How to make much more efficient use of Ontario's hydro power

Almost all of Ontario's hydro power stations are run-of-the-river stations that lack the ability to store their rivers' energy behind big storage dams. The amount of energy that is available changes throughout the seasons as the flow rates vary and according the the amount of rainfall. Since they cannot store the water that flows during the wet periods it is simply allowed to bypass the turbines and the energy is lost forever.

The flow rates for the Ottawa River at the Carillon dam at Hawkesbury are shown in the table below:

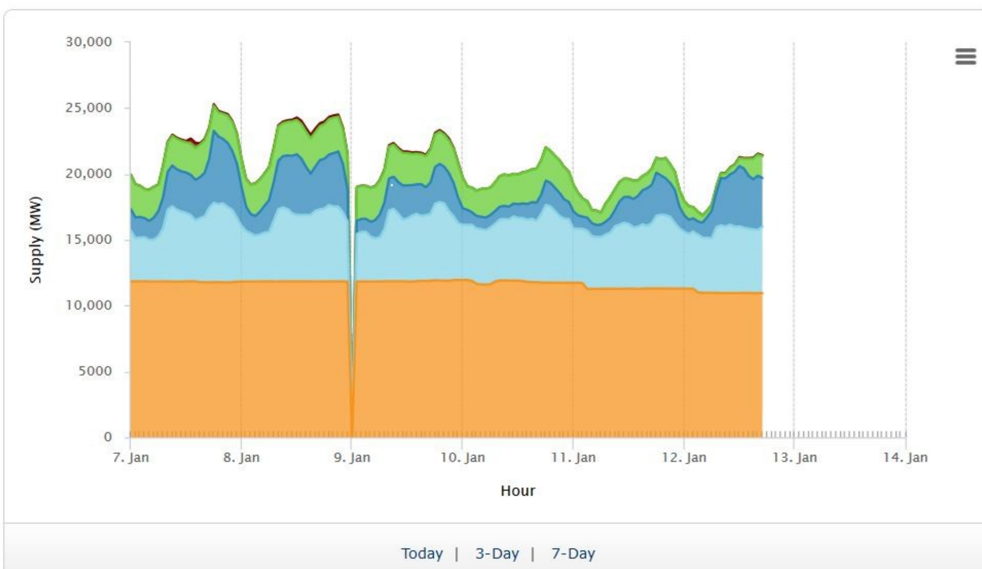
Table 3.4 Ottawa River Discharge Volume as Measured at Carillon Dam

Year	Maximum Flow	Minimum Flow	Yearly Average
2004	4917 m^3/s	534 m^3/s	1960 m^3/s
2003	4792	519	1811
2002	5947	666	2064
2001	4070	563	1700
2000	3205	971	1801

(Source: ORRPB: "Historical Streamflow Summary")

For the year 2004 the flow rate ranged from 534 m3/s to 4917 m3/s, a spread of 9.2 to 1. The average flow rate was 1960 m3/s so the potential annual energy output would be 3.7 times greater if the system could store and recover all of the river's available energy.

Actually the real performance is not as bad as that implies. The run-of-the-river stations do have low dams that create ponds that store enough water to handle the daily load fluctuations. The following graph shows the electricity supply pattern over a typical week (from IESO data):



