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Particle Thermal Energy Storage Components for Pumped Thermal Energy Storage

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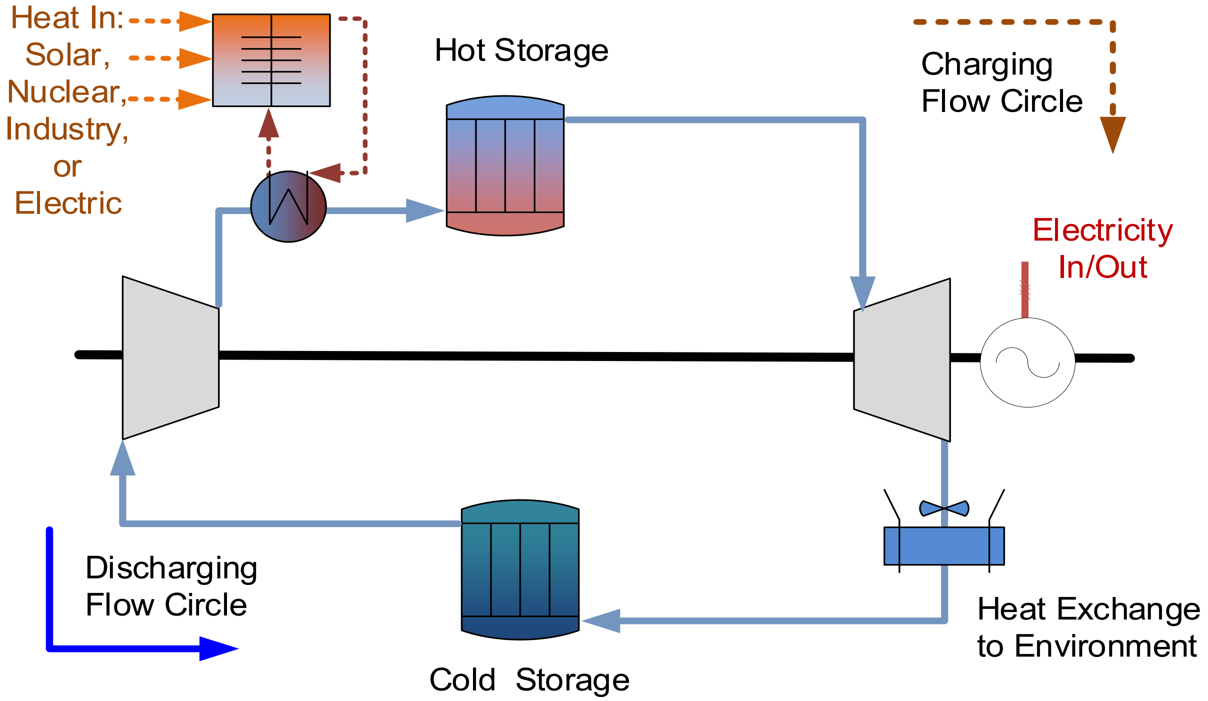
Why Particle Thermal Energy Storage (TES)?

