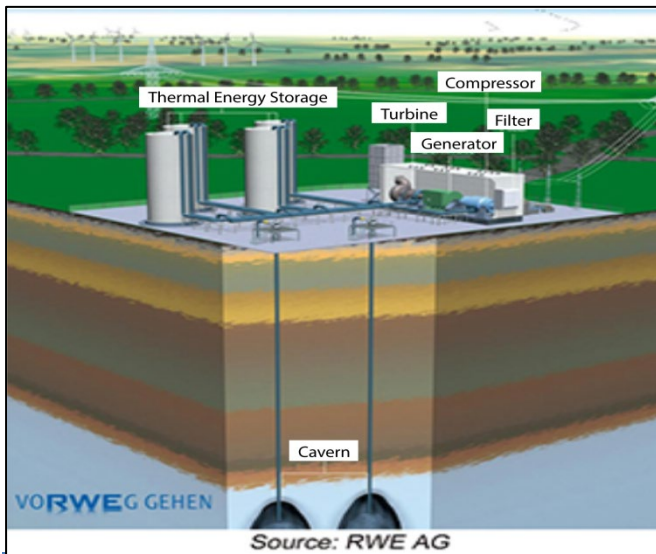
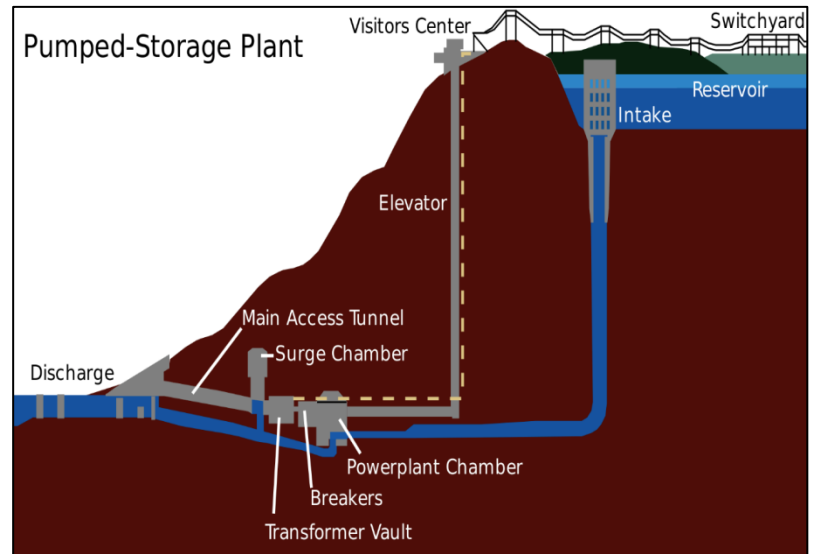


NRRI: Experience in Energy Opportunities

- Mineral process energy optimization
- Biomass conversion to energy products, materials
- Renewable energy storage: state-wide efforts in compressed air and pumped hydro energy storage

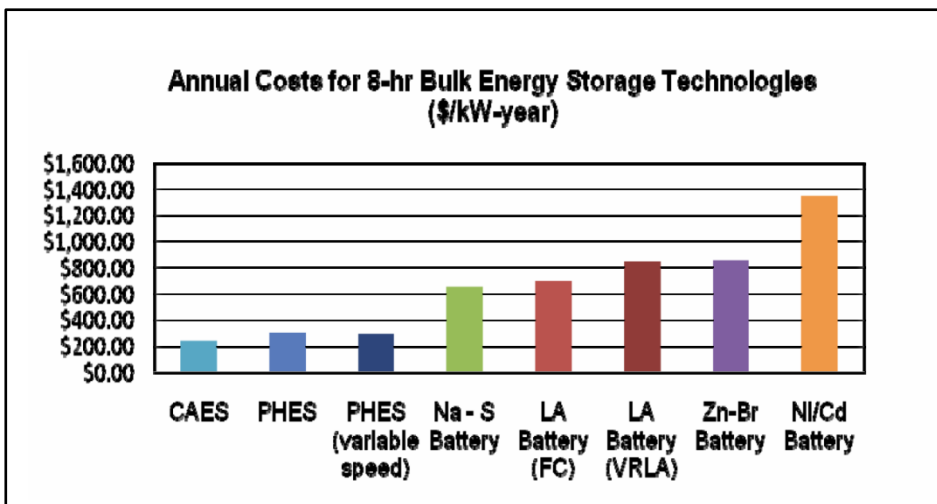


Typical Compressed Air Facility (Energystorage.org)



Typical Pumped Hydro Facility (Wikipedia.org)

