Webinar: Interregional Transmission System Planning with HVDC	
Question	**Answer**
If interregional transmission projects were to be developed offshore, how do the regulatory barriers differ from onshore? Would the development timeline differ?	Offshore permitting is often easier and more cost-effective than building new greenfield onshore transmission. There may be unique low-cost opportunity to create interregional offshore transmission by connecting neighboring offshore wind farms delivering to different market areas. But low-cost interregional transimssion expansion opportunities will also exist onshore (e.g., by upgrading aging existing interregional lines or increasing the interregional capability of the existing system through grid-enhancing technologies)
How does the current long lead times imposed by limited number of OEMs affect the economics of transmission planning? the vendors offer long lead times now	The HVDC supply chain currently is more bottlenecked that the supply chain for most AC grid technologies. Some of the European grid operators have addressed this challenge by pre-ordering the HVDC they expect to need over the next decade. The rapid growth of HVDC technology is already motivating existing OEMs to increase their manufacturing capabilities and is attracting new OEM into the market.
What are the top technical risks from a technology, capex and opex basis for HVDC implementation?	Significant experience with HVDC design, procurement, and grid integration has been gained by HVDC suppliers and European grid operators to reduce these risks to the point where they are no longer preventing them from embracing the technology. U.S. transmission developers and grid operators will be able to take advantage of that experience and learn how to use the technology in planning, project development, and operational settings.
Can merchant HVDC owners exploit the multi benefits through different market products? do they exist now?	Some HVDC capabilities can be monetized in RTO markets, particularly if market optimization of merchant lines is offered through mechanisms such as CAISO's Subscriber PTO framework. Directly interconnected generators will typically be able to participate in the market services offered in the destination market. But most essential reliability services, such as reactive power, system dampening, or run-back schemes to mitigate AC contingencies are not compensated by markets, so could be monitized only through bilateral agreements to system operators.
What are the chances that HVDC transmission may become obsolete in the future when generation and load change location in the future since it is a direct link?	If an HVDC link is solely used as a gen tie, it's usefulness will be tied to the generation facilities, most of which will be repowered at the end of their economic life. But most HVDC merchant lines proposed in the U.S. will ultimately interconnected to the AC grid at both ends. We are not aware of any examples of such transmission lines becoming obsolete. If anything, the value of transmission capability is increasing over time.

Why are project developers converting solar/wind energy to hydrogen and then to Ammonia for exporting energy vs using intercontinental HVDC to export energy?	If there is insufficient local demand for electricity exists or electricity markets are very distant, converting the generation to hydrogen may be a more attractive business opportunity. In addition, because demands for green hydrogen/amonia are growing, some renewable generation is being built solely for that purpose.
Would you be able to put some of the most important technical benefits of HVDC in more plain language that a policymaker would better understand?	lower cost for high capacity, long distance transmission; uses less space and can be undergrounded and used in submarine applications more easily; can be designed to benefit the existing grid by being fully controllable (like adding traffic lights to city streets). Please see the executive summary of our report: https://www.brattle.com/insights-events/publications/brattle-consultants-highlight-the-operational-and-market-benefits-of-hvdc-transmission-to-system-operators-in-new-report/
Hi, are regions in US power grid are completely isolated or there is some weak existing ac interconnection between regions? which voltage levels are these?	See Chapter 2 of https://www.ferc.gov/media/energy-primer-handbook-energy-market-basics and https://jasondoering.substack.com/p/the-grids-org-chart
What about the issue with managing HVDC faults? will this cause stress on the AC sides ?	Faults on HVDC lines can now be managed better than faults on AC lines. Please see discussion in case study No. 9 and myths Nos. 7 and 9 (or search for "fault") in https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf
Wouldn't it be cheaper to build next generation nuclear at load than this plan?	In some cases it may be, but in many cases low-cost resources delivered even over long distances are more cost effective. Importantly, interregional transmission isn't all about delivering distant resources, but about building a more resilient grid that can diversify generating resources over geographic areas that exceed the size of large weather systems.
Wasn't the Plains and Eastern Clean Line cancelled years ago? Why is it on this map?	The rights to the proposed line (including rights of way) were aquired by another developer. Note, though, that the map is only showing proposed lines, recognizing that only some of the the proposed lines will ultimately be realized.
In your cost comparison, does it include cost of converter station vs switching or step down substation for AC?	Yes. See link to MISO analysis. The main reason why the $/mile is declining for HVDC lines is that converter station costs decrease on a $/mile basis.
What about considering HVDC embedded into AC system Vs radial HVDC network (giga grid concept) within US (for example Offshore HVDC network)?	These concepts are being considered. See for example the DOE's Atlantic Offshore Wind Transmision Study (AOSWTS) or DOE's National Transmission Study (NTS). Embedded HVDC lines already exist (e.g., in CAISO, Alberta, and MISO) and new ones (such as in NY) are added to the grid.