A Pumped Thermal Energy Storage (PTES) System

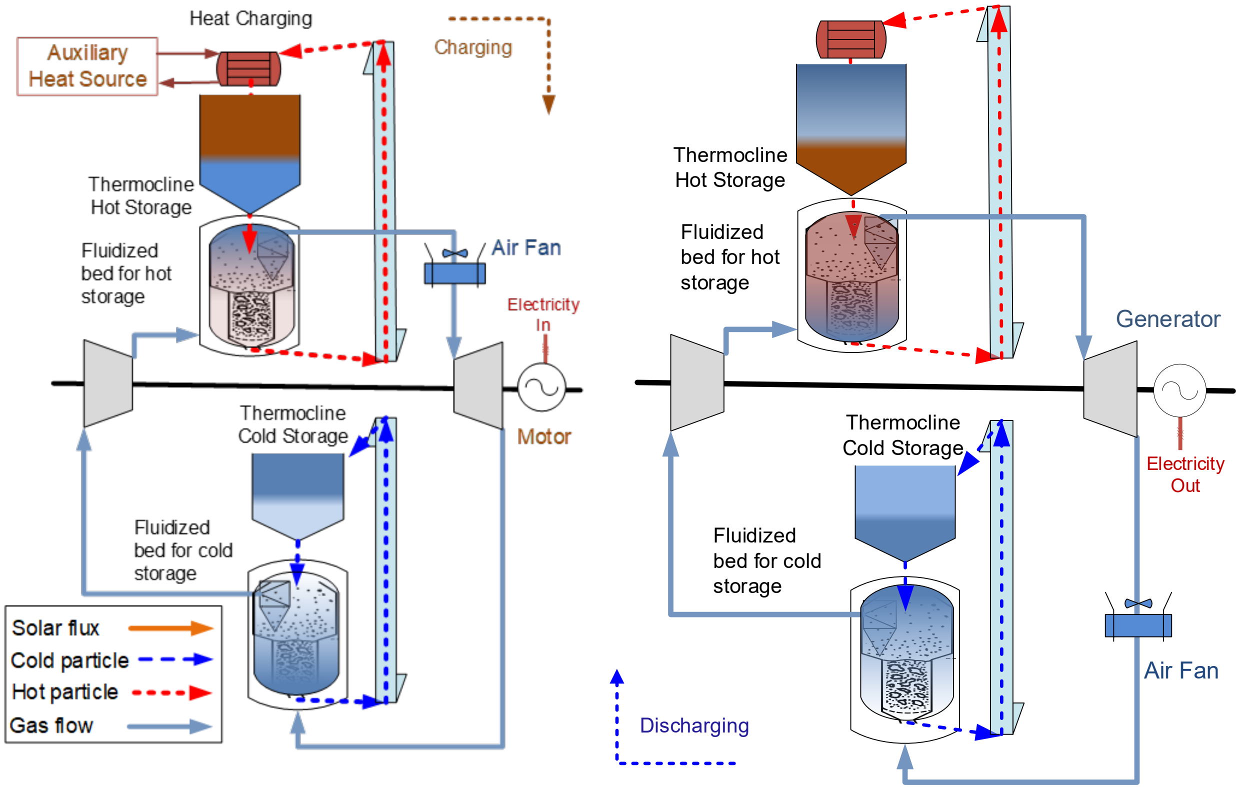


Advantages of particle TES vs molten-salt or rock bed TES:

- No freezing at low temperature and no stability issue at high temperature.
- No corrosion issues.
- Low cost containment and storage materials.
- Flexible configuration due to broad temperature range for cycle selection and optimization.

Increase efficiency, scale, and cost effectiveness of grid energy storage.

A Configuration of Particle TES for PTES



- Economically and efficiently store both cold and hot thermal energy in particles (cost 35$/ton, from <-100°C to >1000°C).
- Direct gas/particle contact avoids heat transfer surfaces and minimizes the exergy loss and heat exchanger cost.
- Avoids cold liquid storage cost and issues of low-temperature containment and fire hazard.

Particle TES is a unique fit to PTES for cost and performance.

Economic Long-Duration Electricity Storage by Using Low-Cost Thermal Energy Storage and High-Efficiency Power Cycle (ENDURING)

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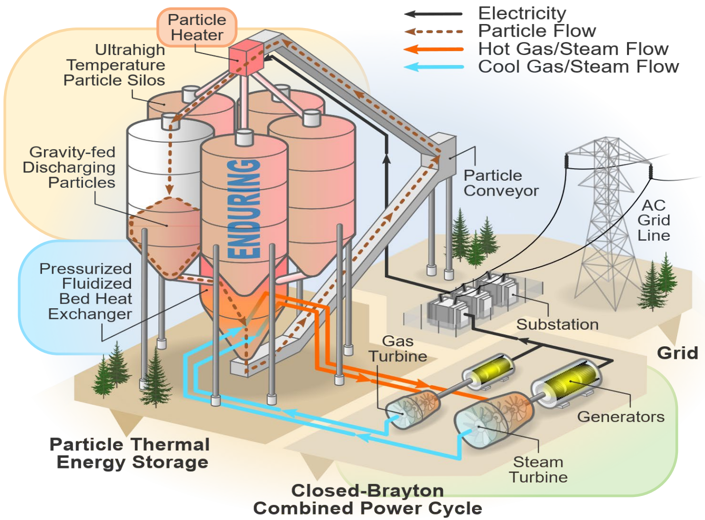

