Sand Thermal Energy Storage (SandTES) Pilot Design

FY22 FECM Spring R&D Project Review Meeting – Energy Storage Program Virtual Session

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Sand Thermal Energy Storage (SandTES) Pilot Design

Summary of DOE Projects

- **Phase I Awarded**: 03/01/2021
- **Funding:** $249k
- **Timeline:** 03/01/2021–02/28/2022
- **Phase II Awarded**: 03/01/2021
- **Funding:** $995k
- **Timeline:** 03/01/2022–02/28/2023
- **Site Host:** Southern's Plant Gaston
- **Team:** EPRI (prime), Andritz, CDM Smith, Southern, and Technische Universität Wien (TUW) / Andritz

Objectives

Phase I: Perform a feasibility conceptual study on the integration of a 10 MWhe SandTES system to Southern's coal-fired Plant Gaston.

Phase II: Perform a pre-front-end engineering and design for a next-step pilot at Plant Gaston. By enacting the pilot, SandTES will advance to Technology Readiness Level (TRL) 6 and enable commercial readiness by 2030.

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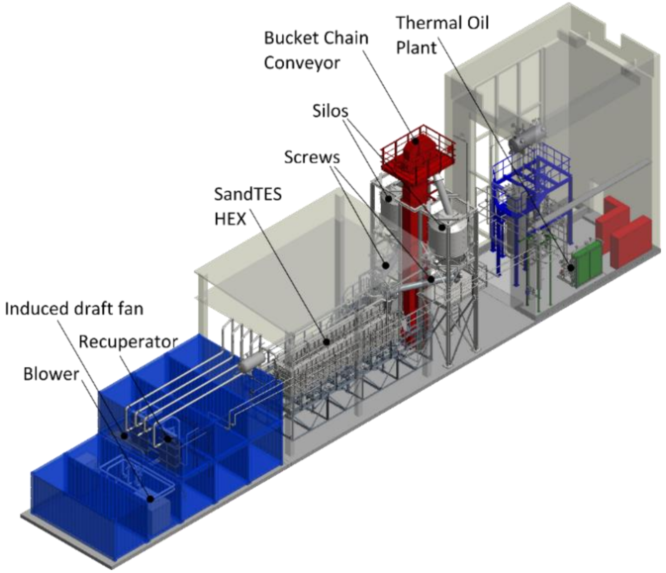
SandTES

How It Works:

Heat from a thermal plant or electricity transferred to and from sand in a counter-current bubbling-bed heat exchanger to generate steam for a steam turbine generator.




Courtesy of Technische Universität Wien

Benefits:	Challenges:
• Low-cost material with high availability: $46/tonne • Small plant footprint • System inertia • Zero fire risk	• Heat transfer process is more complex with a solid material • Requires extensive solids handling equipment that may introduce reliability issues

Applications:

Integration with existing thermal power plants or pumped heat energy storage systems

