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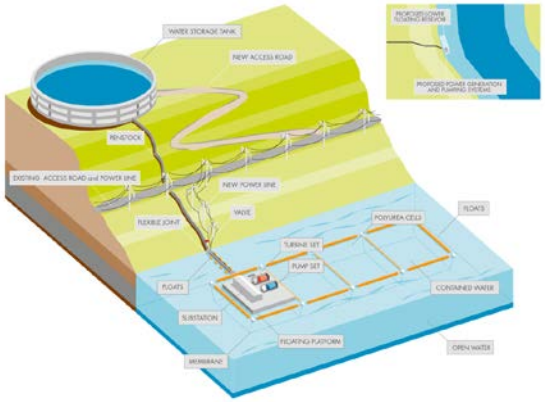
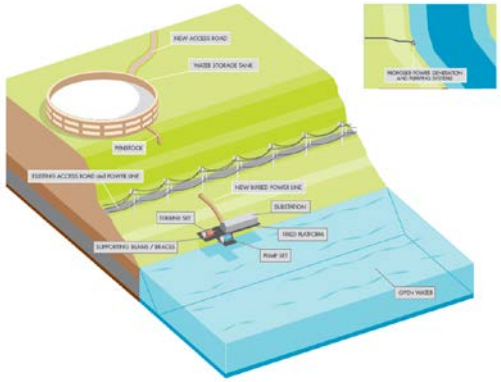


Closed-loop Configuration Option



Open-loop Configuration Option

Hydro Battery Systems Catalog Development

FOA 1455 / EE0008013

Hydropower Program

Wednesday, October 9, 2019

JT Steenkamp

Shell Energy North America

Project Overview

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Project Summary

- Development of a small modular 5MW pumped-storage system including a floating reservoir option through design, modeling, and testing of a full-scale prototype. The balance of systems will undergo detailed engineering design using Pearl Hill, WA as a reference site.
- Market value modeling is being conducted in five market regions (PacNW, CAISO, NYISO, Hawaii, Puerto Rico) to identify value streams within the context of larger renewable energy portfolios.
- A life-cycle carbon intensity analysis and benchmarking of the technology is also being performed.

Project Objective & Impact

- Apart from limited studies, there exists no technology advancements in the field of modular systems for use in water storage for pumped storage projects. The advantages of the proposed technology are innovative modularity and scalable application. To reduce environmental footprints, costs and accelerate pumped storage project deployment, the modularity of this floating reservoir serves specific beneficial purposes: faster and safer deployment, maintenance, and removal.

Project Information

Project Principal Investigator(s)

JT Steenkamp

WPTO Lead

Corey Vezina
Marisol Bonnet

Project Partners/Subs

ORNL (Bo Hadjerioua)
PNNL (Patrick Balducci)
McMillen Jacobs (Mort McMillen)
Western Washington University (Dr. Charlie Barnhardt)

Project Duration

- Project Start Date: 06/01/2017
- Project End Date: 02/28/2020

Alignment with the Program

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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

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Technology R&D for Low-Impact Hydropower Growth

- Enable the design and development of new Standard Modular Hydropower (SMH) technologies for both existing water infrastructure and new stream-reach development. This new approach to systems design for hydropower projects incorporates ecological and social objectives for river systems earlier in design processes
- Leverage new advancements in manufacturing and materials to dramatically lower costs of SMH components and systems designs

- The core project scope is to deliver a standardized small modular pumped storage hydropower systems catalog
- Supply chains and standard equipment from the oil & gas industry are being leveraged in an attempt to lower costs of key components

Alignment with the Hydro Program

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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.
- Investigate the full range of hydropower's capabilities to provide grid services, as well as the machine, hydrologic, and institutional constraints to fully utilizing those capabilities.
- Optimize hydropower operations and planning—alongside other resources—to best utilize hydropower's capabilities to provide grid services.
- Invest in innovative technologies that improve hydropower capabilities to provide grid services