Advanced Research Projects Agency – Energy (ARPA-E) U.S. Department of Energy

3-year | $2.79M DOE funding ($443K cost share)

Project Objectives

1. Develop the ENDURING system & components for long-duration energy storage (LDES) to support grid resilience and security.
2. The ENDURING LDES system addresses large-scale grid integration of intermittent renewables like wind and solar.

arpa·e
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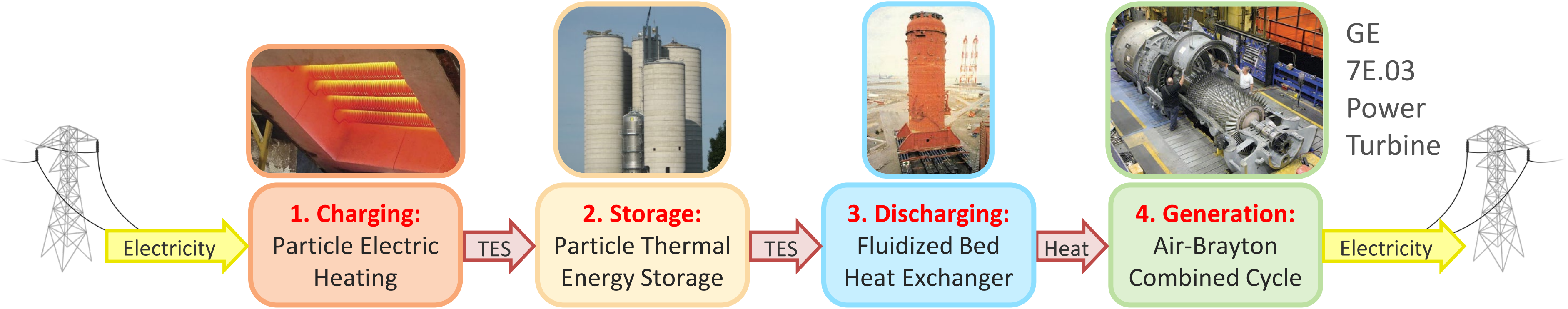
ENDURING Energy Storage System

ENDURING LDES operates as a thermal battery, in a large scale and low cost.



Industry partners:

- Allied Mineral
- Watlow

- Allied Mineral
- Marietta Silos
- Matrix PDM

- Allied Mineral
- Babcock & Wilcox (B&W)

