IESO Engagement

From: Dave Lang
Sent: February 25, 2022 9:51 AM
To: IESO Engagement
Subject: Input to Pathways to Decarbonization
Attachments: replace png with wind and solar IESO.pdf

I have been following some of the discussion on the elimination of gas generation on the Ontario grid for the last several months. I attended the session yesterday which outlined the approach to answering the gas moratorium question and the Pathway to Decarbonization study. I am a member of the Ontario Clean Air Alliance and have concerns with the level of bias in their commentary. I have done some crude analysis that illustrates some of the decarbonization challenges in Ontario.

I put a fair bit of effort into this and I do hope you will take the time to read it.

David Lang
[redacted]

Replace Pickering Nuclear Plant with Wind and Solar Power?

In the last few months there has been a good deal of discussion concerning the electricity grid in Ontario. In a nutshell, the Pickering Nuclear Generating (PNG) plant is scheduled to go out of service permanently in 2025. The grid planners have decided to replace the PNG capacity with natural gas power plants. Environmentalists are calling for all gas generation to be eliminated from the grid and replaced with lower cost, clean renewable energy.

One of the key reasons for the use of natural gas generation on the grid is to back up renewable generation when the sun doesn't shine and the wind doesn't blow. Without the ability to dispatch gas generation during these conditions, according to grid planners, we risk brownouts or even rolling blackouts.

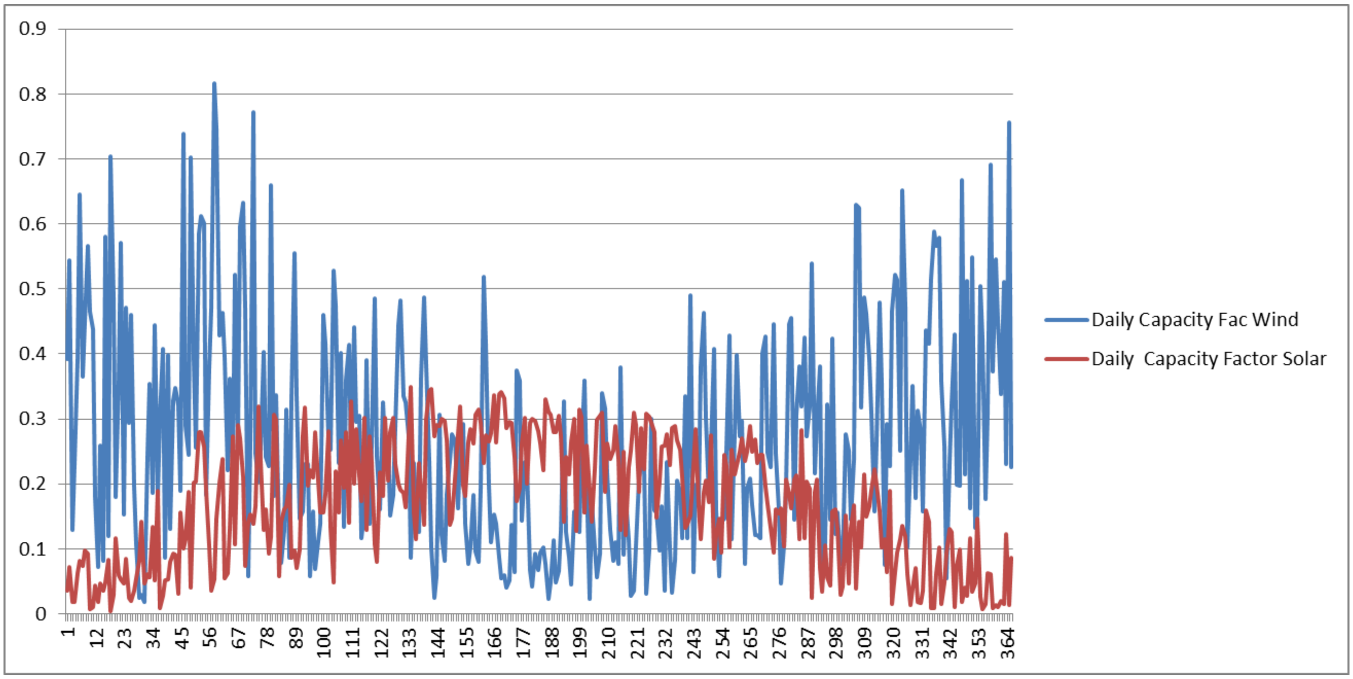
The positions taken by different stakeholder groups on this issue are highly polarized. One one hand, the grid operator (IESO), warns that eliminating gas generation will result in much higher electricity rates and will reduce the reliability of the electrical system. On the other hand proponents of gas elimination insist that renewables can meet our energy requirements and are the lowest cost energy choices. Many Ontario municipalities have passed resolutions calling for the elimination of gas on the grid.