Vital Statistics

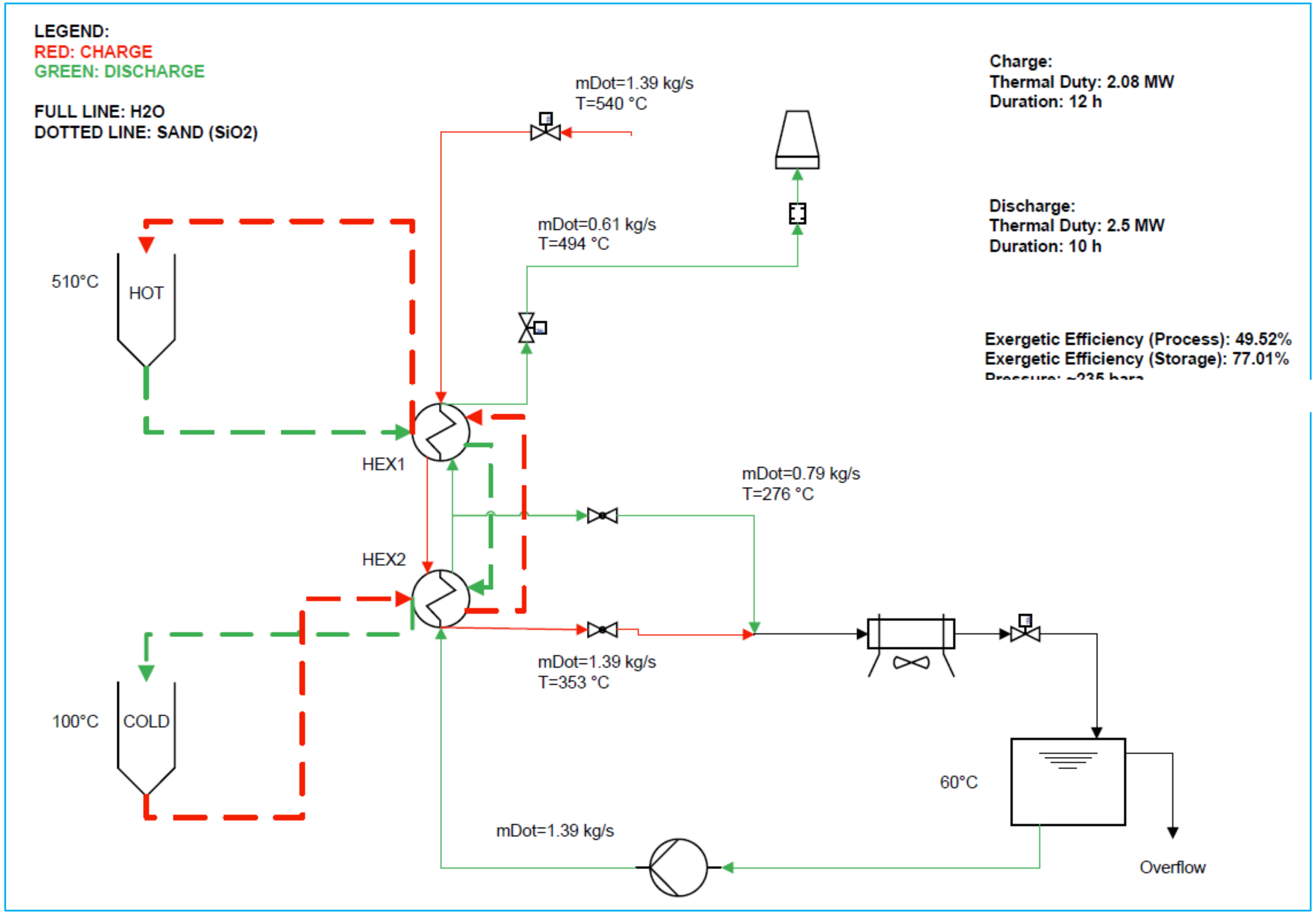
AC RTE:	35–45%	**TRL:**	5
Life:	30 years	**Largest Pilot:**	280 kWth

