STORWORKS POWER

SUPPORTING THE TRANSITION TO A LOW-CARBON FUTURE WITH ENERGY STORAGE SOLUTIONS

TMCES Workshop
August 1, 2024

Bill Capp
Strategic Advisor
Bill.Capp@storworks.com

Concrete Thermal Energy Storage Systems

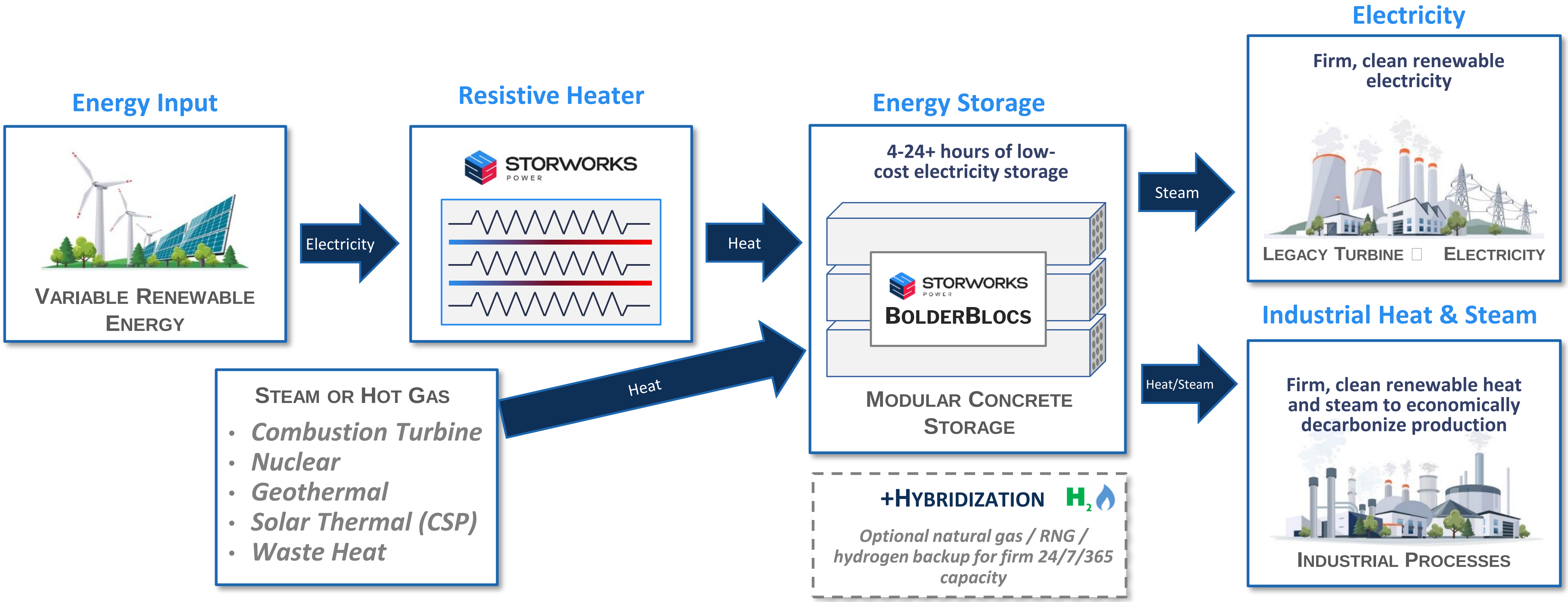
1) Storworks Technology

2) Review of 10 MWhe Southern Company Pilot Project

3) Use Cases for CTES

Storworks Technology

Storworks Conceptual Overview



Storworks' long duration energy storage technology can provide firm clean energy for Electrical and Industrial applications at the lowest available cost

Storworks BolderBloc Modular TES System

- **General Concept:** heat storage in patented high-performance concrete with air channels and/or steel tubing (Proprietary high-temperature concrete formula utilizing fly ash).
- **Proven cycling performance**: 600°C (1110°F), providing steam at industrial temperatures and pressures. Optimized design engineered to discharge at full temperature throughout the entire discharge cycle, without temperature “droop” at the hot end – consistent operations.
- **250 kWh_e per BolderBloc:** high energy density with a much smaller footprint than competing LDES technologies.
- **Duration of Discharge:** 4 to 24+ hours, and unlimited operation with hybrid fuel backup
- **Low-cost modular design:** scales easily for different applications (<$30/kWhe) <u>before</u> IRA tax credit
- **No fire / hazardous materials risk**
- **Low maintenance cost and long life:** 30+ year useful lifespan

Storworks concrete BolderBlocs with embedded steam tubing

Storworks BolderBloc Family

	Air Bloc	HRSG Bloc	Steam Bloc
			
Charge	Hot air	Hot air	Steam
Discharge	Hot air	Steam	Steam
Uses	• Lowest cost storage. Output for industrial heat, conventional power plant HRSG, or feed into HRSG Bloc. • Used for **duration** (MWh)	• Provide steam for electricity generation or industrial processes • Used to add output **power** (MW)	• Charge with steam from coal, geothermal, solar thermal, CHP, biomass or nuclear to provide flexible operation

HRSG = Heat Recovery Steam Generator

Storworks BolderBlocs can be combined to create tailored solutions for a wide range of applications at the lowest possible cost

BolderBloc Thermocline Operation

1) **Charge Phase:**
   - Boiler steam or hot gas, depending on application, flows in one direction through the TES, heating the concrete
   - Charging process creates a thermocline, or temperature gradient, with highest temperature at charging inlet
   - Significant temperature differential is maintained

2) **Discharge Phase:**
   - Air or water is pumped in opposite direction to discharge, and resultant steam exits TES at ~hot end temperature, delivering consistent hot air or high-quality steam
   - Energy is drawn from the middle of the block, and hot end temperature is maintained – key to producing consistent steam quality throughout discharge cycle

