The Case for a BC to California Link

An Opinion Presentation by Guy Van Uytven, P.Eng., M. Eng., MBA, FCSSE
President Canadian Society of Senior Engineers
Associate Member of the Bowman Centre for Sustainable Energy
Class3 Member Western Electricity Coordinating Council

01/31/22

Fact

There is now a general agreement that man-made green-house gas emissions are causing a global temperature increase with resulting consequences of more severe storms, forest fires, desertification, arctic ice melting and population shifts.

One of the Goals

Limit global warming by reducing CO_2 emissions from power sector operations

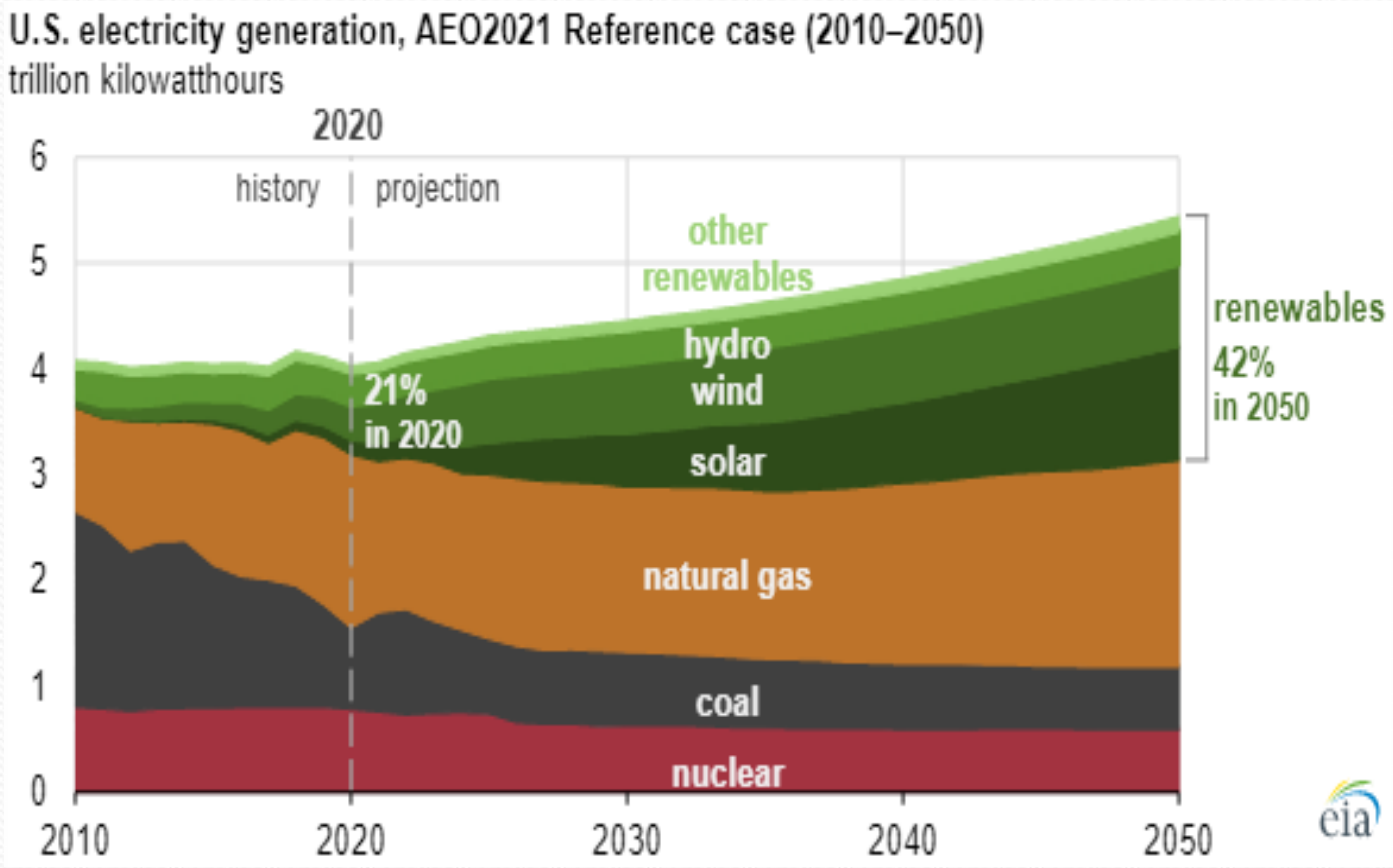
Commitments:

Canada: The Government of Canada is committed to moving to net-zero emissions by **2050**

United States: The Biden administration on September 8, 2021 released a blueprint showing how America could move toward producing almost half of its electricity from the sun by 2050 — a potentially big step toward fighting climate change but one that would require vast infrastructure investments and major enhancements to the electric grid.

The Challenge:

Solar and wind are interruptible renewable sources of energy.
They don't generate electricity if the sun doesn't shine or the wind doesn't blow.

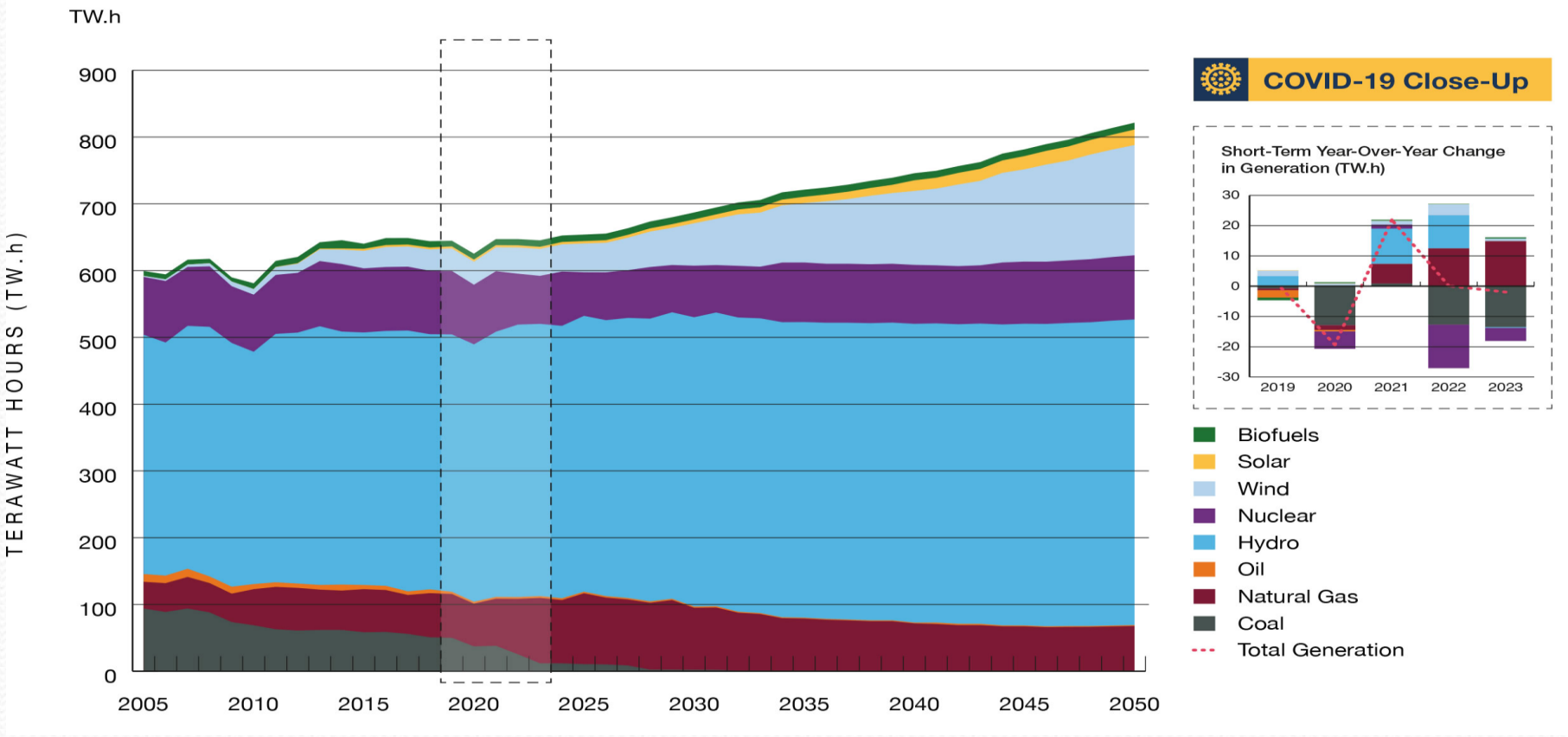


The U.S. Energy Information Administration (EIA) announced on Feb. 8, 2021 that it expected the share of renewables in the U.S. electricity generation mix to increase from 21% in 2020 to 42% in 2050.
Wind and solar generation are responsible for most of that growth.

