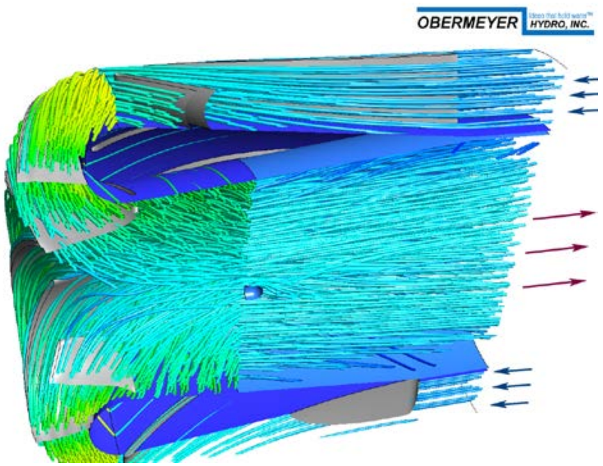
U.S. DEPARTMENT OF
ENERGY

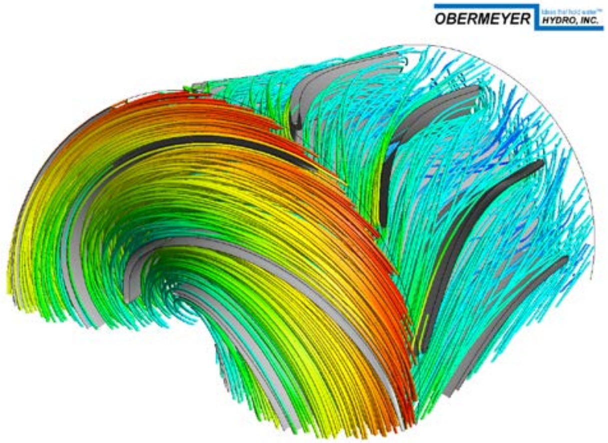
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

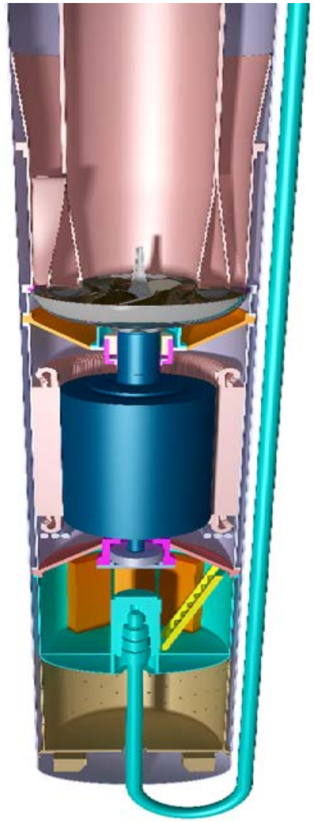
Water Power Technologies Office 2019 Peer Review

Hydropower Program Presentation Template

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy







Cost Effective Small Scale Pumped Storage Configuration

DE-EE0008014

Hydropower Program

October 9, 2019

Henry Obermeyer, PE

Obermeyer Hydro, Inc.

Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Summary

The goal of this project is to design a cost-effective, small-scale adjustable speed pumped storage hydro (AS-PSH) system optimized for the U.S. energy storage requirements. The technology is proven through concept design for exemplar sites including estimated costs. The project demonstrates that the proposed technological innovation is commercially viable and what energy storage needs can be economically met with the proposed system and identified the markets for optimal installation opportunities.

Project Objective & Impact

Since 2000 only one new pumped storage hydropower project has been constructed in the United States. In order to increase the future opportunity for pumped storage development, reductions in cost and scale are necessary. Historically pumped storage projects have required large capacity to overcome the fixed costs associated with custom engineering of complex underground structures with associated geological risk. The Obermeyer Hydro submersible pump-turbine offers a standard, scalable solution which reduces underground construction and risk.

Project Information

Project Principal Investigator(s)

Henry Obermeyer, PE, President
Obermeyer Hydro, Inc.

