Integration of Wind Energy with Compressed Air Energy Storage (CAES)

UNIVERSITY OF Nebraska Lincoln | NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

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Goal:

The main goal of this project is to investigate the feasibility and economic analysis of large-scale energy storage technologies by utilizing Nebraska's natural resources such as High Plains Aquifer and abandoned underground storage facilities for compressed air energy storage (CAES) reservoir. This will potentially foster the growth of Nebraska's intermittent renewable energy sources such as wind, and for their integration into an electric utility portfolio and into the grid

Objectives:

Data Collection, Validation, and Analysis - Collect, organize, validate, and analyze data pertaining the wind plant's technical and economic performance as well as the energy storage systems.

Feasibility Analysis and Simulation - Develop a methodology to determine the feasibility, economic analysis, and environmental assessment of large-scale energy storage technologies suitable for Nebraska. This work will consider CAES for potential application of High Plains Aquifer, pumped hydroelectric energy storage (PHES), and underground pumped hydroelectric storage (UPHS). Perform economic studies to determine payback in the market context. Also, study the impact of natural gas prices on the viability of CAES.

Challenges:

- **Its dependence on geographical location**
- **Difficulty in identifying underground reservoirs**
- **Closeness to the electric grid**
- **Ability to retain compressed air and large enough for the specific application**

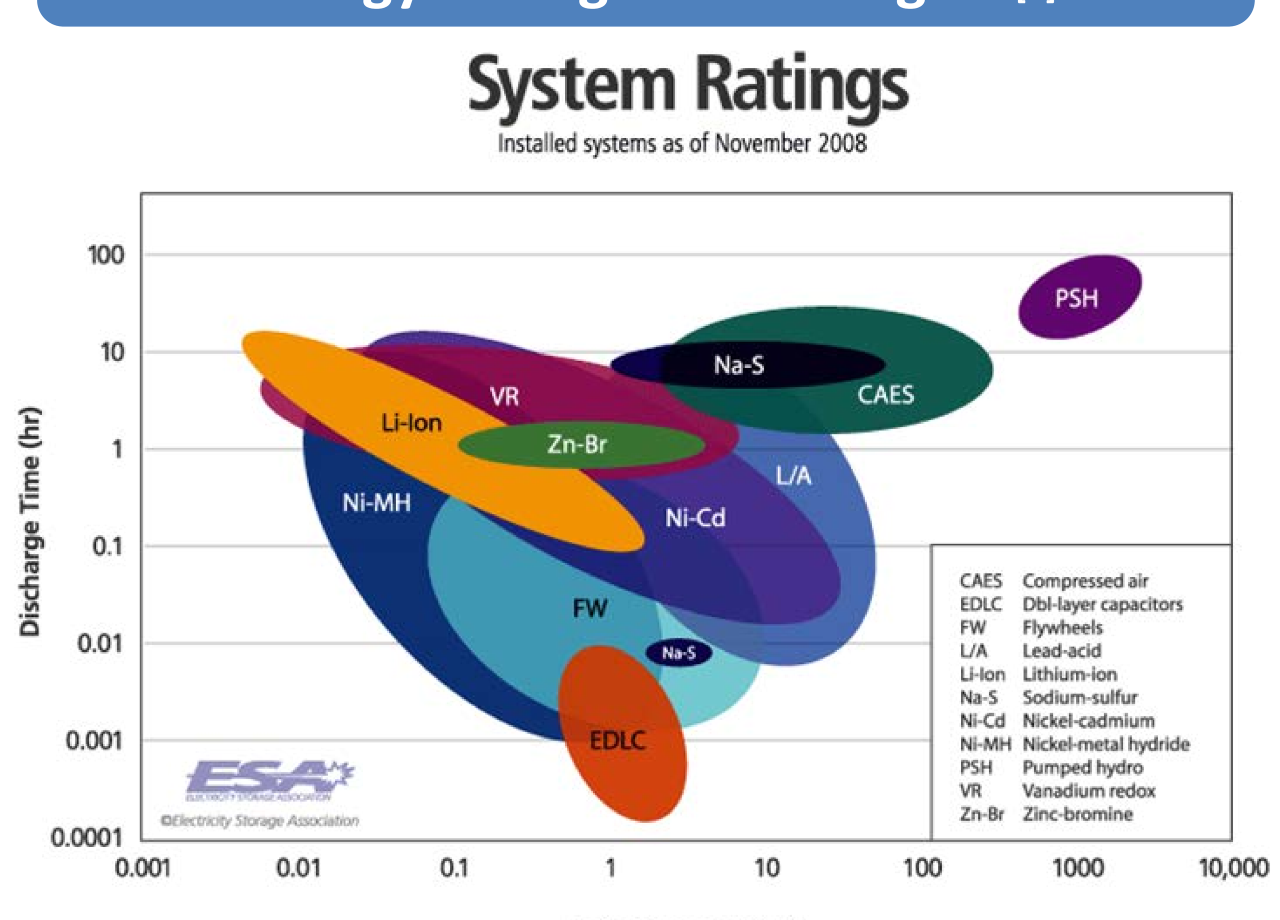
Current CAES implemented projects or R&D places:

Germany; Alabama; Iowa; New York; New Mexico

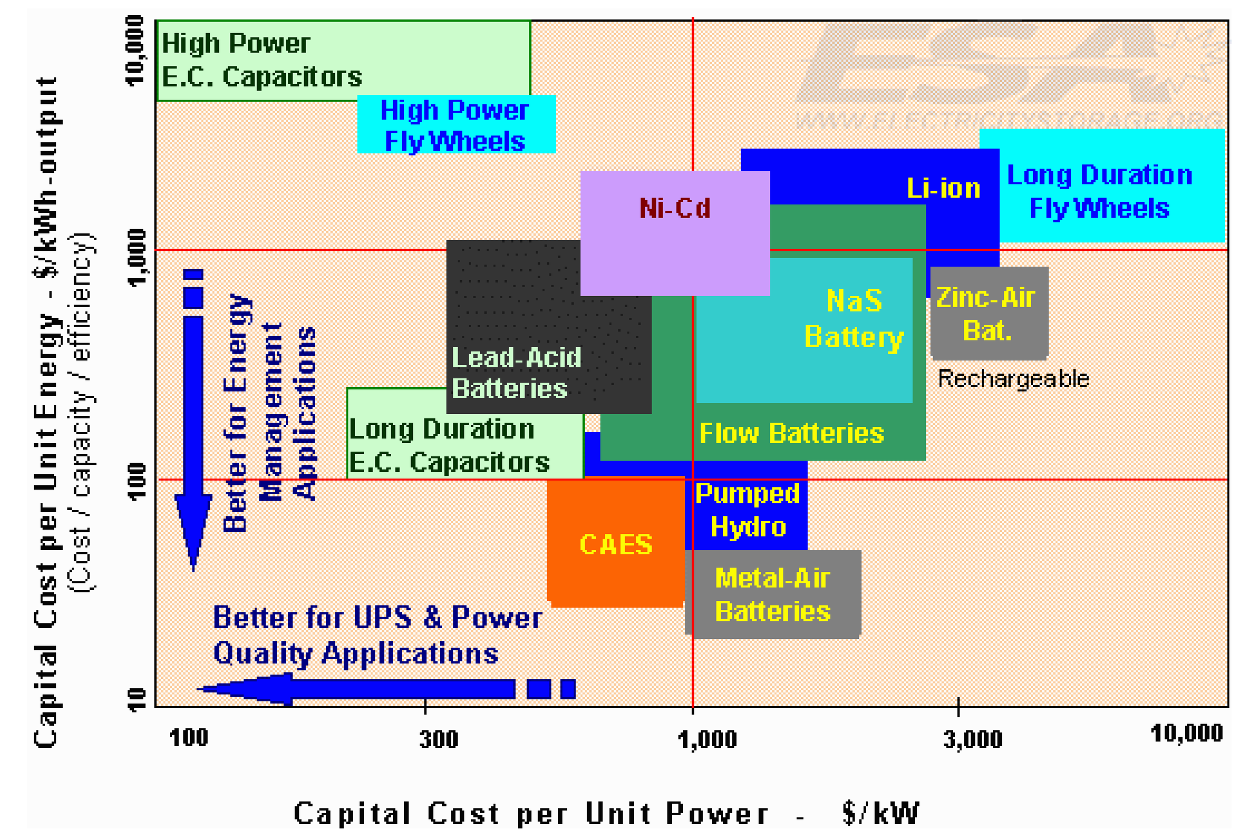
Overview of Energy Storage Techniques

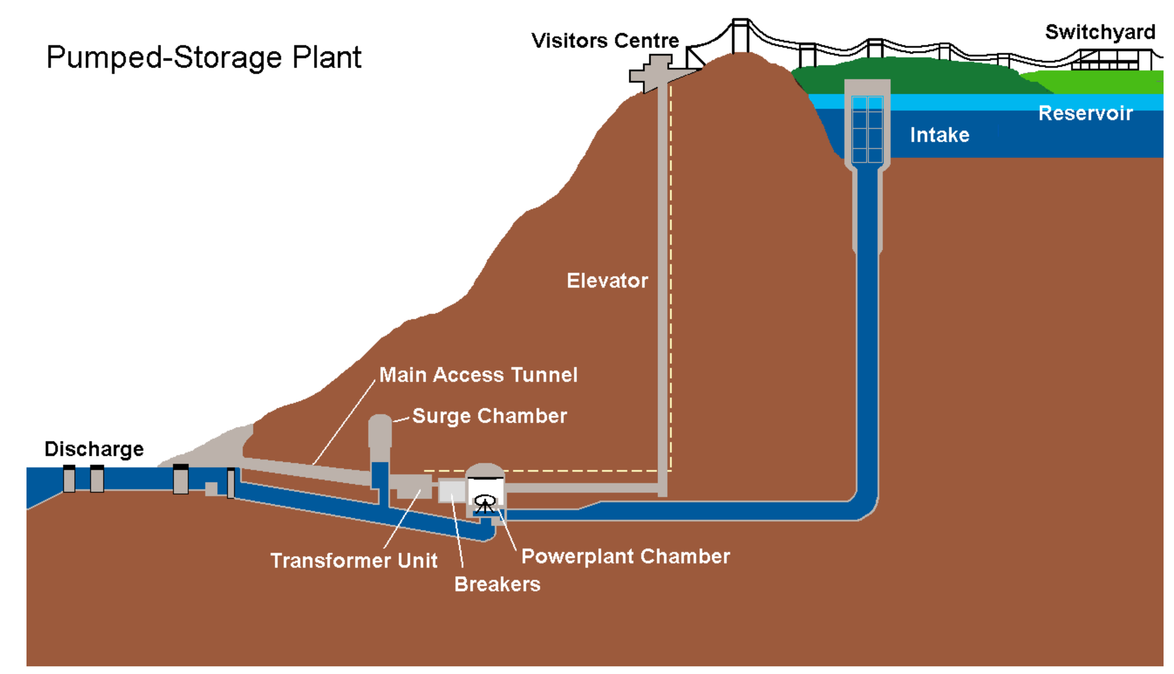
Large Power (>50 MW) and Storage Capacities (>100 MWh)	**PHES** (Pumped-Hydroelectric Energy Storage)	**UPHES** (Underground Pumped-Hydroelectric Energy Storage)	**CAES** (Compressed Air Energy Storage)
Medium Power (1-50 MW) and Storage Capacities (5-100 MWh)	**BES** (Battery Energy Storage)	**FBES** (Flow Battery Energy Storage)	
Medium Power or Storage Capacities	**FES** (Flywheel Energy Storage)	**SCES** (Super-capacitor Energy Storage)	**SMES** (Super-conducting Magnetic Energy Storage)
Energy Storage Systems	**HESS** (Hydrogen Energy Storage System)	**TESS** (Thermal Energy Storage System)	**EVs** (Electric Vehicles)

Practical Power and Discharge Time for Energy Storage Technologies [1]

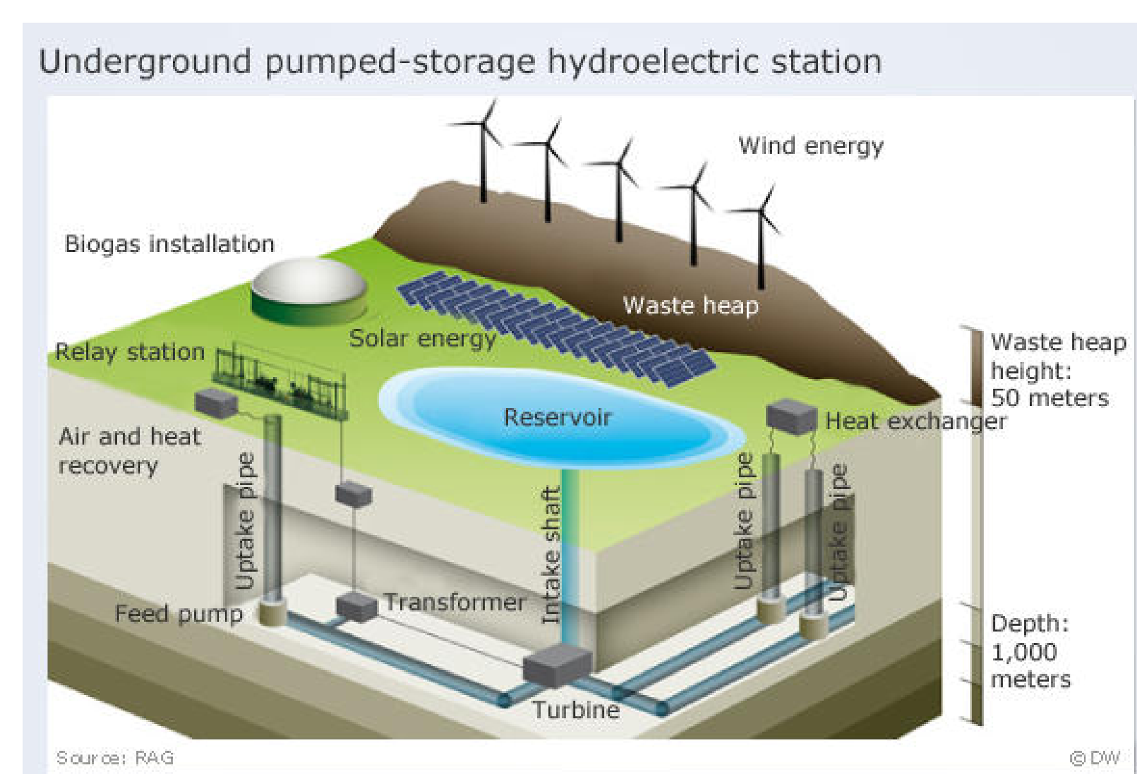


Capital Cost of Energy Storage Technologies [1]



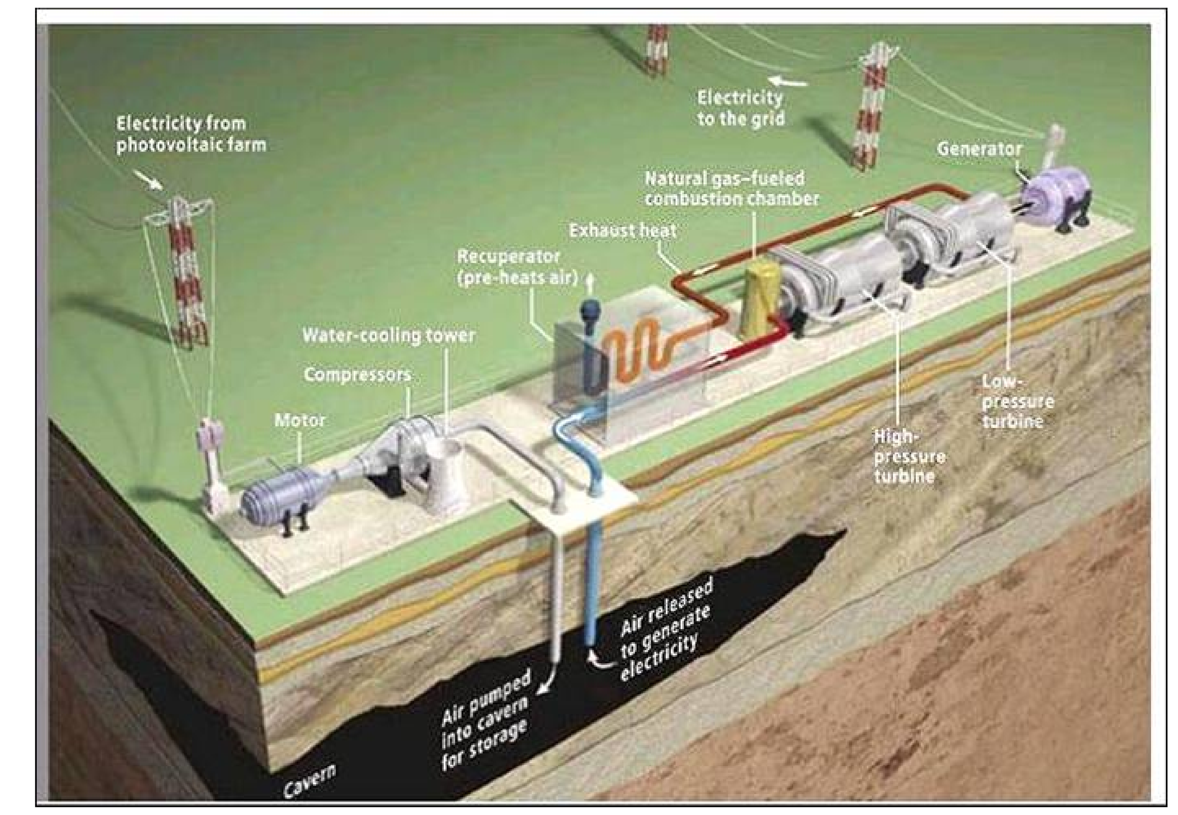


PHES is the most mature and largest storage technique available and consists of two large reservoirs located at different elevations and a number of pump/turbine units. During off-peak electrical demand, water is pumped from the lower reservoir to the higher reservoir where it is stored until it is needed. Once required the water in the upper reservoir is released through the turbines, which are connected to generators that produce electricity [2].



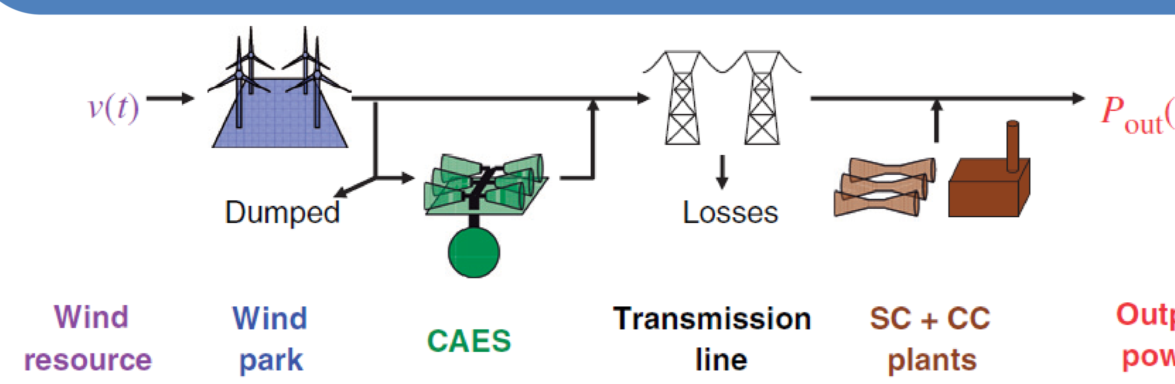
An UPHES facility has the same operating principle as PHES system: two reservoirs with a large hydraulic head between them. The only major difference between the two designs is the location of their respective reservoirs. In conventional PHES, suitable geological formations must be identified to build the facility. However, UPHES facilities have been designed with the upper reservoir at ground level and the lower reservoir deep below the earth's surface [2].