- SENA is looking at this innovative approach as a hydropower opportunity for providing renewable energy integration and other grid services
- A sophisticated computational modeling tool (Battery Storage Evaluation Tool) was adapted by PNNL for Hydro Battery and is being used to co-optimize various use cases in different markets including PacNW, CAISO, NYISO, Hawaii and Puerto Rico

Project Budget

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Total Project Budget – Award Information		
DOE	Cost-share	Total
[$1250K]	[$938K]	[$2188K]

Lab	FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Lab	Costed	Costed	Costed	Total Costed	Total Authorized
PNNL	[$160K]	0	0	[$160K]	[$160K]
ORNL	[$273K]	0	0	[$273K]	[$273K]
TOTAL	[$433K]	[$K]	[$K]	[$433K]	[$433K]

Management and Technical Approach

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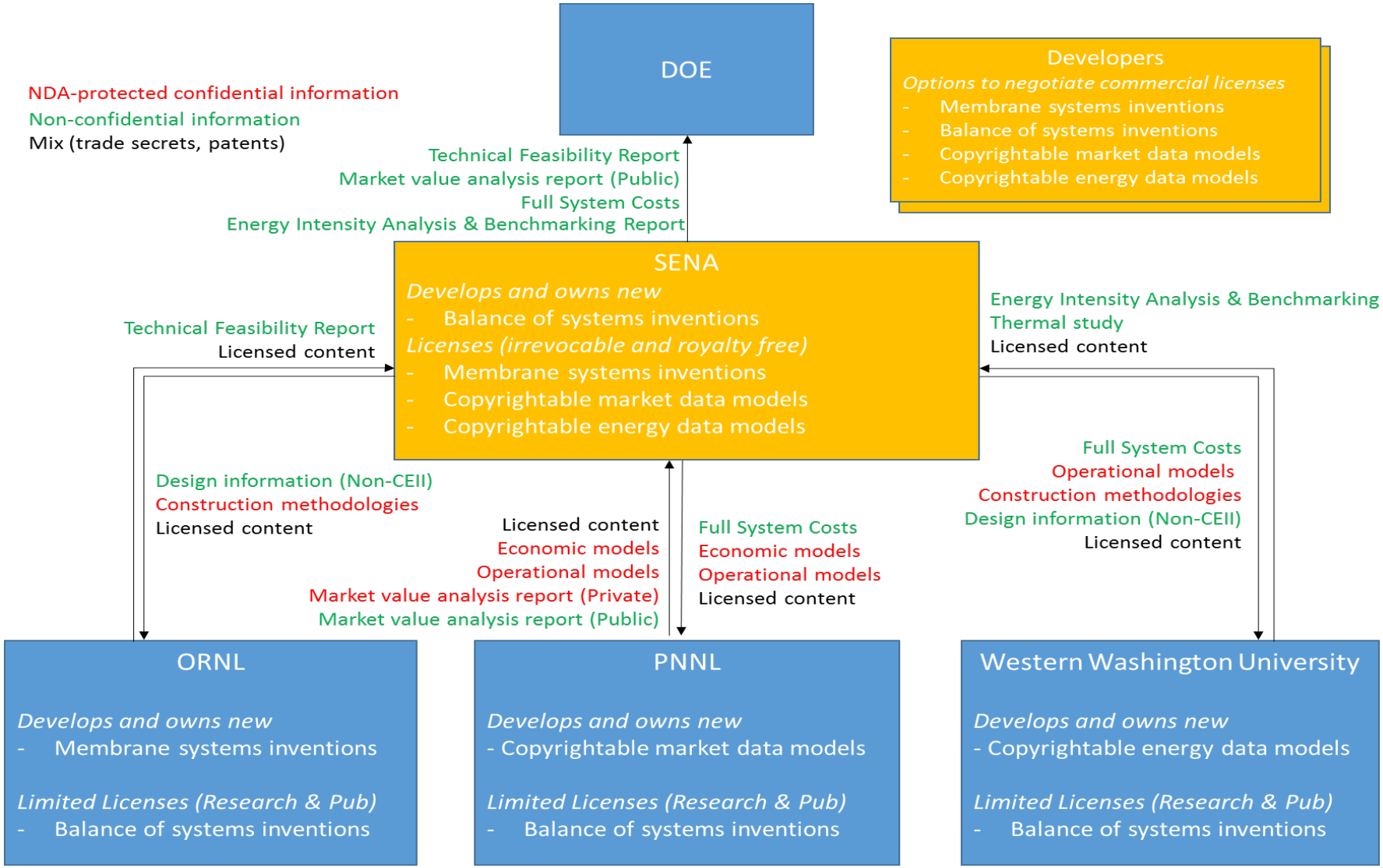

