

Webinar on Carnot Batteries

From CoalAge to StorAge

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Wissen für Morgen





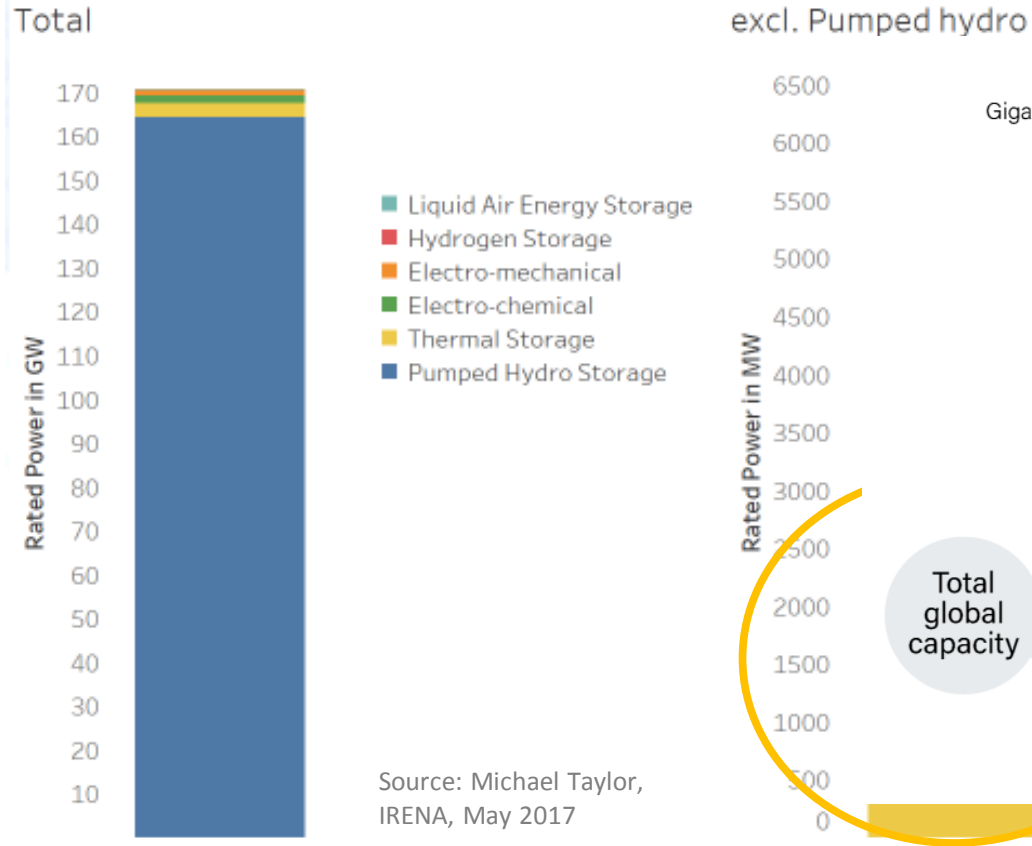
Adapted from EcoEnlightened Charitable Org. Inc.

The Malta Carnot Batteries for “The Age of Storage”

