AE for City Blocks

The atmospheric energy (AE) concept can be applied to a single home, a giant building, or a network of buildings. AE systems utilize four sources of energy:

1) heat (or cold) extracted from the air in the opposite season and stored in the ground
2) heat recovered from air conditioning systems, especially for large buildings
3) natural heat extracted from the ground
4) solar energy
    a) collected by Solar PV panels
    b) recovered from PV panel cooling loops and stored for later use
    c) collected and stored at a high temperature for DHW

The use of four different but complementary energy sources makes it possible to adapt the basic design to handle almost any combination of buildings for both new construction and retrofits. This flexibility is particularly attractive for integrating the energy needs of all of the buildings in a city block (either residential or commercial/institutional) that can share a single heat store located near the middle of the block. AE systems provide both heating and cooling for the buildings, domestic hot water (DHW) and electricity. They completely eliminate the need for using fossil fuels for heating, cooling or DHW and they reduce the annual electrical power consumption of the block, in some cases to a net amount of zero.

The buildings share a common central heat store (which in some cases will be joined by a central cold store) but that is a completely passive component that is permanently buried in the ground and requires no support equipment or controls. Those elements are all located at or within the buildings. Each building meets its own energy demand (in total kWh) but the supply is rationalized. Some buildings, especially ones without solar exposure, will supply the heat or cold to the store via compact air-heat exchangers. Some will have solar thermal collectors and others will have Solar PV collectors. Buildings that are air conditioned will use heat exchangers to feed the expelled heat to the central store and all can share the ground heat recovered by that store. Rationalizing the energy supply simplifies the design and can make the capital costs lower than those of conventional fossil fuelled buildings. Since all of the energy comes from local natural sources such systems are inherently much cheaper to operate than conventionally equipped buildings.

The prototype AE system has been in use for three years in Kingston, Ontario. It supplies only one building (the home of Volker Thomsen) but it utilizes all four sources of energy. To expand such a system to cover all of the homes in a residential block the primary need is to increase the size of the ground store. The Thomsen house uses boreholes that are 20 metres deep. By increasing the depth to up to 300 metres the number of homes could be increased to 15 and by doubling, tripling or quadrupling the number of boreholes the number of homes per block could be increased to 30, 45 or 60 homes, or even more if you could fit that many homes into a city block. The homes themselves could be duplicates of the Thomsen house - no significant redesign is required - but it would be more cost effective to rationalize the supply so that some of the homes utilize air-source collection and the others utilize solar energy. If each house delivers as much heat to the central store as it utilizes over the year then the buildings in the block can be reconfigured over the course of time. This flexibility makes it possible for some of the homes to be in shady locations or oriented in ways that preclude the use of solar collectors.

The Thomsen House Co2 free Sustainable Technologies Integrated Home

(from volkerthomsen.com)

The heat store is located under the front yard. The air-source heat collector is behind the bushes (bottom right). The two thermal solar panels are at the bottom right of the roof. The Solar PV panels are along the top of the roof. The other rectangles of the roof are skylights for the solarium (wintergarden) that is presently not heated by the AE system but that incorporates underfloor piping to make that possible in the future. The solar thermal panels feed their heat directly to the hot water tank rather than to the center of the ground heat store as is recommended for future systems.

The internal components of the system are a 25 kW water-to-water heat pump and a buffer that stores heat from the ground loop during the day and returns that heat at night. The winter temperature in Kingston occasionally falls to -35 degrees C so without the buffer the ground heat exchangers would need to be much longer (and hence more expensive). The system uses ducts and an air handler that incorporates a peak demand electrical heating coil but that coil has not been needed since the buffer was installed. A data logger is presently installed in the house to continuously monitor the temperatures at many points.

