NREL
Transforming ENERGY

Offshore Hybrid Energy Systems

Dr. Jared J. Thomas

Dr. Jennifer King

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Outline

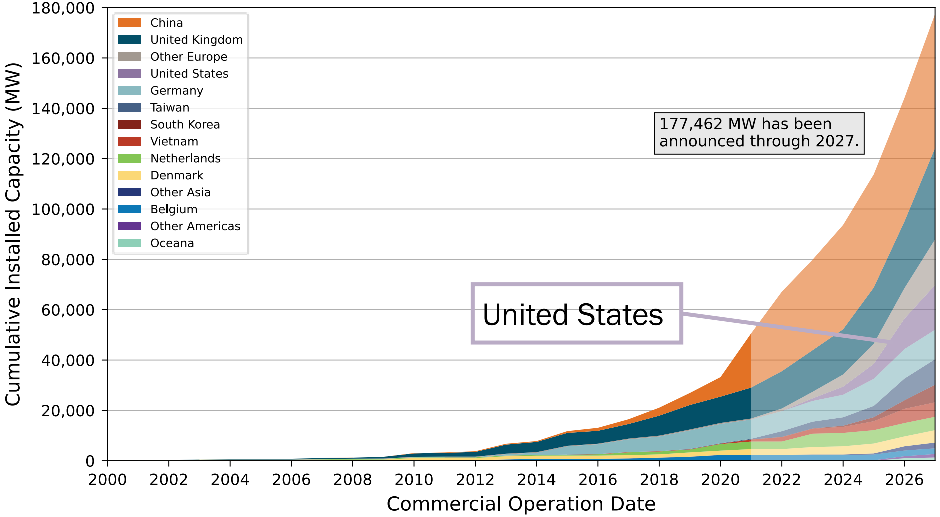
Overview of offshore hybrid energy systems

Example offshore hybrid energy system

Conclusion

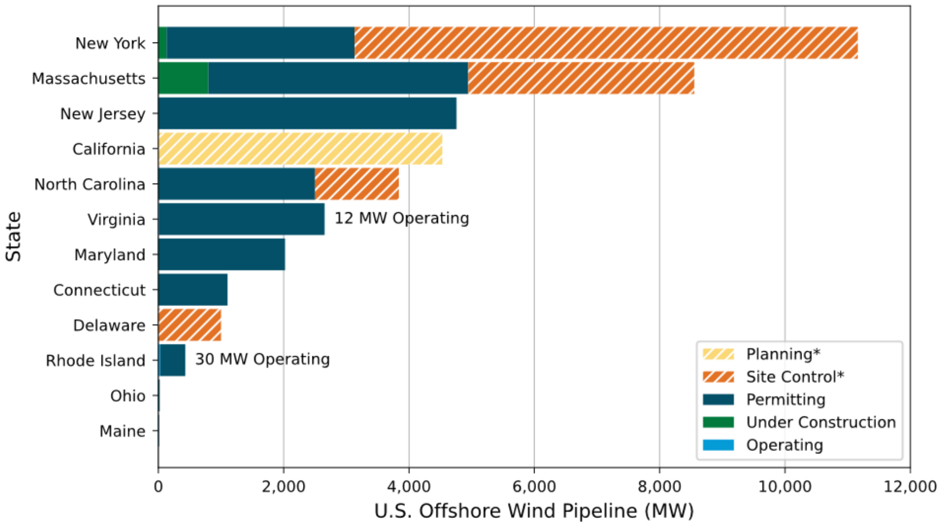
Offshore Hybrid Energy Systems

Offshore Wind Potential



Estimated Cumulative Offshore Wind Capacity by Country

Source: Offshore Wind Market Report: 2022 Edition



U.S. Project Pipeline by State

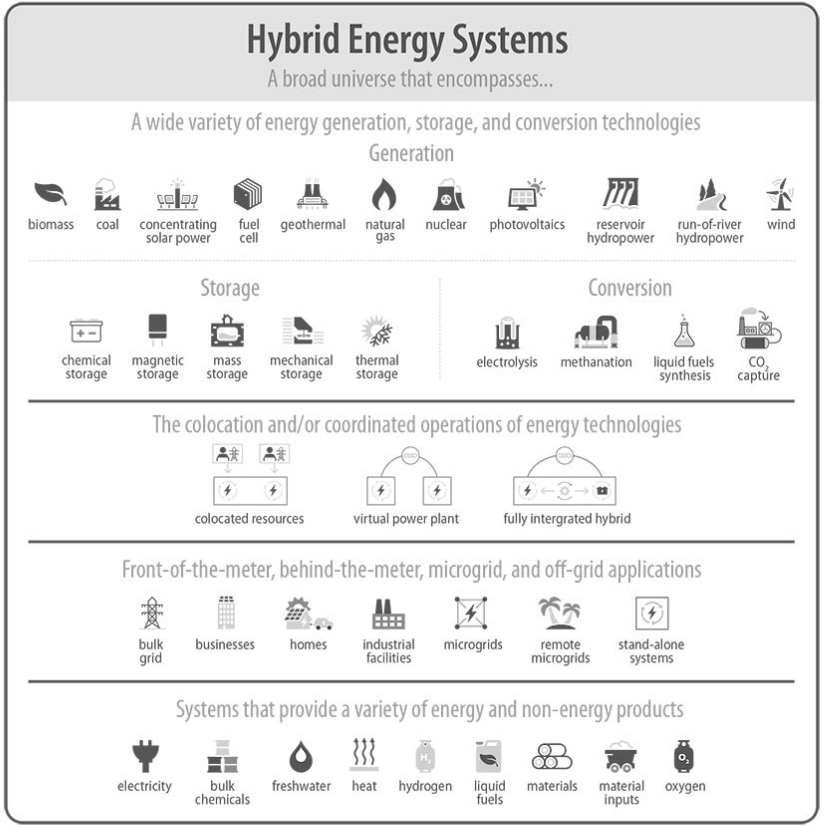
Source: Offshore Wind Market Report: 2022 Edition

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

Source: NREL

What is a hybrid energy system?

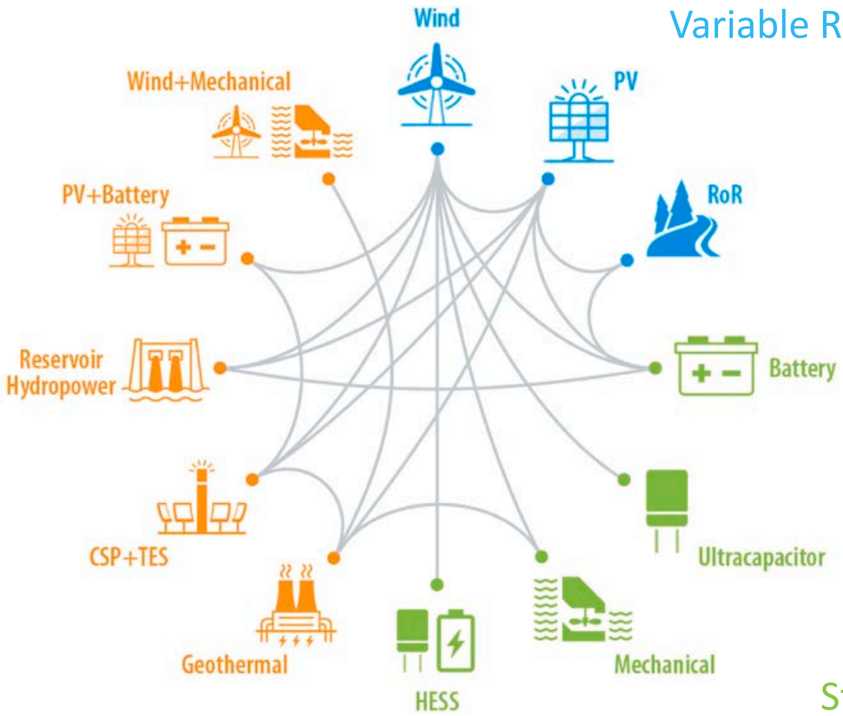


https://www.nrel.gov/news/features/2021/are-hybrid-systems-truly-the-future-of-the-grid.html

What is a hybrid energy system?