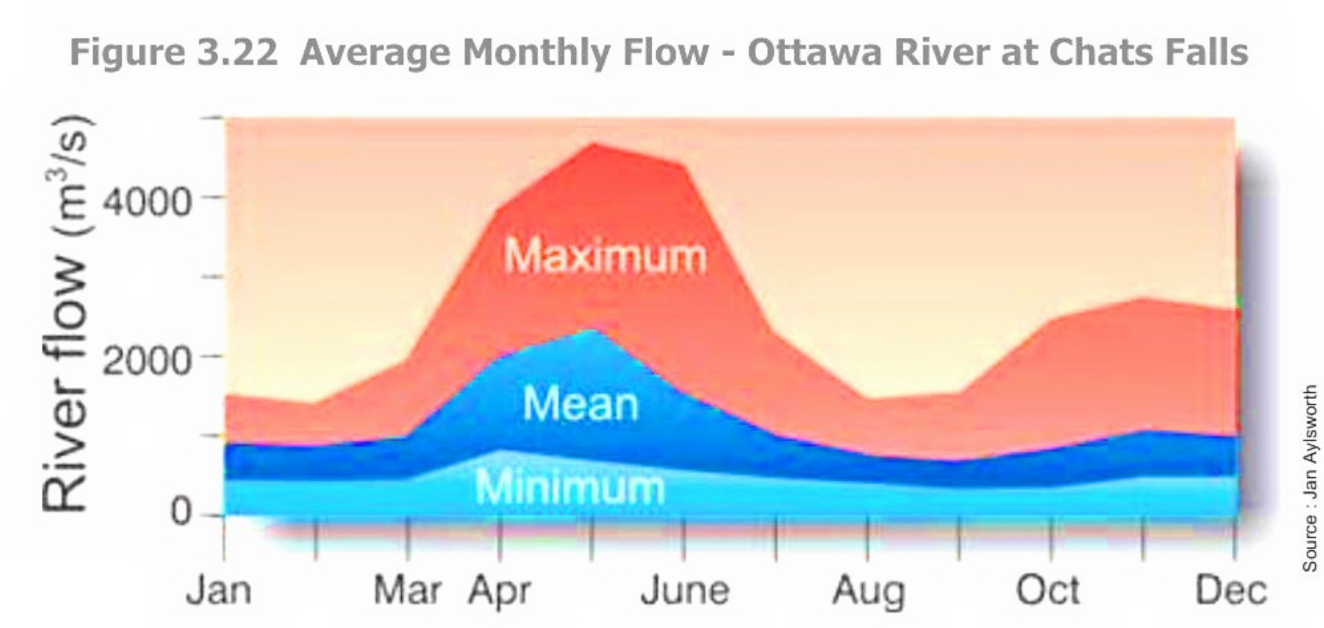
The orange colour represents the nuclear contribution which is relatively stable. Light blue represents the supply of electricity from all of the hydro stations that report to the IESO. Note that the output fluctuates according to the power demand, achieved by spilling some of the water through the spillways or by reducing the flow rate through the turbines which thus raises the pond water level (storing that energy for future use). The dark blue shows the power from natural gas powered peaking stations and the green represents the wind power contribution. The nuclear and hydro pattern shown in this graph is repeated with very little change every day for 365 days per year. The wind contribution varies with the strength of the wind and the peaking station output makes up the difference that is needed to match the supply with the current power load.

The ponding storage makes it possible to install turbines that are larger than what would be needed for the minimum flow case. Taking the data for the R.H. Saunders dam as an example its average output is typically about 72% of the output you would get if the turbines were fully utilized at all times. Putting it another way the turbine is chosen to be 1.39 times larger than what would be needed for the minimum flow rate. If an alternative means of storage were added to the system it could thus increase the annual output by a factor of 2.64 rather than by 3.7. Exergy storage provides two things: (1) a means of storing that excess energy from run-of-the river stations, improving the energy output by a factor of 2.64, making that energy available at the times when it is needed, and (2) a means of collecting and storing energy from other sources, such as the heat from the summer air. There are several sources of local energy that are collectively able to meet all of the thermal energy loads for our buildings, now and for the foreseeable future.

