Optimal Wind Turbine Design for H2 Production

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National Renewable Energy Laboratory (NREL)
WBS 7.2.9.14
June 2022

DOE Hydrogen Program
2022 Annual Merit Review and Peer Evaluation Meeting

Project ID: TA061

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Project Goal

- **Identify optimal wind turbine designs made specifically for hydrogen production with the goal of advancing affordable green hydrogen production**
- This project will couple wind turbine, wind plant, solar plant, and electrolyzer models to predict hydrogen production from variable, renewable power sources. This will be accomplished through:
  - Developing electrolyzer models informed by industry data
  - Optimizing wind turbine rotor diameter, hub height, and power rating for hydrogen production under different conditions and objectives
  - Validating the optimal turbine designs using the Advanced Research on Integrated Energy Systems (ARIES) research platform by scaling the electrical generation of the optimized designs and feeding this signal to a physical electrolyzer.

This project just started and is in its first quarter.

Overview

Timeline and Budget

- Project start date: 04/18/2022 (estimated)
- Fiscal Year (FY) 2022 planned U.S. Department of Energy (DOE) funding (if applicable): $112,000
- Total DOE funds received to date*: $500,000.

  * Since the project started

Partners

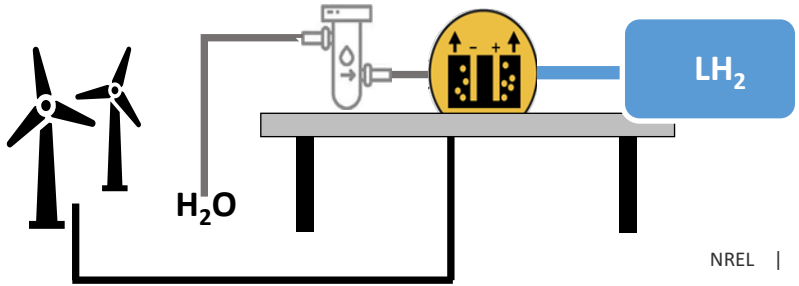
- Project lead: NREL
- Partner organization(s)
  - General Electric (GE) Renewable Energy: advising on turbine design and performance/cost modeling; facilitating end-use customer survey
  - NEL Hydrogen US: advising on electrolyzer performance/cost modeling.

Relevance/Potential Impact

- This work seeks to address the H2@Scale program's goal to "advance affordable hydrogen production" by optimizing the wind turbine design specifically for hydrogen (H2) production objectives within the H2@Scale pillar of technoeconomic modeling and analysis.
- Expected outcomes include:
  - The capability to design wind turbines for hydrogen production to unlock a reduced cost for renewable hydrogen and **accelerate the progress of the green hydrogen economy**
  - **Answers to relevant questions of interest from industry**, including optimal turbine sizing for H2 production, how different design objectives affect optimal technology couplings, and explore the benefits of different electrolyzer types (alkaline vs. polymer electrolyte membrane (PEM))
  - Reduced design cycle turnaround time to inform the optimal development of hybrid plants within the green hydrogen economy earlier in the project lifecycle, **accelerating uptake by industry**
  - **Increased certainty in the H2 production capabilities of hybrid plants**, leading to economic benefit as well as industrial energy savings by tuning plant performance for specific sites.

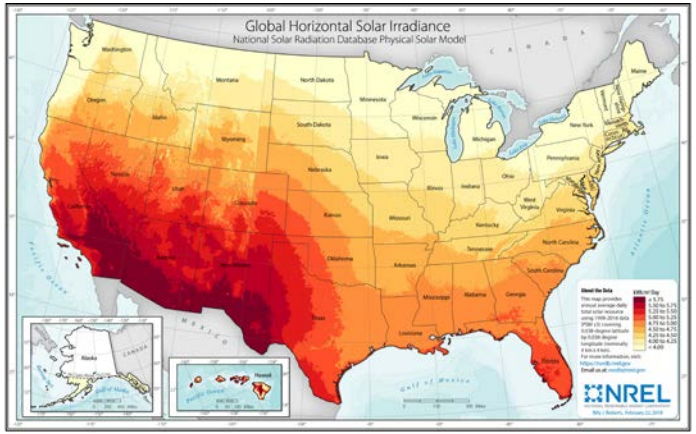
Approach – H2/Wind Coupling

- Develop and couple electrolyzer models with wind turbine/plant performance models
  - NEL Hydrogen US will assist in modeling the coupling to accurately predict hydrogen production
  - GE will advise on turbine performance and cost tunings
- Turbine performance predicted by the engineering models will be validated with higher-fidelity simulations
- Leverage NREL's existing work on the Hybrid Optimization and Performance Platform (HOPP) .



Approach – Customer Survey and Societal Impacts

- Work with GE to conduct end customer survey to identify geographic regions of interest for developing green hydrogen plants
  - Using associated wind/solar data to perform site-specific optimizations
  - Positive impact on the local economy and population will also influence which sites are selected for optimization, aiming to benefit populations that are vulnerable of have a lower socioeconomic status.



