Rapid start up for exergy stores

Since exergy stores are "charged up" with heat in the summer and with electricity (exergy) in the spring it is natural to assume that it will take half a year or more to bring them into operation. However, that is not the case. In practice start up can take less than one day.

There are two different types of buildings to consider: houses and large buildings. Houses primarily use energy for heating whereas large buildings primarily require cooling. Houses are built (or renovated) sequentially, usually over a period of many months, so the heating load for an energy store ramps up over that period and the exergy system does not have to supply the full output on the very first day of operation. Large buildings are normally "opened" on a given day, but their primary need is for cooling, which is easier to put into operation quickly, and their heat stores can be charged while the building is being constructed so either heating or cooling (or both) can be fully operational on the opening day. However, during the first year what happens behind the scenes will be very different from the normal cycle in the following years.

Houses

The cooling loop operates at 4°C in the summer and 7°C for the rest of the year. Since these temperatures are not much below the ambient ground temperature (9.6°C in Ottawa) the outer ring of boreholes will drop quickly to the required temperature, especially as the heat pump will be operating continuously rather than for just 6 hours at night. If the heat store is put into operation a few days before the first house is opened then its air conditioning will be fully functional on the opening day. The capacity of the outer ring to handle thermal load variations will thereafter increase as the temperature profile across each outer borehole widens so cooling should never be a problem. During much of the first year of operation the heat pumps will be operating almost continuously to build up the heat store so the inherent cooling capacity will always be very large.

Exergy stores use conventional electric water heaters for domestic hot water (DHW) but incorporate a heat exchanger so that normally their source of heat is the 60°C heat from the core of the heat store, with the electrical input serving as a safety feature to guarantee that the temperature will never fall to a value that might be subject to the growth of bacteria in the tank. During the first year the core temperature will be ramping up so the electricity will initially provide the DHW heating, in which case it will come to equilibrium overnight.

Nominally the solar thermal collector in an exergy store will provide most of the heat for DHW, even in the winter. A typical hot water tank will have a 4.5 kW heater so in the winter most of that energy will be available (on average) to feed heat back to the core. During the summer the solar collector will be generating a large surplus of heat that will also be fed to the core. The heat exchanger thus provides two functions - delivering heat to the water tank in the normal condition and reversing the heat flow in the summer and during the start up period to help charge up the core.

The core is also being charged up from the other end, with both the primary and the secondary heat pumps operating nearly 24 hours per day. During the summer the air-source collector and the heat being extracted from the house via its air-conditioning loop will result in a quick ramp up time. During the winter the sources of heat will be the heat extracted from the ground and the heat delivered by the solar collector/water heater combo so the ramp up time will be much longer. In that case extra heat can be extracted from the ground to accelerate the process. In either case, the number of homes that can be served for space heating will ramp up in proportion. If the heat store includes a backup generator then both the heat and the electricity from the generator can be used to boost the start up. Note that what we need to do is to get the operating temperature of the core loop up to 60 degrees as quickly as possible. We do not need to achieve the full energy storage state, which will take much longer. During the ramping period about half of the solar/tank heat would be used to supply the homes that are in use and the other half would be used to raise the core temperature, which implies that the hot water heat exchanger must control the amount of heat flow, for example by varying its rate of water flow. If the construction schedule calls for many homes to be completed in the winter then the exergy store should be put into operation in advance, preferably including a period during which air-heat can be accumulated since that will be the primary source of energy for homes. With adequate planning the heating systems should not hinder the schedules for home completions.

Note that during the commissioning stage the homes will be using a lot of electricity, both to operate the heat pumps almost continuously and to continuously provide heat to the hot water tanks. However, a city may have thousands of exergy stores in operation so this temporary power load will not be a problem unless all of the stores were installed at once, which would be impossible because of the lack of crews and facilities to do it all at once.

There is another alternative available. If both heat pumps employ output heat exchangers that have a variable control that feeds heat preferentially to the buildings, sending only any surplus heat to the ground loops, then the system functions as a ground source heat pump system that draws its heat from the ground and that progressively reverts to the normal cycle as the ground loops warm up. The heat extracted from the store's peripheral ground plus the electric heat from the water heaters plus the available solar heat have sufficient capacity to provide all of the startup energy that will be needed. However, this alternative would add extra costs and complexity for the variable heat exchangers.

Large buildings

Very large buildings (millions of square feet) require cooling throughout most of the year but need relatively little heating. Such buildings should store cold rather than heat. While that is readily possible the designs for such buildings are different from those that employ heat stores so they are not considered in this outline.

Most institutional and commercial buildings (schools, churches, stores, office buildings, etc) tend to fall in the middle, so they need substantial amounts of both heating and cooling. As with houses the cooling and DHW do not present a problem - they can be put into operation almost immediately in any season. However, the option of ramping up the heating load is not available for such buildings. The heating system must work at its full capacity in the event that a building is to be opened in the middle of the winter. That does not imply that the heat store must be fully charged to its rated energy capacity - again, the objective is to get the core loop temperature up to 60°C and ensure that it can be held there. The most practical way to do that is to ensure that the operation of the store starts before winter sets in, preferably by September or earlier, so the core loop temperature is raised to 60°C while the primary source of heat is still available. Once it reaches that temperature it can be maintained via the energy that is drawn from the ground plus the solar energy and the electric heat, again bearing in mind that the heat pumps will be operating almost continuously. Obviously the exergy system may not achieve its electricity demand reduction objective during its first year but the building will be functional regardless of its opening date, which is a mandatory requirement.

Exergy storage systems lend themselves to the routine incorporation of ordinary motor-driven backup power supplies because they provide most of a building's energy from local energy sources, so the size of the backup supply is relatively small. Where a building has such a supply it can be used during start up to boost the temperature of the core so it is much less critical that the operation of the exergy store should start by September. Moreover, if the construction schedule for the exergy store should be delayed then an external source of heat could be temporarily hooked up to raise the core loop temperature. The amount of energy that is needed for that boost is actually quite small because it only needs to heat the fluid in the loop and the ground in close contact with the core boreholes. Once that mass is up to its operating temperature the system will maintain it thereafter.

For either type of building the exergy storage systems should not impose a delay in putting the buildings into service at any time of the year. If the operation starts in the spring then all of the functions, including electricity storage, could operate normally right from the outset. If it starts in any other season then the electricity storage function may be compromised for that first year but the buildings can still be put into service.