CAES pre-compresses the air using off-peak electrical power which is taken from the grid to drive a motor (rather than using gas from the GT plant) and stores it in large storage reservoirs. When the GT is producing electricity during peak hours, the compressed air is released from the storage facility and used in the GT cycle. As a result, instead of using expensive gas to compress the air, cheaper off-peak base load electricity is used [3].

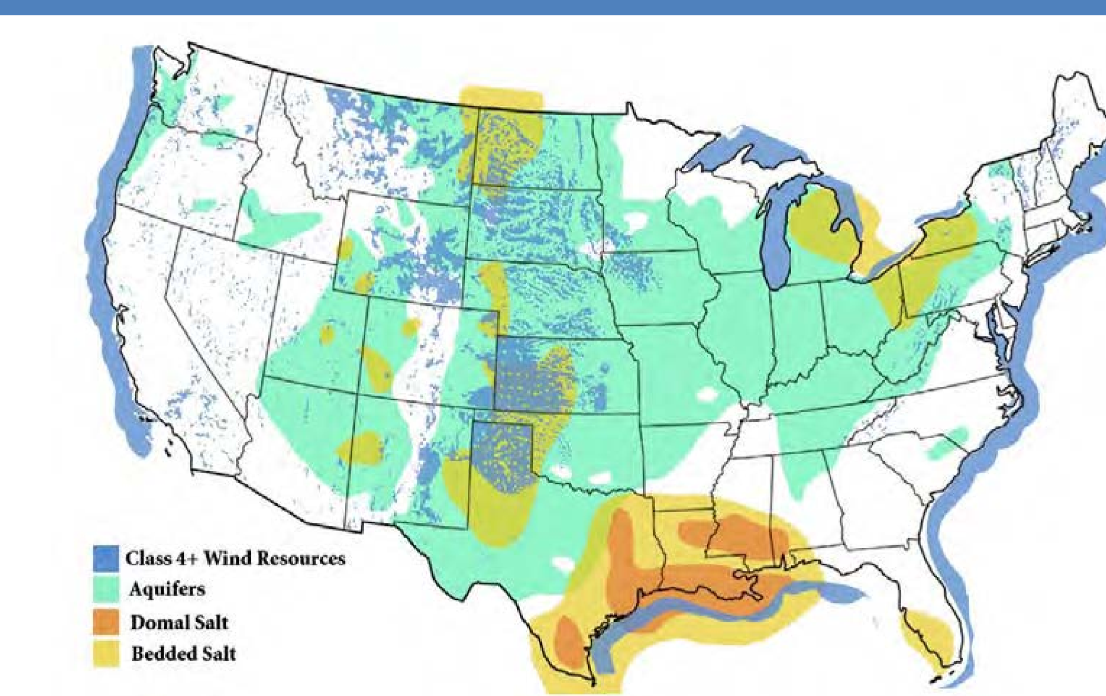


Schematic Diagram of CAES model

The CAES unit compresses air into a storage volume up to a specified reservoir capacity. The CAES expander utilizes this compressed air, along with natural gas, to generate electricity whenever the wind park power falls below the (constant) demand level. Transmitted electricity undergoes power-dependent losses. SC and CC gas turbine plants (if present) are then dispatched to make up any shortfall, up to the required capacity factor [4].



US Areas with Geologies Favorable for CAES and Class 4+ Winds [5]



References:

[1] Electric Storage Association, Technology Comparison, www.electricitystorage.org/technology, April 2009.
[2] http://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity.
[3] Argonne National Laboratory. Compressed Air Energy Storage (CAES) in Salt Caverns. Argonne National Laboratory, 2009.
[4] Greenblatt, J. B. et. al. Baseload wind energy: Modeling the competition between gas turbines and compressed air energy storage for supplemental generation. Energy Policy, 35(3), 1474-1492, 2007.
[5] US Census 2000, NREL, 2001/2/6