When positions are this polarized, people will often align with the camp whose sensibilities best align with their own. Another approach is to gather facts and complete analysis to develop a position that is not influenced by any stakeholder group. To this end, I decided to determine what it would take to replace the PNG plant with a combination of wind, solar and storage without relying on gas for backup. This should not be considered a practical engineering solution but more of a "What if?" exercise to help expose issues and look at some of the solutions that have been proposed.

The following statistics provide insight into the scale of the problem:
The remaining in-service reactors at PNG have a capacity of about 3.1 Giga Watts and produce about 23,000 Terra Watt hours of energy annually. This amounts to about 15% of the current electric energy used in Ontario in a year. For comparison, all of the wind turbines in Ontario produce about 13,000 Terra Watt hours (TWH) or about 8.5% of electric energy used in Ontario annually.

In order to determine the right mix of wind and solar energy and also storage that will be required to replace the PNG a simple model was created. The model is based on the daily wind and solar energy profiles in Ontario along with capacity factors for wind and solar power in Ontario. The IESO provided hourly generator supply data for wind and solar for all of 2020. This data was used to create a daily profile of wind and solar energy. The profiles were normalized using a capacity factor of 27% for wind and 17% for solar. For example, if one Giga Watt of name plate wind capacity is provisioned in the model, the model will distribute this input over the year according to the profile and the average power generated will be .27 Giga Watts.

The graph below illustrates the daily distribution of wind and solar in Ontario during 2020 starting Jan. 1 of 2020.



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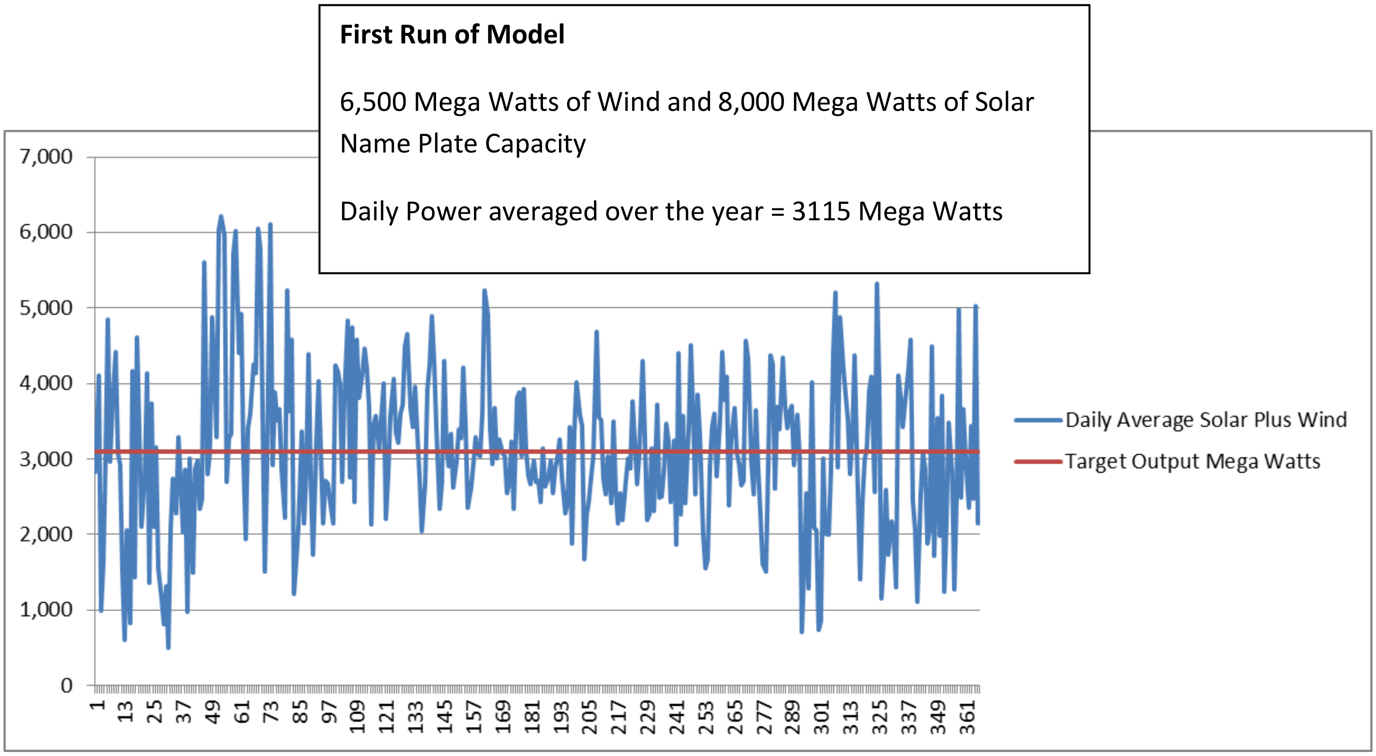
In the chart above a couple of things stand out. First is the extreme day to day variation in both solar and wind energy; second, the seasonality of wind and solar are very pronounced. Fortunately wind and solar energy are somewhat complementary; wind energy is high in the winter and solar energy is high in the summer. There are some days when wind generators are operating at 80 percent of the name plate capacity. Solar peaks at just over 30%. This is because the hourly solar power is averaged over 24 hours and no solar energy is generated at night.