WPTO Lead

Rajesh Dham

Project Partners/Subs

National Renewable Energy Laboratory
Microtunneling, Inc.
Small Hydro Consulting, LLC

Project Duration

- July 1, 2017
- July 31, 2019

Alignment with the Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

Technology R&D for Low-Impact Hydropower Growth	R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet	Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

Alignment with the Hydro Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

- Understand the needs of the rapidly evolving grid and how they create opportunities for hydropower and PSH.
- Invest in innovative technologies that improve hydropower capabilities to provide grid services

This project included both;

(1) the design of an innovative pumped storage technology and

(2) a market assessment to understand the opportunities for the technology and the impact it could have on the grid.

Project Budget

- *The project was completed on budget with no variances*

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1,180K TOTAL, $629K	$425K	$1,605K

Management Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Obermeyer Hydro led the mechanical design while Auburn University led the electrical design, support was provided by Micro-Tunneling, Inc. and Small Hydro Consulting, LLC. The National Renewable Energy Laboratory led the market analysis including the consideration and evaluation of the Levelized Cost of Storage. NREL also verified the CFD analysis of the pump-turbine hydraulic performance. Biweekly meetings were held throughout the project with minutes and action items regarding milestone and deliverables were distributed to the team following meetings.
- Despite significant staffing changes at NREL, the project remained on budget and schedule.

Technical Approach

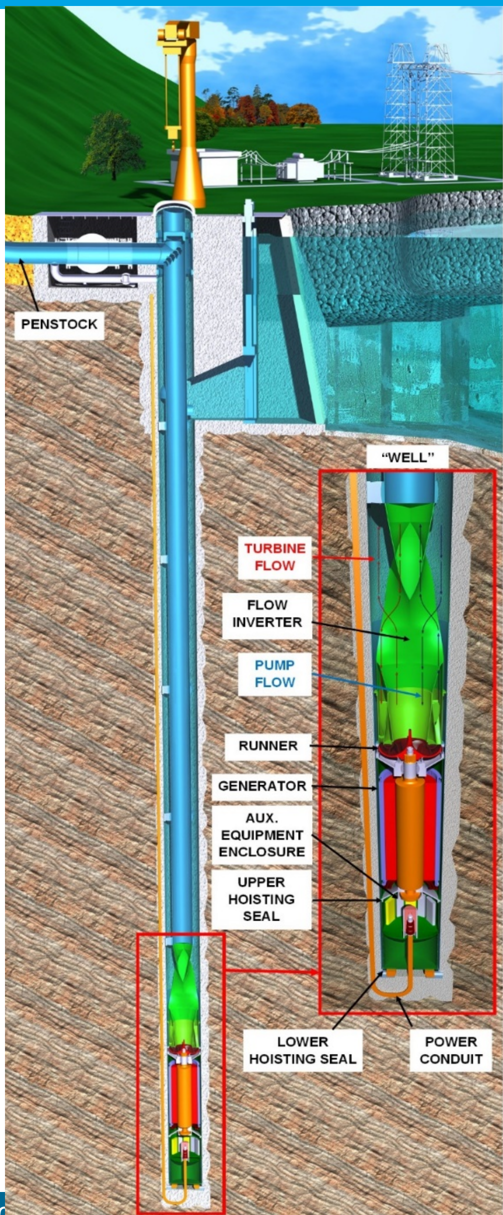
- The Budget Period (BP) 1 work scope consisted of designing and integrating a number of subsystems into complete pumped storage hydro (PSH) system design for an exemplar site, including developing a breakdown of estimated costs. The required subsystems include the pump-turbine itself, the motor-generator, the power converter, control system, and the water conveyance structures including penstock, draft tube, shaft with liner, access cover, and pressure relief valve.
- The BP2 work scope included Levelized Cost of (Electrical Energy) Storage (LCOS), and further refinement of the system design as well as system designs configured for representative sites identified by the Market Value Analysis completed in three FERC regions.
- The technology is an innovative engineering design that has never been considered. The technology enables a civil infrastructure design which does not include an underground powerhouse. The elimination of the underground powerhouse reduces cost and risk significantly.