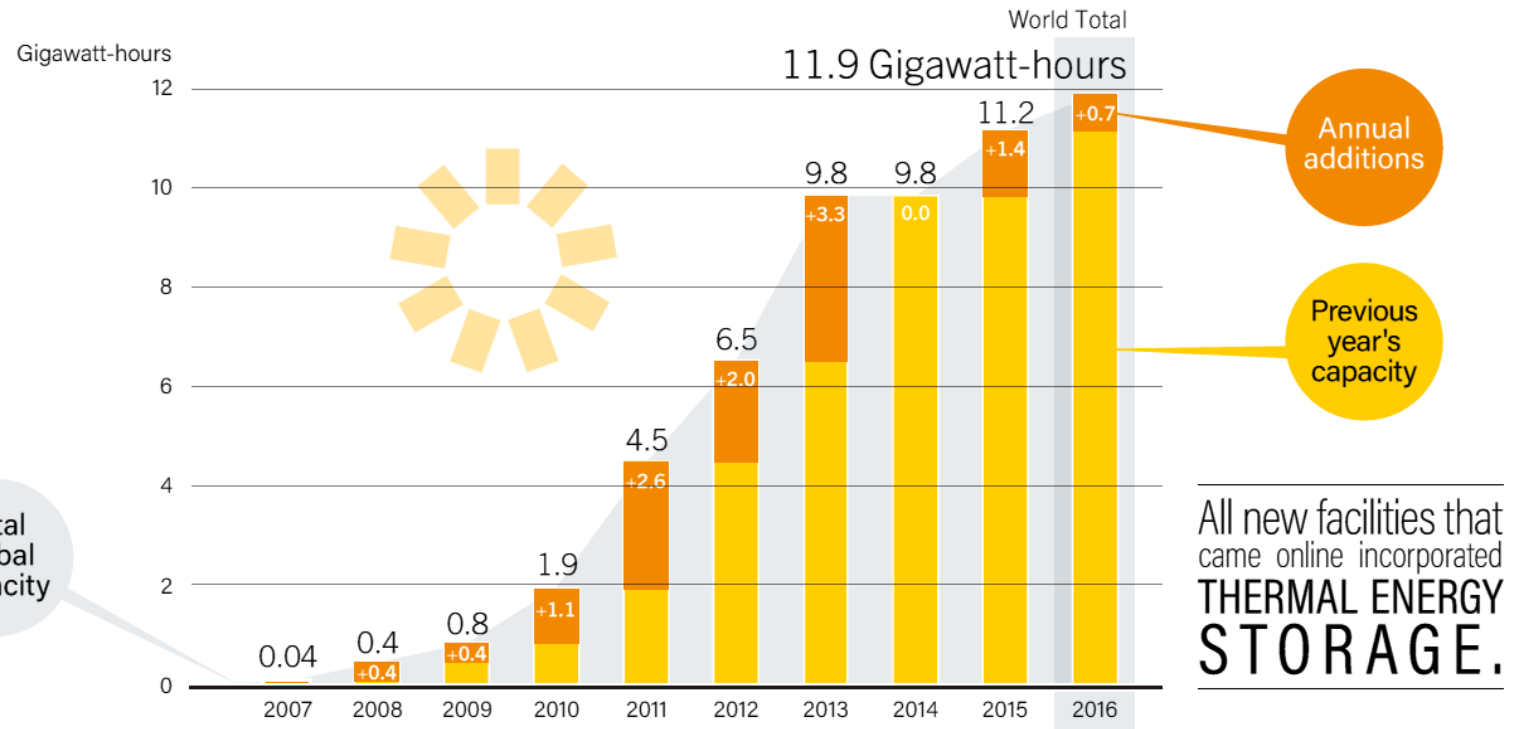
Sebastian Freund, Ph.D

By 2017 there were more MS Carnot-Batteries than electro chemical Batteries

World Storage Capacity in MW by 2017



World Thermal Energy Storage Capacity in GWh by 2016



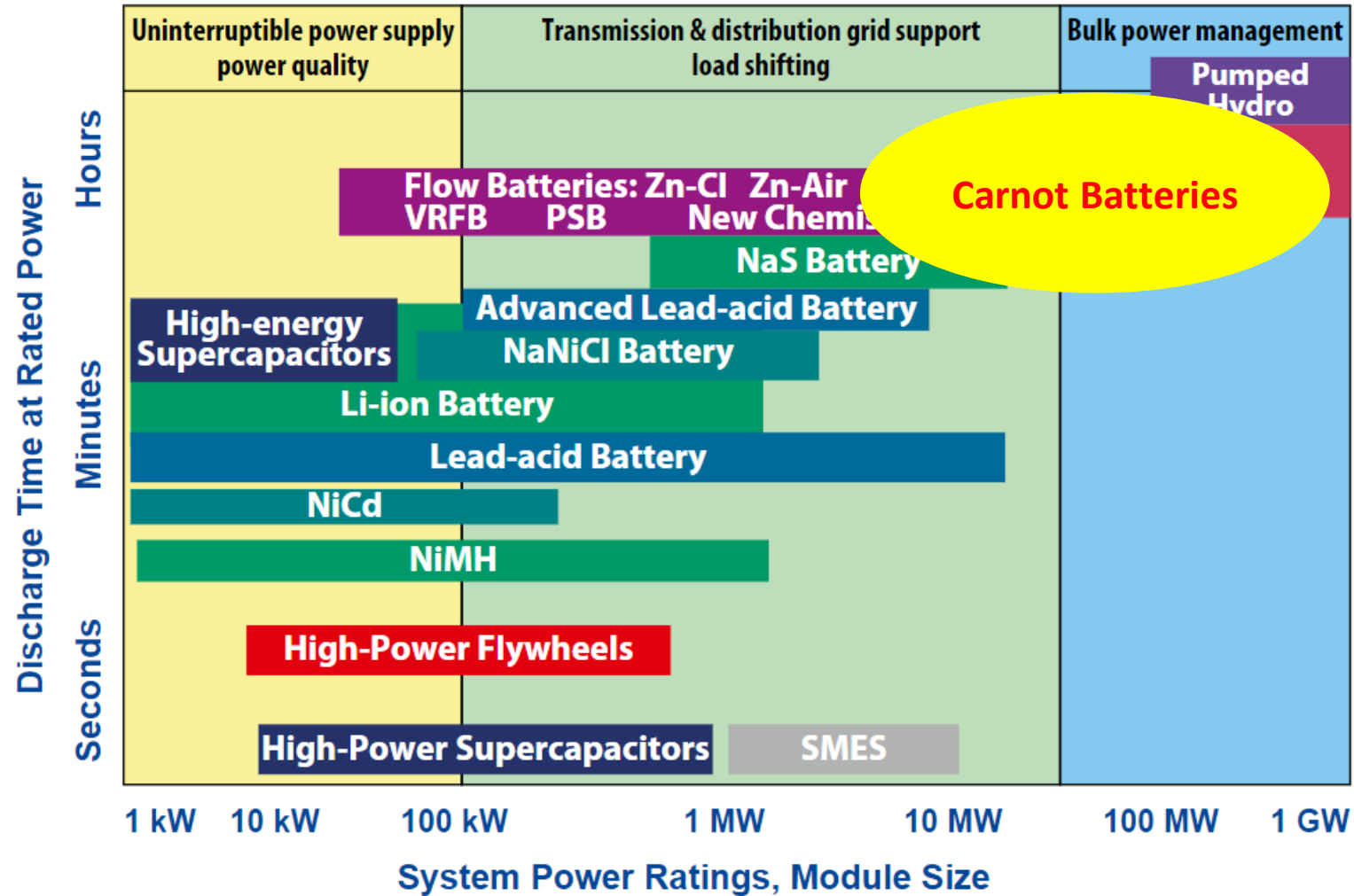
Source: REN21. 2017. Renewables 2017 Global Status Report (Paris: REN21 Secretariat). ISBN 978-3-9818107-6-9