Variable Renewable Energy

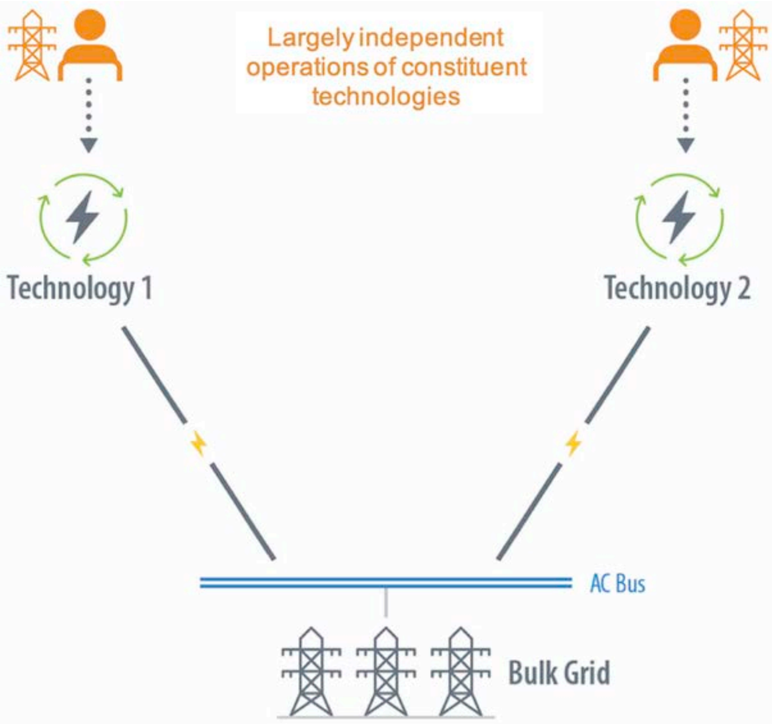
Less-variable
Renewable Energy



Storage

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

What is a hybrid energy system?



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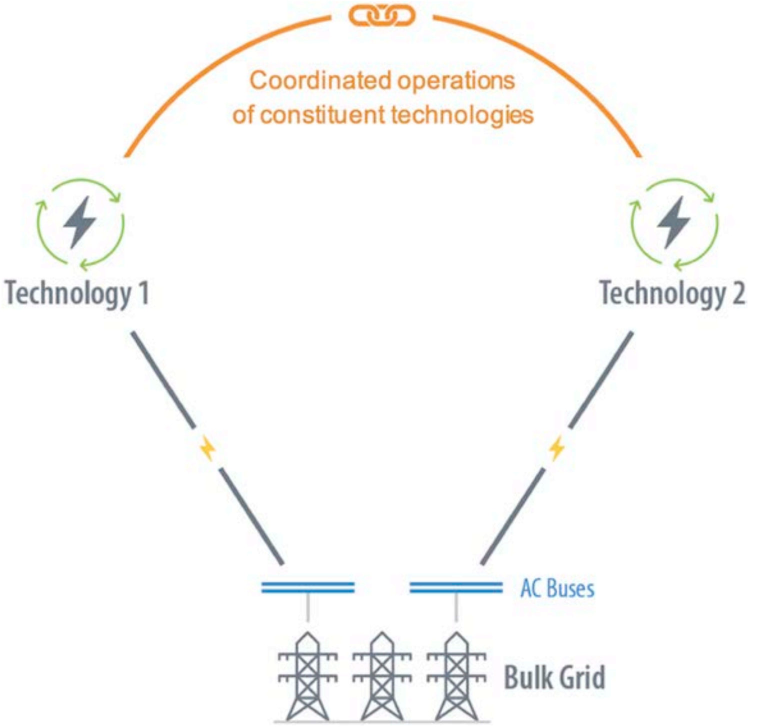

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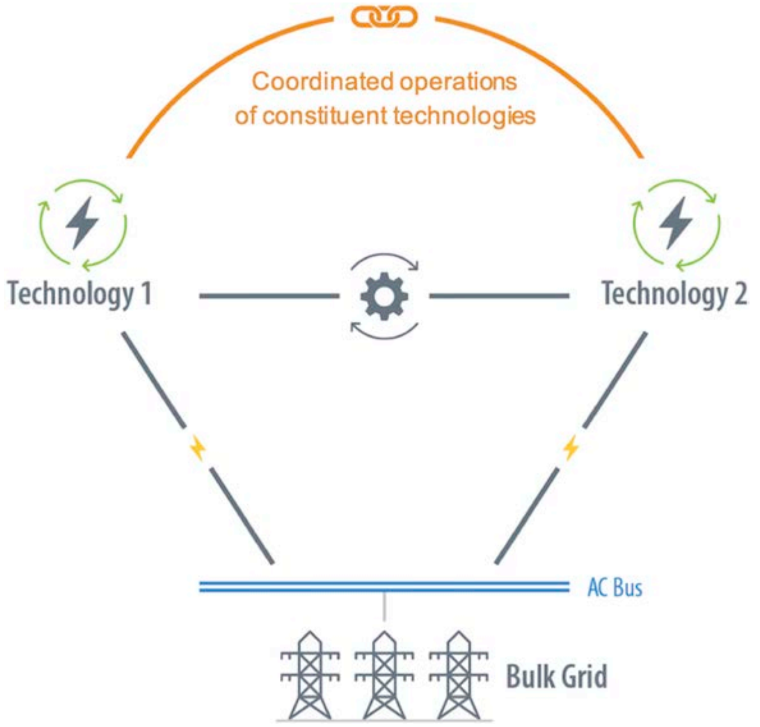

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What renewable energy systems are being considered for offshore hybrid installation?