Thermocline Animation

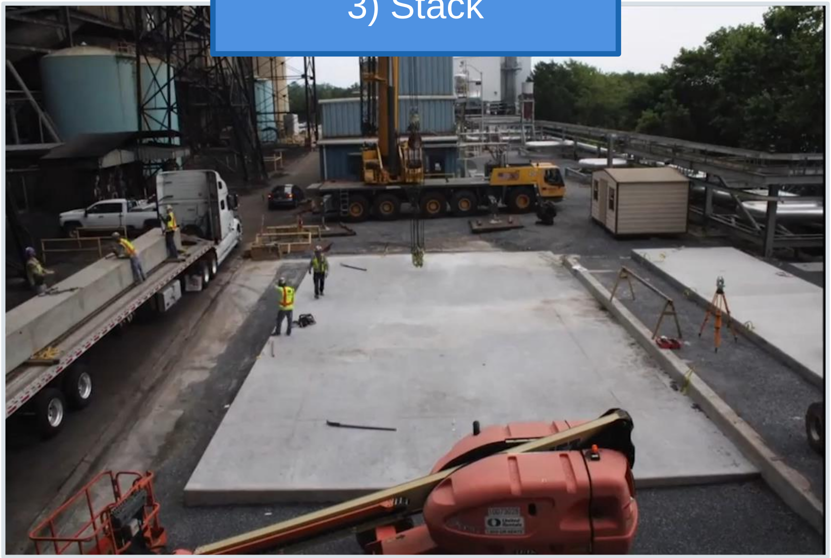
System optimized to maintain thermocline for consistent conditions across full discharge cycle

BolderBloc Modular Construction

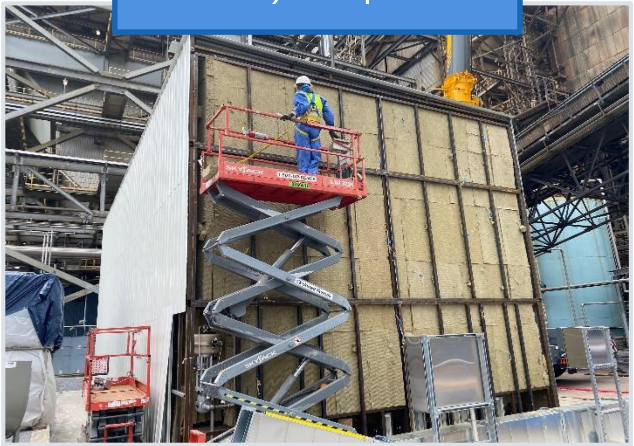
1) Manufacture (locally)

2) Ship (if needed)

3) Stack



4) Wrap



CTES Technical Validation

Plant Gaston Pilot

In-House Testing – Concrete Development

- Concrete material property test equipment:
  - Compression tests with cylindrical samples
  - Thermal conductivity and specific heat capacity measurements
  - Kilns for thermal tests
- Have conducted many dozens of tests and developed database of mixtures and resulting properties
- Temperature Rating Research:
  - Previous testing sponsored by EPRI demonstrated performance at 600°C
  - Positive results from recent early testing at 700°C
  - Increased temperature would reduce number of blocks required
- Materials Research:
  - Beginning a test program to integrate other materials into concrete formulation. Potential to incorporate industrial waste materials (e.g. low-grade fly ash) and reduce amount of Portland cement required

DOE / EPRI Gaston Project

Summary

No: DE-FE0031761

Awarded: 09/01/2019

Funding: $3,910,720 ($4,888,400)

Timeline: 09/01/2019 – 08/31/2022*

Site Host: Southern's Plant Gaston

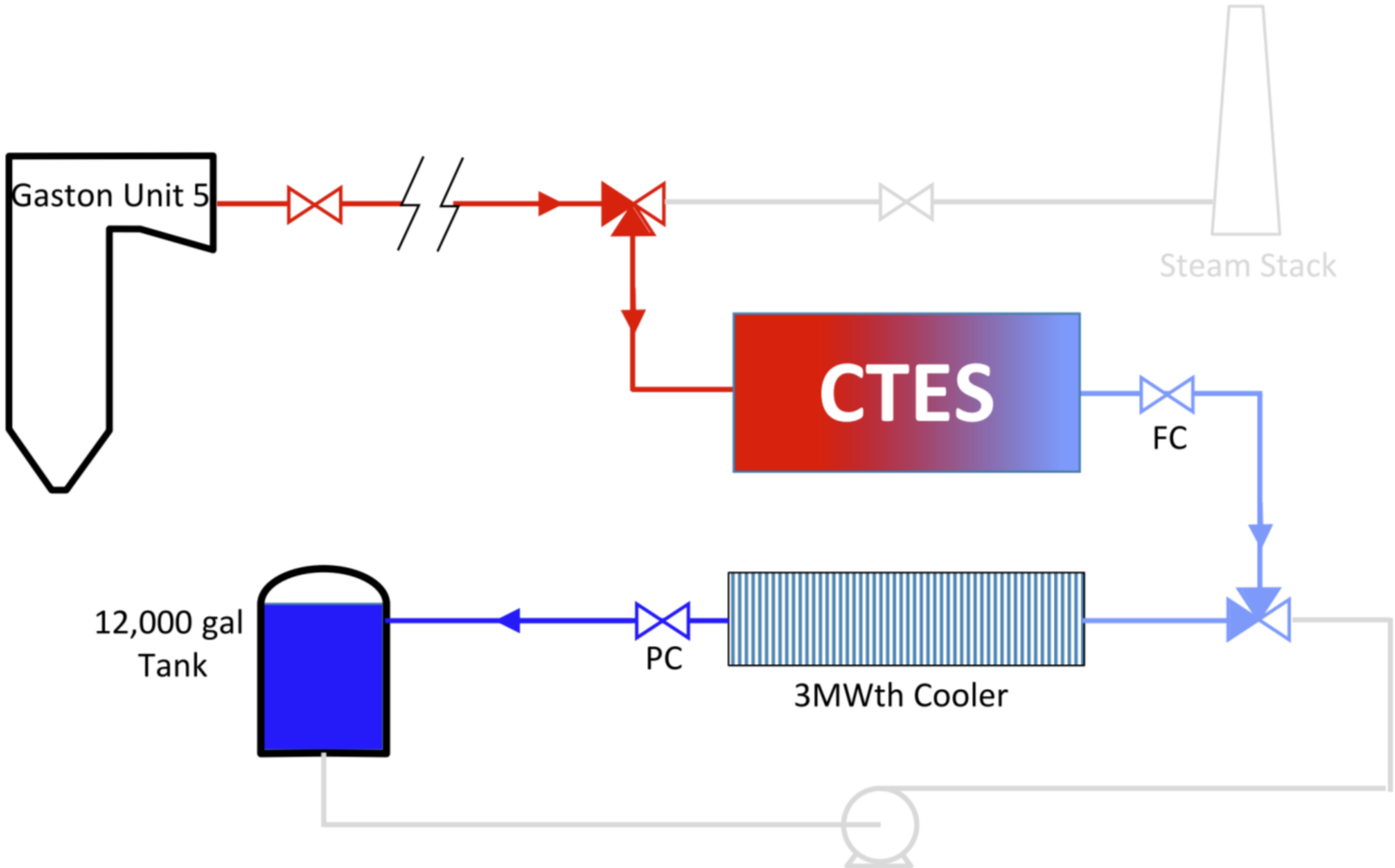
Team: EPRI (Prime)
Southern Company
Storworks Power
United A&E (sub)