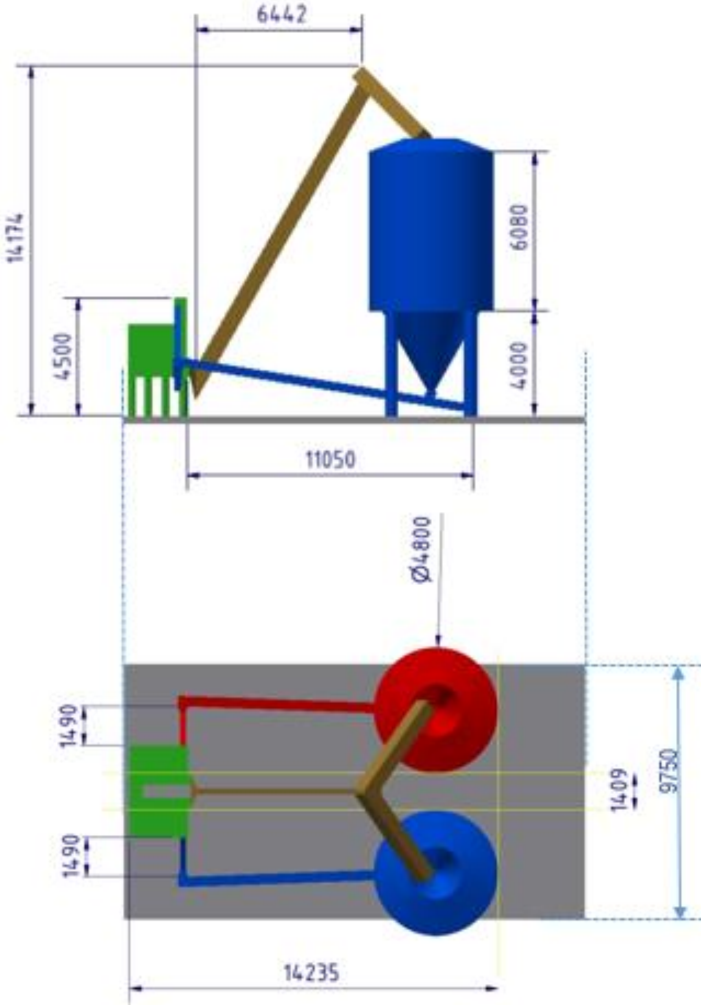
Concept Study Goals

- Fit into the existing infrastructure and footprint for the CTES → *Proposed concept fits seamlessly, reducing risk and cost – a significant portion of the next-step pilot cost would have been constructing infrastructure ($2.5M)*
- Large enough to advance SandTES to TRL 6 → *1 MWe with 10 hours duration was chosen to achieve TRL 6. This is a scale up by factor of ~10. 10 hours was chosen to illustrate the capability to go to longer durations.*
- Two tank or four tank? → *Two-tank design chosen to reduce costs and complexity and fits with most of the commercial designs as well.*
- Keep costs under $5M → *Goal as stated in the bid*

