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Power System Net-Zero Emissions by 2050
How can we get there?

The following are reflections and opinions based on published information. A synopsis of latest news items related to Net-Zero Emissions is provided as an introduction. The intent of this paper is to foster discussions to help energy administrations to achieve proper planning regarding the above goal. It is hoped that this paper will also provide the opportunity for knowledge transfer among interested parties. Through knowledge transfer, parties can learn from each other.

1. Latest News Items

Natural Resources Minister Seamus O'Regan said recently that Canada will join the U.S. in establishing a platform for oil and gas producing countries to figure out how the sector can support implementing the Paris agreement on climate change and achieving net-zero emissions by 2050. Dubbed the Net-Zero Producers Forum, it is intended to develop emission reduction strategies and would include Canada, Norway, Qatar, Saudi Arabia, and the U.S., collectively accounting for about 40% of global oil and gas production.

U.S. President Joe Biden announced on Thursday 22 April, ahead of an Earth Day climate summit with other world leaders, that the United States will work to cut economy-wide greenhouse gas emissions 50-52% by 2030 relative to 2005 levels. The administration is backing efforts to require the U.S. grid to get 80% of its power from emissions-free sources by 2030 and to get to net zero carbon emissions in the grid by 2035[1].

S&P Global said utilities have a "relatively clear path to decarbonization," through renewables and storage, and warned there are risks to the global economy should efforts to address climate risks fail.

[1] EXCLUSIVE White House backs 2030 milestone on path to net zero grid | Reuters

Sen. Martin Heinrich, D-N.M., and Rep. Sean Casten, D-Ill., plan[2] to reintroduce a bill Tuesday that would direct the Federal Energy Regulatory Commission (FERC) to tackle interregional transmission planning.

Casten said FERC seems to be broadly headed in the right direction under Glick's leadership, but that "friendly pressure" from Congress could not hurt. One political barrier Democrats could face in examining transmission siting is how to simultaneously heighten regulatory pressure on the oil and gas sector while trying to build electric transmission as efficiently as possible, he said.

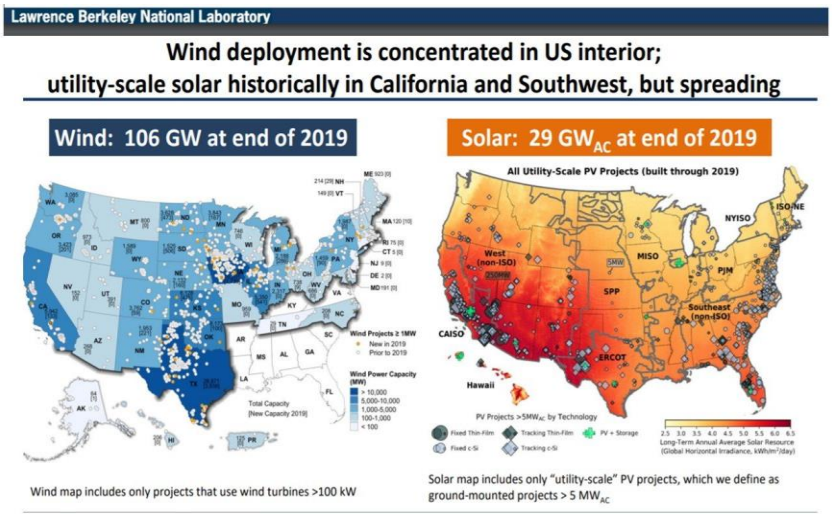
Under President Joe Biden's Build Back Better plan, a provision would establish a Grid Deployment Authority under the Department of Energy to better take advantage of existing rights-of-way and spur investment in new high-voltage transmission lines. But addressing rights-of-way may be complicated in its overlap with the oil and gas sector — a line Congress will have to toe, Casten noted.

We're having those conversations internally," he said. "And I do not know how they're going to resolve, frankly, because I think a lot of people who have very passionate views on the issue are viewing it either as an electric problem or an oil pipeline problem.

There's not a lot of folks who are viewing it more holistically," Casten added. "And I don't see that as a criticism. It is just there are not a lot of people who would have experience in both of those markets. But we need to talk through, and we need to figure it out. And I don't have an easy answer."

2. Strategic Options

As President Biden targets 100% clean electricity, strategies emerge[3] to reliably integrate rising renewables.



[2] Democrats tested over boosting transmission, not pipelines, as bill directs FERC to improve regional planning | Utility Dive

[3] As Biden targets 100% clean electricity, strategies emerge to reliably integrate rising renewables | Utility Dive

Combined, utility-scale wind and utility-scale solar were "58% of all new U.S. generation capacity over the past six years," said Research Scientist Mark Bolinger of DOE's Lawrence Berkeley National Laboratory (LBNL).