President Biden wants to produce half of US electricity generation by solar by 2050. Present forecast is less than a quarter.

About 50% of electricity generation will still be from fossil fuels. As compared to today's 60%

The Canadian Forecast



There are many factors and uncertainties that will influence future trends.

Source: Canada Energy Regulator (CER)

System Planning is Changing

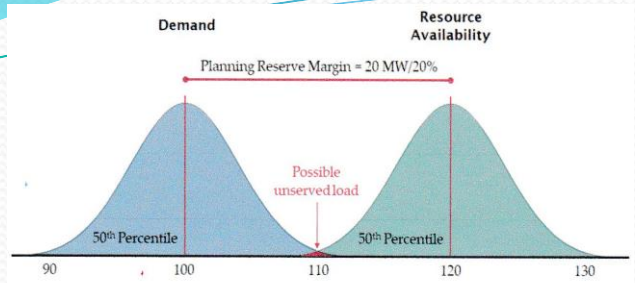


Figure 9: Example Demand and Resource Curves with 20% PRM

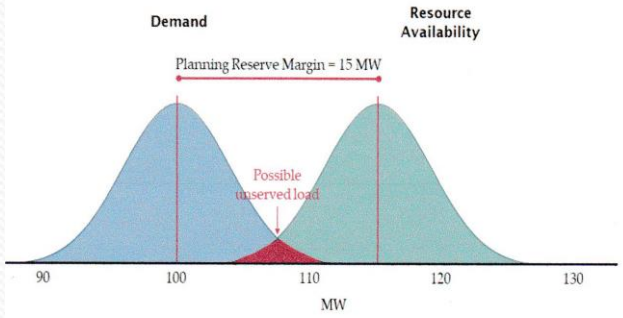


Figure 10: Example Demand and Resource Curves with 15% PRM

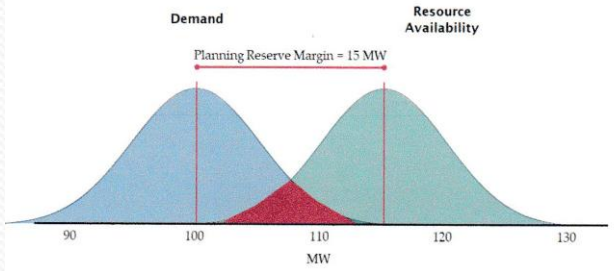


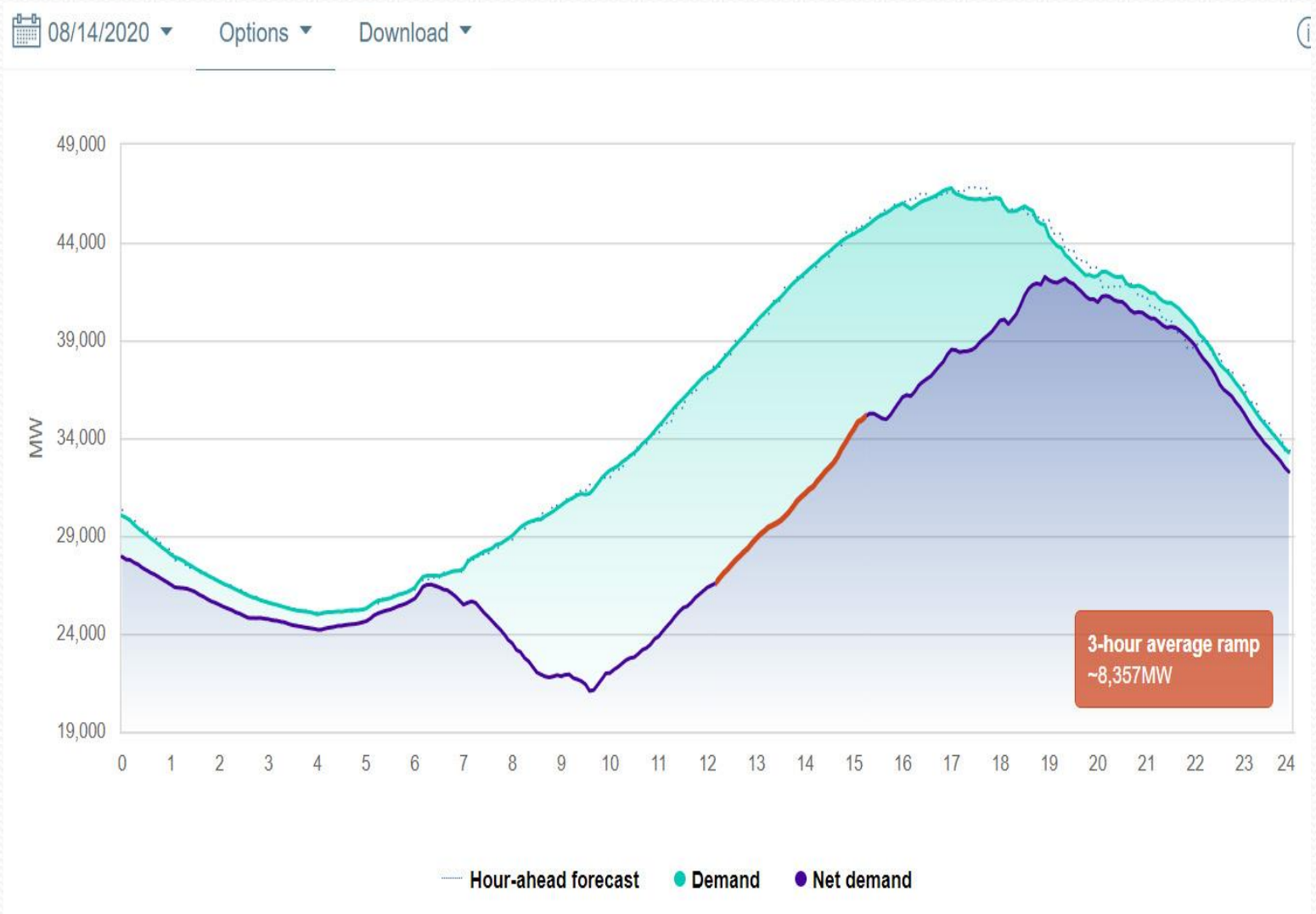
Figure 11: Expanded Demand and Resource Curves with Large Overlap

1. **Deterministic system**: Peak demand is forecasted for some future date. Required dependable generation resources are established with a suitable reserve margin. Traditionally, a 20% reserve margin would be expected to still produce a shortfall of resource capacity one day every ten years.

2. **Probabilistic system**: Demand and available resources are depicted as probability curves which have been defined historically at times when variable energy resources (wind/solar) were small compared to traditional resources (coal, hydro, nuclear). Possible unserved load is determined by the area where the two curves intersect. (Source: WECC WARA report).

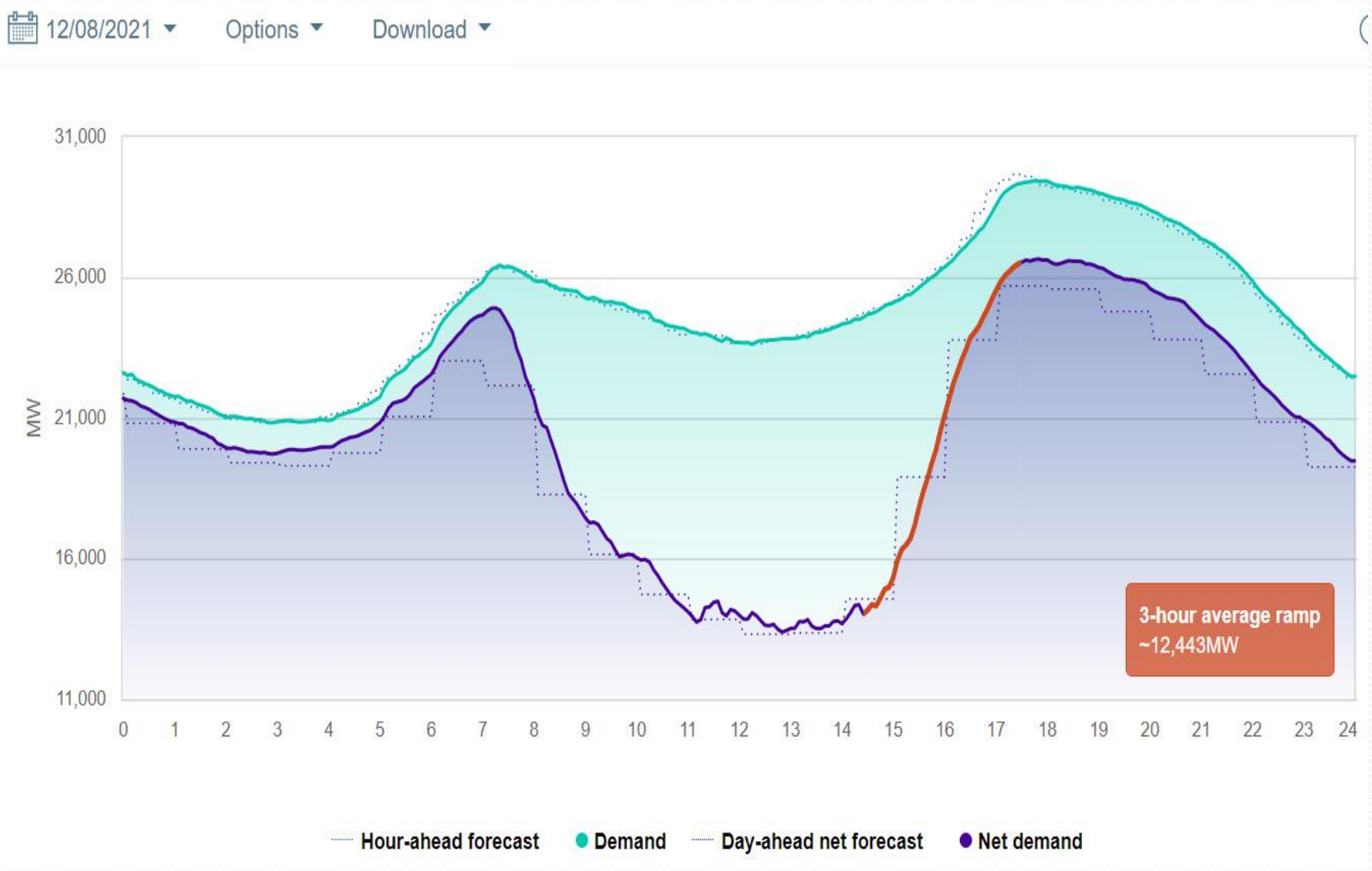
1. With time the shape of the demand curve is being influenced by the increasing amount of extreme weather events. The variability is shown by a widening of the curve.
2. Similarly, the shape of the resource curve is being influenced by the increasing amount of variable energy resources (VER) widening the resource curve. This means that for the same resource margin we now have greater possible unserved load.
3. Consequently, system planners should use a larger reserve margin and/or ensure that long-distance transmission links will exist to connect to regions where the weather effect or the reduction in VER are not happening at the same time.