In this document I have used to the model to examine three scenarios. The first simply provisions enough solar and wind power so that the average of daily power over the year is equal to the power output of the PNG. The second scenario uses over provisioning of wind and solar to eliminate the need for storage. The third scenario uses moderate over provisioning to enable the use of hydrogen as an energy storage solution. Once again, and I need to emphasize this; this is not an engineering solution it is just an exercise to determine how the wind and solar energy available in Ontario (along with storage) could be used to replace the power that is produced by the PNG.

First Run of Model

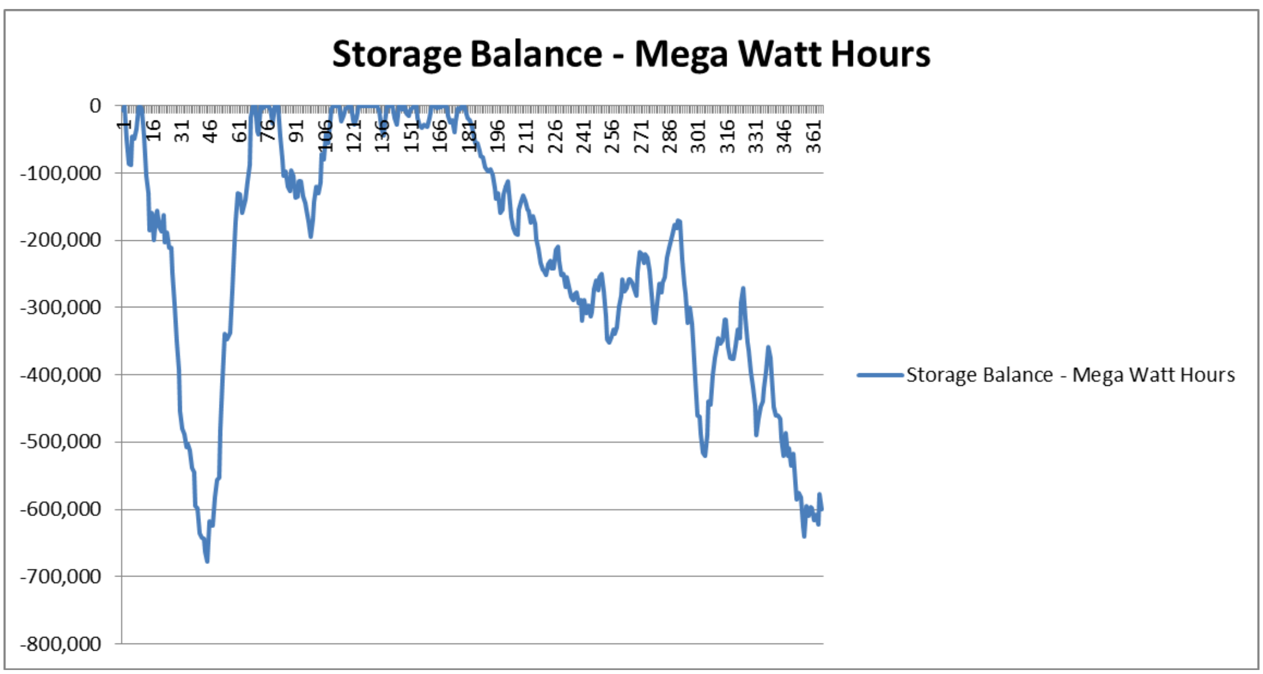
As stated above, the output power of the PNG is about 3.1 Giga Watts. The first run of the model attempted to generate power that is as flat as possible over the year and has an average daily power output of 3.1 Giga Watts. This was done by adding wind and solar capacity and watching the output until the desired conditions were obtained. This was done visually (not mathematically) using graphical output.



The chart above represents the best attempt to flatten the power over the year. In theory, if we ignore any losses associated with storage we should be able to store the power that is above the target output and then use it when the power falls below the target.

Unfortunately there are some issues with this level of output. First, the energy in the storage device will need a generator of some sort to convert the stored energy to electricity which is ready to go out onto the grid. In this case the output power of the generator must be 2.59 Giga Watts. This is not a great deal smaller than the 3.1 Giga Watts Nuclear Plant we are trying to replace. The second and most critical issue is the amount of storage that is required under this scenario.

The storage required in this scenario is calculated by the model and is illustrated in the chart below.



The energy storage requirement in this scenario peaks at about 677 Giga Watt hours. We often hear about storage in conjunction with renewable energy. Generally this is referring to short term storage to facilitate voltage and frequency stabilization on the grid; essentially providing a buffer between the variable power generated and the electrical grid.

Storage of the magnitude required in this scenario is unprecedented. To provide some perspective, pumped water storage is touted as the lowest cost, long term storage technology. The 4.5 Billion dollar Meaford pumped storage project is expected to store eight Giga Watt hours and have a power output of about one Giga Watt. We need 677 Giga Watt hours.