Objectives

Design, build and test a concrete thermal energy storage system at an operating coal fired power plant that can store and deliver 4 hours of energy with a target of achieving a total storage capacity of 10 MWh electrical equivalent.

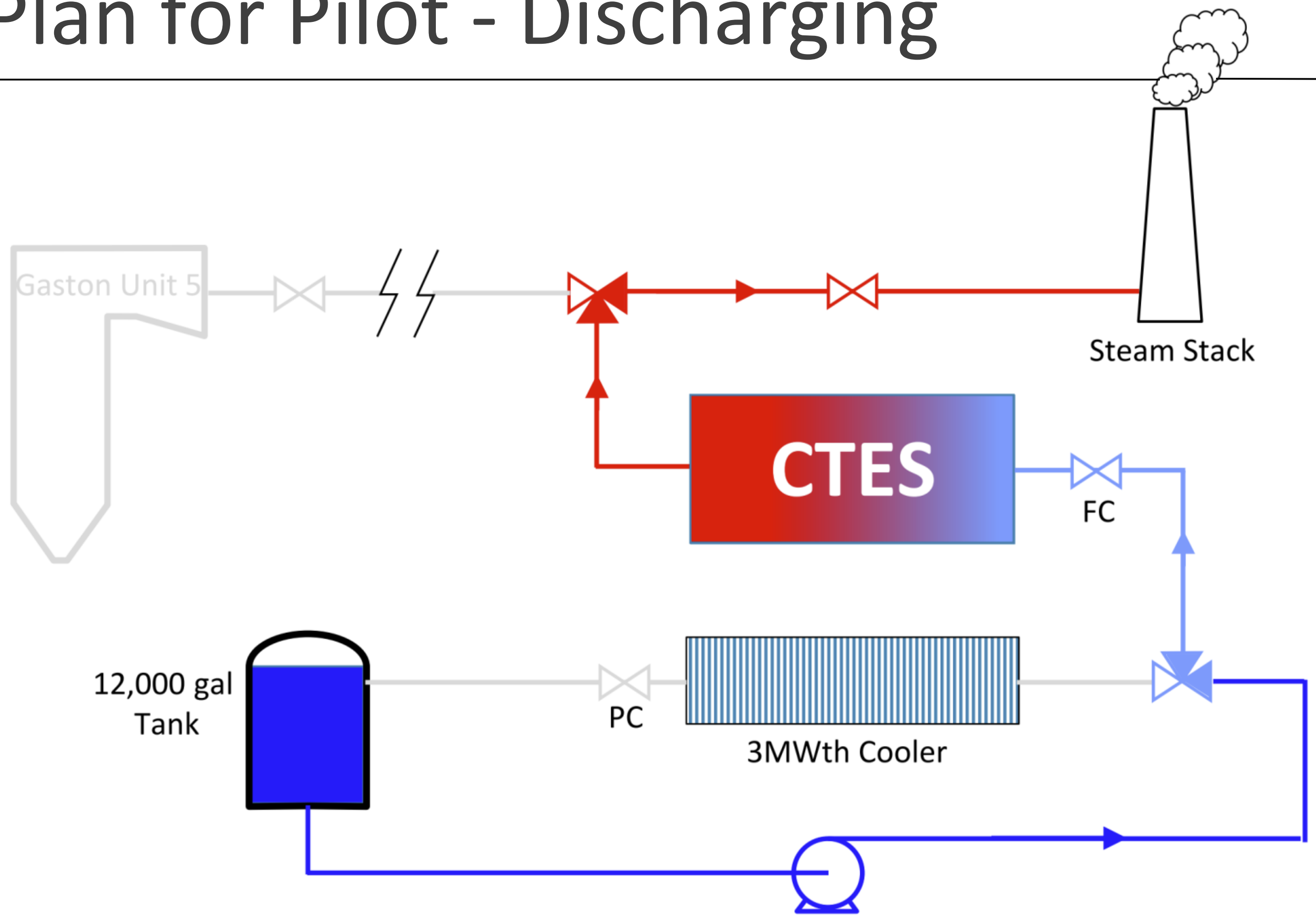
Successful demonstration of this pilot system will ensure power generators with aging coal fired units have viable options for TES integration for continued capacity as an alternative to decommissioning.

