STORWORKS
POWER

TMCES Workshop

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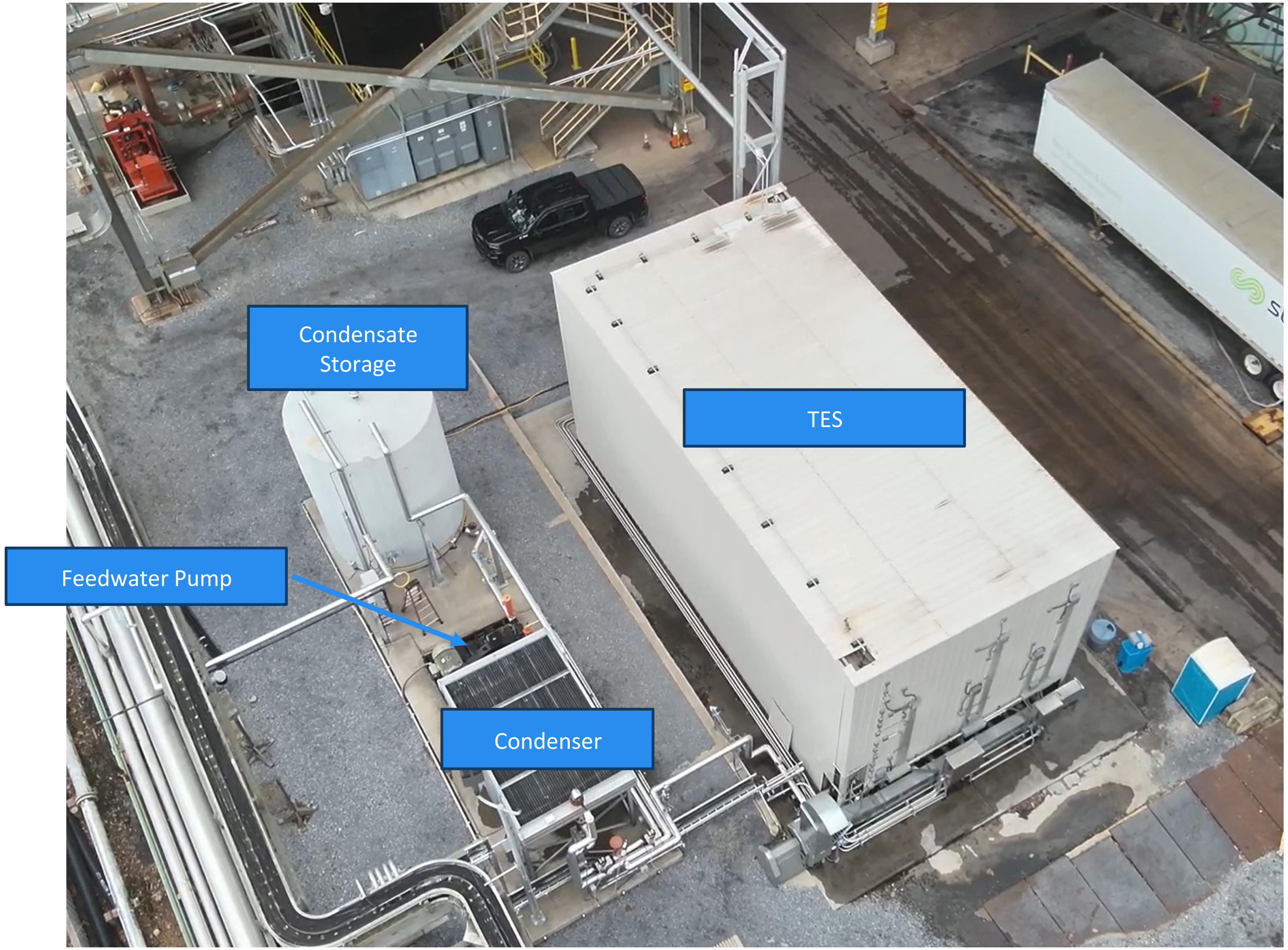
CTES Technical Validation