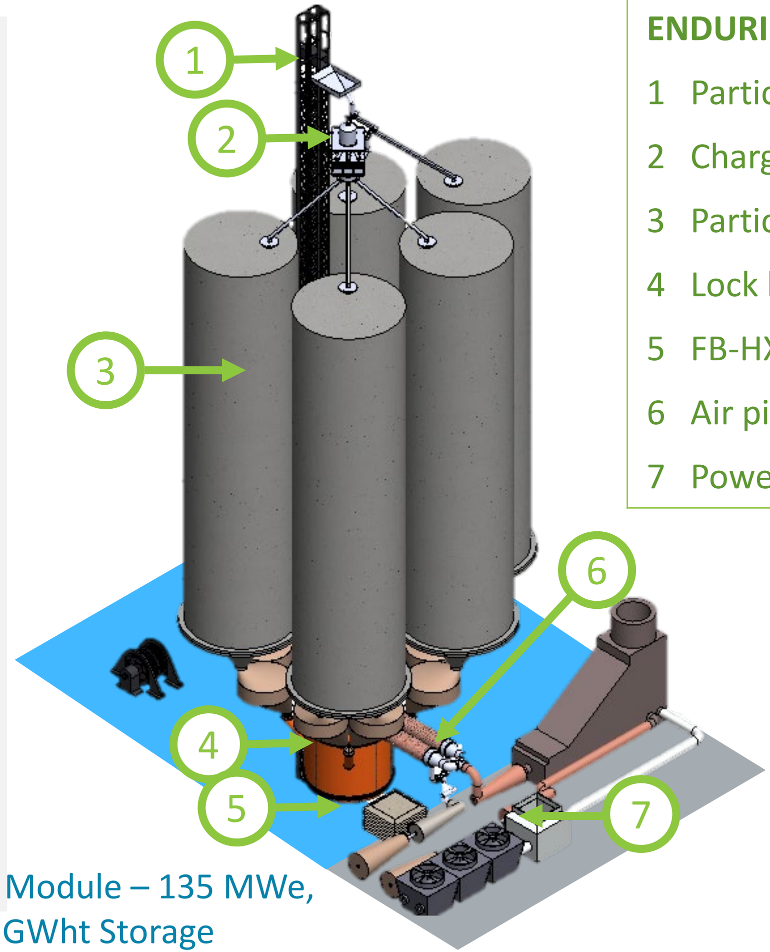
- GE

System integration: Worley-Advisian

- Scalable for 10 – 100 hours of storage, 50 – 400 MWe power.
- Increase cycle efficiency with ultra-high temperature (1,200°C) particle TES.
- Flexible siting can leverage assets from retired thermal power plants.

System and Component Development

- Control component cost: No expensive/ exotic materials and manufacturing.
- Commercialization strategy supported by industry partnerships and market insight.
- Combined modeling and prototype testing to accelerate development cycle.
- Achieve low storage cost of ~$2/kWht by:
  - Use of 30–40$/Ton silica sand and low-cost containment (concrete silo, refractory)
  - Charge/discharge temperature difference of 900°C
  - Containment vessels designed to store both hot and cold particles.



Full Scale Module – 135 MWe, 26 GWht Storage

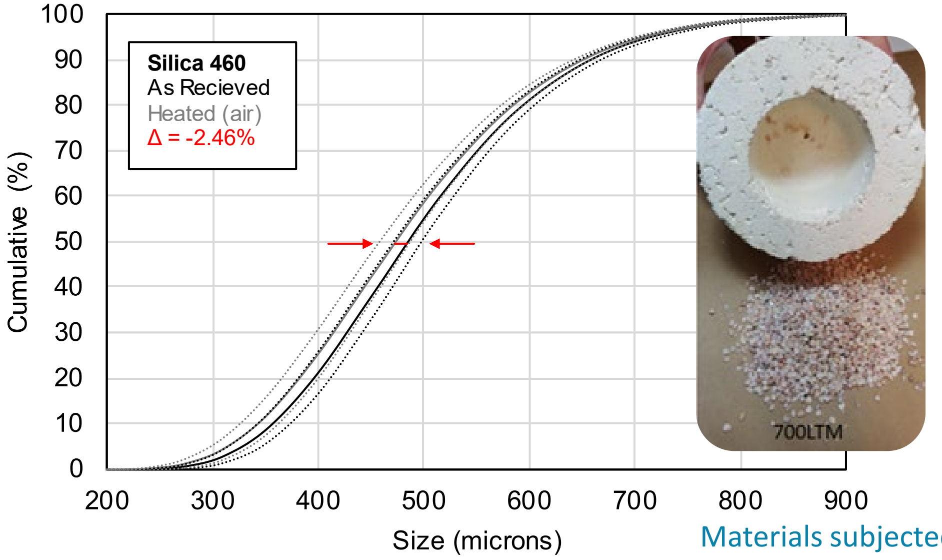
ENDURING :