Operating Plan for Pilot - Charging



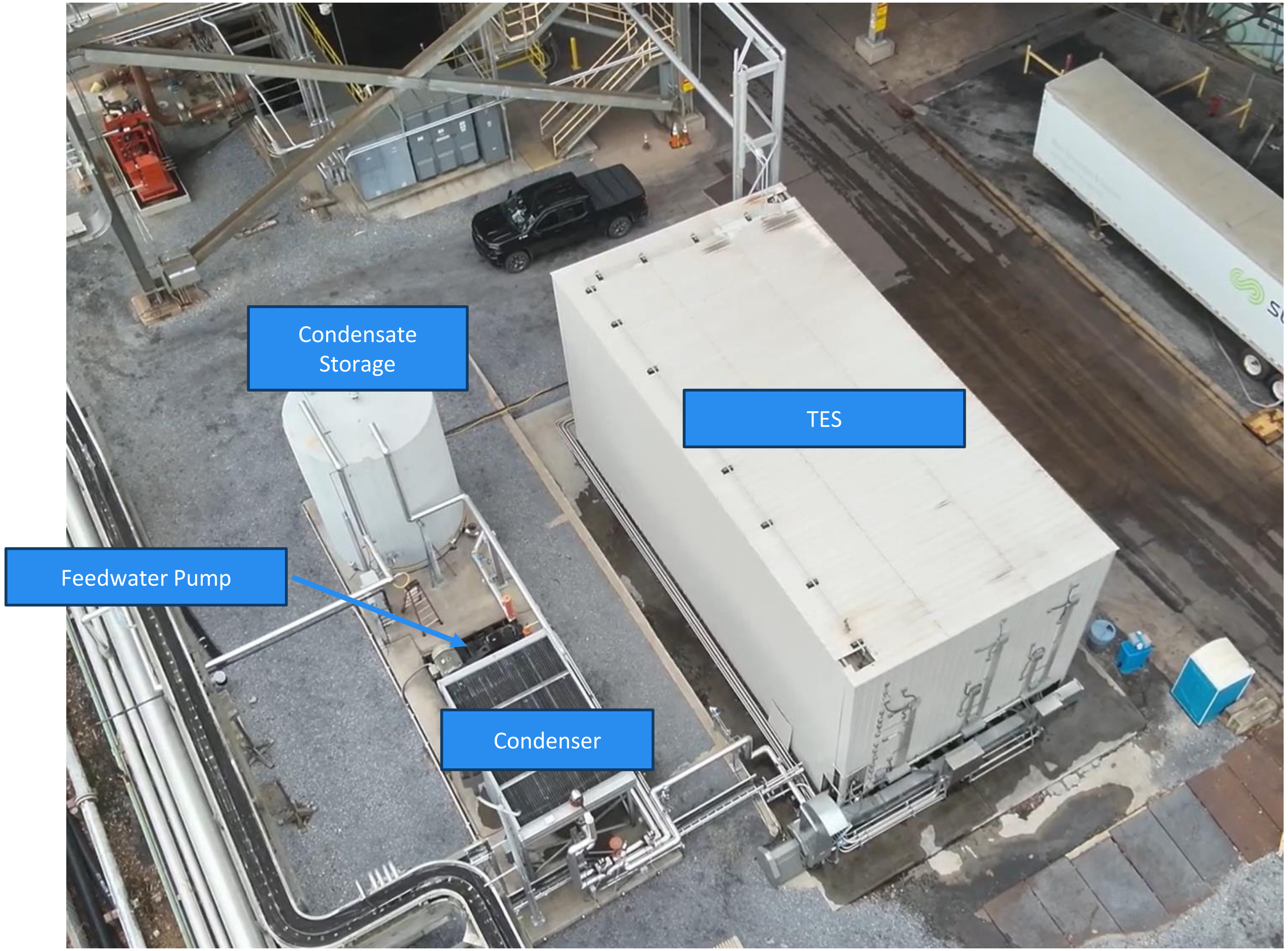
Supercritical steam condensed, cooled and stored

Operating Plan for Pilot - Discharging



Generated steam measured and disposed

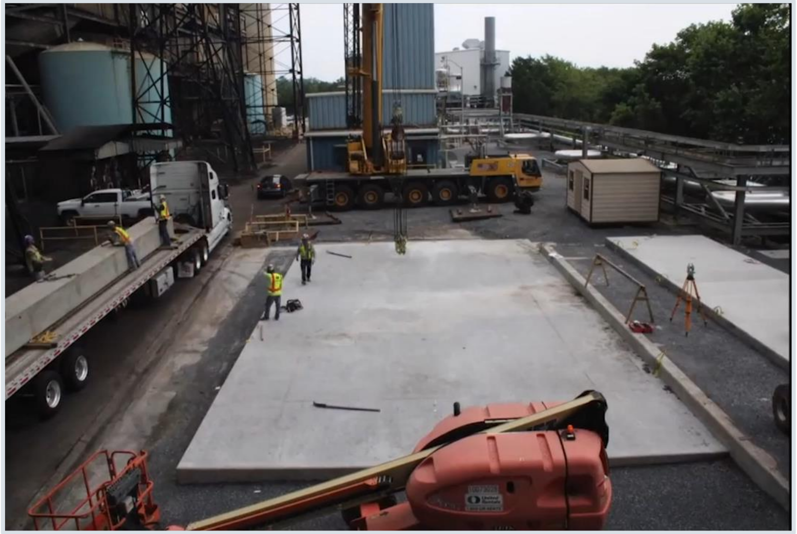
DOE / EPRI Gaston Project – Site Layout



DOE / EPRI Gaston Project – Design Parameters

- $10MWh_e$ / $25MWh_{th}$ pilot plant
  - 42 SteamBlocs with embedded steam tubes
    - Bloc dimensions: 1.05m x 0.9 m x 12.5 m
    - 900 tonnes of proprietary high temp concrete
  - 7 Cooling Blocs on the bottom (thermal isolation)
  - Stack dimensions: 6 m x 6.6 m x 12.6 m
- Supercritical steam at 530°C (1000°F) / 230 bar (3350 psi)
- Began commissioning July 1, 2023
- Completed testing March 23, 2024
  - Plant available for 6 weeks of testing
  - Operated system for 700+ hours,
    with 80+ charge and discharge cycles

