Low-Cost Sulfur Thermal Storage for increased flexibility and improved economics of fossil-fueled electricity generating units

FE0032007

Total Project Cost: $250,000 (Federal Funds: $200,000 + Cost Share: $50,000)

Project Duration: 12 months

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Advanced Energy Storage Initiative Project Review Meeting
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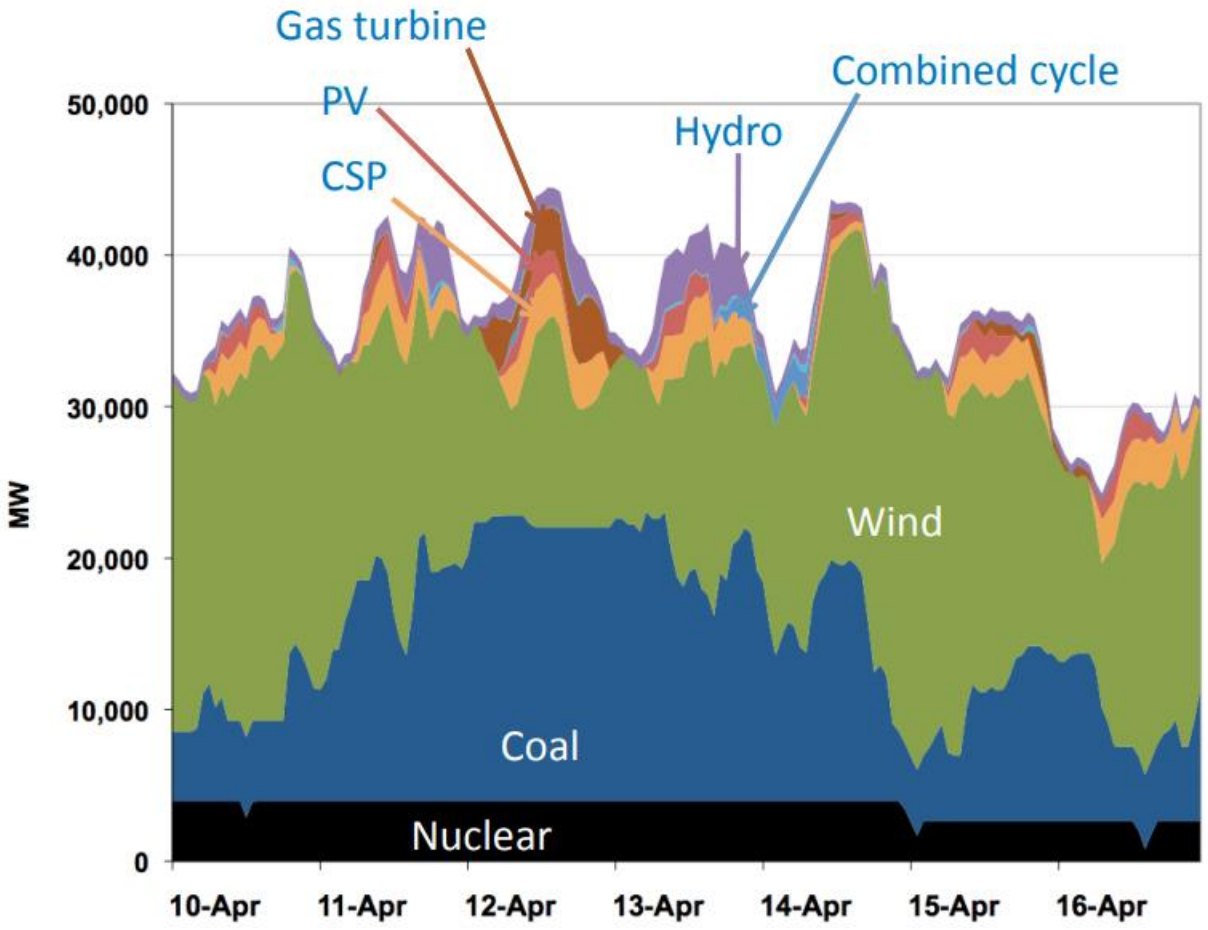
Project Team

Lead Organization — ELEMENT16 TECHNOLOGIES

Sub-Recipient — Advisian, Worley Group

Motivation

Illustration of frequent cycling of fossil-fueled plants[1]