Plant Gaston Pilot

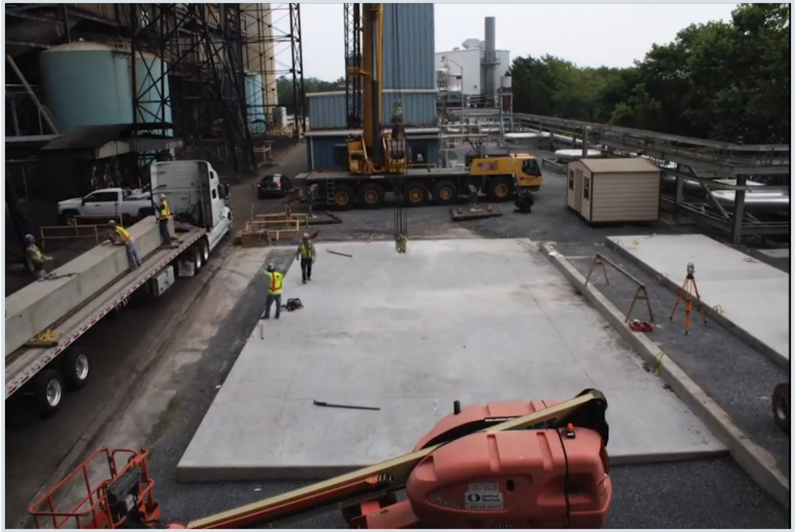
- Summary
- Good News
- Bad News
- Lessons Learned

DOE / EPRI Gaston Project – Site Layout



DOE / EPRI Gaston Project – Details

- 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
  - Stack dimensions: 6 m x 6.6 m x 12.6 m
- Supercritical steam at 530°C (1000°F) / 230 bar (3350 psi)
  - Plant available for 6 weeks of testing
  - Operated system for 700+ hours, with 80+ charge and discharge cycles



Gaston after installation of insulation and cladding

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

Modular Design

Manufacture

Ship

Foundation

Stack

Cladding

Insulation

Integration

Commission

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 each layer's performance. 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

What’s Next?

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

Sensible Heat TES alternatives

Type	Incoming Energy	Charging	Discharging		Energy Out	Applications
		1st conversion	2nd conversion	3rd conversion		
Firebrick 1500 C	Electricity	Resistance Heater – radiant Hx to firebrick – or- conductive firebrick – direct heating	Firebrick conductive Hx to air	Hot air and feedwater to separate boiler	Steam (hot air)	1. Replace gas for industrial heat 2. Drive a steam turbine for electricity
Graphite 2000 C	Electricity	Conductive Graphite – direct heating	Radiant Hx to thermal fluid	Thermal fluid + feedwater to separate boiler	Steam (hot air)	1. Replace gas for industrial heat 2. Drive a steam turbine for electricity
Molten Salt 550 C	Steam or electricity	Steam or Resistance heater - Conductive Hx to molten salt to tank	Molten salt and feedwater to separate boiler	None, but requires pumps and tanks	Steam (hot air)	1. Replace gas for industrial heat 2. Drive a steam turbine for electricity 3. Add flexibility to nuclear generation
Storworks Pilot 600 C	Steam	Condensing steam to concrete	Feedwater to CTES integral boiler, Conductive Hx to water in tubes	None	Steam (hot air)	1. Replace gas for industrial heat 2. Drive a steam turbine for electricity 3. Add flexibility to nuclear generation 4. Convert legacy CT fleet into very flexible CC with better economics and capacity credit
Storworks (type 2)	Hot Gas	CT exhaust or resistance-heated air hot gas conductive Hx to concrete				
Storworks (type 3)	Electricity	Embedded resistance heater - Conductive Hx to concrete				
Storworks Hybrid	Steam or Electricity	See above				

Unique Storworks Opportunity

- There is another boom in demand for new capacity, even greater than the last boom in 2001-2005.
- The market share of simple-cycle generation has doubled in the last five years to achieve fast response to capture lucrative price spikes in real-time markets.
- There may be 60 GW of CT generation built in the last boom in 2001–2005 that had plans to retrofit to a combined cycle “later”, but then the boom died.
- Retrofitting this fleet to CC may be the fastest source of new generation, <u>but</u> it does not offer the desired fast response…..unless a different approach is used.
- Storworks is developing a proprietary CTES/HRSG that utilizes the otherwise wasted energy in the CT exhaust <u>and</u> acts as a temporal buffer, allowing for a <u>doubling</u> of the incremental peak power compared to standard methods.

Unique Storworks Opportunity

	Traditional Retrofit to Combined Cycle (CC)	Storworks Retrofit to "Combined Flexible Cycle" (CFC)
Plant Rating Increase	50% (extract energy from CT Exhaust)	100% (extract energy from CT Exhaust and use CTES to buffer thermal energy)
Heat Rate – original	~10,000 Btu/kWh	~10,000 Btu/kWh
Heat Rate - combined	~7,000 Btu/kWh	~7,600 Btu/kWh (slight loss in RT efficiency)
Cold Start - CT	10-30 min	10-30 min
Cold Start - ST	60 minutes	**10 minutes** (keep ST hot with stored energy)
Discharge duration	Continuous	6-10 hours at peak rating
Capital Cost per incremental MW	$1,800–2,600/kW	~$1500/kW

Up to 60 GW of fast-responding, lower-heat-rate power at existing sites with no additional gas requirements, using new STs with an 18-month lead time, avoiding the 60-month lead time for CT generation

Thank You

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- 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