Pumped Hydro and Compressed Air energy Storage

IREE Funded Studies
Natural Resources Research Institute -- UMD
UM Civil Eng (Duluth and Twin Cities)
St. Anthony Falls Laboratory
Humphrey Institute
Minnesota Power
Great River Energy
July 15, 2015 Update
Teams and Roles:

- **Geology and Geotechnical**: Assess Geology at the locations noted and determine geotechnical limitations associated with the various sites and primary ability to be an actual host site (NRRI, UMD Civil Eng)
- **Facilities**: Assess the modular and larger scale systems and determine rough facility costs for implementing the technology (St. Anthony Falls Laboratory)
- **Policy and Economics**: Assess key governmental policies and their impact on economical technology implementation (Humphrey Institute)
- **Environmental**: Determine key issues that need to be assessed for each site to understand the consequences of implementing the technology (UMD Civil Eng)
Various Energy Storage Strategies are under development

Cost and Storage Capability are key to large scale renewable implementation

Annual Costs for 8-hr Bulk Energy Storage Technologies ($/kW-year)

PHES and CAES Storage Attributes

- Allow firming of overall capacity from renewable sources
- Significant capacity per unit capital cost
- Long term facility life
- Can follow load requirement
- Provide a fast acting spin reserve
- Help regulate system voltage requirements
- Provide transmission systems support and buffer possible congestion
- Employ time of use energy cost management
- Demand charge management
- Add soaking capabilities
- Provide reliable power quality
Pumped Hydro Energy Storage

- Known technology
- Very high capacity
- Predictable capital and operating costs
- Easily integrated into the grid management system
- Requires significant water resource
- Requires power source to move water from lower to upper reservoir
- Modern variable speed systems now achieve 86% overall efficiency

It should be viewed as a facilitation technology for renewable energy implementation
Take advantage of water resources on MN’s Iron Range (MIR) from abandoned mine pits

Close proximity to Minnesota Power’s DC transmission line from North Dakota wind resources

Great River Energy and Minnesota Power have ample transmission line capability near the various mining sites

Allow potential large scale energy storage using a proven technology to aid in adoption of renewable energy from wind
Locations Across Iron Range

Pumped Hydro Energy Storage on the Mesabi Range - Location Map

- USX Minntac
- ArcelorMittal
- Northshore Mining
- Babbitt
- Cliffs Erie/Mesabi Nugget/Polymet

Key:
- Railroad Lines
- Transmission Lines
- Great River Energy
- Xcel Energy, Inc.
- Barr PHES Study Areas
- Iron Formation
- Natural Ore Pits
- Taconite Pits
- Underground Mine Workings

Permitted Mine Lands as of 9/7/2010:
- ArcelorMittal
- Hibbing Taconite
- Keewatin Taconite
- LTV Steel Mining Company
- North Shore Mining Company
- USX Minntac
- United Taconite

Environmental Permit Setting Boundaries as of 9/7/2010:
- ArcelorMittal
- Cliffs Erie
- Cliffs Erie/Mesabi Nugget
- Essar Steel
- Hibbing Taconite
- Keewatin Taconite
- Northshore Mining Company
- USX Minntac
- United Taconite
- United Taconite
1. Morton-South Agnew
2. Hibbing Taconite (Hibtac)
3. Chisholm-Buhl (Hartley)
4. Keetac-North
5. Alpena-Minorca
6. Virginia Horn - South (Laurentian Mine)
7. Virginia Horn – North
8. Minntac (East and West pits)
9. Arcturus
10. Chisholm-Buhl (Discovery Center) - using old underground mine
11. United Taconite Thunderbird South - using old underground mine
12. Keetac - using old underground mine
13. Canisteo (no underground mine utilized)
15. United Taconite - Underground Taconite Mine
16. Chisholm-Buhl Underground Taconite Mine
17. Canisteo Underground (Taconite area)
18. Dunka Pit Underground Taconite Mine

Least expensive sites to develop
Basic Conclusions – PHES

- Topography and Water Resources exist at various sites that could allow a 100 to 200 MW (8 h duration) facility to be constructed ~$125 M Capital Cost
- Various sites have been reviewed and a prioritized list of sites generated
- Potential life cycle, regulatory, environmental, and permitting issues have been reviewed no permanent fatal flaws found
- Economics need to be monetized to reflect all benefits – modeled cost range from $237 to $378 per MWh
Basic rule of Thumb: Need about 35% storage Capacity for a Implemented Wind Farm

Three Sites are being Studied for this effort

- Taconite Ridge Example with 25 MW of Turbine Generators (8.75 MW Storage)
- An Underground site that would be created from taconite iron ore southwest of UTAC at 100 MW Level of Storage
- A site on the Cuyuna that would link shafts of various existing underground mines to create a intermediate scale facility of approximately 25 MW
Advanced Adiabatic CAES

- Use heat storage to re-heat compressed air as replacement of combustion
- No hydro-carbon fuel needed
- Varying pressure
- Efficiency **target** = 70%; Model max efficiency = 54%
  (Samaniego, 2010)
Determining the depth, \( h \), involves ensuring that the force \( W \) (associated with weight of the wedge) balances the uplift force \( P \), associated with the pressure inside the cavern, i.e., \( W = FS P \), where \( FS \) is a factor of safety.
Suppliers of Technology

- **Large Scale Systems:** Dresser Rand (Alabama (110 MW—existing facility; new facility in Texas (317 MW) – Bethel Energy Center))

- **Modular Systems**
  - SustainX (High heat transfer efficiency using foam technology)
  - LightSail Energy (Above ground tanks)
  - General Compression (Fuel free system)
## Factors in The Study

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<td>• DA market price(min/max)</td>
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<td>CAES expander cost</td>
<td>Turbine(Capacity/Efficiency/Ratio)</td>
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<td>Tower+Cable(line) cost</td>
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<td>Right-of-way cost(land cost)</td>
<td>Taxes (Corporate tax rate/Property tax rate / Federal Production tax credit(PTC), Carbon Tax)</td>
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<td>Operation&amp; Maintenance cost according to the size.</td>
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Rough Draft of report in August
  • Review of parts already underway
Final Report in September, 2015
  • Integration between team segments begun
Thanks to Our team Members for their Contributions to these Studies

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Driven to Discover

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