How to phase out both fossil fuels AND nuclear power

If Canada's East-West power grid is robust enough then for its stationary energy needs Canada could rely on just two energy sources for many decades to come - hydro power and the thermal output from exergy stores. These two sources are interactive: as noted in the previous article in this month's Sustainability-Journal the output of the run-of-the-river hydro stations could be greatly increased if you add a means of storing their potential high-flow output via the installation of exergy stores (which store both thermal energy and electricity in the form of exergy), the demand for electricity can be greatly reduced if we stop using electricity for thermal applications and the peak demand for electricity can also be greatly reduced if the timing of that demand is shifted to the middle of the night. The paper "A Dual Function Energy Store" shows quantitatively how Ontario could eliminate its reliance on fossil fuels for buildings and power generation. That capability could be extended to eliminate Ontario's reliance on nuclear power as well by boosting the hydro generation (which presently provides about 23% of its electricity supply) and by reducing and shifting the electricity demand. This solution can be applied to all of the other Canadian provinces as well but each of the provinces has its own supply/demand combination so each will need to be analyzed individually.

The common link is the East-West power grid. The grid is currently being strengthened by linking NL and NS, by improving the links between QC and its neighbours, and by linking SK and AB to their neighbours who have greater hydro resources. With those changes the East-West grid may well be robust enough to satisfy the "If" requirement of the opening sentence without needing further investment. However, to quantitatively analyze the situation for the individual provinces we first need to consider the capacity of the stores to store electricity in the form of exergy.

Previous reports on exergy storage have noted that the heat for the hot core of the store could come either from solar thermal collectors or by using heat pumps to extract heat from the middle zone, raising its temperature and concentrating it in the core. Another alternative is to use both methods together. In such a combined system the solar heat will still be be employed very efficiently but there are often long periods with little direct sunshine in the winter so the systems would employ a second heat pump to maintain the core temperature, using heat extracted from the middle ring of the store. That would require that additional energy be supplied to the middle ring but that can be easily accomplished by increasing the contribution from the summer air, an energy source that has a virtually unlimited supply capacity.

Although the summer air could supply whatever quantity of energy is needed it depends on electricity to run its heat pump and it is that electricity that provides the exergy that is being stored. That component of the storage is not recovered by converting it back into electricity but rather by reducing the later demand for electricity. Reducing the demand has the same impact on the grid as injecting the same amount of electricity with the caveat that the grid must incorporate a physical source of electricity for non-thermal needs, which is provided by the hydro power in this case. The caveat only applies in the extreme case where the exergy stores are providing most of the total energy consumption on a national scale, but in that case Canada is already producing enough hydro electricity to avoid that problem. In the combined core-heating system the solar thermal collectors add both energy and exergy to the system, and both are stored, so the combined system is much less reliant on an external source of electricity. That makes it particularly attractive in provinces (like Ontario) that have relatively limited hydro resources.

Solar thermal collectors are about six times more efficient than solar PV collectors (compared to currently installed PV cells, not lab units having higher efficiencies). Exergy stores lose very little energy during the storage period but they will lose exergy in the summer. As the heat flows out into the body of the store its temperature falls, and that drop results in a loss of exergy even though no energy is being lost. However, for about eight months of the year the temperature gradient surrounding the heat exchangers prevents the flow of heat away from the boreholes during that period so very little exergy is lost. As a consequence, although solar thermal cells do not directly produce any electricity at all they do achieve the same end result by reducing the electricity demand. In effect they are contributing about four times as much electricity to the grid as you would get from solar PV cells of the same size, and about six times as much energy, and the system is at the same time providing storage for both.

Note that since the local exergy stores are providing all of the thermal energy that the buildings need plus much of the exergy (i.e., electricity), and that they at the same time flatten the grid load, the capacity of Canada's existing power grid should be sufficient to enough to cope with the electricity distribution requirements with only minor modifications. The total amount of energy being distributed in electrical form will be greater but it will happen in the middle of the night when the grid load is presently very low.

The combination core gives the system designer greater design flexibility. In some situations solar energy may not be available because the buildings are shaded. In others the designer might need to cope with periods of excess supply (to cope with either low demand periods or highly variable sources like wind power) so the ability to absorb that supply might be paramount. In other cases the transmission capacity might be the limiting factor, etc.

The solar/heat pump combination also combines the hot water and space heating outputs, simplifying the design of the services for the buildings. Since the space heating loop operates at 60 degrees instead of 40 degrees the facilities for distributing the heat within the buildings will be simpler and less expensive. The combination also provides for regulation of the output temperature, eliminating the need for blending heat at different temperatures that was needed in the previous design. Such systems need to cope with wildly varying thermal loads. That is achieved in this design by varying the temperature of the middle ring and by controlling the storage of heat in the zones between the rings. The hot and cold outputs thus remain constant in temperature throughout the year even though there are radical changes happening in the heat flow pattern inside of the store.

These concepts provide the building blocks for an energy supply system that is permanently sustainable, that produces no greenhouse gases, that would be much less expensive, and that would be almost invisible. It is based on building a large number of small stores that will be located at the consumer end of the supply chain but that should be built and operated by the electricity suppliers who would recover their investment via increased sales of electricity. The cost of meeting peak demands by utilizing storage is much less than that of adding to the electricity generation capacity, and the cost of the energy itself is zero. The design of the stores themselves is straightforward - the challenge is not in the technology or the economics but rather in addressing the reluctance of energy suppliers to even consider such changes.