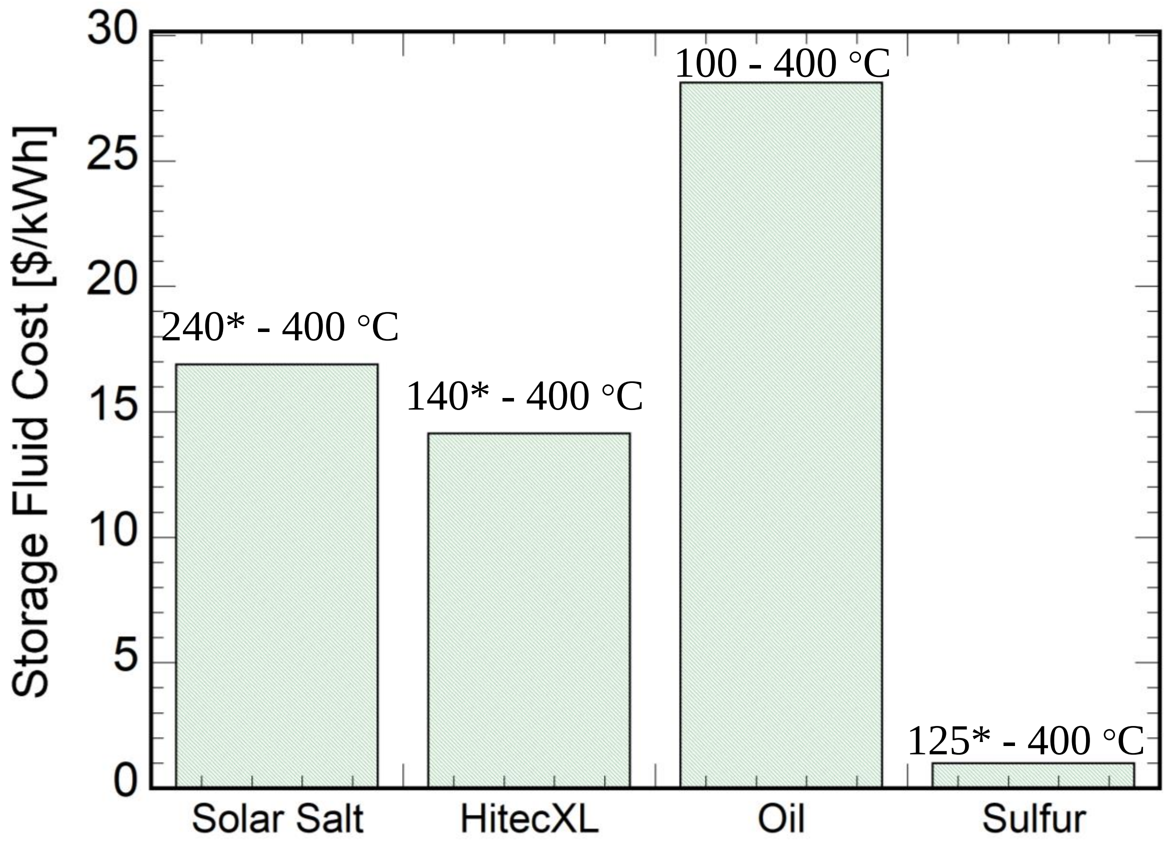
- Fossil-fueled units subjected to increased demand for operational flexibility
  - Due to variable renewable penetration
- Constant cycling results in higher operational expenses
  - Wear and tear on thermal equipment
  - Unstable boiler chemistry leading to excessing pipe corrosion
- Operate at minimum load for long periods of time
  - Decreases plant efficiency and revenue
  - Increased emissions per kWh

Low-cost thermal energy storage (TES) is critical to increase the utilization, improve flexibility and economics of fossil fuel asset

[1]Lew et al.., The Western Wind and Solar Integration Study Phase 2, NREL/TP-5500-55588