1 Particle lift
2 Charge heater
3 Particle TES
4 Lock hopper
5 FB-HX
6 Air pipes
7 Power island

Storage Media Thermal Stability Tests

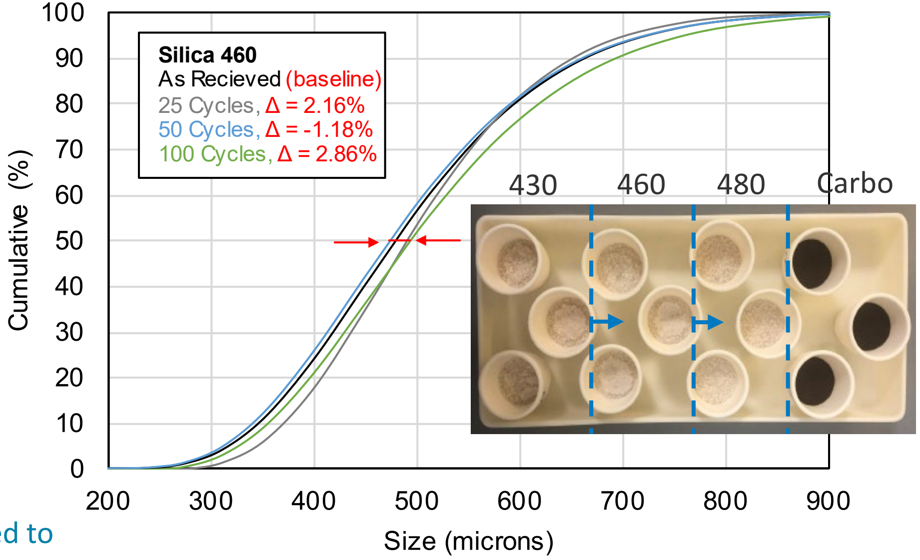
Particle size distribution changes of silica sand are small after the thermal tests.

500-hour heating test at 1,200°C



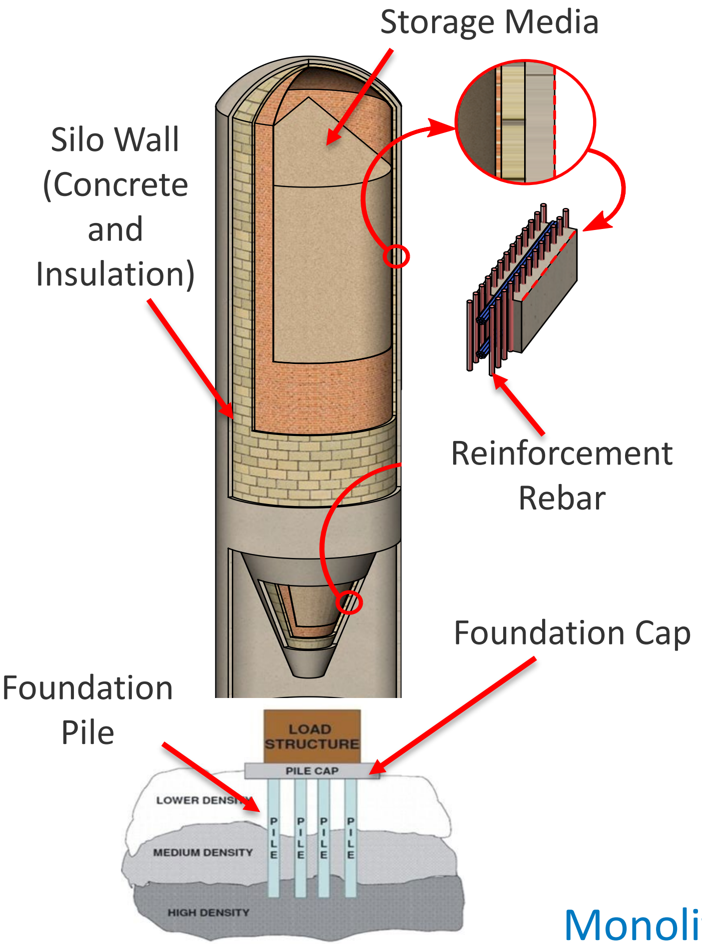
Materials subjected to thermal stability tests

Performed 100 cycles at 300°C – 1,200°C



- >99% silica of high stability allows thermal storage from < -100°C to > 1000°C.
- Abundant reserve in Midwest and reusable without environmental impact.