CAISO: the Case of Disappearing Renewables



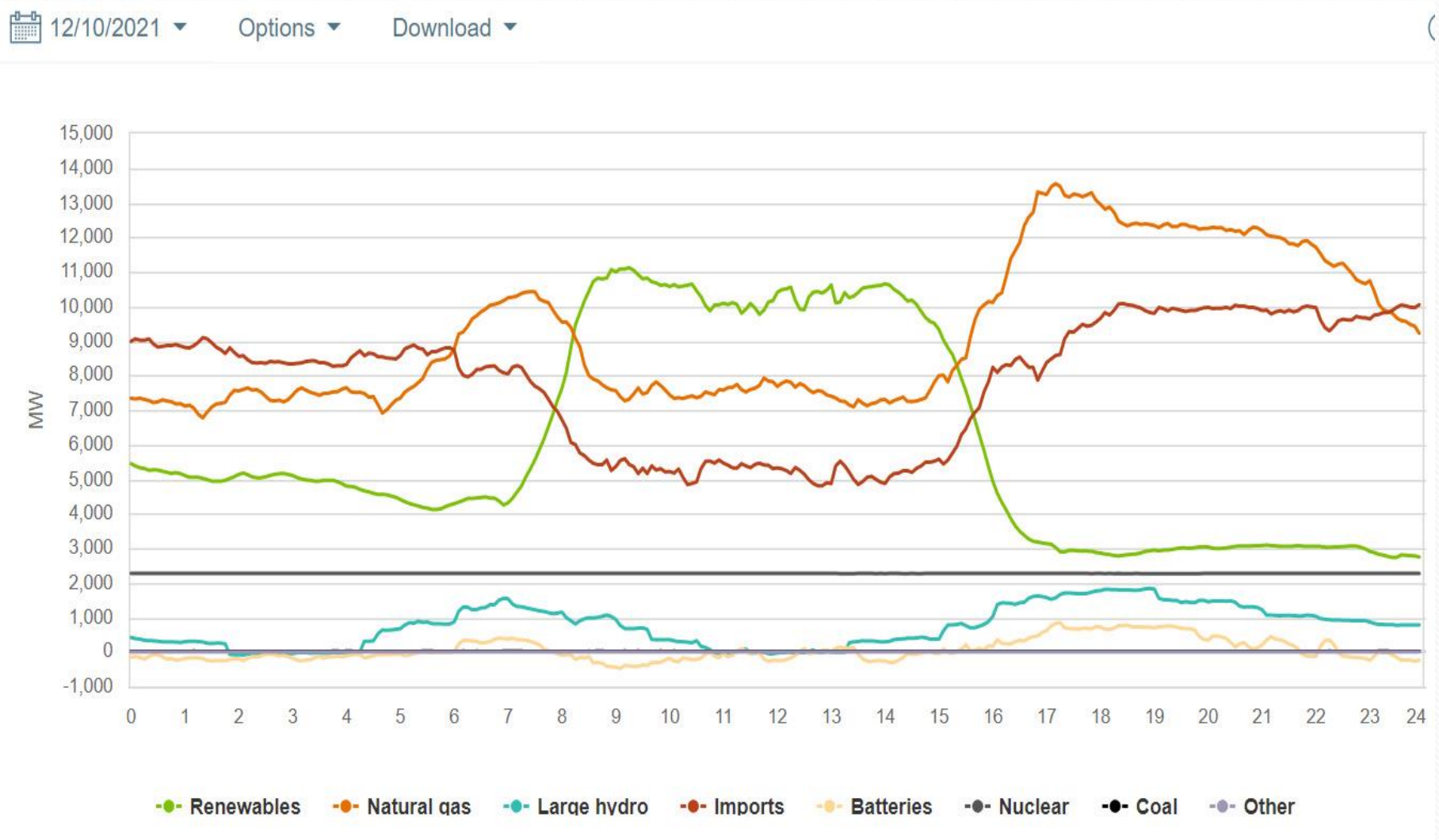
1. On 14/15 August 2020 forced outages in California were necessary to prevent the grid from collapsing (no sun, no wind).
2. Demand peaks in late afternoon, early evening (47,000 MW)
3. Net demand is demand less renewables (peaks at 42,000 MW). Only a 1,000 MW cushion after sun is down.
4. CAISO Final Report: The Final Analysis confirms there was no single root cause of the August outages, but rather, finds that the three major causal factors contributing to the outages were related to extreme weather conditions, resource adequacy and planning processes, and market practices.
5. Among the recommendations: collaboration and input from stakeholders within California and across the western United States. (WECC includes BC and Alberta).

The Problem when the Sun Disappears



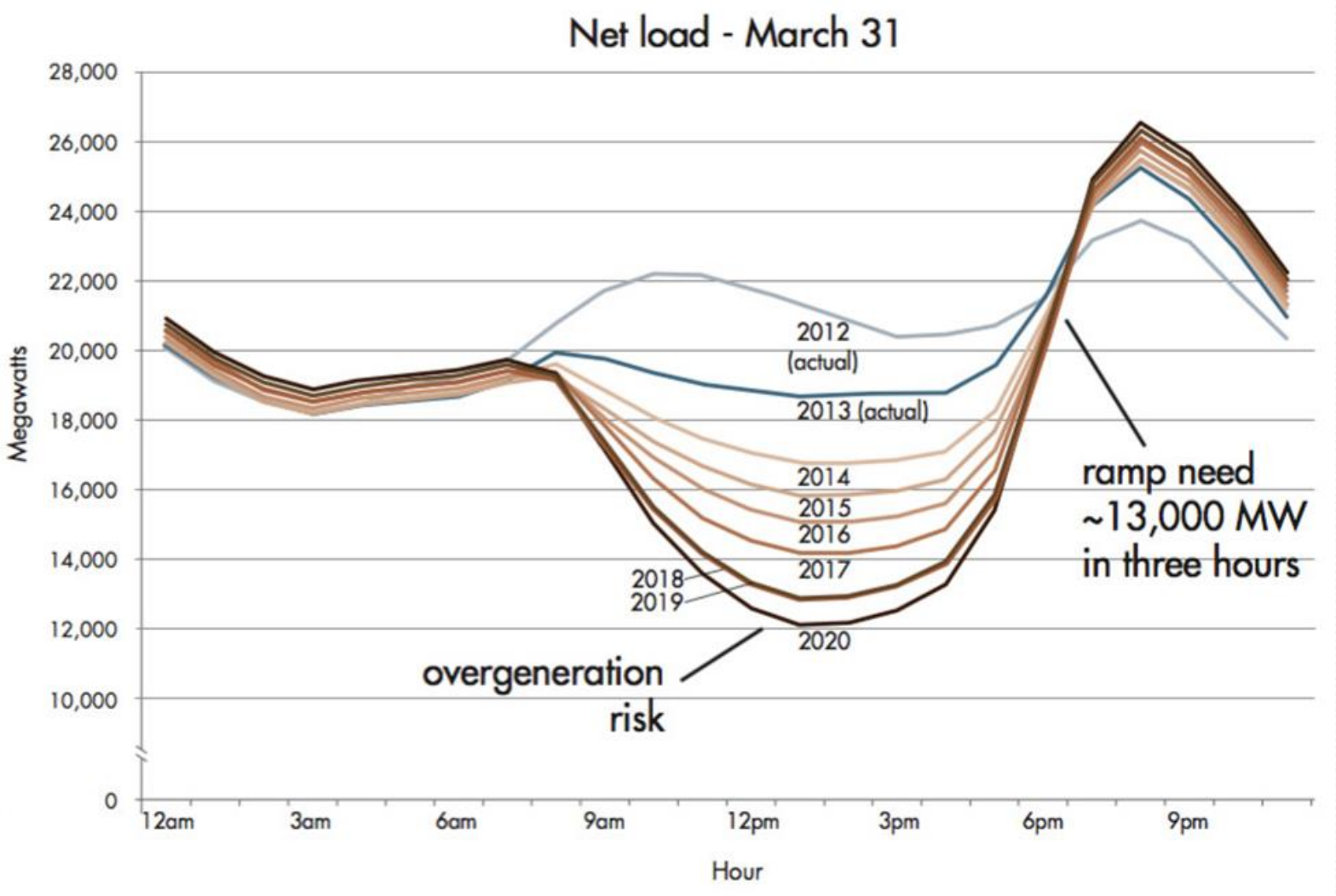
1. Winter demand is lower (30,000 MW) but presence of wind provided a 3,000 MW cushion)
2. When sun goes down gas generation needs to be quickly brought online (over 12,000 MW in a period of 3 hours)
3. Where does this 12,000 MW extra generation come from?