An interesting solution to this problem has been proposed by several, but notably Charles Rhodes of Xylene Power Ltd. Rhodes suggests the use of Lake Erie as the upper reservoir of a pumped storage system with Lake Ontario as the lower reservoir. A key statement from a 2020 paper by Charles Rhodes is as follows:
"***Thus in changing from the fully charged state to the fully discharged state the pumped storage system could supply 5 GW of electricity for 3820 hours. Canada's share of this storage capacity would displace much of the existing fossil fuelled peaking electricity generation in Ontario"***

If we multiply 5 Giga Watts by 3820 hours we get 19,100 Giga Watt hours, for our project we are looking for a paltry 677 Giga Watt hours. The down side of this is that the cost is estimated at about $40 Billion.

As much as this concept is intriguing, the risk associated with taking on an international mega project to provide clean energy is fairly risky. As recent events have shown, a change in government on either side of the boarder could spell disaster for such an undertaking.

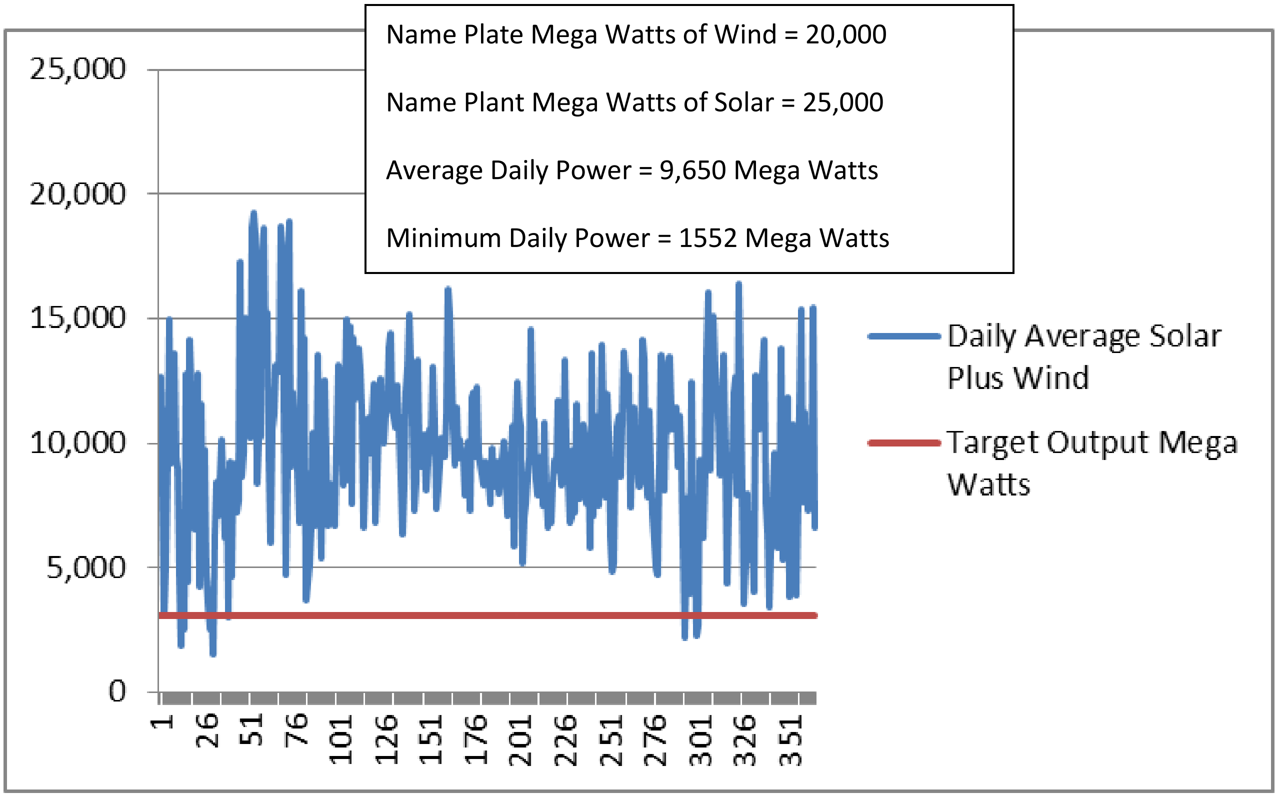
There are some very significant challenges associated with the first run of the model. There is no simple solution to the storage problem.

Second Run of Model

In a May 2019 article titled ***"A radical idea to get a high-renewable electric gird: Build way more solar and wind that needed"*** Richard Perez and Karl R. Rabago make the following key statements about over provisioning wind and solar in order to address the storage problem.

Storage is getting cheaper, but even assuming the most optimistic long-term cost projections, our study led us to conclude that applying storage alone to firm wind or solar will remain prohibitively expensive because of the size of multi-day and seasonal gaps. Wind and solar are becoming much less expensive as well, especially solar, to the point where overbuilding is increasingly affordable. This is true even when the output from wind and solar generators is essentially dumped, or "curtailed," and not fed into the grid.
Oversizing reduces production gaps because more energy output is available during periods of low solar and wind availability. Overbuilding also reduces storage requirements.