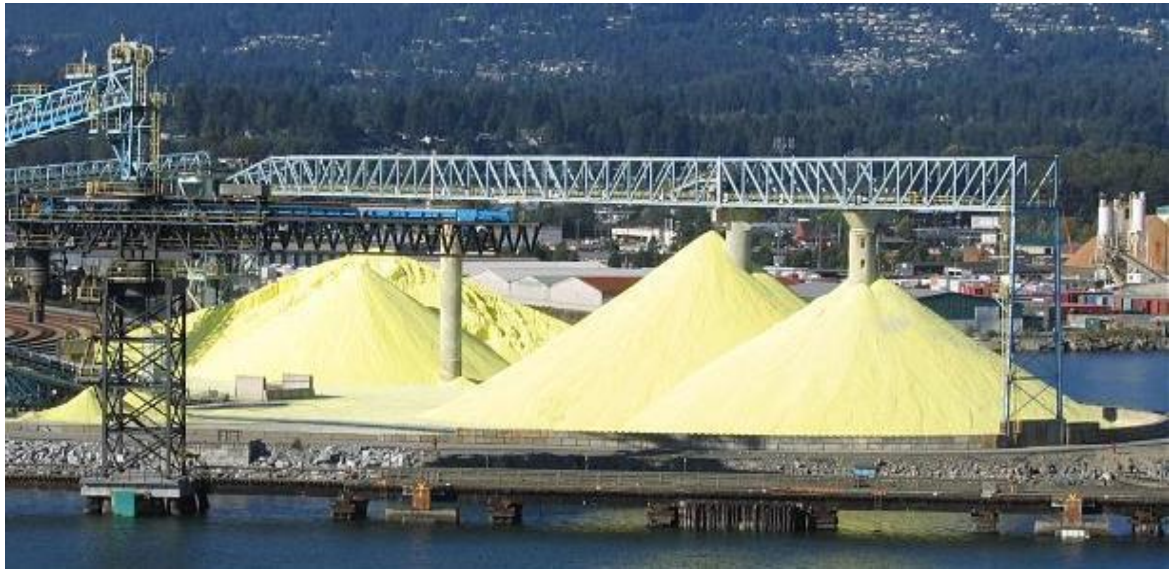
Innovation/Novelty

Use of low-cost molten sulfur as the heat storage fluid



For heat in the temperature range of 100 °C – 400 °C

*In the comparison chart, bottoming temperature for molten salt and sulfur is chosen to be 20 °C above their freezing point.



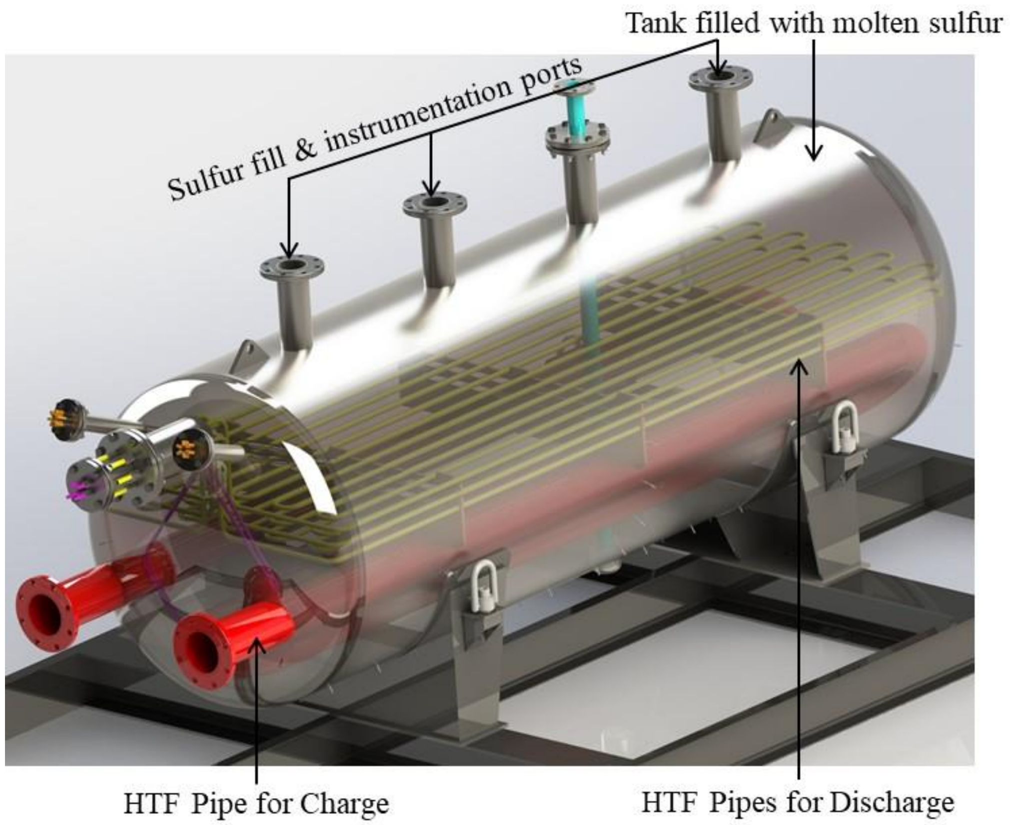
Benefits of Sulfur

- Dirt cheap (~$0.04/kg - $0.08/kg)[1]
- Highly abundant
- Chemically stable
- Low freezing point (~105 °C)[2,3] compared to SOA solar salt (~220 °C), ensures low parasitic load and low O&M cost