Present Generation Options



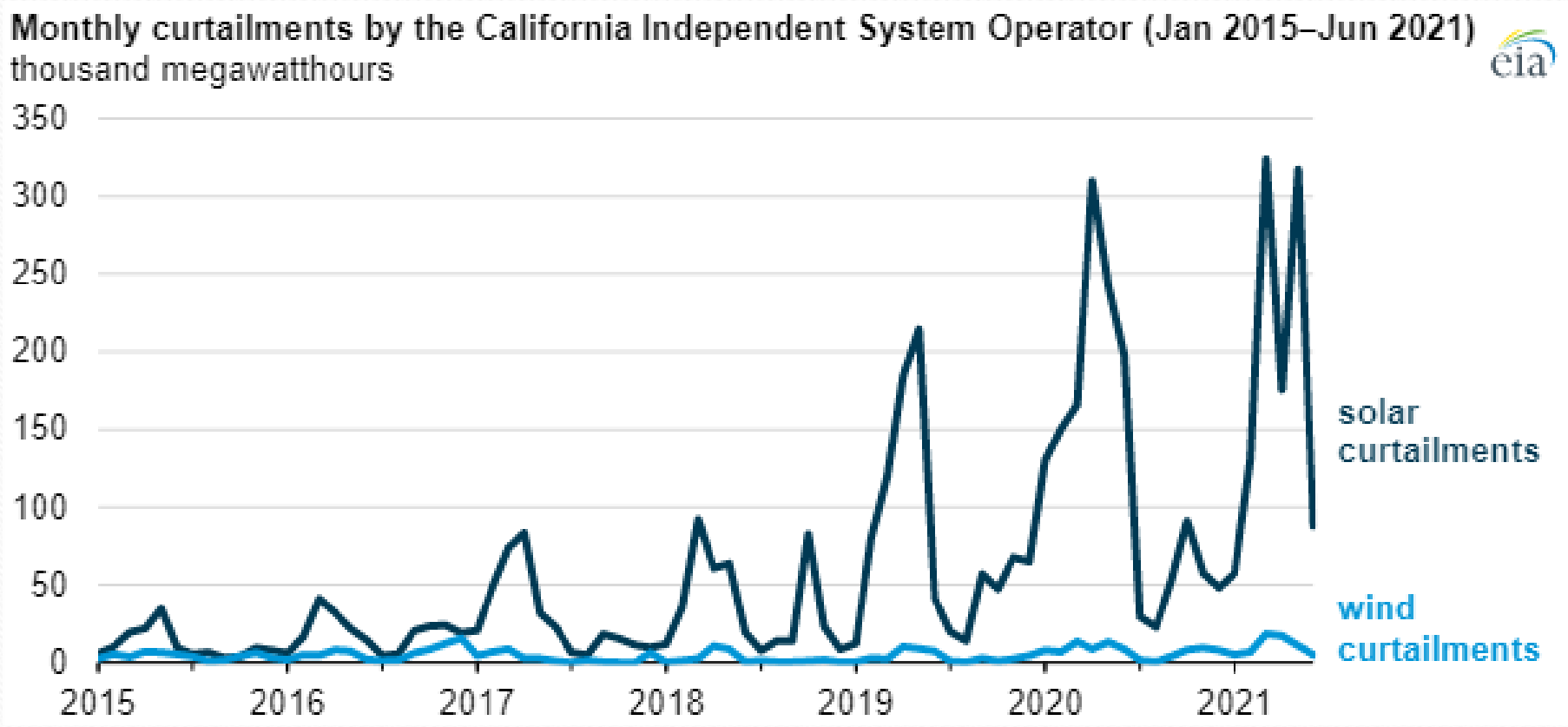
1. In winter after 4pm main generation options are gas peakers and imports (plus 6,000 MW gas and plus 5,000 MW imports)
2. Large hydro (in State) provides extra 1,000 MW
3. To replace the gas there is the option of battery energy system storage (BESS) and more imports

The California Duck Curve

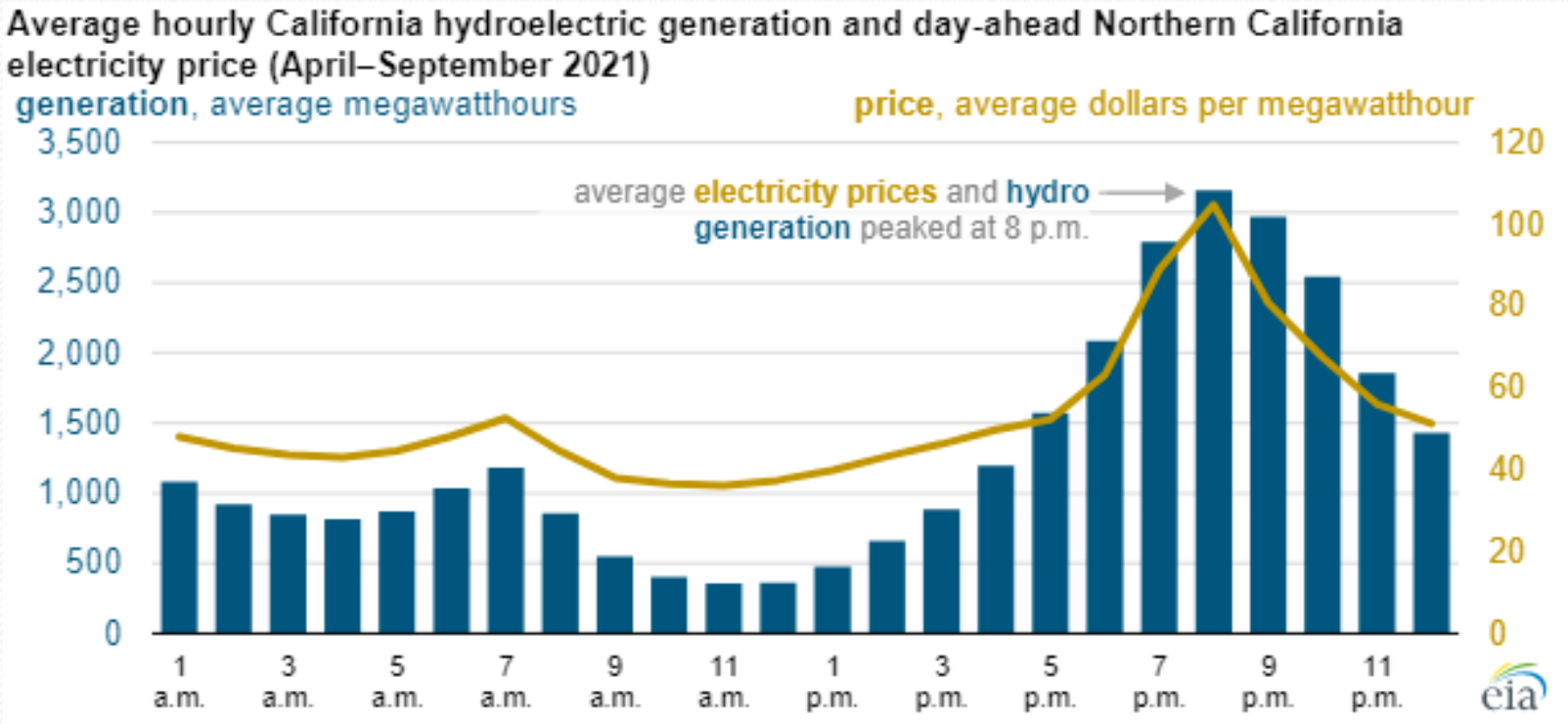


1. Developed in 2013 but recent analysis confirms that the future years shown are pretty close to reality
2. It shows the net load, actual load less renewables (solar and wind) during a spring day (31 March)
3. Effect of more and more rooftop generation
4. As the sun disappears generation needs to ramp up quickly with mostly gas fired plants which can ramp up quickly and increased imports if available
5. To reach net-zero emissions we will need the addition of massive renewables, massive storage and almost certainly more nuclear to reduce required storage capacity
6. The amount of storage can be reduced by increasing the amount of base load generation (nuclear)
7. This would mean more renewable curtailment, unless the extra renewable generation can be exported via a supergrid.

