INL/CON-19-54775-Revision-0

# Poster for High Temperature Storage Conference on TES Selection for JUMP

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operated by Battelle Energy Alliance

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**http://www.inl.gov**

**Prepared for the**
**U.S. Department of Energy**

**Under DOE Idaho Operations Office**
**Contract DE-AC07-05ID14517**

# Phenomenon Identification Ranking Table Development for Identifying Thermal Energy Storage for Near-Term Integration with Light Water Reactors

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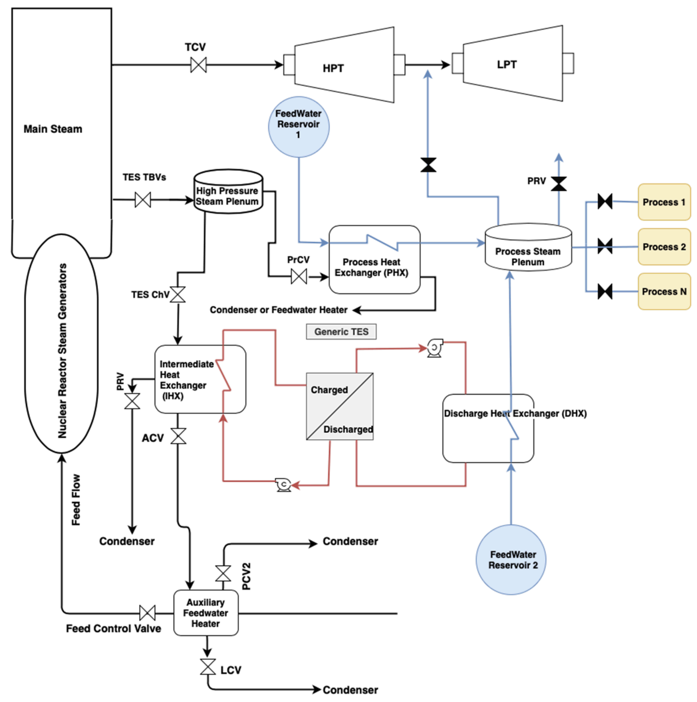
## Introduction and Background

As electrical grids continue to integrate more intermittent renewable energy sources, the value of energy storage has increased. Concentrated solar power (CSP) plants have already implemented thermal energy storage, usually in the form of molten salt sensible heat storage. CSP plants use thermal energy storage to increase the capacity factor of those systems by allowing the heat produced during daylight hours to be discharged as needed over the full 24-hour period. The nuclear power industry's interest in energy storage is effectively the opposite of CSP methods. With increased penetration of intermittent renewables, traditionally baseload plants have been required to operate flexibly to avoid periods of electricity oversupply or selling electricity at a loss. Energy storage could allow nuclear reactors to avoid power cycling during these periods of low baseload demand, instead storing the energy in order to discharge it later.

Idaho National Laboratory, in conjunction with the Department of Energy, NuScale, and Utah Area Municipal Power Systems, is planning a Joint Use Modular Plant program that will allow use of one module within a small modular reactor (SMR) plant for research for research, development, and demonstration (RD&D) purposes. A primary research application for JUMP is to demonstrate energy storage connected to an SMR.

Rendering of conceptual 12-module NuScale power plant
(Figure reference: https://inl.gov/trending-topic/carbon-free-power-project/)

Nuclear reactors generate large amounts of thermal energy. To avoid losses that occur during energy transformations, thermal energy storage (TES) is pre-selected for coupling with the JUMP module. A ranking system must be established to select a specific technology to pursue in the engineering design phase, accounting for as many energy storage attributes and integration requirements as possible.




Pre-conceptual design of a possible two tank sensible heat storage system for load following

## Phenomenon Identification Ranking Table Criteria

| | | | |
|---|---|---|---|
| **TRL:** Is the technology ready for near term deployment? (3-5 years) | **Charge:** Can the TES directly accept heat from LWR steam? | **Discharge:** Can the TES store and discharge at high temperatures? | **Ancillary Market:** Will the TES open up grid ancillary market participation? |
| **Capacity:** Can the TES be made large enough? (400MWht) | **Ramp:** Can the TES change its discharge power quickly? | **Frequency:** How often can the TES completely charge and discharge? | **Realignment:** How often will the TES be unavailable in order to reset? |
| **Cost:** What is the price per unit energy of storage? | Phenomenon Identification Ranking Table Criteria | | **Lifetime:** How long will the storage last? |
| **Geography:** Is the TES location specific? | **Environment Impacts:** Are there significant environmental concerns? | | **Turndown:** Will the TES need minimum heat input? |

| Technology | TRL | Charge | Discharge | Ancillary Market | Capacity | Ramp | Cycle Frequency | Realignment | Geography Reqs. | Environment Impacts | Turndown Reqs. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UTES | 9 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 14 |
| Hot/Cold Water | 9 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 19 |
| Concrete | 5 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 20 |
| Firebrick | 3 | 0 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 14 |
| Geothermal | 2 | 1 | 2 | 0 | 2 | 1 | 2 | 1 | 0 | 0 | 0 | 11 |
| Therm. Chemicals | 4 | 1 | 2 | 0 | 2 | 0 | 0 | 1 | 1 | 1 | 0 | 12 |
| Phase Change Materials | 4 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 16 |
| Thermocline Molten Salt/Thermal Oil | 5 | 1 | 2 | 1 | 2 | 2 | 2 | 0 | 1 | 1/0 | 0/1 | 17 |
| Two-Tank Molten Salt/Thermal Oil | 9 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1/0 | 0/1 | 23 |
| Steam Accumulators | 9 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 22 |

PIRT evaluation results table. Each of the numerical categories are presented above.

## Thermal Energy Storage Options

### Underground Thermal Energy Storage

Underground thermal energy storage uses aquifers or boreholes to seasonally store hot and cold water for municipal or HVAC purposes.

### Hot and Cold Water Storage

Above ground chilled and heated water storage allows for daily production of necessary hot or cold water for later use.

### Concrete Thermal Energy Storage

Specialized concrete cast around piping allows for heat to be stored in the concrete. By reversing flow direction in the piping, a thermocline system can be established in the concrete.

### Firebrick

Ceramic bricks heated by resistance heaters to as high as 1850°C store heat until discharged via air blown through internal channels.

### Geothermal

Deep caverns store high temperature water, pressurized near the ambient pressure at the storage depth.

### Thermochemicals

Endothermic chemical reactions absorb heat, and the products are stored separately until they can be recombined for exothermic energy release.

### Phase Change Materials

Latent heat of vaporization, fusion, or sublimation is stored as materials change from one phase to another with heat input or release.

### Thermocline Sensible Heat Storage

A single tank contains cold and hot stores of a working medium separated by thin but steep thermal gradient.

### Two Tank Sensible Heat Storage

Two tanks separately store cold and hot masses. Heat is stored in the temperature change in the storage medium.

### Steam Accumulators

Steam accumulators store saturated mixtures in a pressure vessel, allowing for the liquid to flash into more steam during discharge.

## Preliminary Results

Preliminary results of the PIRT suggest that **two-tank** molten salt or thermal oil systems, **steam accumulators**, and **concrete** TES systems should continue to be evaluated.

This research was supported by the DOE Office of Nuclear Energy Crosscutting Technology Development Integrated Energy Systems Program at Idaho National Laboratory under U.S. Department of Energy contract DE-AC-07-05ID14517.

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