There were 106 GW of installed U.S. wind capacity by 2020, up from 11.5 GW in 2006, and there were 29 GW of installed utility-scale photovoltaic (PV) solar, up from 1.7 GW in 2012, LBNL reported. Solar is now competitive with wind, and "most developers are now active in both markets," Bolinger added.

"Since 2010, average installed costs in dollars per watt have fallen about 40% for wind and roughly 70% for PV," Bolinger said. As a result, PV has "rocketed to the top of grid interconnection queues" and 28% of queued PV at the end of 2019 "was paired with a battery," LBNL reported.

Most of the wind deployment is in the interior where the resource is strongest, he said. "Solar started in the desert Southwest but is spreading to other parts of the country, and with falling costs and increased pairing with storage, solar is expected to pass wind by 2023."

The Biden administration's focus on climate is likely to drive even more clean power integration because renewables are winning the market, according to a July 2020 report from the American Council on Renewable Energy (ACORE).

The demands of rapidly expanding clean power on "antiquated and inadequate" power system infrastructure have resulted in "big interconnection queues" that must be addressed, ACORE's Wetstone said. There is increasing recognition that "**transmission is a critically needed element to solving the climate problem.**"

The 734 GW of proposed projects in U.S. interconnection queues at the end of 2019 "is not a solar or wind issue, it's a renewables issue" because 90% of it was new wind, solar and storage, according to a January 2021 report from ACORE affiliate Macro Grid Initiative.

New transmission and distribution (T&D) infrastructure can reduce those queues by increasing the system's capacity while protecting reliability, the paper reported. And advanced technologies can add new grid efficiencies and operational flexibility to manage the greater capacity.

This need for new T&D infrastructure to integrate resource portfolios made up of more variable and distributed renewables is demonstrated in Brattle Group's January 19 New York Power Grid Study.

From the Brattle Group's study:

- Further studies will be required to more completely understand the generation and storage technology options that will be needed after 2035 to cost-effectively reduce emissions to zero by 2040, and the extent of how these technologies will impact grid investment needs. The Zero Emissions Study projects that emissions could be eliminated fully with approximately 20,000 MW of backstop thermal generation that is fueled with landfill gas, biogas, or other renewable natural gas. This option yields high congestion costs, which makes bulk-power transmission upgrades from upstate to downstate cost effective. At this point, however, the projected solution should be seen mostly as a placeholder until more clarity exists about available future technologies, such as green hydrogen and long-duration storage.

- As noted above, both Off-Shore Wind (OSW) and Zero Emissions Studies show that substantial amounts of battery storage on Long Island and in New York City will play a crucial role in integrating OSW generation. The studies place 3,000 MW (by 2030) and 15,500 MW (in 2040) of storage into specific locations on the grid. For example, by 2040 over 4,000 MW of storage may be needed in New York City and over 3,000 MW of storage may be needed on Long Island. If OSW injections into the Long Island system grow faster than projected in the studies, this amount of storage will need to be procured even more quickly.

- The study retains significant amounts of thermal generation capacity to meet locational reserve margins and to provide operational flexibility through 2040. To achieve zero emissions by 2040, these plants are assumed to be fueled by renewable natural gas (which is assumed to be significantly more expensive than fossil natural gas). However, significant uncertainty exists about how a zero emissions grid will evolve between 2030 and 2040. Load growth and electrification trends may differ significantly from study assumptions and possible future innovations (such as in vehicle-to-grid technologies) must be expected to change both needs and available solutions. Specific technologies, such as green hydrogen and long-duration Initial Report on the New York Power Grid Study 90 storage, may emerge as a more cost-effective substitute for the assumed renewable natural gas technology. If so, the projected 2040 production costs and relatively high wholesale energy market prices and associated congestion costs could be lower.

- Further studies will be needed to better understand future generation and storage technology options that may be available after 2035 to cost-effectively eliminate the residual emissions necessary to achieve a zero emissions grid by 2040 and the extent to which these technologies will impact grid investment and operational needs.