Too much Solar Generation?



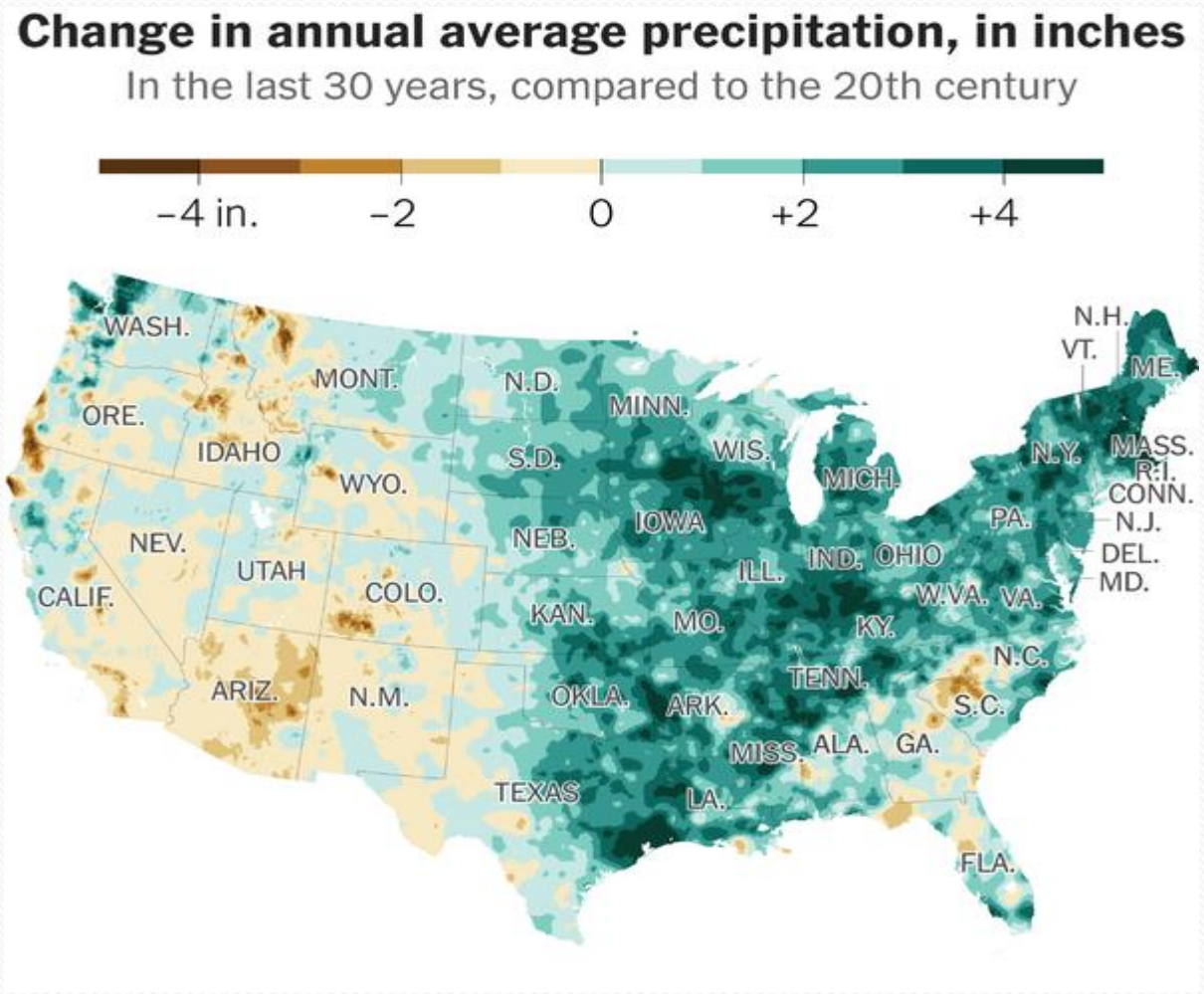
Effect on Price



When solar disappears bringing 13,000 MW of generation online in 3 hours has its effect on price.

The average electricity price increases from a low of 40 to a high of 100 $/MWh.

Effects of Global Warming



Source: NOAA's National Centers for Environmental Information

1. US Southwest can become a massive hub for solar energy supply but there will be a need for energy storage for when the sun doesn't shine.
2. BC is already a big hydro supplier. Rainfall established new records in the fall of 2021, Reservoirs are full.
3. BC supplies 2,000 MW to the SW through the existing HVDC Pacific Intertie This is a one-way energy transfer.
4. A Western HVDC link, with voltage source convertors (VSC) which would allow reciprocal energy exchange, could create a win-win situation.

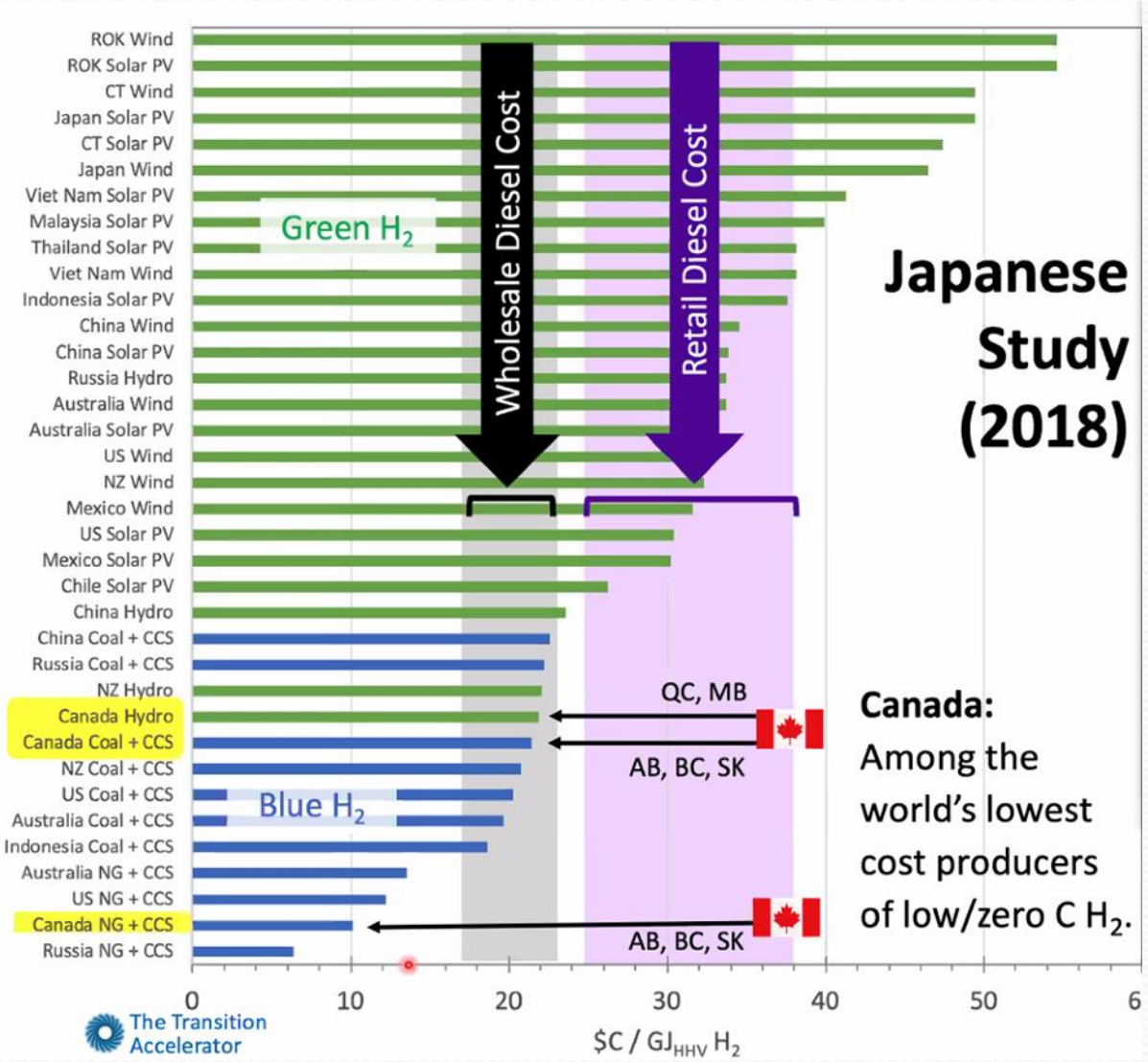
Options for Massive Energy Storage

Storage options	Comments
Hydro	Existing and potential hydro reservoirs in Canada can provide efficient and reliable energy security
Pumped storage	More expensive than hydro they can convert surplus energy into stored energy
Batteries (BESS)	A proven energy storage option. But questions remain whether massive storage can be achieved economically, whether duration would be adequate or whether needed ingredients will remain available
Hydrogen	The new kid on the block.(Blue, Green or Pink)