Goal: Develop a pilot design with the highest chance of success

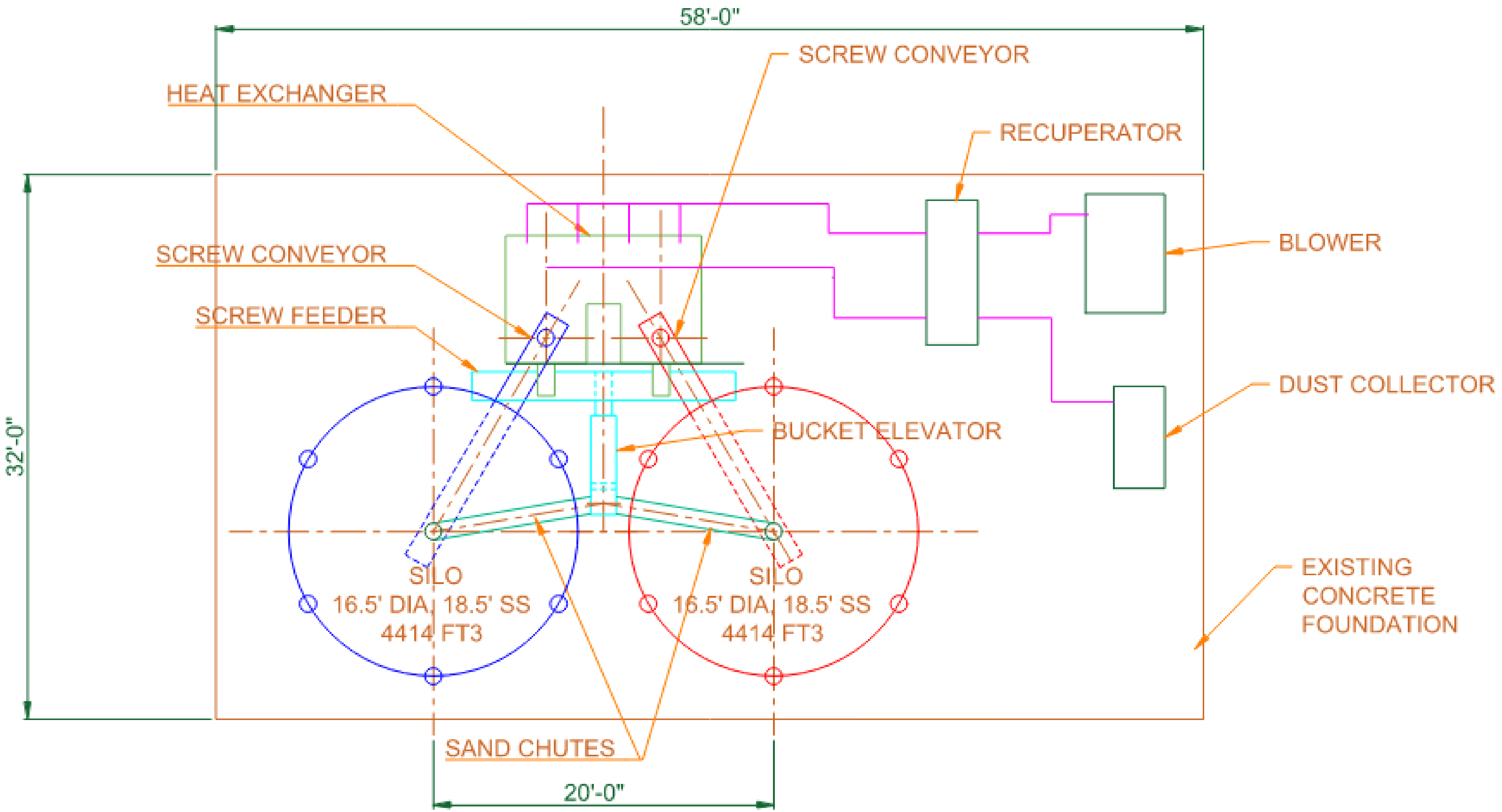
Pilot Design Overview



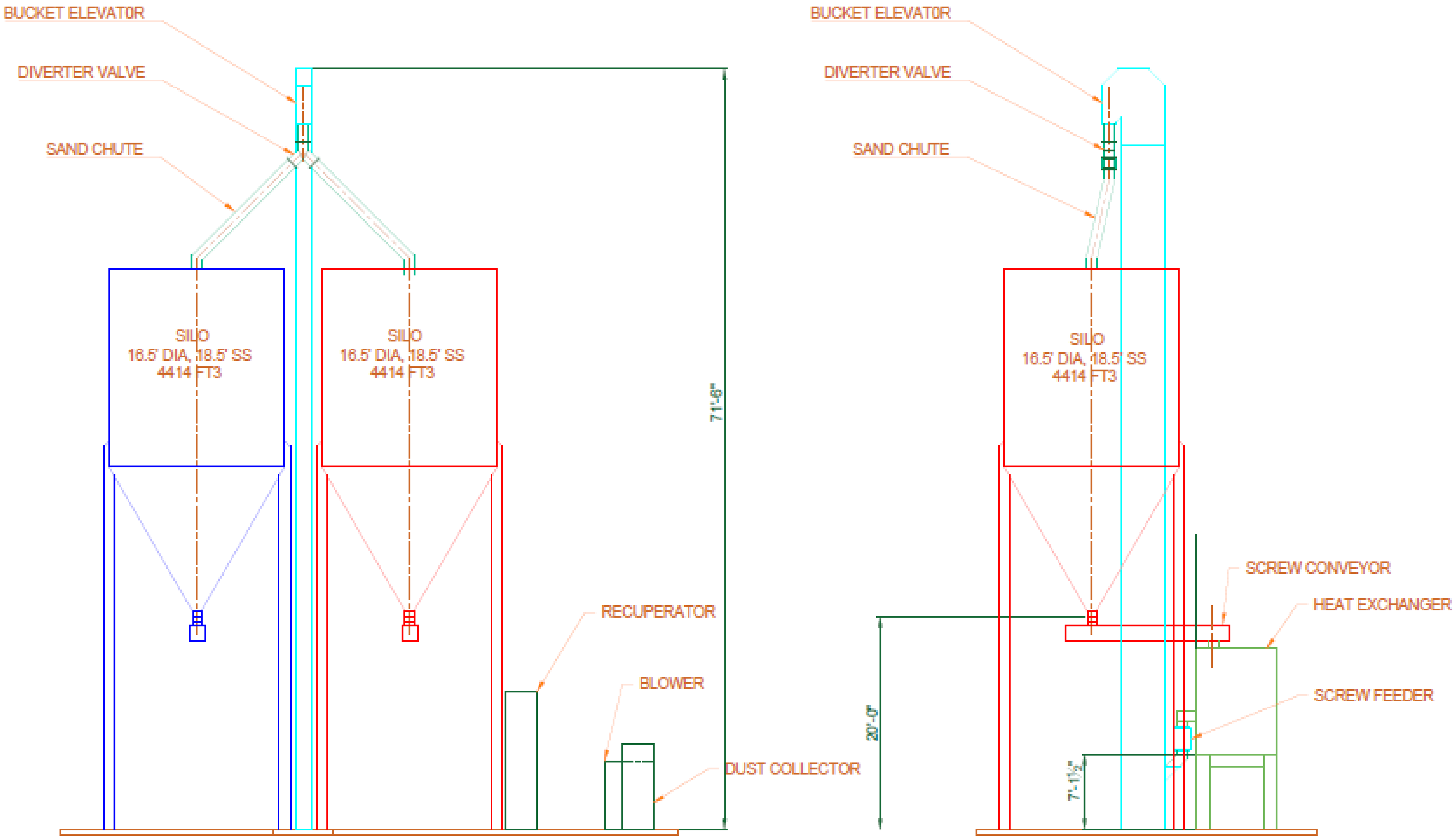


Exergetic efficiency = 77%; Charge thermal duty of 2.1 MWth and 12 hours duration; Discharge thermal duty of 2.5 MWth and 10 hours duration

Pilot Design Plan View



Pilot Design Side View



Capital Costs

- Capital cost estimate comprised two pieces:
  - TUW developed a capital cost for the most novel component in the SandTES system: the fluidized-bed heat exchanger and its associated system
  - CDM Smith compiled capital cost estimates for all the other components in the system and the balance-of-plant, as well as for things like final engineering and construction management. Primarily this was done via vendor quotes.
- The two efforts were then combined to elicit the final capital cost estimate for the SandTES pilot plant at Plant Gaston

AACE Class 5 capital cost estimate

Capital Cost Summary

Item	Amount
Structural	$140,000
Electrical	$215,000
Mechanical	$1,039,000
Engineering	$181,000
Construction Management	$139,000
Contractor OH&P	$257,000
TUW Equipment (fluidized-bed heat exchanger)	$1,000,000
Total Costs	**$2,971,000**

Quotes from: Advance Tank (silos) and Materials Handling Equipment Company (sand material handling equipment)

Operating Costs Overview

- Plan emulates a similar plan being used for the DOE-funded Concrete TES (CTES) pilot at Plant Gaston:
  - 9 months of testing operation and 3 months of commissioning
  - Southern Company will be providing resources to operate the pilot during testing
  - Technology developer, TUW, will be on-site during commissioning along with EPRI
  - Consumables (electricity, water / steam, and air) costs are based on known unit rates for the Plant Gaston site