3. Analysis and Opinions

The above extracts from the Brattle Group study shows that about 20,000 MW of backstop generation would be required in 2040 to secure the grid from insufficient wind/solar or other equipment malfunctions. The study notes that about 4,000 MW of storage (batteries) need to be installed by 2040 in seven stations in the city of New York. Is there enough space and will the cost be acceptable, compared to other options, to make such large battery installations feasible? At present the World's largest battery (Gateway Energy Storage) at 250 MW is installed in San Diego[4]. Two or three of these large battery systems will need to be installed in each of these seven substations. Is this realistic? The study notes that future technologies, such as green hydrogen, may be available by then. Note that

[4] World's Largest—For Now—Battery Storage Project Online in California (powermag.com)

no mention is made of blue hydrogen which according to a Dutch report is about two to three times less expensive[5] than green hydrogen, provided there is natural gas of course. From the Dutch report:

> ***Green hydrogen production (emissions-free) will take time to reach scale*** *as it needs to piggy-back off wind and solar generation which itself must prioritise direct power to the grid. Blue hydrogen (made from natural gas where most emissions are captured and stored or reused) is* ***2-3 times cheaper than green*** *and has* ***proven technology that can be scaled up faster****.*
> The most important advantage of blue over green hydrogen, however, is the fact that **blue can provide the large hydrogen volumes that are needed already very soon**. The decision to build a CO2 transport and storage infrastructure has been taken and **plants for steam methane reforming can be built within a few years from now**. The technology is proven.
> The Netherlands intends to generate its renewable power, which is needed for the production of green hydrogen, **primarily from offshore windfarms**. Using a load factor of 5,000 hours per year we arrive at some 40 GW of installed capacity needed to produce 3.5 Mt of hydrogen per year. Note that this capacity should be exclusively dedicated to the production of hydrogen. **The idea that electrolysers could run on excess power only during periods when there is more wind than needed is not realistic**. The volume of hydrogen produced would be too small and the costs per unit too high because of the under-utilisation of electrolyser capacity.

In an appearance on the *Over A Barrel* podcast produced by the Canadian Heavy Oil Association, Armando Montes and Devin Lacey from GLJ, a top Canadian energy resource consulting firm, lay out the many comparative advantages Canada, and in particular energy powerhouse Alberta, have to become global leaders in the hydrogen economy[6].

> As a potentially very low-cost producer, Canada has the opportunity to emerge as a leading exporter, according to GLJ, which has developed a scorecard that ranks various aspects of a country's ability to develop a hydrogen economy. "Most countries are looking at it as a domestic solution to decarbonizing their energy mixes, whereas there's only a select few countries that have the high production scorecard opportunity to really be global players in the export market," said Lacey. On a global stage Canada is already regarded as a top 10 hydrogen market. "If we think big, we could lead our country into the business of exporting hydrogen to global markets," said Montes. "If we can start to make ourselves a real player early using blue hydrogen, which we can produce at world class inexpensive costs, then as green hydrogen progresses … we are already going to be intertwined at that point [with] hydrogen distribution potentially to the [United] States and other provinces.

Both Canada and the U.S. have a common goal to achieve net-zero emissions by 2050 and have agreed to cooperate on this. In order for the U.S. to achieve an emissions-free electricity sector by 2035 a practical, economic and efficient energy storage system has to be made available. A blue hydrogen

[5] The Netherlands: a Blue Hydrogen economy now will ease a transition to Green - Energy Post

[6] Canada poised to lead the blue hydrogen transition - JWN Energy

storage hub can be set up in Alberta using existing salt domes and/or depleted gas fields. The stored hydrogen can be converted to electrical power to replace renewables (wind/solar) when these are deficient, but also to supply capacity during peak demand thus reducing the need for generating reserves by the utilities. Because sending energy by wire is the cheapest form of transporting energy a North American Supergrid[7] should be established thus allowing blue hydrogen, and available Canadian hydro storage, to provide relatively inexpensive capacity.

To achieve the 2035 goal planning should start now.

For example, as a start an HVDC line could be build from the hydro generating station at Site C (BC) to Edmonton (Alb.) to the U.S. South West to transmit hydro/hydrogen power. This line could also be used to send solar power back up North to compensate for use of the hydro reservoir. European experience with their Trans-European Network has shown that such energy interchanges are worth doing, even with the HVDC line buried at a cost of over six times the cost of going overhead. In the U.S., an example of buried HVDC is the Cascade Renewable Transmission tie in Oregon which can transmit 1,100 MW of renewable power over 105 miles of +/-320 kV submarine cable (it is installed for a large part at the bottom of the Columbia river).

Clock is ticking, time to start planning. A bilateral Canada-U.S. Committee should be set up to start looking at a North American Supergrid.

Guy Van Uytven, P.Eng., FCSSE April 2021

[7] https://viengsoc.ca/2021/04/25/on-strengthening-north-american-electrical-energy-security-with-a-view-on-net-zero-emissions/