NRRI Renewable Energy Portfolio with Industry Partners



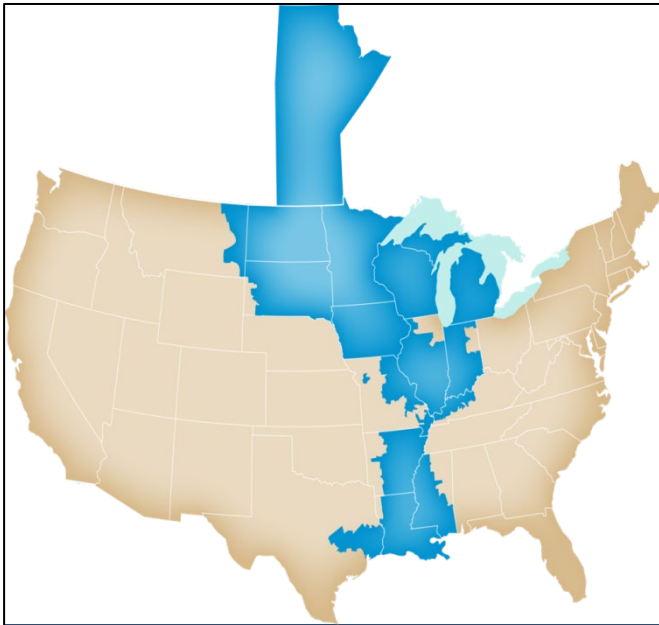
Return on investment: Relative costs for 8 hour bulk energy storage (NRRI, 2011)

- Advanced Compressed Air Energy Storage (ACAES) employing water assets associated with legacy mining and energy infrastructure
- Alternate battery material technologies utilizing Minnesota mineral resources (Iron, Cobalt, Manganese...)
- Biomass conversion to solid and liquid fuel products

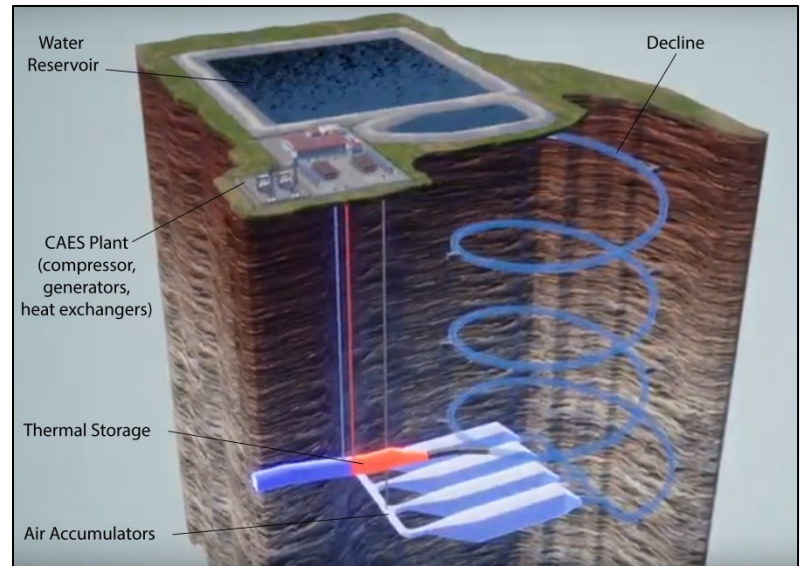


Advanced Compressed Air Energy Storage (ACAES)

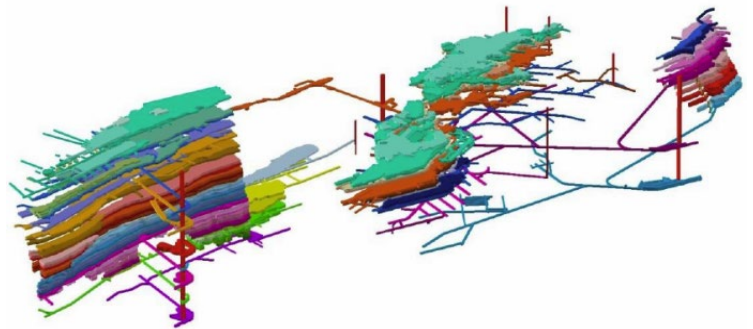
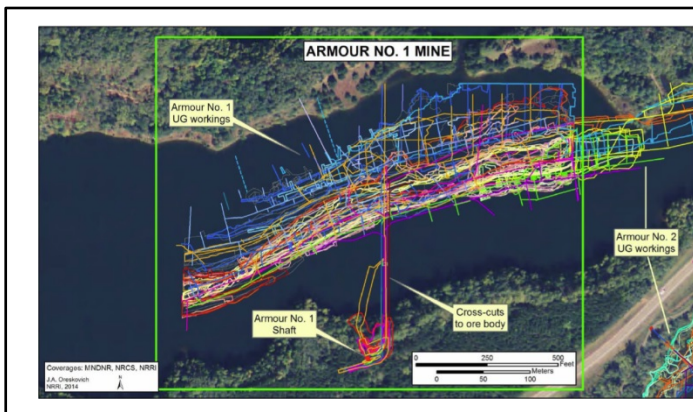
- Large scale, cost effective options
- Transforms mining infrastructure and features into regional renewable energy resource
- Impact: Large-scale storage relevant to Midcontinent Independent System Operator (MISO)
- Partners: Canadian energy storage company, Minnesota energy supplier
 - Minnesota is a prime candidate; systems favor brownfield sites
 - 300-500 megawatt demo vs gas peaker plant capacity



Minnesota has the potential to sell energy across the entire MISO Grid (Wikipedia.org)



Cross-section of an advanced compressed air energy storage system (modified from Hydrostor.ca)



Surficial map (left) and cross-section (right) of legacy underground mine infrastructure in Minnesota's Cuyuna District with potential for energy storage. (NRRRI, 2015)

The mission of the Natural Resources Research Institute is to deliver research solutions to balance our economy, resources and environment for resilient communities.

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