Canada: Among the World's Lowest cost producers of 'Blue' & 'Green' H_2

From fossil fuels (NG) coupled to carbon capture and storage (CCS)

From water electrolysis using very low C electricity (wind, PV, hydro, nuclear)



Adapted from Asia Pacific Energy Research Centre. 2018. Perspectives on H_2 in the APEC Region. (Figure 3.4)
https://aperc.ieej.or.jp/file/2018/9/12/Perspectives+on+Hydrogen+in+the+APEC+Region.pdf

Dr. David Layzell

The Case for a North American Supergrid

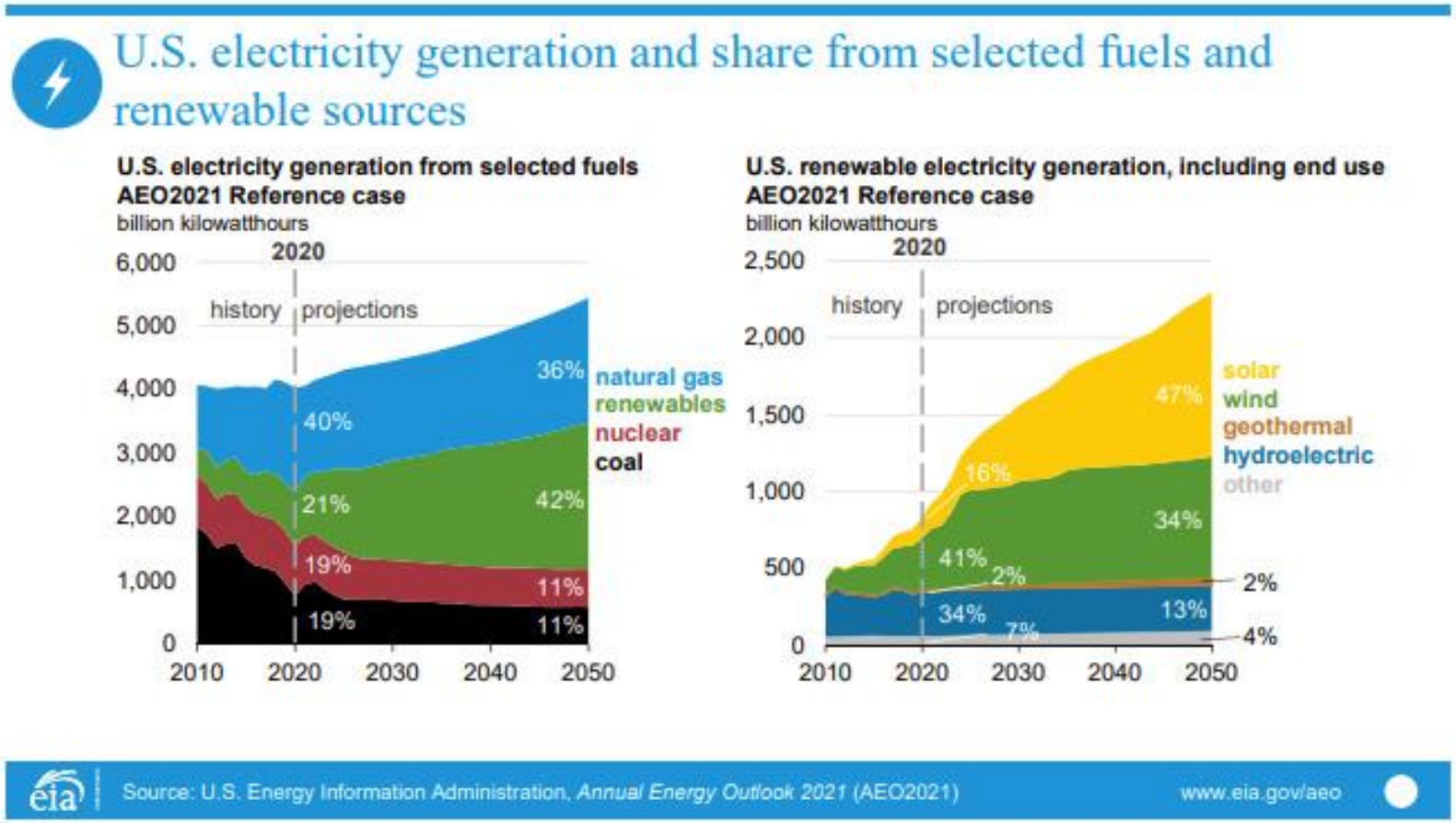
The White House made an announcement last April that underscored the Administration's commitment to accelerating the needed expansion and modernization of America's power infrastructure to build a more reliable electric grid. It set a target to create a "carbon pollution-free power sector by 2035". This was followed up in November by FERC creating a Federal-State Task Force on Electric Transmission with a strong emphasis on incorporating state perspectives into regional transmission planning

Variable energy resources (VERs) are expected to be the predominant new resources in all the Regional Transmission Operators (RTOs) and Independent System Operators(ISOs). VERs account for almost 90% of nameplate generation seeking interconnection to the transmission systems across the United States.

There are over 35 electric transmission interconnections between the Canadian and US power systems, forming a highly integrated grid. This integration is set to continue expanding, with multiple cross-border transmission projects currently in various stages of development.

With hydro and hydrogen resources North of the border and solar south of the border there is a strong case to be made for a North American Supergrid, instead of concentrating on independent national Canadian and national US grids.

GHG Emissions Challenges



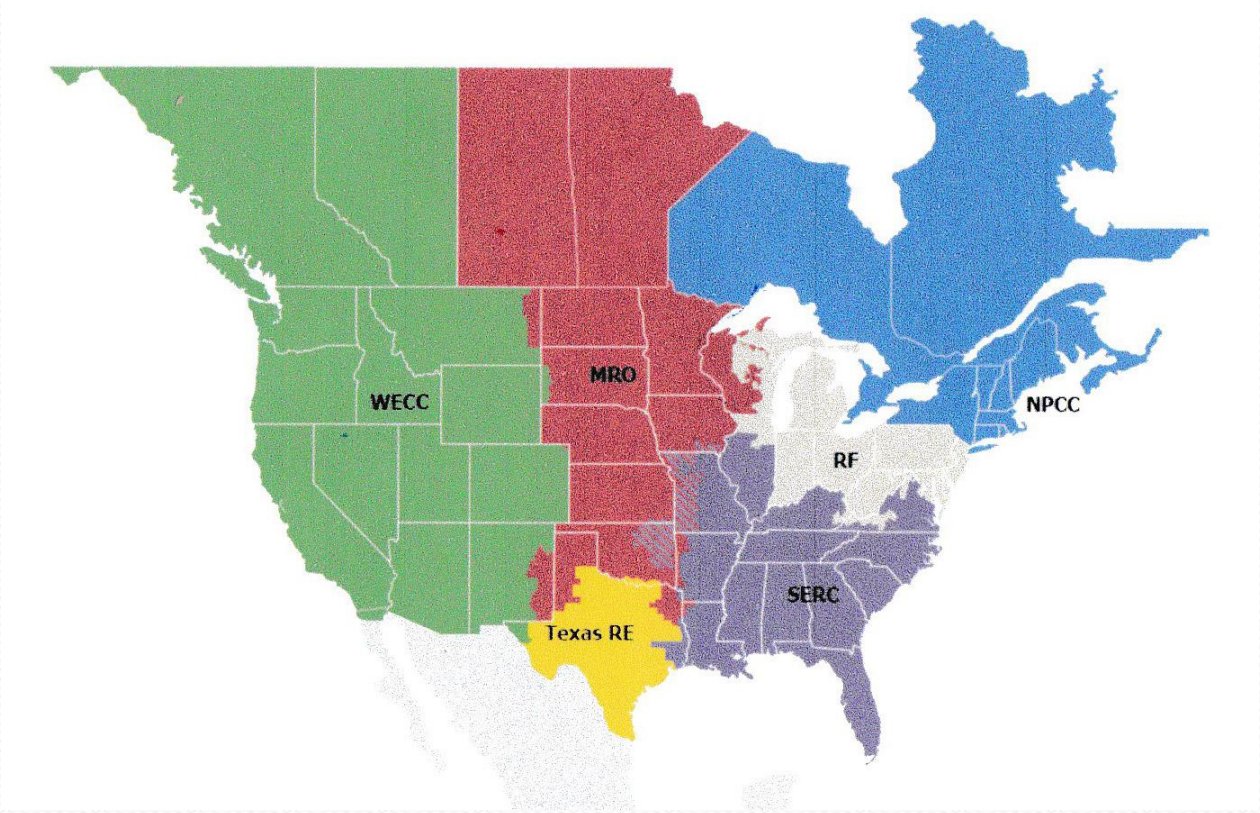
Renewables will be the largest generating source by 2030.

