WBS 1.2.3.405 – Life Cycle Assessment of Storage Technologies

Greg Stark
Hydropower Technical Lead
National Renewable Energy Laboratory

Greg.Stark@nrel.gov

July 27th, 2022

NREL/PR-6A20-83277

Project Overview

Project Summary

Our objective is to perform a full lifecycle assessment (LCA) of new pumped storage hydro (PSH) projects in the U.S. This LCA includes all project phases (resource extraction, construction, operation, end-of-life). The functional unit is 1 kWh electricity delivered by system to grid substation connection point and the estimated lifetime is 80 to 100 years. Data used in this study are based on a representative range of potential prospective closed-loop PSH in the U.S. The project approach, data sources, and assumptions have been guided by a technical review committee of stakeholders. Greenhouse gas emissions (GHG) and energy return on investment (EROI) from PSH will be compared to other storage technologies.

Intended Outcomes

- Results from this project will be published in a suitable journal and will include the global warming potential and energy return on investment of new PSH installations as compared to competing energy storage technologies.
- Sensitivity analysis will be performed to identify the major drivers, understand impacts of different configurations, and future energy markets.
- The data and source code used for this analysis will also be made available to the public.

Project Information

Principal Investigator(s)

- PI: Daniel Inman, PhD

Project Partners/Subs

Project Status

Sunsetting

Project Duration

- October 1, 2020
- September 30, 2022

Total Costed (FY19–FY21)

$161,784.00

Project Objectives: Relevance and Approach

Relevance to Program Goals:

Addressing Environmental Impacts and Climate Change: *Establish metrics to understand environmental impacts, improve performance, evaluate sustainability of new hydro development.*

- This project's results will improve the communities understanding of the environmental impacts and sustainability of new PSH projects and how PSH compared to other storage technologies. Results from this project include the global warming potential (IPCC 100a) and Energy Return on Investment.

Lack of Access to Information Necessary to Support Decision-Making: *Improve capabilities to analyze multifaceted types of hydropower and water data to better identify opportunities and weigh potential trade-offs at basin-scales*

- The data and analysis framework developed from this project will be made publicly available. The modeling framework is open-source and is both generalizable and extensible to multiple hydro technologies and multiple spatio-temporal scales. In addition, results from this study will be published in a suitable journal.

Project Objectives: Relevance and Approach

Approach:

- To date, few studies have been published that examine the LCA impacts from new PSH projects in the U.S.
- This project uses data from 31 prospective closed-loop PSH in the U.S. with plant data and specifications available as a basis for analysis.
- The data, approach, methodology, and assumptions have been reviewed and vetted by an external technical review committee comprised of stakeholders from academia, industry, and government.
- The data and scenarios are analyzed using Brightway 2, an open-source LCA library developed in Python. Data and analysis code base are open-source. This allows for broad dissemination, collaboration, generalizability, and extensibility of the code base.
- Rigorous sensitivity will be performed to understand the major contributors across the lifecycle and to explore alternative configurations (e.g., green- vs brown-field site selection) as well as to understand impacts of maximum capacity, and possible future market conditions (e.g., electricity generation mix).

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- Lifecycle inventory data for a range of potential PSH installations in the U.S.
- An open-source LCA code base and analysis framework for PSH.
- Conference presentation at HydroVison 22.
- Published LCA of closed-loop PSH installations in the U.S.

Outcomes:

- Results from this project are being disseminated to stakeholders for review and vetting throughout the project.
- Results will be published and will inform the PSH community and provide a benchmark from which the LCA impact from PSH may be compared to other storage technologies.
- Data and results will provide guidance to decision makers and project developers.

Project Timeline

FY 2021

Literature review of LCA studies of PSH and competing storage technologies.

Establishment of a technical review committee **(TRC) to serve as reviewers and to provide feedback on the modeling approach, data, and assumptions.**

Complete lifecycle inventory data for potential PSH installations in the U.S.