End-User Engagement and Dissemination Strategy

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- **Project beneficiaries are include:**
  - Technology developers could design, manufacture, and sell modular systems or components which support the floating membrane storage system.
  - Electric utilities and project development interests could increase pumped storage development feasibility by constructing or investing in the floating membrane storage systems, and increased availability of pumped storage energy could provide increased renewable energy that is reliable and rapidly responsive to loading conditions.
  - SENA may identify the modular pumped storage system as a viable technology to complement the growth of their renewables portfolio, and may choose to invest further in advancing the technology or other complementary research and development activities.

Technical Accomplishments

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- ORNL developed the design specification for the prototype and found the floating reservoir concept technically feasible through hydrodynamic modeling and discovery of commercially available materials
- ORNL applied for a patent relating to this concept

Technical Accomplishments

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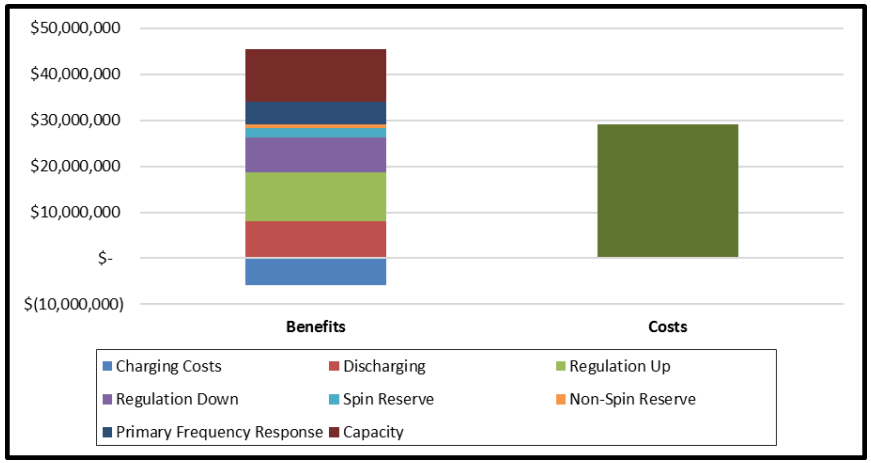
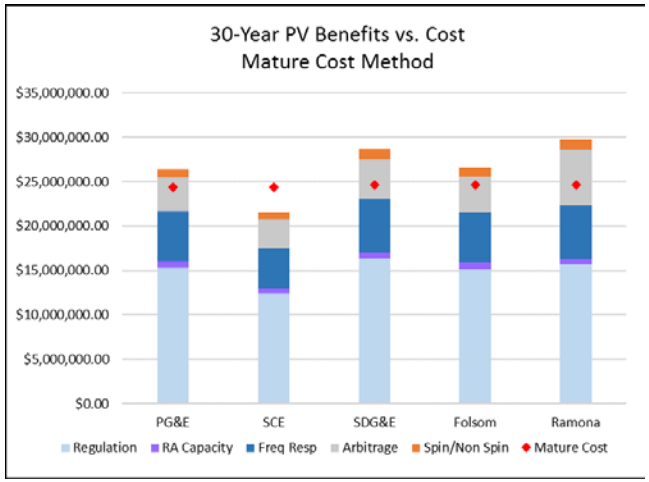
- PNNL developed and published market value models for PacNW, NYISO, CAISO and Hawaii with Puerto Rico to follow

