Offshore Hybrid Energy Systems

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Outline

Overview of offshore hybrid energy systems

Example offshore hybrid energy system

Conclusion
Offshore Hybrid Energy Systems
Estimated Cumulative Offshore Wind Capacity by Country


U.S. Project Pipeline by State

Key Challenges to Offshore Systems

• Cost reductions of offshore wind energy
• Expanded, just, and sustainable deployment
• Domestic supply chains, including ports and manufacturing
• Transmission development
• **Cogeneration and storage applications**
• Floating Offshore Wind Shot™: 70% reduction in levelized cost of energy (LCOE) by 2035
What is a hybrid energy system?

Hybrid Energy Systems
A broad universe that encompasses...

A wide variety of energy generation, storage, and conversion technologies

Generation
- biomass
- coal
- concentrating solar power
- fuel cell
- geothermal
- natural gas
- nuclear
- photovoltaics
- reservoir hydropower
- run-of-river hydropower
- wind

Storage
- chemical storage
- magnetic storage
- mass storage
- mechanical storage
- thermal storage

Conversion
- electrolysis
- methanation
- liquid fuels synthesis
- CO2 capture

The colocation and/or coordinated operations of energy technologies
- collocated resources
- virtual power plant
- fully integrated hybrid

Front-of-the-meter, behind-the-meter, microgrid, and off-grid applications
- bulk grid
- businesses
- homes
- industrial facilities
- microgrids
- remote microgrids
- stand-alone systems

Systems that provide a variety of energy and non-energy products
- electricity
- bulk chemicals
- freshwater
- heat
- hydrogen
- liquid fuels
- materials
- material inputs
- oxygen

What is a hybrid energy system?

C.A. Murphy, A. Schleifer, K. Eurek, A taxonomy of systems that combine utility-scale renewable energy and energy storage technologies, Renewable and Sustainable Energy Reviews, Volume 139, 2021, 110711, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2021.110711, – used with permission
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What renewable energy systems are being considered for offshore hybrid installation?
The types of energy systems that are most complementary depend on the location.
Inflation Reduction Act: Policy Considerations

- Three common scenarios:
  - No Policy – Baseline
  - Base – Lowest 100% value
  - Max/Bonus – includes 5X and bonus values
- Provision can be stacked
- Additional considerations:
  - Prevailing wage and apprenticeship (5X)
  - Domestic content bonus (10%)
  - Energy community bonus (10%)
  - Internal Revenue Code (IRC) Section 45Q carbon capture, utilization, and storage (CCUS) credit
    - “Base” $17/ton
    - Prevailing wage $85/ton

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<th>ITC (% )</th>
<th>PTC * ($/kWh)</th>
<th>H₂ PTC ** ($/kg-H₂)</th>
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* = 1992 dollars  
** = 2022 dollars  
ITC = investment tax credit
PTC = production tax credit
Example Systems that Have Been or Are Being Built

Integrated systems

**FPP – Floating Power Plant**
- Floating wind and wave
- Tested in-ocean.

**W2Power – Enerocean**
- Floating wind and wave
- Only wind tested in-ocean.

Connected systems

**Crosswind (Joint Venture)**
- Anticipating operational 2023
- Primarily a wind farm
- Small scale hybrid (1 turbine)
- Fixed wind, floating solar, batteries, and hydrogen.

**Haiyang**
- Existing wind farm
- Hybrid operational 2022
- Fixed wind, floating solar.

Note: All of these are in Europe or Asia.
Floating Power Plant (FPP) Hybrid Floating Platform

OceanSun – Haiyang Plant
An intelligent wind farm

The wind doesn’t always blow consistently. So how can a wind farm provide electricity when there is little wind? CrossWind and its partners are exploring five different innovations designed to address these challenges. Through these innovations an offshore wind farm is capable of providing electricity, no matter the wind conditions.

1. Addressing the wake effect
   The wake effect describes how wind can slow after hitting a turbine, affecting the wind further ahead. CrossWind is looking at ways of using real-time data to reduce this across the entire wind farm.

2. Intelligent wind turbines
   CrossWind and its partners are exploring a range of technologies that can help wind turbines in a range of conditions. Using real-time data, intelligent wind turbines can respond to changing conditions within seconds and help to keep stability across the energy grid.