Particle Containment



Particle TES Single Silo Specifications

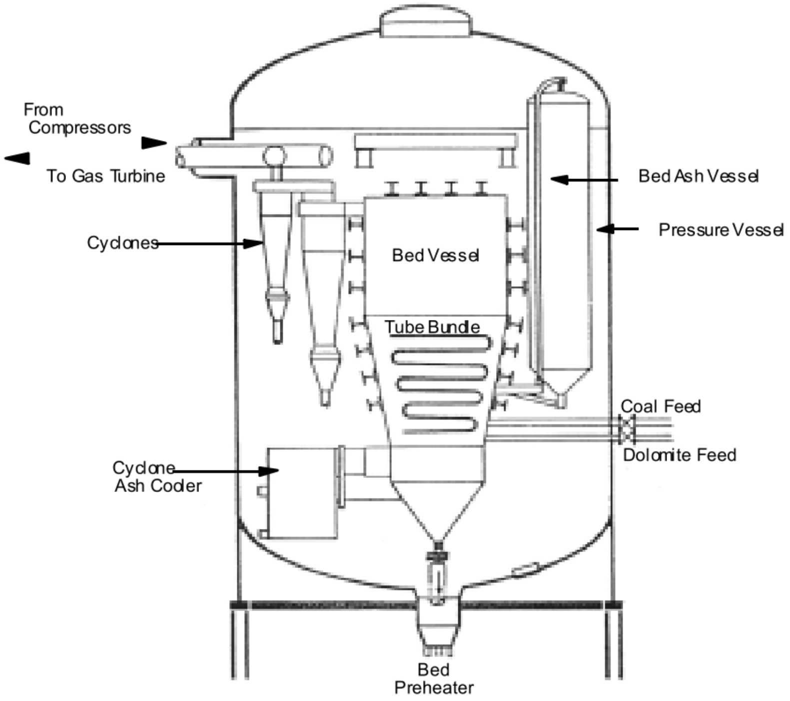
Parameters	Units	Values
Whole System Silo # Required	-	12
Particle Weight in One Silo	ton	22500
Silo Height (cylinder section only)	m	65.8
Silo OD (followed 3-to-1 ratio)	m	20
Total TES Energy Capacity (single silo)	GWht	6.37

Particle TES (6.37GWht) Cost Breakdown

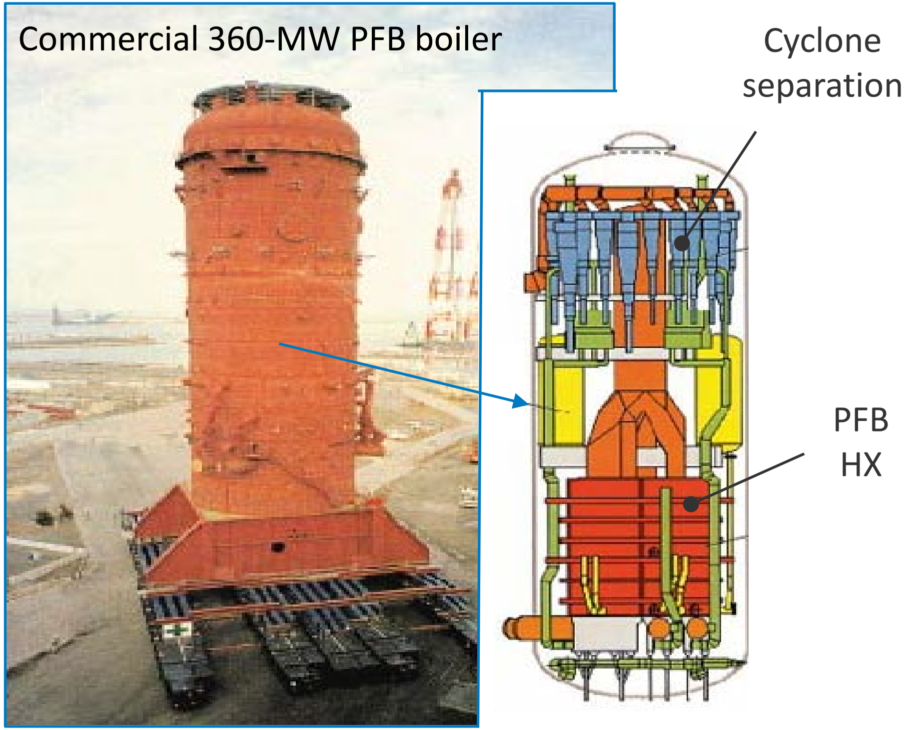
Categories	*Units*	*Cost Values*
Single Containment Capital Cost	**$**	**12,503,325**
Single Silo Containment Construction Cost	$	11,731,455
Silo and Foundation Construction	$	*3,857,262*
Insulation Cost	$	*7,874,193*
Storage Media (Silica Sand) Cost	$	771,870
Containment Cost per Unit TE Stored	**$/kWh_th**	**1.96**