U.S. DEPARTMENT OF ENERGY | EPRI ELECTRIC POWER RESEARCH INSTITUTE | Southern Company | UNITED



Gaston after installation of insulation and cladding

Results; Good News, Bad News and Opportunities

Good News

- CTES blocks were reliable, only minor leak repairs needed
- The system calculations were predictive of performance
- Despite host site availability, > 700 hours of testing were completed
- The system demonstrated 8 MWHe energy storage; below the 10 MWhe goal, but consistent with reduction in number of blocks that reduced the cost of the pilot

Bad News

- Building a pilot plant during a global pandemic was challenging – resulted in two years of delays. Because it was late, it was also over budget
- The availability of steam was routinely curtailed along with the operation of Unit 5

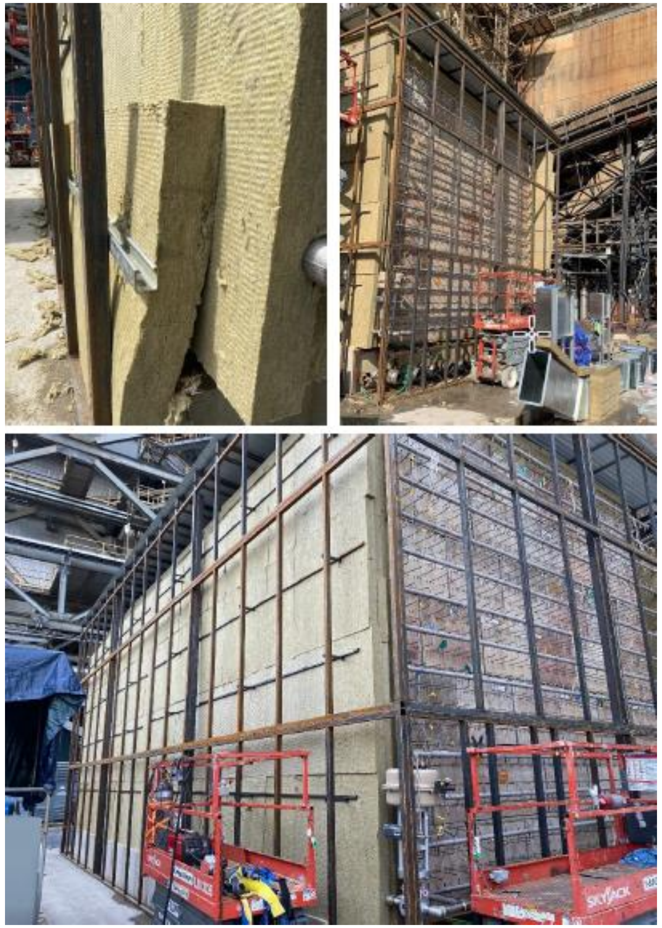
Results; Good News, Bad News and Opportunities

Opportunities for Improved Performance

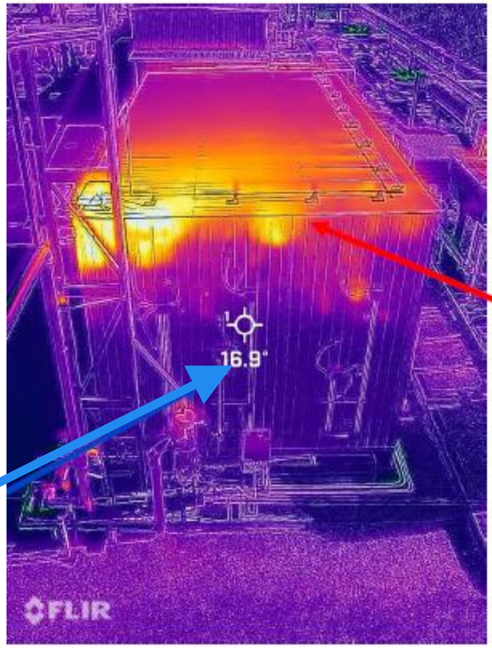
- Flow imbalance between layers (top to bottom) reduced capacity. Provide improved flow controls to maximize performance of each layer. This is similar to the function of a BMS system in a BESS.
- Improved insulation design to avoid thermal losses. With large scale CTES and improved insulation, expect 1-2% per day losses

Insulation Opportunity

Installation process



Loss Mechanism



Top corner shows heat losses

Majority of cladding shows good thermal containment

Heat losses identified as being from convection within distribution cavity that leaks through insulation/cladding at roof