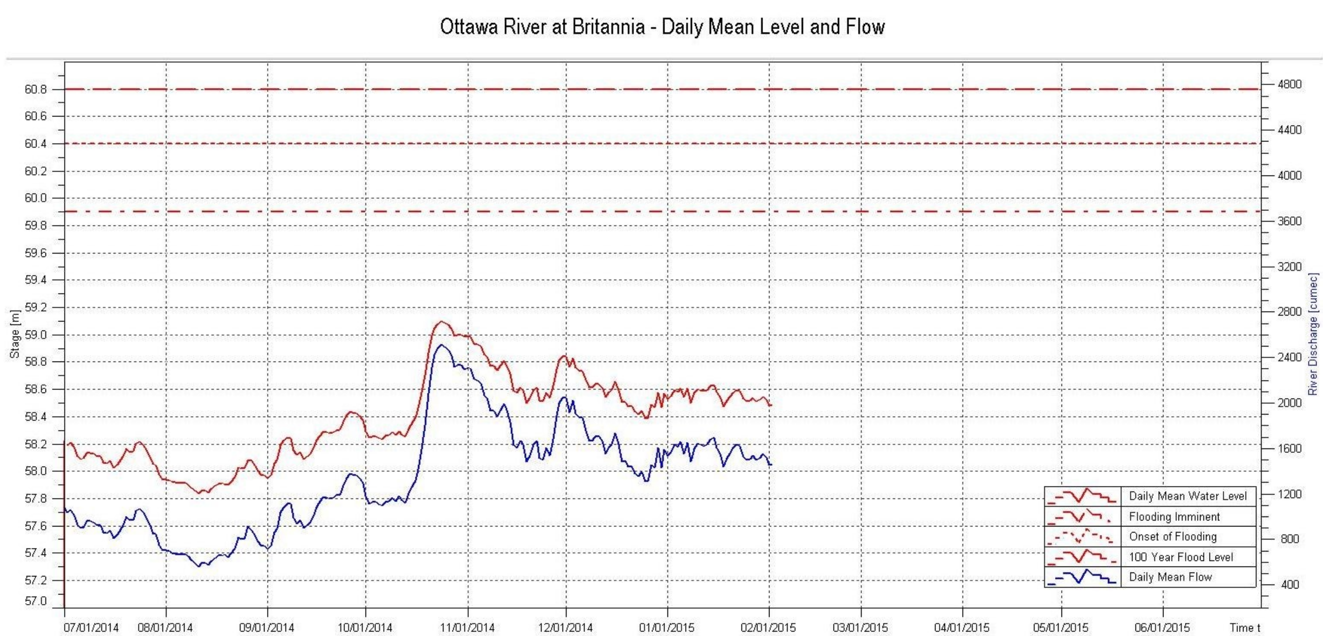
The amplification factor for these local energy sources is determined by the storage system design. If the storage system relies heavily on solar thermal energy then the amplification factor might be as high as 10x but the system cost will be relatively high because of the cost of the collectors and there must be unobstructed sites for the solar collectors. At the other extreme the solar collectors could be small (or non-existent), and the summer air would be the source of local energy but in that case the amplification factor could drop to 3x.

Ontario's electricity consumption in 2011 (the most recent year for which Stats Can data is available) was 327 PJ/year. The hydro contribution was 23% of that, or 75 PJ/year. If the hydro stations made use of exergy storage the combined effect of the greater electrical output and the added energy from local sources would bring the energy supply to 75x2.64x(3 to 10) = 594 to 1980 PJ/year. The former is short of the amount of energy that is currently needed so the deficit would have to be made up by continuing to use nuclear power, by expanding the wind power generation, by importing power from Quebec or by some combination of these. The higher generation figure of 1980 PJ/year would numerically exceed Ontario's total energy consumption but only a small part of the energy output would be in the form of electricity so there is still a need to make up that part of the deficit.