Significant amount of testing will take place with many cycles

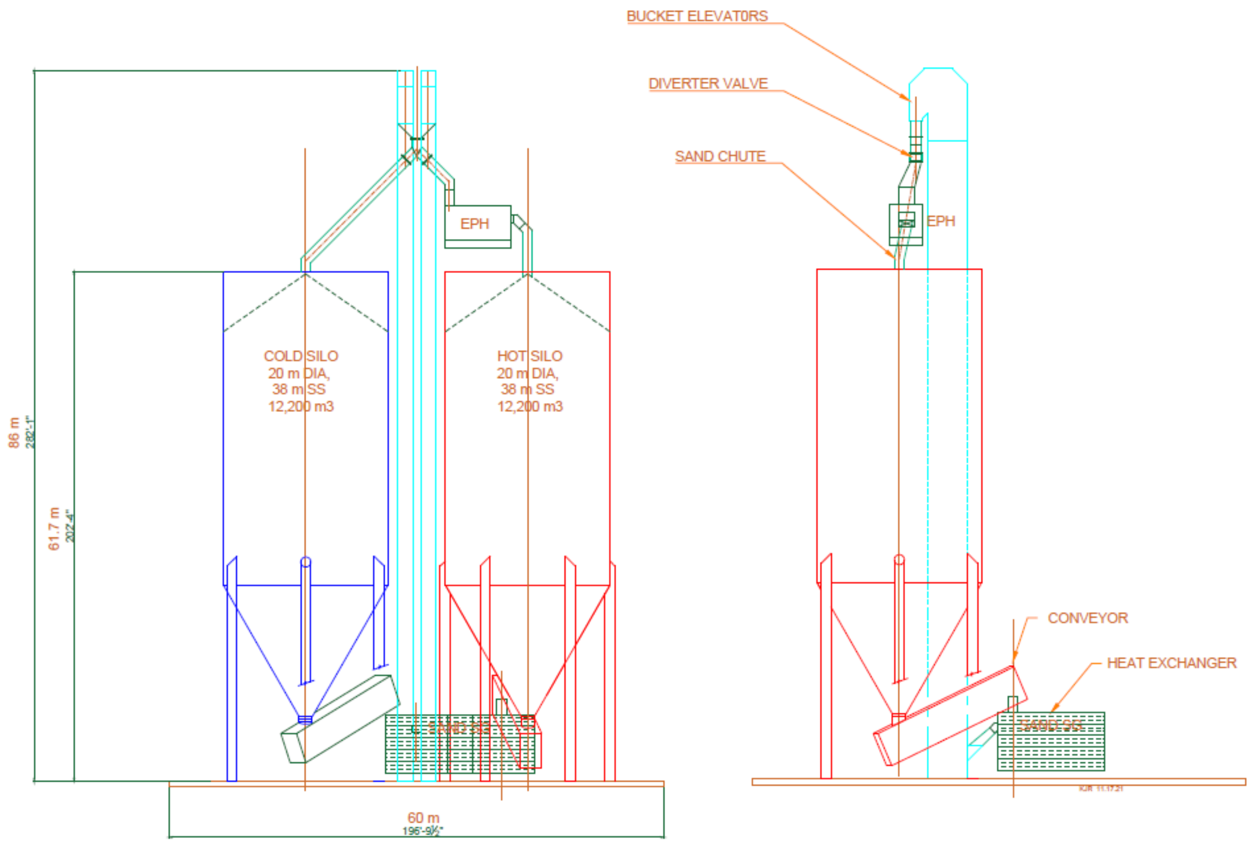
Operating Cost Summary

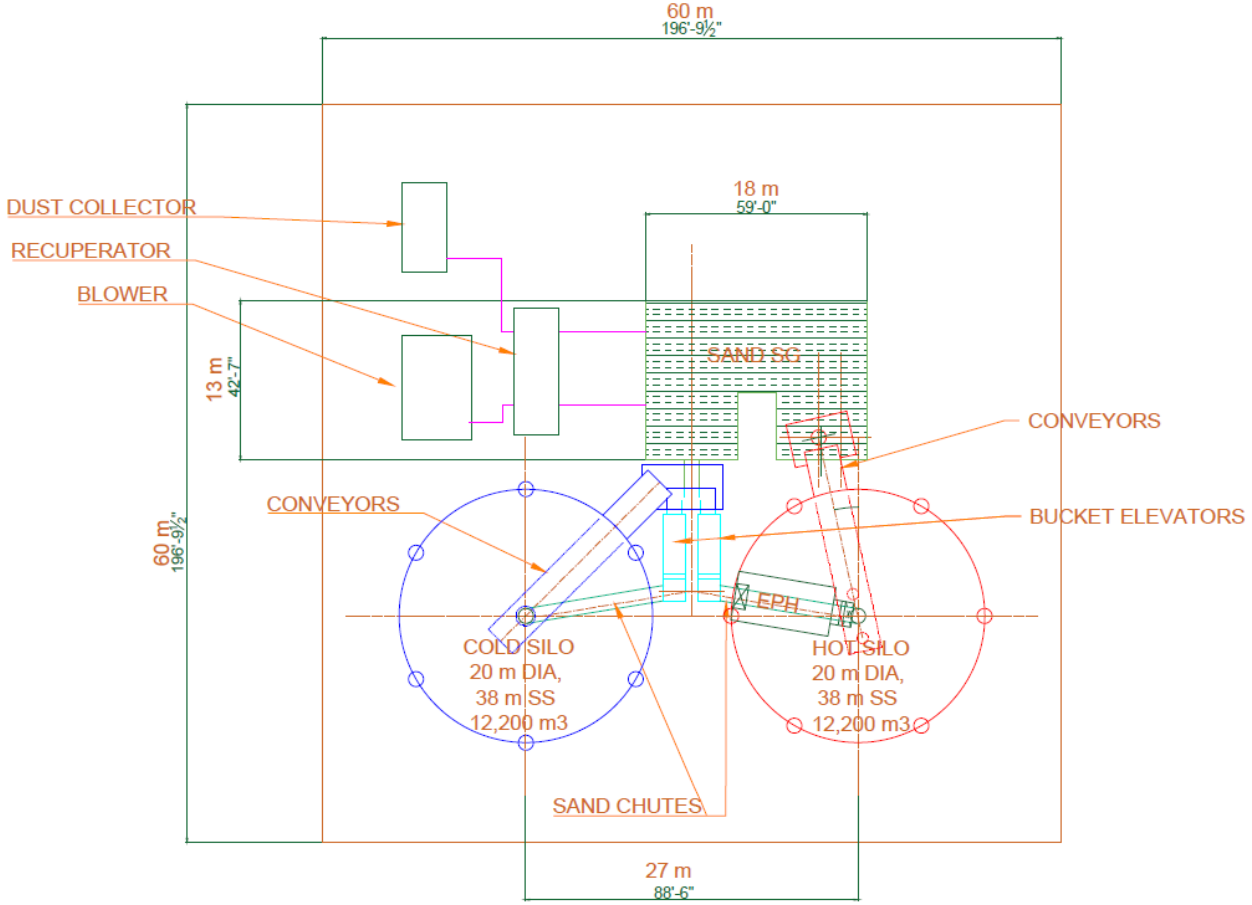
Parameter	Per Month	Totals	Comment
Electricity	$3000	$27,000	150-hp (111 kWe) pump during discharge (4 hours/cycle)
Demin Water	$1140	$10,260	Water use is limited
HP Steam	$4786	$43,074	5-hour charge at up to 20,000 lb/h (9070 kg/h)
Filtered Water/Compressed Air	$1000	$9000	Valve actuation and N_2 generator
Subtotal for 9 Months	---	$89,334	---
Operations Support (Labor)		$112,860	Operations oversight (not full time)
Mechanical Hardware		$25,000	10% spares for elevator hardware based on a $250,000 capital cost
Commissioning Support		$35,000	3 months for 1 person from TUW
Total Cost for Testing	**---**	**$262,194**	**---**