<https://www.irena.org/-/media/Files/IRENA/Costs/Slides/Battery-storage-Council-23-May-2017-MICHAEL-TAYLOR-PDF.pdf?la=en&hash=B61257FC3AB1AF0C516EA8D241890DD426980974>

http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

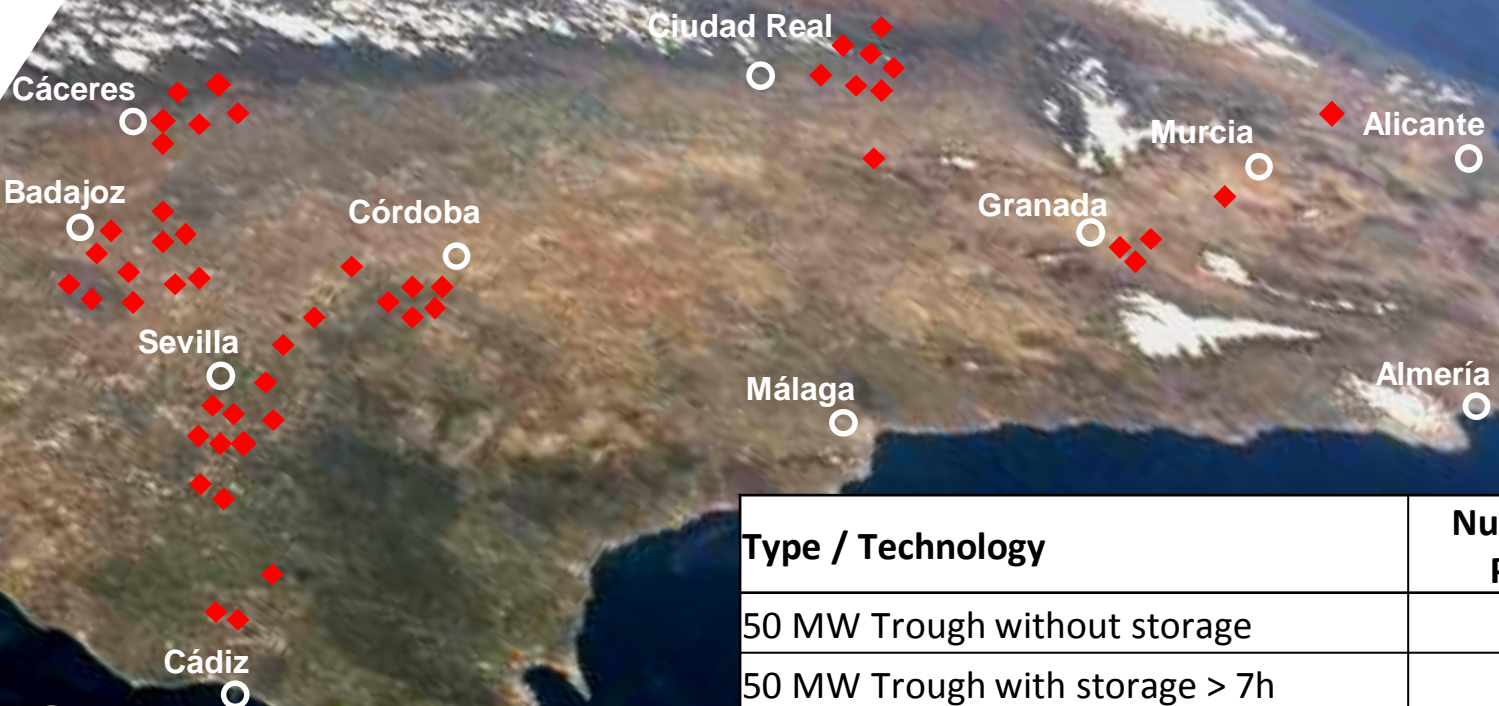


Application of Carnot-Batteries



In Spain 17 plants of this type were built with 6500MWh storage

◆ 2018 Spanish CSP plants in operation (49 plants / 2300 MW)



Type / Technology	Number of Plants	Capacity (MW)	Storage (MWh)
50 MW Trough without storage	27	1350	0
50 MW Trough with storage > 7h	17	850	6500
Towers with sat. steam receiver	2	31	31
Tower with molten salt receiver and storage > 15h	1	20	300
Fresnel linear reflectors	1	30	0
Hybrid Parabolic trough with Biomass	1	22	0
TOTAL	49	2303	6831