Long-distance East West transmission links will allow energy transfer across the continent taking advantage of the 3-hour solar time differential.

Peak demand in California occurs after 6pm when solar energy in the East will be of no help.

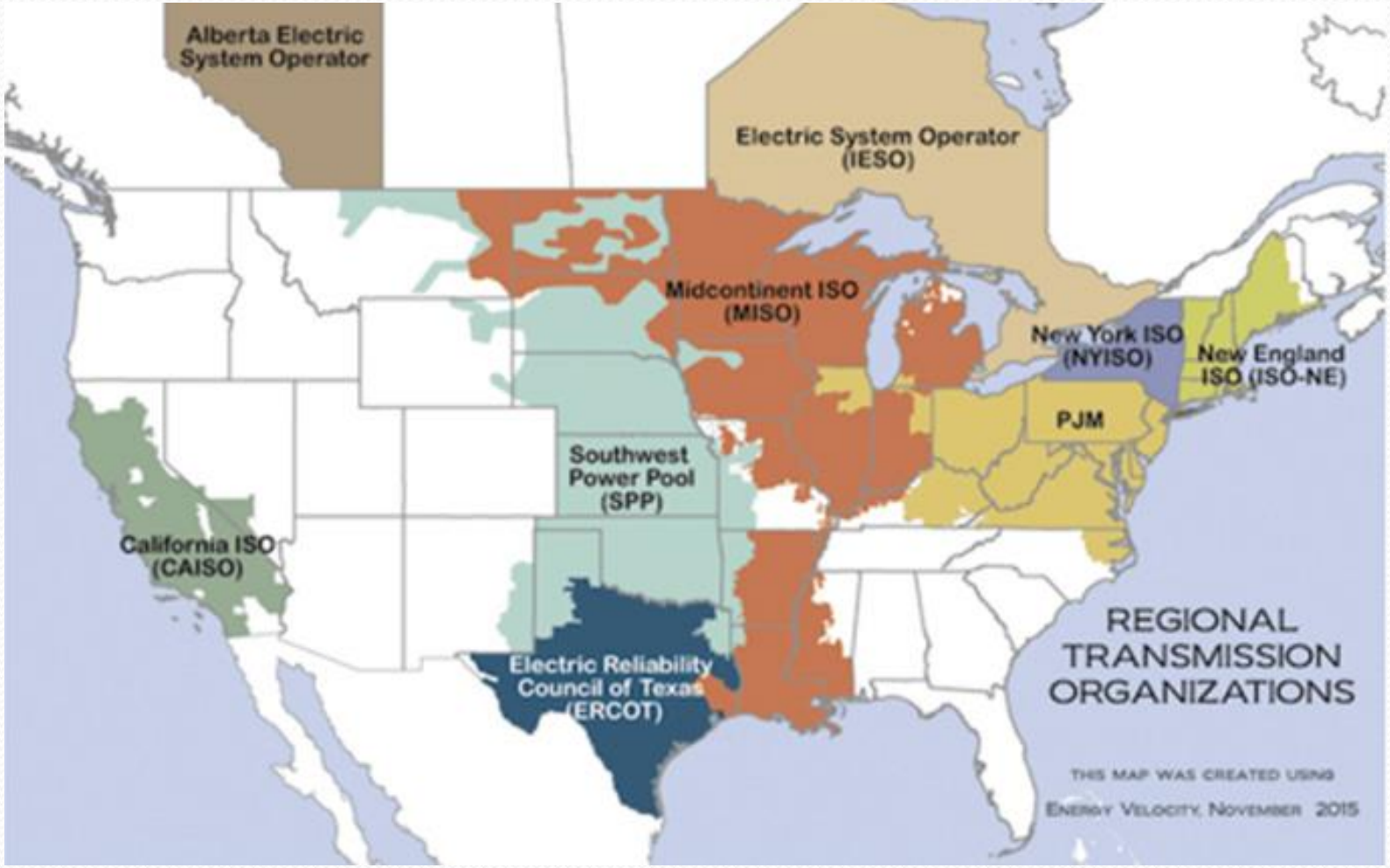
Hydro stored energy in BC, Manitoba and Quebec are huge energy batteries which can provide reliable energy at all times. These reservoirs could be refilled (recharged) and water use optimized by sending surplus solar or wind energy North.

Consider a new Strategic HVDC North<->South Link



1. The North American BPS is made up of six regional entities.
2. An MIT study concluded that it would be beneficial to have two-way energy interchange between Quebec's hydro and US East coast wind and solar. A similar concept makes sense for Western North America.
3. The challenge is big to get to net-zero emissions in the power sector by 2035, even by 2050.
4. The Western Electricity Coordinating Council (WECC) exists to assure a reliable Bulk Electric System in the geographic area known as the Western Interconnection. Two Can. Provinces, 14 Western States and Northern Baja Calif.
5. Massive development of renewables in the SouthWest would create a big need for generation reserve which could be supplied by hydro and hydrogen storage in the NorthWest. Cheap solar power sent North could optimize reservoir regulation (at present BC Hydro's existing generating resources will show a lack of energy as soon as 2025, before planned resources).

Who's in Charge?



1. In colour are the regional transmission organizations (RTOs) who are in charge of planning their transmission networks.
2. Transmission planning in the white states/provinces is performed by local utilities.
3. There is talk about creating a Western RTO

The Western HVDC link

The savings in system operation brought about by the link (reduce new generation capacity, reduce solar curtailments, reduced GHG emissions) will be much larger than the cost of the needed HVDC connection.

It takes years to plan and obtain new right-of-way for the new transmission link.

A better (and faster) option could be to bury the new link on existing right-of-way (for example using the 500 kV right-of-way).

Or how about a submarine cable off the western coast from BC (Alaska?) to LA?

Is this practical?

The German Suedlink

- With a target to generate 65% of its power from renewable sources by 2030 and 80% by 2050, Germany's power grid needs to be significantly updated to accommodate this transition
- The SuedLink high-voltage direct current (HVDC) transmission line being developed in Germany is expected to be the longest underground HVDC power cable in the world.
- Covering a total route length of 750km, the 525kV underground power line will be capable of transmitting up to 4,000 MW of offshore wind power from north to south Germany while also facilitating the transmission of solar energy from south to north Germany.
- The SuedLink HVDC line will also be connected to the 525kV NordLink HVDC subsea interconnector that brings hydropower (stored energy) from Norway to Germany.
- The SuedLink HVDC has also been identified as a Project of Common Interest (PCI) as part of the European Union's (EU) Trans-European Network (TEN) initiative.
- Renewable generation is much less expensive in North America than in Germany hence the case for a buried Western link would make even more economic sense.

