IPRO 302 – Alternative Metropolitan Power Strategy 2.0

Objective

Provide carbon-free electric power to Chicago

System

- ❑Nuclear Base – constant, 80% of average yearly production
- ❑Wind – intermittent, 20% of average yearly production
- ❑Storage – to compensate for the unpredictable behavior of wind with respect to the fluctuating demand for electricity

Goal

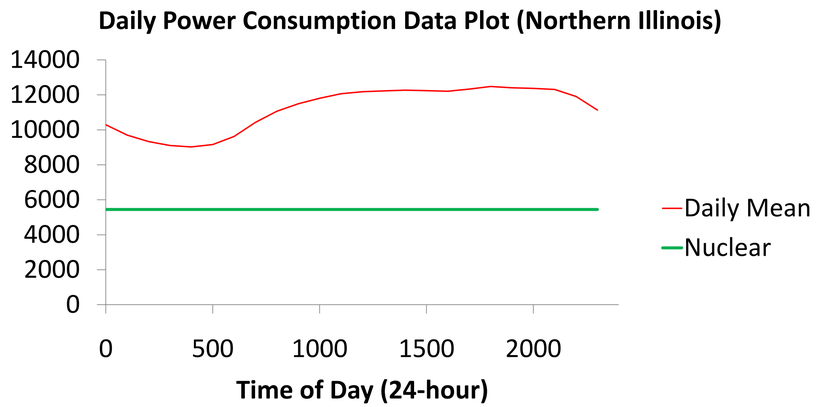
- ❑Evaluate and rank the currently available storage technologies and determine the most cost efficient combination of power production and storage

Assumptions

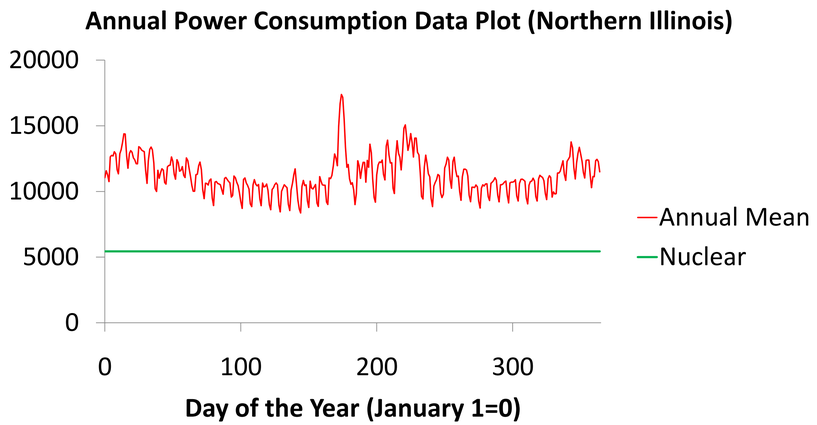
- ❑The city of Chicago uses 16% of the power used by Northern Illinois
- ❑20% of the power produced is from renewable energy sources