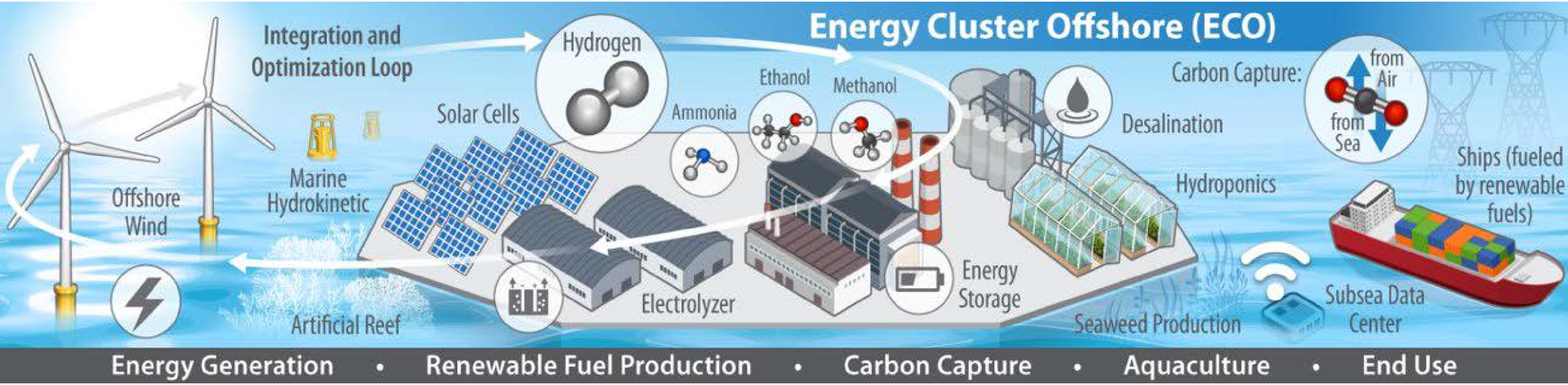
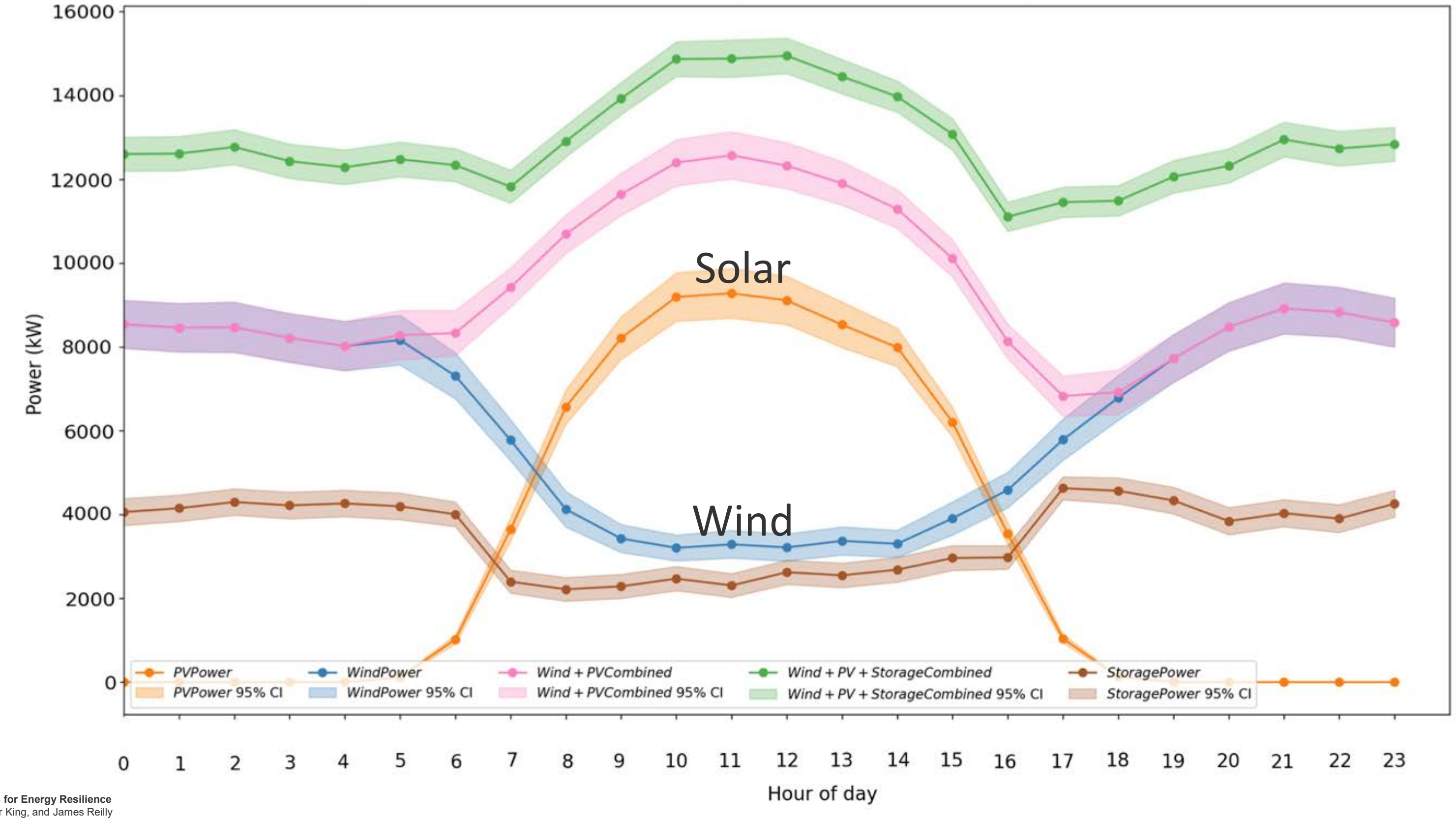


Image from NREL Laboratory Directed Research and Development funded project "Energy Clusters Offshore (ECO)" (see funding statement slide)

The types of energy systems that are most complementary depend on the location.



Wind and Solar Hybrid Power Plants for Energy Resilience
Caitlyn E. Clark, Aaron Barker, Jennifer King, and James Reilly
Used with permission from the author
https://www.nrel.gov/docs/fy22osti/80415.pdf

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

Policy	ITC (%)	PTC * ($/kWh)	H_2 PTC ** ($/kg-$H_2$)
No Policy	0	0	0
Base PTC	0	0.003	0.60
Max PTC	0	0.015	3.00
Bonus PTC	0	0.0165	3.00
Base ITC	6	0	0.60
Max ITC	30	0	3.00
Bonus ITC	40	0	3.00

* = 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.

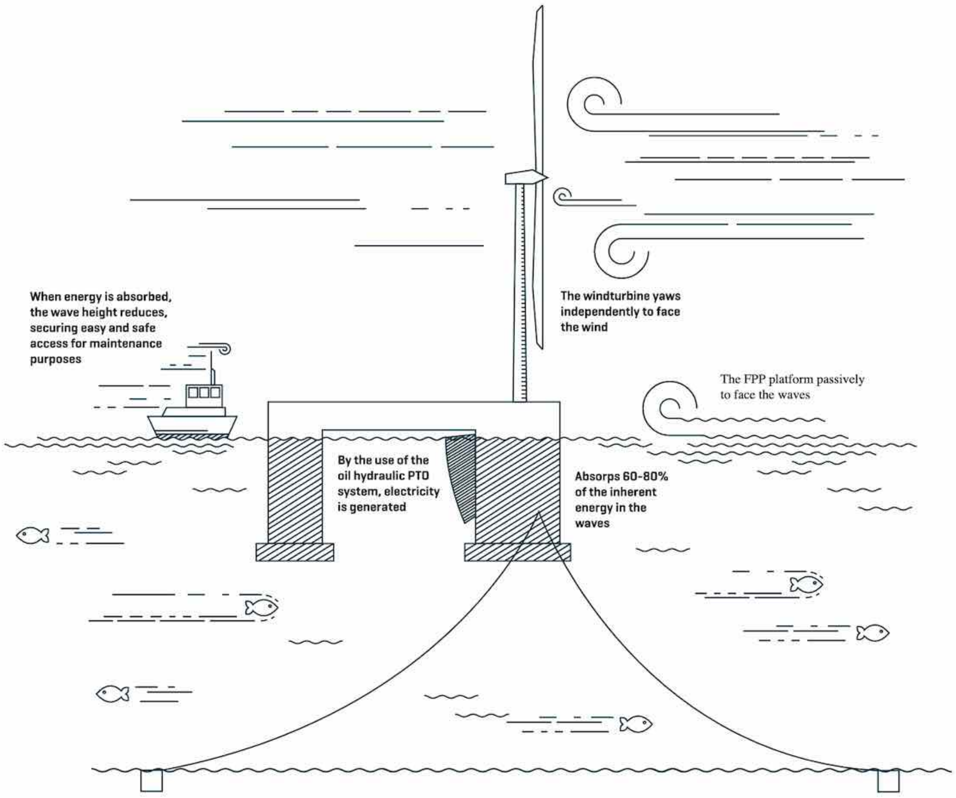
Connected systems

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



https://reneweconomy.com.au/first-full-scale-hybrid-floating-wind-and-wave-energy-platform-bound-for-canary-islands/