Project Budget

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	**Costed**	**Costed**	**Total Costed**
$K	$K	$162K	$162K

End-User Engagement and Dissemination

- A key aspect of this project has been our engagement with the TRC. The TRC is comprised of nine representatives from industry, government, and academia. The institutions represented include: The Paul Scherer Institute, Ames Construction, The University of Pforzheim, The U.S. Department of Energy, General Electric, McMillen Jacobs Associates, Electricity of France (EFD), and Argonne National Laboratory. The TRC has provided valuable guidance on our data sources, assumptions, modeling approach, and dissemination efforts.
- As part of this project, we contributed substantially to the International Forum on Pumped Storage Hydropower (IFPSH) working group 2. This work was presented at the World Hydropower Congress meeting on 2021.09.16.
- We have also been engaged with the National Hydropower Association in their efforts to characterize LCA impacts from PSH. Engagement with the National Hydropower Association will continue throughout FY 22.
- Results from this project will be shared broadly and published in a peer reviewed journal.
- The data and code base will be made available to the public and will aid in decision making, benchmarking, and comparisons to other technologies.

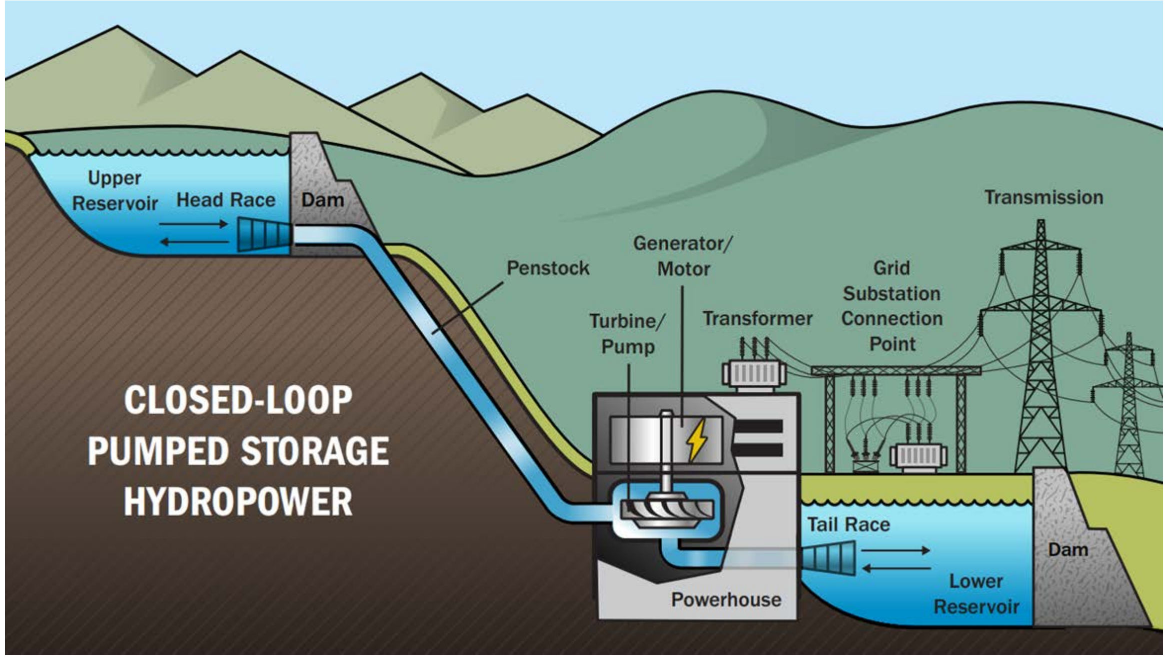
Performance: Accomplishments and Progress