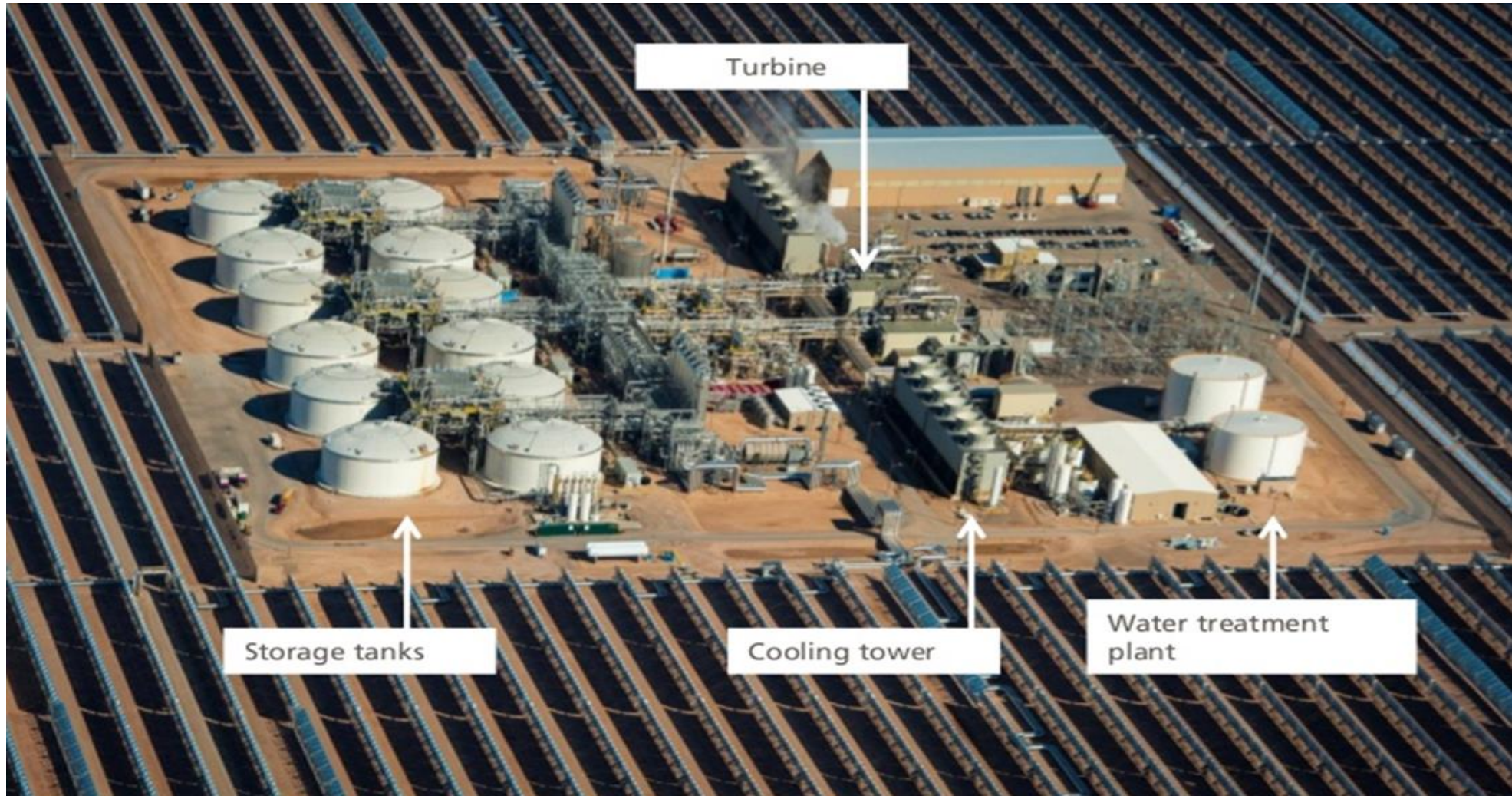
PROTERMO
SOLAR



**In 2012 world's largest molten salt storage system started operation
- the 6-hour storage of 280-MW Solana plant in Arizona**



In 2012 world's largest molten salt storage system started operation - the 6-hour storage of 280-MW Solana plant in Arizona



Source: Abengoa



Most recent: 150MWe molten salt tower at Noor 3 in Morocco - with 7.5 hour 565°C high temperature molten salt storage



Location: Oarzazate , Morocco (DNI 2.635kWh/m²yr)

Source: Masen, Acwa, Sener



Most recent: 150MWe molten salt tower at Noor 3 in Morocco - with 7.5 hour 565°C high temperature molten salt storage



Source: Masen, ACWA, SERI



German Coal Commission published Jan 28, 2019
its report to step out from coal by 2038

Today 46GW coal plants

- 2022 to be shut down 7GW
- 2030 to be shut down 23GW
- 2038 to be shut down remaining 23GW