OceanSun – Haiyang Plant

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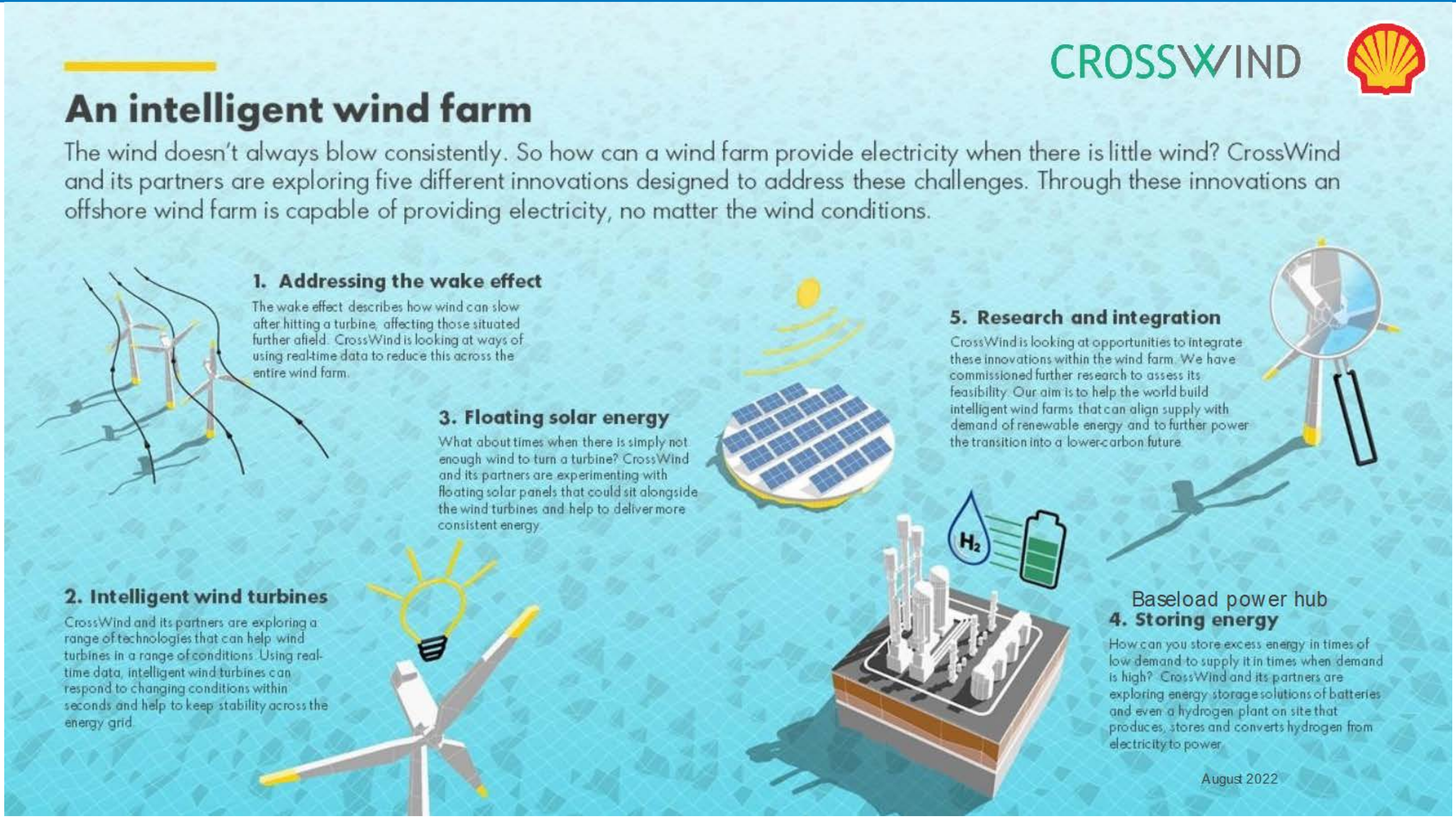
Crosswind



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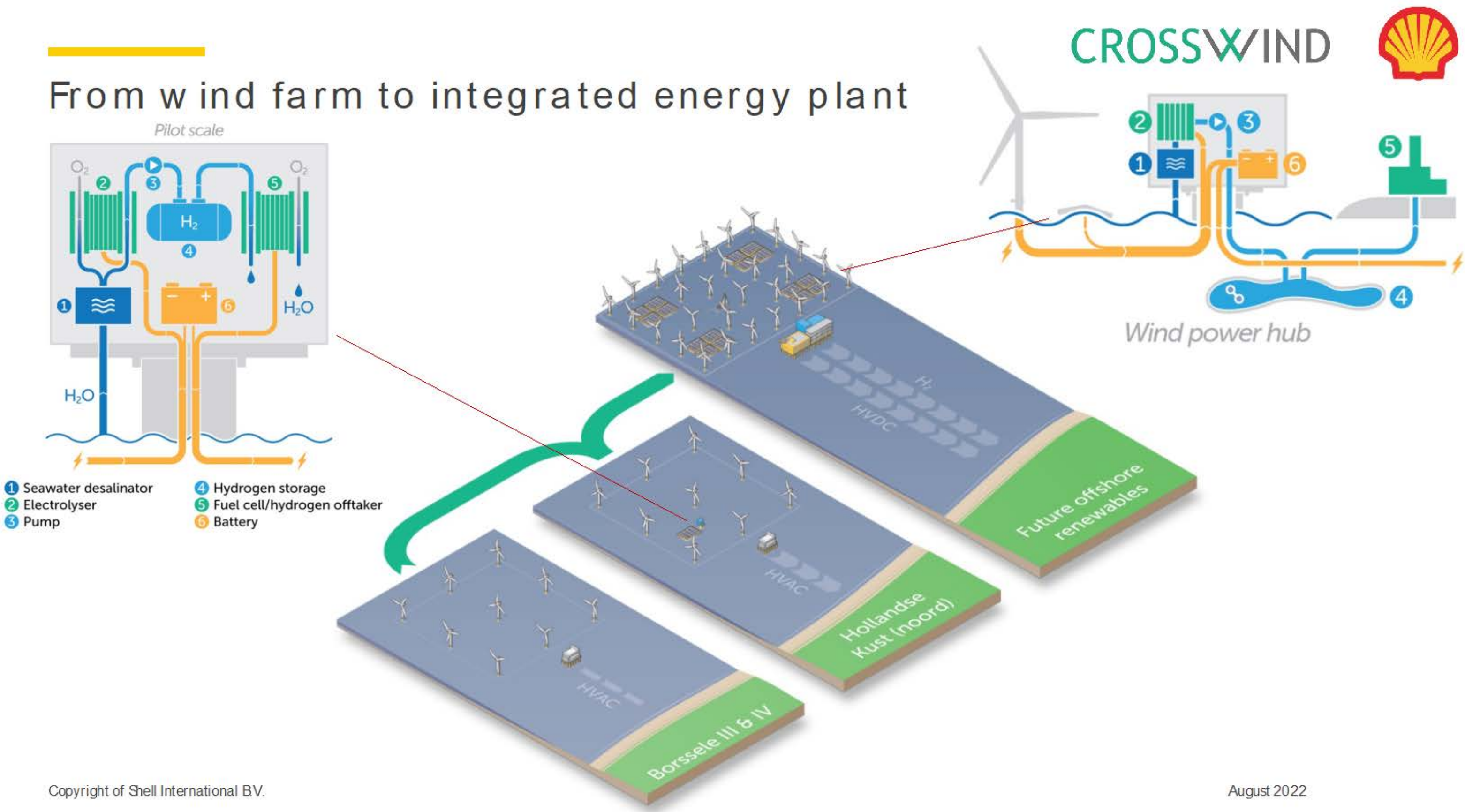
Crosswind



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How will these systems be connected?

https://www.energy.gov/sites/default/files/2022-09/offshore-wind-market-report-2022-v2.pdf

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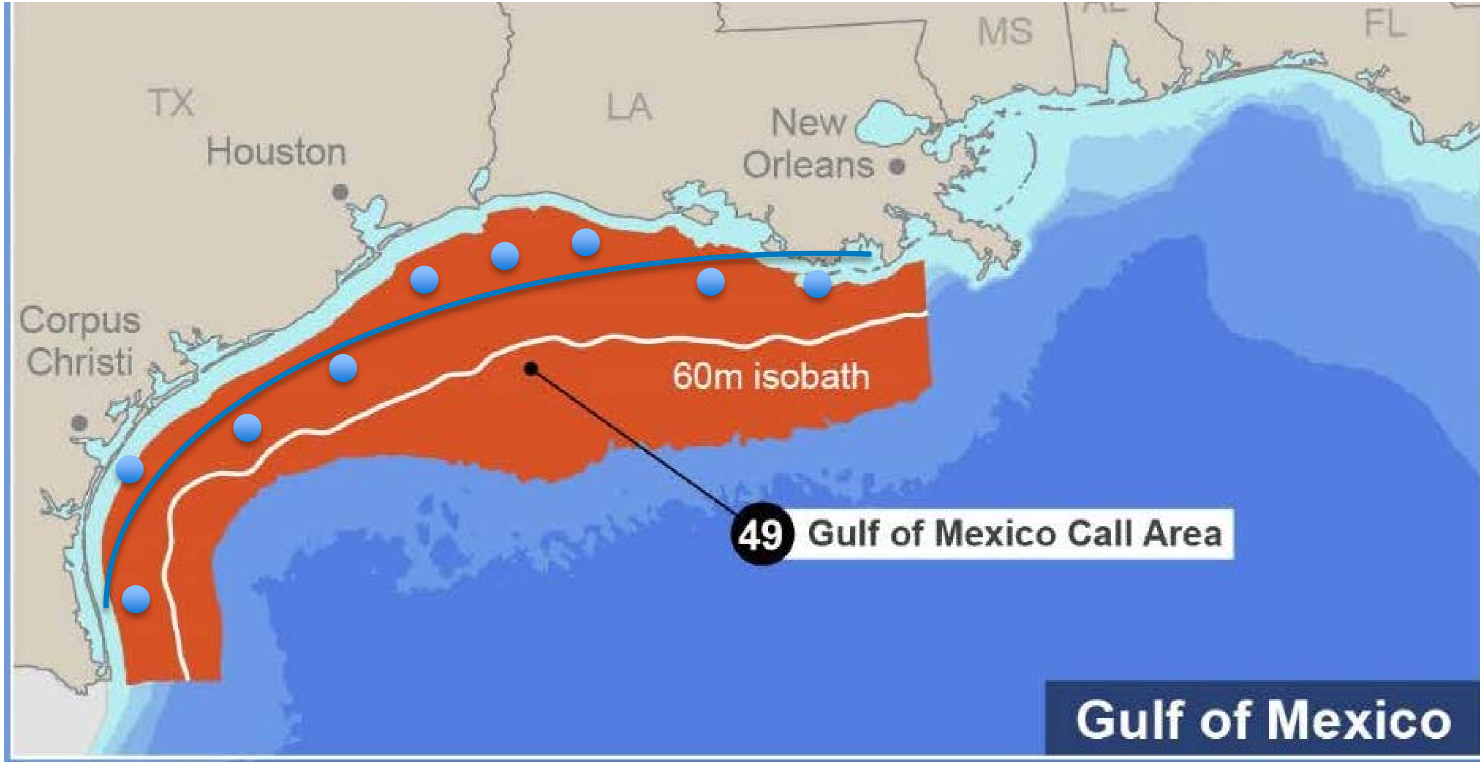