End-User Engagement and Dissemination Strategy

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Developers and existing facility owners and operators are potential end-users of the commercialized product. The team has engaged with multiple prospective end-users through existing relationships and an outreach advertisement hosted by HydroWorld. This outreach provided information regarding the need for the equipment and characterization of potential sites as well as increasing knowledge and interest for the commercial product.
- Results from the project have been shared at multiple conferences including six presentations at HydroVision International. Marketing materials for the technology are available on Obermeyer Hydro's website along with being distributed at conferences throughout North America and Europe and Africa.

Technical Accomplishments



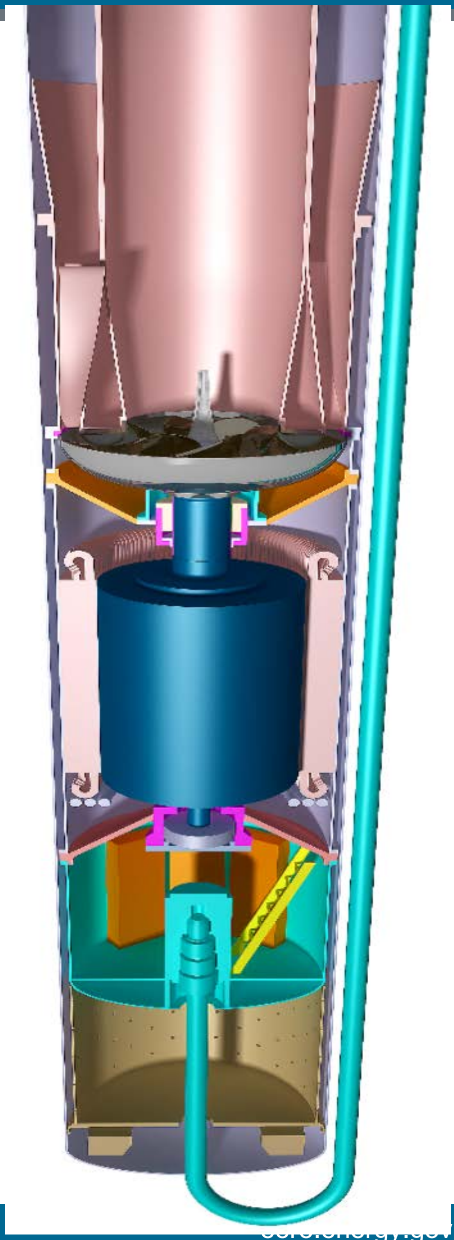
Innovative Solution Components:

- Runner and Diffuser with co-axial inlet / outlet
- Motor-Generator (variable speed direct drive with heat pipe cooling)
- Flow Inverter to direct high pressure flow to removable penstock segments
- Novel Air Pressure Balanced Pressure Relief Valve
- Pitless Adapter (removable connection between buried penstock, pressure relief valve, and removable segmented penstock)
- Electrical Connection (water tight plug connection from below)
- Hoisting System uses pressurized water from below to lift unit to above-ground service position
- Auxiliary Equipment Enclosure includes all equipment needed for extended periods of unmanned operation.

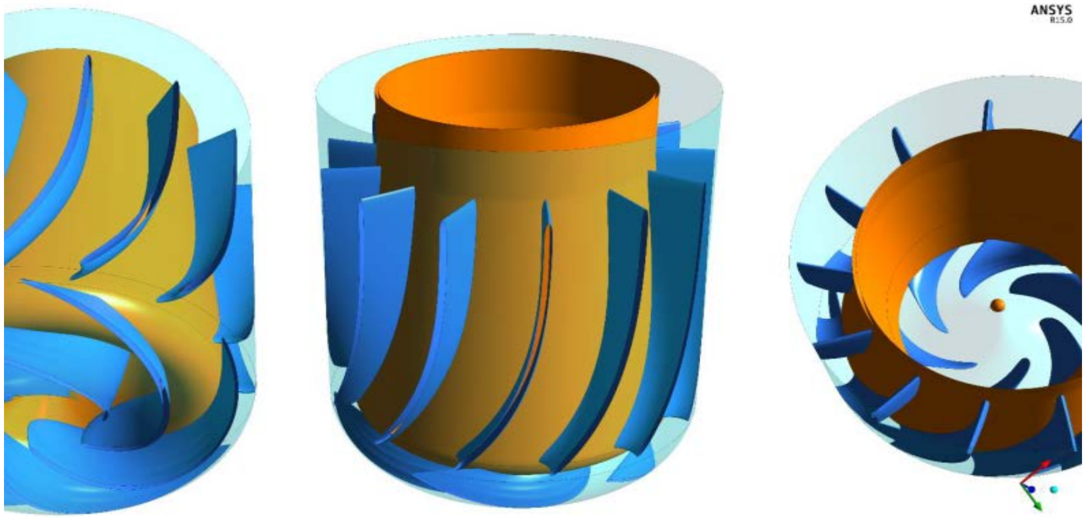
Technical Accomplishments (Cont.)