Selected Storworks Use Cases

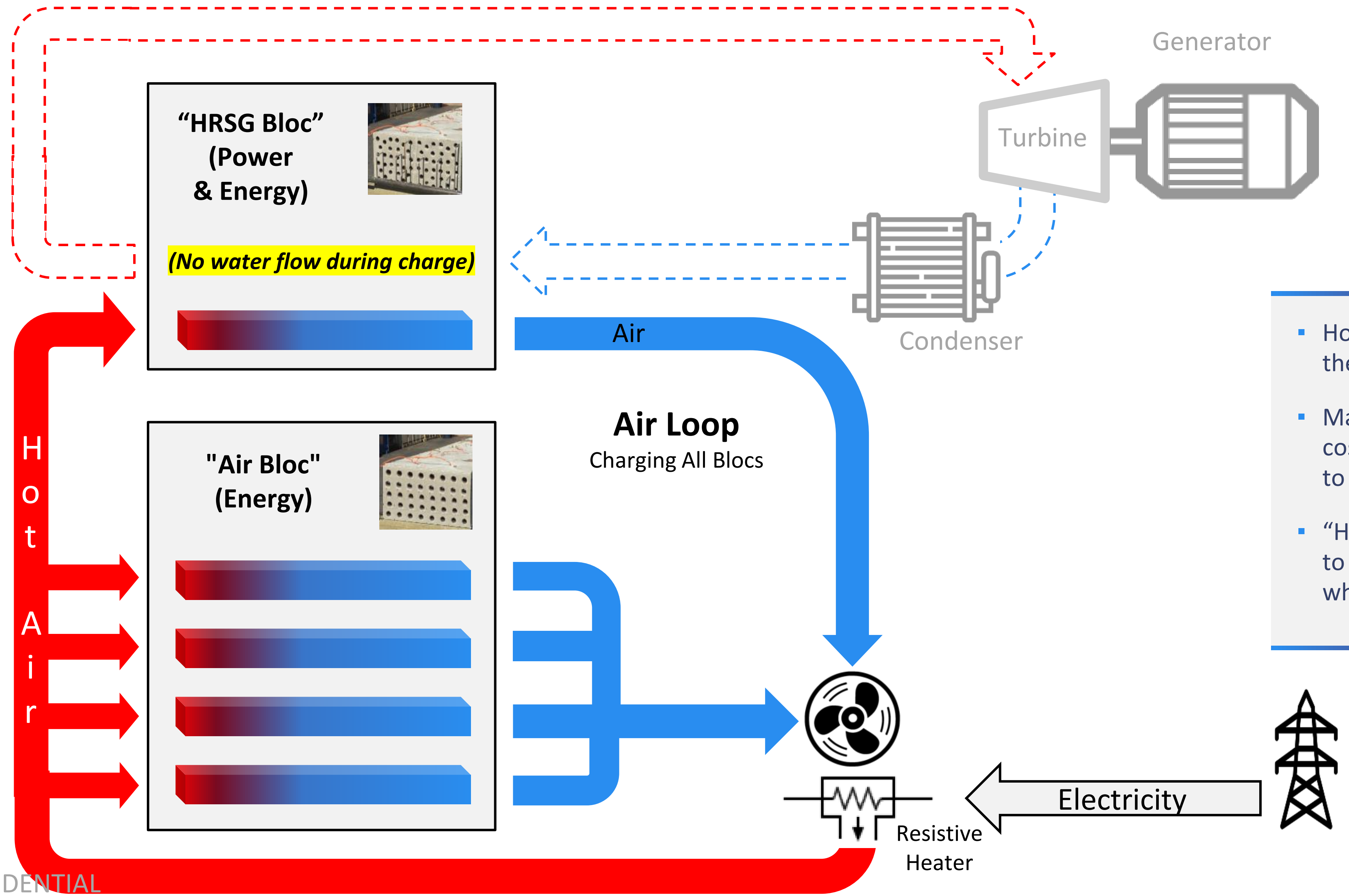
1) Convert fossil generation plants into energy storage

2) Add flexibility to thermal plants

3) Industrial decarbonization

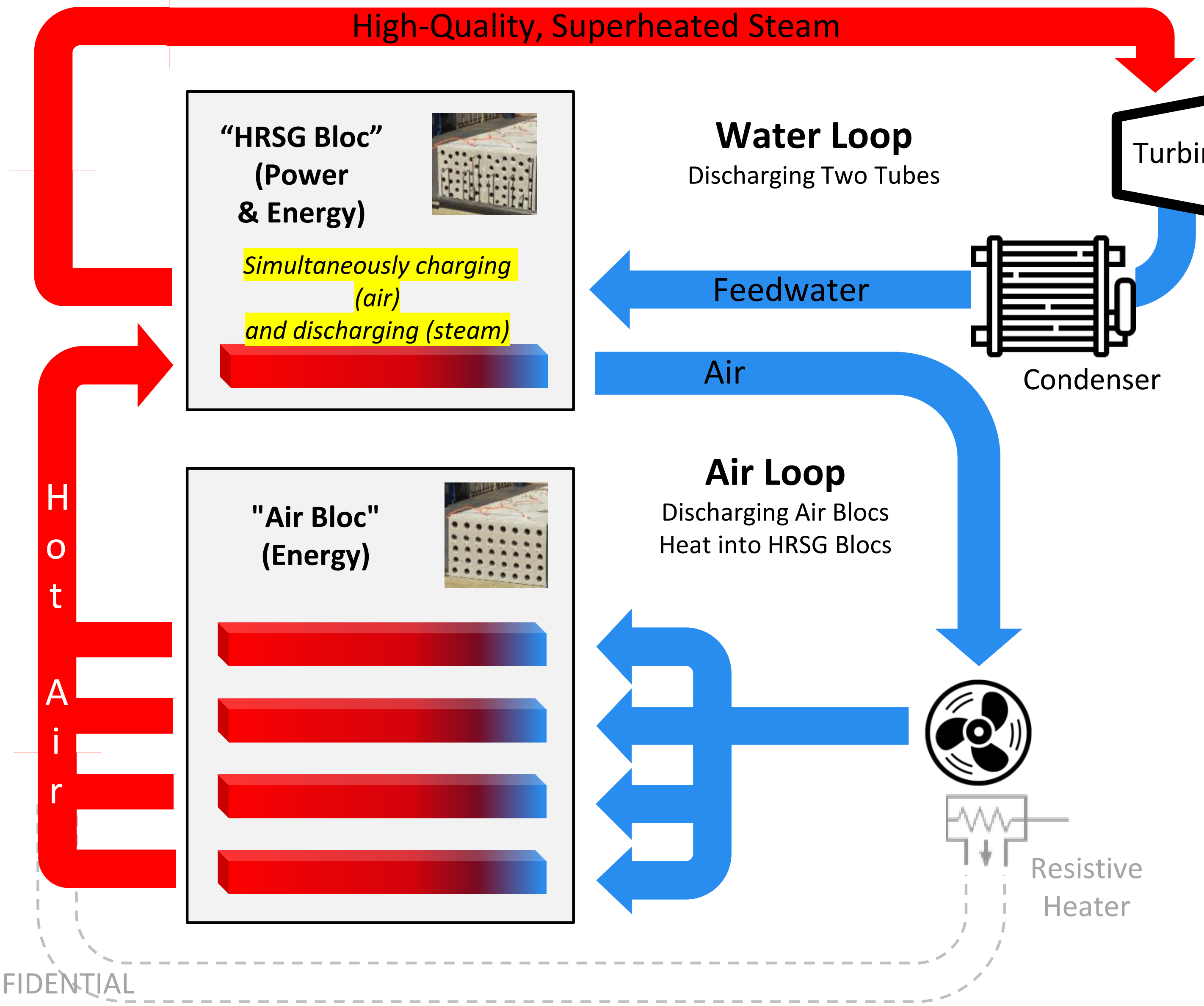
FlexJoule
Electricity Storage based on Coal Plant Conversion