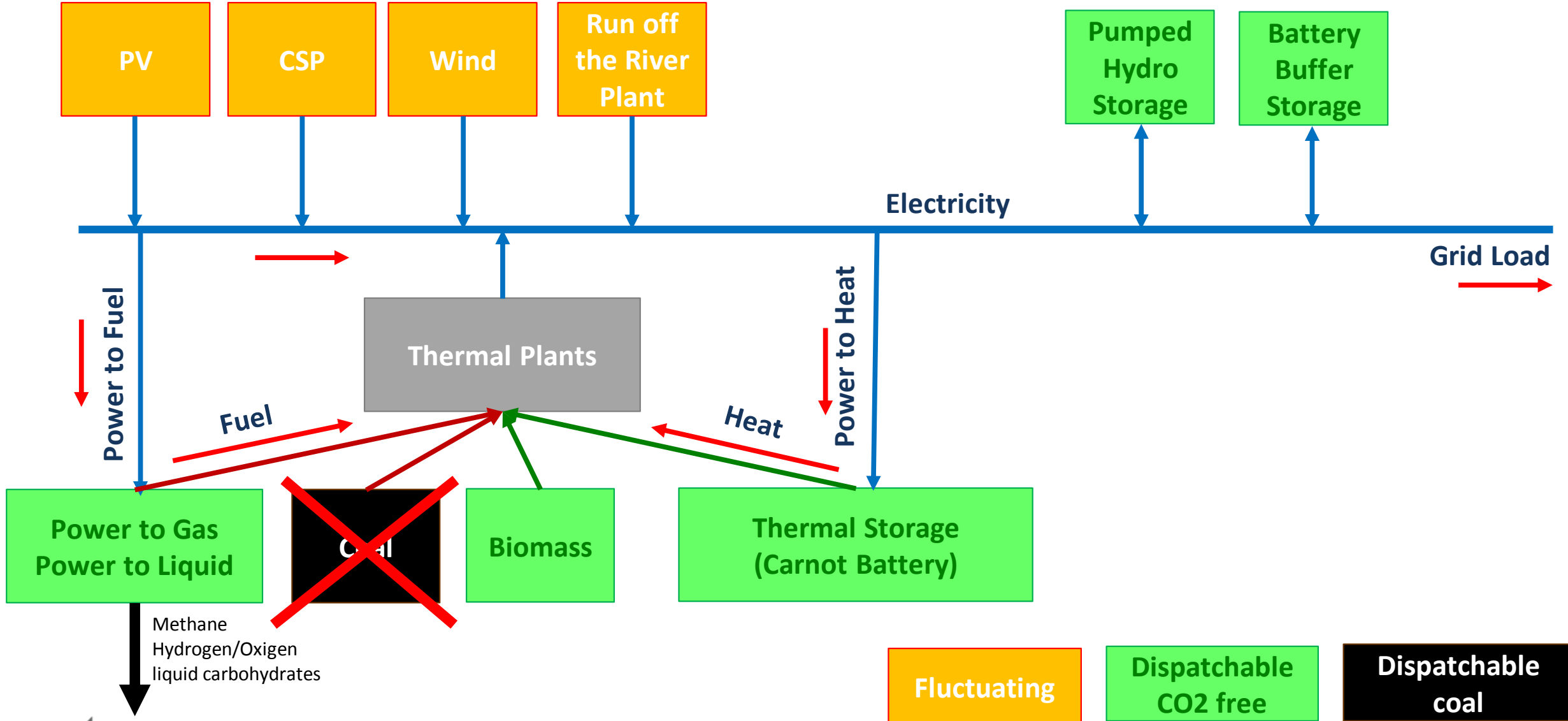


German renewable gross production to be increased to 65% by 2030

- from 38% in 2018
- to 65% in 2030
- and 85% in 2050



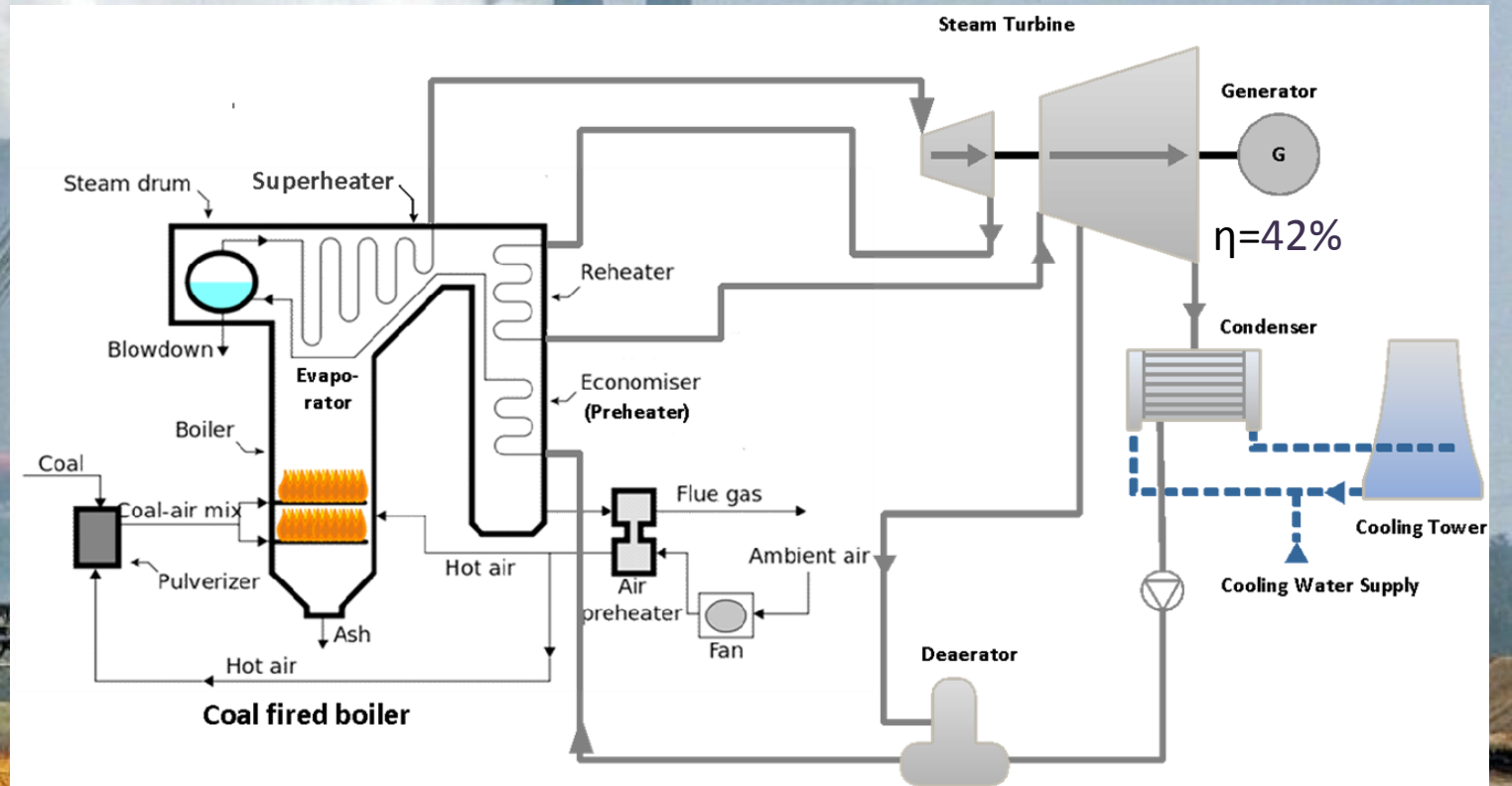
Carnot Batteries for decarbonization



Conversion of existing coal plant in a Carnot Battery thermal storage plant