Monolithic Insulation is expensive, to be optimized for lower cost.

Leverage Pressurized Fluidized Bed (PFB) Technology

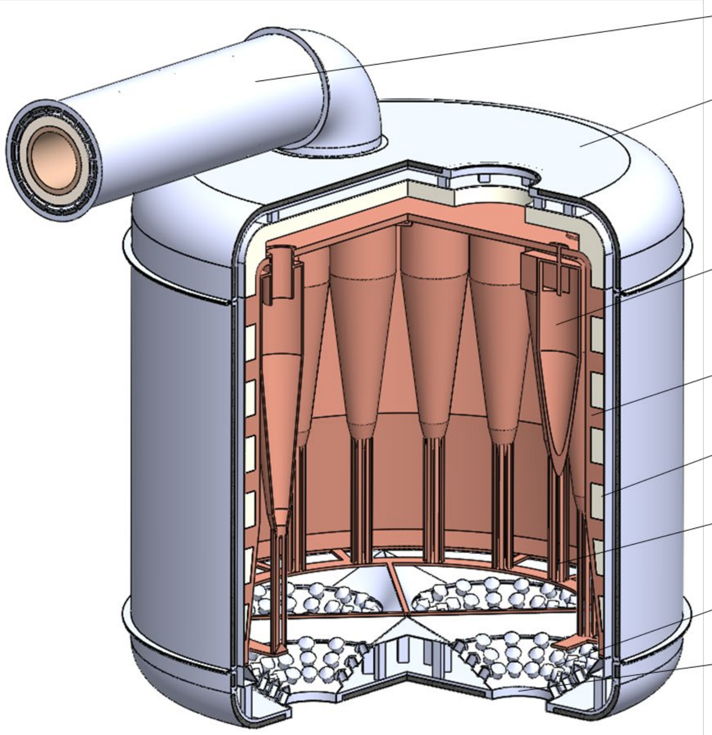


Babcock &Wilcox (B&W) 70MW Tidd PFB demonstration plant



A commercial PFB boiler and cross-section for a 360-MWe power plant built in Karita Japan.

PFB Heat Exchanger



Develop both cold and hot prototypes to test operating conditions.

Design Specifications

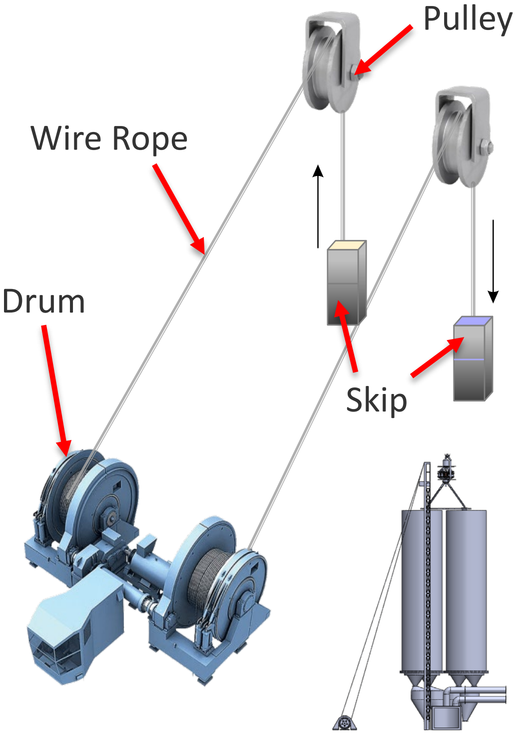
Parameter	Unit	Value
PV Inner Dimensions (*ID* × *H*)	m	15 × 15
PV OD	m	15.53
Inner Bed Size (*D* × *H*)	m	13.00 × 10.00
Heat Capacity 7E.03 turbine	MWt	270
Particle Separation Cyclone		
Cyclone Separation Efficiency	%	99.98
Cut Diameter, d_{50}	µm	8.71
PFB System Pressure Drop	kPa	39.44

