EB-2016-0152 Sustainability-Journal.ca Final Argument

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1.0 SUMMARY

The energy planning for Ontario (which is done in secret behind closed doors) appears to assume that the future will be virtually the same as the past: Ontario will continue to use natural gas as its primary energy source (used for heat and peaking power) and it will continue to rely on nuclear power for its baseload electricity. There are two substantial changes that are occurring at the present time – the source of gas has changed from by-product gas coming from Alberta to fracked shale gas, mostly coming from Pennsylvania, and the Pickering nuclear station will soon be closed. The former change is barely visible in the planning documents but it carries an explosive risk, and the latter change is somewhat offset by declining electricity demand.

Neither OPG nor the OEB is responsible for energy planning in the broad sense but both are likely to be strongly impacted by upcoming changes, some of which may not be directed or managed by the government. This report attempts to explain how Ontario could (and should) deal with the consequences, and why both OPG and the OEB should be very cautious in making long term commitments.

The problem with the shale gas is that only a small part of the gas in the shale (about 2%) is recovered via the drilling pipe. Most of the rest remains thankfully sealed in the shale rock where it has resided for 360 million years. However, a significant amount is released from the shale but is not recovered by the extraction pipe. In the case of the fracking fluid typically about half of the fluid is recovered when the fracking pressure is relieved so the amount of released but uncaptured gas may be comparable. We know how much natural gas we are using and how much CO2 is produced when the gas is burned (about 30 megatonnes) and we know that the appropriate GWP for the methane in the natural gas is 86 (according to IPCC) , so the amount of released gas is likely to produce about 30*86 = 2580 megatonnes of GHGeq. That is a huge number, much bigger than Ontario's entire reported GHG from all sources. The gas is at a depth of about one kilometre and it is likely to take years to reach the surface but once it has been released from its shale prison it is free to diffuse through the relatively porous surrounding rocks, find a rock fault as a pathway, be caught by groundwater movements, move through the shattered shale, or eventually escape via a corroded pipe.

The other fundamental problem with the OPG plan is that is is highly unlikely that nuclear power will be competitive in the future. Renewable energy sources (hydro, solar, wind) are, or soon will be, less expensive and their traditional problem (intermittent output) can be solved by using electricity storage, notably exergy storage (concurrent storage of heat and electricity) as explained in this report. Most of that renewable energy can be collected locally so the days of centrally controlled monopolies over energy may be ending.

For the sake of simplicity this report assumes that exergy stores will be used in the future. There may well be other alternatives but we need to start with the consideration of a solution that we know will work and that offers the potential to meet the total demand for both heat and electricity, that handles the diurnal and seasonal fluctuations in both supply and demand, and that is substantially cheaper than the status quo systems that are currently in place (OPG is engaged in supplying power from several sources).

Exergy stores collect and store heat and cold to be used to meet the thermal demands of our buildings and in so doing they also store electricity. The heat is collected and returned as heat but the electricity is returned via five indirect processes, for example by absorbing electricity at times of excess supply and then returning the energy in the form of heat at times of peak power demand (i.e., achieving demand reduction). Our peak demands for electricity are seasonal, so thermal systems can flatten those seasonal fluctuations, and they can also flatten the daily demand fluctuations caused by daytime activities. (See Section 3 for explanations)

1.1 Why the OPG proposed hydro rate is too high

The existing hydro facilities could produce much more electricity (TWh) if any excess electricity is stored, in which case:
(a) they could make use of the spring runoff
(b) they could make use of high flow rates after rainfalls
(c) they could make use of electricity produced during low power demand periods

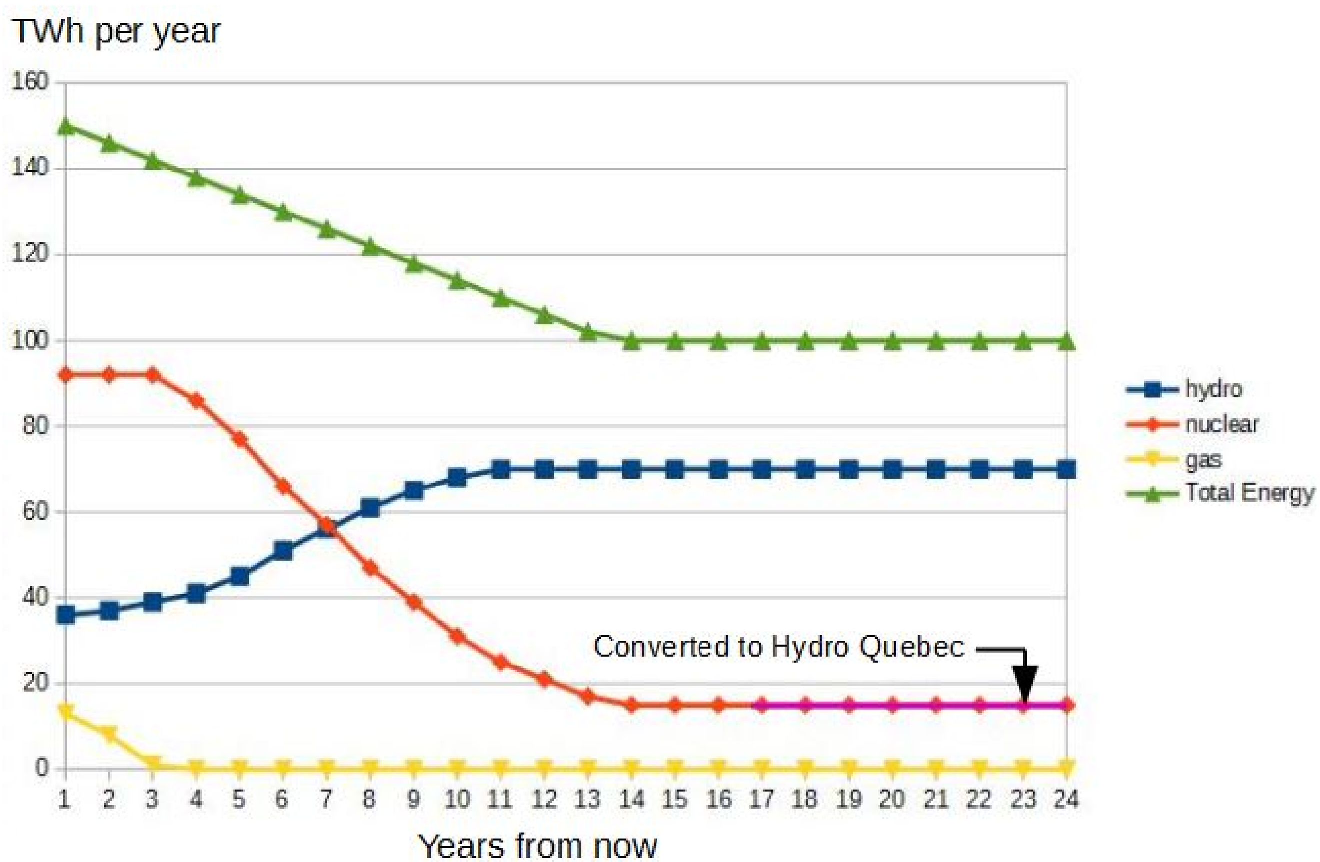
(d) they could provide electricity storage for other power sources without paying a penalty in efficiency

If the storage is provided externally (e.g., at the consumer end of the distribution network) then a large increase in the production (TWh) could be achieved with negligible increases in the capital and operating costs, with the result that the approved hydro rate would be much lower.

In its proposal OPG has failed to evaluate this potential.

1.2 Why the OPG proposed nuclear rate is too low

Ontario has 9000 MW of hydro capacity that could generate 76,000 TWh of electricity if it were employed at 100% efficiency. Ontario presently uses 150,000 TWh of electricity but one third of that is used for thermal applications like space heating and cooling and domestic hot water. If exergy stores were used to store both heat and electricity the demand would be reduced to 100,000 TWh, including a rapidly growing contribution of 13,000 TWh from wind, solar and imported electricity resources. That leaves a balance of only 11,000 TWh that could be met by retaining only a couple of nuclear reactors, or by adding turbines to make better use of the hydro power potential of the existing stations, or by increasing the contribution of wind and solar electricity, or by importing more power from Quebec.



The choice of the method to be used to provide the 11,000 TWh balance is outside of the scope of this OEB hearing but the question of how we could improve the conversion efficiency of the hydro stations is central to determining the rates that should apply to both hydro and nuclear power.

1.3 Compatibility with primary government objectives

The primary objective of the electricity supply system is to provide power in the required quantity at as low a cost as possible. Given a means of storing excess electricity then hydro, wind and solar power are all capable of delivering power at a lower cost than nuclear. Of course the systems must also be safe, stable, reliable and sustainable, and again the renewables alternatives are superior to nuclear power in all of those respects, providing they incorporate storage. Clearly there is no remaining justification for paying a premium price for nuclear power once storage is available.

The Ministry of Energy went to a great deal of trouble to set up a system that would price electricity at a competitive market rate, but then added on a flat rate Global "adjustment" that now accounts for most of the bills that consumers are charged. That defeats the purpose of creating the market-pricing system. There is a need to revisit this billing procedure.

A primary government objective is to achieve radical reductions in GHG emissions. Ontario's target is to reduce the overall emissions by 80% by 2050 but under the Paris Accord the signatories will need to achieve much greater reductions than that for the applications that offer the biggest reduction potential, such as for heating and power generation. Other applications, like aircraft and ship propulsion have relatively little potential to achieve reductions so effectively we need to phase out the use of fossil fuels completely for the favourable applications. Superficially it might appear that neither nuclear nor hydro power is affected since they do not generate GHG but if the government commits us to the use of nuclear power for generation then that would rule out the widespread use of exergy storage which depends on the concurrent storage of both heat and electricity. Most of our GHG from the buildings sector comes from the use of fossil fuels for heating. We need to stop that practice completely and exergy storage, which uses stored summer heat, appears to be the only practical way of achieving that goal. Exergy storage would as a side benefit of its electricity storage capability make our existing hydro generators much more efficient, thus reducing the cost of electricity as well as reducing GHG.

1.4 Setting objectives: Power or Energy?

Although consumers purchase electricity on the basis of the amount of energy used (MWh) the cost of the facilities for producing electricity depends primarily on the peak power demand. The peak power demands occur in the summer (for air conditioning) and in the winter (for space heating). If the demand can be levelled, for example by using storage, then the same amount of energy can be delivered at a much lower cost. In Ontario generation planning is commonly based on the assumption that about 36,000 MW of power will be required, but if the load were constant only 17,000 MW would be sufficient, and if the thermal loads do not use electricity then less than 11,000 MW would be needed. Since exergy stores do not cost anything at all to the power suppliers they provide an extremely attractive means of reducing the capital cost of generation facilities, potentially by as much as a factor of three.

In addition to the seasonal demand fluctuations there is also a need to consider the daily fluctuations related to the high demand during the daytime and the low nighttime demand. Those fluctuations are mainly due to the consumption of electricity for non-thermal applications. Exergy stores can also flatten these grid load variations because the distribution of energy can be exchanged between the thermal and the electrical storage. At times when the electricity supply exceeds the demand the excess energy can be stored in the form of heat. Such systems can also deliver electricity when the grid demand exceeds the supply. It does that by using the hydro storage capacity of the station ponding that is made available where it is no longer needed to provide power supply/demand matching for the nuclear power stations.

Ontario's energy demand for thermal applications is much larger than its need for electricity. As a consequence its exergy storage capacity is inherently capable of storing enough heat and enough electricity to cope with the demand fluctuations for both forms of energy. That paves the way to achieving radical changes in Ontario's electricity supply mix as shown in the graph in section 1.2. It also means that erratic electricity sources like wind turbines can contribute to the pooled storage of grid energy so they effectively become baseload generators. The combined potential extra capacity of Ontario's hydro stations, wind turbines and solar sources grossly exceeds the small gap between the average load and the current hydro capacity.

Such a change will not occur automatically. Natural gas is a cheap source of energy and it is almost universally available so there is very little economic incentive for homeowners to switch to the use of stored heat. Shale gas is also an extremely high GHG producer if you include the upstream emissions (that Ontario conveniently ignores) so there is a substantial (but hidden) social cost. The potential cost savings are large enough to fund a switch from gas to stored heat but the present billing systems would not pass the savings on to the consumers who would foot the bill for the stores.

On a smaller scale the closure of the Pickering nuclear station will further aggravate the GHG problem because most of its output will need to be made up by using gas-fired generators under the OPG plan. The reactor refurbishments will add to that stress because up to several reactors at a time will be out of operation during the refurbishment process.

1.5 Achieving sustainability and resilience

If the OPG plan is approved as presented then Ontario will face high costs for the near term (the refurbishment costs plus the high cost of operating the OPG and Bruce facilities) and a huge future cost when the time comes to replace the nuclear stations with a new design. It is questionable whether Ontario can afford these expenditures. Alternatives like exergy stores, solar and wind have already become less expensive and are less fraught with risks, hazards and long term costs so we need to anticipate the consequences, not wait until it is too late to react. The nuclear venture is a bubble that has already reached its bursting point. It is not sustainable.

The OPG plan calls for generating somewhat less nuclear power, partly matching the trend to declining demand, but Ontario still has no plans for replacing gas for heating. Provinces like BC and Quebec use electricity for heating but Ontario lacks sufficient hydro generation to do that, and the neighbouring provinces don't have enough capacity to help. The power demand could be reduced by using ground or air source heat pumps but that would be more expensive than exergy storage and would still require an unmanageable increase in our electricity generation capacity. Conceptually we might use super-insulated homes but that is not practical to for most of our housing stock. Exergy storage may well be the only practical solution, but we are starting from a point where most people have never even heard of it! Ontario needs a lot of heat. If we do not develop an appropriate plan in 2017 then in another decade we will face the prospect of either spending an enormous amount of money to generate more electricity or of reverting to the use of fossil fuels out of sheer desperation.

1.6 Comparative capital costs

This comparison is easy! The OPG plan calls for expenditures of 12.8 billion dollars for refurbishing the Darlington reactors. The cost to the power industry of utilizing exergy storage to replace those reactors is zero.

The capital cost burden is switched to the consumers. How much they spend will depend on their application. If they are prepared to use electricity but want to switch the demand from day to night then they will need two storage tanks, one to store heat and one to store cold, at a cost of about $1,000 per home. If they want to reduce the electricity consumption then they can add two solar collectors, a solar PV collector to drive the heat pump for the cold store and a solar thermal collector to heat the hot store. These would add several thousand dollars to the capital cost but the capital costs would be offset by the grid power reduction.

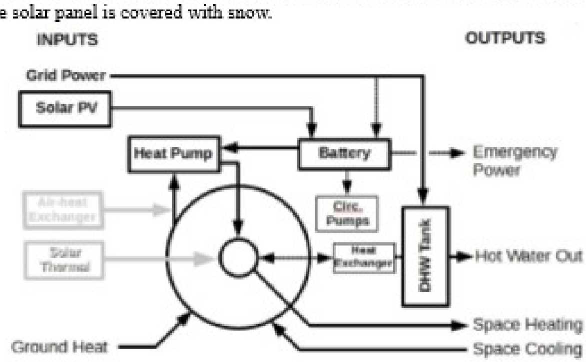
A full exergy store needs a ground storage component in order to provide seasonal storage. This is a much more efficient design because the collection of both heat and electricity is so much more efficient in the summer and because it enables buildings to be heated by summer heat, including the heat that was extracted for air conditioning. Exergy stores use relatively shallow boreholes and low power heat pumps, but a shared ground store would add a few thousands in additional capital costs, with the carrying charges again being offset by the reduction in grid power costs.

Heat storage tanks have a tiny capacity in comparison to the ground stores but they recycle 365 days a year so they are very effective in spite of their small capacities (and low cost). However, they work by concentrating the grid power consumption at night instead of during the daytime peak demand periods so they do not materially reduce the total power consumption. They are very useful in cases where solar collectors and ground storage cannot be used, but their biggest attraction is that they enable a cluster of buildings to be converted to storage with an eye to adding a communal ground store at a later date. Communal ground stores are more cost effective and less disruptive than relying on individual stores for each building.

Standard Exergy Store

It is anticipated that the most common configuration for exergy stores will be as shown in Figure 1. Since the core of an exergy store is trickle charged through all four seasons of the year and the charging process can be interrupted for many days if the sun isn't shining this is an ideal application for using a small solar PV panel to drive the heat pump, making the system independent of both natural gas lines and the power grid (with net metering). The power grid will still be used for non-building applications like cooking, laundry, etc. The exergy storage system is able to absorb and store excess electricity so it will make hydro, wind, solar and nuclear power supply systems much more efficient. Since the solar PV panel will deliver extra electricity during the summer the system can equalize the seasonal solar input by storing that extra energy and drawing some grid power during the winter. That both reduces the size of the store and provides a higher operating temperature for winter space heating. Exergy stores can be retrofitted to old buildings.

In some cases the solar input is not feasible so the heat pump can be run at night from grid power. In such cases there is still no consumption of peak power, no need to use electricity for air conditioning and there is still the enhancement of the capacity of hydro stations, etc., so such systems will still make big contributions to the power grid. Nighttime heat pumping can also be used when the solar panel is covered with snow.



Fully Off Grid Systems Systems that need to operate completely off grid will look like Figure 2 (our Testbed system in Kingston) with both solar PV and solar thermal collectors on the roof. Solar thermal collectors have much higher efficiencies than solar PV collectors so in this type of system they enhance the electricity supply capacity by more than solar PV collectors would. However, off grid systems will require large electricity storage batteries so they will be relatively expensive to build.

Enhancements Systems that have very high thermal loads or that need to handle grid power spikes can utilize isothermal buffers that use paraffin wax for heat of fusion storage. Similarly, buildings that need high cooling capacity in the summer can utilize buffers that use water as the heat of fusion storage medium. Applications that extract excessive amounts of heat from the ground can use summer air-heat exchangers to replenish the ground heat. By starting from a standard system design the various models will generally share the same components and will share the same design procedures. The physical size of the components will vary according to the required system capacity.

1.7 Comparative operating costs

The operating costs for the Darlington nuclear station is substantial (the table below shows quarterly figures). The operating costs for the standard exergy stores (type 3 of the described designs) are nearly zero for the building owners and are of course zero for the power generators. For types 1 and 2 stores some grid power is drawn so the operating costs are not zero, but they both use inexpensive nighttime power so the costs are less than the cost of regular electric baseboard heating. The intent for Types 1 & 2 is that they will eventually be upgraded to type 3 systems. That provides for an interim period when the capital costs are low, followed by a phase in of the ground storage that will require capital expenditures but the operating cost will decline to nearly zero.

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Exhibit A2-1-1
Attachment 1
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FOURTH QUARTER

Discussion of Results

	Three Months Ended December 31	
(millions of dollars) (unaudited)	**2013**	**2012**
Regulated generation sales	**801**	821
Spot market sales	**87**	106
Variance accounts	**37**	272
Other	**249**	(4)
Revenue	**1,174**	1,195
Fuel expense	**176**	207
Variance accounts	**(9)**	(8)
Total fuel expense	**167**	199
Gross margin	**1,007**	996
Operations, maintenance and administration	**720**	734
Depreciation and amortization	**236**	169
Accretion on fixed asset removal and nuclear waste management liabilities	**189**	181
Earnings on nuclear fixed asset removal and nuclear waste management funds	**(166)**	(170)
Restructuring	**2**	-
Property and capital taxes	**10**	7
Income before other income, interest, and income taxes	**16**	75
Other income	**(7)**	-
Income before interest and income taxes	**23**	75
Net interest expense	**23**	28
Income before income taxes	**-**	47
Income tax (recovery) expense	**(4)**	16
Net income	**4**	31

Net income decreased by $27 million during the fourth quarter of 2013, compared to the same quarter in 2012. The following summarizes the significant items which caused the variance in net income:

1.8 Comparative GHG emissions

At the present time approximately 30 megatonnes of greenhouse gases are produced by burning natural gas in Ontario, primarily for heating. The government does not report on the upstream GHG emissions (which are generated outside of Ontario) and it has declined to report on what fraction of the gas consumption currently comes from shale deposits. However, it is evident that most of the natural gas that is consumed in Ontario will soon be shale gas, including a large part that comes from the US and a smaller shale gas contribution from western Canada.

The appropriate IPCC value of the global warming potential for methane (the principal constituent of natural gas) is 86. In the fracking process the amount of gas that is collected is believed to be comparable to the amount that is released from the shale but not recovered. Given the known production of CO_2 from combustion of the gas (30 megatonnes) the amount of equivalent CO_2 (i.e. the GHG) can therefore be calculated (30x 86 = 2580 megatonnes per year). This GHG may remain in the ground for a long time but it is no longer sealed in the shale rock in which it has been trapped for 360 million years. The shale is now shattered so it cannot retain that escaped methane, the gas is mobile where it encounters faults, ground water flow or diffusion through the other rock types that lack shale's retention. Moreover, the drill pipes will eventually corrode, so it is only a matter of time until much of the methane will escape to the surface. There is no known method for collecting this methane, which may diffuse widely. Once it has been released it represents an enormous environmental time bomb.

1.9 Recommendations

1) The extension of the licence for the Pickering reactors proposed by OPG provides a window of opportunity to extend the heat+electricity storage capacity on a useful scale.

2) OPG should be asked to analyze the potential for making much more efficient use of the available flow energy of their existing hydro stations.

3) Given a substantial increase in the hydroelectric energy output (TWh) the number of nuclear stations should be reduced.

4) The nuclear rate is largely dependent on fixed costs that depend on the number of units in service. The plans for the Darlington station (and the Bruce stations) make provisions for "Off Ramp" choices that are highly likely to be exercised but no provisions have been made for determining the new payment rates that would result.

5) OPG has already proceeded with the refurbishment of Darlington Unit 2, which accounts for nearly half of the total refurbishment costs. No rate estimate has been provided for this unit so there is nothing for the OEB to approve.

2.0 EVIDENCE

2.1 Why the OPG proposed hydro rate is too high

OEB Staff Submission
Ontario Power Generation Inc.
2017-2021 Payment Amounts (EB-2016-0152)

1. INTRODUCTION

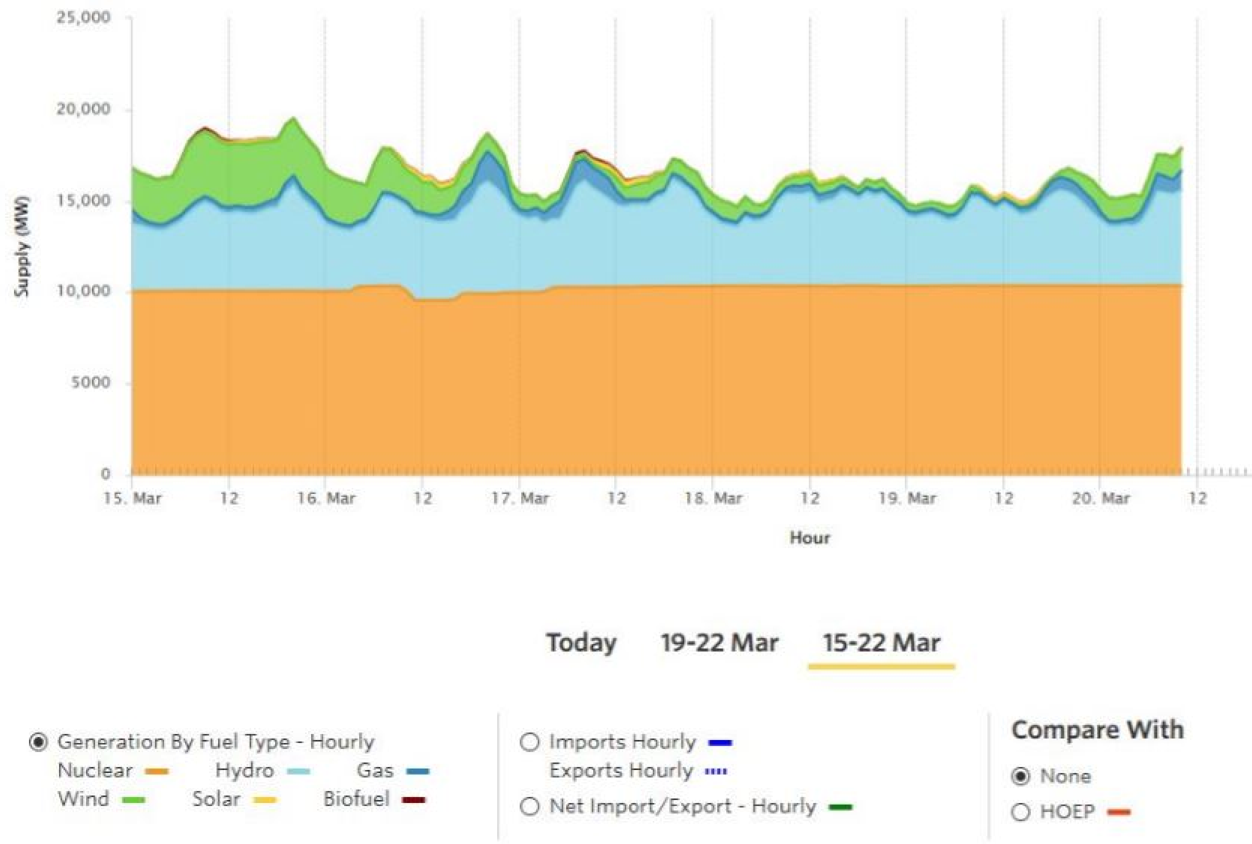
Ontario Power Generation Inc. (OPG) filed an application with the Ontario Energy Board (OEB) on May 27, 2016, seeking approval for changes in payment amounts for the output of its nuclear generating facilities and the regulated hydroelectric generating facilities for the period January 1, 2017 to December 31, 2021.

The application is underpinned by the OPG 2016-2018 business plan but was updated through impact statements filed on December 20, 2016, February 22, 2017 and March 8, 2017. In addition, further evidence was filed relating to nuclear liabilities and the capacity refurbishment variance account for the regulated hydroelectric facilities.

As of March 8, 2017, OPG is seeking approval of a hydroelectric payment amount of \$41.71/MWh effective January 1, 2017 and a deferral and variance account rider of \$1.44/MWh applied to the output of the hydroelectric facilities from January 1, 2017 to December 31, 2018. OPG seeks approval of its proposed IRM formula for the hydroelectric facilities for the period 2017-2021.

As of March 8, 2017, OPG is seeking approval of a nuclear revenue requirement of \$16.8 billion over the period 2017-2021. The proposed revenue requirement reflects a stretch factor that OPG has applied as part of its Custom IR application. OPG also seeks approval of a deferral and variance account rider of \$2.85/MWh applied to the output of the nuclear facilities from January 1, 2017 to December 31, 2018. In accordance with O. Reg. 53/05 (*Payments Under Section 78.1 of the Act*), OPG proposed smoothed nuclear payment amounts and deferred revenue requirement amounts in its application, as filed on May 27, 2016. The regulation was amended on March 2, 2017 and OPG has amended its application to reflect a smoothed weighted average payment amount (WAPA) proposal. The following table summarizes OPG's current payment amount request for the nuclear facilities:

OPG is requesting that the payment rate for hydro should remain constant but the potential exists to substantially increase the productivity of the hydro system if the end users incorporated electricity storage. At the present time hydro power plays a subservient role to support nuclear power. The nuclear plants can only operate at a fixed load so the hydro system's output is varied to match the combined supply to the varying load as shown in the graph below. This reduces the average output from the hydro stations. If the end users incorporate storage then the hydro stations could operate at their full capacity of up to 9000 MW and the stations could deliver approximately twice as much power. Moreover, if the turbine capacity of one of the larger hydro stations is increased the hydro capacity could be further increased. The potential to utilize the energy of the spring runoff and high rain periods is very large, but it depends on the ability to store the excess electricity.



The need for storage is rather dramatically illustrated by the graph below, showing the flow fluctuations of the St. Lawrence river.

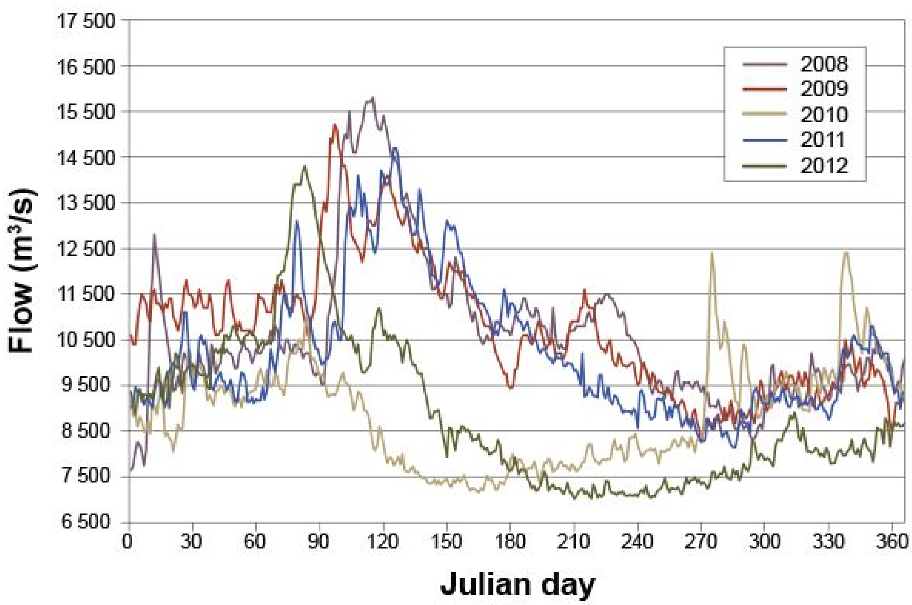


Figure 6. Annual flow pattern in the St. Lawrence River at Sorel from 2008 to 2012

2.2 Why the OPG proposed nuclear rate is too low

Filed: 2016-05-27
EB-2016-0152
Exhibit B1
Tab 1
Schedule 1
Page 1 of 8

RATE BASE

1.0 PURPOSE

This evidence presents the rate base for the nuclear facilities, including drivers of period-over-period differences. In addition, it provides a description of each of the components of rate base and the methodology with which these components are determined.

2.0 OVERVIEW

This evidence supports OPG's request for approval of a rate base for the nuclear facilities for the test period. The forecast of rate base for the nuclear facilities is $4,119.8M in 2017, $4,239.0M in 2018, $4,124.7M in 2019, $8,118.6M in 2020 and $8,549.2M in 2021 (Ex. B1-1-1, Table 2). The evidence also presents the rate base for the nuclear facilities for 2013 to 2015 (actual) and 2016 (budget).

The components of rate base and the methodology used to calculate them are the same as those reflected in the rate base approved by the OEB in EB-2013-0321, EB-2010-0008 and EB-2007-0905.

OPG's forecast of rate base for the bridge and test periods is based on a forecast of net fixed/intangible in-service assets (including nuclear asset retirement costs or "ARC") and working capital associated with the nuclear facilities. The rate base amounts for the historical period are based on actual balances for those years. As in EB-2013-0321, EB-2010-0008 and EB-2007-0905, working capital consists of cash working capital, fuel inventory, and materials and supplies.

Nuclear rate base including ARC is forecast to increase significantly over the 2017 to 2021 period, primarily due to the in-service additions in respect of the Darlington Refurbishment Program ("DRP"). As shown in Ex. B3-1-1 Table 1, nuclear rate base reflects net plant of $852.3M in 2017, $955.2M in 2018, $929.7M in 2019, $5,031.4M in 2020 and $5,476.2M in 2021 related to the DRP. The net plant rate base value for the Pickering station is close to fully depreciated by the end of the test period, in line with the current accounting end-of-life

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("EOL") date of December 31, 2020. Nuclear rate base for the test period also includes a decrease in ARC of $417.5M recorded at the end of 2015 related to the change in the nuclear asset retirement obligation ("ARO") reflecting changes in the nuclear station EOL dates, for accounting purposes, effective December 31, 2015. The 2015 change in ARO and ARC is discussed in Ex. C2-1-1, and the nuclear station EOL dates in Ex. F4-1-1 section 3.2.

The fixed/intangible asset component of rate base is discussed in section 3.1. Working capital is discussed in section 3.2. A more detailed comparison of rate base over the 2013 to 2021 period is presented in section 4.0.

3.0 COMPONENTS OF RATE BASE

3.1 Fixed and Intangible Assets

3.1.1 Overview

The forecast net plant rate base values for the nuclear facilities, including ARC, are projected at $3,408.3M in 2017, $3,541.3M in 2018, $3,453.2M in 2019, $7,469.9M in 2020 and $7,914.7M in 2021. The net plant for the nuclear facilities is presented separately for each of Darlington, DRP, Pickering, Nuclear Support Divisions, and ARC in Ex. B3-1-1 Table 1. All fixed assets under construction and intangible assets under development are excluded from the rate base for the period 2013 to 2021.

As in EB-2013-0321, EB-2010-0008 and EB-2007-0905, fixed and intangible assets used by both the regulated and unregulated generating business units continue to be held centrally. These assets are not included in rate base. Instead, all generating business units are charged an asset service fee for the use of these assets, as discussed in Ex. F3-2-1.

If the number of reactors is reduced then the nuclear payment rate will need to be higher because many of the costs are fixed costs that will not decline in proportion to the number of units. Since Off Ramp provisions are part of the plan the nuclear payment rates should be shown in a table based on the that number. The selection of the number of units will presumably be made by the Ministry of Energy, not OPG or the Board.

Numbers may not add due to rounding.

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Exhibit B1
Tab 1
Schedule 1
Table 2

Table 2
Prescribed Facility Rate Base - Nuclear ($M)

Line No.	Rate Base Item	2013 Actual	2014 Actual	2015 Actual	2016 Budget	2017 Plan	2018 Plan	2019 Plan	2020 Plan	2021 Plan
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	Gross Plant at Cost[1]	6,042.7	6,284.0	6,521.7	6,741.2	7,627.1	8,122.9	8,416.1	12,887.2	13,763.5
2	Accumulated Depreciation and Amortization[1]	3,038.9	3,315.9	3,605.6	3,898.5	4,218.8	4,581.6	4,962.9	5,417.3	5,848.8
3	Net Plant[1]	3,003.8	2,968.1	2,916.1	2,842.6	3,408.3	3,541.3	3,453.2	7,469.9	7,914.7
4	Cash Working Capital[2]	32.0	9.3	11.0	11.0	11.0	11.0	11.0	11.0	11.0
5	Fuel Inventory[2]	330.6	316.1	301.4	280.3	251.9	242.2	224.2	210.7	208.6
6	Materials & Supplies[2]	413.5	420.8	426.7	438.7	448.7	444.5	436.3	427.0	415.0
7	Total	3,779.8	3,714.4	3,655.2	3,572.6	4,119.8	4,239.0	4,124.7	8,118.6	8,549.2

The details for the facility will likewise be dependent on the number of reactors, which may be very difficult to determine at the present time.

2.3 Compatibility with primary government objectives

There are many people who object to the use of nuclear power as a matter of principle. Clearly the Ontario government does not agree with that principle. To avoid endless and insoluble clashes over that difference of opinion the government issued Regulation 53/05 that states that “the Board shall accept the need for the Darlington Refurbishment Project....”. Sustainability-Journal.ca agrees that disputes on that basis would be unproductive. For example the hazards incurred by using nuclear power are less significant than those that relate to Climate Change. However, Regulation 53/05 does not stipulate that any particular number of reactors must be built, and indeed the plan has provisions for any or all of the refurbishment projects to be cancelled via its Off Ramp provisions. Our view is that the number of reactors should be drastically reduced because they are not needed, not because they are inherently unacceptable. Ontario’s need for power can be met by using electricity storage to make better use of hydro, wind and solar electricity sources, and the concurrent capacity to store and efficiently utilize heat as well provides a two-way benefit at very little extra cost.

2.4 Setting objectives: Power or Energy?

This was not discussed in the hearings. See Sections 1.4 and 3.4.

2.5 Achieving sustainability and resilience

OPG is required to consider environmental issues for its operations. Although neither hydro nor nuclear stations directly produce much GHG the OPG plan calls for nuclear power to displace the opportunity to employ renewable energy sources and that is particularly a problem for exergy storage, which could eliminate the GHG from heating but would be prevented from doing so by having its electricity storage capacity blocked.

Environmental Performance

OPG's Environmental Policy states that "OPG shall meet all legal requirements and any environmental commitments that it makes, with the objective of exceeding these legal requirements where it makes business sense." This policy commits OPG to:

- establish and maintain an environmental management system
- work to prevent or mitigate adverse effects on the environment with a long-term objective of continual improvement
- maintain, or where it makes business sense, enhance significant natural areas and associated species at risk.

Environmental performance targets also form part of OPG's annual business planning process. Performance is monitored and communicated to internal and external stakeholders.

OPG monitors emissions into the air and water and regularly reports the results to regulators, including Ontario's Ministry of the Environment, Environment Canada, and the CNSC. The public also receives ongoing communications regarding OPG's environmental performance. OPG has developed and implemented internal monitoring, assessment, and reporting programs to manage environmental risks. These risks include air and water emissions, discharges, spills, the treatment of radioactive emissions, and radioactive wastes. OPG also continues to address historical land contamination through a voluntary land assessment and remediation program.

In 2013, OPG managed air emissions of nitrogen oxides (NO_x) and sulphur dioxide (SO_2) through the use of specialized equipment such as scrubbers, low-NO_x burners, Selective Catalytic Reduction equipment, and the purchase of low sulphur fuel. For the years ended December 31, CO_2 and acid gas (SO_2 and NO_x) emissions from OPG's coal-fired stations were as follows:

	2013	**2012**
CO_2 *(million tonnes)*	**3.2**	4.3
SO_2 and NO_x *(gigagrams)*	**14.8**	16.1

2.6 Comparative capital costs

Numbers may not add due to rounding.

Filed: 2016-05-27
EB-2016-0152
Exhibit B1
Tab 1
Schedule 1
Table 2

Table 2
Prescribed Facility Rate Base - Nuclear ($M)

Line No.	Rate Base Item	2013 Actual	2014 Actual	2015 Actual	2016 Budget	2017 Plan	2018 Plan	2019 Plan	2020 Plan	2021 Plan
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	Gross Plant at Cost[1]	6,042.7	6,284.0	6,521.7	6,741.2	7,627.1	8,122.9	8,416.1	12,887.2	13,763.5
2	Accumulated Depreciation and Amortization[1]	3,038.9	3,315.9	3,605.6	3,898.5	4,218.8	4,581.6	4,962.9	5,417.3	5,848.8
3	Net Plant[1]	3,003.8	2,968.1	2,916.1	2,842.6	3,408.3	3,541.3	3,453.2	7,469.9	7,914.7
4	Cash Working Capital[2]	32.0	9.3	11.0	11.0	11.0	11.0	11.0	11.0	11.0
5	Fuel Inventory[2]	330.6	316.1	301.4	280.3	251.9	242.2	224.2	210.7	208.6
6	Materials & Supplies[2]	413.5	420.8	426.7	438.7	448.7	444.5	436.3	427.0	415.0
7	Total	3,779.8	3,714.4	3,655.2	3,572.6	4,119.8	4,239.0	4,124.7	8,118.6	8,549.2

The capital costs of nuclear stations is extremely high. In comparison the capital cost of exergy stores would be zero for the power generation industry and would be comparatively low for the consumers who install exergy stores. Those consumers would recover their investment via reduced cost within a reasonable time so there is no need to subsidize their construction but there is a need to ensure that the power rates they pay do not penalize them.

2.7 Comparative operating costs

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DISCUSSION OF OPERATING RESULTS BY BUSINESS SEGMENT

Regulated – Nuclear Generation Segment

(millions of dollars)	**2013**	**2012**
Regulated generation sales	**2,552**	2,719
Variance accounts	**55**	300
Other	**287**	41
Total revenue	**2,894**	3,060
Fuel expense	**296**	310
Variance and deferral accounts	**(59)**	(49)
Total fuel expense	**237**	261
Gross margin	**2,657**	2,799
Operations, maintenance and administration	**2,022**	1,930
Depreciation and amortization	**626**	480
Property and capital taxes	**29**	26
(Loss) income before other income, interest and income taxes	**(20)**	363
Other income	**(1)**	(1)
(Loss) income before interest and income taxes	**(19)**	364

The operating costs of exergy stores are very low, so again their economic advantage is huge. The primary cost is the maintenance of the heat pumps and circulation pumps.

2.8 Comparative GHG emissions

Not discussed in the hearings. See Sections 1.8 and 3.8.

2.9 Recommendations

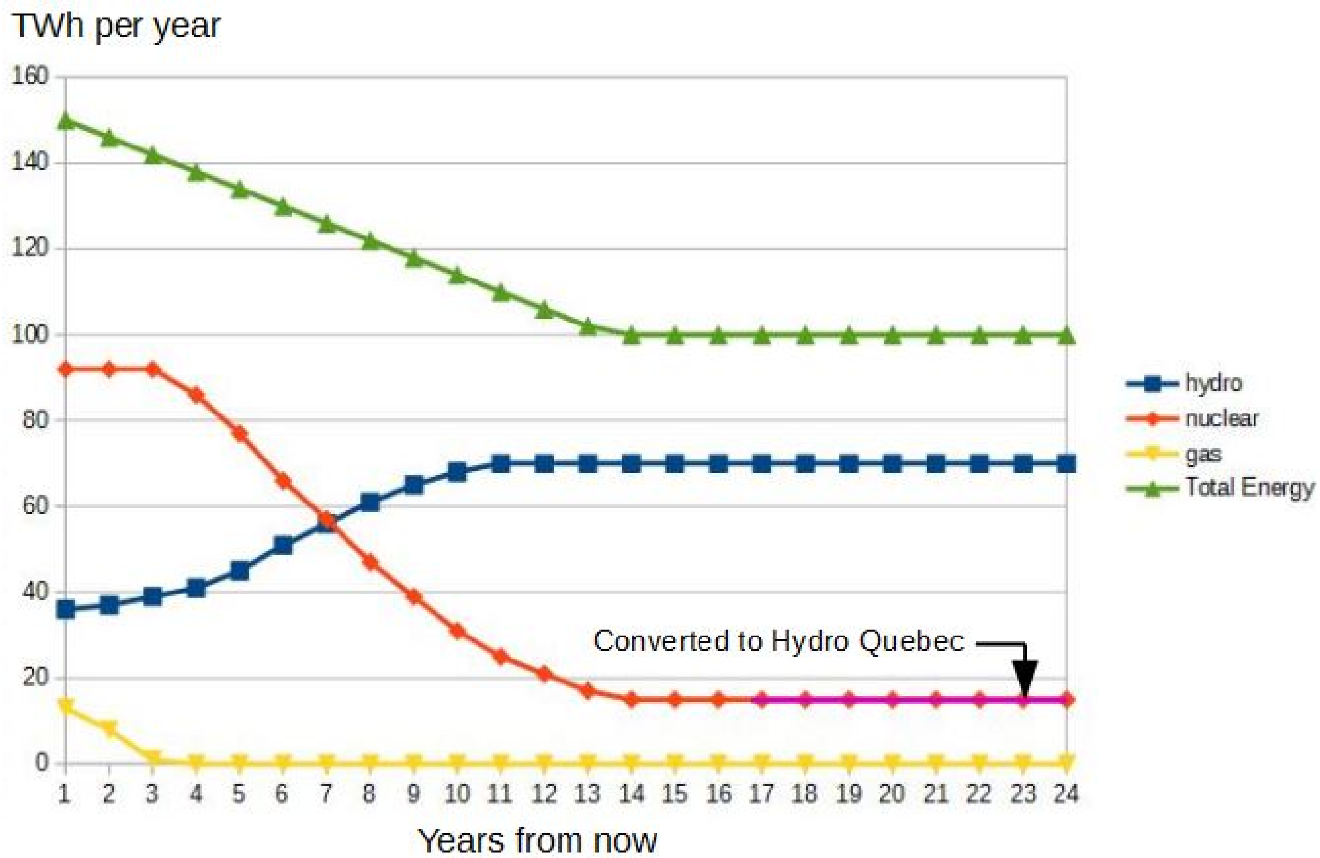
Listed in Section 1.9.

3.0 EXPLANATIONS

3.1 Why the OPG proposed hydro rate is too high

The OPG rate application proposes that the hydro production (and the hydro rate) should remain at their previous level. Such a policy represents a poor value for ratepayers because the existing hydro facilities could produce much more electricity if they made use of storage to store the excess electricity that can be produced when the river flow rates are high but the power demand is low. It is commonly assumed that you need electric batteries to store electricity but it is about 1000 times less expensive to use exergy storage, which has the capability to be applied on a very large scale, and that delivers energy in its own right even as it stores the electricity.

The graph shown in Section 1.1 needs further explanation:



The graph shows how the use of gas (and oil) peaking generators could be quickly phased out (yellow line), the output of the existing hydro stations (blue line) could be raised to nearly their theoretical limit imposed by their generator capacities, and the need for nuclear power could be drastically reduced as a result (red line).

The electricity generated by the existing wind turbines is not shown in the graphs but it was included in the calculations.

The solar PV contribution to this grid energy supply graph is not shown because it is classed as "embedded generation" that does not contribute or detract from the annual energy totals, although the solar panels would supply some power to the grid in the summer and would extract a comparable amount of grid energy in the winter.

The total electrical energy produced per year (green line) is the sum of the gas, hydro, nuclear and wind generation, using the current IESO data. This total declines over the first 15 years of operation because the exergy stores would progressively remove the 50 TWh load that relates to the use of electricity for thermal applications (heating, cooling and domestic hot water).

The graph for nuclear power assumes that the licence for the Pickering reactors will be extended as proposed by OPG. This provides a period for the storage systems to take effect. If the CHRC should reject the Pickering extension then the slack would be taken up by gas-fired generation, which is the same solution as that proposed by OPG.

All but two of the OPG and Bruce reactors would be shut down on dates that are close to their existing licence expiry dates, but the actual individual timings would be adjusted in order to produce a smooth curve. The remaining reactors (or some alternative) are needed to provide for a production shortfall since the hydro stations do not currently have sufficient capacity to fill the gap.

This solution imposes hardly any demands on the existing power generation system. The only major response is to provide for the 17 TWh deficiency that prevents the nuclear stations from being phased out completely. Otherwise the existing power stations remain in place with their current turbines and the reactors are shut down nearly in accordance with their present licence expiry dates.

One option for the 17 TWh gap is to extend the licences for two of the Darlington/Bruce reactors but there are alternatives. The 17 TWh might be imported from Quebec, or the turbine capacity of one of the hydro stations might be increased, or the wind turbine capacity might be increased (which is attractive because the wind output increases in the winter when it is most needed), or the size of the embedded solar panels might be increased, etc. The key point is that the gap has been reduced to a magnitude that can be readily handled via a combination of these alternatives.

The impact on the hydro rate is that the annual output would be doubled without making any new capital investments or increases in operating costs, leading to the potential for a corresponding reduction in the hydro rate.

3.2 Why the OPG proposed nuclear rate is too low

The effects on the nuclear rate would be even greater, but in the opposite direction. The nuclear rate is strongly dependent on the capital expenditures and on fixed operating costs relating to safety systems, fuel disposal, etc. Reducing the nuclear output from 93 TWh to 17 TWh without a corresponding reduction in those fixed costs will radically raise the nuclear rate.

3.3 Compatibility with primary government objectives

The standard exergy store provides a means of achieving numerous government objectives, including the reduction in GHG emissions, achieving sustainability for both thermal and electrical needs, and reducing the cost of energy in both forms. (See the next page).

How does it work?

An exergy store has three basic components: an inner and outer ring of boreholes containing heat exchange tubes and a heat pump that extracts heat at a low temperature from the large outer ring and concentrates the heat in the smaller inner ring. Moving the heat adds only a small amount of energy. The central zone will be at a much higher temperature because it contains the same amount of energy in a smaller volume - in physics terms its exergy has been raised, hence the name 'exergy store'. The velocity of heat flow out of the core is slow so the outflow does not reach the outer ring until the fall, making it possible to use the outer ring for cooling in the summer. The heat pump operates in all four seasons, collecting heat in the summer, boosting the temperature of the stored heat in the fall, replenishing some of the heat that is extracted from the core in the winter, and bringing the temperatures back to their starting point in the spring. The stored heat and cold are used directly for space heating and cooling without assistance from a heat pump during recovery.

Conceptually this provides a means for cooling buildings in the summer, heating them in the winter and for providing domestic hot water throughout the year. In practice the system may need some help - in the summer the temperature of the heat pump's input loop can be stabilized by adding heat extracted from the air and throughout the year heat can be injected into the core via a solar thermal panel to reduce the power demand of the heat pump. Since the heat pump operates whenever power is available throughout the year and its power demand is very low compared to that of a GSHP it is feasible to use a small solar PV panel to provide the power. The solar PV panel will generate more power than is needed in the summer and that excess electricity can be fed to the grid via net metering. In the winter the grid will supply the needed power but the heat pump runs only at night so it never draws any power from the grid during high grid demand periods.

The results for homeowners (and commercial/institutional buildings) are:

*** the net power demand can be reduced to zero**
*** the system does not require any fossil fuels or produce any GHG**
*** the system can provide 100% of the heating, cooling and DHW for the building(s) it serves**
*** the cost of the heat and of the electricity that the system itself draws is zero (but the buildings will use electricity for other applications so they will continue to draw power for those needs)**
*** the capital cost (per MWh) of such systems is much less than the capital costs for the existing gas and grid power systems but there will be a need to establish procedures that assign the appropriate part these capital costs to the relevant beneficiaries (i.e. not to put all of the funding burden on homeowners)**

Exergy stores also provide major benefits to the electricity supply systems:

*** the power demand could be cut by 1/3rd because much of the grid demand is used for heating, cooling and DHW**
*** the exergy systems draw no power at all during peak demand periods. Moreover, they can optionally store large amounts of power at night, thus flattening the daily demand graph**
*** the exergy stores can optionally utilize excess power produced by the spring runoff, after rainfalls, or on windy days to increase the energy production of existing power generation systems**
*** the pond storage capacity of existing hydro power stations can be reassigned to boost electricity storage capacity**
*** the losses and the costs of the energy distribution systems can be reduced, along with the costs of new generation**

Individual exergy stores provide all of these benefits but the supply system benefits are shared by all power users. There is thus a need to establish a procedure to assign some of the capital and operating costs to the other ratepayers. For example, the power rates for exergy system owners might be reduced in accordance with the supply system benefits. In Ontario a Global Adjustment factor is used to keep track of such costs and apply them to individual users. Normally such costs increase the cost of power but in this case the result is a cost reduction. Cities might utilize the existing provisions for Local Improvement Charges (LIC's) to spread out the capital expenditures for the building owners. Although that means that the building owners would ultimately be paying for 100% of the capital costs part of those costs would be offset by the GA reduction and part of the costs (for everyone) would be further offset by general power rate reductions since the present expenditures of billions of dollars on new generation facilities could be eliminated.

Potentially exergy stores could be using local thermal energy sources on a scale that would enable all of Canada to rely on just the existing hydro power generation facilities for many decades to come, without having to rely on nuclear power, expensive building changes, carbon taxes, subsidies or elaborate national and provincial Climate Change plans. More details on the system design are available in the paper "Compact Exergy Storage Systems".

Conclusion: ***Exergy storage solves two problems - eliminating GHG and reducing energy costs***

3.4 Setting objectives: Power or Energy?

OPG appears to be in the position that its role is simply to provide a preset amount of electricity via its hydro and nuclear stations, employing long established procedures and facilities. Issues relating to objectives, competence, innovation, productivity, economy, the environment, etc., are perceived to be primarily “somebody else’s” responsibility. The proposal is to spend 12.8 billion dollars without regard for whether the objectives are rational, the systems design is sound, the proposal is cost effective or the plan is in the public interest. OPG is presumably operating under strict marching orders but the responsibility of the Intervenors should be to consider the issues from the public’s point of view. **This is a bad plan**. The plans for both hydro and nuclear power generation are highly questionable.

3.5 Achieving sustainability and resilience

Hydro, solar and wind energy sources are all subject to substantial fluctuations from year to year, and the fluctuations in demand are also substantial. Electricity storage alleviates some such problems but ideally a mix of these various sources should be employed to minimize the risk.

3.6 Comparative capital costs

No further comments required.

3.7 Comparative operating costs

No further comments required.

3.8 Comparative GHG emissions

Canada has a deservedly poor reputation for its management of GreenHouse Gas (GHG) issues, primarily because the responsible government agencies have a habit of looking the other way, usually with the excuse that it is someone else’s problem. In this case if the OPG application is approved and the program proceeds it will result in the production of about 2500 megatonnes of GHGe per year for the foreseeable future as explained in Section 2.8. Neither the hydro stations nor the nuclear reactors directly produce significant quantities of GHG and environmental issues are not the responsibility of the OEB so why is this an issue?

The answer lies in the way we heat our buildings. In Ontario most buildings are heated with natural gas and Ontario has misguidedly turned to the use of fracked shale gas as its source of natural gas. The upstream GHG produces most of the GHG but the mobilized methane from the natural gas fracking remains underground for a considerable time and it is unrecoverable so the gas industry pays very little attention to it, the federal Dept. of Environment and Climate Change makes no effort to measure it because it is produced in the US, the provincial Environment Ministry doesn’t report it either because they use federal data for their GHG reports, and the Energy Ministry, IESO and OEB assume that someone else is minding the store.

The problem is that in Ontario there are only three practical ways to heat our homes: we can use gas or other combustible fuels, or we can use electricity (including variants like ground source heat pumps) or we can use seasonal storage of heat. However, if we use gas there will be a huge increase in our GHG emissions at a time when our governments are promising to reduce such emissions to nearly zero. If we tried to substitute electricity for heating the demand for electricity would be unsustainable because we need more energy for thermal applications than for all of the present electricity applications. That leaves thermal storage as the only remaining option, but the design of effective heat stores requires the use of electricity to manage the heat flow and to provide the delivery temperatures so they are inherently combined heat and power systems. That dual nature makes it possible to store heat and electricity concurrently in a single system and that in turn is what makes it possible to operate our hydro facilities more efficiently and consequently to radically revise the nuclear power plans.

3.9 Recommendations

Outlined in Section 1.9

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