The system diagram is the same for an AE system that supplies energy to a single house, to a large block of homes, to a large building or to a mixed use block of buildings that includes various sizes and types of building. Large buildings and smaller buildings that produce a lot of heat present a special problem. They could transfer their heat into the ground store and up to a point that works well because the cooling systems are using the cool ground as the heat sink instead of the hot outside air and that achieves high COP's for the heat pumps, with corresponding low electrical power demand. However, large buildings will commonly need to get rid of more heat than is required by all of the buildings in the block put together. If you dump that excess heat into the air it means going back to power consuming air-sink heat pumps. A better solution is shown in dotted lines in the diagram. It uses a second ground store that stores cold rather than heat, using an air-source heat exchanger to collect the cold from the winter air. Very large buildings (millions of square feet) would use a grid array rather than a concentric configuration for the cold store. Such systems do not require heat pumps for air conditioning. The City of Toronto uses such a cold storage system (employing water as the storage medium) for cooling most of the big buildings in its downtown core.

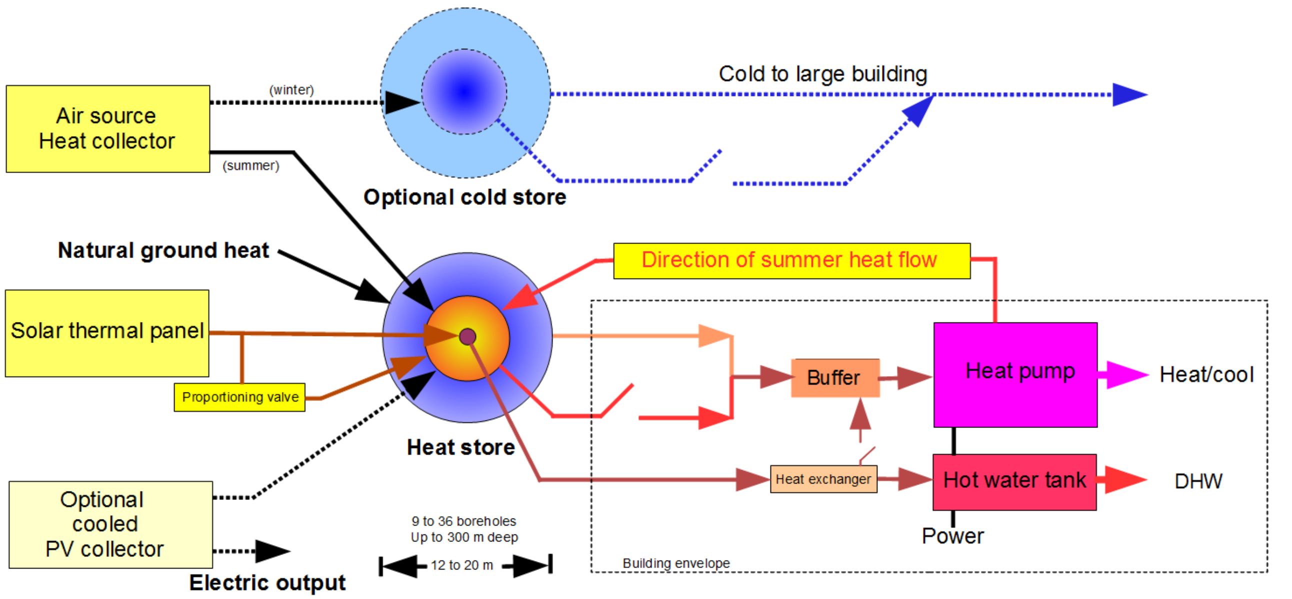

Figure 2. Block diagram of City Block Stored Energy Supply

The optional cold store is used only if the block incorporates one or more very large buildings or buildings that generate a lot of heat, such as IT buildings. By collecting and storing cold as well as heat such two-store systems can handle the situation where the building needs to expel more heat than it needs for winter space heating and in appropriate climates the extra cooling can be accomplished without the need for heat pumps, which avoids the corresponding electricity consumption. In residential applications in Canada the heating demand always exceeds the cooling demand so only the heat store will be used.