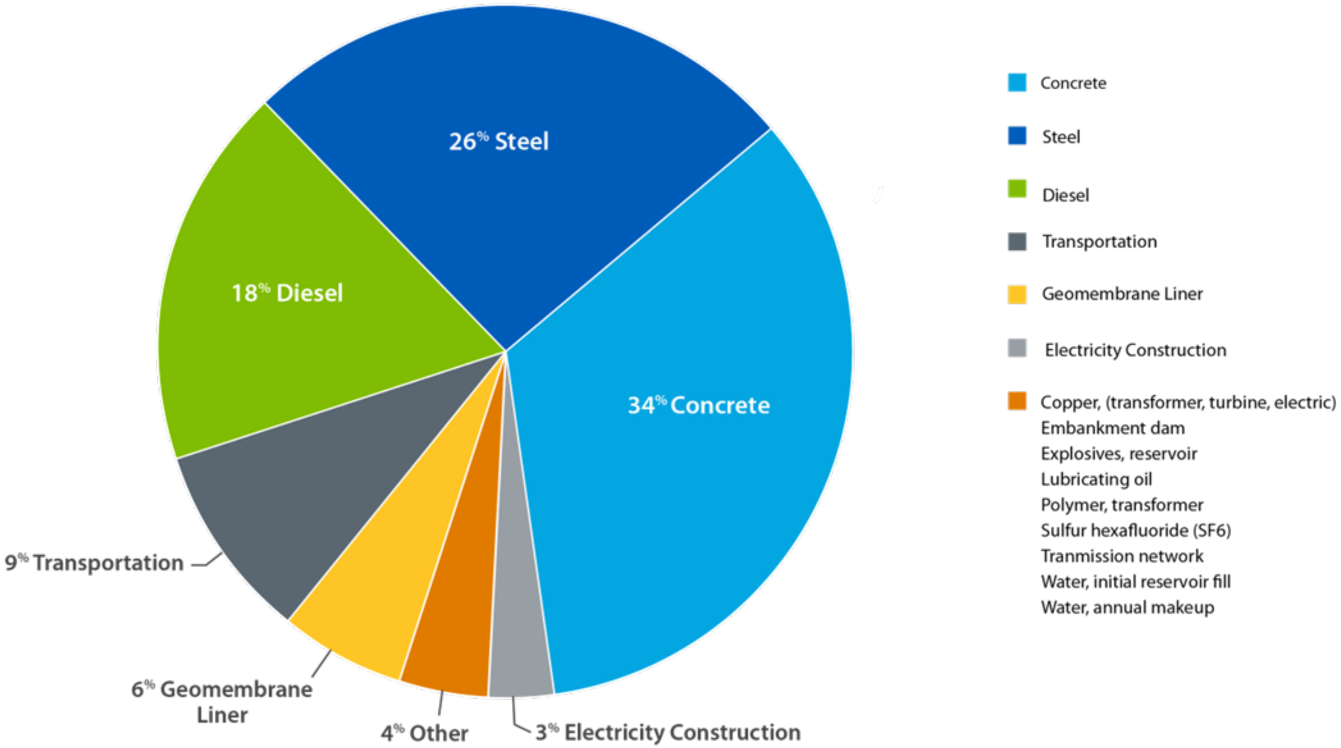
- Formation of and engagement with the technical review committee (TRC):
  - The TRC was formed in Q1 of FY21.
  - We have had four webinars with the TRC to review our modeling approach, data sources, and lifecycle inventory (LCI).
  - The TRC has provided us with substantial guidance on our modeling approach as well as data for incorporation into the LCI.
- Completion of the LCI:
  - The lifecycle inventory phase is a critical aspect of LCA.
  - We collected detailed data on 31 potential PSH sites across the U.S.
  - The LCI will serve as the basis for the final LCA.
- Modeling and data workflow and framework completed:
  - We developed a database-driven open-source modeling framework to be used in this study.
  - This approach allows for the codebase and data to be openly shared.
  - This workflow promotes consistency, tractability, and cataloging of data and results.

Performance: Accomplishments and Progress (cont.)

- This project contributed to the IFPSH working group 2 effort.
- The results of this effort were presented at the World Hydropower Congress meeting on 2021.09.16.
- The report from the WHC is available here: https://www.hydropower.org/publications/working-paper-on-sustainability-of-pumped-storage-hydropower

Recent Progress: FY22 Results





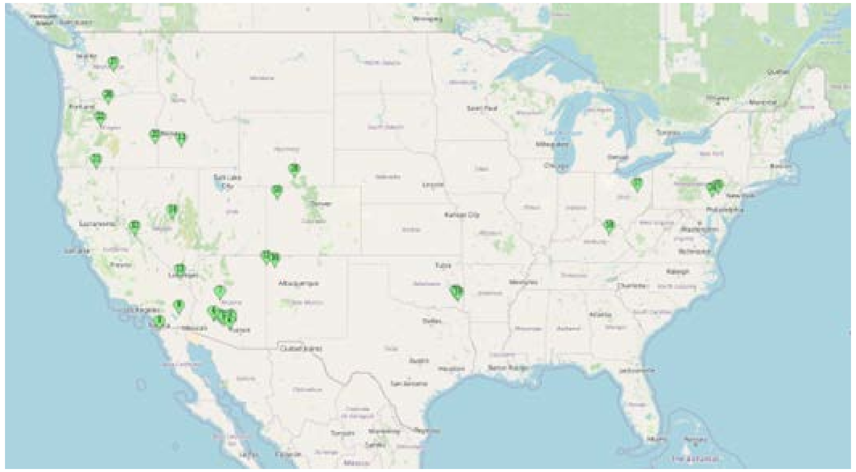
Functional Unit: *1 kWh of electricity delivered by system to grid substation connection points*