Total pilot costs = $3,233,194

Commercial Design and Cost Estimate

Southern's NGCC Plant Rowan
193 MWe bottoming cycle





Capital costs: $293.3M ($151.6/kWhe) for 10 hours duration

Technical Approach: Tasks for Phase II

1. **Project Management and Planning:** Monitor and control the project and project reporting and review needs for the next-step pilot.
2. **Complete a Pre-FEED Study:** Detailed design effort for the integration of SandTES to the designated host site, Plant Gaston, at 10-MWhe scale, including AACE Class 4 capital costs and performance estimates.
3. **Update the Phase I Technoeconomic Study:** Update on the cost and performance for commercial-scale applications of SandTES integrated with a thermal power plant for several markets.
4. **Update the Phase I Technology Gap Assessment:** Update based on learnings from the pre-FEED study on potential gaps of SandTES and how they will be addressed to be commercial by 2030.
5. **Complete an Environmental Information Volume:** Compilation of an Environmental Information Volume (EIV) for the site, in preparation for the National Environmental Policy Act (NEPA) process.
6. **Update the Technology Maturation Plan:** Update the technical review of the technology readiness level (TRL) for the system and the plan to advance it through TRL 9, commercial readiness.
7. **Update the Commercialization Plan:** Update the plan for commercializing SandTES based on the evolving energy storage market.

Seven tasks in the one-year project

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Phase II Schedule

Anticipated Start Date: 03/01/2022	Key Person	Duration	2022 Q1	2022 Q2	2022 Q3	2022 Q4	2023 Q1
BUDGET PERIOD 1 [4 Quarters]		**4Q**					
Task 1.0: Project Management and Planning	**Andrew Maxson, EPRI**	**4Q**					**F, C**
1.1: Project Management Plan		**4Q**	**K**	**Q**		**Q**	**Q**
1.2: Technology Maturation Plan		**4Q**					
1.3: Adjust Project Team and Obtain Cost-Share Commitments		**4Q**					
Task 2.0: Complete a Pre-FEED Study	**Kevin Montesano, CDM Smith**	**4Q**					
2.1: Update Technical Design		**3Q**			**R**		
2.2: Capital and Operations Costs		**3Q**					
2.3: Performance		**2Q**					
Task 3.0: Update the Phase 1 Technoeconomic Study	**Scott Hume, EPRI / Markus Haider, TUW**	**3Q**					**R**
Task 4.0: Update the Phase 1 Technology Gap Assessment	**Scott Hume, EPRI**	**2Q**					
Task 5.0: Complete an Environmental Information Volume	**Kevin Montesano, CDM Smith**	**3Q**					
Task 6.0: Update the Technology Maturation Plan	**Andrew Maxson, EPRI**	**2Q**					
Task 7.0: Update the Commercialization Plan	**Markus Haider, TUW**	**3Q**					
7.1: Market Assessment		**2Q**					
7.2: Domestic and International Market Applicability		**2Q**					
7.3: Development of Use Cases		**2Q**					
7.4: Advantages of the Technology		**2Q**					
Milestone 1: Updated PMP			◆				
Milestone 2: Kickoff Meeting			◆				
Milestone 3: Updated TMP				◆			
Milestone 4: Review of Pre-FEED Design					◆		
Milestone 5: Review of the Technoeconomics							◆
Milestone 6: Final Report							◆
Milestone 7: Closeout Meeting							◆

(C = closeout, F = final report, K = kickoff, Q = quarterly report, and R = review meeting)

Project is underway

Benefits

- If heat is obtained from a fossil plant, system can operate base load, reducing cycling and shutdowns and maintenance costs and extend life. Emissions are reduced on a MWh basis.
- If heat is obtained from electricity when SandTES is installed at a decommissioned fossil plant, it uses the existing infrastructure, greatly reducing capital costs, and maintaining jobs in the area
- Cost of storage for SandTES at 24 hours duration is $63/kWhe – less than half the cost of molten salt
- As renewables grow, markets are adding capacity payments and other auxiliary services – driving the value for longer-duration energy storage

Significant benefits for integrated SandTES

Conclusions

- Pilot will be located at Plant Gaston and take advantage of existing infrastructure, greatly reducing cost, time, and risk
- Two-tank system that produces ~1 MWe at 10 hours duration. This is a 10x scale up and will highlight the ability to provide longer durations.
- Estimated cost for the pilot is $3,233,194, which is substantially lower than the target cost of $5M
- Efficiency is 77% with a charge thermal duty of 2.1 MWth for 12 hours and a discharge thermal duty of 2.5 MWth for 10 hours
- Has the potential for significant benefits and to be a low-cost system

Decisive scale-up and validation for this promising technology

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