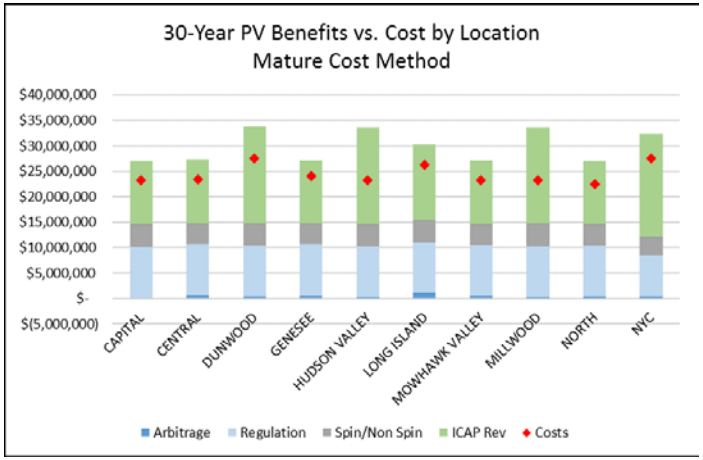
PacNW



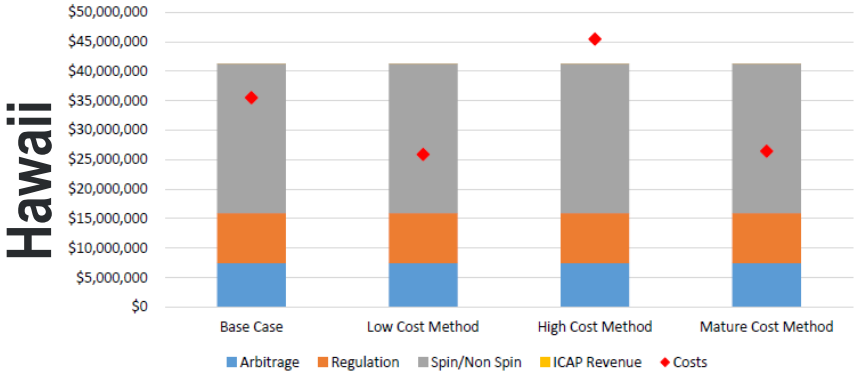
CAISO



NYISO



Hawaii



Technical Accomplishments

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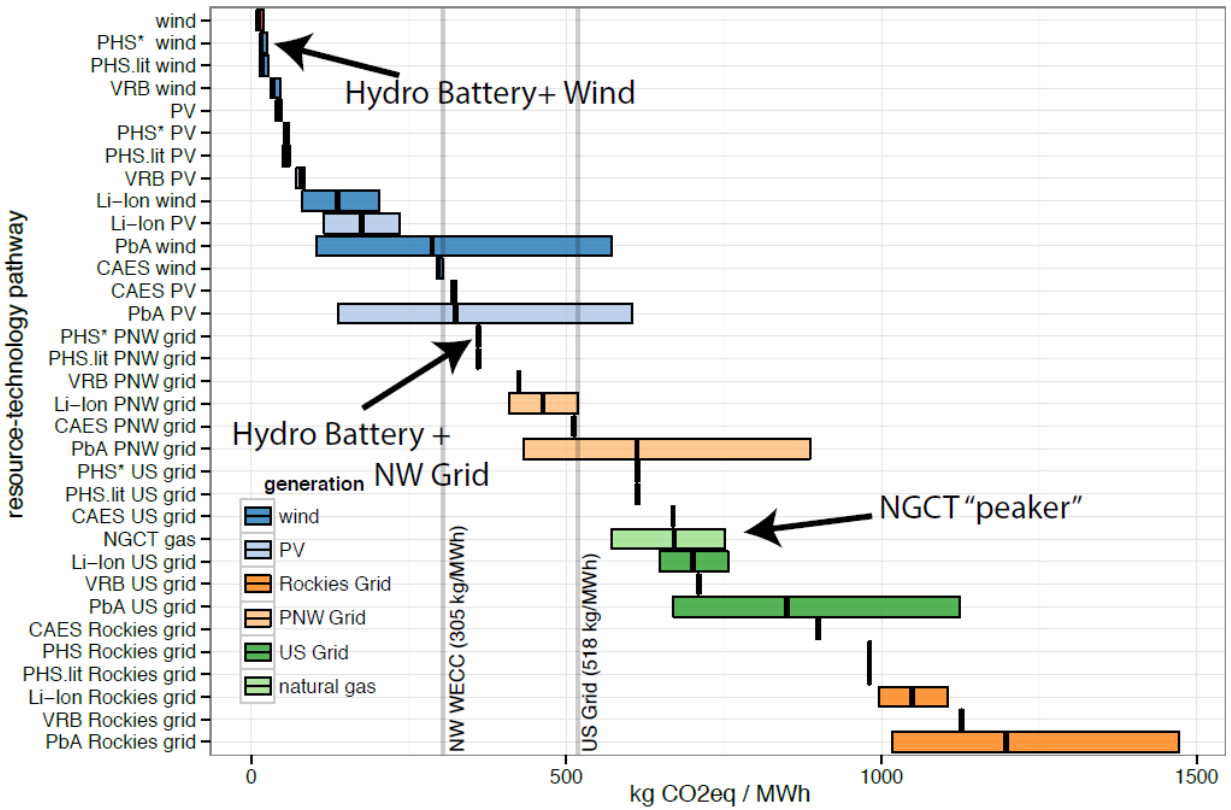
- Western Washington University analyzed the hydro battery concept and discovered it has an exceptionally life-cycle carbon intensity relative to alternative integration technologies