In the heat store all four energy sources feed heat to the inner ring of boreholes and the solar thermal collector also feeds heat to the bundle of from one to four boreholes in the center of the store. A proportioning valve maintains the core temperature at 55 degrees C with the excess summer heat from the solar collector being fed to the inner ring. The heat that is fed into that ring in the summer slowly travels out and the travel distance is selected so that the heat reaches the outer ring just when the need for winter space heating starts. Extracting heat from that outer ring drops its temperature below the ambient ground temperature so natural heat from the ground can also be used for space heating, thus preventing the loss of the injected heat. The amount of natural ground heat that is utilized can be controlled by adjusting the spacing between the inner and outer rings. If that distance is reduced then the temperature of the outer ring will cycle above and below the ambient ground temperature so that there is either no net flow into or out of the heat store or else there is a small residual net flow which ensures that the direction of heat flow outside of the system is always towards the center, so that there is no mechanism for heat loss.

Any building can optionally include a Solar PV panel on its roof to generate electricity that is fed to the power grid. Solar cells lose a lot of their efficiency when they are hot. By water cooling the Solar PV panels this loss of efficiency can be avoided, considerably increasing the electrical output of the panels on hot summer days when the power is most needed. In the process the heat collected from the Solar

PV panels adds to the heat being accumulated in the heat store. The combined energy collection of the Solar PV collector is several times greater than the panel's electrical output.

If there is only one building, as is the case for the Thomsen House, then it will be festooned with all of the collectors. If there are multiple buildings than it is more rational to have each building provide only one collector which might be an air-source collector, a solar thermal collector or a Solar PV collector. All of the buildings will feed their air conditioning waste heat into the heat store and they will all share any residual ground heat that is accumulated. If each building contributes as much energy as it consumes then the combination of buildings can be altered as needed over a long period of time without upsetting the system balance.

The dotted box shows what is included within the envelope of each building. Note that there are only four components, all of which are quiet and compact. One is a conventional electric hot water tank that can be quite small because most of the heat that is needed is being stored in the ground and is only recovered when it is needed. The hot water tank regulates the DHW temperature and can handle any ground heat supply deficiency even if the heat from that source should fall to zero. The heat exchanger enables the heat to flow to the hot water tank while isolating the physical liquids to prevent any possible contamination of the DHW.

The heat pump is reversible. In the winter it extracts heat from the ground store and warms the building. In the summer it is reversed to cool the building, sending the extracted heat to the heat store. The heat pump's energy efficiency is much higher than that of a conventional air conditioning system because the heat sink is the cool ground rather than the hot summer air. The buffer is a short term heat store that collects heat during the day (when the heating demand is lower) and returns that heat at night. Stabilizing the diurnal demand of the buildings reduces the size of the heat store.

While it is possible for such systems to meet all of their annual net energy needs they require electricity from the grid in the winter to power the heat pumps, returning Solar PV power in the summer. Canada produces so much clean hydro power that it could theoretically eliminate GHG emissions from both power generation and from heating systems if it made widespread use of AE systems. An interesting variant would be to use wind driven pumped storage to make remote communities completely independent of external energy supplies other than for transportation. That would make the development of Canada's northern communities much more practical.

AE systems integrate all of the energy needs of buildings. The principles that are employed are all in use now - the Enwave system is an example of a cold storage system, GSHP's use natural ground heat, the Thomsen House collects summer heat from the air, the Drake Landing project stores heat in the ground at a high temperature, the UOIT campus and a large IKEA in Denver use huge seasonal stores and there are many examples of buildings that use the ground as the heat pump's heat sink or that use cooled Solar PV panels. These represent a wide variety of building types. It is considerably cheaper to combine all of those functions into a single system as opposed to the current practice of installing single function systems that only heat or cool or provide electricity or hot water. It is also much more practical for all of the buildings in a city block to share a single ground store than to have individual stores for each home.

Draft - Sept. 20, 2012 Ron Tolmie (tolmie129@rogers.com)
With help from Volker Thomsen, Dave Wilson, Bryan Brahn, Ed Lohrenz, Marc Rosen and many others.