3. Floating solar energy
   What about times when there is simply not enough wind to run a turbine? CrossWind and its partners are experimenting with floating solar panels that could sit alongside the wind turbines and help to deliver more consistent energy.

4. Storing energy
   How can you store excess energy in times of low demand to supply it in times when demand is high? CrossWind and its partners are exploring energy storage solutions of batteries and even hydrogen, plant on site that produces, stores and converts hydrogen from electricity to power.

5. Research and integration
   CrossWind is looking at opportunities to integrate these innovations within the wind farm. We have commissioned further research to assess its feasibility. Our aim is to help the world build intelligent wind farms that can align supply with demand of renewable energy and to further power the transition into a lower-carbon future.

Baseload power hub
August 2022
Crosswind

From wind farm to integrated energy plant

1. Seawater desalinator
2. Electrolyser
3. Pump
4. Hydrogen storage
5. Fuel cell/hydrogen off-taker
6. Battery
7. Wind power hub
8. Future offshore renewables
How will these systems be connected?

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Example Offshore Hybrid Energy System

Wind + hydrogen production + hydrogen storage
Systems to Consider in Design

- Electricity Generation
- Electricity Transport
- Desalination
- Hydrogen Production
- Hydrogen Storage
- Hydrogen Transport
Electricity Generation

Offshore Wind Turbines

- Capacity: 6.0 MW
- Rotor Diameter: 150 m
- Hub Height: 103 m

2019
- Specific Power: 340 W/m²

2035
- Specific Power: 346 W/m²
- Capacity: 17 MW
- Rotor Diameter: 250 m
- Hub Height: 151 m

Graphic by John Frenzl, NREL
Electricity Transport
Desalination
Hydrogen Production
Hydrogen Transport

Hydrogen Blending as a Pathway Toward U.S. Decarbonization
Jan. 24, 2023, Photo from Natasha Nguyen, Contact media relations

Photo by Dennis Schroeder, NREL – NREL image gallery image 40033
Hydrogen Storage
## Physical Scenarios

### Electrolysis

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<th>Platform</th>
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### Transportation

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### H₂ Storage

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HVDC = high-voltage direct current
Example 700-MW Offshore H$_2$ Plant

Note: Not for engineering design. These figures are only intended to show relative size and general location.

* Generic size, size not calculated for actual plant.
Example 700-MW Offshore H₂ Plant

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Example 700-MW Offshore H₂ Plant

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Where will offshore hybrid energy systems likely be built in the United States?

These are preliminary results for DOE funded by HFTO and WETO

Gulf of Mexico = 85 km
Central Atlantic = 110 km
New York Bight = 80 km
California = 45 km
Preliminary Results

These are preliminary results for DOE funded by HFTO and WETO.
Conclusion
Key Takeaways for Offshore Hybrids Systems

There is significant interest in offshore hybrid systems as we target our offshore wind deployment goals, Floating Offshore Wind Shot™, and offshore hydrogen/fuel production.

Offshore hybrid energy systems can maximize the use of offshore infrastructure, and minimize the risk of transmission build out.

Offshore hybrid systems usually include large areas and will likely be on the scale of gigawatts per lease area.

The Inflation Reduction Act will drive near-term investment.
Research Question Areas

- Improved hybrid system design
  - Cost reductions
  - Operational improvements
  - Environmental benefits
  - Power to X
  - Grid services
- Hazard prevention and protection
  - Adversarial hazards (cyber and physical)
  - Natural hazards
  - Connections between natural and adversarial hazards
NREL Hybrid Capabilities and Tools

The REopt® techno-economic decision support platform is used by NREL researchers to optimize energy systems for buildings, campuses, communities, microgrids, and more.

**SAM**

The System Advisor Model (SAM) is a free techno-economic software model that facilitates decision making for people in the renewable energy industry.

**ReEDs**

NREL designed the Regional Energy Deployment System (ReEDS) to simulate electricity sector investment decisions based on system constraints and demands for energy and ancillary services.

**HOPP**

The Hybrid Optimization and Performance Platform (HOPP) is a software tool (part of the NREL suite of systems engineering tools) that enables detailed analysis and optimization of hybrid power plants down to the component level.
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Pertaining to the figure on slide 11

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