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Description:	Requestion for information 23-ERDD-01: RFI Deep-Water HVDC Substations for Offshore Wind - Carbon Trust response
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Organization:	The Carbon Trust
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RFI RESPONSE

HVDC substations for floating offshore wind

California Energy Commission

9 August 2024

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The Carbon Trust's mission is to
accelerate the move to a decarbonised future.

Prepared for:

California Energy Commission

Prepared by:

Robert Keast, Senior Manager, Carbon Trust

CARBON TRUST

California Energy Commission
Docket Unit, MS-4
Re: Docket No. 23-ERDD-01
715 P Street
Sacramento, CA 95814-5512

9 August 2024

Dear recipient,

RE: Requestion for information 23-ERDD-01: RFI Deep-Water HVDC Substations for Offshore Wind

Thank you for the request for information on deep-water HVDC substations for offshore wind. Please find our response below. If you have any questions, please let me know.

Yours faithfully

Robert Keast
Senior Manager, Offshore Wind
Carbon Trust

Question	Response from Carbon Trust
1. What information or analysis is needed to inform timely and cost-effective development and deployment of deep-water substations and associated offshore electrical infrastructure in existing and future California WEAs? How can publicly funded research and development (R&D) address technological, economic, and environmental uncertainties and better inform strategic technology advancement, feasibility, standards development, and component selection and procurement?	- Information and analysis of a lobal market overview will be key. This will include the key aspects: regulatory landscapes, technology standardisation, procurement strategies, and supply chain availability. ○ California needs to understand what progress has been made in other markets in their offshore HVDC network development. Globally, there are various approaches to the development of offshore networks, procurement and technology standardisation. California must review and understand these various approaches in order to benefit from them by selecting the best elements of each approach. Market leaders in bottom-fixed HVDC offshore networks are currently Netherlands and China. UK is taking a different approach to those countries and it is not going as well as in Netherlands and China. Floating HVDC networks are nascent, with countries like Japan, Norway and the UK leading. - International alignment ○ Coordinated, meshed offshore HVDC networks are nascent. International collaboration, alignment and standardisation will be essential to accelerate and de-risk the roll out of offshore HVDC networks. ○ California should therefore build on the global market analysis (above) and actively seek / lead the alignment between various US TSOs (California, West Coast, East Coast, Gulf) as well as coordination with other markets and international manufacturers in Europe and Japan. - Supply chain clarity and availability

Question	Response from Carbon Trust
	○ HVDC manufacturing capacity is currently limited. There are long lead times. To reduce this, California (and all other states / regions / countries) must give the supply chain as much clarity and stability as possible. This should be done through setting clear, internationally standardised technology specifications, and placing a sequential, steady, continuous stream of orders many years in advance. This will bring costs down for all, but will require strong coordination and leadership.
2. What key metrics or factors are required to inform systems integration of offshore wind components, deep-water substations, associated electrical infrastructure, communication networks, data collection, environmental monitoring, and ancillary services such as secondary generation, hydrogen production, and storage?	- Cost – DEVEX, CAPEX, OPEX - Supply chain availability for key components – domestic, US-wide, international - Technical Readiness Level - Commercial Readiness Level - Integration Readiness Level - For ancillary services only: “system strength” and “inertia” are two key metrics. However, the definition of these two terms for inverter based resources is not well understood and is the subject of ongoing research and debate internationally. Clarity on these metrics will be key before setting requirements on the HVDC network capability to provide ancillary services. - For hydrogen and storage: “long term energy storage” is the key metric, which must be well defined and understood.
3. What specific technical, economic, or other factors are crucial for understanding the viability and success of offshore electrical infrastructure technologies for FOSW development in California? What key performance characteristics and metrics are anticipated to be challenging for California's existing and future WEAs?	N/A