- **Submersible Pump-Turbine**

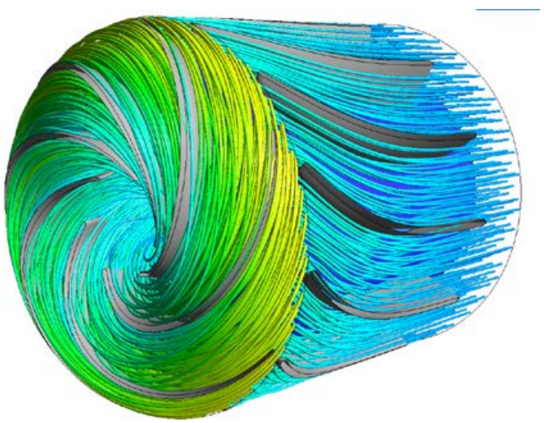
  - Runner and generator are located well below tailwater in a vertical "well".
  - Submergence is achieved without an underground powerhouse.
  - Factory assembled units up to 100 MW in size.
  - Coaxial penstocks in "well" to lower reservoir
  - Single penstock extends to upper reservoir.
  - 180 degree flow reversal within the runner.

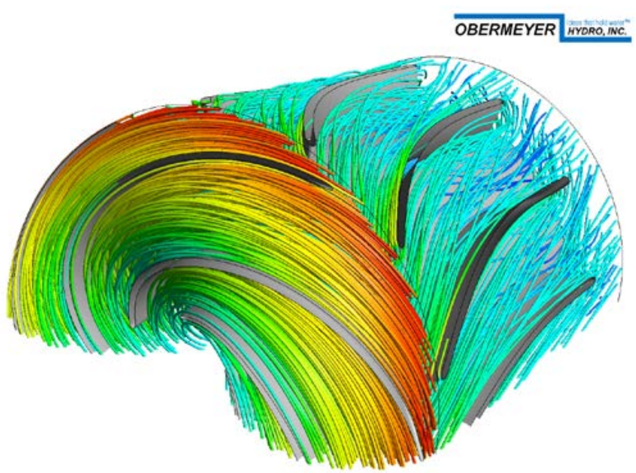


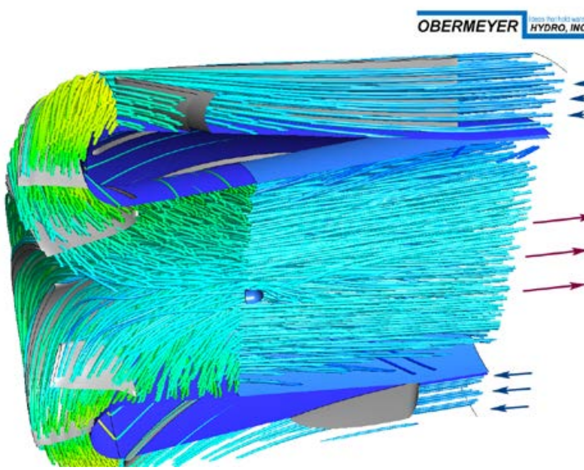
- Pump-Turbine Runner – CFD modeling



Hydraulic Best Efficiency:
Pump Mode = 95.2%