addendum: Flow data

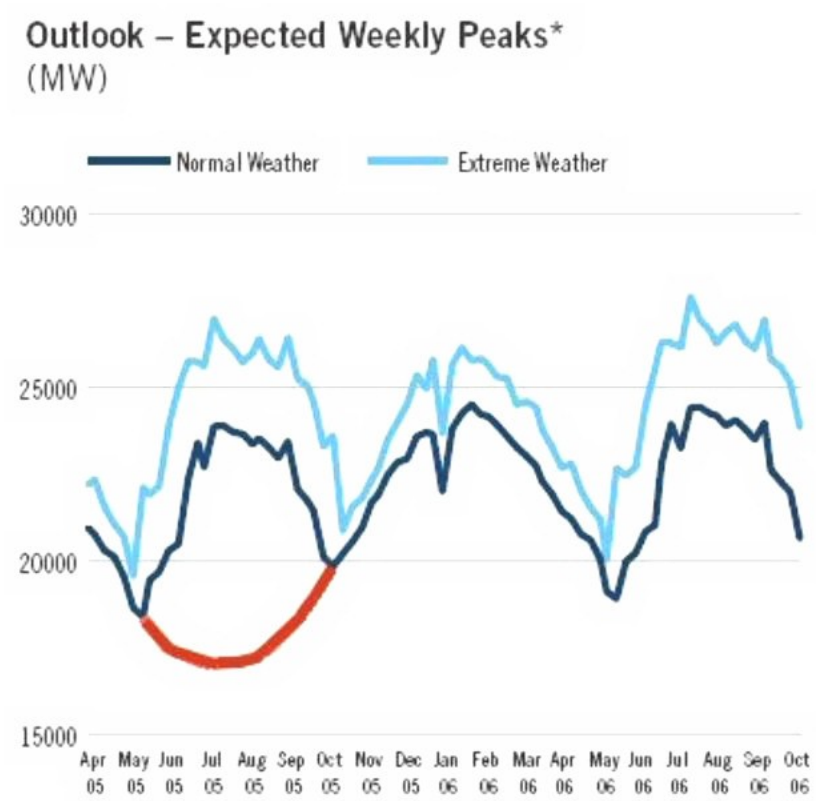


The Ottawa River has numerous dams that control its flow so it tends to have smaller variations than many other rivers but since all of the Ontario generators are run-of-the-river generators they cannot store the potential energy that is available during peak flow conditions. Given an external means of storing the energy their potential power output can thus be greatly increased. Note that the flow peaks in the Spring, coinciding with the period when the stores need to be recharged.



The bottom line (blue) shows the detail for the river flow at Britannia (downstream from Chats Falls). The plot above that line (red) shows the river height.

The minimum flow rate (and hence power output) occurs in the month of August but as more exergy stores are installed they will reduce the summer power demand and that demand reduction more than makes up for the reduced August generation, especially as some of the generators are primarily reserved for demand peaking periods. If a supply deficit should ever occur then some power could be borrowed from Quebec in August and returned at other times of the year. An agreement for such an exchange is already in place between the provinces but it needs only to cover a modest amount of electricity even if Ontario were to completely phase out its use of nuclear (and other non-hydro) power sources. Canada's hydro supply capacity is sufficient to enable the whole country to rely on just hydro power for its electricity grid if exergy stores are widely distributed.



The above graph shows the power demand for two summers, with one winter in between. Given a full set of exergy stores the summer power demand for air conditioning will disappear, although there will continue to be a nighttime power demand for the heat pumps for the stores. The graph will then look something like the red line in the graph and the difference between the red line and the blue lines represents the power that will be available for other applications. There will be a complementary flattening of the winter power demand peak as well because a substantial amount of electricity is presently used for winter heating.

The combination of reduced power demand plus the potential for increased power generation will make it possible for all of Canada to rely on just hydro power alone for many decades to come, with the side benefits that the cost of energy will be reduced by tens of billions of dollars per year and the emissions of GHG's from these sectors can be eliminated.

Of course none of this can happen until our governments are willing to consider the use of exergy storage. The economic benefits of such storage accrue primarily to the electricity producers so we cannot make any progress until our governments kick the habit of relying on fossil fuels and nuclear power.