Question	Response from Carbon Trust
4. What environmental, ecosystem, health, and social impacts, including, both direct and indirect impacts, should be evaluated in deep-water substation and offshore electrical component design, procurement, and deployment for California's existing and future WEAs? How should knowledge about these impacts be used to better inform more sound design, procurement, and deployment of deep-water substation and offshore electrical components?	- Benthic ecology o Colonisation of deep-water electrical infrastructure and changes in species assemblages, reef effects, and associated ecological effects o EMF effects of underwater electrical infrastructure and associated ecological impacts - Installation effects o Consideration of installation procedures and effects, including underwater noise o Assessment of sensitivity of deep-water species to underwater noise emissions from installation - Social impacts o Consider effects to fisheries and potential benefits of deep-water solutions vs. traditional substations - Knowledge about impacts should be used to inform guidance around installation procedures, potential mitigation requirements, and design of components to deliver net-positive ecological effects
5. Are there other pressing needs or challenges relating to FOSW electrical infrastructure or transmission R&D that EPIC should consider?	Coordinated, meshed offshore HVDC networks must be designed to be black startable / restorable if they suffer a black out. This would be achieved currently by energising them from onshore sources (i.e. the onshore national grid). However, if OSW is due to become a backbone energy source, the OSW farms themselves must be able to black start the offshore HVDC network, and the offshore HVDC network must be capable of being black started from offshore sources. This is a reversal in thinking of current offshore network design. To achieve this, this capability must be built into the OSW farms and the offshore network at the time of construction (retrofitting this capability will not be possible).
6. What technical barriers will have the largest impact on development of deep-water HVDC substations in California? How could	- Water depths on west coast of the US are significantly deeper than elsewhere with commercial floating offshore wind leases. This is therefore unchartered territory for

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publicly funded R&D be most effectively applied to help increase timely and cost-effective deployment of new offshore deep-water HVDC substations in existing or future California WEAs?	the industry and although some learnings can be applied from oil and gas, there will need to be further de-risking in the following areas.
	- Dynamic cables
	  ○ Array cables at 66 kV and 132 kV.
	  ○ Export cables.
	- Mooring line failure mitigation
	  ○ There will likely be a number of mooring line failures on an array over the course of a year, and it is currently not known the number of mooring lines that will be required and their material for each asset. Inspection requirements and the need for a redundant mooring system will be key for a substation installation. Oil and Gas data can be used for failure rates but this needs to be managed in terms of how it is used.
	- Mooring line failure prevention
	  ○ Novel concepts like load reduction devices to reduce CAPEX and increase lifetime need to be proven.
	  ○ The overall system design needs to be CAPEX efficient, but balanced and managed against the failure rate and O&M requirement.
	- Quick connections/disconnections to floating turbines and substations.
	  ○ There are no (or very limited) learnings in this area from oil and gas – this is a new area for floating offshore wind that needs development.
	- Port size limitations
	  ○ HVDC substations are very large and only certain ports can host their construction, storage, and maintenance.
	  ○ There is limited capacity for ports in California, and there is competition for it with other industries. Lack of

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	current capacity is a major barrier in California - Meshed offshore networks are novel, with DC circuit breakers for meshed offshore networks being a key question mark (there are some operational in China, but nowhere else). DC circuit breakers are enormous and difficult to get offshore.
7. What key cost factors are critical to the timely deployment of deep-water HVDC substations and associated offshore electrical infrastructure that could be addressed through technology advancement or analysis?	- Supply chain availability ○ There is already an international shortage of supply chain for HVDC networks due to it being a nascent area ○ Addressing supply chain availability through international cooperation, standardisation, clarity and long-term, reliable, consistent procurement strategies will be key - Ports availability ○ HVDC substations are very large and only certain ports can host their construction, storage, and maintenance. ○ There is limited capacity for ports in California, and there is competition for it with other industries. Lack of current capacity is a major barrier in California - Risk ○ Floating offshore wind and floating HVDC substations are higher risk than bottom fixed, increasing financing costs. ○ Need to reduce risk, through international learning, cooperation, knowledge sharing, research, innovation and demonstration. - Ancillary services and stability ○ Prevention of electrical system instability, tripping events and black outs is critical. Nascent technologies exist to strengthen renewable-dominated electrical systems. However, these need