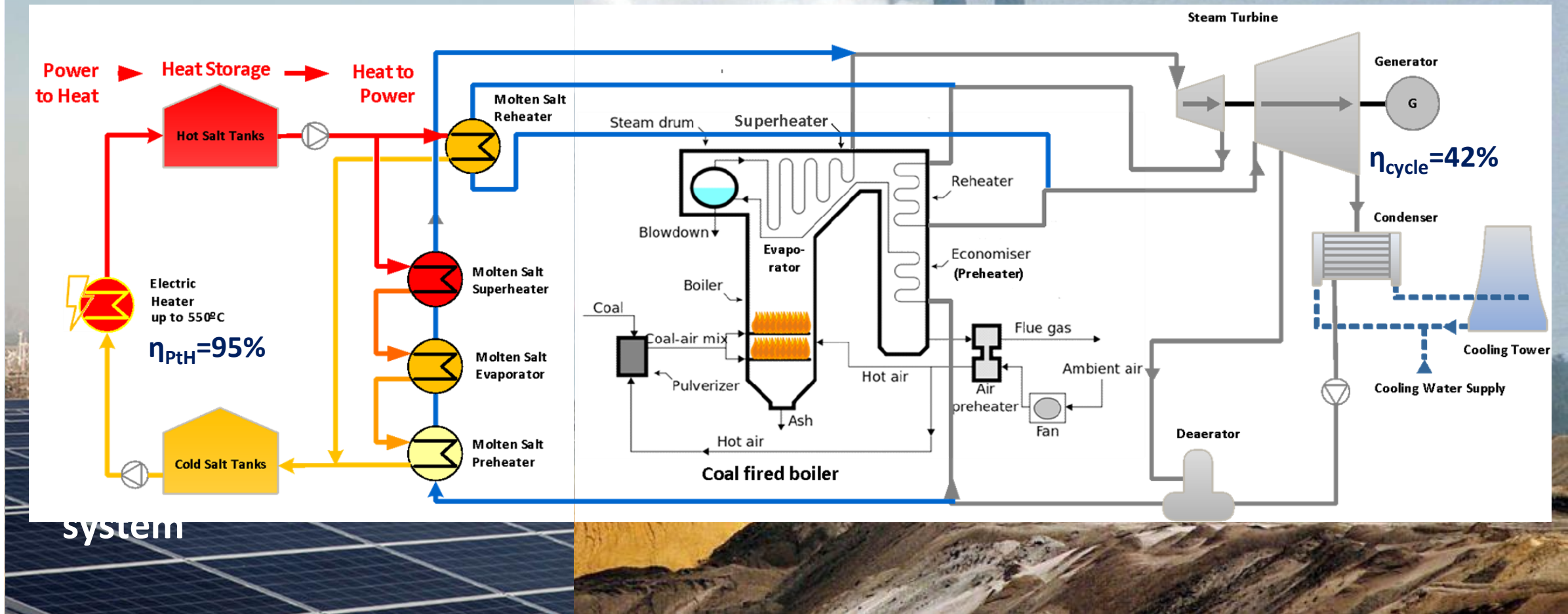


Conversion of existing coal plant in a Carnot Battery thermal storage plant



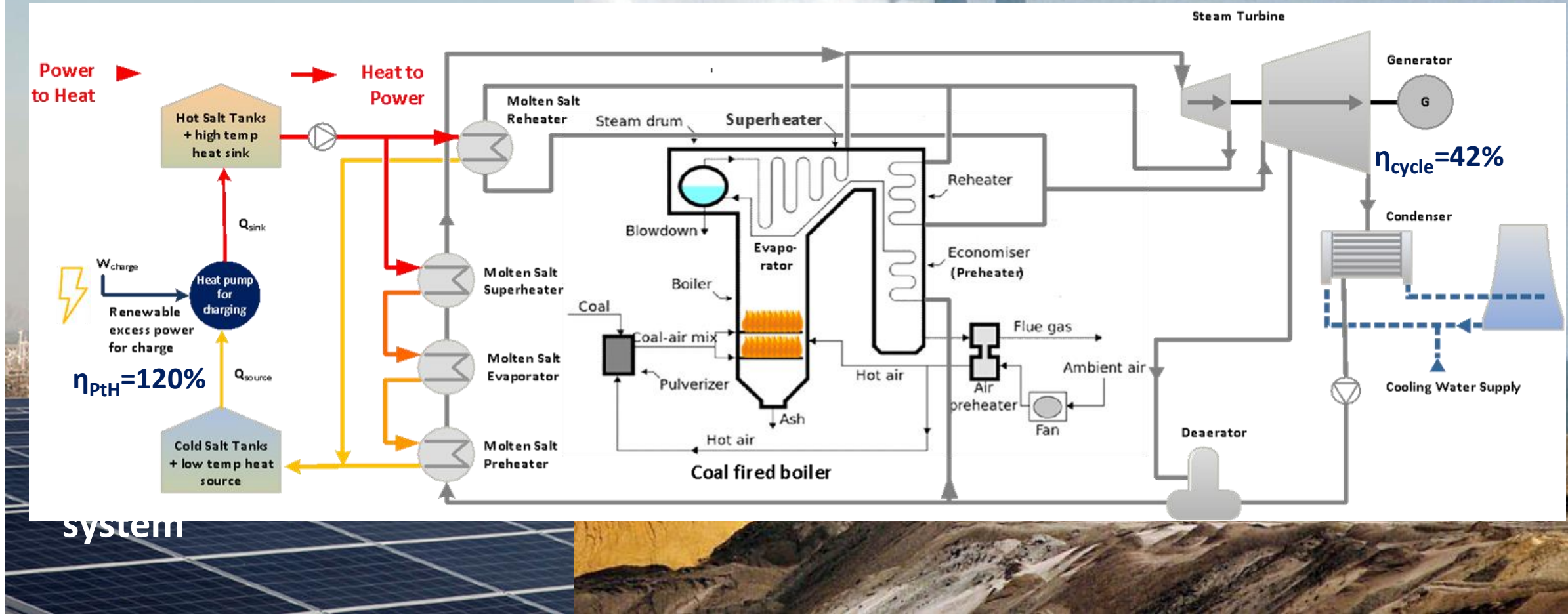
Addition of the molten salt storage island to the existing Rankine Cycle

Phase 1: Pilot integration of molten salt storage in existing coal plant – proof of concept $\eta_{\text{roundtrip}} = 40\%$