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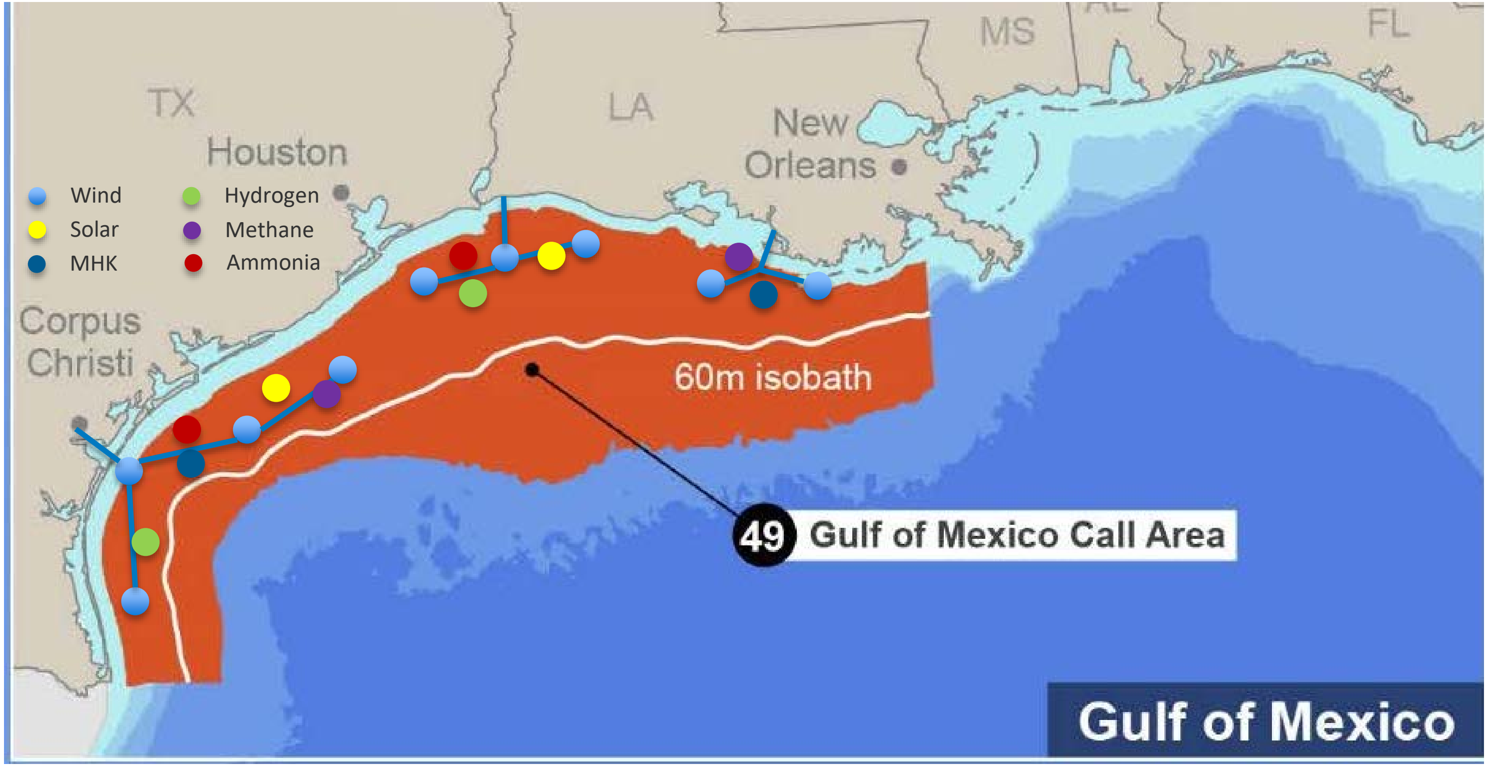

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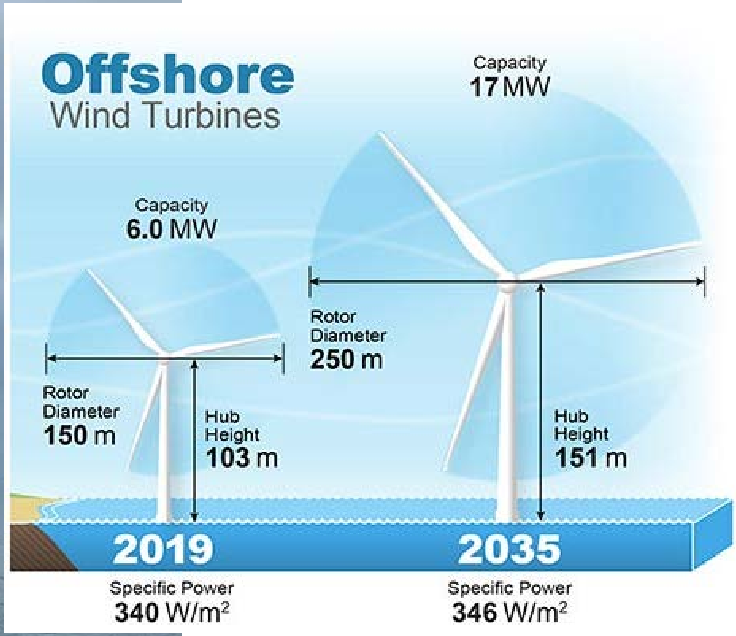
Example Offshore Hybrid Energy System