Turbine Mode = 94.5%

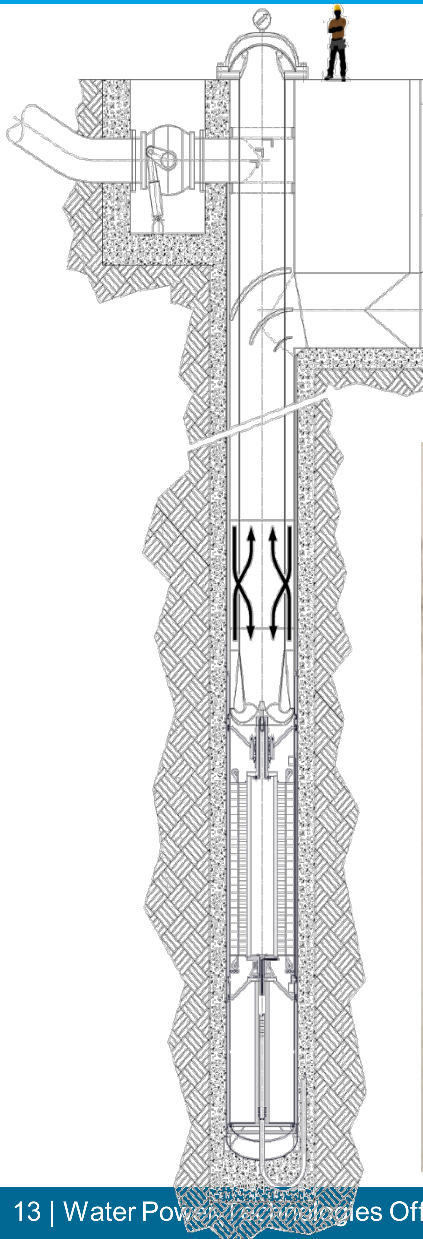


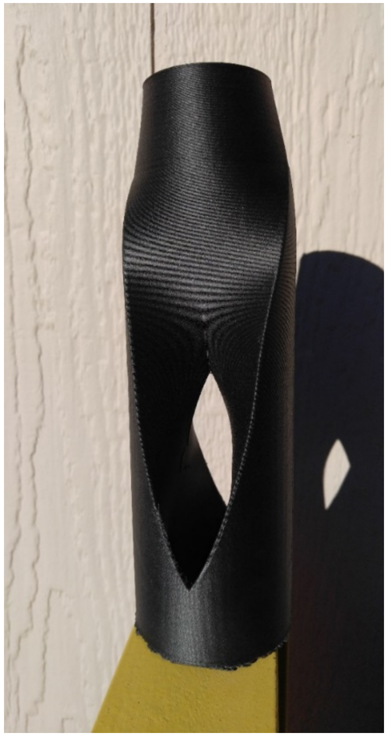




Technical Accomplishments (Cont.)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





- **Flow Inverter**
  - When in pumping mode, the Flow Inverter takes flow from the exterior annulus and routes it to the interior of the pump runner (the intake of the pump).
  - On the discharge side of the pump, flow is routed from the exterior of the pump runner to the interior annulus.
  - This allows the interior penstock to be the high-pressure conduit, eliminating buckling pressures.