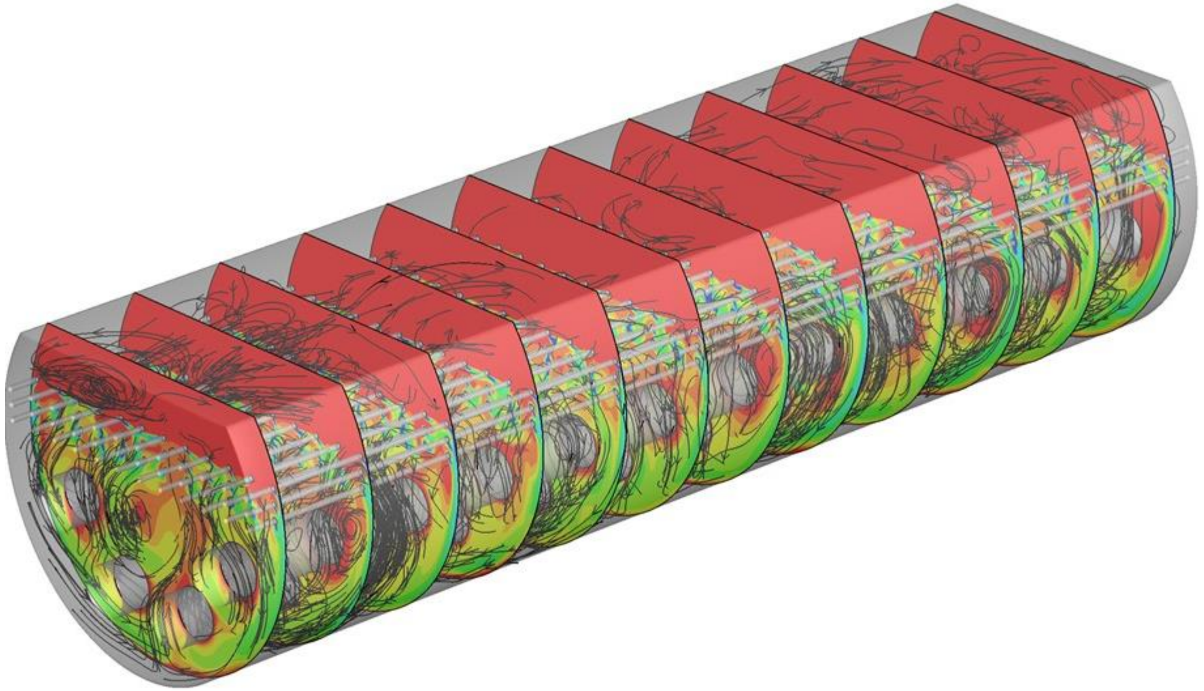
[1] *https://www.statista.com/statistics/1031180/us-sulfur-price/*
[2] *Meyer, Chem. Rev., 1976;* [3]*Nithyanandam et al., IJHMT, 2018*

Sulfur TES Design & Performance

Design rendering of sulfur TES



CFD Characterization



- Single tank design that involves HTF tubes located within molten sulfur bath.
- Natural convection currents enable efficient storage and retrieval of heat from sulfur thermal storage

Sulfur TES Technology Development

Current Projects

(funded by California Energy Commission)

- ❑ Skid-mounted 350 kWh molten sulfur TES prototype in small-scale combined heat and power unit with natural gas microturbine
  - ➢ Adds flexibility for improved reliability and economics
  - ➢ Design, CFD characterization, and testing completed in-house by Element 16, fabrication by PCL Industrial Services
- ❑ Waste heat capture for energy efficiency improvement in an industrial facility
  - ➢ Energy and water savings, Emissions reductions
- ❑ Molten sulfur TES as Carnot battery for electricity storage
  - ➢ 1500 kWht molten sulfur TES prototype
  - ➢ Charge using electric heater and discharge using Rankine cycle