Technical Accomplishments

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- SENA developed the preliminary designs for the balance of systems (power platform, penstock, reservoir tank, control system)

System	Highlights of Results
Power Platform	Modular semi-transparent deck and piling system deployable from barge
Penstock elements	Common O&G Pipe, 40ft 36″ API 5L Grade X70 pipe with a 0.469″ wall thickness. Buried or surface run on railway ties
Pump module	Standard O&G vertical turbine type, binary 1.5MW building block, with additional hydraulic short-circuit capability, and optional fish screen attachment
Turbine module	Pelton type, 5MW element, with additional spinning reserve capability
E-House module	Skid mounted substation
Control System	Remotely operable with enhanced cyber-security architecture
Upper Reservoir Tank	Corrugated steel type, insulated

Technical Accomplishments

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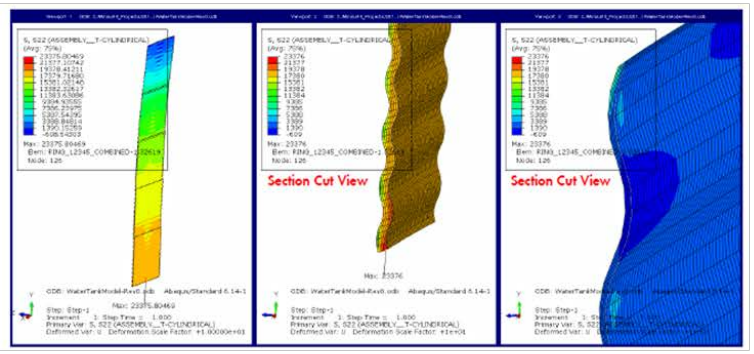
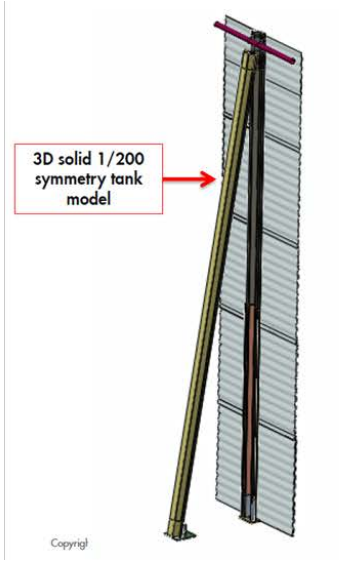
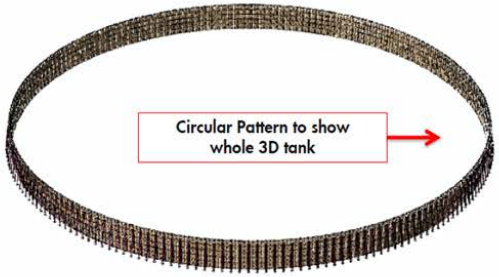
- An impressive result of the terrestrial systems preliminary design was the validation of a low-cost 6-week-deployable pre-engineered reservoir, with up to 68,000 deep cycles life
- The first hydro battery could likely feature the world's largest corrugated steel tank at 9M gallon capacity (300ft diam x 20ft h)