System Boundary: *Sourcing → construction → operation → end of life*

PSH Base Case % GHG Contributions

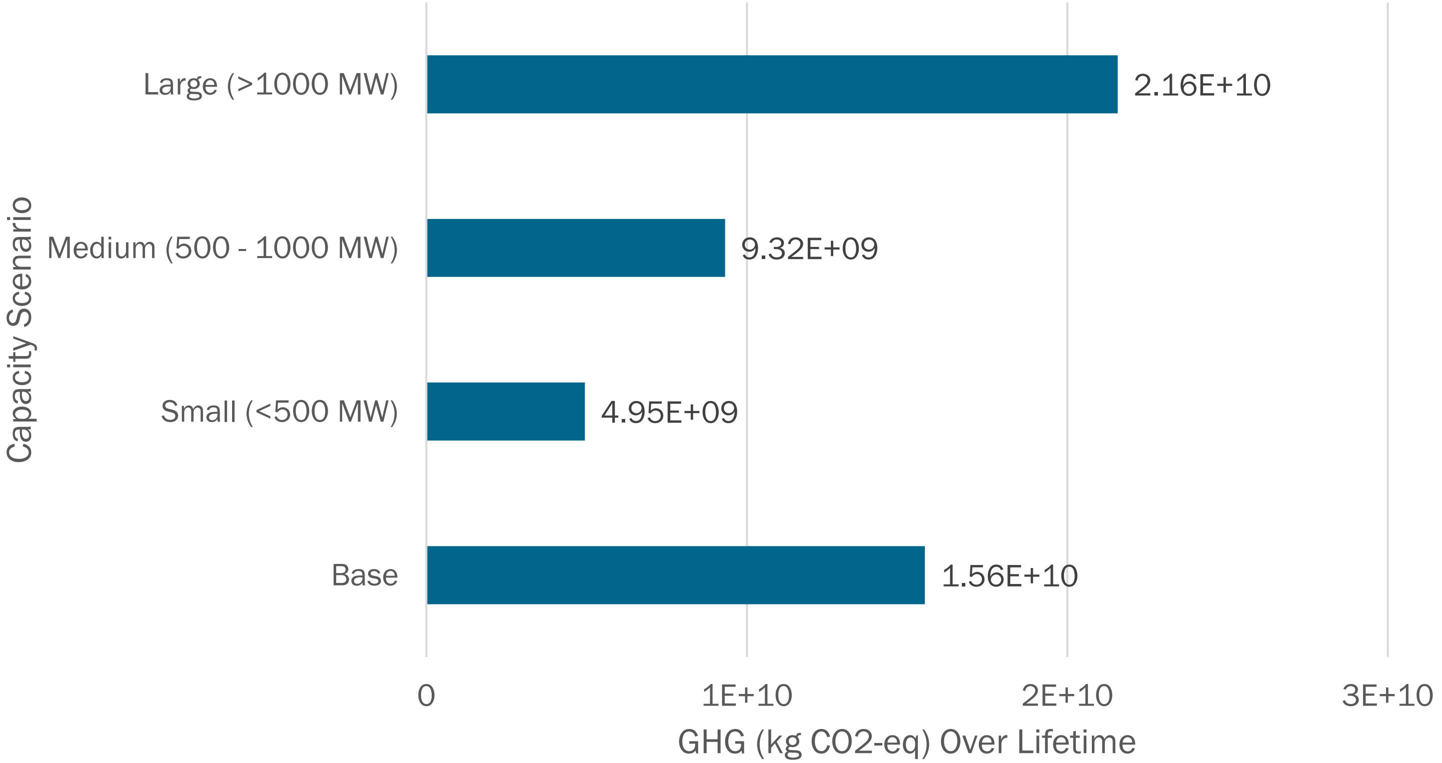
$$Total\ GHG:\ \ 0.086\ kg\ CO_2 - eq\ per\ kWh\ delivered$$

Recent Progress: FY22 Results



There are 32 individual sites contributing data; three sites have two complete alternatives included.

- Not all new U.S. closed-loop projects are included, just those with data available.
- Not every location includes data for each construction or operational input.



Impact of project size on GHG emissions over 80 years.