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	rapid development, understanding and roll out. The key thing is to ensure the offshore network is built to be stable and resilient. This may require more up-front cost, but will be significantly cheaper than having to fix problems in the future. - Vessel availability for installation o Current tonnage capacity is limited globally for floating wind installation across the subcomponent areas. Jones act compatibility will be a potential limiting factor (currently only 1 US flagged installation vessel)
8. What novel technologies or design concepts proposed for HVDC substations have been successfully demonstrated in a physical or simulated dynamic offshore environment and can provide economic benefits and costs savings for California ratepayers? Are there any specific substation platforms, mooring systems, HVDC electrical components, or other substation technologies that provide clear benefits and advantages for use in the existing or future California WEAs? How could R&D funding be most effectively applied to improve and optimize these technologies further to reduce cost and improve their technical suitability for California's WEAs?	- 132kV dynamic array cables o Using 132 kV as the WTG voltage (up to the HVDC substation) will enable larger turbines and lower the LCOE - Ancillary service-ready HVDC network o Specifying upfront all stability and resiliency requirements for the HVDC offshore network will ensure it is built correctly first time. Ensuring the HVDC-connected windfarms can provide services like inertia, system strength and black start to the onshore national grid will be critical. If the HVDC network is designed without this capability, the opportunity will be lost. This is a once in a generation decision: once the network is built, it is built, with limited opportunity for upgrading / retrofitting ancillary service capability). If not included up-front, ancillary services like inertia, system strength and black start will need to be provided from other sources, which will be pure

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	additional cost to rate payers in California. A key part of this will be the role of energy storage (BESS / Supercapacitors) and "grid forming" inverters in the HVDC offshore network and at the connection point to the onshore AC network.
	- DC circuit breakers
	  o Critical component for meshed HVDC networks. They are currently enormous (> football pitch) and therefore difficult to get offshore. Development work required.
	- Mooring technologies
	  o Safe and cost-effective mooring lines will be required. This may include load reduction devices or novel synthetic materials, in addition to traditional metal chain-link moorings from oil and gas.

9. What key technologies or capabilities are needed in-state, regionally, and nationally to facilitate supply chain, manufacturing, installation, and operations and maintenance needs for deep-water HVDC substations and associated electrical infrastructure? What are the environmental, ecosystem, health, and social impacts associated with these technologies or that should be evaluated for these technologies?	- Strong centralised planning authority informed by engineering reality (rather than economic philosophy) with clear responsibility for the development of the offshore HVDC network. - Supply chain capacity. - Port capacity. - Simulation engineers for network design.

10. What technologies or processes can monitor the condition and performance of deep-water HVDC substations and offshore electrical infrastructure? What are the current resolution capabilities of these technologies? Are these technologies or processes adequate for application in existing or future California WEAs? What are additional operations and maintenance needs for deep-water HVDC substations?	- Cable monitoring
	  o Traditional methods like Distributed Acoustic Sensing (DAS) and Distributed Thermal Sensing (DTS)
	  o Novel methods like Distributed Electric Sensing (DES)
	  o However, for all monitoring methods there are question marks exactly over how they

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	work and how to optimally use the data to prevent failures, improve O&M strategies, reduce costs and reduce insurance premiums, particularly for dynamic cables for floating wind. - Environmental monitoring o If California is planning to do post-installation monitoring of birds / bats, ensuring that turbines and substations have suitable capability to host monitoring equipment (sensors, cameras, etc.) is important. This should happen up-front in the design stage and before installation, e.g. by designing-in suitable platforms for sensing technologies and suitable data storage / transmission facilities. It is difficult to retrofit this capability and to install sensing equipment without this in-built capability due to warranties on the offshore equipment.
11. Are there any other questions or information the CEC should consider for research on deepwater HVDC substations for offshore wind that is not otherwise covered by the questions above?	N/A

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