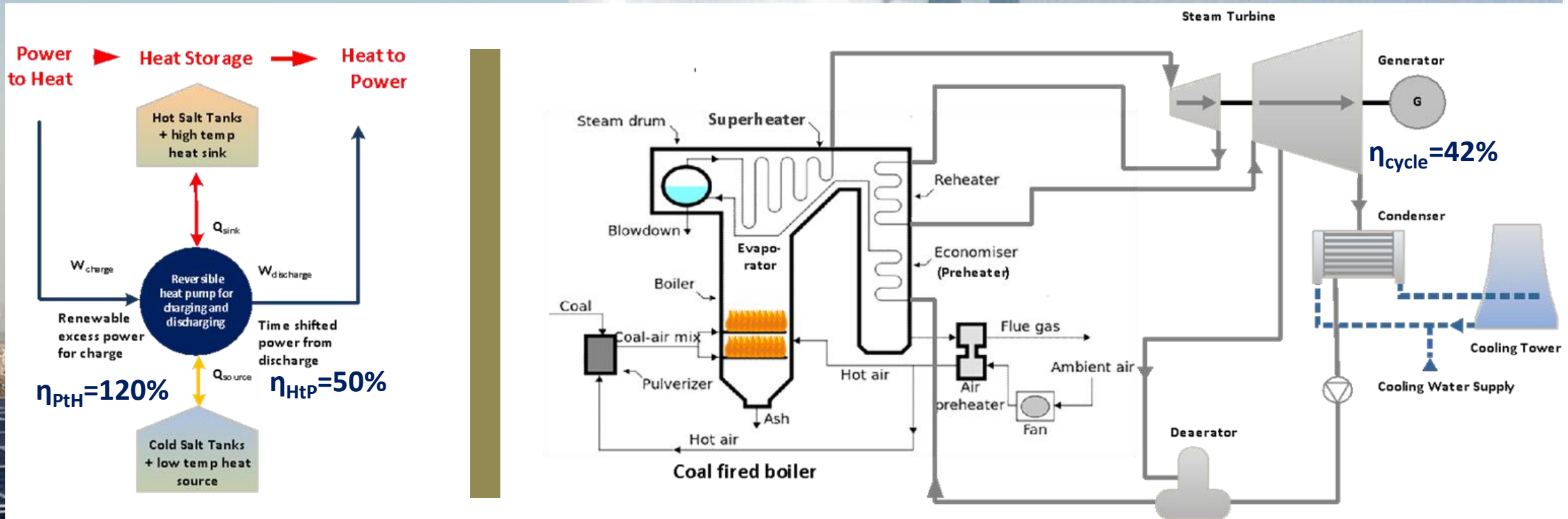
Substitution of resistance heater with heat pump to improve charging efficiency

Phase 2: Substitute resistance heater by heat pump for charging – proof of concept $\eta_{\text{roundtrip}} = 50\%$



Conversion of existing coal plant in a Carnot Battery thermal storage plant

Phase 3: Pilot demonstration of reversible heat pump – proof of concept $\eta_{\text{roundtrip}} = 60\%$



system

Malta Grid-Scale Energy Storage

Electricity
from the
Grid



Electricity
back to the
Grid When
it is Needed

Technology Overview

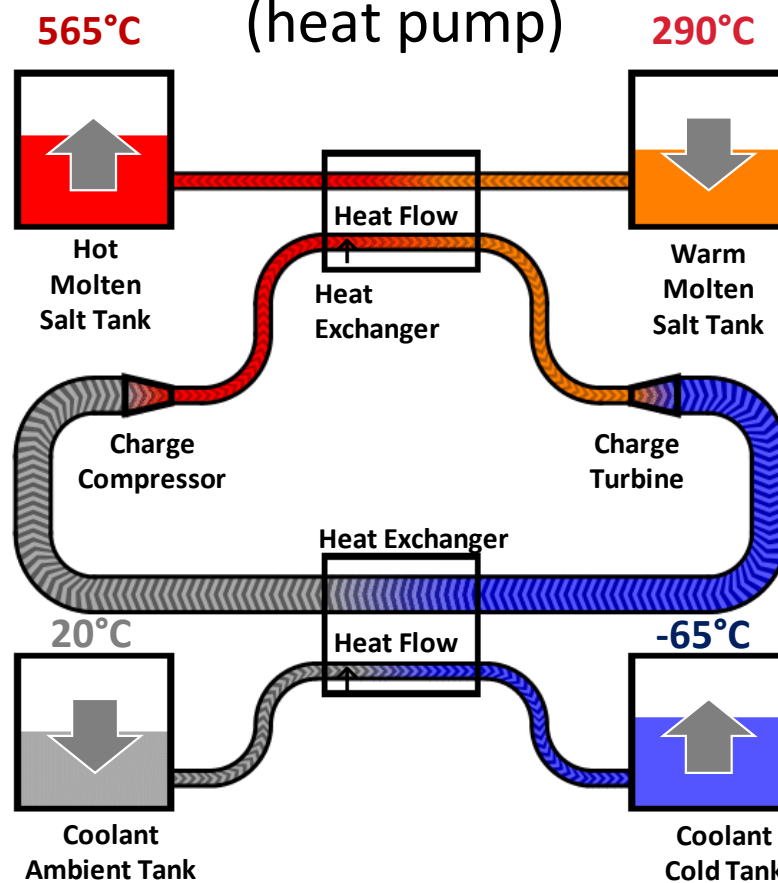
Unique features:

- Air working fluid
- Liquid storage
- Hot & Cold

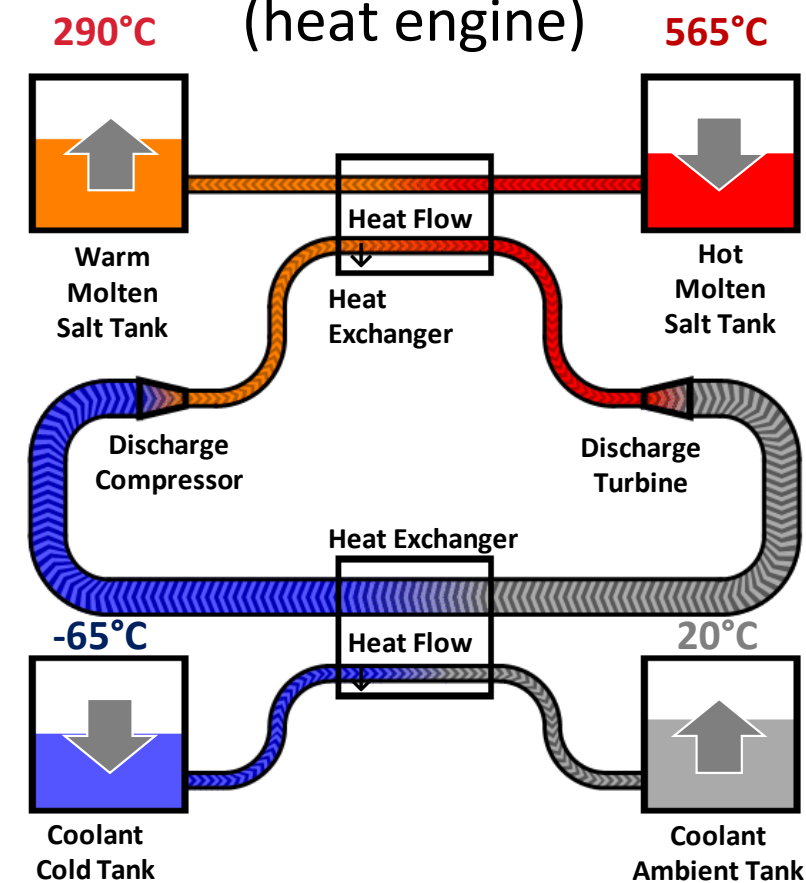
“New” Component Challenges

- Custom TM
- Affordable low-temperature coolant
- Affordable large heat exchangers

Charge Mode (heat pump)



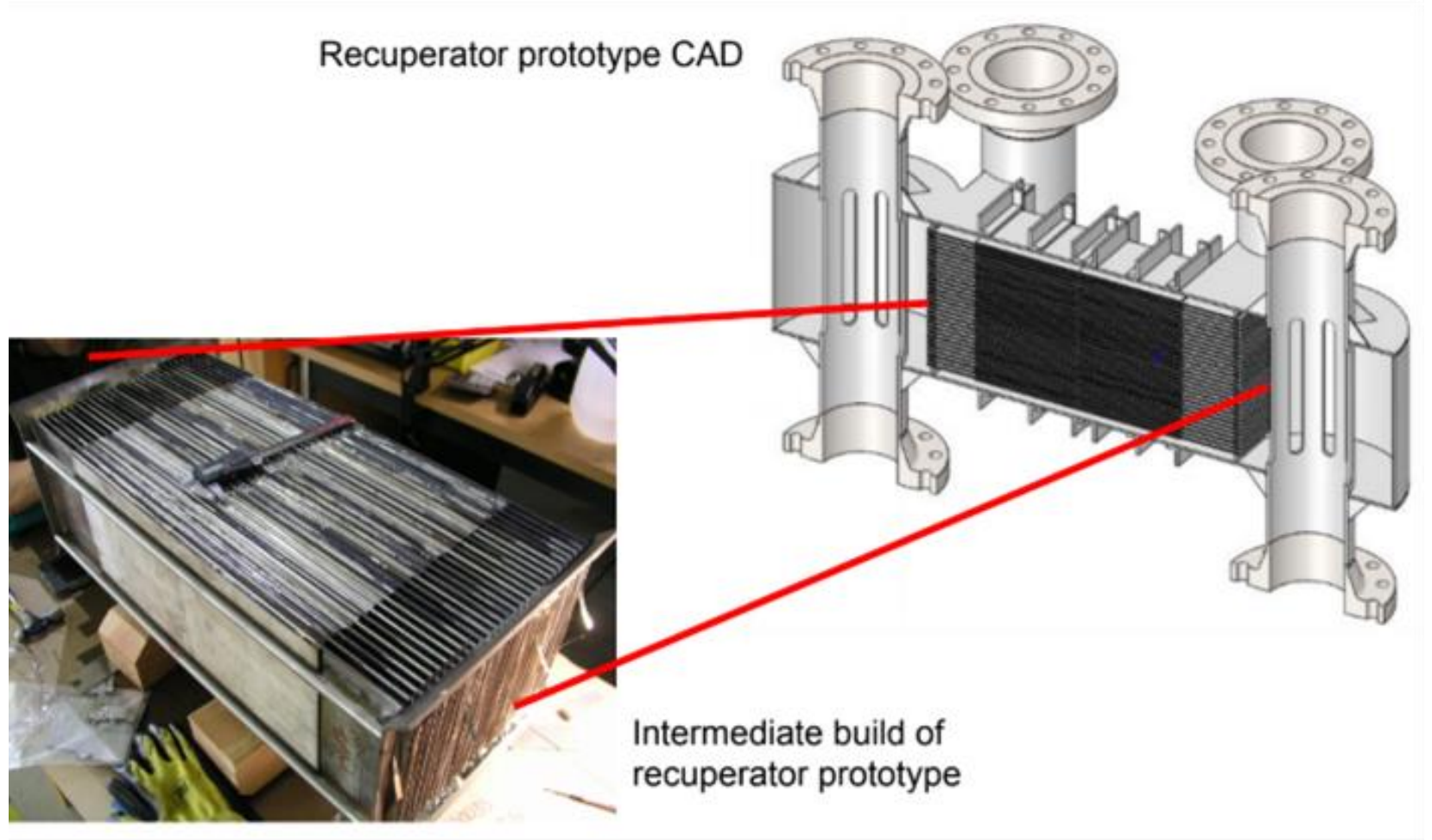
Discharge Mode (heat engine)



Heat Exchangers

Minichannel PFHX

- Developed by contractor
- Test unit manufactured and tested
- Next: plant-scale design and manufacturing by OEM partner



Turbomachinery

Axial “Gas Turbine” units for charge and generation

- Developed by contractors
- Small-scale design CFD and CAD for feasibility
- Next: plant-scale design, manufacturing by OEM partner



Plant Design - Modeling and CAD

Major component layout and CAD rendering

- 10MW and 100MW plant design
- CAD developed by contractor
- Control concept, steady and transient simulation models
- FEED and detailed engineering by EPC partner