Wind + hydrogen production + hydrogen storage

Systems to Consider in Design

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

Electricity Generation



Graphic by John Frenzl, NREL

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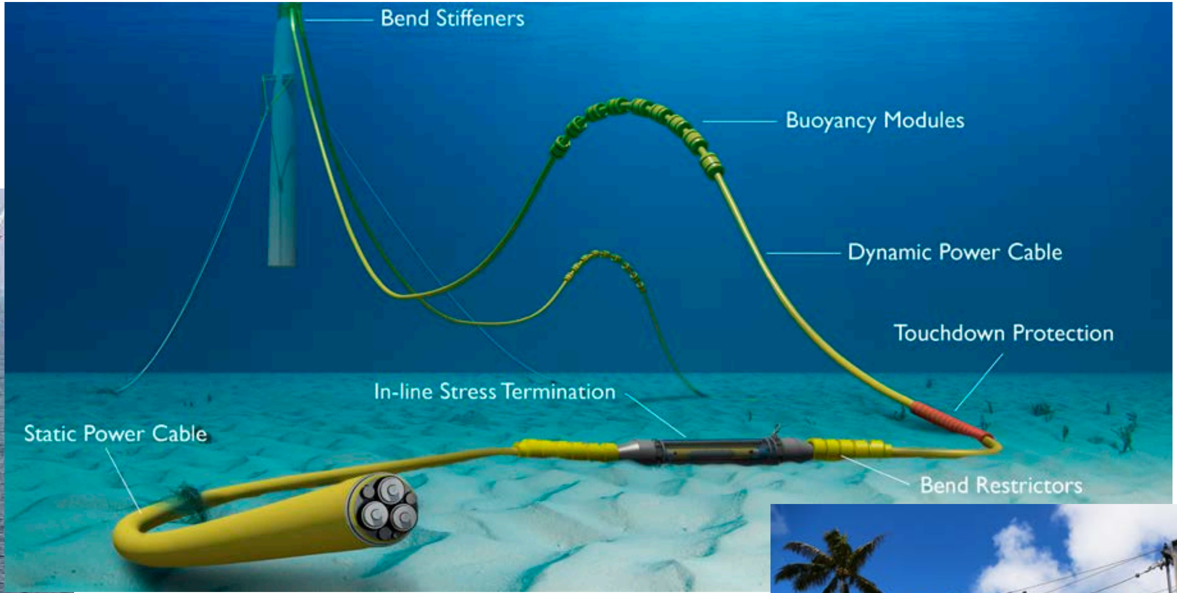
Electricity Transport



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Desalination

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Hydrogen Production

Photo by Werner Slocum, NREL - NREL image gallery image 74986

Hydrogen Transport

Photo by Dennis Schroeder, NREL – NREL image gallery image 40033

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

Hydrogen Storage

Photo by Werner Slocum, NREL – NREL image gallery image 66367

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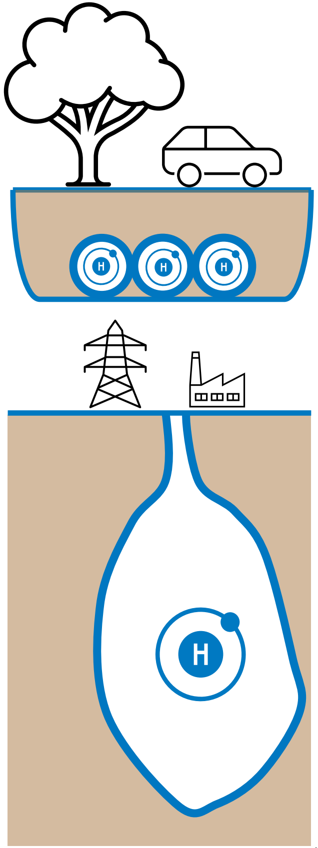
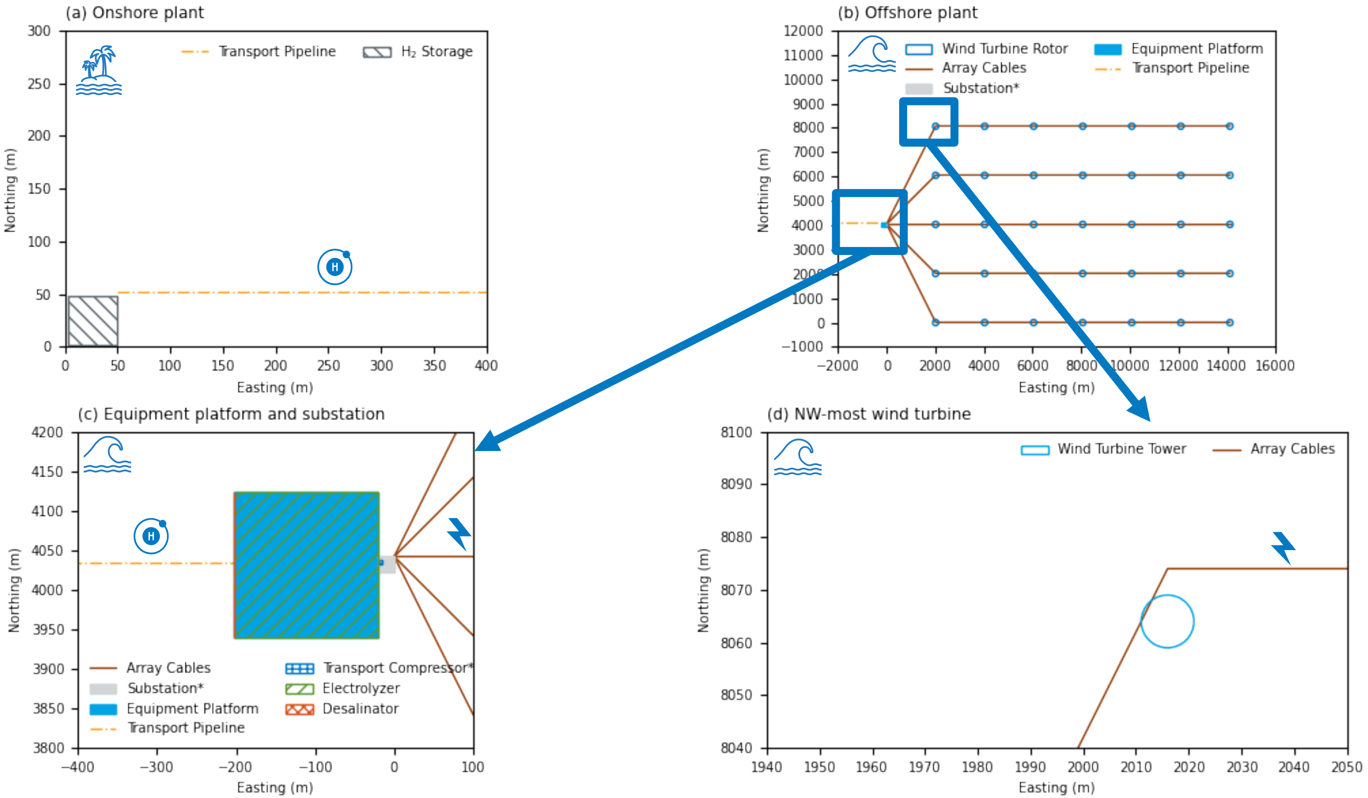


Physical Scenarios

	E **Electrolysis**			T **Transportation**			S **H_2 Storage**		
Scenario	Onshore	Turbine	Platform	None	HVDC	Pipeline	Onshore	Turbine	Platform
1									
2									
3									
4									

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.

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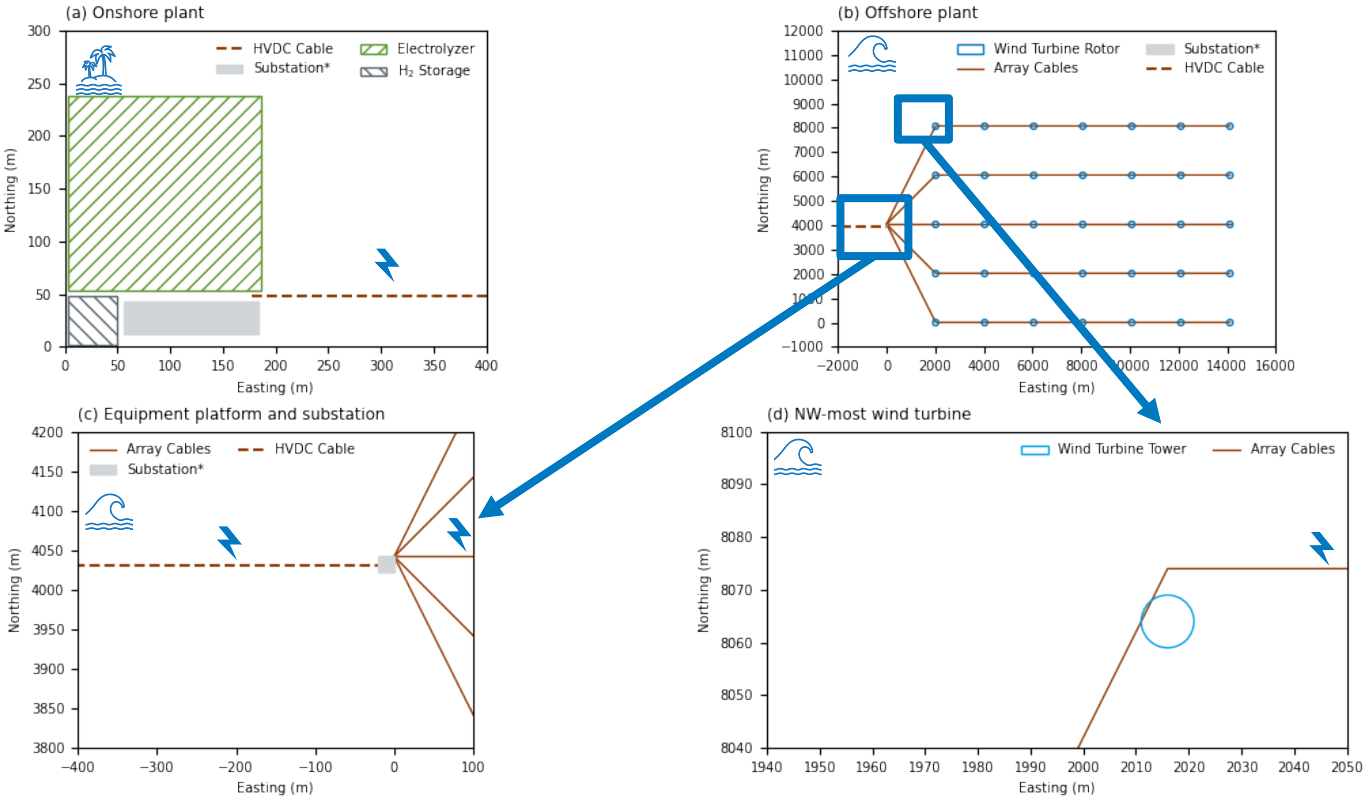

