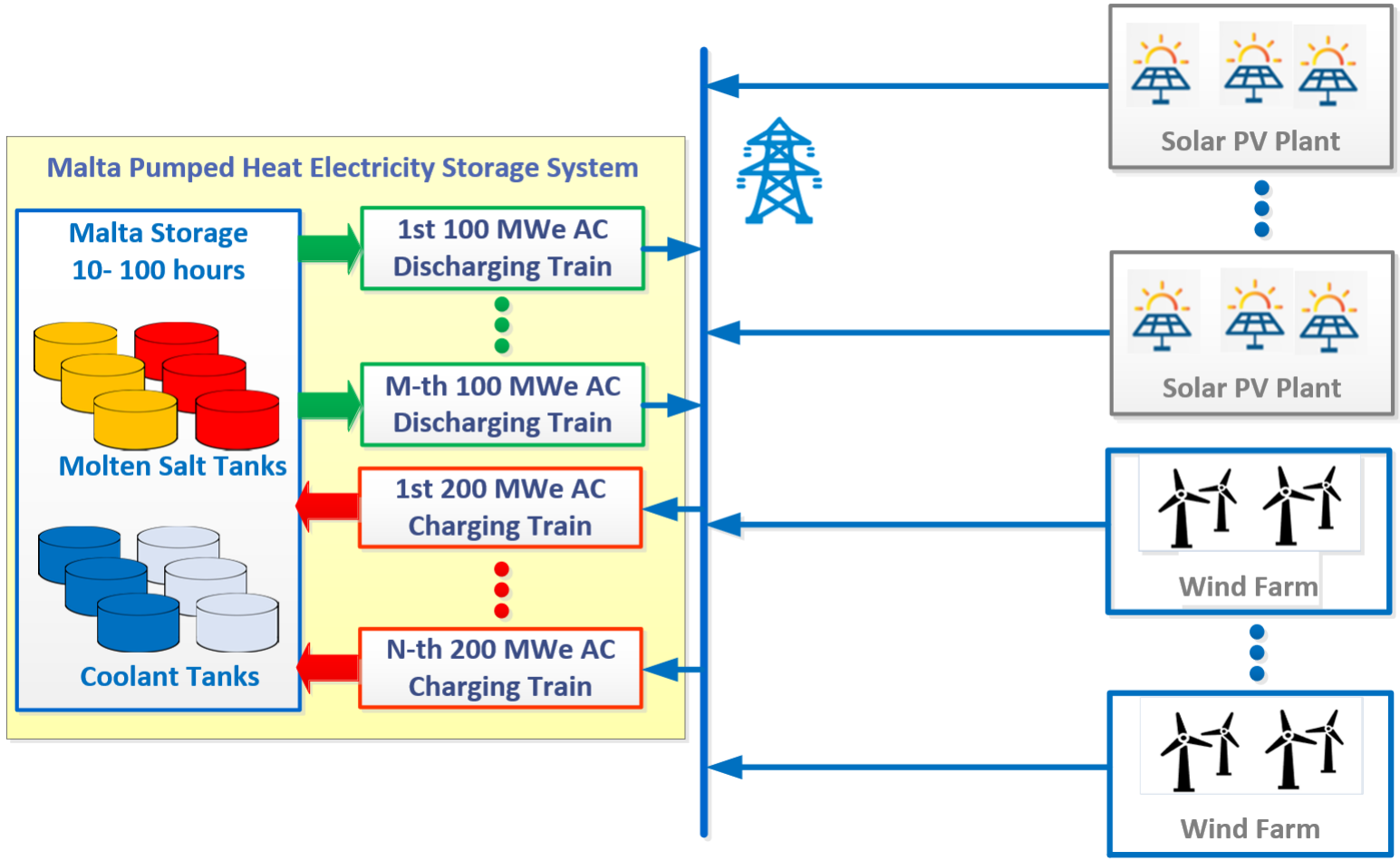
The working fluid, air, is compressed in the discharge compressor, heated up in the recuperator and then further in the molten salt HX. It drives the discharge turbine-generator which provides electricity to the grid. The air is then cooled down in the recuperator, the heat recovery HX and the coolant HX before it enters the compressor again. The waste heat from the cycle can be used as process heat at 120 °C.



Malta M100 Storage Interconnection Options



Flexible Scale-Up of Capacity, Charge and Discharge



PHES Pilot System at South West Research Institute, USA

- **Southwest Research Institute (SwRI) Pilot demonstration of shared hot, cold, and recuperator heat exchangers, liquid hot thermal storage and liquid cold thermal storage—and functions as a small-scale pilot system of the Malta technology**
- **Design and construction of a pumped heat energy storage system with the same basic architecture as the Malta system—charge heat pump powertrain and discharge heat engine powertrain**

Thank You

Long-Duration
10 - 24+ Hours

Grid-Scale
100 MW+

Low-Cost
<€200/kWh

MALTA