Exporting energy

At the present time it is generally assumed that the export of fossil fuels is synonymous with the export of energy but if you examine the opportunities from a basic physics point of view the future for Canada may lie in exporting electricity, not oil. For Canada that opportunity is the result of the physical location of our populace, at about 45 degrees latitude. Because of that location the densely populated parts of the country experience very wide seasonal temperature changes that can be exploited to make the entire country a massive generator for both electricity and thermal energy.

In the summer the temperature rises to over 30°C but the ground temperature remains at about 10°C, creating the opportunity to collect energy by making the heat flow from the hot source (primarily the air) to a storage facility in the ground. That energy can be stored in the ground until it is needed in the winter, at which time it can be recovered and put to good use for large scale applications like heating our homes. In the winter the temperature falls to below -30°C but the ground is still at 10°C so the temperature difference is about twice as much as in the summer, again creating the potential for thermal storage to be usefully employed, for example for cooling our homes, most particularly for large buildings which typically require more cooling than heating.

This capacity to heat and cool our buildings using the natural temperature swings has a direct consequence for power generation in Canada. Buildings are presently cooled by using heat pumps which creates a large electricity demand peak in the summer that would vanish. We also use a substantial amount of electricity for heating buildings and for providing DHW. Eliminating these power loads would have a major impact on power generation, particularly hydro power. Hydro power presently accounts for 59% of Canada's electricity generation but if you eliminate the consumption related to the thermal loads the existing hydro capacity would approximately be sufficient to handle the full power load, with no need for expensive nuclear power or dirty fossil-fuelled generators.

As explained in previous reports the ability of ground stores to accumulate and store energy makes it possible to greatly increase the electricity output of most Canadian hydro stations, which are most commonly run-of-the-river generators. In the case of the Ottawa river the potential gain would be up to a factor of 3.7x. That value would need to be examined for the other rivers that are used for power generation but there is no reason to expect that the Ottawa river would not be typical. There are two other mechanisms that could further magnify the energy supply capacity: the potential of exergy stores to collect, store and recover exergy and their potential to use a part of the extra electricity generation to collect, store and recover thermal energy from the four local sources that surround all of our buildings. Together, those two mechanisms could magnify the extra hydro electricity generation by something like a factor of 5x (the actual amount is determined by design considerations). The two gain factors could theoretically mean that the output of energy could be increased by a factor of 18.5x. In 2010 Canada generated 348 TWh of electricity from hydro stations so the potential exists to produce up to 6438 TWh of energy from the combination. That would leave the country with a very large surplus of energy that would be available for export.

It is physically difficult to transmit heat over long distances. Because of our cold winters Canada needs a lot of heat but not 6438 TWh of it. The concept of locating the thermal stores near the buildings they serve, such as all of the homes in a city block, makes it practical to use this concept for any portion of our heating load, from a single house to the entire country, but their total thermal output should be designed to match the actual heat demand. That implies that a large part of the 1288 TWh (3.7x348) of electricity would be available for export. That does not include the exergy contribution.

Exergy stores are particularly attractive if they use solar thermal energy to provide a substantial portion of the heat for their central cores. The solar energy is stored with very little energy loss but some of its exergy is lost because of the drop in temperature as the heat flows out from the central heat exchanger. In the winter the amount of this exergy loss is very low because as heat is extracted from the core the temperature gradient surrounding the heat exchanger falls are you approach the pipe. Heat cannot flow "uphill" so it is retained close to the pipe and there is very little loss in its exergy. That is important because stored exergy is effectively stored electricity. Every kWh of solar energy that can be stored at its input temperature results in a kWh reduction in electric power need to drive the store's heat pumps. If we could reduce the electrical input power to nearly zero (which is actually possible) then almost all of the 1288 TWh of power would be available for domestic use and export. Of that, the component available for export could range up to 940 TWh. At 7 cents per kWh the value of that export would be up to 66 billion dollars per year. To put it in perspective, the current value of Canada's oil exports is under $30 billion/y.

The amount of exergy to be supplied by the solar collectors is a design choice. If the choice were to make the electrical input and the solar exergy input equal then the total contribution to the power grid would be 2,576 TWh and the thermal power for heating and DHW applications would be 10,304 TWh. If the current wholesale value of energy is 7 cents per kWh then **the value of the energy could amount to up to nearly a trillion dollars per year**. Note that most of that value would be the result of the energy and exergy collected and stored by the local exergy stores. The concept enables local renewable energy sources that are presently almost completely neglected to provide the energy we need for our buildings. It also enables the power companies to reduce their capital expenditures on generation and transmission facilities so for them the economic benefits to be realized for each store that is installed are almost immediate. The difference is very large because it is much cheaper to drill a set of holes in the ground than to build a nuclear power station or an alternative power generation facility.

If the electricity is being transmitted from North to South then the system design would need to make allowances for the differing electricity use patterns. Southern US cities use up to four times as much electricity per capita as northern cities. This is the consequence of their greater need for air conditioning. Exergy stores can store either heat or cold but there are substantial design differences. The amount of lift needed for the cold store is much smaller than that for a heat store so the COP of the heat pumps will be higher. On the other hand you could not use solar thermal collectors for a cold store so (depending on the design choice for the exergy contribution) the COP advantage would be commensurately negated. Because of their smaller temperature lift the boreholes for the cold store will need to be deeper or else the store's diameter will need to be increased to compensate.

In a previous report it was estimated that the use of exergy storage might reduce the cost to residents of Ontario by $44 billion per year so the combined potential for increased export income plus domestic economies warrants serious consideration. Note that this "upper limit calculation" is based on the Ottawa River variation (3.7x the actual average power output) and it does not take into accont the diversion of water for irrigation, the use of energy for heating (which could be provided by a local exergy store) etc. Most of the energy from the exergy stores is collected locally so there are no transmission or distribution markups on that part of the delivered energy.

There are other advantages to the use of exergy storage. As things stand our power demand fluctuates over a very wide range from day to night. Storage provides a means of greatly reducing both the daily and seasonal fluctuations. Local energy collection and storage means that relatively little electricity is consumed, which reduces the cost of electricity transmission and makes it possible for an electricity supplier to serve distant markets (if Canadian power were serving US markets then most of the energy being used in the US would actually come from their own local thermal sources). Since most of the required energy is locally stored the problems of coping with power outages are simplified. The GHG emissions are eliminated. The stores are safe, invisible and very long lived. They can be built in a matter of weeks. The concept can be applied to other renewable energy sources like wind power, etc.

The primary limiting factor at the present time is the lack of attention to this concept.