Electricity Demand

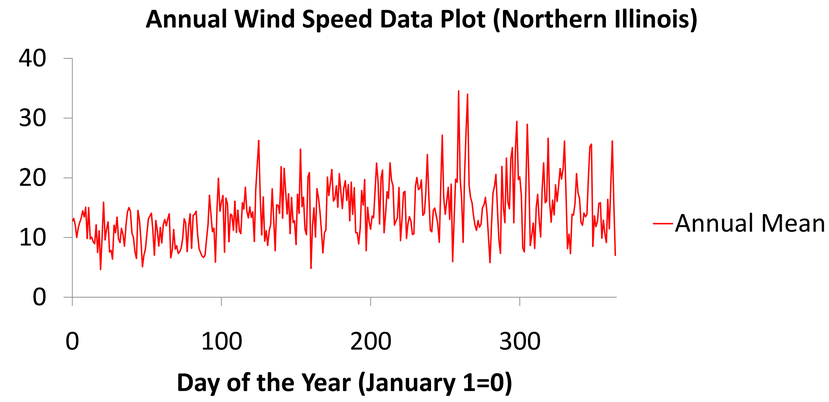
Daily Demand



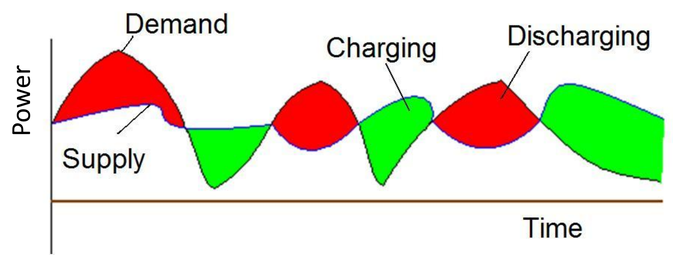
Daily demand during the year



Wind-Generated Power



Storage



Final requirements for storage

Power: 1600 MW
Short Term Capacity (Day Cycle): 2,371 MWh
Long Term Capacity (Three Month Cycle): 316,630 MWh

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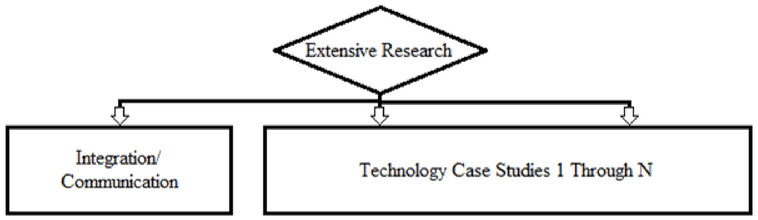
Storage Evaluation Factors

- Capital Costs
- Operations & Maintenance Costs
- Storage Efficiency
- Self Discharge
- Energy Density
- Power Density
- Stage of Development
- Political and Environmental Factors

Methodology of Evaluation

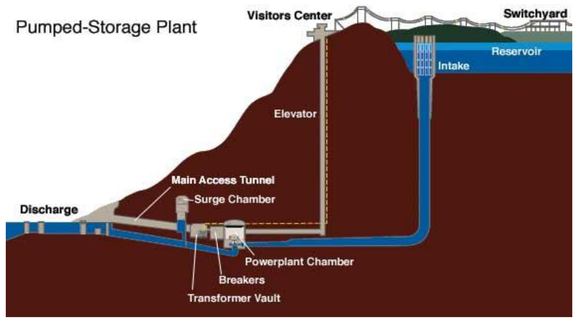


- Sub-teams consider storage factors to **research various technology cases**.
- Integration team evaluates storage technologies using a **levelized cost** (LEC).

$$\mathrm{LEC} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Pumped Hydro

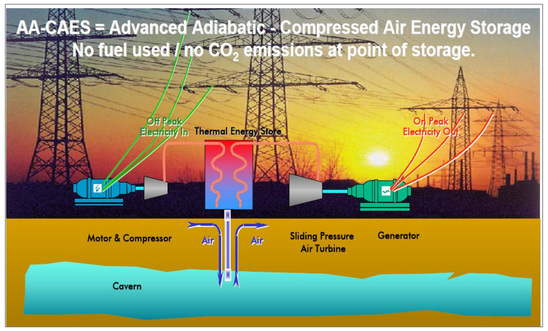
A type of hydroelectric power generation that stores energy in the form of water by pumping from a lower elevation reservoir to a higher elevation.



Schematic of a Pumped-Storage Plant

Adiabatic Compressed Air

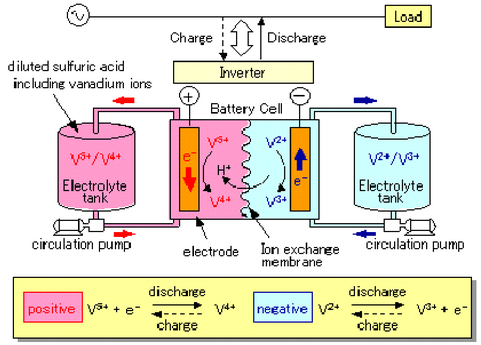
Stores electricity in the form of compressed air by using a motor-driven compressor to pump air into a sealed underground reservoir.



Schematic of a Adiabatic Compressed Air System

Vanadium Flow Batteries

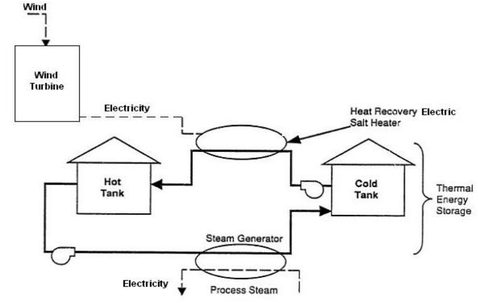
An energy storage technology that stores electricity as chemical energy in Vanadium electrolytes.



