Lossless storage of core heat

The '**City Block**' ground heat store design stores heat at a relatively high temperature in its central zone which is surrounded by a second zone that operates at a lower temperature. The higher temperature heat comes from solar thermal collectors or from the output from heat pumps that transfer heat from the outer zone to the core in order to boost its exergy as part of the procedure for storing electricity. Heat is also injected into the outer zone by extracting it directly from the air, using a heat exchanger to transfer it into a fluid that carries it into the ground via sealed heat exchange pipes that are inserted into the middle ring of boreholes. Most of the heat injected into both zones is eventually recovered by extracting it via an outer ring of borehole heat exchangers. Almost none of the injected heat is lost because the outermost ring of the concentric heat store cycles annually above and below the ambient ground ground temperature so that there is normally no net heat flow into or out of the concentric store (but surrounding ground heat can serve as an emergency source of heat).

The higher temperature zone can serve three purposes:
1) as a source of heat for the DHW system
2) as a source of high temperature heat for periods of very cold weather (augmenting the heat from the outermost ring)
3) as the "hot body" for the exergy (electricity) storage

It also results in a comparatively large total heat storage for a given size of storage field and a given total borehole length, considerably reducing the cost of the storage field, which is normally the most expensive component of such systems.

In the summer none of the heat that was injected into the core during that summer is lost because it takes several months for the heat injected at the core to travel to the outer zone. However, for the balance of the year there is a steady flow of heat from the central zone to the outer zone and that has an impact on all three of the purposes listed above. Heat that escapes from the central zone is not lost from the point of view of the heating system (which is the primary purpose of such systems) because it will be captured by the outermost ring but there is a loss for the other three purposes that must be taken into account in the system design.

In October the conditions rather abruptly change. By that time the system is withdrawing heat from the ground for heating the buildings, and some of that heat is coming from the core. By that time the rate of heat injection into the core has also dropped so the central temperature falls. It may temporarily rise at times, for example on sunny days when the solar thermal collectors may be injecting heat, but a fraction of a metre out from the central injection point the averaging prevails so there is a temperature gradient exhibiting a falling temperature towards the center. Heat cannot flow "uphill" so none of the heat that is injected from October to the following summer will be lost. The upshot is that for nearly nine months of the year none of the heat injected into the center will be lost and it will not suffer from a degradation of its exergy. It is just as well protected against loss as it would be if it were enclosed in a giant Dewar flask.

Obviously the summer months are the most productive period for collecting solar energy but solar thermal collectors are capable of delivering substantial amounts of heat throughout the year. In such systems the rate of heat flow in the core zone is relatively constant so for three quarters of the year the high temperature injection is well protected against loss. The sun's energy may be relatively feeble in January but the storage system will be much more energy efficient at that time so the DHW system will work quite well throughout the year. Solar heat that is collected during the cool seasons does not need to be stored for a long period of time so that reduces the total storage capacity requirement which in turn reduces the system cost.

If the core is being used for storing exergy then the charging period for collecting heat will be the summer months when heat is collected during the day and the heat pumps are used at night to transfer the heat into the core. The power used for driving the heat pumps represents the electricity going into this kind of "battery". Some of that summer heat will eventually flow into the outer zone, which makes little difference to the heating system because it can be extracted from either zone. However, it does represent a loss of exergy so again that protection against loss for three quarters of the year is very important. It also means that if the heat pumps are operated in the cold months they will not suffer from an exergy loss so the grid operator has the option of "charging the battery" at whatever times are optimal during the long "cold" season. In practice the heat pumps are most likely to be used at night, particularly during the spring and fall, when the price of power is low and there is the greatest danger of oversupply of grid power.

From the point of view of the grid operator this kind of "battery" is 100% efficient. He puts in X kWh of electric power into running the heat pumps and the system can be managed so that he get X kWh back at the times when the power is most needed. So long as that balance is achieved the building operators also recover nearly 100% of the heat that was injected into either the central or outer storage zones. Technically some of the exergy was lost when heat flowed out of the core but if the above tradeoff is employed then that loss will be invisible to both parties.

Overall the grid operator gains a system that stores electricity in the geographic areas that need it, at times that are largely under his control, and in quantities that can be controlled by involving the appropriate number of sites. If the grid supply has a problem during the summer the heat pumps can be turned off without incurring any serious problems. At other times of the year the pumps can be turned ON when there is a need to recharge the exergy store or a need to deal with an oversupply, for example from a high output from wind turbines, or the pumps can be turned OFF and the heat can be extracted from the core when there is a need to recover the electricity from the "battery". The grid operations are all but invisible to the building operators so long as the system is properly designed and managed. The overall efficiency arises partly from the lossless storage of heat and the apparently lossless storage of the exergy that serves as the medium for storing electricity.