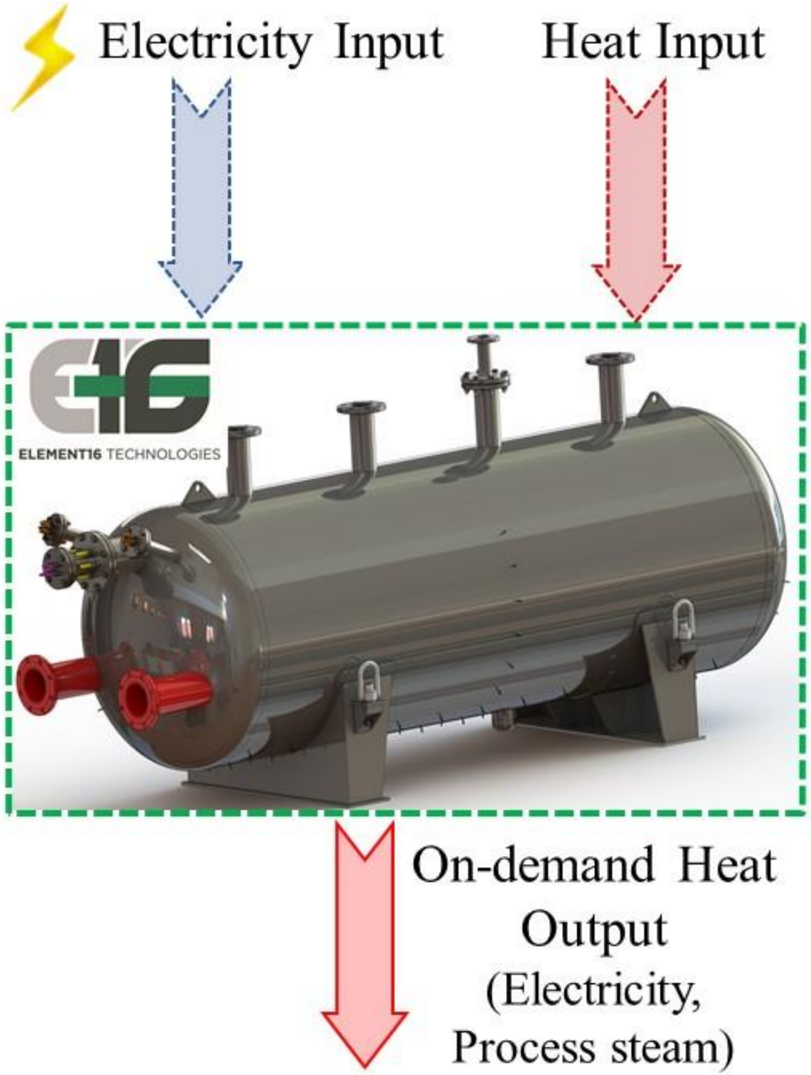
350 kWh Prototype in Arcadia, CA

Project Objectives & Impact

- Quantify the value of sulfur thermal energy storage (TES) integrated with fossil fuel assets.
  - Increase in plant utilization, Cost savings, Emissions reduction, etc.