Schematic of a Vanadium Redox Flow Battery

Thermal Energy Storage

Stores electricity in the form of thermal energy by raising or reducing the temperature of a material.



Schematic of a Modified high temperature TES cycle

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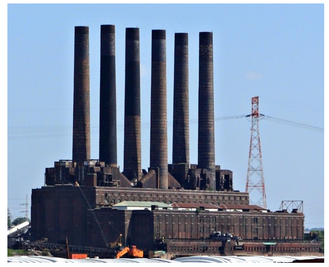
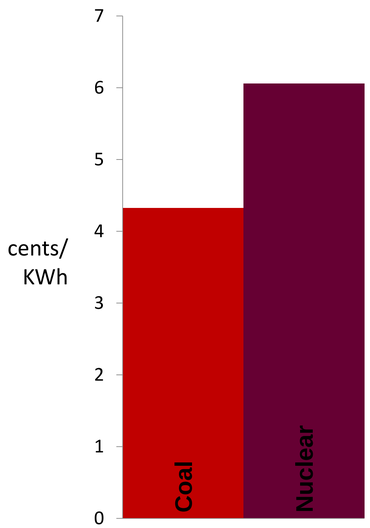
Current Problem

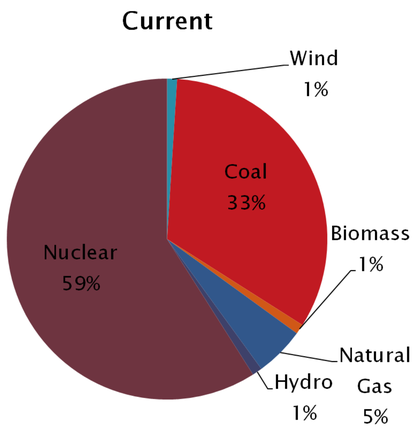
+



Carbon Emissions from coal and gas

Current Electricity Production Costs



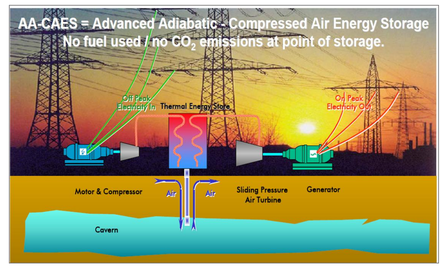


Solution

80%

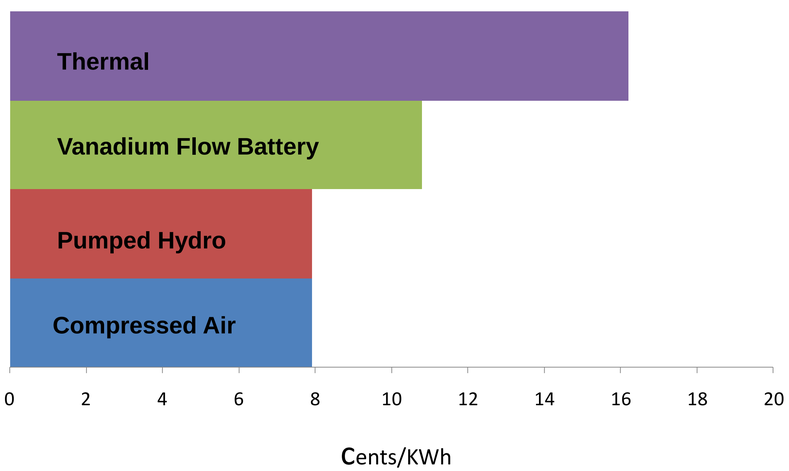
+ 20%

+



Carbon Free Emissions

80/20 Carbon Free Electricity Production Costs with Storage



Conclusions

- The topography in northern Illinois is not favorable for Pumped Hydro Storage
- Vanadium redox flow batteries are a good alternative when PHS and ACAES are not viable solutions
- Northern Illinois has favorable geology for underground compressed air storage
- Adiabatic Compressed Air Electric Storage (ACAES) is the best storage option for northern Illinois
- Price of electricity will rise significantly