For the second run of the model the **minimum** daily power output was constrained to 50% of the target daily power output of 3.1 Giga Watts. It is assumed that the gap between this level of output (1.55 Giga Watts) and the target can be bridged with demand management, imports and adjustments on other parts of the grid. This constraint will cause the over provisioning of wind and solar to eliminate the storage requirement. The results of this run are in the chart below.



In this run of the model there are only nine days where the daily power output dropped below 3.1 Giga Watts and it never dropped below the 50% threshold.   That is the good news. The bad news is that in order to achieve this it was necessary to provision more than three times the target average daily power.

The average wind turbine has a name plate capacity of 2.5 Mega Watts. In the second model run it was necessary to provision 20,000/2.5 = 8,000 new wind turbines. In addition it was necessary to provision 25,000 Mega Watts of solar power.   The surface area alone of the solar panels in this scenario would total about 38,000 acres.

We often hear how successful solar power is in Northern Australia or how reliable wind power is in Denmark. I think the lesson here is that Ontario is not Northern Australia or Denmark. Renewable energy experience in other jurisdictions may be quite different from what is experienced in Ontario.

I have seen cost studies that suggest that a wind and solar alternative like the one in model run two is much more cost effective than say a solution that involves Small Modular Reactors (SMRs). I have also seen cost analysis that shows the exact opposite. It is difficult to avoid bias in these studies. It is important to examine the source to detect a reason for bias.

I am certainly no expert on electricity costing but I have to wonder what the reaction to the following news headline would be. ***“8000 New Wind Turbines and 38,000 Acres of New Solar Panels Slated for Ontario by 2025”***

The bottom line is that the second run of the model produced a solution that could work. The cost, driven by excessive over provisioning might impact future electricity prices.

Third Run of Model

In a Dec, 2020 article titled **"Optimizing Renewable Energy Storage with Hydrogen Fuel Cells Megawatt Fuel Cell Stationary Power"** Roy Segev makes a case for green Hydrogen and Megawatt Fuel Cell Power plants as a solution to interment renewable energy. Some key comments from this article are below.

For producers of renewable power, the primary challenge is meeting user demand—which requires consistent, predictable patterns—with power from intermittent and, some would say unpredictable sources. Wind power depends on weather patterns. Solar power is impacted by cloud cover and seasonal shifts in daylight.

As producers well know, renewable power generation will range from surplus to insufficient, sometimes in the same day. Reliable, stable and long-term energy storage is the solution: store the surplus energy at times of peak production, and distribute it at times of peak demand.

The math just makes sense.

Rechargeable batteries are commonly used for renewable energy storage. However, batteries are only viable for short-term storage. For longer storage—from overnight to seasonal—the best solution is hydrogen supported by fuel cells.

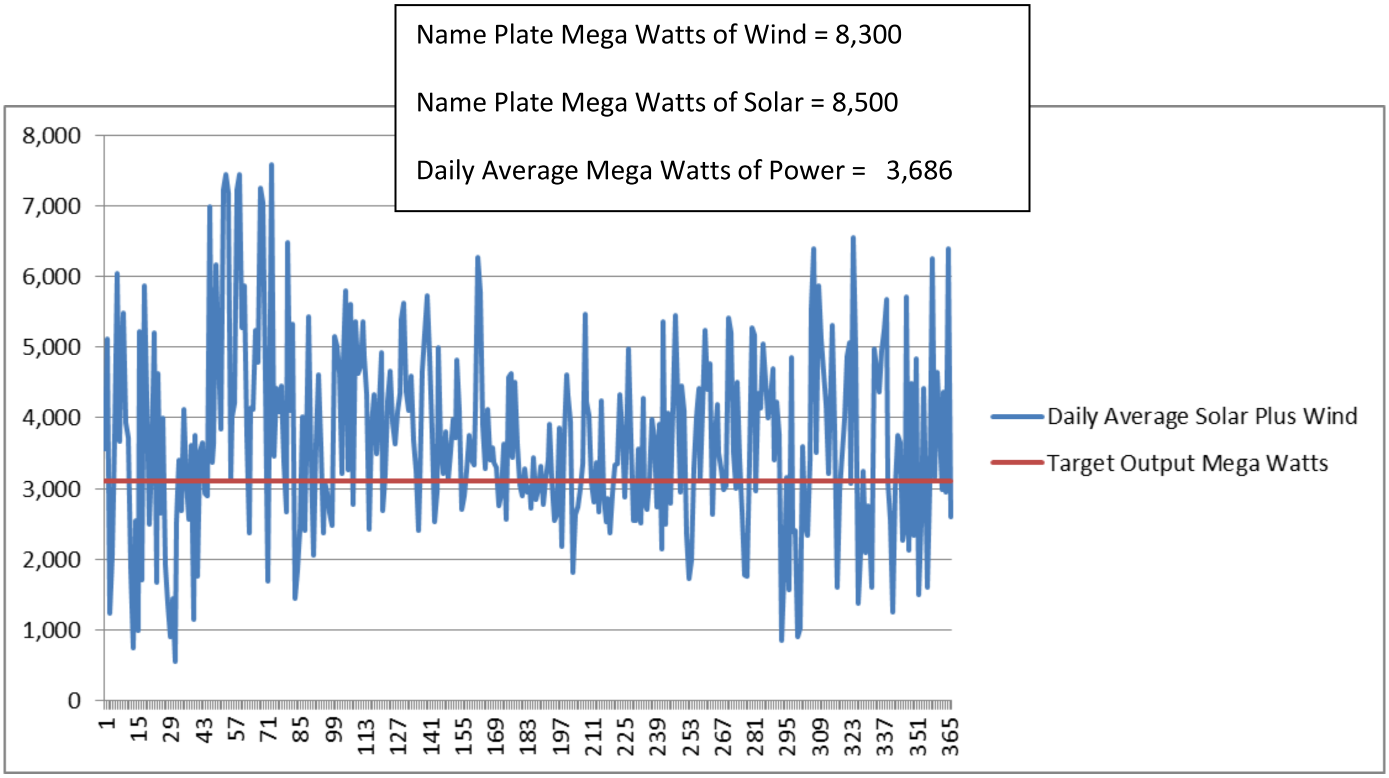
The hydrogen is produced by electrolysis using low cost renewable surplus electricity, then stored, and then converted back to electricity using fuel cells—a zero emission and time proven process. The result is reliable, stable, energy at grid scale.

Canada's climate change plan is very focused on the expanding role of hydrogen in the economy. In addition Canada has developed a detailed hydrogen strategy. The document is titled: "***Hydrogen Strategy for Canada Seizing the Opportunities for Hydrogen - A Call to Action, December, 2020".***

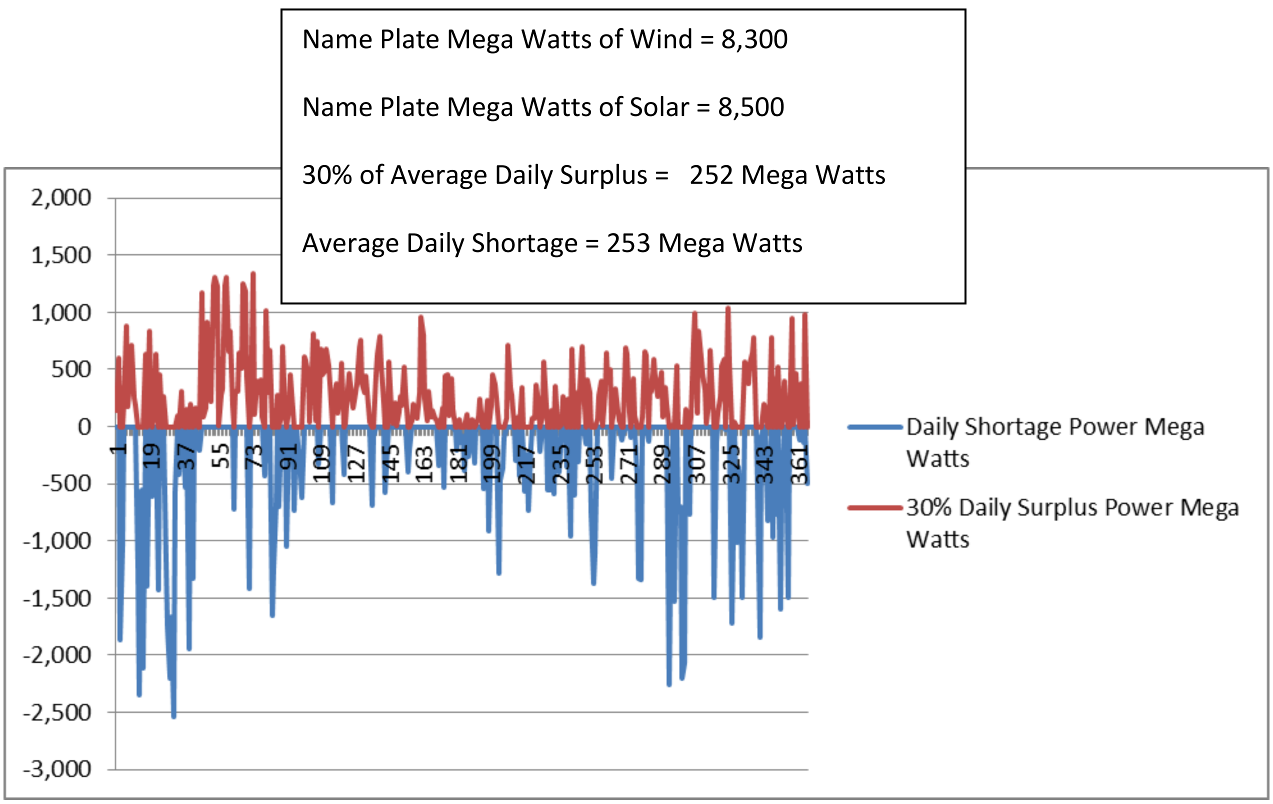
The Canadian hydrogen strategy has a strong focus on steam reforming of natural gas using carbon capture and storage to eliminate the release of CO2 to the atmosphere in the hydrogen production process. There is also support for the production and use of hydrogen in conjunction with renewable energy. This is a quote from the hydrogen strategy document: "***Hydrogen can also play a role in daily to seasonal storage of variable renewable resources, enabling a higher penetration of intermittent renewables on the grid."***

The end to end process involving the production of hydrogen using electrolysis, storage and finally using a hydrogen fuel cell to generate electricity has an overall efficiency of about 30%. The average daily power generated on model run three must be adjusted upward to take this efficiency into account. For comparison, a lithium battery has round trip efficiency of about 83%.

The results of the third model run are illustrated in the charts below. There is some over provisioning but it is greatly reduced over what was required in the second model run.



The chart below illustrates the distribution of 30% of the surplus daily power and all of the daily shortage power. A significant cost associated with Hydrogen is the storage of the Hydrogen once it is produced. It is important to optimize the mix of solar and wind power so that the power produced tracks as much as possible with demand. This will shorten the time between when surplus power is generated and converted to hydrogen and when stored hydrogen is converted to electricity to satisfy demand.



An interesting observation from the third model run is that a fairly small amount of over provisioning can have a large impact in reducing storage requirements. Although storage requirements are reduced considerably we still need over 2.5 Giga Watts of generation power to meet the target power output during periods when there is very little wind or solar power. The world's largest fuel cell power plant operating in Incheon South Korea has a power output of about 79 Mega Watts. The total project cost of this plant was about 340 Billion Won or about $375 Million Canadian. This $375 Million excludes the costs associated with electrolysis and storage. We would need about 30 of these plants.

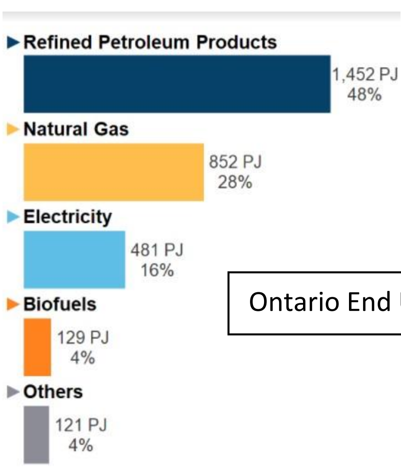
Hydrogen energy storage is more flexible than battery storage. If too much hydrogen is produced, there is a market for it so it and it can be transported and sold. Since hydrogen is being made with, essentially surplus electricity, the cost of hydrogen production would be quite reasonable. At the current time, the cost of hydrogen fuel cell electricity generation is very high. These costs will likely come down significantly as the world embraces hydrogen as a flexible energy carrier.

The production of green Hydrogen using electrolysis and the use of Hydrogen fuel cells to generate grid scale electricity are still very much at the demonstration stage. The technology is promising but economic deployment on electrical grids is still several years away.

What about Hydro Power from Quebec?

A common refrain from the environment community (of which I consider myself a member) is that Ontario's energy needs can be met with wind and solar plus storage, conservation and cheap hydro power from Quebec. As I write this at 4:00 pm on December 30, 2021 the demand for electric power in Ontario is 16,662 Mega Watts. The wind supply component is 48 Mega Watts and the solar supply component is about 42 Mega Watts (transmission and distribution connected). The bottom line is that right now, at this hour, wind and solar are providing less than .6% of the power demand in Ontario. The data presented so far, I hope, have demonstrated that storage is not a trivial problem and must be considered seriously.

In Ontario only about 16% of the energy we use comes from electricity. The bulk of our energy use comes from burning fossil fuels. The chart below illustrates this.



Ontario End Use Energy

At least 75% of the energy we use must be diverted from burning fossil fuels to using clean electricity. The Canadian Climate Action Plan "A Healthy Economy and a Healthy Environment" says the following on this subject:

"*Canada is fortunate to have world-leading clean power resources. One of the most important ways to fight climate change is to use electricity to power cars and factories and to heat and cool Canada's buildings. That's why the Government of Canada is phasing-out coal-fired power across Canada by 2030, increasing the supply of non-emitting power generation from coast to coast to coast, and working to ensure more parts of the economy are connected to the electricity system and able to use it as a fuel source. In order to accelerate the electrification of its economy, Canada will need to generate even more affordable, clean energy than it does today.* ***By 2050, Canada will need to produce up to two to three times as much clean power as it does right now."***

Today, Ontario uses about 150 Terra Watt Hours (TWH) of electricity per year. In order to decarbonize our economy this will have to increase to over 400 TWH. Quebec is further along when it comes to decarbonizing (about 35 percent of Quebec's energy use is electricity) but still has significant challenges ahead. To put the current Quebec surplus energy in perspective, the sum total of all of Quebec's power exports is about 36 TWH; some of this is tied up in long term contracts with US states. In the future, Quebec surpluses will decline in order for Quebec to meet internal demand tied to decarbonisation.