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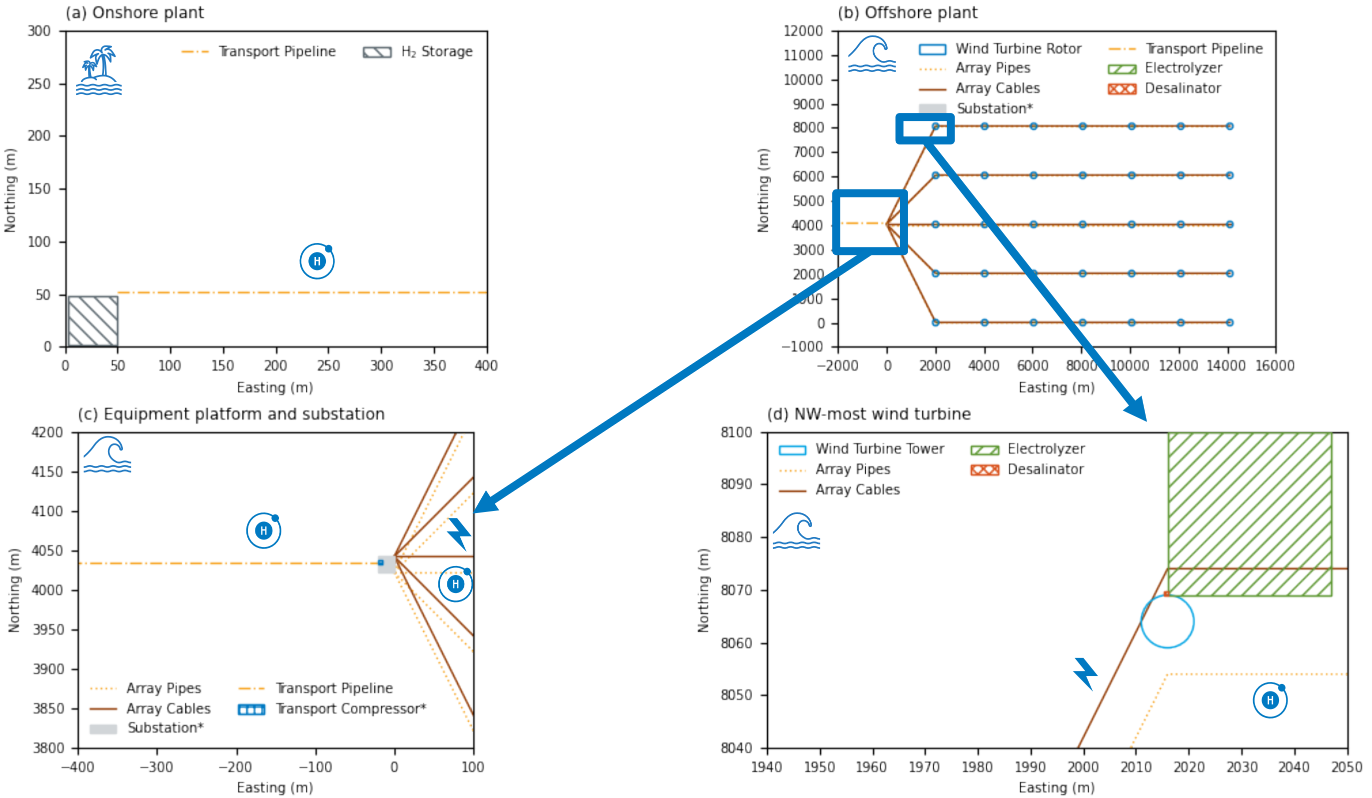

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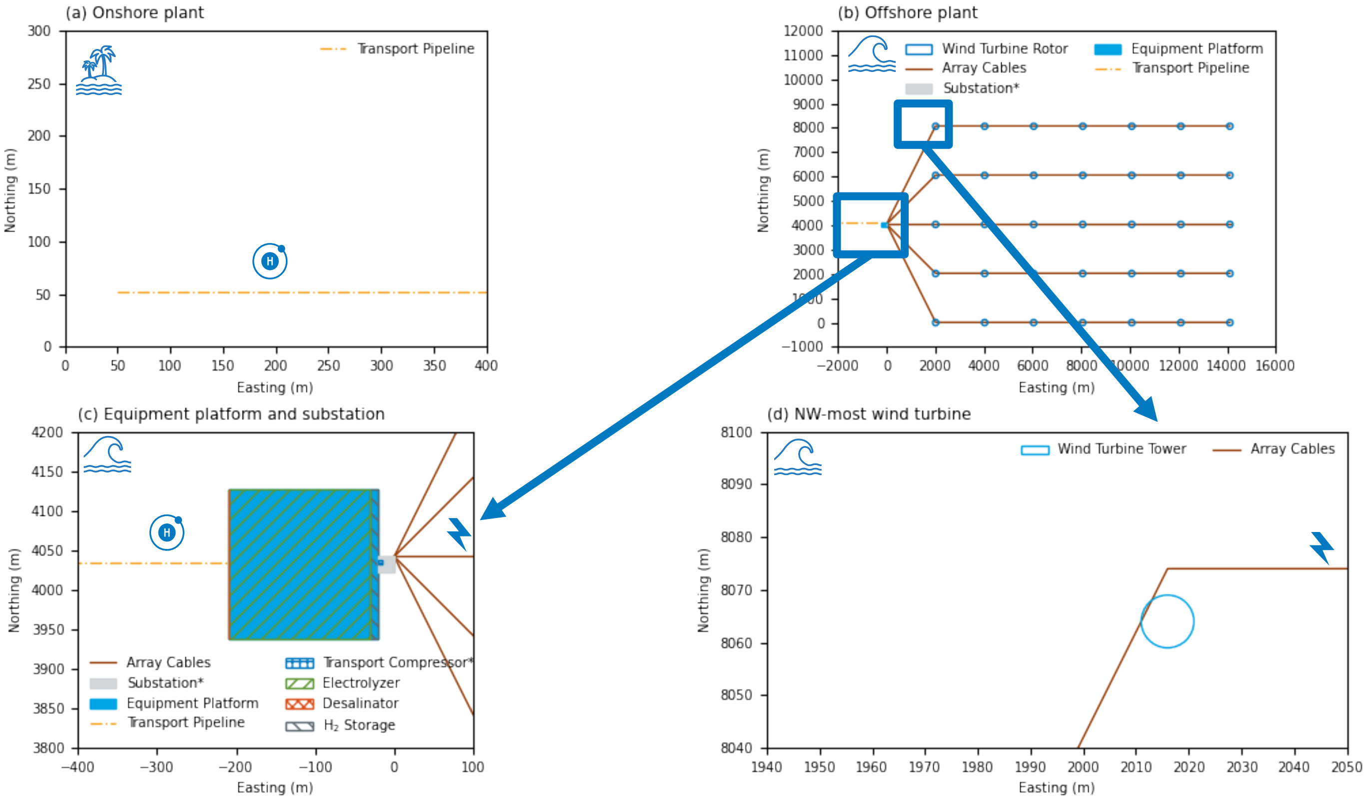