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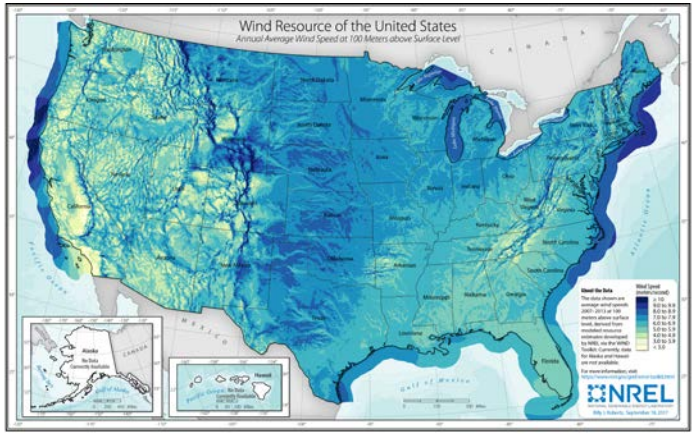
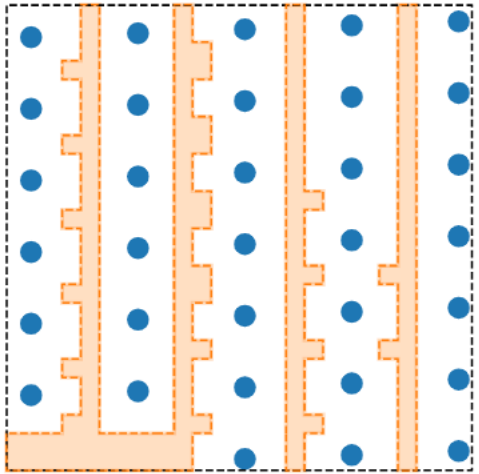


nrel.gov/gis/wind-resource-maps.html

Approach – Site-Specific Optimization for H2 Production

Optimize wind turbine design for H2 production at sites of interest by:

- Focusing first on single turbine-electrolyzer combinations, expanding to full plant optimizations
- Considering multiple objective functions including minimizing levelized cost of H2, maximizing H2 production, and simplified financial metrics (e.g., revenue or profit)
- Applying design variables, such as rotor diameter, hub height, rated power, electrolyzer ramp rates, and plant capacity
- Plant-level optimizations will be considered for both alkaline and PEM electrolyzers.



Example wind/solar optimization for a specific site.

Approach – Validate Wind Turbine Designs With ARIES

- NREL's Advanced Research on Integrated Energy Systems facility will be used to validate the turbine designs
  - Wind turbines will be virtually modeled, producing an electric signal that will be fed to a physical electrolyzer to verify improved H2 production
  - Industry partner NEL will advise on electrolyzer modeling and operation (PEM electrolyzer at ARIES)
  - A go/no-go decision will be made for the testing based on one of the optimized designs demonstrating at least a 5% reduction in levelized cost of hydrogen (LCOH).

Hydrogen storage at ARIES. *Photo by Werner Slocum, NREL*

Approach – Milestones

Date	Milestone/Deliverable (status as of 4/8/2022)	Complete
6/30/2022	Electrolyzer model developed and detailed in slide deck	0%
9/30/2022	Coupling of electrolyzer and single turbine simulated for 12 hours	0%
12/31/2022	Coupling of electrolyzer with 20-megawatt (MW) wind/hydrogen plant simulated for 12 hours	0%
12/31/2022	Recruit student to team with focus on recruiting from underrepresented communities	100%
3/31/2023	Complete first turbine design optimization	0%
6/30/2023	Go/no-go decision to move ahead with experiments	0%
9/30/2023	Complete original research paper draft on optimal turbine design for H2 production	0%
12/31/2023	Analysis showing societal impacts of proposed optimizations	0%
3/31/2024	Complete original research paper draft on ARIES experiments	0%

This project just started and is in its first quarter.

Accomplishments and Progress

- This project has just started and is in its first quarter of performance
- Kick-off meetings with the project partners have been held
- Progress toward the Q1 milestone of the electrolyzer model development has been made
- This project has not been previously reviewed at an Annual Merit Review.

Collaboration and Coordination

- This project has two industry partners:
  - **General Electric Renewable Energy** (sub)
    - Provide feedback on turbine designs
    - Give valuable insight on tuning of turbine performance/cost models
    - Facilitate the end customer survey to ensure optimizations are relevant based on current markets
  - **NEL Hydrogen US** (sub)
    - Provide feedback on electrolyzer modeling and cost tuning
    - Ensure successful demonstration of H2 production at ARIES.

Remaining Challenges and Barriers

- Delays related to COVID-19 have pushed back the delivery and installation of the electrolyzer for ARIES
- Coupling the various models involves many interacting parts that will be difficult and computationally expensive to validate and optimize.

Installing hydrogen storage at ARIES. Photo by Werner Slocum, NREL

Proposed Future Work

- Remainder of FY 2022:
  - Develop electrolyzer model and detail performance
  - Demonstrate coupling of electrolyzer model to a single turbine for 12 hours of simulation, building to full coupling of electrolyzers with a wind plant
- FY 2023:
  - Complete coupling of electrolyzer model with a 20-MW hydrogen/turbine plant, simulating 12 hours of performance data to be validated against available data from industry partners/existing experiments
  - Finish first turbine design optimization for site-specific scenario
  - Begin experimental validation work at ARIES.

Any proposed future work is subject to change based on funding levels.

Summary

- This project aims to lower the cost of green hydrogen through the design and optimization of wind turbines specifically for H2 production (as opposed to maximal energy production/levelized cost of energy reduction as is currently done)
- Model development and coupling will leverage existing NREL work.
- Turbine and electrolyzer modeling and cost estimation will be informed from GE and NEL Hydrogen US, respectively
- Wind turbine designs will be validated using the ARIES research platform at NREL.

Thank You

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NREL/PR-5000-82639

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Hydrogen and Fuel Cell Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Technical Backup and Additional Information

Technology Transfer Activities

- Tech-to-market could include publicly released models, findings, and modifications to Wind-Plant Integrated System Design & Engineering Model (WISDEM®) or HOPP
- Will pursue additional funding from DOE's Hydrogen and Fuel Cell Technologies Office and DOE's Wind Energy Technologies Office; will consider Hydrogen Hub Funding Opportunity Announcement once released
- GE and NEL Hydrogen US are immediately interested in the results of this project to inform direction of investments.