For maximizing the utilization of interconnectors will require multi market participants in RTOs should be able to trade. Is this a barrier in US RTO Markets?	There are seams-related barriers to trade, particularly in 5-minute real-time markets that are too volatile for bilateral transactions. As a result many interties between markets currently are poorly utilized. Optimization of interregional transmission is, however, already achieved by the energy imbalance markets in the western U.S. and "intertie optimization" has been recommended to address the current inefficiences between other regional markets in North America. See: https://www.brattle.com/insights-events/publications/brattle-consultants-discuss-the-need-for-intertie-optimization-in-new-report/
What is DOE/Government doing to breakdown the regulatory barriers to build long transmission lines?	The U.S. DOE has numerous initiative supporting the development of HVDC technology, supply chain, planning, and development of transmission projects. See, for example, https://www.energy.gov/oe/hvdc-cost-reduction-core-initiative
Can you elaborate on what is VSC technology?	Please see Chapter 2 in: https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf
How would buried HVDC on existing linear rights-of-way, such as highway corridors, speed up permitting? Any cost-benefit study for that?	The SOO Green project is proposing to do that with rail corridors and DOE has offered support with highway rights of way. Undergrounding HVDC is less expensive than undergrounding HVAC and can go long distances without reactive compensation and high losses, but underground HVDC is still significantly more expensive than overhead HVDC. Permitting advantages of underground are substantial, however, as the German HVDC cable projects demonstrate as well. See case study No. 1 in: https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf
RTO's do need Multi value Benefit to Cost ratio indices to assess the value of competitive transmission planning options? is there any move on this?	At least 90% of US transmission is planned solely to address reliability needs, with a preference for less expensive but reliable solutions. No benefit-cost analyses are conducted for these projects that would consider "values" (such as congestion relief) beyond addressing the identified reliability need. However, significant experience with multi-value planning processes already exists in North America, Europe, and Australia, as we summarized in Section 4 of our report: https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf
Could you please elaborate on blackout capability of VSC HVDC	For blackstart and system restoration capabilities of HVDC lines, see case studies Nos. 2 and 14 and myth No.10 in https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf
What are the power / energy losses while transporting long distance, especially intercontinental?	For example, the annual losses of the 400kV, 1000 MW, 150km Nemo-Link were 2.4% during its first year of operation. HVDC losses consist of converter losses (0.7% per converter) and line losses. Even when using the same conductors as HVAC lines, DC line losses are lower because the DC current is able to utilize the conductor more fully (no skin effect).

Why EU is more ambitious in planing Multi terminal HVDC and offshore wind energy that the US?	For the most part, Europe is more serious about reducing fossil fuel consumption. Fuel costs are also higher. Since Europe is surrounding large bodies of water (such as the North Sea), many "interregional" transmission projects are submarine HVDC links by necessity. With offshore wind generation located in the same bodies of water
Lower customer costs are just part of the discussion, need to also look at what are the benefits to my region?	Most "transmission benefits" that can be monetized are avoided costs or reduced costs in the rest of the grid (generation dispatch, generation investments, avoided cost of refurbishing aging facilities, avoided smaller reliabilty projects) that lower customer costs. These benefits can be quantified for each region and cost allocation can be structure such that each region sees net benefits that reduced customer costs (or increase reliability).
Does CAISO co-optimize generation/tranmission dispatch, or modify network model used to calculate network constraints between security constrained ED iters?	The CAISO market engine co-optimizes the dispatch of generation and controllable transmission facilities (HVDC lines and phase shifters) subject to constraints on the free-flowing AC grid.
We have ISO's are proposing larger increases in resource requirements as high as 45%. They give little credit for imports, how should HVDC be used to help	ISO need to recognize how interregional transmission capability (even if not designated to the import of specific resources) can reduce region-internal resource requirements. Once they recognize these benefits, HVDC can be more valuable because power flows can be controlled instantaneously (e.g., to compensate for AC line contingencies).
Labor and construction dollars are spent in someone else's area?	The question is unclear. Jobs and construction dollars spent may be one of the considerations for benefits that can support certain cost allocations. Cost allocations and shared project ownership may justify how labor and construction dollars are spent in different regions.