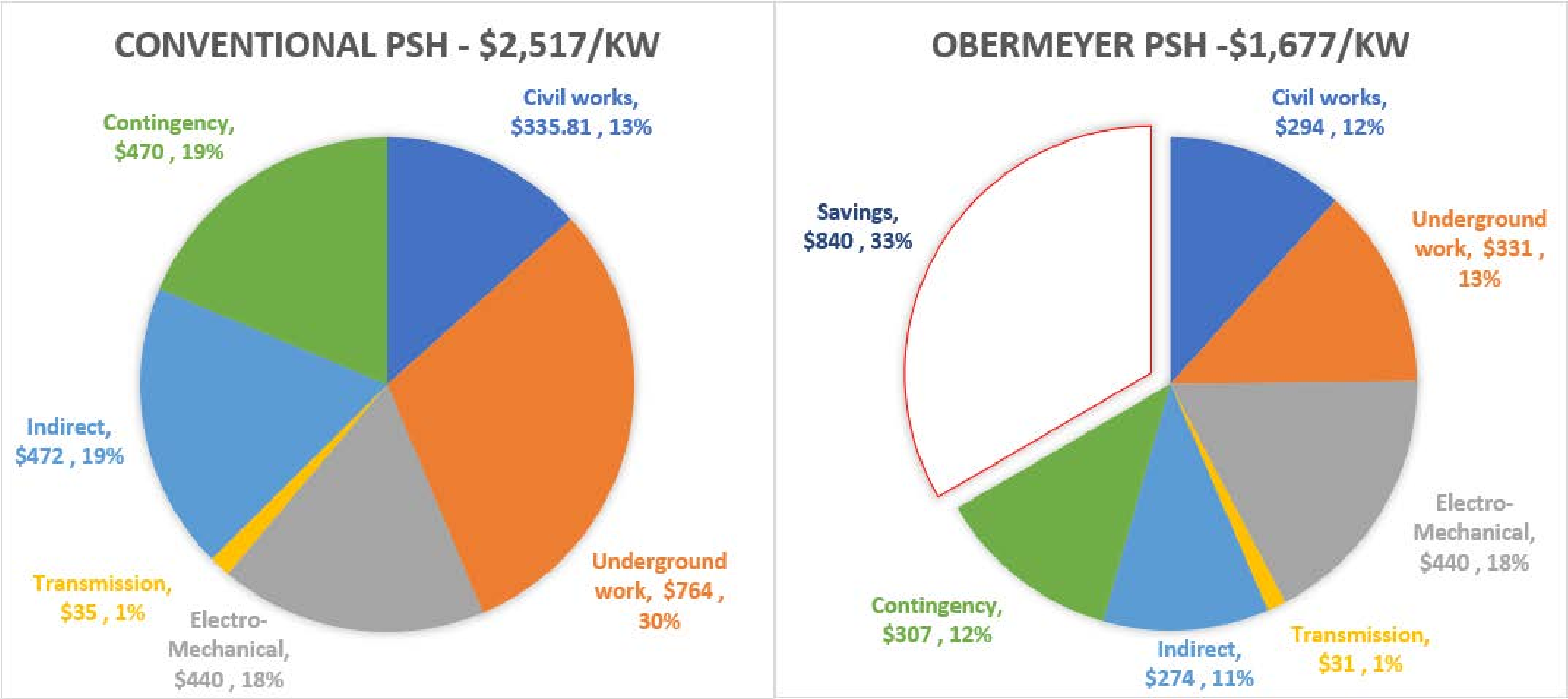
- System Round Trip Efficiency

	1600 rpm	1200 rpm
Pump Hydraulic Efficiency	95%	95%
Electrical System Efficiency Pumping (motor, drive, transformer, cables)	94.6%	96.1%
System Hydraulic Efficiency while Pumping	98.5%	98.5%
Turbine Hydraulic Efficiency	95%	95%
Electrical System Efficiency Generating (motor, drive, transformer, cables)	94.6%	97%
System Hydraulic Efficiency while Generating	98.5%	98.5%
Round Trip Efficiency	78.4%	81.6%

Technical Accomplishments (Cont.)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Estimated Cost Saving



Technical Accomplishments (Cont.)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **Range of Applications**

As well as providing a cost-effective Pumped Storage Hydropower equipment solution, the technology could be used for a range of other applications, including;

- Medium head turbine with Generator Above Grade
- High-Efficiency Pumping
- Off-Channel Reservoir Filling (and generating)
- Spinning Reserve Capabilities
- Storage of Variable Renewable Generation

Progress Since Project Summary Submittal

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Market Analysis Conclusions:

The best metric for comparing storage technologies and projects was considered in great detail.

This high-level analysis showed larger (100 MW), longer-term (50 year) projects to be the most economical with improved NPVs.

The required annual value of ancillary services to bring these systems to the break-even point were calculated.

Then the proposed installed cost (i.e., CapEx) reductions (33.3%) anticipated due to the novel Obermeyer single shaft approach to PSH were accounted for and the analyses re-run.

The results showed very positive impacts across all scenarios with the required valuations for ancillary services being greatly reduced or brought to zero.

Progress Since Project Summary Submittal

Prototype construction:

Obermeyer continues the design with prototype cast runner:

Generator for prototype unit: