DRAFT for COMMENT

Wind and the Electrical Grid

December 13, 2011

Photo Courtesy of the Canadian Wind Energy Association

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Executive Summary

The purpose of this document is to inform the Ministry of Energy about the technical challenges of integrating Wind to the Electrical Grid with recommendations to develop guidelines for the Ministry and its agencies that will ensure Ontario specific engineering expertise is used during the development of policies, strategies, directives and implementation plans of technically complex programs and projects.

The Ontario Society of Professional Engineers (OSPE) has undertaken this review of wind generation and its impact on Ontario's electrical grid because of growing problems with surplus base load generation (SBG) and more recently with the need to pay our neighbouring grid operators to take our surplus energy. These problems will exacerbate the expected rise in electricity prices identified in Ontario's Long Term Energy Plan. This in turn negatively affects our member engineers who are dependent on the health of various industries that use large quantities of electricity.

The Independent Electricity System Operator (IESO) in their September 2011 18 Month Outlook for the electrical grid expressed serious concern about the state of integration of renewable energy into the grid. The electrical grid is a large, highly complex engineering system. The integration of large amounts of intermittent renewable generation into the electrical grid requires the application of Ontario specific power engineering expertise during the execution of the Green Energy Act mandates. This is a serious concern for OSPE members and for the general public who could be forced to pay unnecessary additional costs for their electricity through higher rates or higher taxes and who could suffer the resulting reduction in economic activity in the province if that engineering expertise is not applied.

Specialized engineering knowledge and skills are critical in the development of effective policy, directives and implementation plans that affect large and complex engineered systems such as our electrical grid. While politicians, environmentalists, and the general public have legitimate roles to establish overall policy goals for our electrical grid and to hold technical organizations accountable to meet them, they cannot be tasked to design the grid. The required technical functionality and facilities required to meet society's goals must be funded and included in the long term plans. Failure to do so will result in higher operating costs and inadequate technical performance with impact on public safety, power quality and electrical system reliability.

Every energy source has its advantages and disadvantages and each has a legitimate role to play in Ontario's electrical energy future if we are to meet the public's energy and environmental needs. The key to doing it right in a complex electrical grid is to get the engineering right. We need to use the various energy sources in ways that play to their strengths and minimizes their weaknesses. In that way all these sources with their differing performance characteristics can co-exist harmoniously on the same electrical grid. In most cases, some engineering needs to be done to ensure each energy source can be integrated effectively into the grid, especially as the grid becomes more complex. Wind generation is no exception.

The Ontario grid is currently lacking integrated, maneuverable base load generation facilities (hydraulic, nuclear and wind). This has resulted in severe surplus base load generation (SBG) and the need to pay our neighbouring grid operators to accept our surplus energy. In 2011 SBG reached almost 3,500 MW that needed to be exported at negative prices. By 2019 the IESO

expects the SBG to reach 6,000 to 7,000 MW depending on whether the medium growth or low growth planning scenario contained in the 2010 Long Term Energy Plan occurs. By 2030 the SBG is expected to reach 7,000 to 11,000 MW depending on whether the medium growth or low growth planning scenario respectively occurs. In the near future (likely by spring of 2013) the shutdown of some of these base load generating facilities will be necessary to maintain electrical grid stability because we will reach the grid's maximum export capability.

The IESO's plans to dispatch wind (essentially shutdown wind turbines) when severe SBG occurs is a reasonable and effective short term solution. However, we need to find better long term solutions to the two problems of surplus SBG and the lack of zero greenhouse gas (GHG) backup generation for our growing intermittent renewables fleet. We need to make solving these two problems a higher priority. If we don't, we will:

- waste some of our investment in renewable generation.
- undermine our Green Energy Act environmental goals.

There is strong public support for solar and wind (with the notable exception of industrial wind farms in rural areas and near residences). There is not enough room on the grid for both non-maneuverable nuclear and wind generation with its natural gas back up generation. Wind generation is intermittent and can't be shut down too frequently or it becomes uneconomic. To provide more room for wind generation there is a need to either phase out low cost non-maneuverable nuclear or you need to make nuclear electrical output maneuverable and have nuclear generation provide the backup for wind generation.

OSPE recommends that the Minister establish guidelines for the Ministry of Energy and its related agencies that will ensure Ontario specific engineering expertise is used during the development of policies, directives and implementation plans of technically complex programs and projects.

OSPE also recommends that the Minister of Energy authorize detailed engineering studies to:

1. Determine the extent of the SBG problem over the same planning horizon as the Long Term Energy Plan (LTEP) and make those findings public as part of the Integrated Power System Plan (IPSP).

2. Determine the long term sustainable volume of biomass available in Ontario to provide zero GHG backup generation for our intermittent renewables fleet.

3. Determine the economic feasibility of incorporating electrical output maneuverability at our nuclear plants to eliminate the SBG problem, to provide additional room for wind generation growth and to provide zero GHG backup to our intermittent renewables fleet.

4. Determine if there are sufficient customer loads that can accommodate energy use patterns that match the energy production pattern of intermittent generation. If sufficient customer loads are identified then determine how best to enable the IESO to manage that load in order to reduce the amount of backup generation required for the intermittent renewables fleet. If this proves fruitful, undertake a pilot program to fine tune the program before it is launched more broadly in the marketplace.

OSPE further recommends that the Minister of Energy authorize a study into alternative pricing models for wind generation that do not require the measurement of the energy that is <u>not</u>

produced during dispatching. The objective of this recommendation is to simplify the measurement and settlement process before wind dispatching becomes operational.

Section 8 – Recommendations contains a more complete list of our recommendations.

Table Contents

1. Introduction

The Ontario Society for Professional Engineers (OSPE) was founded in 2000 through the collaborative efforts of Professional Engineers Ontario and the Canadian Society of Professional Engineers (CSPE). OSPE's mission is to advocate for the interests of engineers and to provide them member services.

OSPE's interest in advocating for an affordable, balanced energy policy stems from the fact that many of our members are employed in the energy sector and most of our other members are impacted by the cost of electricity. OSPE's nuclear, manufacturing and resource processing engineers have been negatively affected over the past several years. Energy policy has a major impact on those sectors.

In the autumn of 2010 OSPE representatives met with the then Minister of Energy, the Honourable Brad Duguid, to express concerns related to recent policy initiatives, directives and decisions regarding proposed changes to the electrical grid. OSPE identified unintended consequences that would drive up electricity rates. The Minister was interested in seeing a more detailed analysis of those concerns and asked OSPE to provide him with an objective engineering assessment of Ontario's Long Term Energy Plan and any recommendations OSPE believes the Ontario government should consider.

OSPE's Energy Task Force undertook a series of analyses which resulted in the following submissions to the Ministry of Energy or its regulatory bodies:

- On March 8, 2011, a report was submitted to the Minister of Energy which identified a number of requirements unique to Ontario's electrical grid that should be included in the specifications for new and refurbished nuclear plants in Ontario (R28).
- On March 9, 2011, a submission was forwarded to the Ontario Energy Board which identified an alternative time of use rate structure that would more fairly allocate costs for peak power to those customers that create a peak demand. The new rate structure would encourage those customers to invest in demand leveling technologies thereby reducing the need for peak load generating plants (R29).
- On June 13, 2011, a submission was forwarded to the Ontario Power Authority which outlined a number of concerns that were not adequately addressed in the 2011 Integrated Power System Plan and that should be resolved when the Plan is revised (R30).
- This document, which is being submitted to the new Minister of Energy, the Honourable Chris Bentley, outlines OSPE's concerns over the state of integration of wind generation with the existing base load generating facilities. We offer potential solutions and recommend engineering studies that should be undertaken to select the most economical solution(s) to help achieve our future GHG reduction goals.

OSPE's understanding of the government objectives in restructuring the electrical energy supply system includes:

- The reduction of air and water pollution and other negative health impacts,
- The reduction of greenhouse gas emissions,
- The reduction of energy intensity (conservation and improved energy efficiency),
- The reduction of peak electrical demand (flatten the demand profile),

- The improvement of sustainability (less dependence on declining resources), and
- The increase of green (clean and sustainable) energy jobs in the Ontario economy.

OSPE supports the governments objectives listed above. However, in pursuing those objectives it is important that the government does not lose sight of the engineering principles that must be followed to ensure the restructured electrical grid continues to be safe, dependable and affordable in addition to being environmentally responsible.

In the September 2011 IESO 18 Month Outlook for the electrical grid (R23), the IESO continues to be concerned about the state of integration of renewable energy into the grid. The electrical grid is a large, highly complex engineering system. The integration of large amounts of intermittent renewable generation into the electrical grid requires the application of Ontario specific power engineering expertise during the execution of the Green Energy Act mandates. This is a serious concern for OSPE members and for the general public who could be forced to pay unnecessary additional costs for their electricity through higher rates or higher taxes and who could suffer the resulting reduction in economic activity in the province if that engineering expertise is not applied.

During the Green Energy Act implementation, no provisions were made to integrate large amounts of base load intermittent wind generation with existing non-maneuverable hydraulic and nuclear generation. In 2011 about 15 million dollars (R3) were spent exporting surplus power at negative prices because of a lack of capability to manage surplus base load (SBG) generation. We are getting uncomfortably close to having to shut down wind or nuclear generation thereby wasting the investments in those facilities.

Specialized engineering knowledge and skills are critical in the development of effective policy, directives and implementation plans that affect large and complex engineered systems such as our electrical grid. While politicians, environmentalists, and the general public have legitimate roles to establish overall policy goals for our electrical grid and to hold technical organizations accountable to meet them, they cannot be tasked to design the grid. The required technical functionality and facilities required to meet society's goals must be funded and included in the long term plans. Failure to do so will result in higher operating costs and inadequate technical performance with impact on public safety, power quality and electrical system reliability.

The data presented and used in the analysis for this document has been obtained from publicly available sources such as the Independent Electricity Operator (IESO), Ontario Power Authority (OPA), the Ontario Ministry of Energy (MOE) and energy industry associations. The specific references we used are at the end of Appendix A. The IESO data for public use is provided in hourly interval format so more detailed analysis of fast transients is not possible without obtaining the second-by-second data available from the IESO. Unfortunately those data files would be enormous and a more selective request of data would be more appropriate for later detailed studies around specific periods of interest.

2. Ontario's Electrical Grid and Its Load Profile

In this document we will use the term "grid" to mean the Ontario electrical generation, transmission, inter-grid connections, distribution, customer connections and related control facilities. The term "power" will be used to represent the instantaneous amount of electricity flowing in the wires and is typically expressed as thousands (kilo) of watts or simply kilowatts (kW). The term "energy" will be used to represent a measure of the ability of electricity to do useful work and the units are typically expressed as thousands of watts multiplied by time in hours or simply as kilowatt hours (kWh). When the quantities are very large we typically will replace thousands or kilo (k) with larger units of million or mega (M), billions or giga (G) and trillions or tera (T). Therefore, the symbols used in this document for power will be kW, MW, GW and TW and for energy will be kWh, MWh, GWh and TWh.

Also, the terms load ramping, load following, load cycling, load maneuvering have slightly different meanings in the industry. For the purposes of this report we will simply refer to a change of power output as a load maneuver and we will not get into the specific details of each type of load change. The term "dispatch" is used in the context of the IESO sending out commands for generators to move their output to a specified MW level at a specified time.

Generating station and unit sizes vary according to the technology used. The Sir Adam Beck I and II stations at Niagara Falls have 26 units and can produce a total of about 2,000 MW. The Darlington nuclear station near Oshawa has 4 units that can produce about 3,500 MW. The Nanticoke coal fired station near Port Dover has 6 units that can produce about 3,000 MW. The Sithe Goreway gas fired combined cycle station near Brampton has 4 units that can produce about 900 MW. Wind turbines are typically 1 to 3 MW each and are often clustered into large wind farms of 50 to 200 MW each in order to reduce the total installed capital cost per kW.

Ontario has interconnections to neighbouring electrical grids in Manitoba, Minnesota, Michigan, New York and Quebec. The practical limit of our export/import capability to those neighbouring grids is about 4,800 MW (R9)(R22) provided those neighbouring grids are all willing to import or export at the same time.

Ontario's grid is administered by the Independent Electricity System Operator (IESO). The IESO operates a wholesale market that determines which generating plants run and at what power level through an auction process. The generators offer prices for their output and the IESO selects sufficient sources to meet the demand at the lowest price. The price where supply and demand are in balance is the market clearing price. That price is paid to all generators that are providing power. The price is set every 5 minutes. For a more detailed description see Appendix A, Section A1.

Electricity cannot be stored directly and economically in large quantities in Ontario with present technology. As a result the electrical grid is operated in a manner that balances the supply and demand of electricity on a moment-to-moment basis. When customer demand is lower than the minimum output of our base load generators, the system experiences what is called excess base load generation or SBG.

Since supply and demand must be balanced at all times, the auction process forces those generators who want to remain on-line and not be dispatched off to bid lower prices into the electricity market. If neighbouring grids do not take the SBG then the price continues to fall and can go negative as generators compete to stay on-line to avoid the high cost of a shutdown. Eventually the low or negative prices in Ontario attract demand from our neighbouring grids.

Ontario consumers would incur a high cost to shutdown a CANDU nuclear unit because it takes about 2 to 3 days to restart that reactor once it is shut down. During those 2 or 3 days the cost of replacement power (likely natural gas generation) would typically add about $30 to $40 per MWh to the fuel cost to produce that electricity. Consequently it is cheaper to pay our US neighbouring grids to shut down their fossil fired generation or for Quebec to store the energy in their large hydraulic reservoirs. However, this can only be done if sufficient transmission capability exists to export that power. Ontario is getting very close to reaching that maximum export capability. When that limit is reached, likely sometime in early 2013, Ontario will need to either shutdown some of its wind turbines or nuclear units.

North American utilities all subscribe to the philosophy that consumer demand should not be interrupted unless there is a crisis on the electrical grid. Consequently, most day-today control efforts are directed at managing supply to match the demands of consumers at all times.

Another important consideration in grid operation is the current policy in Ontario to allow wind turbines to generate all their output without dispatching restrictions. They have priority access to the grid for the purposes of generating power (R36). This has been done for two reasons. Firstly, if you don’t capture the energy when nature provides it, then you lose it. Secondly, wind turbines have a high installed capital cost of typically $2,500 to $3,500 per kW (R13) and low capacity factor of about 25% in Ontario (R3). If you dispatch wind that capacity factor would fall and the cost of electricity from wind turbines would rise significantly.

This priority access by wind generators makes sense if the electricity price is positive but if it is negative, then Ontario consumers effectively subsidize power exports to US and Quebec consumers. At that point it would be better to dispatch wind to prevent the price from falling below zero, or better yet, below the incremental cost of production.

Unfortunately, if a significant amount of dispatching is imposed on wind generators they effectively become uneconomic because the required additional price subsidies that would be needed to pay for the facility would be difficult to justify to consumers or taxpayers.

The Ontario electrical grid is among the cleanest electrical grids in the world. That was true even before the introduction of wind and solar technology. The reason is that Ontario chose to invest primarily in hydraulic and nuclear generation for base load generation. Coal and gas fired generation were used primarily for peak demand in more recent years.

Customer Demand

The Ontario customer demand for electricity varies throughout the year (R10). The lowest demand day occurred on the Victoria Day holiday, May 23, 2011. The minimum load that day was 10,799 MW at 5:00 AM. The highest demand day occurred on a weekday in the summer on July 21, 2011. The highest demand that day was 25,450 MW at 4:00 PM. Figure 1 and Figure 2 on the next page shows the demand variation during both days.

Figure 1
Lowest Demand Day in 2011

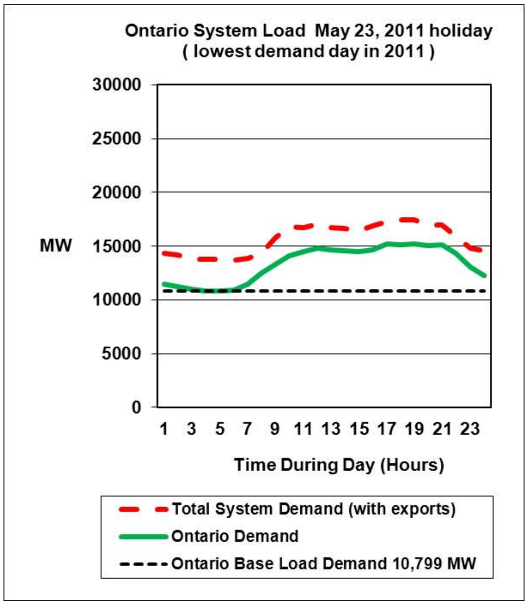
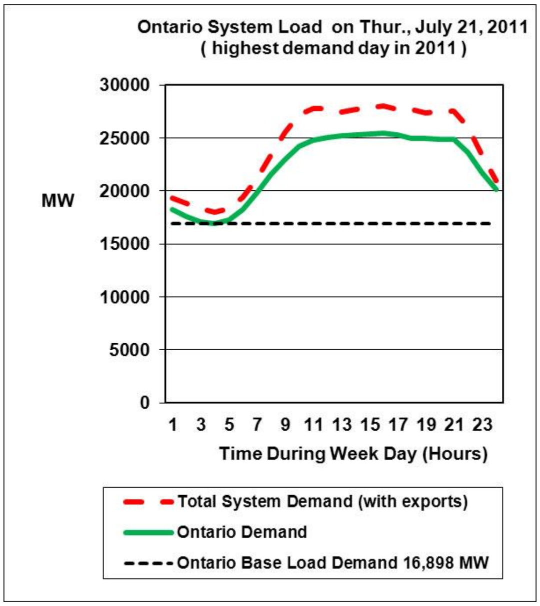


Figure 2
Highest Demand Day in 2011



Available Supply

Ontario's generating resources fall into two categories: base load and peak load generators. Base load generators are best suited to continuous and steady power output. These typically have higher capital costs, lower fuelling costs and limited maneuvering capability. Some examples are run-of-the-river hydraulic and nuclear generating plants. Peak load generators are best suited to variable power output. These typically have lower capital costs, higher fuelling costs and good maneuvering capability. Some examples are coal fired and gas fired generating plants.

Ontario had 34,882 MW of nameplate capacity, on May 24, 2011(R9). Table 1 below shows a more detailed breakdown by generating type. The Ontario Long Term Energy Plan (R5) indicates the planned capacity of the electrical grid by 2018 and 2030 will be 38,580 MW and 41,900 MW respectively. However, a significant percentage of this capacity (28% and 27% respectively) will be intermittent renewable generation that cannot be depended on to be available on the annual peak demand day in the summer.

Table 1
Present Ontario Electrical Energy Supply (R9)

Generating Station Type	Installed Capacity (May 24, 2011)		Energy Delivered In 2010	Forecast Capacity At Summer 2011 Peak	
Nuclear	**11,446 MW**	**33%**	**55%**	**11,249 MW**	**38%**
Natural Gas	**9,549 MW**	**27%**	**14%**	**7,914 MW**	**27%**
Hydraulic	**7,947 MW**	**23%**	**20%**	**5,809 MW**	**20%**
Coal	**4,484 MW**	**13%**	**8%**	**4,267 MW**	**14%**
Other Renewables	**1,456 MW**	**4%**	**4%**	**226 MW**	**1%**
- Wind	1,334 MW	4%	2%	189 MW	<1%
- Solar	0 MW	see (*)	0%	0 MW	see (*)
- Bioenergy	122 MW	<1%	1%	37 MW	<1%
TOTAL	**34,882 MW**	**100%**	**100%**	**29,465 MW**	**100%**

(*) Note: The data above excludes generation within customer or distribution utility systems such as combined heat and power (CHP), solar and wind that are not part of the IESO administered market.

Base load generating plants in Ontario do not maneuver so their total capacity should ideally be lower than that day's minimum demand. As the data in Figure 1 and Figure 2 above shows, the minimum demand varied throughout the year from 10,799 MW to 16,898 MW. Since large nuclear and fossil fired units require maintenance on a regular basis, we can schedule that maintenance to reduce the SBG but only up to a point. In 2011, 16,898 was the maximum base load capacity we should have had operating at the summer peak day. In fact, in 2011 Table 1 shows the grid had an installed base load generating capacity of over 20,000 MW. Over 11,000 MW was nuclear generation, almost 8,000 MW was hydraulic generation and over 1,300 MW was wind generation. Fortunately not all of that capacity was available so we managed to get through the September 15, 2010 to September 14, 2011period with only 56 nights of negative electricity prices and 15 million dollars of export subsidies.

As we add more wind and hydraulic generation and refurbish or build more nuclear plants the potential SBG will get worse unless we get some significant growth in our customer demand, or we modify our base load plants so they can maneuver their electrical output.

System Utilization

Another growing concern is that the ratio of the summer peak load to the spring minimum load is rising. A flat customer demand profile (both daily and seasonal) is preferred because as the ratio of peak demand to base demand increases, the system becomes less efficient at utilizing generating plants and the average cost of electricity per unit energy (kWh) rises. Figure 1 and Figure 2 above show that Ontario has had some success in flattening the daily load profile from about 11 am to about 9 pm. Unfortunately, the increased use of air conditioning has resulted in a significant difference between summertime day and night demand and between summer and spring demand. A flatter demand profile also reduces the need for peak load generating plants and transmission and distribution capacity that would operate with a low capacity factor and high unit energy cost.

Ontario's electrical demand, as measured by the IESO, has actually fallen about 5% on power demand (MW) and 6% on energy demand (MWh) over the past 5 years. This reduction is due to a number of factors including: conservation efforts, the weak economy and the installation of small generation projects within the lower voltage distribution system that are not part of the IESO administered grid.

In Ontario our base load generating facilities are run-of-the-river hydraulic and nuclear CANDU plants. These facilities were designed to run continuously with preferential access to the demand with little provision for load maneuvering. In the past this was acceptable because there was sufficient demand that there was little surplus base load generation (SBG). However, this situation changed in the mid-1980's as electrical load growth slowed considerably compared to the 1960's and 70's. Also Ontario has added significant new base load generation facilities over the past few years. Today, there are periods of SBG during the year when customer demand drops significantly below the base load generating capacity.

Adding more base load generation such as non-dispatchable wind, and non-maneuverable nuclear or hydraulic generation at this time makes the SBG situation even worse. Unfortunately, SBG will continue to get worse over the next 7 years because of generation that has already been approved. Ontario will add 1,500 MW of refurbished nuclear base load generation in 2012, about 1,000 MW of hydraulic generation and approximately 6,000 MW of base load intermittent wind generation (R4) over the next several years. Some combined heat and power (CHP) and micro-FIT facilities are also expected to be installed over the next several years and they will also contribute to a further reduction in the customer demand that is managed by the IESO.

Unfortunately, Ontario's existing grid is not well suited for a large increase in intermittent wind generation that is prescribed in the province's Long Term Energy Plan (LTEP) without additional investment to manage that intermittency. Some solutions to wind's variability and the growing SBG problem are discussed in section 4 of this report.

3. Wind Generation Performance Characteristics and Concerns

Wind generation is environmentally friendly (when deployed in a manner that addresses local residents' concerns), is easily distributed geographically, and has very low operating costs. Unfortunately, wind generation is intermittent, has a low capacity factor and it delivers its energy when nature provides it rather than when consumers want it. These weaknesses make wind one of the most technically challenging and costly energy sources to integrate into the electrical grid.

Wind generates a significant amount of its energy during low demand hours. This is why wind should be considered a base load generating resource. Wind generation cannot replace coal fired generation from a performance point of view without significant amounts of seasonal hydraulic storage which is not available in Ontario. The required hydraulic dams and reservoirs are very expensive to build – typically about $5,000 to $7,000 per kW (R2) or about double the cost of the wind turbines themselves.

The existing base load generating plants are not presently designed to accommodate such large and rapid changes in load that wind generators require of them. The IESO continues to be concerned about the amount of SBG and the lack of maneuvering capability in base load generation resources. They are also concerned about the current non-dispatch status of wind generation.

Environment Canada data (R12) shows that in Ontario, summer is the lowest wind production season and spring, autumn and winter the highest. Ontario's grid is now a summer peaking grid and spring and autumn are lower demand seasons. This means that the wind is out of step with the actual seasonal electrical demand profile. IESO wind generation production data (R3) also shows that wind tends to blow strongest at night when demand is falling and weakest during the morning when demand is rising. See section A3 in Appendix A for details.

Wind has similar variability across most of southern Ontario where most of the wind turbines are located. There is some smoothing of overall generation variability compared to individual wind turbines over minutes and hours but the daily and seasonal variation must be managed by a backup source of energy. Presently, Ontario is using gas fired generation to provide that backup with a lesser contribution from some hydraulic and nuclear generation that have some limited maneuvering capability.

Because of wind's variability, the remaining generating stations see a residual demand that is much more variable. This means they operate in a much less efficient manner when wind is on-line. The minimum base load demand available to the remaining base load generating plants is lower than the available capacity. There is also insufficient export capability to absorb the surplus energy that will be available when all the wind generation in the LTEP is installed.

Ontario's electrical grid suffers from imbalances created by:

- too much intermittent wind generation, or
- too little nuclear maneuvering, or
- too little storage.

In 2011 we exported approximately 3,500 MW of SBG on one particular day. By 2019 with an additional 4,000 MW of base load generation we could reach over 7,000 MW of SBG if the low electrical demand growth scenario occurs. By 2030 with an additional 8,000 MW of base load generation we could reach over 11,000 MW of SBG for the low growth scenario and over 7,000 MW of SBG for the medium growth scenario. These are large SBG quantities, well beyond our export capability and that suggests a significant frequency and duration of shutdowns for wind or nuclear generation.

During 2011 the SBG problems were managed by the IESO with exports and some limited maneuvering capability at hydraulic stations and Bruce B nuclear station. However, there were 138 hours of negative electricity prices, on 56 evenings in 8 of the months between September 15, 2010 and September 14, 2011. Approximately 15 million dollars of subsidies were paid to our neighbouring grids to take that surplus energy. That occurred with only about 1,400 MW of installed wind generation. By the end of 2018 we will have almost 7,500 MW of installed wind generation.

The SBG situation will get worse and more costly as more wind, hydraulic and nuclear base load generation capacity is added over the next few years unless we shutdown our wind turbines or we make our nuclear plants more maneuverable with respect to their electrical output.

4. Potential Solutions to Wind Generation Variability

Wind variability and the more problematic SBG problem caused by strong winds when customer demand is low can be managed in a number of ways.

Supply side solutions provide grid flexibility so that wind can be integrated effectively. The three primary methods to provide grid flexibility are:

- improving maneuvering capability of the existing generating units,
- improving storage capability on the grid to absorb excess intermittent supply when nature provides it and deliver it when it is needed by consumers,
- Constraining (or dispatching) wind production when the grid cannot accept the energy.

Demand side solutions try to provide a more flexible demand. When wind is available customers draw more power and when wind is not available during the day customers delay their power consumption until the off-peak hours. During off-peak hours the peak load plants can be operated for additional hours to accommodate that demand.

These potential solutions are discussed in more detail below.

Using Hydraulic Maneuvering to Manage Wind Variability

Modifying hydraulic stations to get more maneuvering capability may not be economically viable. Detailed studies can confirm this but qualitatively both wind and hydraulic generation are green and renewable sources of energy. Whether we dispatch wind or hydraulic generation, doesn't matter to the environment. The operating flexibility provided by existing hydraulic stations is being fully utilized. Therefore, dispatching wind is much easier and cheaper to do as compared to the additional costs and complexities that would be required to further maneuver hydraulic stations. Consequently dispatching wind generation to manage SBG should be economically and technically preferable to maneuvering hydraulic generation.

Using Nuclear Steam Bypass to Manage Wind Variability

Nuclear generation is a clean source of energy. Nuclear has sufficient installed capacity in Ontario to manage all the wind variability it they could maneuver their electrical output. The nuclear units would need a robust continuously rated steam bypass system. With nuclear maneuvering, the SBG problem disappears and we get zero GHG emission from both the wind production and its nuclear backup.

The electricity market rules force generators that have high shutdown costs to bid large negative values into the auction process to ensure they are not dispatched off. Typically these are nuclear and hydraulic generators. If however, nuclear plants had robust steam bypass systems, they could offer their true incremental costs of production into the market. If the price fell below that value they would simply maneuver their electrical output down and operate on steam bypass at a much lower cost than a full 2 or 3 day shutdown. The market would operate more efficiently and large negative electricity prices would not occur.

How much would steam bypass cost? It depends on how long the grid is operating in each of the major operating regimes. There are 3 major operating regimes:

- SBG Regime A – where there is not enough load for nuclear irrespective of wind.
- SBG Regime B – where there is not enough demand for both nuclear and wind combined.
- Non-SBG Regime – where there is sufficient demand for all the nuclear and wind.

In SBG Regime A, a steam bypass system eliminates the need for costly nuclear plant shutdowns. Dispatching wind off does not guarantee a solution to the negative electricity price problem when the grid is operating in SBG Regime A. In this regime, wind is not setting the price, nuclear is. Therefore it is important that nuclear is able to dispatch down to avoid a large negative electricity price. A steam bypass system enables nuclear generators to offer a more reasonable price into the market.

In SBG Regime B, a steam bypass system would allow the market the option of either shutting down wind or dispatching nuclear electrical output down. The easy way out is to dispatch wind. But that means the investment in wind generation is wasted. The other option from a broader provincial viewpoint is to give wind priority and force nuclear plants to innovate and provide additional environmental benefits for the province as a whole. If we choose to dispatch nuclear instead of wind, then two other environmental opportunities arise:

- Zero GHG steam is available at the nuclear plants when their steam bypass system are operating to help offset gas fired industrial process steam.
- There is a strong incentive to do the R&D work to enable safe reactor power maneuvering so that we can reduce the amount of nuclear fuel consumption during steam bypass operation.

In the Non-SBG Regime, a steam bypass system would allow nuclear plant capacity to be increased to move into the peak load area of the customer demand profile. This would allow nuclear generation to back up both wind and solar with zero GHG emissions and to offset some gas fired backup and peak generation. It would also allow the maximum amount of wind and solar generation to be increased because the SBG problem would not be the limiting criteria.

There are economic limits to how far nuclear generation can move up into this Non-SBG Regime. The nuclear plant capacity factor would get lower. At some point the environmental benefits would not provide sufficient offsetting compensation for the higher nuclear energy cost compared to gas fired backup. The degree of flatness in the customer load profile will have a significant impact on this breakeven point.

The cumulative costs and environmental benefits provided by nuclear steam bypass are dependent on the number of operating hours in each of the 3 regimes above. These can be studied with reasonable accuracy using system simulation studies using supply, demand and wind data from IESO's data library and OPA financial data. Parametric studies can be done to optimize the cost/benefits for steam bypass capacity.

Steam bypass capability at the nuclear plants provides considerable grid operating flexibility in case planning assumptions do not materialize as expected. It also provides the IESO additional operating options during normal and abnormal operating conditions including system blackout restoration (R28).

Using Gas Fired Generating Plants to Manage Wind Variability

Gas fired generation is the current preferred backup to wind generation to manage its variability because our nuclear plants do not have a robust steam bypass system to allow them to maneuver their electrical output. Gas fired backup does not work at all in SBG Regime A and has limits to what it can do in SBG Regime B. Wind dispatching is required in both SBG Regime A and B if nuclear cannot maneuver its electrical output.

Also, gas fired backup still produces half of the GHG emissions of coal fired generation so it does not meet the objectives of the Green Energy Act with respect to moving our electrical energy supply to zero GHG sources.

Using Bio-Mass Generation to Manage Wind Variability

Ontario Power Generation is currently repowering its Atikokan station to use bio-mass and is making provisions to use bio-mass at its Thunder Bay station that is being converted from coal firing to gas firing (R33). The coal fired plants already have transmission line connections so that is one expense that will be avoided if bio-mass is used as fuel at those facilities. Bio-mass generating plants can maneuvered. They are also carbon neutral so the environment will not be negatively impacted when the appropriate post combustion filtration is installed. Bio-mass should be sustainable from waste streams and not from bio-mass that can be used for food production (including soil nutrients) or building materials. **To the extent that waste bio-mass is available in Ontario it can be used to provide a zero GHG back up to wind and solar generation.** Bio-mass generation is more economical when developed close to its fuel source.

Using Storage to Manage Wind Variability

Storage is an option to manage wind variability. Its advantage is that it does not use either fossil or nuclear fuel.

There are several commercial storage technologies available. Some storage solutions can deliver small to moderate amounts of power transfer (kW to MW) over a short time frame (seconds to days) such as batteries, fuel cells, flywheels, compressed gas, hot fluids, etc. Others are capable of large amounts of power transfer (MW to GW) over very long time frames (days to months) such as dam storage or pumped hydraulic storage. **Unfortunately long term storage, which is often referred to as seasonal storage, is about 10 times more expensive than either gas fired or nuclear backup.** Seasonal storage also has a very significant environmental footprint for the large hydraulic storage reservoirs that are required.

Regardless of the technology used, short term storage is also useful when it is necessary to improve the local distribution system stability (e.g.: voltage control). A number of US utilities are now deploying MW scale short term storage to smooth out the rapid fluctuations that are created by wind and solar output variability inside their distribution systems. Because storage is expensive, it is deployed sparingly where absolutely necessary for electrical voltage stability. Short term storage is not as useful on the high voltage transmission system where the power flows are measured in GW's. Here, large hydraulic storage or generation maneuvering are more practical solutions.

A more detailed description of the storage options can be found in Appendix A, section A4.2.

Dispatching Wind Generation to Manage Wind Variability

Wind generation can easily be dispatched down. However, wind generation cannot be dispatched up beyond the maximum power available in the wind at any moment in time. This means that dispatching wind generation down is not a complete solution to manage wind variability. A dependable backup supply is also required when wind energy falls off below the required dispatch value.

Simply adjusting the rotor angle will reduce the amount of wind energy delivered to the grid. For those wind turbines that have load dispatching capability, dispatching their output down eliminates their contribution to the SBG problem. There are of course economic and environmental consequences. The IESO still needs to pay wind generators not to produce. Also the environmental benefits of wind generation do not materialize if wind generation is turned off too frequently.

In the short term, it will be necessary to dispatch wind down to manage SBG because it takes time to implement other engineering solutions. However, in the longer term the capability to back up wind without GHG emissions will maximize the environmental benefits of wind generation.

Controlling Demand to Manage Wind Variability

Theoretically a mismatch between supply and demand can be eliminated by forcing the demand to equal the supply. This requires the IESO to be able to lower and raise customer demand. This of course is easier said than done because the capability to raise customer demand is currently not available to the IESO.

The OPA and IESO have programs in place to reduce customer demand such as the demand response program and the dispatchable load program. However, these programs are designed to reduce customer demand only when supply is not adequate to meet the demand.

In order to effectively manage wind generation variability the customer loads must be sufficiently flexible that they can directly use or store the energy when the wind is blowing. Those loads need to have some form of storage built in or the ability to displace other fuels such as natural gas. Applications include:

- chilled storage for space air conditioning,
- heated storage for space heating,
- pumping water for municipal or industrial domestic water into storage towers,
- charging of electric plug-in vehicle batteries,
- production of process steam, or
- production of other industrial commodities such as hydrogen gas, etc.

The customer also needs to be able to get their energy during off-peak hours to satisfy their remaining daily energy needs if the wind is weak on any given day.

To make this type of demand flexibility effective at counteracting wind related SBG, more willing customers are needed than the required dispatching amount. The reason is that some customers may not be able to provide a demand on some days because their storage is full or their production is shutdown. A smarter information and control interface are required between the

IESO and the customer facilities. Developments in the smart grid marketplace may result in products that will enable such control in the near future. Also, to attract sufficient interest in this type of IESO direct control of customer demand, it may be necessary to offer customers price incentives and create a new class of customers with special metering functionality. Consequently this is not a simple solution to manage wind variability.

5 Life Cycle Costing

Most utilities now are using life cycle costing as the basis for deciding what technology will be added to the supply. It has different names in different places. Examples include: life cycle costing, levelized unit energy cost or levelized cost of electricity (LCOE) in the international literature. LCOE includes the impact of capacity factor, capital cost, financing costs, fuel costs, operating costs and maintenance costs into the total anticipated costs of the facility recovered via an average cost per unit of energy produced. LCOE is expressed as cents/kWh in North America. LCOE can also include future costs such as carbon taxes, decommissioning costs or long term waste disposal costs.

While LCOE is fairly well understood and established. It is affected significantly by the underlying assumptions used in the analysis. For example, the expected capacity factor of the facility has a significant impact on the LCOE for all facilities. For fuel burning facilities the assumptions for future fuel costs also have a significant impact on LCOE. For higher capital cost plants with long construction schedules such as nuclear and hydraulic plants, the financing discount factor will significantly affect the LCOE. Also projected future costs are important for strategic decisions about energy sources for the future. For example renewable generation costs especially solar PV are dropping faster than expected so what may seem expensive today may be economic tomorrow. Consequently, due diligence is recommended when comparing LCOE numbers to ensure the underlying assumptions are clearly understood and accepted.

Comparisons of LCOE data for several technologies from there recognized sources are provided in Table A5-1 in Appendix A, section A5. In Ontario, the data varies from about 5 cents/kWh for conservation and nuclear refurbishment up to about 80 cents/kWh for solar roof top units.

Significant amounts of SBG will create upward pressure on electricity prices. A long term solution to SBG needs to be found to mitigate an avoidable rise in electricity prices.

Dispatching affects the LCOE of generating plants. Figure 5-1 below demonstrates how LCOE changes with capacity factor changes due to dispatching for solar, wind and nuclear generation with steam bypass.

Figure 5-1 shows that the increase in electricity prices caused by nuclear dispatching (electrical output maneuvering) to accommodate wind is modest. This strategy also provides considerably more room for wind on the electrical grid and no GHG emissions compared to using gas fired backup.

Figure 5-1also shows that if a significant amount of dispatching occurs, the LCOE for wind and solar rises very dramatically to extremely high values. Even if wind and solar are a small fraction of capacity, these very large LCOE values will impact electricity rates significantly.

Figure 5-1
Comparison of Solar, Wind & Nuclear (R2)

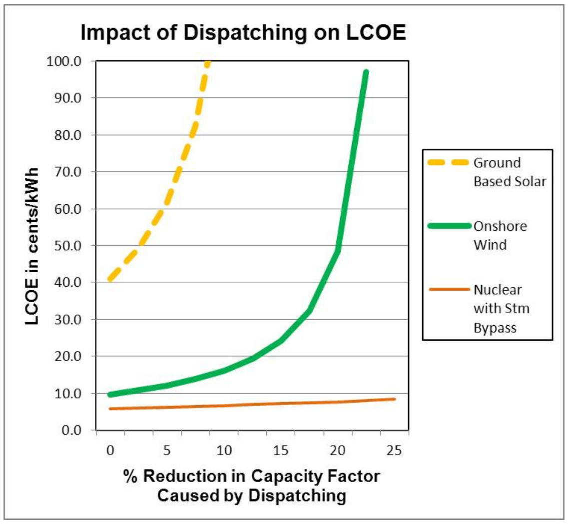
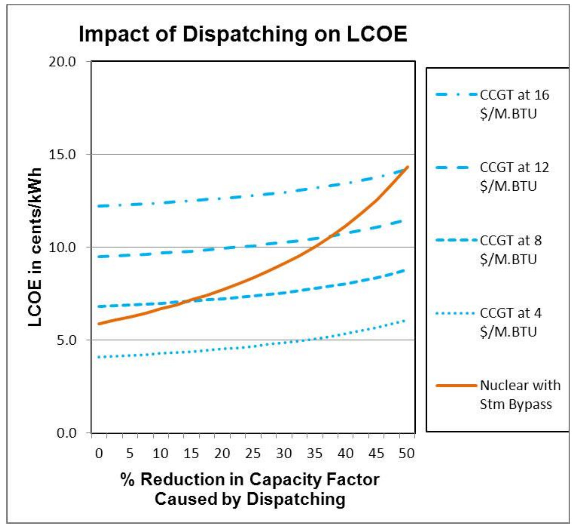


Figure 5-2
Comparison of Gas and Nuclear (R2)



Gas fired generation does not consume fuel for the portion of production that is dispatched down. Consequently its LCOE curves are less steep than for nuclear plants with steam bypass. This means that gas fired generation is better suited to peak load demand that occurs for only a few hours a day. For base load applications such as backup for wind generation where dispatching is limited to at most 25% capacity factor, nuclear plants with steam bypass systems are competitive with gas fired plants if fuel costs are above $8 per million BTU. Figure 5-2 below shows the comparison of LCOE for nuclear and gas generation when they are dispatched. Currently gas prices in Canada are about $4 per million BTU. In Europe they are $12 and in Japan they are about $16. As additional liquefied natural gas transportation capability is developed, the North American prices are expected to rise as gas is diverted to European and Asian markets. Also as carbon taxes or cap and trade is introduced to limit GHG emissions, nuclear generation with steam bypass will become more cost effective.

6. Greenhouse Gas Emissions

One of Ontario's objectives to use renewable energy was to reduce greenhouse gas emissions. Coal fired generation emits about 973 g/kWh of carbon dioxide and gas fired generation emits about 398 g/kWh (R27). Bioenergy, hydraulic and nuclear generating plants are all zero GHG sources of energy. The overall mix of generation technologies in Ontario resulted in a weighted average of about 134 g/kWh of carbon dioxide emissions for electricity production 2010.

One area where we can make further improvements is to substitute a zero GHG emitting energy source to back up wind and solar generation. Bio-mass generation is one option. It is best suited for local production. However, the sustainable quantity of biomass in Ontario is limited. Sustainable bio-mass is the non-usable waste product from various bio-mass sectors. There will be about 7,500 MW of wind generation and 2,400 MW of solar generation by the end of 2018 that will need a backup energy supply (R5).

An alternative option is nuclear generation. However, nuclear needs a robust steam bypass system to allow the generator to maneuver its electrical output without requiring the reactor to change power. There would be a number of potential technical problems and licensing issues that would need to be studied and resolved prior to maneuvering the reactor itself on a daily or minute-to-minute basis. Consequently, we are not recommending that reactor power maneuvering be considered at this time. However, we believe that once steam bypass operations begin, opportunity to make money and reduce wasted energy will drive innovation. Industrial steam loads will be found to make use of the surplus steam, as Ontario Hydro did at the Bruce A site in the mid 1970's. Also, R&D efforts will find ways to safely maneuver the reactor power to reduce nuclear fuel consumption when the steam bypass system is being used.

Nuclear energy should be viewed as a transition fuel. It helps solve our GHG emission problems for the electricity sector now and buys us lots of time to find a way to generate most if not all of our energy needs from affordable renewable sources in the future.

7. Conclusions

General

- Ontario's electrical grid is a very large, complex, dynamic engineered system. It is becoming more complex as the public demands more challenging environmental and economic performance.
- Every energy source has its advantages and disadvantages and each has a legitimate role to play in Ontario's electrical energy future to meet the public's energy and environmental needs.
- Wind's strengths are that it is environmentally friendly (when deployed in a manner that addresses local residents' concerns), it is easily distributed geographically, and it has very low operating costs.
- Wind's weaknesses are that it has a low capacity factor and it produces it's energy when nature provides it rather than when consumers want it. This later weakness makes it one of the more technically difficult and economically costly energy sources to integrate into an existing electrical grid that is already 75% based on hydraulic and nuclear energy.
- We currently have a large amount of excess base load generation in Ontario - some nuclear and most of the wind/gas backup that was recently added.
- Electricity prices are falling to negative values during severe SBG periods.
- The SBG problem is getting worse and we need to find a solution before we reach our export limits of 4,800 MW likely in 2012 or early in 2013.

The Root of the Growing SBG Problem

- When the Green Energy Act was enacted it incorporated policy initiatives used in other jurisdictions that appeared to be working well.
- Unfortunately, Ontario has a very different grid than most other jurisdictions.
- Ontario's grid energy supply was already about 75% clean using hydraulic and nuclear plants, before the Green Energy Act was enacted.
- Ontario's grid has relatively little storage capability.
- Ontario's base load generating facilities have very little maneuvering capability.

- Ontario's grid cannot easily accommodate wind generation without storage or nuclear maneuvering.
- The Green Energy Act made wind generation with no storage highly attractive to investors by paying a premium price for wind energy and made access to the grid easy.
- Wind generation without storage displaces the energy of existing generating plants.
- In Ontario, wind generation during off-peak hours displaces base load hydraulic and nuclear generation which was already in surplus.
- The IESO is in the process of implementing a solution to this problem by dispatching down wind (wasting wind energy). This is a reasonable short term solution under the circumstances.
- A better long term solution is required because wind generation dispatching will result in higher electricity costs with no benefit to the environment for that portion of the wind energy that is wasted.
- The public wants more renewable generation built and we need a long term solution to renewable integration that will allow additional renewable generation to be added.

Opportunity is Knocking – a Zero GHG Grid for Ontario

- By the end of 2018 Ontario's Long Term Energy Plan targets the installation of approximately 7,500 MW of wind generation. The production of such a large amount of variable or intermittent generation can be either a serious economic problem or an opportunity depending on how we respond to the integration challenge.
- Using nuclear generation to backup the variability of wind generation is uniquely available to Ontario because it has large amounts of both nuclear and wind generation on its grid. Ontario's nuclear generation capacity is sufficient to manage all of the nearly 10,000 MW of intermittent renewable generation planned for 2018.
- The benefits would be:
    - A nearly zero GHG emission grid for all of the base demand (excluding gas fired combined heat and power facilities which should proceed due to their high efficiency),
    - No additional transmission lines,
    - No global warming penalties for our industrial production in the future for electricity that comes from hydraulic/nuclear/wind energy,
    - Industrial process steam would be available near our nuclear plants with a zero GHG footprint, and
    - Reduced natural gas demand competition between space and industrial heating loads and electricity production.
- As the economics improve with R&D or changing carbon tax policy, the surplus electrical power could be used directly to produce hydrogen for the industrial or transportation sector.
- Nuclear currently enjoys strong local community support for refurbishment and new build projects in Ontario.
- Nuclear energy creates a far greater number of well educated, high paying, long term, local jobs near the nuclear plants and their supporting industries compared to other forms of energy.
- Once built, nuclear plants have approximately 1/5 to 1/10 the fueling cost of a gas fired plant so future electrical energy prices will be less sensitive to fuel price increases.

Electrical Grid Planning

- The intermittent nature of wind requires that it be explicitly and effectively integrated into the existing grid.
- While social, economic, environmental and political goals can be included as requirements, the actual design and operation of the electrical grid must be based on established power engineering principles so that mandatory technical performance requirements will be met.
- The present grid operating problems related to wind integration demonstrate that additional engineering studies, benchmarking and Ontario specific power engineering expertise should have been included in the implementation planning for wind generation.
- Ontario's electrical grid suffers from:
  - too much intermittent wind generation, or
  - too little nuclear maneuvering, or
  - too little storage.
- The present electricity market price instability during surplus SBG periods will get worse as more wind generation is added if it is not effectively integrated.
- The massive buildup of wind generation (7,500 MW by the end of 2018), while well intentioned, ignores the performance challenges wind generation places on existing base load hydraulic and nuclear generation facilities. The existing facilities have not been designed to cope with the new maneuvering demands imposed by wind generation. Either the existing base load facilities need to be modified to better integrate with wind generation or substantial storage capacity needs to be added to the grid or wind needs to be dispatched down thereby wasting a portion of the investment.
- Current IESO plans to dispatch wind will help to alleviate the technical performance problems. However, dispatching wind frequently, in the absence of other planning and control actions, will result in wind becoming uneconomic in Ontario as wind capacity increases as a share of total generation.

Some Surprises

- As wind production increases, GHG emissions will increase for the base load component of electrical power production in Ontario. This will occur because gas fired backup generation for wind will begin to occupy a larger share of base load generation.
- The shutdown of nuclear generation during severe SBG periods can result in energy shortfalls the following 2 or 3 days during peak demand hours. This could necessitate importing relatively expensive power from neighbouring grids. This would drive up electricity rates.
- Strong winds during low customer demand periods create severe SBG conditions. This drives electricity prices negative and Ontario consumers subsidize energy sales to consumers in Quebec, New York and Michigan.
- The public believes that wind generation is replacing coal fired generation in Ontario. This is not the case because coal is a peak load supply and wind is a base load supply.
- Ontario has a different contractual arrangement with OPG for nuclear and hydraulic generation compared to private generators. OPG does not get paid if it bypasses steam at its nuclear plants when it gets dispatched down, but Bruce Power that leases the Bruce B plant from OPG does. Because OPG gets paid more for nuclear power than for hydraulic power it is more economic for OPG to spill hydraulic energy, for example at Niagara Falls, rather than modify its Darlington reactors to be able to

reduce their electrical output. Bruce Power on the other hand has improved its Bruce B steam bypass system and can offer some limited assistance to the IESO when severe SBG conditions are present.

8. Recommendations

OSPE proposes that the Minister of Energy authorize detailed engineering studies to:

1. Determine the extent of the SBG problem over the same planning horizon as the Long Term Energy Plan (LTEP) and make those findings public as part of the Integrated Power System Plan (IPSP).

2. Determine the long term sustainable volume of biomass available in Ontario to provide zero GHG backup generation for our intermittent renewables fleet.

3. Determine the economic feasibility of incorporating electrical output maneuverability at our nuclear plants to eliminate the SBG problem and to provide zero GHG backup to our intermittent renewables fleet.

4. Determine if there are sufficient customer loads that can accommodate energy use patterns that match the energy production pattern of intermittent generation in combination with off-peak supply availability. If sufficient customer loads are identified then determine how best to enable the IESO to manage that load in order to reduce the amount of backup generation required for the intermittent renewables fleet. If this proves fruitful, undertake a pilot program to fine tune the program before it is launched more broadly in the marketplace.

OSPE also proposes that the Minister of Energy establish guidelines for the Ministry of Energy and its related agencies that will ensure appropriate engineering expertise is included during the development of policies, directives and implementation plans of technically complex programs and projects.

OSPE recommends that the Ministry of Energy undertakes a study into alternative pricing models for wind generation that do not require the measurement of the energy that is <u>not</u> produced during dispatching. The objective is to simplify the measurement and settlement process before wind dispatching becomes operational.

OSPE recommends that OPG contract conditions for their regulated nuclear and hydraulic plants should be reviewed with a view to improving consistency with their private sector competitors. Currently OPG is treated differently than private generators with respect to how they get paid when their regulated nuclear and hydraulic facilities are dispatched down. This leads to decisions at OPG that are not consistent with private sector responses to dispatch requests by the IESO.

OSPE recommends that the present approach of approving capacity and energy charges be reviewed. The OPA approves private contracts in a confidential process. The OEB approves OPG regulated generation contracts in a public process. The wholesale market has evolved into marginal cost of production market. The capacity charges are built into a global adjustment charge separate from the wholesale market price setting mechanism. Effectively, OPA administered contracts are a government regulated charge on electricity prices without the benefit of a public review. OPG's share of the electricity market has dropped significantly since the mid 1990's. Consequently, there is less justification now for OPG to be treated differently than their competitors.

Flattening the daily demand profile and the seasonal variation of demand will significantly improve the economic and environmental efficiency of the electrical grid including reducing the amount of SBG. Recommendations to help achieve this will be included in a future report by OSPE's Energy Task Force when it reviews the Integrated Power System Plan in more detail.

9. Abbreviations

Abbreviations can be found in section A7 in Appendix A.

10. References

References can be found in section A8 in Appendix A.

11. Acknowledgements

OSPE is grateful to the following individuals who have provided comments on the draft version of this document:

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- Michael Monette, P. Eng.
- Marius Vartolomei, P. Eng.
- Laszlo Zsidai, P. Eng.
- Kristian Kennedy, OSPE Staff
- Edwina McGroddy, OSPE Staff

Appendix A - Technical Data and Analysis Results

A1. Ontario's Electrical Grid

Ontario's electrical "grid" (generation, transmission, inter-grid connections, distribution, customer connections and related control facilities) is a very large, complex, dynamic engineered system. It is becoming more complex as the public demands more challenging environmental and economic performance.

Ontario has interconnections to neighbouring electrical grids in Manitoba, Minnesota, Michigan, New York and Quebec. The interconnections improve reliability due to the supply/demand support that is available from neighbours during system disturbances. The interconnections also provide a means to import or export power for economic reasons. While the theoretical import/export capability is over 6,000 MW the system configuration is rarely in the optimum state so the practical maximum transfer capability is closer to 4,800 MW (R22) provided all neighbouring grids are willing to accept our power at the same time.

Electricity prices are set in the wholesale market for large consumers and under an OEB approved regulated price plan for retail consumers. Details can be found at the IESO website for those interested in more details of the various pricing options that each category of consumer has available. The wholesale price is adjusted by a global adjustment to ensure the total cost of power paid to regulated suppliers that have defined price contracts with the OPA are fully recovered from the various consumers of electricity in Ontario. Recently the wholesale price has averaged slightly above 3 cents per kWh and the global adjustment has averaged slightly below 4 cents/kWh. Consequently the total average cost of electricity in Ontario for the energy portion of the bill is just over 7 cents/kWh (R21). The wholesale price in effect is the incremental cost of putting the next unit of energy on the grid. The global adjustment represents the cost to build capacity, to pay for the subsidies needed to encourage renewable generation development and to export surplus energy at a loss.

The description below of how the wholesale electricity market operates is provided courtesy of the IESO (R20).

Running Ontario's power system and the wholesale electricity market is a 24-hour operation, with offers to supply electricity coming in and prices being set every five minutes. Here's a step-by step explanation of how Ontario's IESO maintains a reliable supply of electricity and, at the same time, determines the wholesale price of electricity.

Step 1 - How much electricity do we need?

Each day, the IESO issues forecasts of how much energy will be needed throughout the following day and up to the month ahead - including an "energy reserve," of roughly 1400 MW above what is actually consumed. This is extra supply that is on standby and called upon in emergencies. These forecasts are continually updated as new information comes in -- such as changes in weather. Typically, the IESO's day-ahead forecasts are highly accurate, with less than a two per cent variance from the actual demand figures.

Step 2 - Let the bidding begin.

Generators and importers of electricity review the forecast information and determine how much electricity they can supply and at what price. They send these "offers" to supply electricity into the IESO. Similarly, large-volume consumers of electricity that have the ability to change their consumption patterns on very short notice decide whether there are times of the day when they can cut back on energy use, and offer that into the market as well.

Step 3 - Matching Supply with Demand.

The IESO then matches the offers to supply electricity against the forecasted demand. It first accepts the lowest priced offers and then "stacks" up the higher priced offers until enough have been accepted to meet customer demands. All suppliers are paid the same price - the market-clearing price. This is based on the last offer accepted. This "stacked" price approach encourages generators to keep their offer prices low in expectation of selling all or most of their potential energy output at the prevailing market price. Without the stacked market-clearing price, the overall result could be a much more volatile marketplace. The Market Clearing Price approach ensures the lowest possible price while maintaining reliability of the system.

Step 4 - The Price is Set.

The IESO collects bids and offers until two hours before the energy is needed, so called "pre-dispatch" prices, or the price of electricity before the bidding window has closed, can fluctuate as new bids come in. The IESO will issue its instructions to power suppliers based on the winning bids, who then provide electricity into the power system for transmission and distribution to customers. The IESO runs a real-time market, meaning purchases of electricity are made as they are needed.

There are occasions, when the best priced energy may not be available due to limitations on the transmission lines. In this case, that generator's offer is still used to help set the price, but another generator may be asked to provide the electricity.

The market works on the principles of supply and demand. When there is tight supply and high demand, the wholesale price can be expected to be higher than average. Demand is also affected by weather and human behaviour. By reducing demand, customers save money on their own electricity bills and help lower the wholesale price of electricity. Supply is determined by the operating capability of existing generators as well as when planned generation comes into service.

Authors Note: It is important to realize that if the customer demand in Ontario is very low, generators will be dispatched to zero if the market price falls below their offer price. Those generators that cannot shutdown for technical reasons (hydraulic) or economic reasons (nuclear) are forced by the bidding process to lower their price sufficiently so that someone (a neighbouring grid) will be persuaded to take the available energy at a price above their offer price. Under severe surplus base load generation conditions, the offer prices can be driven into negative values as constrained generators lower their offer price to ensure they are selected to stay on-line. The negative price means that the IESO must pay our neighbouring grids to export power to them. The cost is passed on to customers through the global adjustment because many of these generators have guaranteed regulated prices for their energy regardless of the market price.

A2. Electrical Grid Supply and Demand

Every energy source has its advantages and disadvantages and each has a legitimate role to play in Ontario's electrical energy future if we are to meet the public's energy and environmental needs. The key to doing it right in a complex electrical grid is to get the engineering right. We need to use the various energy sources in ways that play to their strengths and minimizes their weaknesses. In that way all these sources with their differing performance characteristics can live harmoniously on the same electrical grid. In most cases, some engineering needs to be done to ensure each energy source can be integrated effectively into the grid, especially as the grid becomes more complex. Wind generation is no exception.

The Ontario electrical grid is among the cleanest electrical grids in the world. That was true even before the introduction of wind and solar technology. The reason is that Ontario chose to invest primarily in hydraulic and nuclear generation for base load generation. Coal and gas fired generation were used primarily for peak demand in more recent years. Ontario had 34,882 MW of nameplate capacity, on May 24, 2011 (R9, R16), with the breakdown shown in Table A2-1 below. The capacity that is available to meet the summer peak demand is lower than the rated capacity for most generators. Nuclear and coal fired plants are de-rated when lake water temperatures are high. Gas turbine plants are de-rated when air temperatures are high. Hydraulic plants are de-rated when water run-off is low. Wind turbines are de-rated when wind speed is low and solar plants are de-rated when there is reduced sunshine. There may also be plants that are shutdown for repairs. The 2011 forecast of dependable capacity available to meet the summer peak demand is show in the right column of Table A2-1.

Table A2-1
Present Ontario Electrical Energy Supply

Generating Station Type	Installed Capacity (May 24, 2011)		Energy Delivered In 2010	Forecast Capacity At Summer 2011 Peak	
Nuclear	**11,446 MW**	**33%**	**55%**	**11,249 MW**	**38%**
Natural Gas	**9,549 MW**	**27%**	**14%**	**7,914 MW**	**27%**
Hydraulic	**7,947 MW**	**23%**	**20%**	**5,809 MW**	**20%**
Coal	**4,484 MW**	**13%**	**8%**	**4,267 MW**	**14%**
Other Renewables	**1,456 MW**	**4%**	**4%**	**226 MW**	**1%**
- Wind	1,334 MW	4%	2%	189 MW	<1%
- Solar	0 MW	see note	0%	0 MW	see note
- Bioenergy	122 MW	<1%	1%	37 MW	<1%
TOTAL	**34,882 MW**	**100%**	**100%**	**29,465 MW**	**100%**

Note: data above excludes generation within customer or distribution utility systems such as combined heat and power (CHP), solar and wind that are not part of the IESO administered market.

The Ontario Long Term Energy Plan (R5) outlines the planned capacity of the electrical grid by 2018 and 2030. Table A2-2 summarizes that future capacity data.

Table A2-2
Future Ontario Electrical Energy Supply

Energy Source	Installed Capacity (Dec 31, 2018)		Installed Capacity (Dec 31, 2030)	
Nuclear	**8,507 MW**	**22%**	12,000 MW	29%
Natural Gas	**10,373 MW**	**27%**	10,100 MW	24%
Hydraulic	**9,000 MW**	**23%**	9,000 MW	20%
Coal	**0 MW**	**0%**	0 MW	0%
Other Renewables	**10,700 MW**	**28%**	10,700 MW	27%
- Wind	7,500 MW	(see note 2)	7,500 MW	(see note 2)
- Solar	2,400 MW	(see note 2)	2,400 MW	(see note 2)
- Bioenergy	800 MW	(see note 2)	800 MW	(see note 2)
TOTAL	**38,580 MW**	**100%**	**41,900 MW**	**100%**

Note 1: the data above excludes generation within customer or distribution utility systems such as CHP, solar and wind that are not part of the IESO administered market.

Note 2: the final breakdown of the 10,700 MW of renewables was not specified in the OPA 2011 IPSP. The data above has been estimated based on using the same ratio of renewables for the 10,700 MW as that identified in the list of the existing, committed and directed projects in the IPSP Planning and Consultation Overview, Table 4, page 3-14 (R4).

Note 3: the drop in nuclear capacity in 2018 is due to Pickering retirement and refurbishment programs at the other nuclear plants.

In order to understand the impact of wind generation on the electrical grid and the problems that can be created by poor integration of wind generation we need to have a basic understanding of how the electrical grid works. Wind generation does not operate in isolation of other supply facilities.

Electricity cannot be stored directly and economically in large quantities in Ontario with the present state of technology. As a result the electrical grid is operated in a manner that balances the supply and demand of electricity on a moment-to-moment basis. Any sustained imbalance in supply-demand will cause the grid frequency (normally at 60 cycles per second) to speed up or slow down until safety parameters are reached which trigger the shutdown of equipment on the grid to prevent permanent damage. If the imbalance is large, the rapid change in frequency will create a cascade of equipment shutdowns that can end in a total grid collapse and a widespread blackout. This is what effectively happened in August 2003 when the north eastern Canadian-USA grid collapsed and created a blackout affecting some 50 million people.

Ontario's grid is part of a large interconnected set of regional grids. When there is a supply/demand imbalance in Ontario, power flows into or out of our neighbouring grids before the prevailing frequency of 60 Hertz changes. There are limits on the maximum amount of power that can be transferred, without the other party's agreement. Therefore the IESO must maintain a reasonably tight supply/demand balance within Ontario's own grid.

Also, North American utilities all subscribe to the philosophy that consumer demand should not be interrupted unless there is a crisis on the electrical grid. Consequently, most day-to-day control efforts by system operators are directed at managing supply to match the demands of consumers at all times.

The control of supply is managed in three ways:

- Changes that occur within seconds are too fast for human control so they are managed by automatic speed governor controls at all generating stations. Most plants incorporate a small dead-band near 60 Hertz to ensure the speed governor controls are not actuated during normal grid operating conditions. The amount of additional generation that can be provided by speed governor action is limited because many plants operate at all times near their full load operating point and others cannot change load by large amounts without reaching safety parameters that will shut the plant down.
- Slower changes that occur within several minutes are also too fast for human control so they are managed by automatic generation control (AGC) loops - typically one per regional grid. Ontario has one AGC loop that can maneuver the output of several generating units to automatically manage the grid's supply/demand balance to control both frequency and power transfers between neighbouring grids. Maintaining these units at part load to assist with AGC control is expensive so the amount of AGC control that is available at any moment is also limited.
- Changes that occur more slowly than several minutes are managed manually by humans with support from computerized dispatching programs that can send dispatching commands to various generating stations every 5 minutes. The commands are received by the generating unit operator who then manually maneuvers the unit to the required power level. Each unit's capabilities including magnitude, rate and direction of change are programmed into the dispatch program so that only safe demands for a power change are sent to the generating station operators.

It is important to note that the preferred sequence of controlling supply is the reverse of that listed above. The IESO first relies on manual dispatch to minimize the burden on AGC control. Then AGC automatically manages the imbalance in supply by monitoring both frequency and interconnection transfer errors and adjusting supply to ensure the station speed governor control is not relied upon during normal operations. As a result, speed governor control is normally only relied upon to help manage more serious grid disturbances.

The speed and magnitude at which a specific generating station can change output depends on various engineering design factors for that facility. Typically, nuclear units do not participate in load maneuvering, fossil fired plants maneuver at about 2% of full power per minute and hydraulic plants maneuver at 5% or more per minute. Faster maneuvering rates for all plant types can be engineered but at higher capital and operating cost.

Another important consideration in grid operation is the current policy in North America of allowing wind turbines to generate all their output without dispatching restrictions (R19). They have priority access to the grid for the purposes of generating power. This has been done for two reasons. Firstly, if you don't capture the energy when nature provides it, then you lose it. Secondly, wind turbines have a high installed capital cost of typically $2,500 to $3,500 per kW (R13) and low capacity factor of 25% in Ontario (R3). If you don't generate power when nature provides it then the capacity factors drop further and the average price per unit of energy goes up very rapidly. If a significant amount of dispatching is imposed on wind generators they effectively become uneconomic because the required additional price subsidies that would be needed would be difficult to justify to consumers or taxpayers.

This preferred access policy places heavier demands on the remaining generating facilities and the system operators to maintain a balance in total supply-demand when both customer demand and wind/solar generation is changing. To make matters worse, the rapid changes in customer demand during the daily load pickup and dropout often coincides with the opposite dropout and pickup respectively of wind and solar generation. This makes the imbalance that must be counteracted by the remaining generating stations much worse.

The IESO has hesitated from dispatching wind and solar generation in the past for the reasons mentioned above. However, Ontario has decided to continue to invest in intermittent wind and solar sources of energy. The additional quantities that are planned (6,000 MW for wind and 2,400 MW for solar) over the next several years is greater than what the existing generation plants can accommodate. Also, no nuclear generator owner has voluntarily offered to modify their plants to accept deep, fast and continuous load maneuvers. Consequently, the IESO has correctly identified that they need the ability to control wind output otherwise the grid will not be controllable in the future. The IESO has requested and is in the process of obtaining authority and establishing market rules and procedures to dispatch wind generation. Dispatching will essentially force wind generators to back down when the grid cannot accept the available wind power.

To get an appreciation for the difficulty in balancing supply and demand, we can compare the highest load day (typically hot summer day) with the lowest load day (typically a holiday weekend in the spring) during the September 2010 to September 2011 period. Below, Table A2-3 compares the data and Figures A2-1 and A2-2 show the data graphically.

Table A2-3
Comparison of the Highest and Lowest Demand Days in 2011

Item	May 23, 2011 (lowest Ontario demand)	July 21, 2011 (highest Ontario demand)
Minimum Ontario Demand	10,799 MW at 05:00 hours	16,898 MW at 04:00 hours
Maximum Ontario Demand	15,193 MW at 19:00 hours	25,450 MW at 16:00 hours
Base Portion of Demand	10,799 MW	16,898 MW
Peak Portion of Demand	4,394 MW	8,552 MW

Note: The hourly market data was obtained from the IESO website (R3).

Generating facilities fall into two categories:

- plants best suited for base load operation. Some examples are run-of-the-river hydraulic and nuclear generating plants.
- plants best suited for peak load operation. Some examples are coal fired and gas fired generating plants.

Figure A2-1
Lowest Demand Day in 2011

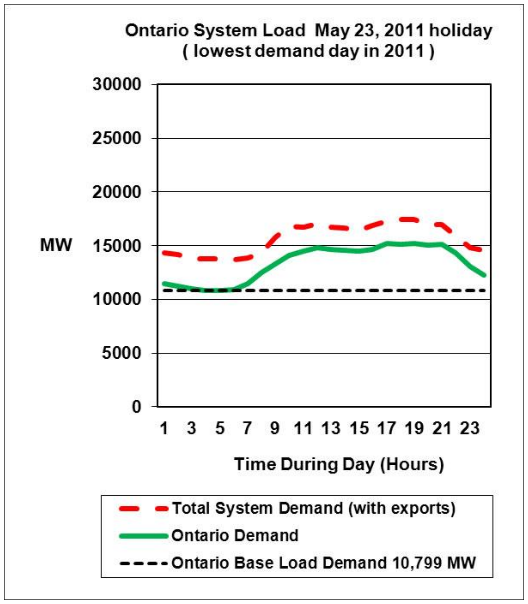
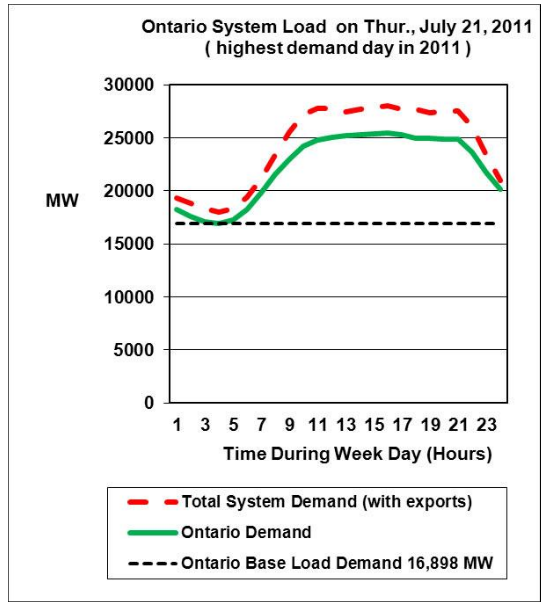


Figure A2-2
Highest Demand Day in 2011



Demand can be met by either base load facilities or peak load facilities. Base load facilities are designed to operate at high power for extended periods of time. They typically deliver the lowest unit energy cost because they operate at maximum efficiency and at maximum capacity factor. Peak load facilities are designed to be more maneuverable to match changes in customer demand. Consequently they operate at lower capacity factors.

To optimize overall energy costs, a combination of base load and peak load generating plants are installed on most electrical grids. Seasonal variations in demand can be managed by careful planning of generating station annual maintenance outages. This means it is more economic to install more base load generating plants than the yearly minimum daily base load demand (10,799 MW in our case in 2011). However, if too much base load generation is installed, there will be frequent periods of excess or surplus base load generation (SBG). The SBG can be exported, or wasted (spilling water, or dumping steam), or some of the base load stations can be shut down. However, frequent shutdowns can cause significant wear and tear and life consumption for base load stations. Also some base load stations such as nuclear cannot restart for up to 3 days if they are shutdown. That means the customer demand for the next 2 or 3 days has to be supplied by other plants. If demand during the subsequent 2 or 3 days is high, there could be a power shortage.

Prior to 2000, the Ontario grid was a winter peaking grid. That means the highest electrical demand occurred in winter. However, over the past 20 - 30 years consumers have become more dependent on air conditioning in the summer. Ontario is now a summer peaking grid much like the US grids. Table A2-4 below compares the data for winter and summer peak demands for 2011 and Figures A2-3 and A2-4 show the data graphically.

The data in Table A2-4 shows the peak portion of the load in winter is 5,932 MW but in summer it rises to 8,552 MW. That means that nearly 2,600 MW of additional peak generating capacity needs to be available to supply the summer peak demand.

Table A2-4

Comparison of the Summer and Winter Peak Days

Item	**Jan 24, 2011 (highest winter peak)**	**July 21, 2011 (highest summer peak)**
Minimum Ontario Demand	16,801 MW at 03:00 hours	16,898 MW at 04:00 hours
Maximum Ontario Demand	22,733 MW at 19:00 hours	25,450 MW at 16:00 hours
Base Portion of Demand	16,801 MW	16,898 MW
Peak Portion of Demand	5,932 MW	8,552 MW

Note: The hourly market data was obtained from IESO website (R3).

Figure A2-3
Winter Peak Demand Day in 2011

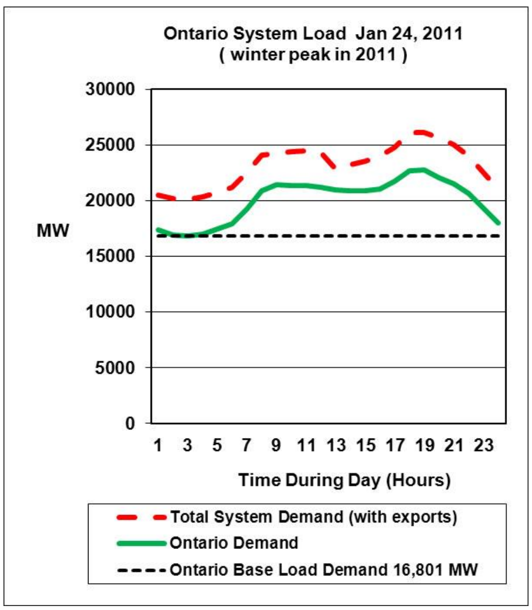
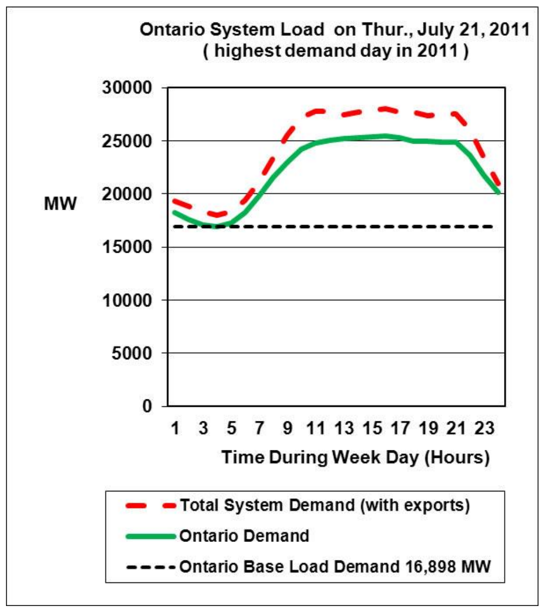


Figure A2-4
Summer Peak Demand Day in 2011



Ontario was expecting a small annual growth in energy demand over the past several years. This growth did not materialize partly due to conservation efforts and partly due to the weak economy. In fact the peak customer demand over the past 5 years has actually dropped by over 5% or 1,500 MW and the total annual energy demand has dropped by 6% or 9 TWh (R10). It should also be noted that some of this drop is due to small embedded generation that has been installed in customer facilities or in distribution system facilities and that does not participate in the IESO administered electricity market. The impact of this imbedded generation as seen by the IESO is a lower customer demand.

Ontario has added significant new base load generation facilities over the past few years. SBG will get worse over the next 7 years. Ontario will add 1,500 MW of nuclear base load generation when 2 Bruce A units return to service next year, about 1,000 MW of hydraulic generation and approximately 6,000 MW of base load intermittent wind generation (R4). Some combined heat and power (CHP) and micro-FIT facilities that are expected over the next several years will also contribute to a further reduction in the customer demand managed by the IESO.

Another complication is the fact that some gas fired generating facilities have proven to be less maneuverable than the coal fired stations they replaced. Gas fired generators have difficulty reducing power quickly by more than 50%. This means that any wind or solar generation that needs to be backed up by gas fired generation will result in a non-maneuverable base load generation component of up to 50% of that intermittent generation. In other words, fired gas generation comes with a significant base load component that must be planned for. This situation is expected to get worse when the remaining 4,484 MW of coal fired generation is removed from service by 2014.

A flat customer demand profile (both daily and seasonal) is preferred because as the ratio of peak demand to base demand increases, the system becomes less efficient at utilizing generation facilities and the average cost of electricity per unit energy (kWh) rises. Figure A2-4 above shows that Ontario has had some success in flattening the daily load profile during on-peak hours. Unfortunately, the increased used of air conditioning has resulted in a significant variation between summertime day and night demand and between spring and summer demand.

The shape of the demand profile is also important when deciding what types of renewable energy sources are best for the Ontario grid. Solar is a peak generation resource because it only produces power during peak hours. Wind on the other hand is a base generation resource because much of the energy is produced during non-peak hours and primarily during fall, winter and spring. In fact the OPA (R4) only considers that a maximum of 12 to16 % of installed wind generation capacity can be depended upon to meet the peak demand in the summer. In comparison, about 35 to 55% of solar generation can be depended upon.

After 2014, gas fired generation plants will be the primary source of peak generation supplemented by some hydraulic and bioenergy generation that is capable of raising output during peak hours. Wind and solar generation, to the extent they are available, also are used to meet peak loads. However, wind and solar must be backed up by some form of dependable and maneuverable generation.

In Ontario our base load generating facilities are run-of-the-river hydraulic and nuclear CANDU plants. These facilities were designed to run continuously with preferential access to the demand with little engineering provision for load maneuvering. In the past this was acceptable because there was sufficient demand that there was little surplus base load generation (SBG). However, this situation changed in the mid-1980’s as electrical load growth slowed considerably compared to the 1960’s and 70’s. Today, there are periods of SBG during the year when customer demand drops significantly below the base load generating capacity. Adding base load wind generation at this time makes the SBG situation even worse.

Ontario has relatively modest “usable” hydraulic storage upstream of its dams and there is only one relatively small pumped hydraulic storage facility at Niagara Falls. Consequently, Ontario is one of the least favourable electrical grids in the world to introduce wind generation. This situation can be changed by suitable investments to make the existing base load facilities more maneuverable or investing in significant amounts of storage (dam storage or pumped hydraulic storage). These options unfortunately increase the actual costs to consumers of introducing wind generation into the grid.

Installing large quantities of wind generation capacity without proper integration of those facilities will simply force the IESO to dispatch down wind generation to maintain technical performance standards that must be met. "Dispatch down" is just fancy grid terminology for paying wind turbine owners not to produce power. If this dispatching down occurs too often it will result in a waste of the financial investments in wind generation and distribution system upgrades and a waste of a clean renewable energy resource.

The sad truth is that Ontario's existing grid is not well suited for a large increase in intermittent wind generation that is prescribed in the province's Long Term Energy Plan (LTEP) without additional investment to manage that intermittency.

A3. Wind's Impact on the Grid

Wind's strengths are that it is environmentally friendly (when deployed in a manner that addresses local residents' concerns), it is easily distributed geographically, and it has very low operating costs.

Wind's weaknesses are that it has a low capacity factor and it delivers its energy when nature provides it rather than when consumers want it. This later weakness makes it one of the more technically difficult and costly energy sources to integrate into the electrical grid.

Wind generates a significant amount of its energy during low demand hours. This is why wind should be considered a base load generating resource. The popular notion that wind is replacing coal fired generation in Ontario is simply not correct. Wind generation cannot replace coal fired generation from a performance point of view without significant amounts of seasonal hydraulic storage which is not available in Ontario and is very expensive to add.

The existing base load generating plants are not presently designed to accommodate such large and rapid changes in load that wind generators can impose on them. The IESO continues to be concerned about the amount of SBG and the lack of maneuvering capability in base load generation resources. The IESO and the Market Surveillance Panel (R34) are also concerned about the current non-dispatch status of wind generation. In their September 2011, 18 Month Outlook, the IESO stated (R23):

> *"Surplus base load generation (SBG) remains an ongoing concern for the IESO. Throughout the fall of 2011, Ontario can expect periods of SBG similar to 2009 and 2010. There should be a brief reprieve during the higher demand winter months, followed by a re-appearance of surplus conditions in spring 2012. Maximum flexibility from all resources is imperative to successfully managing operations and costs, and having this option available for renewable resources will help the IESO manage SBG when renewable generation is high."*
>
> *"The IESO is currently working with stakeholders to address potential future operability issues associated with the growing amount of renewable resources expected to come into service over the next few years."*

> *"A low demand period with heavy winds, during freshet with neighbours either unwilling or unable to take our exports may lead to a nuclear unit shutdown, which in turn would cause that generation to be unavailable for 48 to 72 hours."*
>
> *"With wind and solar becoming more prominent resources on our system, the need for maximum flexibility from all resources has become integral for the reliable and efficient operation of the grid."*

Before we get into details of how to integrate wind production with other generating sources to meet consumer demands, let us look at when the wind blows.

When Does the Wind Blow ?

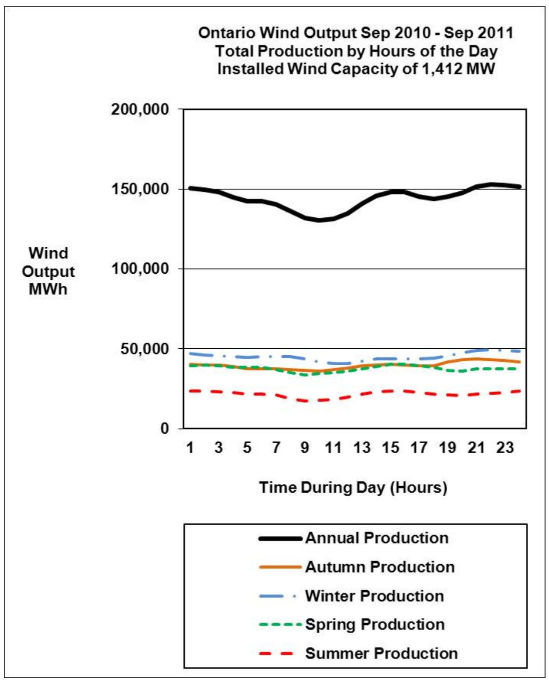
Environment Canada data (R12) shows that in Ontario, summer is the lowest wind production season and spring, autumn and winter the highest. Ontario's grid is now a summer peaking grid and spring and autumn are lower demand seasons (R3, R10). This means that the wind is out of step with the actual seasonal electrical demand profile.

Figure A3-1 to the right shows the cumulative production from approximately 1,400 MW of wind generation capacity in Ontario from September 21, 2010 through to September 20, 2011 by the hours of the day that the production is delivered. Figure A3-1 also shows the seasonal production differences. Figure A3-1 does not show the worst case daily variations.

Figure A3-1 identifies two of the problems with wind generation that the IESO needs to manage:

(1) summer is a high customer demand season but wind generation drops to about half that for the other 3 seasons.
(2) wind blows stronger at night when customer demand is low and drops off during the morning when customer demand is rising.

Figure A3-1
Ontario Cumulative Wind Output by Hours of the Day



Both daily and seasonal storage are needed to better align wind production with customer demand. Seasonal storage is much more expensive and has a much greater environmental footprint. Dam storage at existing hydraulic stations is superior to separate pumped hydraulic storage stations because it doesn't suffer from energy conversion losses.

There is not much energy in falling water so you need very large flows and significant elevation drops to get thousands of MW's of hydraulic storage capacity. You also need to transport the power to and from the storage reservoir so large high voltage transmission lines are also required.

Wind's Geographical Variability

Supporters of wind generation have long maintained and still believe that wind generator output variability in one area of the province will be smoothed out by opposite wind generator output variability in another area. This is a perceived benefit of geographically distributing the wind generators across the province. Actual operating data from Ontario's wind farms supports this view over short time periods (minutes and hours) but does not over a longer period of time (daily or seasonal).

Ontario and its adjoining provinces and US states are simply not large enough in geographical terms to achieve an effective smoothing of the wind generation output over periods of days to months. This means that Ontario and its neighbouring grids experience similar wind conditions simultaneously. This consistency in wind conditions at most locations around the Great Lakes can be illustrated with Environment Canada data shown for 4 monitoring stations in Figures A3-2 through A3-5 below. The 4 monitoring locations are near Ontario wind farms in southern Ontario in an area about 500 km by 200 km where most of Ontario's wind farms are currently located.

Figure A3-2
Windsor Wind Speed Map
(near Gosfield Wind Farm, 51 MW)

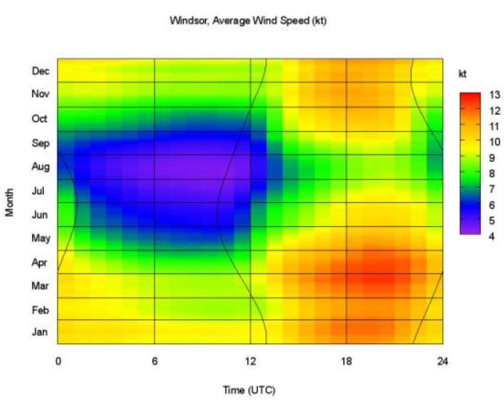


Figure A3-3
London Wind Speed Map
(near Spense Wind Farm, 99 MW)

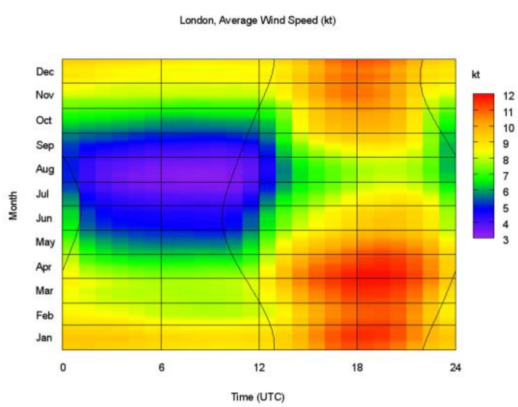


Figure A3-4
Wiarton Wind Speed Map
(near Underwood Wind Farm, 181 MW)

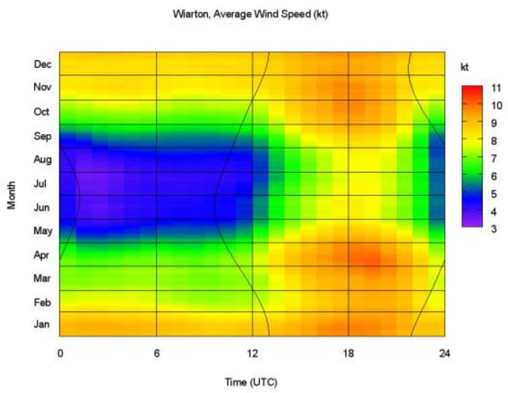
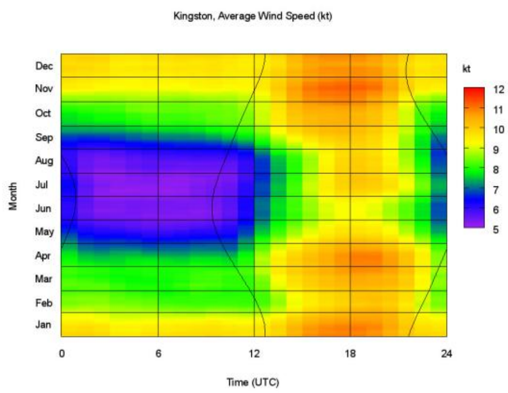


Figure A3-5
Kingston Wind Speed Map
(near Wolfe Island Wind Farm, 198 MW)



The violet and blue colours in the figures (dark colours in a black and white print) indicate poor average wind speed. The green and yellow indicate moderate average wind speed. The orange and red indicate high average wind speed. The bottom of the maps represents January 1 of the year, the top of the maps represents December 31. The left hand side is midnight, the center is noon and the right side is the following midnight. The shape of the graphs are similar which means that all four areas of the province experience similar average wind conditions, namely:

- Poor wind in the summer months especially in the early hours of the day
- Moderate wind conditions in the spring and fall during the early hours of the day
- Good wind conditions in the winter months
- Good wind conditions in the spring and fall during the afternoon and evening hours

It is important to note that these wind conditions are the opposite of the present customer demand profile. Customer demand is highest in the summer months and lowest in the spring and fall months. Also, hydraulic generation tends to be highest during the spring freshet when snow is melting.

Wind's Hourly and Seasonal Variability

For the examples that follow, we have assumed the low demand growth scenario and an increase in wind generation capacity from 1,400 MW in 2011 to 7,500 MW by the end of 2018 as indicated in the LTEP and 2011 IPSP. We have assumed a no load growth scenario because we believe the CHP and conservation programs will be successful especially with electricity prices rising over the next several years.

We have analyzed the high and low customer demand day and the highest and lowest wind generation day for illustration purposes. A more thorough data analysis can be done to ensure all the problems that wind can create, as its capacity rises, are identified.

The Lowest Customer Demand Day

A more detailed view of the hourly wind generation data from the 4 wind farms listed in Figures A3-2 through A3-5 are shown in Figures A3-6 and A3-7 below for the lowest customer demand day (May 23, 2011).

Figure A3-6
Wind Generation - Lowest Demand Day

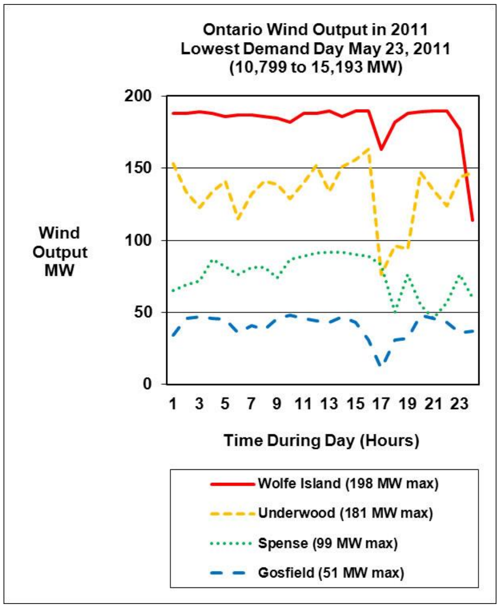


Figure A3-6 and Figure A3-7 to the right show that a significant amount (over 70% of maximum rated capacity) of base load wind generation was operating simultaneously across Southern Ontario throughout the day (about 1002 MW at 4:00 pm) even though customer demand was relatively low. Then a rapid loss of output occurred during the daily peak demand period simultaneously across Southern Ontario. About 35% or 347 MW of wind generation was lost at 5:00 pm (17:00).

Figure A3-7
Wind Generation in 2019
on Lowest Demand Day

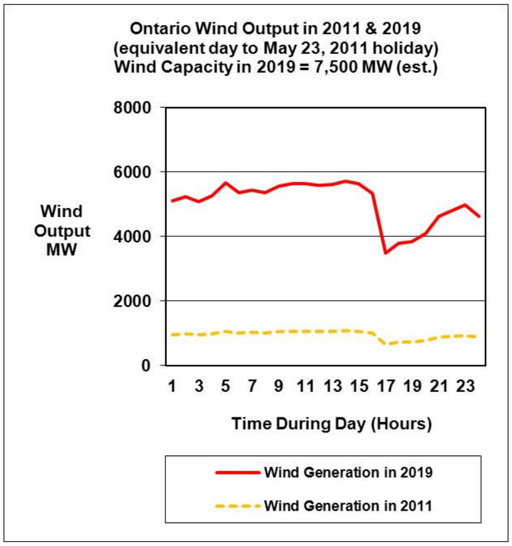
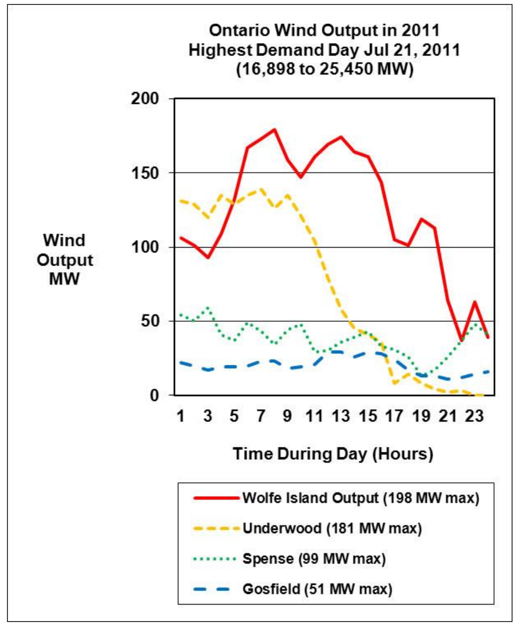


Figure A3-7 to the right shows the total wind generation in 2019 when wind capacity is at 7,500 MW. We have assumed a similar wind day as on May 23, 2011.

The Highest Customer Demand Day

A more detailed view of the hourly wind generation data from the 4 wind farms listed in Figures A3-2 through A3-5 are shown in Figures A3-8 and A3-9 below for the highest demand day (July 21, 2011).

Figure A3-8
Wind Generation - Highest Demand Day



Figures A3-8 and A3-9 to the right show that a significant amount of wind generation that was operating earlier in the day (799 MW at 8:00 am) gradually fell during the daily peak demand period across all of Southern Ontario. A 443 MW drop to 304 MW occurred by 20:00 or 8:00 pm. While some smoothing did occur over a period of a few hours between the Wolf Island and Underwood sites (300 km apart), the general trend over the whole day was down at both sites and the rest of Southern Ontario.

Figure A3-9
Wind Generation in 2019
Highest Demand Day

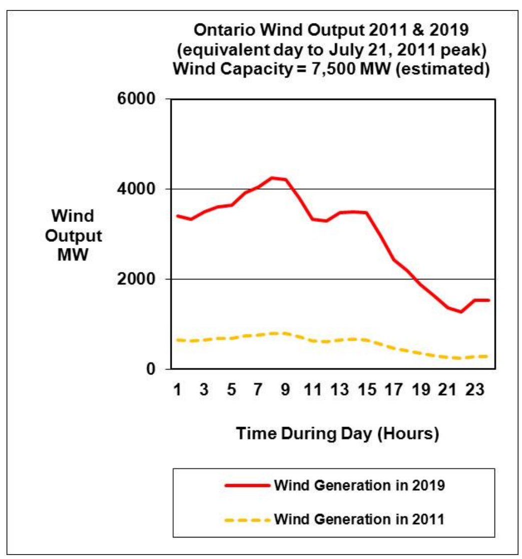


Figure A3-9 to the right shows the total wind generation in 2019 when wind capacity is at 7,500 MW. We have assumed a similar wind day as on July 21, 2011.

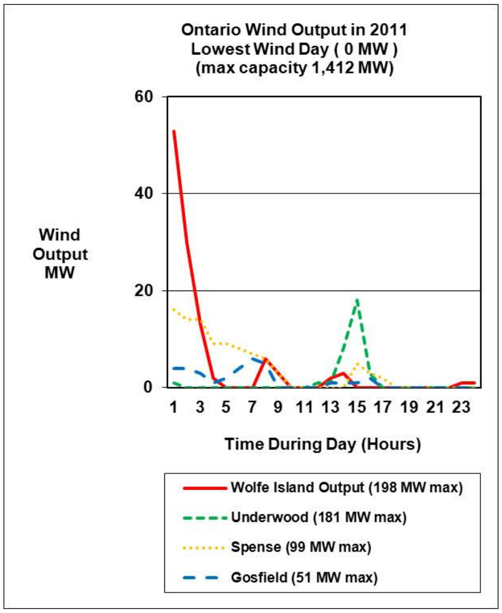
The Lowest Wind Day

A review of the lowest and highest wind days also show a consistent trend across Southern Ontario. Figure A3-10 to the right shows wind generation during the lowest wind production day on March 31, 2011. Wind generation can disappear for most of the day or longer. In this example wind generation dropped to below 2 MW in all of Ontario for 9 hours in the evening of March 31, 2011 until the early hours of April 1, 2011.

Also of interest is the fact that the lowest wind day in 2011 occurred in the spring when typically we expect wind to produce above average output.

This example demonstrates that wind generation does need a dependable backup to meet customer demand.

Figure A3-10
Wind Generation - Lowest Wind Day
(March 31, 2011)



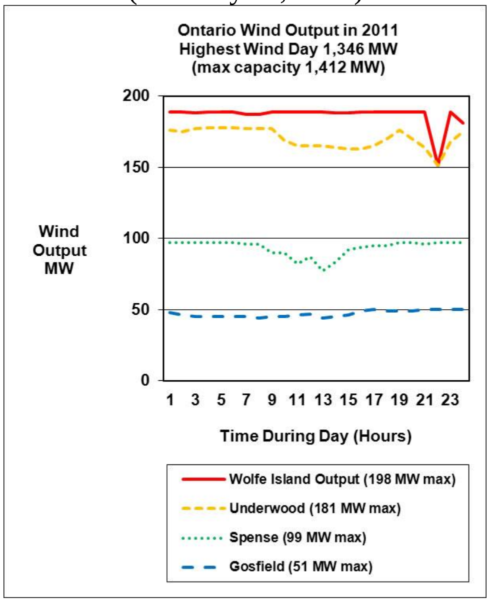
The Highest Wind Day

Figure A3-11 to the right shows wind generation can reach its maximum capacity rating throughout most of the day but not necessarily on a high customer demand day.

On February 18, 2011, a moderate electrical demand day, wind generation reached its highest value in 2011 at 1,346 MW or 95% of the wind generation maximum rated capacity in 2011. Only 4 wind farms are shown in Figure A3-11 but in fact all the wind farms were producing close to their maximum output most of that day.

This example demonstrates that to effectively integrate wind generation, you need some means to absorb unwanted generation.

Figure A3-11
Wind Generation - Highest Wind Day
(February 18, 2011)



Wind's Impact on Other Base Load Generators – The Lowest Demand Day

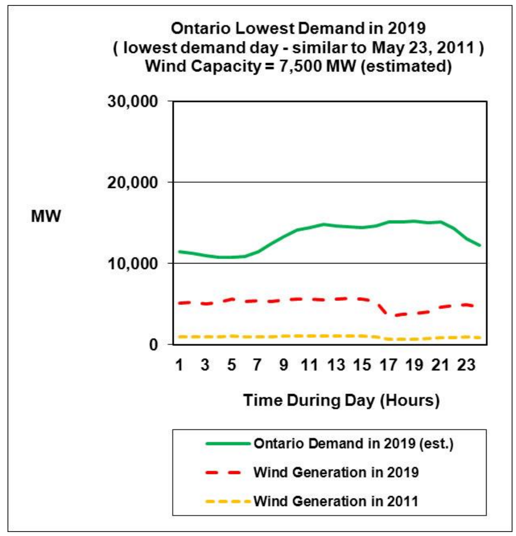
Another problem with wind generation is the daily wind production profile. Hourly wind generation does not match the hourly customer demand profile.

This incompatibility between wind generation and consumer demand means that other generating plants need cope with the much greater variability of the remaining demand.

Figure A3-12 to the right shows the total Ontario demand and the wind generation contribution as it will be on the Victoria holiday in 2019 assuming a similar demand and wind day as the low demand day in 2011. Note the rapid drop of about 2,000 MW in wind production between 16:00 and 17:00 hours while the customer demand is still rising. The large and rapid change must be managed by the IESO.

The distance between the 2019 demand and wind generation lines in Figure A3-12 is the residual demand that the remaining generating plants must provide. This difference is plotted in Figure A3-14 below.

Figure A3-12
Demand and Wind Generation in 2019
Lowest Demand Day



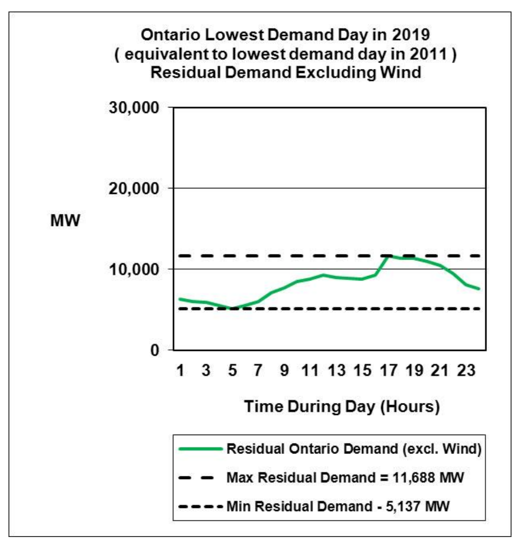
The base load portion available to nuclear and hydraulic plants is shown below the lower dotted line in Figure A3-14. The peak load portion available to gas fired and solar plants is shown between the 2 black dotted lines.

The base load portion of demand has decreased from 10,799 MW in Figure A3-13 to 5,137 MW in Figure A3-14.

The peak load portion of the demand has grown from 4,394 MW (ie: 15,193 – 10,799) in Figure A3-13 to 6,551 MW (ie: 11,688-5,137) in Figure A3-14.

The ratio of peak to base demand has increased from 1.41 in Figure A3-13 to 2.28 in Figure A3-14. This is a rather high ratio historically and suggests the remaining generating stations will be utilized less effectively.

Figure A3-14
Residual Demand After Wind Gets Priority on the Lowest Demand Day



In addition to the operational concerns described above:

- There are only 5,137 MW of base demand for the remaining base load generating plants.
- Ontario has over 17, 500 MW of hydraulic and nuclear generation capacity in 2019 and most of this capacity will not be in a maintenance outage.
- This means there will be insufficient residual base load demand for both hydraulic and nuclear generation and the potential SBG will be quite large.
- The export capability is currently limited to a practical maximum of 4,800 MW (R22).
- This means we cannot export our way out of this SBG problem at any price.

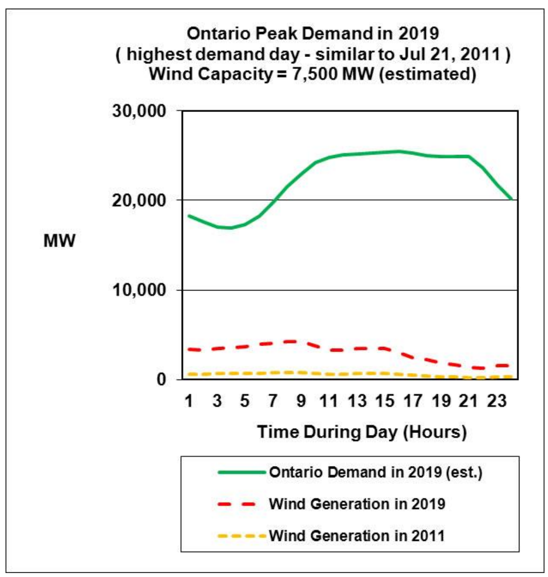
To maintain the supply-demand balance, the IESO will be required to shutdown either the wind generators or the nuclear generators. If the IESO shuts down nuclear generators there could easily be a power shortage the following 2 working days on Tuesday and Wednesday as industrial and commercial demand return. Nuclear units cannot return to service until typically 2 or 3 days after a shutdown. The IESO would therefore likely shut down the wind generators (the lesser of 2 evils).

What this situation highlights is that the Ontario electrical grid in 2019 will have one or more of the following planning deficiencies:

- too much intermittent wind generation, or
- too little nuclear maneuvering, or
- too little storage (typically hydraulic) to shift the wind energy to a time when customer demand can use it.

Wind's Impact on Other Base load Generators – The Highest Demand Day

Figure A3-15
Demand and Wind Generation in 2019
Highest Demand Day



The situation in 2019 for the highest demand day can be examined by referring to Figure A3-15 to the right and Figure A3-16 below.

Figure A3-15 to the right shows the total Ontario demand and the wind generation contribution as it will be in 2019 assuming a similar wind and load day as the peak in 2011.

The distance between the 2019 demand and wind generation lines in Figure A3-15 is the residual demand that the remaining generating plants must provide. This difference is plotted in Figure A3-16 on the next page.

Figure A3-16 to the right shows the demand that remains after wind generation has been assigned its portion of the customer demand.

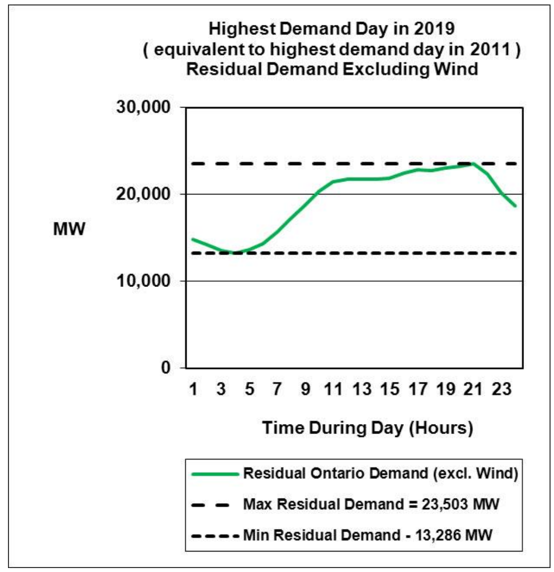
The base load portion available to nuclear and hydraulic plants is shown below the lower dotted line. The peak load portion available to gas fired and solar plants is shown between the 2 black dotted lines.

The base load portion of demand has decreased from 16,898 MW in Figure A3-15 to 13,286 MW in Figure A3-16.

The peak load portion of the demand has grown from 8,552 MW (ie: 25,454 – 16,898) in Figure A3-15 to 10,217 MW (ie: 23,503-13,286) in Figure A3-16.

The ratio of peak to base demand that the remaining generating stations must supply has increased from 1.51 in Figure A3-16 to 1.77 in Figure A3-17. This higher ratio suggests the remaining generating stations will be utilized less effectively.

Figure A3-16
Residual Demand After Wind Gets Priority on the Highest Demand Day



In addition to the operational concerns above:

- There are only 12,227 MW of base demand for the 17,500 MW base load generating capacity. Some hydraulic capacity may not be available if the summer is dry.
- There is a peak demand of 10,217 which is close to the 10,373 MW capacity of the gas fired generating stations without considering the reserve requirements of typically 1,400 MW of dependable supply or demand management. About 1/3 of the estimated 2,400 MW solar capacity should be available to help the situation but cannot be used for reserve because it is not dependable.
- Export capability is 4,800 MW so that the excess base load generation in this case could likely be exported and the deficiency in peak generation could likely be imported.

This situation re-enforces the earlier findings that the Ontario electrical grid in 2019 will have one or more of the following planning deficiencies:

- too much intermittent wind generation, or
- too little nuclear maneuvering, or
- too little storage (typically hydraulic) to shift the wind energy to a time when customer demand can use it.

In 2011 we exported approximately 3,500 MW of SBG on one day. By 2019 with an additional 4,000 MW of base load generation we could reach over 7,000 MW of SBG if the low growth scenario occurs. By 2030 with an additional 8,000 MW of base load generation we could reach over 11,000 MW of SBG for the low growth scenario and over 7,000 MW of SBG for the medium growth scenario.

We have not carried out an analysis of the 2030 period in this report but at that time additional nuclear capacity will be available due to the completion of the refurbishment program and the new build at Darlington. Consequently we would expect the SBG problem to be worse if customer demand has not increased by that time. These are large SBG quantities and suggest a significant frequency and duration of shutdowns for nuclear or wind generation.

<u>Dispatching Wind Generation – Pros and Cons</u>

To mitigate the SBG problem, the IESO is putting market rules and procedures in place to dispatch wind generation. This effectively means the wind generation will not be allowed to produce when the grid cannot absorb the wind power. The key question is whether the dispatching will be infrequent and of short duration (an economic option) or will it be frequent and of long duration (an uneconomic option in the long run). If the amount of dispatching is significant, it could render the installation of wind generators in Ontario uneconomic.

Studies to investigate the amount of dispatching required in the future and actions to mitigate this waste of wind energy should be undertaken now. An early start is important because some of the alternatives require design and construction work that needs to be preceded by engineering studies to optimize the design requirements and changes that will be required.

Simulation studies can be performed to determine to a higher confidence level the amount of wind energy that will not be utilized if the IESO elects to use dispatching as a long term solution. From a simple inspection of the graphical data presented above for the 2019 period, if there is no demand growth, a significant amount of wind energy will likely be wasted by dispatch instructions. This suggests we should be looking at better long term solutions now while we have time to implement them.

From an operational point of view, dispatching wind generation will effectively reduce the excess SBG problem. However, it is not a complete solution for a loss of wind unless you shut down the entire wind turbine fleet. You cannot dispatch wind generation up above the prevailing maximum wind power. That means that you still need a backup generation source if wind generation is on-line. Presently that backup is gas fired generation. It has high fuel costs and it emits approximately ½ the GHG emissions of coal fired generation.

Also, as wind generation capacity rises, additional amounts of gas fired backup generation will be needed. This gas fired generation will begin to occupy a larger share of base load generation resources. Effectively, zero GHG emitting nuclear base load generation would be displaced by gas fired generation. This means that GHG emissions for the base load component of electrical power production in Ontario will rise as wind generation capacity rises even if wind generation dispatching is implemented.

If both wind and nuclear capacity are already built or contracted for, then another option to manage SBG presents itself. Rather than dispatch wind generation, we can dispatch nuclear electrical output if the nuclear plant has a steam bypass system rated for continuous service. Effectively we would be backing up wind generation with nuclear generation. The big benefit here is that no GHG emissions occur. And, in the longer term, a secondary benefit arises. The bypassed steam is available as process steam to industry to displace some of their own natural gas consumption and associated GHG emissions.

What would be needed to enable electrical maneuvering at our nuclear plants is an investment in a robust steam bypass system that is rated for continuous duty. Since our nuclear plants are already close to their thermal discharge limits to the lake, the bypass system will likely have to be an air cooled steam condenser that is mounted on the roof of the plant. These air cooled condensers would be similar to the ones used to cool the combined cycle gas plants that have been built recently in Ontario. However, they would operate at higher temperature and pressure. The size of steam bypass required can be tailored to the needs identified during the simulation studies mentioned above. However, there are many other nuclear plant operational advantages that would result if the air cooled steam bypass system was at least 40% of the reactor's maximum rating (R28). For example, grid blackout recovery capability would be significantly improved from the present 1 to 3 days to less than 8 hours which is the IESO's performance expectation in their Ontario Blackout Restoration Plan and Resource and Transmission Assessment Criteria (R31)(R32).

Consequently, for Ontario, there appear to be only two viable options to manage SBG if the grid does not have seasonal storage. One is to dispatch wind down (with GHG emissions from gas fired backup generation), the other is to dispatch nuclear electrical output down (with no GHG emissions using steam bypass systems).

Negative Electricity Prices

Why do we have negative wholesale prices? Can't generating stations be shut down when the energy is not needed before prices become negative? While the technical answer is YES, the economic answer is NO.

In Ontario, many of our hydraulic plants are run-of-the-river plants. That means they generate power equal to the flow of water. If the water flow is stopped, flooding will occur upstream and low water levels will occur downstream. Consequently, you can't stop the water flow through a run-of-the-river plant. Even if turbine bypass gates exist to keep the river water flowing, many of these plants do not have automatic means to quickly actuate the bypass gates remotely. It may take many hours to position these bypass gates manually especially at remote unmanned sites. Consequently these plants cannot participate in daily power maneuvers.

The Niagara River does have a control structure that can store only small amounts of the water flowing to the Beck power plant. The Saunders plant on the St. Lawrence River can also maneuver its output to a limited extent. There are also a few smaller hydraulic stations that have some limited storage that can be used for maneuvering output. Finally there is a relatively small pumped storage station at Niagara Falls that can be used to maneuver hydroelectric output. Ontario Power Generation has used these capabilities during SBG conditions to assist the IESO to reduce production when the power cannot be exported at economic prices. However, the total capability is not sufficient to manage the present 1,400 MW of wind generation throughout the year let alone 7,500 MW by 2019.

The nuclear plants are also limited in their maneuvering capability. Ontario's current CANDU reactors are designed to operate at constant power once they are running. Ontario has chosen CANDU nuclear units for a number of technical and economic reasons. CANDU reactors fuel daily on-line using fueling machines. This means they do not have extra fuel in their reactor cores that would be needed for deep load maneuvers and daily restarts from a shutdown condition. They have been designed as base load plants that operate at constant power. If they are shutdown, they cannot return to full power operation for about 3 days. This means if you shut them down one evening to avoid excess generation, you lose them for the next 3 days of customer demand. The replacement power cost would be very expensive over the full 3 day cycle. Consequently, nuclear units are not shutdown nor are they maneuvered daily.

The staff at Bruce B nuclear station have made some improvements to the plant over the years that allows them to divert steam from the steam turbine to the plant's turbine condensers for several hours on an periodic basis. This allows the plant to keep the reactor at high power and lower the generator electrical output. Unfortunately, this improved steam bypass system is not designed for continuous daily use. Consequently Bruce B units only maneuver down a portion of their electrical output and only periodically when the grid is in a severe SBG condition.

To make matters worse, governments everywhere, including Ontario, are rushing to add wind generation onto their grids because it is environmentally more friendly than coal fired generation. Wind unfortunately does not blow only when customers want their power. As we have seen earlier, it often blows at night and on weekends when demand is low. During these times, if customer demand is low and wind generation is high, an SGB condition can be made worse. The more wind capacity you build into the grid the worse the SBG condition can become.

In Ontario the wholesale electricity market is an auction market. During periods of low customer demand, dispatched generators can be dispatched down (forced to shutdown) if their bid price is above the current supply-demand balance price. Generators that have a high cost of shutdown such as all nuclear plants, most hydraulic plants and some gas fired plants, have a strong incentive to offer very low prices (even negative prices) into the auction market so they will not be shutdown. As the customer demand drops, the electricity price at the supply-demand balance point begins to drop. Ideally, neighouring electrical grids like Quebec, New York and Michigan would accept electrical imports from Ontario when our prices drop below their own incremental production costs.

There are however, four problems that can limit Ontario's exports to our neighbouring grids at prices that can at least recover our marginal production costs. They are:

- The neighbouring grid customer demand profiles are similar to Ontario's so their customer load is also low when ours is low,
- As we have already seen earlier in this document, the neighbouring grids wind production is likely high when ours is high because they too are located near the Great Lakes and experience similar wind conditions,
- The neighbouring grids base load generators also incur significant cost to shutdown, and
- The transmission line export capacity in Ontario is limited in practical terms to 4,800 MW if all neighbouring grids accept the maximum transfer. Depending on the system configuration, the actual maximum export capability could be lower at the time the SBG occurs.

When our neighbouring grids cannot comfortably accept all our available SBG, prices begin to fall much lower and can actually go negative. The prices will continue to fall until they are low enough to compensate our neighbouring grid generators to shut down their base load generating facilities or entice a large Ontario industrial load in the wholesale market to increase their consumption or painful enough that we shutdown our nuclear generators. If the SBG condition becomes severe, prices will go negative as generators compete to stay in production by lowering their energy prices.

Fortunately in the past, most of our SBG could be exported at reasonable prices and the rest was dumped either as hydraulic spill or as steam bypass at our Bruce B nuclear units. The amount of spill and steam bypass in the past was relatively small so it was not considered a serious problem.

Unfortunately, as more wind generation is added to the grid, there will be more frequent and longer periods of severe SGB that will result in negative electricity prices. Negative electricity prices means Ontario consumers subsidize exports. The IESO essentially pays our neighbours to take the surplus energy off our hands so we don't need to shut down our own nuclear stations.

In the last few years Ontario has been experiencing negative electricity prices on the wholesale market during some nights and weekends at greater frequency and longer duration as wind generation has increased.

On January 1, 2011 (a holiday) we saw our worst negative hourly wholesale price in 8 years at almost negative 13.9 cents/kWh or negative $139 per MWh for 1 hour at 9 am. The negative price period that day lasted 8 hours. Ontario wind generators were producing approximately 1,000 MW or 70% of their maximum output and total exports were approximately 3,000 MW. Ontario paid its neighbouring grids about 2 million dollars to take that excess power off our hands during that 8 hour negative price period from 3 am to 10 am.

Table A3.1 shows the periods of negative wholesale prices in Ontario's electrical market.

Table A3-1
Negative Electricity Price Periods
in the Ontario Wholesale Market

Annual Period Sep 15 to Sept 14	Hours with Negative Prices	Days with Negative prices	Months with Negative Prices	Lowest HOEP $/MWh	Exports at Negative Prices in GWh	Cost to Export in M$
2002/03	0	0	0	11.54	0	0
2003/04	0	0	0	5.25	0	0
2004/05	0	0	0	8.6	0	0
2005/06	1	1	1	-3.1	0.8	0.002
2006/07	3	2	1	-1.66	3.8	0.004
2007/08	32	11	6	-14.59	72.4	0.414
2008/09	319	62	9	-52.08	391.0	3.211
2009/10	58	31	5	-128.15	83.7	1.004
2010/11	138	56	8	-138.79	278.2	15.162
Totals	**551**	**163**	**30**		**829.9**	**19.798**

HOEP is the Hourly Ontario Electricity Price (wholesale market)

What is disturbing is the trend to more frequent and longer duration negative prices with only 1,400 MW of wind generation on the grid in 2011. By the end of 2018 Ontario will have approximately 7,500 MW of wind generation on the grid. If the same customer demand and wind conditions prevail on January 1, 2019 as on January 1, 2011 the wind generation would be over 5,000 MW. That's an additional 4,000 MW of wind generation that would need to be exported. The nuclear refurbishment program will eliminate 3,000 MW of nuclear capacity for a time but those units will return to service later. By 2030 the total SBG for export would be well beyond Ontario's export capability if customer demand does not grow significantly.

It is clear from Table A3-1 that the SBG situation is getting worse and the cost of exporting power is getting higher. From Sept 15, 2010 to Sept 14, 2011 the IESO paid about $15 million dollars to export power at negative prices. A successful conservation program, a weak economy from 2008 to 2011 and increasing amounts of base load wind generation have all contributed to a growing and more costly SBG situation.

It is important to note that in addition to exports at negative prices there were also exports at below the incremental cost of production during the SBG periods. Those statistics are not included in Table A3-1 above.

A4. Potential Solutions to Wind Generation Variability

In order to accommodate intermittent green energy sources such as wind or solar, integrating solutions can be applied at either or both the supply side or the demand side.

Supply side solutions try to provide grid flexibility so that wind can be integrated effectively. The three primary methods to provide grid flexibility are:

- improving maneuvering capability of the existing generation sources,
- improving storage capability on the grid to absorb excess intermittent supply when nature provides it and deliver it when it is needed by consumers,
- Constraining (or dispatching) wind production when the grid cannot accept the energy.

Demand side solutions try to provide a more flexible demand so that when wind is available customers draw more power and when wind is not available customers delay their power consumption until the off-peak hours. During off-peak hours the peak load plants can be operated for additional hours to accommodate that demand.

A4.1 Improved Maneuverability of Base Load Generation

Ontario has 3 major base load generation resources. Hydraulic, nuclear and wind generation are considered base load supplies because they either do not maneuver or they deliver a significant portion of their total energy during off-peak hours. Combined heat and power (CHP) plants also constitute a base load supply but they are not a major component of the grid supply at present.

Coal fired, bioenergy and natural gas fired generation are normally considered a peak load facility because they are maneuverable. However, some more complex plants have limits on their maneuverability and that non-maneuverable portion should really be considered base load. For example the new high efficiency combined cycle gas fired generating plants typically have limits on their maneuverability that restricts their usefulness in managing wind generation variability.

Each generating station type has its own performance characteristics. The solutions to achieve greater maneuverability to better match customer demand are different for each.

Hydraulic Generation

Hydraulic generating plants in Ontario are primarily of the run-of-the-river type. Ontario did not invest in massive reservoirs like Quebec mainly because the local geography did not allow for it. Ontario installed coal fired plants to provide the extra power when hydraulic generation was low. This allowed the hydraulic plants to be built at lower cost and lower environmental impact on communities near those hydraulic plants. Most of Ontario's hydraulic plants do not have additional storage or operating flexibility that isn't already being utilized. As we mentioned earlier, the Niagara River has a control structure with only limited ability to store the water flowing into the Beck stations, and the Saunders station has some storage capability. There are also some smaller hydraulic stations that have some limited storage capability upstream of their dams. Ontario also has a relatively small pumped storage capability near Niagara Falls. However, the total maneuvering capability of our hydraulic generating stations is limited to a fraction of their capacity and is being fully utilized.

Improving the storage capability upstream of our dams would be useful because wind energy can be stored at 100% efficiency if we hold back the water before it passes through the power plant. Unfortunately in most cases this is not a practical option for both environmental and economic reasons. It is difficult and expensive to modify existing dams and change the permissible minimum and maximum water levels upstream and downstream of our hydraulic plants. The Beck and Saunders plants which are the largest hydraulic stations would involve substantial water elevation changes along the St Lawrence River system and the Great Lakes which are strictly regulated under international treaties. Therefore such elevation changes are impractical.

An alternative is to bypass our dams through existing sluiceways so the water can continue to flow but no electrical power would be produced. Again there are economic and environmental, as well as public safety consequences. The cost of modifying existing dams to further automate sluicegates can be significant. Environmentally, if we bypass our hydraulic stations we are wasting clean renewable energy. Further, opening sluiceways can take additional time due to the need ensure public safety (i.e. the sluiceways are clear of people). If we need to dump clean renewable energy it is easier and much cheaper to simply turn off the wind turbines rather than spill water. Consequently, modifying hydraulic stations to manage SBG is not economically viable.

During production of this report we discovered that Ontario has a different contractual arrangement with OPG for hydraulic generation than its competitors. While the Niagara and Saunders stations are guaranteed revenues by way of regulation through the Ontario Energy Board, OPG's unregulated hydraulic stations do not get paid if they spill water when being dispatched down, whereas wind generators do if they are dispatched down. This effectively means that tax payers (OPG's owners) rather than the electricity consumer pays for the loss of revenue from hydraulic spill. This contractual arrangement should probably be changed so that all generators are paid on the same basis.

Nuclear Generation

Ontario's nuclear reactors are currently not designed to maneuver their electrical output to any significant degree. However, if we have an alternative place for the steam to go (say a steam bypass condenser), we could decouple the turbine generator operation from the reactor operation.

We could then maneuver the turbine generator down, without changing reactor power, and divert the unused steam to a condenser to get rid of the excess energy. Nuclear fuel costs are relatively low at about 0.5 cents per kWhr or about 1/5 to 1/10 the fuel cost of a gas fired plant. This means steam bypass is not very expensive at a nuclear station.

With the exception of the capital cost of the steam bypass equipment, there is no difference financially between paying wind to shut down or paying nuclear plants to bypass steam. The total cost to the electricity consumer is the same.

As we discussed earlier, dumping steam at a nuclear plant has two major advantages compared to dumping wind energy. There would be no GHG emissions from the nuclear backup for wind generation. Also the bypassed steam would be available for industrial process steam. That process steam with zero GHG emissions could displace some gas fired process steam. This would be especially attractive to industry if carbon taxes or other types of carbon penalties or limits are imposed on industry in the future.

A nuclear plant supplying both electricity to the grid and steam to industry would be operating as a dual energy supply facility. Electricity would continue to be supplied at about 30% thermal efficiency but the bypassed steam would be supplied at close to 100% efficiency. The Bruce A nuclear station provided process steam to the nearby heavy water plant and industrial/agricultural complex from the mid 1970's to the mid 1990's. At the time, some electrical generation was locked-in due to a limitation on transmission capacity. The surplus nuclear steam energy offset oil consumption at the heavy water plant.

Ontario has about 12,000 MW of nuclear capability. Consequently, there is enough nuclear capacity to provide the required maneuverability to back up all the wind. This would create a zero GHG emission grid for most of the base load generation. The present gas fired generating plants would still be needed for reserve power, for plant outages, for peak demand and to back up the solar generation.

Some nuclear plant modifications will be required because the current steam bypass systems have not been designed to be used daily on a continuous basis. The good news is that the technology (the air cooled condenser) exists, the costs are a fraction of that for large scale hydraulic storage and the environmental impact is minor compared to either hydraulic storage or gas fired backup.

How much will it cost? It depends on which SBG operating regime the grid is operating in. There are 3 operating regimes with respect to SBG:

- SBG Regime A – Where there is not enough load for nuclear irrespective of any wind.
- SBG Regime B – where there is not enough demand for both nuclear and wind combined.
- Non-SBG Regime – where there is sufficient demand for both nuclear and wind.

In SBG Regime A you cannot maintain stable grid operations unless:

- With no steam bypass capability:
  - you incur a potential loss to export surplus power, or
  - you shutdown wind generation, and
  - you shutdown some nuclear and replace the lost nuclear generation with gas fired generation until the plant(s) returns to service 2 or 3 days later.

- With steam bypass capability you face the following options:
  - you can dispatch nuclear electrical output to ensure exports are not a loss to the system, and
  - you can shutdown wind, or
  - further dispatch nuclear electrical output to avoid shutting down wind, also
  - you have surplus steam available at the nuclear site to sell to displace gas fired industrial process steam,
  - nuclear plant owners have an incentive to do the R&D necessary to implement reactor power maneuvering to minimize the nuclear fuel consumption during operation in SBG Regime A.

In SBG Regime B you cannot maintain stable grid operations unless:

- With no steam bypass capability you face the following problems:
  - you incur a potential loss to export surplus power, or
  - you must shutdown some wind generation, or
  - you shutdown some nuclear and replace the lost nuclear generation with gas fired generation until the plant(s) returns to service 2 or 3 days later.

- With steam bypass capability you face the following options:
  - you can dispatch nuclear electrical output to ensure exports are profitable to the system, and
  - you can shutdown wind, or
  - further dispatch nuclear electrical output to avoid shutting down wind, also
  - you have surplus steam available at the nuclear site to sell to displace gas fired industrial process steam,
  - nuclear plant owners have an incentive to do the R&D necessary to implement reactor power maneuvering to minimize the nuclear fuel consumption during operation in SBG Regime B.

In the Non-SBG Regime:

- With no steam bypass capability:
  - you must backup wind with GHG emitting gas fired generation

- With steam bypass capability:
  - nuclear generation can occupy the peak load region of the demand profile and displace GHG emitting gas fired peak generation,
  - you can add nuclear capacity to backup wind and solar with zero GHG emissions,
  - you have surplus steam available at the nuclear site to sell to displace gas fired industrial process steam,
  - nuclear plant owners have an incentive to do the R&D necessary to implement reactor power maneuvering to minimize the nuclear fuel consumption during steam bypass operation.

The cumulative costs and environmental benefits you get with nuclear steam bypass are dependent on the number of operating hours in each of the 3 regimes above. These can be studied with reasonable accuracy using system simulation studies using supply, demand and wind data from IESO's data library and OPA financial data. Parametric studies can be done to optimize the cost/benefits for steam bypass capacity.

The electricity market rules force generators that have high shutdown costs to bid large negative values into the auction process to ensure they are not dispatched off. Typically these are nuclear and hydraulic generators. If however, nuclear plants had robust steam bypass systems, they could offer their true incremental costs of production into the market. If the price fell below that value they would simply maneuver their electrical output down and operate on steam bypass at a much lower cost than a full 2 or 3 day shutdown. The market would operate more efficiently and large negative electricity prices would not occur.

Dispatching wind off does not solve the negative electricity price problem when the gird is operating in SBG Regime A. In this regime, wind is not setting the price, nuclear is. Therefore it is important that nuclear is able to dispatch down to avoid a large negative electricity price. This can only be done if the plant has a stream bypass.

Steam bypass capability at the nuclear plants provides considerable grid operating flexibility in case planning assumptions do not materialize as expected. It also provides the IESO additional operating options during normal and abnormal operating conditions including system blackout restoration (R28).

During production of this report we discovered that Ontario has a different contractual arrangement with OPG for nuclear generation compared to Bruce Power. OPG does not get paid if it bypasses steam at its nuclear plants when it gets dispatched down, but Bruce Power that leases the Bruce B plant from OPG does. This has led to an odd situation. Because OPG gets paid more for nuclear power than for hydraulic power it is more economic for OPG to spill hydraulic energy at Niagara Falls rather than modify its Darlington reactor to reduce its electrical output. Bruce Power on the other hand has improved its Bruce B steam bypass system and can now offer some limited assistance to the IESO when severe SBG conditions are present. This OPG contractual arrangement should probably be changed so that all nuclear generators are paid on the same basis.

Another anomaly is that private power contracts are established by the OPA in a confidential process whereas OPG's power contracts for their regulated facilities are established by the OEB in a public process. The wholesale market has evolved into a marginal cost of production market. The capacity charges are built into a global adjustment charge separate from the wholesale market price setting mechanism. Effectively, OPA administered contracts are a government regulated charge on electricity prices. Consequently, there appears to be little reason why OPG should be treated differently than their competitors. This is another aspect of energy pricing that likely needs review by the government.

Gas Fired Generation

Gas fired generating stations are maneuverable but not to the same extent as coal fired stations. Gas fired generating stations can be made more maneuverable but it typically involves bypassing steam energy to a condenser. Natural gas fuel costs are a large component of the cost of operating a gas fired plant. Typically fuel costs are in the range of 60 to 80% of the electricity cost for gas fired plants. Consequently, this means that installing steam bypass systems at a gas fired plant to improve maneuvering capability would be prohibitively expensive to operate. The cheaper option is to use nuclear steam bypass.

When gas fired generation is used to back up wind generation it needs to be able to maneuver quickly in both directions. With wind generation capacity rising to 7,500 MW by the end of 2018, the current maneuvering rate of gas fired generation may be inadequate. The Market Surveillance Panel recently reported its concerns about the morning customer load pickup and the wind generation output to fall off during the same period (R34). Figure 1-10 in their November 2010 to April 2011 report shows that with only 1,400 MW of wind capacity the fall of in wind generation was typically 100 to 150 MW with an occasional 300 MW drop. With wind capacity rising to 7,500 MW by the end of 2018 that early morning drop will rise to about 500 to 750 MW with occasional drops of 1,500 MW. Gas maneuvering must be capable of responding to these large and rapid power changes. Simulation studies can be used to determine both the magnitude and rate of power output changes that are required.

Gas fired backup does not work at all in SBG Regime A and has limits to what it can do in SBG Regime B. Wind dispatching is required in both SBG Regime A and B if nuclear cannot maneuver.

Bio-Mass Generation

Ontario Power Generation is currently repowering its Atikokan station to use bio-mass and is making provisions to use bio-mass at its Thunder Bay station that is being converted from coal firing to gas firing (R33). The coal fired plants already have transmission line connections so that is one expense that will be avoided if bio-mass is used as fuel at those facilities. Bio-mass generating plants can maneuvered. They are also carbon neutral so the environment will not be negatively impacted when the appropriate post combustion filtration is installed. Bio-mass should be sustainable from waste streams and not from bio-mass that can be used for food production (including soil nutrients) or building materials. To the extent that waste bio-mass is available in Ontario it can be used to provide a zero GHG back up to wind and solar generation. Bio-mass generation is more economical when developed close to its fuel source.

A4.2 Storage

There are several commercial storage technologies available. Some storage solutions can deliver small to moderate amounts of power transfer (kW to MW) over a short time frame (seconds to days) such as batteries, fuel cells, flywheels, compressed gas, hot fluids, etc. Others are capable of large amounts of power transfer (MW to GW) over very long time frames (days to months) such as dam storage or pumped hydraulic storage.

Short Term Storage

Regardless of the technology used, short term storage is useful when it is necessary to improve the system stability margins (eg: for voltage control). A number of North American utilities are now deploying MW scale short term storage to smooth out the rapid fluctuations that are created by wind and solar output variability inside their distribution systems. Storage is expensive so it is deployed sparingly only where absolutely necessary for electrical voltage stability typically at the lower voltage distribution level.

A number of concepts and technologies have been discussed in the literature and often are advocated with a smart grid control component to maximize the effectiveness of the storage capability. These include:

- “Micro storage” units say around 1 to 10 MWhr energy capability installed in a distributed manner either at the consumer’s facilities, distribution stations or near renewable energy facilities such as near the wind turbines themselves. The technology used will determine to a great extent their location because some technologies (eg: high speed flywheels) are not likely to be accepted by customers in their own facilities.
- Stationary fuel cell units at distribution stations.
- Plug in electric vehicles, which are not being operated, can supply energy or store energy as required during the day. Some limits and software smarts are necessary to ensure the battery is fully loaded when the owner plans to use his/her vehicle at the prescribed time.

Short term storage is not as useful on the high voltage transmission system where the power flows are measured in GW’s. Here, large hydraulic storage or generation maneuvering are a more practical solution.

Dam Storage

Dam storage can be either short term (days) or long term (seasonal) depending on the size of the reservoir and the water elevation changes that are permitted.

Seasonal storage is the most valuable to the grid. It can be provided by dam storage or hydraulic pumped storage plants. As we discussed earlier, dam storage is the best from an efficiency point of view but is not economically or environmentally practical in Ontario. However, Quebec is fortunate to have considerable seasonal dam storage. Once Ontario has some viable options to manage SBG, Quebec may be persuaded to negotiate a more reasonable price for access to their seasonal storage. In any case the amount of power transfer capability with Quebec is limited so not all of Ontario’s problems with SBG can be resolved by striking a deal on storage with Quebec.

Pumped Storage

Pumped hydraulic storage plants work by pumping water up to a higher reservoir at night when demand is low and then running that water through a turbine and down to a lower reservoir during the day. The problems associated with pumped storage are:

- Seasonal storage (from autumn/spring to winter/summer) is very expensive. Massive storage reservoirs are required because falling water does not contain much energy per unit of water mass.
- These plants waste some of the energy in the extra energy conversion step compared to dam storage. Some energy is lost to pump the water up to the reservoir.
- These facilities typically cost $5,000 to $7,000 per kW. Pumped storage facilities have a low capacity factor because they can’t deliver energy while they are storing it. That means the cost on a delivered kWh basis is about 10 times higher than the cost of nuclear maneuvering or gas fired backup.
- These facilities are very large. Typically the capacities are in GW. They need to be financed as a capacity charge to the grid because when they operate they can affect the price of electricity in an auction market. They tend to raise the price at night and lower the price during the day. The price difference between storage and delivery periods can become too narrow to generate enough revenue for the owner to pay for the facility. Ideally the storage facility should be managed by the IESO to eliminate SBG and to meet peak demand in an economically optimum way.

A4.3 Dispatching Wind

Wind generation can easily be dispatched down. However, wind generation cannot be dispatched up beyond the maximum power available in the wind at any moment in time. This means that dispatching wind generation down is not a complete solution to manage wind variability. You also need to provide a dependable backup supply if wind energy falls off below the required dispatch value.

Simply adjusting the rotor angle will reduce the amount of energy delivered to the grid. For those wind turbines that have load dispatching capability, dispatching their output down eliminates their contribution to the SBG problem. There are of course economic and environmental consequences. The IESO still needs to pay wind generators not to produce and the environmental benefits do not materialize if wind generation is turned off too frequently.

One problem that needs to be resolved is the difficulty in determining the actual amount of energy that is not generated. Wind speed must be accurately measured, in theory, at the same accuracy as normal commodity transfers that are covered by Canadian laws and standards. Also the relationship between wind speed and electrical power output needs to be precisely determined for each wind turbine. A second problem is the strong financial incentive that is created for wind operators not to report technical problems with their wind turbines so they can be paid not to run, regardless of the state of their equipment.

A study into alternative pricing models for wind generation that do not require the measurement of the energy that is not produced during dispatching should be undertaken. The objective is to simplify the measurement and settlement process before wind dispatching becomes operational.

Economically, the less we generate from wind turbines, the more it costs for what we do get because the total cost of the wind generator still has to be paid. The more we dispatch wind down, the higher the global adjustment to electricity rates to pay for the lost production. Consumers don't save any money when the IESO dispatches wind. However, we may increase the maintenance costs on the rotor positioning mechanisms because as wind speed varies, the positioning mechanisms need to readjust the rotor angle to limit the electrical output to the dispatched value within an allowable dead-band and time period.

Environmentally, we installed the wind turbines and paid them a premium price to deliver clean, renewable energy. If we dispatch them down we are wasting the wind energy and are reducing the environmental benefit we receive for the same total dollars spent. In the short term, this is necessary but in the longer term we should be able to find better solutions that do not waste the environmental benefits of wind generation. We should be able to find solutions with no GHG emissions that can back up wind.

A4.4 Control of Demand and Smart Grid Capabilities

Theoretically if you have a mismatch between supply and demand you can eliminate the mismatch by forcing the demand to equal the supply. This requires the IESO to be able to either lower or raise customer demand. This of course is easier said than done because the capability to raise customer demand is currently not available to the IESO.

The OPA and IESO have programs in place to reduce customer demand such as the demand response program and the dispatchable load program. The demand response program is designed to reduce customer load under the control of the IESO. The dispatchable load program is designed to allow either the IESO to initiate a reduction in demand or the customer to initiate a reduction in demand based on the market price exceeding a specified price. These types of control actions above are designed to reduce customer demand during system peaks to help the IESO balance supply and demand. They can also be used to help the IESO balance supply-demand when wind production is falling. However, they do nothing to help when wind production is rising and base load generation is at minimum load – an SBG condition.

When wind production is rising, and SBG conditions are present, the IESO needs to raise customer demand to reduce the SBG. The IESO needs customer loads that are able to use more energy following a dispatch signal from the IESO to **raise** consumption.

Clearly the loads must be sufficiently flexible that they can directly use or store the energy when the wind is blowing. Applications include:

- chilled storage for space air conditioning,
- heated storage for space heating,
- pumping water for municipal or industrial domestic water into storage towers,
- charging of electric plug-in vehicles,
- production of process steam, or
- Production of other industrial commodities such as hydrogen gas, etc.

The customer also needs to be able to get their energy during off-peak hours to satisfy their remaining daily energy needs if the wind is weak on any given day.

Finding sufficient customers with that type of demand flexibility and that are willing to let the IESO control their energy use 24 hours a day will be a challenge. To make this type of demand flexibility effective at counteracting wind related SBG, you need far more willing customers than the required dispatching amount. The reason is that some customers may not be able to provide a demand on some days because their storage is full or their production is shutdown. You also need a smarter information and control interface between the IESO and the customer facilities.

To convince customers it is in their interests to complicate their operations the IESO may need to offer the power at attractive prices. This will most certainly be the case if the customer is expected to invest in additional smart grid control and communication capability or additional plant equipment to permit this type of grid dispatching capability.

A pilot program would likely be required to determine if direct control of demand by the IESO is practical and sufficient to meet the grid's needs.

A5. Life Cycle Costing

Most utilities now are using life cycle costing as the basis for deciding what technology will be added to the supply. It has different names in different places. Examples include: life cycle costing, levelized unit energy cost or levelized cost of electricity (LCOE) in the international literature. LCOE includes the impact of capacity factor, capital cost, financing costs, fuel costs, operating costs and maintenance costs into the total anticipated costs of the facility recovered via an average cost per unit of energy produced. LCOE is expressed as cents/kWh in North America. LCOE can also include future costs such as carbon taxes, decommissioning costs or long term waste disposal costs.

While LCOE is fairly well understood and established. It is affected significantly by the underlying assumptions used in the analysis. For example, the expected capacity factor of the facility has a significant impact on the LCOE for all facilities. For fuel burning facilities the assumptions for future fuel costs also have a significant impact on LCOE. For higher capital cost plants with long construction schedules such as nuclear and hydraulic plants, the financing discount factor will significantly affect the LCOE. Also projected future costs are important for strategic decisions about energy sources for the future. For example renewable generation costs especially solar PV are dropping so what may seem expensive today may be economic tomorrow. Consequently, one should be a little suspicious when comparing LCOE numbers until the underlying assumptions are clearly understood and accepted.

With that cautionary note, Table A5-1 below shows some LCOE data from 2 sources related to the cost of electricity in US dollars. The OPA column shows the current Canadian costs of new plants which incorporates Ontario's expected capacity factors for each type of facility. The cost of carbon taxes for CO2 emissions has been removed from the IEA/NEA data.

In Ontario, another important cost that is not reflected in Table A5-1 below is the cost of managing surplus base load generation (SBG). Ontario has severe SBG because of over building of base load generation facilities such as hydraulic, nuclear and wind generation.

Table A5-1
New Plant Levelized Cost of Generating Electricity

Type of Plant	IEA/NEA (R2) cents/kWh	US DOE/EIA (R26) cents/kWh	OPA (R4) cents/kWh
Conservation Programs	n/a	n/a	5 to 7
Large Hydraulic	7 to 23	6 to 12	8 to 28
Small Hydraulic	5 to 11	n/a	12 to 13
New Nuclear	6 to 8	11 to 12	n/a
Nuclear Refurbishment	n/a	n/a	5 to 9
Simple Cycle Gas	8 to 11	9 to 12	14 to 54
Combined Cycle Gas	7 to 10	6 to 8	7 to 20
Combined Heat & Power	8 to 27	n/a	11 to 49
Onshore Wind Farms	5 to 14	8 to 12	13 to 14
Solar PV	21 to 63	16 to 32	44 to 80
Bioenergy	5 to 13	10 to 13	10 to 20
Coal to Gas Conversions	n/a	n/a	17 to 47

Notes: The US and CAN dollars are assumed to be at par in the data above. IEA/NEA costs for developed countries have been used and reflect the costs for a 2015 in-service date and a discount rate of 5%. US DOE/EIA data is in 2009US$'s for a

2016 in-service date and a real discount rate of 7.4%. The OPA costs are current costs in 2011.

The current method used by the IESO to manage SBG is to export the excess to neighbouring grids in New York, Michigan and Quebec. This a viable strategy for small amounts of SBG. However, as the quantities have grown over the last few years, the attempt to export SBG has resulted in negative price hours during the night when customer demand is low. Because Ontario has limited export capability the surplus SBG will soon rise to a level that cannot be exported as more wind generation is added to the grid.

The IESO is arranging to put market rules and procedures in place that will allow it to dispatch wind down. This will reduce the SBG but will increase the real LCOE of wind generation as more wind capacity is added to the grid over the next few years. That cost will be passed on to customers via the global adjustment mechanism in the rate structure.

Even with dispatching wind down, some SBG will still remain during low demand periods of the year and when hydraulic resources are also producing at their peak during spring freshet.

Consequently, adding new wind generation or non-maneuverable hydraulic or nuclear generation into the Ontario grid will make the SBG problem worse and contribute to higher LCOE for those facilities unless there is significant growth in electricity demand.

In order to demonstrate the impact of dispatching on LCOE we have analyzed data from the median cost case for each generation type published in the *Projected Costs of Generating Electricity, 2010 Edition*, International Energy Agency and Nuclear Energy Agency (R2). The data in those median cases are close to the actual costs in Ontario. We should also note that the design capacity factors for the various plants are different so dispatching affects them differently. Solar generation is the most sensitive to dispatching because it has only a 15% capacity factor in Ontario. Wind generation is the next most sensitive because it has a 25% capacity factor in Ontario. Nuclear and CCGT gas fired generation plants are the least sensitive because they can operate at base load with an 85% capacity factor. The impact of dispatching on LCOE for various generation types is shown in Figures A6-1 and A6-2 below. The data below does not include carbon taxes or cap and trade costs. If these are introduced to limit GHG emissions, nuclear generation with steam bypass will become more cost effective.

Figure A6-1 below also shows that nuclear dispatching is competitive with natural gas dispatching at prices above $8 per million BTU's. Gas is currently about $4 in Canada, $12 in Europe and $16 in Japan. As liquid natural gas (LNG) transportation capability is developed, the North American price is expected to rise as supplies are diverted to European and Japanese markets.

Figure A6-1 and Figure A6-2 below demonstrates how quickly wind cost rises as dispatching lowers its capacity factor. Wind only has a design capacity factor in Ontario of 25% so the rise in LCOE is very rapid as dispatching lowers the capacity factor by a maximum of 25%.

Figure A6-2 demonstrates that the increase in electricity prices caused by nuclear dispatching (electrical output maneuvering) to accommodate wind is modest. This strategy also provides considerably more room for wind on the electrical grid and no GHG emissions compared to using gas fired backup.

Figure A6-2 also shows that if a significant amount of dispatching occurs, the LCOE for wind and solar rises very dramatically to extremely high values. Even if wind and solar are a small fraction of capacity, these very large LCOE values will impact electricity rates significantly.

Figure A6-1
Comparison of Wind, Gas and Nuclear

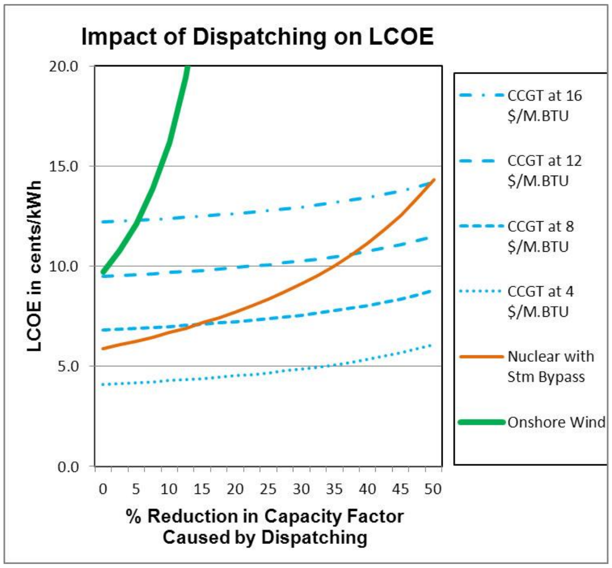
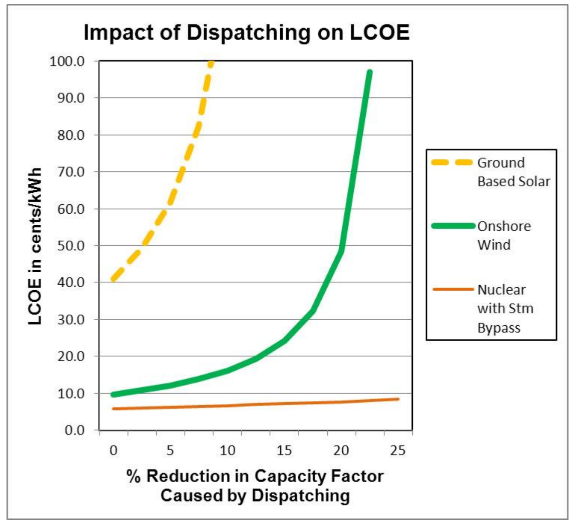


Figure A6-2
Comparison of Solar, Wind and Nuclear



A6. Greenhouse Gas Emissions

One of Ontario's objectives to use renewable energy was to reduce greenhouse gas emissions. Burning fossil fuels releases large amounts of GHG's that have been stored in the earth as coal, oil and natural gas over hundreds of millions of years by natural processes. The rapid release by human activities is expected to contribute to significant global weather changes referred to as global warming.

Table A6-1 below shows the GHG emissions from electrical generating stations expressed in units of grams per kWh.

Wind generation has zero GHG emissions during operation but its gas fired backup does. Unfortunately wind generation requires a backup energy source when the wind speed drops. Since wind produces energy only about 25% of the time, then natural gas backup will produce a considerable amount of GHG emissions because it still has an emission rate of about ½ that of a coal fired plant. The gas fired backup emissions for the 2% of wind generation in Table A6-1 is included in the 14% of energy production from natural gas.

The conclusion here is that, if we are serious about reducing GHG emissions, then a better solution is to find a way to back up wind generation with a zero GHG emitter such as hydraulic, nuclear or bioenergy generation.

Table A6-1
CO2 Emissions from Generating Stations

Generating Station Type	CO2 Emissions (g/kWh) (R27)	% of Ontario Energy Production in 2010 (R9)
Nuclear	0	55%
Natural Gas	398	14%
Hydraulic	0	20%
Coal	973	8%
Wind	0	2%
Bioenergy	0	1%
Weighted Aver.	**134**	**100%**

Note: The data for natural gas is for an average 45% cycle efficiency. The data for coal is for an average 35% cycle efficiency. Bioenergy is considered neutral with respect to CO_2 emissions.

Nuclear is not a renewable energy source but it doesn't produce GHG emissions. Nuclear energy provides us with time to transition away from fossil fuels to renewables, improve our energy efficiency and reduce our energy intensity. Consequently nuclear (fission) power should be seen as a transition fuel that buys us the time we need to adjust our energy use practices. Simply switching from coal to gas is not a satisfactory solution because the GHG releases from gas firing is still about ½ that of coal. It is better than doing nothing but for a modest increase in cost we can get GHG emissions close to zero for our electricity supply in Ontario. We will need that performance in our electricity sector to counteract the slower pace we will face with the transition of our transportation sector away from oil.

Ontario is in the very favourable position of having already invested in a large nuclear generation fleet. Instead of suffering through periods of severe SBG, dispatching wind down frequently and backing wind up with GHG emitting gas fired generation, we can achieve much better GHG performance by leveraging those nuclear assets.

Bioenergy generation is also an effective zero GHG backup for wind generation. Unfortunately, bioenergy is more suited as a local, smaller scale energy source. There is insufficient sustainable biomass available in Ontario to adopt bioenergy generation on a large scale for all our wind generation.

A7. Abbreviations

The following abbreviations have been used in this document:

AGC – Automatic Generation Control

ASME – American Society of Mechanical Engineers

CCGT – Combined Cycle Gas Turbine

CHP – Combined Heat and Power

CSPE – Canadian Society of Professional Engineers

DOE – US Department of Energy

ETF – OSPE's Energy Task Force

FGD – Flue Gas Desulphurization

FIT – Feed in Tariff

GHG – Greenhouse Gases

HOEP – Hourly Ontario Energy Price (wholesale market)

IEA – International Energy Agency

IESO – Independent Electricity System Operator

IPSP – Integrated Power System Plan

LCOE – Levelized Cost of Electricty

LTEP – Long Term Energy Plan

LNG – Liquefied Natural Gas

NEA – Nuclear Energy Agency

OEB – Ontario Energy Board

OECD – Organization of Economic Co-operation and Development

OME – Ontario Ministry of Energy

OPA – Ontario Power Authority

OPG – Ontario Power Generation Inc.

OSPE – Ontario Society of Professional Engineers

PV – Photovoltaic

R&D – Research and Development

SBG – Surplus Base-load Generation

SMD – Supply Mix Directive

US – United States of America

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