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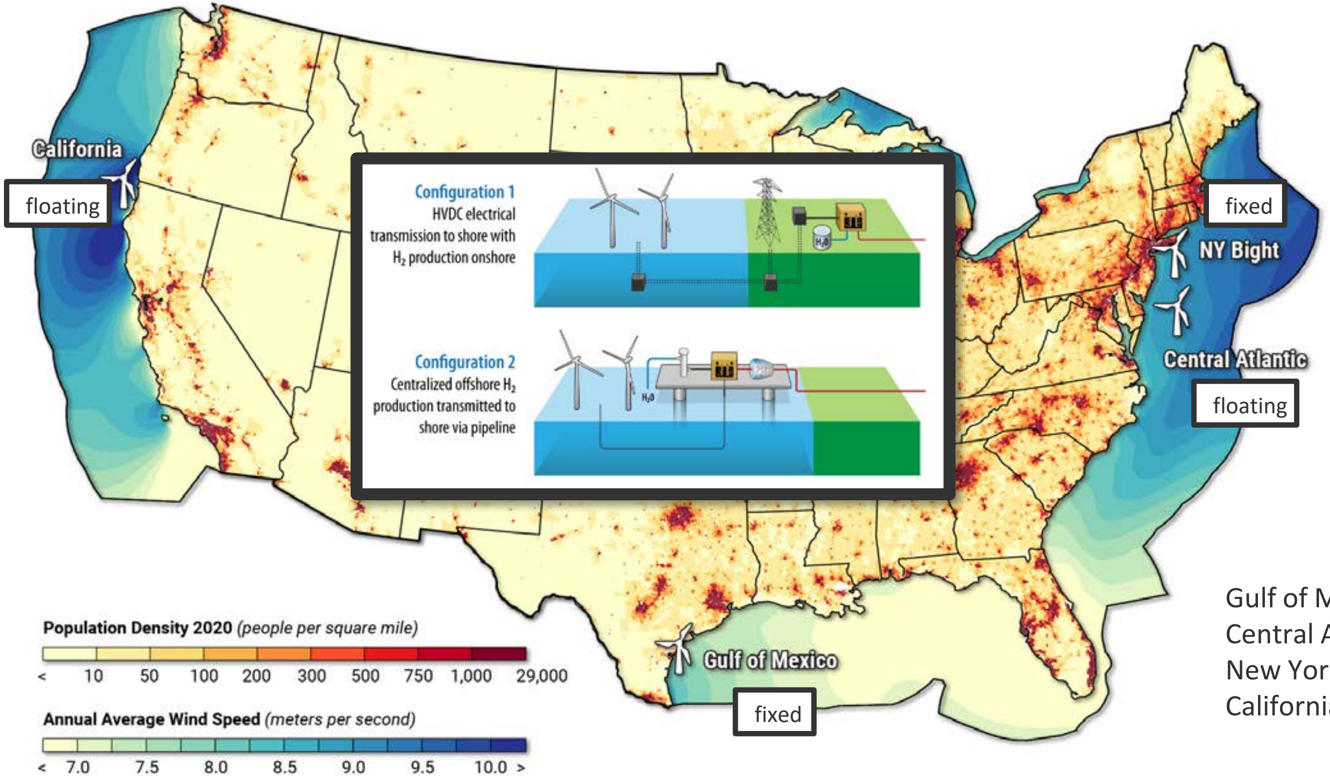
Where will offshore hybrid energy systems likely be built in the United States?

These are preliminary results for DOE funded by HFTO and WETO

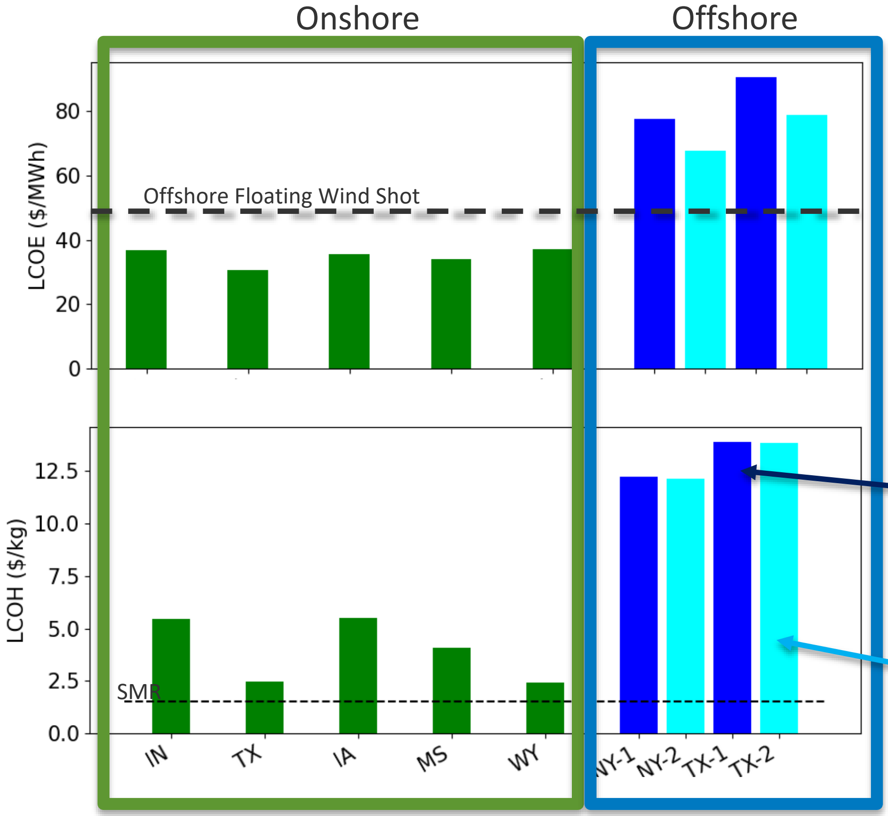


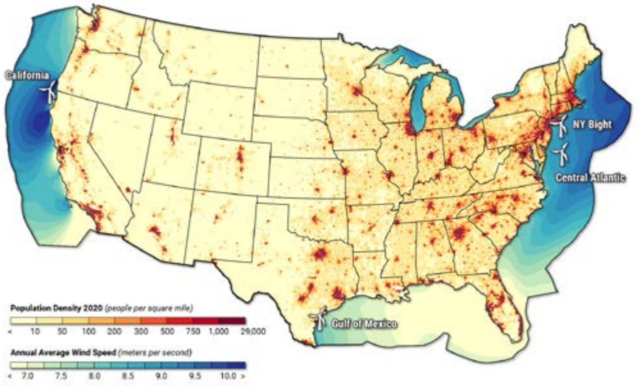
Gulf of Mexico = 85 km
Central Atlantic = 110 km
New York Bight = 80 km
California = 45 km

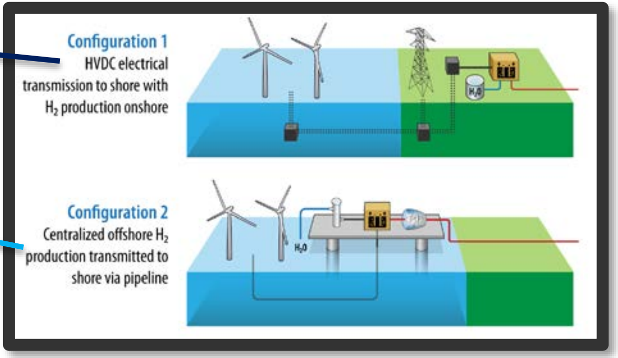
HVDC = high-voltage direct current

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

REopt

Renewable Energy Integration and Optimization

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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Questions

www.nrel.gov

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Offshore hybrid energy systems

- Dr. Jared J. Thomas
- jared.thomas@nrel.gov
- Dr. Jennifer King (Annoni)
- jennifer.king@nrel.gov

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Funding

Pertaining to the figure on slide 11

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