Batería Carnot, una alternativa posible

Repurposing of existing coal-fired power plants into Thermal Storage Plants for renewable power in Chile

Dr. Ing. Michael Geyer, Dr.rer.nat. Franz Trieb, Stefano Giuliano (DLR)
Rainer Schröer (GlZ)
Results from GlZ Contract PN: 69.3020.0-001.00
“Decarbonization of the Chilean Energy Sector”
DLR in facts and figures

20 sites, 40 institutes and facilities, the Space Administration and Project Management Agencies

Total budget:

- Aeronautics research: 253
- Space research: 402
- Transport research: 73
- Energy research: 89
- Project management agencies: 104

Personnel:

- Total number of employees: 8127
  - Non-scientific staff: 3404, of which 51% are female
  - Scientific staff: 4723, of which 10% are female

Average age: 40 years

2587 men, 5540 women
DLR TESIS Thermal energy storage test facility for molten salts
What is a Carnot Battery?

Process is
1. Sun to Heat
2. Heat to Storage
3. Heat from Storage
4. Heat to Power
By converting Concentrated Solar Power Storage into a Carnot Battery

Process is
1. Power to Heat
2. Heat to Storage
3. Heat from Storage
4. Heat to Power
Climate Changed

Germany’s Coal Plants May Be Converted to Giant Batteries

By Brian Parkin and William Wilkes
10 de abril de 2019 9:01 GMT-4

The storage units “could be converted from the mid-2020s to innovative, long-term power plants storing surplus wind and solar power,” the Economy and Energy Ministry said in its 32-page report on coal phaseout planning. No particular storage technology has been selected for the switch yet, according to the April 4 report.
From fossil lignite coal to dispatchable clean renewable power generation
From fossil lignite coal to dispatchable clean renewable power generation

- Optional gas backup firing
- Molten salt steam generator
- Steam turbine
- Generator
- Renewable power on demand
- Electric salt heater
- Feedwater pump
- Cooling tower
- Hot molten salt tank
- Cold molten salt tank
- Cheap renewable electricity
Give Greek Coal Plants a Second Decarbonized Life

Molten Salt
Tanks

Molten Salt
Steam Generator

Existing Coal Plant

Storage Retrofit

Molten Salt
Electric Heater

Elektrischer
Erhitzer

heißer
Salztank

kalter
Salztank

Wärme Speicheranlage
mit Dampferzeuger

Verbraucher

Vorhandenes Kraftwerk

Dampfturbine
mit Generator

Kühltürm

Elektrische
Stromerzeugung

Erneuerbare

Molten Salt Tanks
Equipment to be retrofit to coal plant

- Electric heaters for charging molten salts - fired by PV/wind power
- Molten salt tanks – hot and cold
- Molten salt steam generators for discharging

Source: Volcanic S.A.
Source: Aalborg CSP
Chile coal plants have space to add molten salt storage systems
We start with an existing coal plant

Conversion of existing coal plant in a Carnot Battery thermal storage plant
We start with an existing coal plant and add a power to heat molten salt storage system. The addition of the molten salt storage island to the existing Rankine Cycle is the focus of Phase 1: Pilot integration of molten salt storage in existing coal plant – proof of concept $\eta_{\text{roundtrip}} = 40\%$.

The efficiency of the system is described by:

- $\eta_{\text{PTH}} = 95\%$
- $\eta_{\text{cycle}} = 42\%$
- $\eta_{\text{roundtrip}} = 40\%$
### Analysis of a 250MWe Chilean Coal Plant

#### Added Molten Salt Storage
- Thermal storage capacity ranging from 3.33GWht to 8.79GWht
- Electric salt heater 68% efficiency
- Ranging from 180MWe to 900MWe
- Molten salt steam generator 600MWe
- 301°C Molten salt cold tank
- 565°C Molten salt hot tank

#### Existing Coal Plant
- Thermal load 600MWht 550°C steam
- Cycle Efficiency 38-43% gross
- Steam turbine with generator Nominal Power gross 260MWe
- Cooling tower

#### Sensitivity Variant

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Sensitivity of duration of charging and discharging

V1-01: 5h charging / 5h discharging (current regulation on capacity payments)

V1-12: 10h charging / 14h discharging (allows 24/7 combined with PV)

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Case study Chile of a 250MWe coal plant retrofit with molten salt storage Charging
Case study Chile of a 250MWe coal plant retrofit with molten salt storage

Discharging
Annual charging/discharging electricity and annual roundtrip charging/discharging efficiency

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Investment cost (CAPEX) estimate for the retrofit of a molten salt storage

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Levelized cost of discharge electricity for the retrofit of a molten salt storage

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Adding storage plants to Planificación Energética de Largo Plazo (PELP)

(a) Scenario A

(b) Scenario A-SP
Adding storage plants improves secured firm capacity

![Bar chart showing load & capacity (MW) for different years and scenarios.](chart.png)

- **Firm Capacity Scenario A**
- **Peak Load Scenario A**
- **Firm Capacity Scenario A-SP**

Model Year:
- 2020
- 2025
- 2030
- 2040
- 2050

Load & Capacity (MW):
- 0
- 5000
- 10000
- 15000
- 20000
- 25000
Adding Storage Plants to Planificación Energética de Largo Plazo (PELP) reduces specific generation cost and CO2 emissions

a. Total annual Chilean power generation cost versus b. Specific Chilean cost of electricity versus its specific total annual carbon emissions per kWhe
Chile has world wide best conditions for repurposing coal plants

- World best solar resource => lowest cost of solar electricity.
- Import of coal => relatively high cost of coal electricity.
- Storage retrofit of plants decarbonizes the Chilean power park while granting 100% secure dispatchability of the power demand for the mining industry. Fossil backup firing option can be maintained.
- Storage thermal plants in the Northern grid system avoiding/reducing curtailment of PV electricity in Northern Chile.
- Chilean thermal power plants are relatively new and have a lot of space around their construction area, facilitating repurposing.
- Storage thermal plants make perfect use of existing power plant infrastructure and grid connection in strategic points of the electric transmission system.
- Operation experience and salts are locally available (SQM, CSP, Atacama Desert).
- Maintaining operations in existing sides, is maintaining jobs, avoiding social implications of energy transition.
Chile has also world best mineral resources for electricity storage systems

Lithium Mining in the Atacama

Solar Salt Mining (NaNO₃ and KNO₃) in the Atacama