Material Type	Properties	Value @ 70 °F	Unit
ASTM A653 Grade 50	Modulus of Elasticity	29,400	ksi
	Yield Strength	50	ksi
	Ultimate Tensile Strength	70	ksi

Technical Accomplishments

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- Water quality impacts from temperature fluctuations can be avoided by reservoir insulation
- It was found that for the reference site case, a combination of 2.5cm insulation and operational flexibility of cycling the tank will allow the system to meet water quality standards

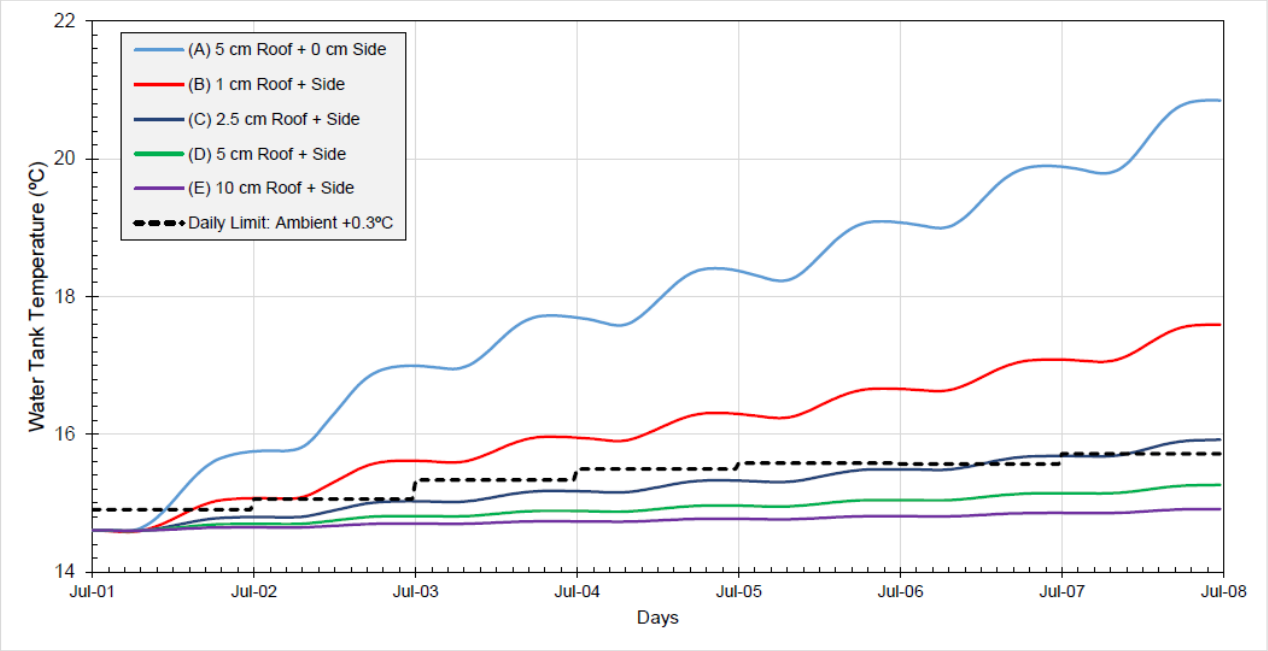

Figure 3: Predicted Storage Tank Water Temperature for Various Levels of Insulation

Technical Accomplishments

Future Work

- Floating Membrane Prototype Design Completion, Procurement, Deployment & Testing
- Balance of Systems Design Completion
- Market Value Analysis: Add Puerto Rico, and update BP1 markets (CAISO, PacNW, NYISO, Hawaii)
- Energy Intensity Benchmarking updates with final design