Storing heat for DHW

<u>from the article on Sustainable Communities:</u>

Ontario has 4.6 million residences that consume 528.1 PJ of energy (of all types) per year so the average is 31,900 kWh per residence. The application breakdown is as follows:

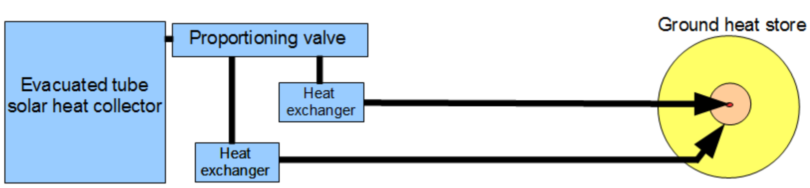
Space heating	*20,097 kWh*
DHW	*5,902 kWh*
Cooling	*670 kWh*
Other	*5,231 kWh*
TOTAL	*31,900 kWh*

Although domestic hot water (DHW) is only 29% of the space heating component it is nonetheless a comparable challenge because the heat must be delivered at a much higher temperature (typically 55-60 degrees). If the entry water temperature is 10 degrees then its temperature must be raised by 45-50 degrees, which is difficult to achieve with a single stage heat pump. One consequence is that if a heat pump is used it will have a poor COP and will therefore consume a lot of electric power.

Solar thermal collectors are widely used for DHW but such systems require a means of storing heat and a means of controlling the output water temperature. On an annual basis solar DHW systems typically require roughly half of the heat to come from another source such as natural gas or electricity. Both approaches are therefore not very efficient and they are complicated and expensive (circa $7000 in capital cost).

What if we use the ground for storing DHW heat?

Seasonal heat stores using ground storage are currently in use for storing heat at even higher temperatures at sites like the Drake Landing development in Okotoks, Alberta. Because of the high temperature such systems lose about half of their heat via losses from the periphery of the heat store but if the high temperature store is at the center of an AE type of heat store then nearly all of that loss is recovered by the surrounding rings of boreholes, using the "lost" heat for space heating. The potential result is very high energy efficiency, plus no need of heat pumps for the DHW and a simple, relatively inexpensive solution for multi-home installations (Drake Landing has 52 homes, so it is comparable in size to what we are proposing for city block systems).



The drawing shows how such a system would work. Each house would have a small conventional electric hot water tank that would would operate at a low power because its feed water would be preheated to very nearly the operating temperature via the input heat exchanger. Most of the thermal storage capacity is provided by the ground. The houses that have good solar exposure would have conventional evacuated tube solar collectors that would feed most of their heat to the ground store. When the solar collector is operating part of its heat would be redirected by a proportioning valve (not shown) to the heat exchanger, thus minimizing the heat loss in the ground store. The proportioning valve would limit the heat exchanger's input temperature to 60 degrees. The balance of the collector's output would go to a borehole at the center of the ground store. The number of collector tubes would be set at a value that will maintain the ground heat store at 55 degrees. The amount of hot water that is used in a house is roughly the same in the winter and summer but a collector set at a 45 degree angle would deliver considerably more heat in the summer than in the winter. The collector would therefore be set at an angle that maximizes its winter collection and any summer heat surplus from the solar collector would be directly fed via a heat exchanger into the inner ring of boreholes so that it is used for space heating. The result will be a water feed system that operates at nearly 55 degrees throughout the year with any fine adjustments being handled via the conventional water tank, which should therefore require very little power.

Such a system would be very energy efficient but most of the collected solar heat will actually go to space heating rather rather than to the hot water system. In a building that requires 5,902 kWh of DHW energy per year the solar contribution to the space heating would exceed 10,000 kWh (it depends on the size of the ground store), substantially reducing the contribution needed from the air-source collectors. Bearing in mind that the outer rings of the ground store will drop to nearly 0 degrees by the end of the winter the air-source collectors could be used to replenish the heat from April to July after which the solar input would take over and would provide the heat input from August until the following April. The two sources could not be concurrently used in the late summer because the injection loop temperature would be too high to permit air-source collection.

In the event of a long term interruption of supply, such as a long cloudy period, the core temperature will fall below 55 degrees but the only consequence would be an increase in the electricity consumption by the water tanks. The buffer in the space heating loop provides a similar protection for the space heating system, with the effects of such an interruption being diminished by the use of four different heat sources (air, solar, ground and AC rejection heat). The total energy storage capacity of the core volume would be very large but since the supply and demand rates are comparatively constant (with no seasonal swings) it is only called upon for short term storage. However, the large size does imply that it will take a long time (a couple of years) to reach an equilibrium temperature.

The solar collectors deliver heat at a high temperature so the space heating part of the ground store could function at a higher temperature (by a few degrees) enhancing the COP of the heat pump and increasing its thermal storage capacity. At the same time the storage requirement is reduced because a lot of extra energy is being fed into the store during the fall and winter, negating the need to store that heat for more than a short time. These two factors work together to reduce the size (and cost) of the seasonal heat store well below the already low values of a regular AE system.

In practical applications some of the buildings that are parts of the city block system will have good solar exposures and some will not. Obviously those that do would collect the solar energy and the others would have air-source collectors. Homeowners have the option to install Solar PV collectors on their roofs and if they use water cooled PV collectors the heat from the cooling loops would be sent via heat exchangers to the air-source loop. Those homes would contribute over 8000 kWh of electricity per year plus about 40,000 kWh of heat and in Ontario they could collect substantial microFIT grants to offset the capital cost of the Solar PV collectors. Each home would thus have a choice of three different ways of feeding energy to the shared store and they would all benefit by sharing the hot water and the space heating capacity. All three of the choices are capable of delivering more than the 26,000 kWh average thermal load per house so they should be sized to meet that objective, scaled up or down in accordance to the actual building size. The heat losses in such a system would be made up by the natural ground heat contribution, which must be positive to meet the no-loss condition for the ground store, and by the heat recovered from the air conditioning.

The cost of the ground heat store would amount to several thousand dollars per average house but that is a sealed, passive system that is buried underground and that would have a lifetime of about a century. The cost of the components inside of the homes would be substantially less than those of a conventionally heated home (i.e., using a furnace and an air conditioner). The only new internal elements are the heat exchanger for the hot water tank and the buffer for the heat pump. There is no need of a furnace, a chimney or an external heat exchanger for the air conditioning. The new capital cost element would be the cost of an air-source collector, or the bank of evacuated solar collector tubes or the Solar PV installation, with each homeowner (or the developer) choosing one of those options. The operating cost for hot water should be reduced by an order of magnitude. The operating cost for space heating is reduced to the cost of the power for the heat pump and the circulation pumps. The GHG emissions are zero.