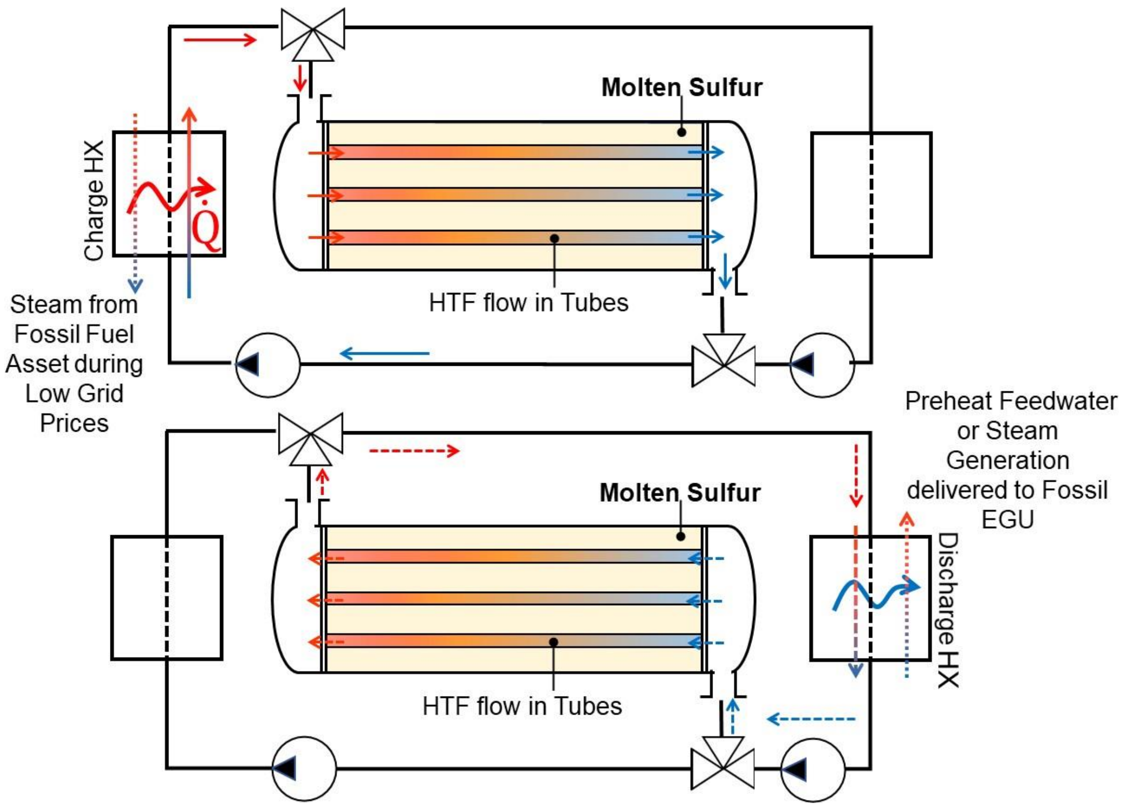
- Complete feasibility study to establish economically viable TES integration scenarios for responsive operation of conventional fossil fuel assets.
  - Charge and discharge heat rates, Discharge duration, Levelized cost of storage, etc.

- Project Impacts:
  - *Security*: Increased reliability of power plants improves grid resiliency
  - *Environment*: Decreases greenhouse gas emission intensity by enabling coal plants to operate at the highest efficiency
  - *Economy*: Decreases fuel cost and O&M expenses, Energy arbitrage

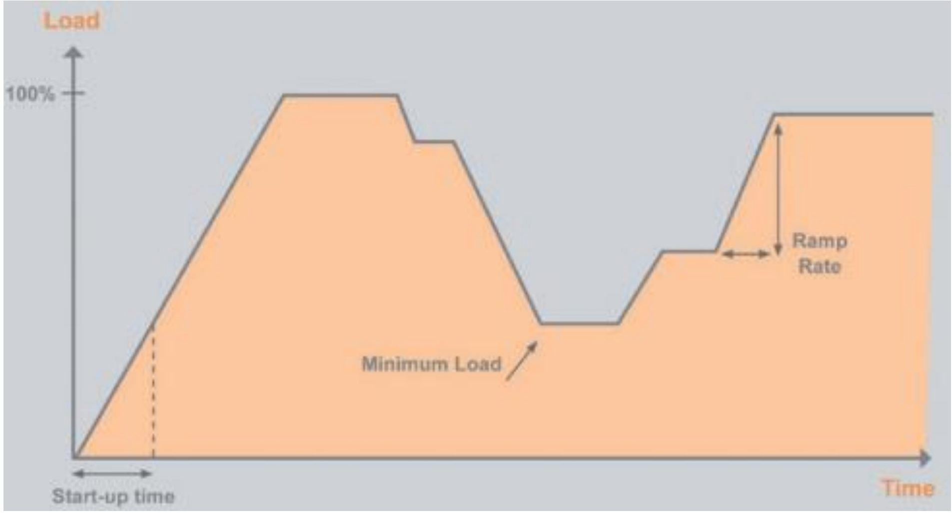


Integration with fossil-fueled assets

Coal EGUs respond to grid demand without increased thermal cycling stress



Schematic illustration of sulfur TES for generating steam or preheating feedwater in a fossil fuel electricity generating units (EGUs)



Dynamics of flexible power plant operation[2]

- ❑ Boost steam production during peak demand without ramping thermal equipment
- ❑ Capture thermal energy and reduce power production when value of electricity is low or negative
- ❑ Capture overgeneration from external energy resources
- ❑ Repurpose retiring fossil power plants

[2]Flexibility Toolbox: "Compilation of Measures for the Flexible Operation of Coal-Fired Power Plants", VGB Power Tech, VGB-B-033, March 2018

ELEMENT16 TECHNOLOGIES

THANK YOU

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