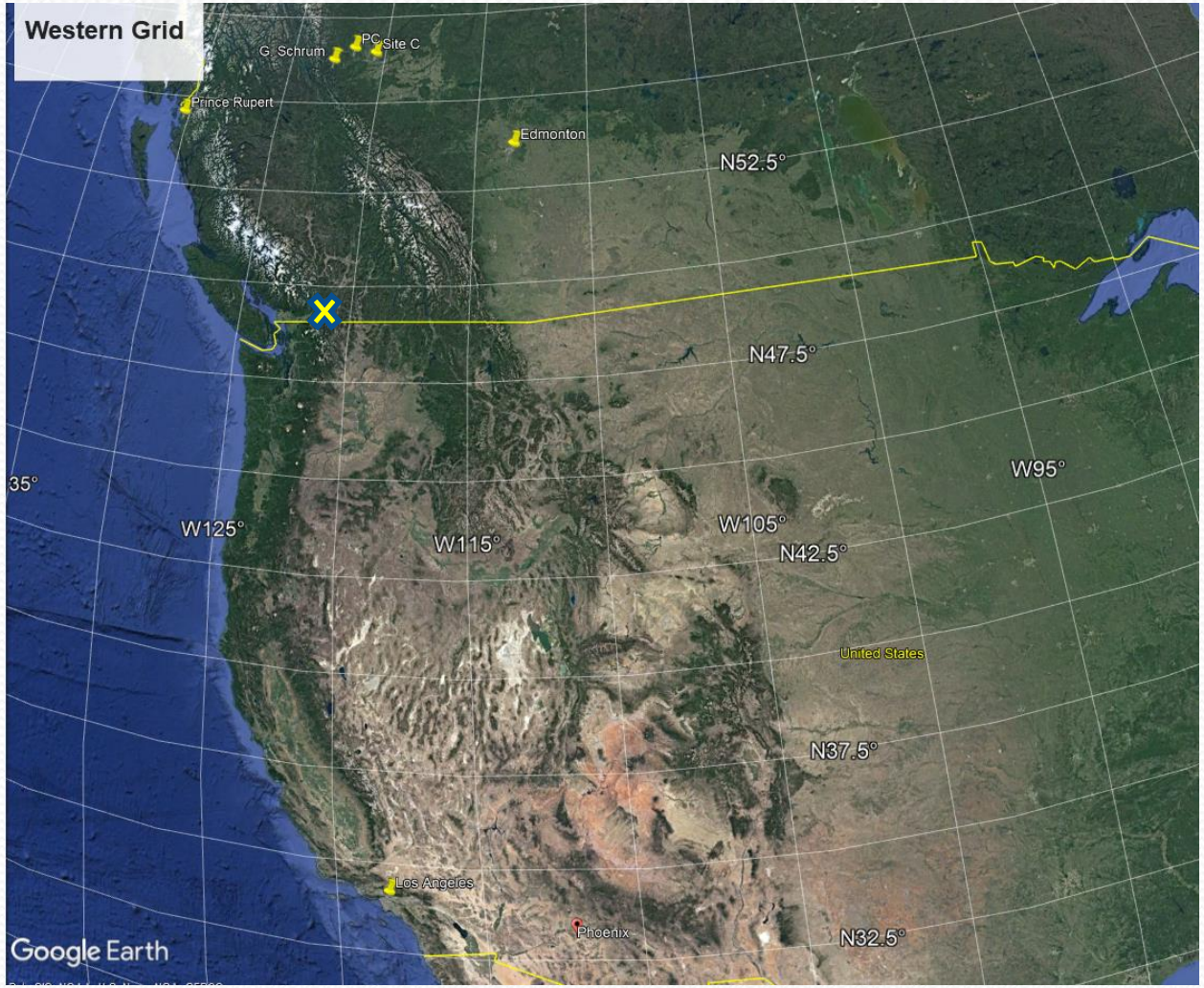
The North Sea Link

- Two mass impregnated HVDC cables
- Buried in trenches on the sea floor
- 720 km long, at present longest submarine cable
- 525 kV
- 700 MW per cable for a total of 1,400 MW
- In testing mode
- Cost estimated at 2.5 BC$

As shown for the German Suedlink cable, this proves that buried, or submarine cables could be economical options to transfer renewable energy over long distances.

Planned: A connexion to export solar energy from Australia to Singapore (over 3,500 km)

How Will the Western Grid Evolve



Straight distances (km)

Prince Rupert – L.A.	2,500
Edmonton – L.A.	2,200
Prince Rupert – Site C	640
Site C – Edmonton	560
Prince Rupert – Edmonton	1,100
X – L.A.	1,800

Factors coming into Play

Interventions by States/Provinces
Right-of way acquisition
Environmental action
Terrain
Reliability
Cost

Some Economic Considerations re. BC to California Link

Hypothesis:

1. Supply 1,400 MW of hydro energy from BC to L.A. from 5 pm to 11 pm (6 hours of base energy)
2. Supply 1,400 MW of solar energy from L.A. to BC from 9 am to 3 pm (6 hours of renewable energy)
3. Note that, omitting losses, no net energy will be exchanged.
4. Caiso will pay BC 80 US$/MWh while BC will pay CAISO 40 US$/MWh (see slide 10)

Analysis:

1. Benefit to CAISO:

a) Reduces base load generation capacity by 1,400 MW. Savings: 1000 $/kW x 1,400 MW = 1.4 BUS$

b) Estimated levelized cost of combustion gas turbines is 45 US$/MWh (Statista)

Savings: 1,400 MW x 6 hours x 45 US$/MWh = US$378,000/day (138 MUS$/year)

b) Reduces emissions by 2,000 TCO_2/day (based on 0.235 TCO_2/MWh)

c) California is linked with Quebec in enabling a cap and trade system to reduce GHG emissions. The present (Nov. '21) forward auction in this system is 34 US$/ton of CO_2 emission. The 2,000 TCO_2/day thus corresponds to a value (reduction) of 68,000 US$/day (**24.8 MUS$/yr**).

d) An alternative option to cap and trade is carbon pricing. The social cost of carbon (SCC) is a metric designed to quantify climate damages, representing the net economic cost of carbon dioxide emissions. The SCC can be used to evaluate policies that affect greenhouse gas emissions. Simply, the SCC is a monetary estimate of the damage done by each ton of carbon dioxide that is released into the air. The central SCC estimate of around $41 per ton of CO_2 (in 2016 dollars) is the best available estimate.

SCC = 2,000 TCO_2/day x 41 = 82,000 US$/day of potential savings <u>each day</u> (**29.93 MUS$/yr**).

2. Benefit to BC: financial (80 – 40) US$/MWh x 6 hours x 1,400 MW = 336,000 US$/day (**123 MUS$/yr**)

Cost of a Western Interconnection (Ex. BC to L.A.)

Point X to L.A. 1,800 km
Midcontinent Independent System Operator (MISO) 2021 Transmission Cost Guide.
Costs include a 30% contingency and 7.5% allowance for Funds Used During Construction (AFUDC)

500 kV HVDC line cost: 2.6 MUS$/mile
500 kV VSC station cost: 549 MUS$
Total cost: 2.6 x 1,800/1.61 + 2 x 549 = 4 BUS$

On the Sealink project Prysmian Group was awarded a contract worth £393m (533 MUS$) to manufacture, supply and install approximately 950km of onshore and offshore cables for a route length of 470km of the interconnector project in July 2015. That corresponds to a route cost, assuming 5% inflation added for 5 years, of:

533/470 x 1.61 x (1.05)^5 = 2.3 MUS$/mile

Note: A buried transmission link (on land or in sea) will be about the same cost as an overhead line with the added advantage of being more reliable (fire, storms, geomagnetic disturbances or attacks).

The cost of the interconnection is thus low compared to the cost of installing an additional 1,400 MW of capacity, operation costs, and the cost of the resulting cap and trade CO_2 emissions over the life of the interconnection.

How about Installing a Battery Energy Storage System (BESS)

While still relatively early in their technology lifecycle, utility-scale batteries can provide short-term storage and shift output from renewables (such as solar power) into periods with more demand. While this technology remains relatively expensive and has limited storage duration today, costs are expected to decline, and its capabilities are expected to increase (BC Hydro 2021 Integrated Resource Plan).

In many systems, battery storage may not be the most economic resource to help integrate renewable energy, and other sources of system flexibility can be explored. Additional sources of system flexibility include, among others, building additional pumped-hydro storage or transmission, increasing conventional generation flexibility, and changing operating procedures (NREL).

It does not make sense to hold a battery 's charge for long periods of time

The longevity of BESS is only a fraction (less than 50%) of the longevity of a hydro transmission system and has higher maintenance costs.

But it isn't a choice between long-distance transmission or BESS. With the huge demand for storage we will need both.

How to Proceed? That is the Question!

Washington, D.C., August 24, 2021—Most analyses find that to manage climate change, the United States will need to double or triple the size of its electric transmission system to move low-cost wind and solar energy around the nation and back it up with always-on power plants. But a newly released report from Clean Air Task Force and the Niskanen Center finds that the current piecemeal, project-by-project approach to expanding U.S. electricity transmission won't get us there. It instead calls for a new system to rapidly scale capacity — including by potentially establishing a **National Transmission Organization** that would plan, site, and fund a national grid to ensure that burdens and benefits are fairly shared. (source: Niskanen Center).

Last November FERC organized the first Federal-State Task Force on Electric Transmission. The Task Force will focus on topics related to planning and paying for transmission.

Need for a North American Transmission Organization (bi-lateral). As a start, a CanAm bilateral study group could be created tasked with overseeing a scoping study.

In the case of the Western HVDC link, since B.C. Hydro , Alberta and Western U.S. States are all members of the Western Electricity Coordination Council (WECC), WECC may be the logical choice to host scoping studies, once a Heads of Government bilateral Memorandum of Understanding has been signed.

Or, WECC could be instrumental in creating a Western RTO. It could then evaluate how the reliability risks to the Western Interconnection could be reduced by considering a separate BC to California link which would also free up North-South transfer capacity in the existing bulk system.