FlexJoule | Electrically Heated Charge



- Hot air charges both the HRSG Blocs and the Air Blocs during charge mode
- Majority of energy is stored in ultra-low-cost "Air Blocs". Can be added modularly to achieve the required **energy** (MWh)
- "HRSG Blocs" are added to the system to provide discharge steam **power** at whatever MW level is required

FlexJoule | Steam-Generating Discharge



- During discharge, air is heated by the Air Blocs and is fed into the HRSG Blocs.
- Feedwater is fed into the HRSG Blocs and generates high-quality superheated steam.
- If Air Blocs are fully discharged, +Hybrid systems (not pictured) can use natural gas or hydrogen to heat the HRSG Blocs, providing firm 24/7 operation

350 MW Coal Plant Conversion PreFeed Study

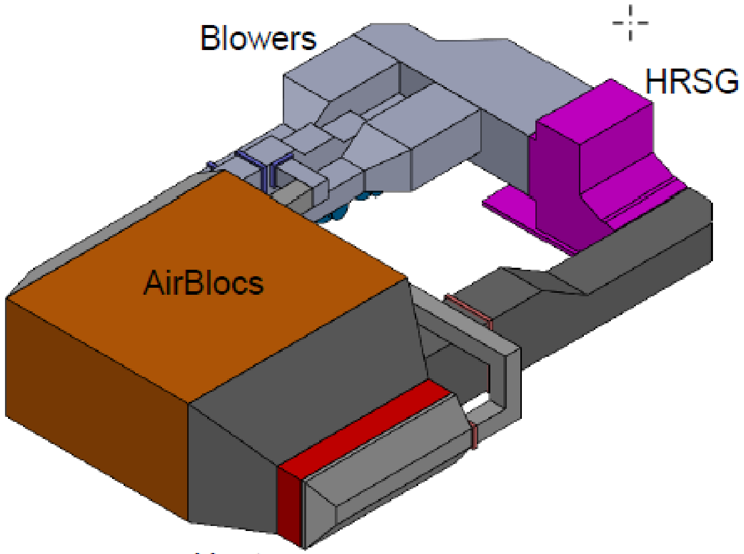
System: 350 MWe (gross) with 5 hours storage (1750 MWhe) and 160 MW charging

Overall Footprint: ~120m x ~122m (CTES only: 51m x 55m)

Major Components:

- CTES - 6,264 AirBlocs (8.32 m3 concrete each)
- Heater – 18 modules x 8.5 MWe each, hot air up to 700C
- HRSG – 2 units providing steam conditions of 538C, 150 bar
- Blowers – 4 fans, 5000 kW each

AirBlocs



Add Flexibility to Thermal Generation

Coal Plants

- Many locations face daily periods wholesale prices below operational cost due to variable resources
- Choice between selling energy at a loss or facing huge increase in O&M by cycling off and on
- Buffering output of steam from boiler allows zero generation while continuing to operate the coal processing/boiler system – then use regenerated steam to run the steam turbine

Geothermal, Nuclear, CSP

- Buffering steam to:
    - Increase maximum output to increase capacity payments (may require additional steam turbine)
    - Vary output to maximize revenues (line up output with market prices)

CTES For Industrial Decarbonization

Industrial Heat and Steam Market

The Industrial Sector is a massive emitter of CO_2, accounting for **30% of global energy consumption**

Decarbonization of the US economy alone represents a **$4 trillion market opportunity** in renewables + energy storage, according to NextEra[1]

Numerous factors are driving companies to decarbonize:

Key Drivers of Industrial Decarbonization

ESG Commitments	**Customer Demand for Green Products** (green aluminum, green packaging, low carbon fuels, etc.)	**Fossil Fuel Price and Supply Uncertainty**
Falling Cost of Renewable Energy	**Carbon Prices**	**Stricter Permitting and Regulations**

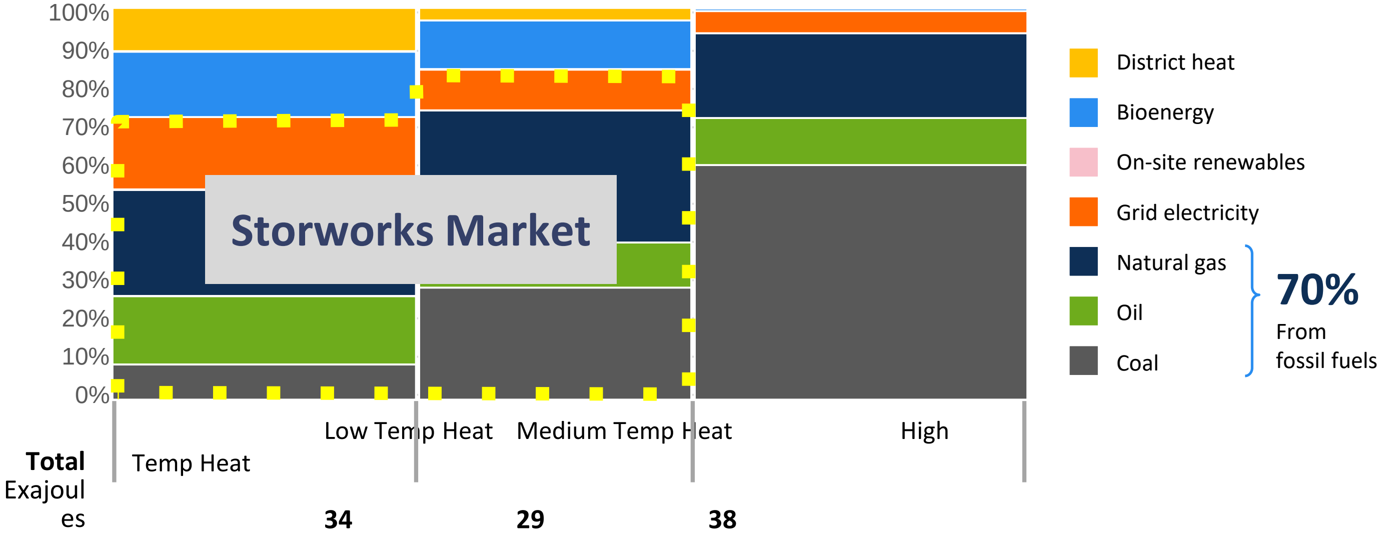
1. https://www.investor.nexteraenergy.com/~/media/Files/N/NEE-IR/news-and-events/events-and-presentations/2023/February_Investor_Presentation_vF.pdf