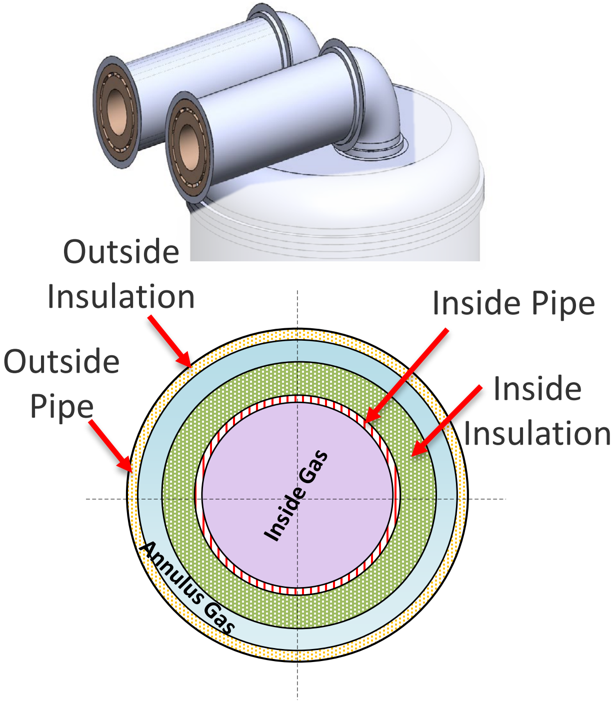
PFB HX Component Cost Breakdown

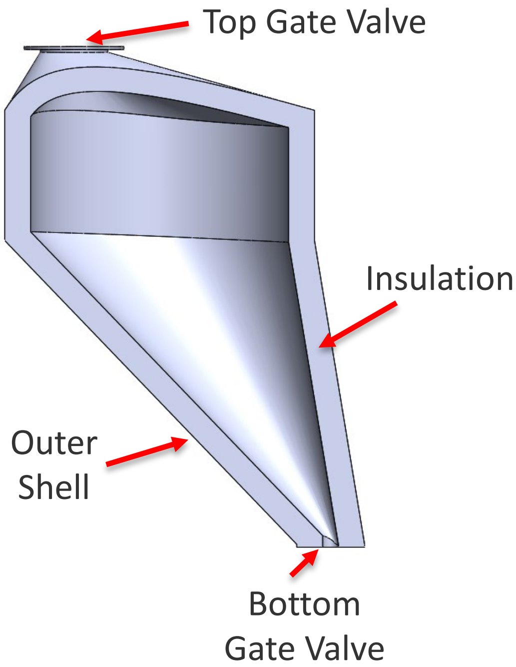
Categories	***Units***	***Cost Values***
Equipment Costs		
PFB Pressure Vessel Cost	$	2,071,334
PFB Heat Exchanger Cost	$	4,574,561
Particle Separation Cyclone	$	109,854
Single PFB System Capital Cost	**$**	**9,795,836**
Cost of Unit Power Capacity	**$/kWe**	**72.56**

Auxiliary Components

Particle lift skip hoist | Pipe-in-pipe gas line | lock hopper







Designed and analyzed gas and particle handling equipment.

Thank you

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Questions?

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https://www.frontiersin.org/research-topics/10251/long-duration-and-long-term-energy-storage-for-renewable-integration