In an August 2021 report titled "Electrification Pathways for Ontario to Reduce Emissions - Procuring Ontario's energy future" Marc Brouillette of Strategic Policy Economics had the following to say on the subject of Quebec hydroelectricity: "…*Instead, plans have continued to rely on the supposed ability to import electricity from Quebec and the U.S.. These have been respectively shown to be infeasible on the one hand and at significant risk from U.S. climate policy objectives on the other.* ***Quebec cannot meet Ontario's growing winter heating load, and instead currently relies on imports from Ontario in the winter. Both import options would lead to less energy security for Ontario."***

Quebec's electricity infrastructure is based on reservoir hydroelectric generation. Quebec was busy building dams and flooding land while Ontario was building nuclear plants. Environmental and Indigenous rights considerations make additional development of this type today very challenging.

Quebec's reservoirs can store about 176 TWH. This storage is a resource that should not be squandered by using it for base load power. This amount of storage could enable the decarbonisation of a great deal of Eastern North America if it were judiciously exported to provide stability to grids with a high percentage of variable power. Quebec should expand its use of non-hydro renewables domestically and rely on the reservoirs to supplement during periods of low wind and solar energy. This will stretch this valuable resource much further. Quebec distributes power over a broad geography for this reason the likelihood that all importing jurisdictions will need a large amount of power at the same time is significantly reduced.

A caution here is that water power must be used within tightly controlled parameters. When wind and solar power is reduced, the use of stored hydro is limited by the amount of water that can be safely released down river.

What about Using EV Batteries for Grid Storage?

It is expected that EVs will become common place over the next few decades. Some have proposed using EV batteries as a source of grid storage and part of the solution to the elimination of gas generation. This capability was initially proposed in Japan with the" Leaf to Home" concept. More generically it referred to as vehicle to grid (V2G).

Most of the research in this area is focused on managing congestion on the distribution grid caused by large numbers of EV's plugging in at roughly the same time. It is more of a demand management strategy than a grid storage solution. Distribution congestion caused by EV charging could become a very significant problem unless it is addressed early and proactively. The V2G concept with elaborate demand management algorithms may well be part of the solution.

Issues around EV battery warranties and compensation to EV owners for the use their battery are just a few of the issues that will need to be addressed.

Conclusion and Closing Remarks

Ontario is at best a mediocre jurisdiction when it comes to wind and solar power. The capacity factor for wind power in Ontario is about 27%. In the US the fleet wide wind capacity factor is about 35%. This is close to a 30% advantage for the US just based on capacity factors and not considering differences in wind variability. As we have seen from the analysis in this document, the variability of wind has very large impact on storage requirements and costs. Solar capacity factors in the US average about 24.7% compared to about 17% in Ontario.

One way that Ontario can offset its disadvantage in available wind and solar energy is through excellence in demand management and by making shrewd choices for energy storage.

In Ontario, maximizing the use of Hydro power should be perused aggressively. I have often thought that the development of new Hydro resources in conjunction with the development of the Ring of Fire is something that might appeal to some First Nations in the area - modern electricity, roads and jobs in exchange for co-operation on Hydro projects (I prospected in the Ring of Fire in 07/08 so I am a little biased here).

If Ontario could apply the learning's from its past experience with nuclear energy implementation then perhaps SMRs will be a significant contributor to decarbonisation in Ontario.

Ontario's path to decarbonisations is not clear. The IESO grid plan to 2040 calls for a very modest increase grid capacity and forecasts a significant increase in CO_2 emissions as gas generation is planned to replace nuclear capacity. The Ontario plan is totally disconnected from the federal climate change plan.

In his national statement at COP26 Justin Trudeau said the following: *"… We need to find solutions that work for our citizens in their daily lives. That is why Canada has set a goal of selling only zero-emission cars* ***and establishing a net-zero emissions electricity grid by 2035."***

The statement above highlights the chasm between the aspirations of the federal government and the reality of Ontario's provincial plan for the electrical grid.

I think that Federal leadership is required. The Federal government should announce a new 25 year program to help the provinces decarbonize and triple the capacity of electricity grids in Canada. Carbon tax revenue from across the country should be used to keep electricity rates low, provide decarbonisation incentives and support people in the transition.

The provinces will be encouraged to work together to develop clean grid expansion plans and form partnerships with each other to reduce risk.

This announcement will stimulate the clean energy industry to bring new solutions to the table. Overall the economy will be invigorated and focused on clean growth. New industrial activity will be attracted to take advantage of low cost green energy. This is a bold "if you build it they will come" strategy.

The key to decarbonisation is a high capacity decarbonized grid. This must be the corner stone of a climate change mitigation plan.   Without Federal leadership in this area Canada's climate change plan is doomed to failure.