Industrial Heat and Steam Market

Low to Medium temperature heat and steam (<500°C) represents 60% of Industrial sector energy consumption globally

- In the United States, the figure is higher – approximately 77% is less than 500°C, due to a lower proportion of high temp steel and concrete energy use
- Key industries include: refineries, chemicals, metals and minerals processing, pulp & paper, food products, etc.

Global industrial final energy consumption by heat temperature[1]



> ***Switching from fossil fuels to electricity is the single most effective way to reduce emissions in industry***
>
> -Bloomberg New Energy Finance, New Energy Outlook 2021

Storworks Thermal Energy Storage is optimized to be the lowest-cost solution for medium temperature heat and steam for a wide range of industrial decarbonization applications

1. McKinsey Global Energy Perspective

Industrial Applications | Thermal Storage for Heat and Steam

INDUSTRIAL DECARBONIZATION

FlexHeat – Energy Storage for Industrial Decarbonization

- Lowest cost decarbonized heat and steam for industrial processes
- Proprietary resistive heater to heat air, which heats Blocs (can also use heat pumps or waste heat)

Firmed On-Demand Energy

- Firms renewable energy, providing on-demand heat and steam for 24/7/365 loads
- Scales from 10s to 10,000 MWh_{th} using modular components
- Proven cycling at 600°C (1110°F)

Flexible Operation

- Transforms constant-demand loads into flexible, demand-response loads, able to respond to grid conditions and capitalize on most attractive power prices

Lowest Cost Energy Storage

- Marginal capital cost less than $10/$kWh_{th}$
- Very low cost concrete, rather than ceramics or graphite
- Over 95% round-trip efficiency
- Low maintenance cost & 30-year useful life

Seamless Integration

- Can provide heat & steam at a range of temp and pressure
- Can generate steam directly or provide heat to existing boilers
- High energy density / small footprint
- No fire / hazardous materials risk

Economic Benefit of TES in Process Electrification

Without Storage

Electricity purchases must match steam schedule

Fixed demand on grid resources results in high demand charges sized to peak input

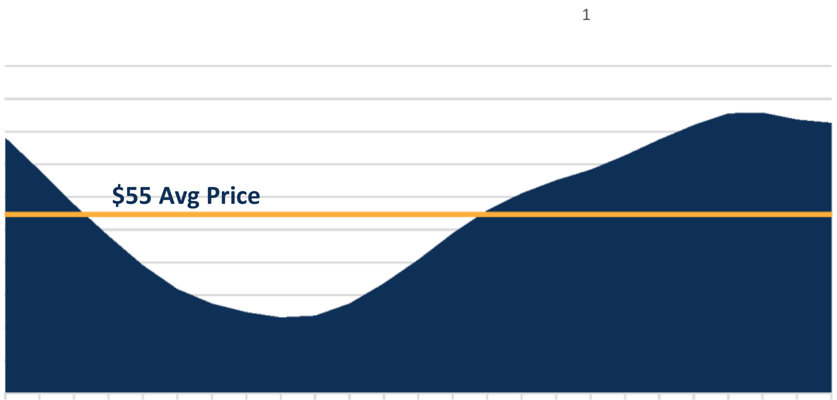
Poor overall electrification economics

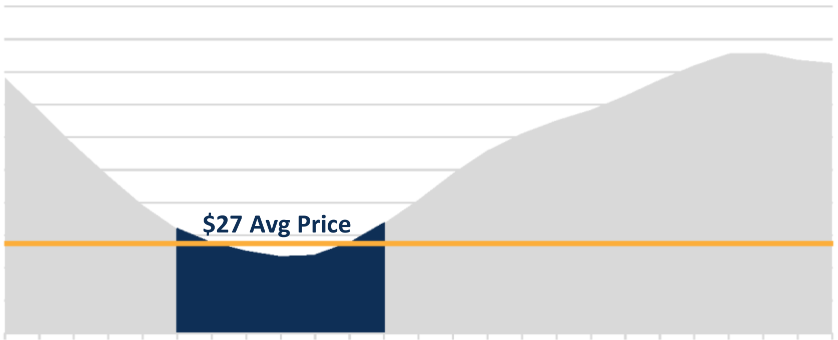
With Thermal Storage

Electricity to charge TES can be purchased at times of optimal low pricing

Flexible demand to respond to grid conditions / demand response

Significantly reduced cost of electrification





1. Southwest Power Pool, South_Hub, 2022 Day-Ahead LMP

Please reach out to discuss your needs for storage

Thank You

Bill Capp
Strategic Advisor
Bill.Capp@storworks.com

Very inexpensive storage media – low cost energy storage technology

Extremely low marginal capital cost (<$10/kWh$_{thermal}$)

Low technology risk

Proven cycling performance at 600°C (1110°F)

Low maintenance cost & 30-year useful life

High energy density / small footprint

No fire / hazardous materials risk

Widely available materials / No critical minerals