How to Achieve Resilience

In the event of a power grid failure an AE City Block system will continue to collect energy normally and it will continue to heat and cool the buildings, to provide DHW, and it can optionally continue to provide the electricity needed for normal operations within the buildings.

The most basic requirement is that the various circulation pumps keep operating. Since these pumps do not require much power they can be run from a battery that is charged by the solar PV panel so they are not affected by grid failures.

Cooling A large building that uses a cold store does not need a heat pump (in most of Canada) so its operation depends only on the circulation pumps and distribution fans. It can therefore operate indefinitely without needing grid power.

Homes and medium-size buildings normally rely on heat pumps that reject the building heat into the "hot" store. Since the heat pumps need a relatively large amount of power they do not function when that power is not available. However, the summer ground temperature in the outer ring of boreholes is in the range 6 to 14 degrees C so the heat from fluid circulating through the pipes in those boreholes can be redirected to the air handler heat exchangers (or in some cases to in-floor heating/cooling pipes) to provide cooling that may not be as good as that from the heat pumps but is nonetheless adequate.

Heating Normally a heat pump is used to provide heating in both large and small buildings. If the heat pump cannot operate then heat can be extracted from the hot water loop instead and that heat is redirected to the space heating facilities. Although there are only one eighth as many boreholes devoted to the high temperature core it is at such a high temperature (55 degrees) that the rate of heat transfer is about the same as is normally achieved with the much larger number of outer tubes. The core stores a very large amount of heat so this source can provide emergency heating (and also continue to provide DHW) for more than a week. The core temperature will fall during this period but the hot water tank will still regulate the temperature of the hot water so long as the battery can supply enough power. The PV cells will continue to recharge the battery and the solar thermal collector will replenish the heat in the core so the emergency operating period depends on the amount of sunshine.

Large buildings require comparatively little heating so this procedure does not normally present any special problems for them.

Since the circulation pumps require little power the size of the battery can be quite modest, and for the same reasons the PV panels will supply the required power as soon as it gets light in the mornings. It is not necessary to have bright sunshine to provide sufficient power, but when the sun is shining most of the normal functions of the buildings can resume during the daytime even if the grid is not operating.

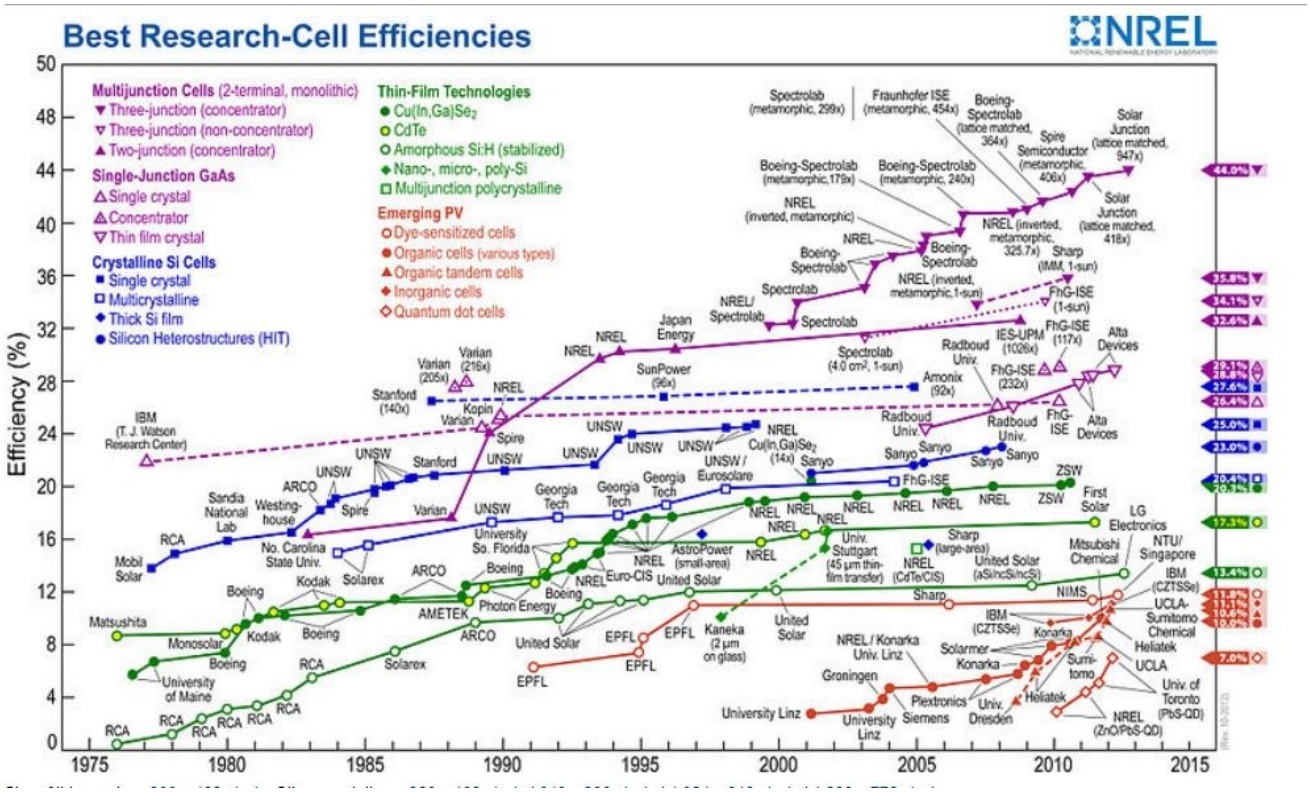
Domestic hot water DHW heat is extracted from the ground at 55 degrees and does not require a heat pump since its final temperature is determined by the regulator in the hot water tank. Hot water should be used sparingly at night during emergency periods to avoid discharging the battery.

Electricity The PV panels will deliver up to about 6 kW per house (at the present time) but since the electricity is stored it can be recovered at much higher rates. However the battery that is needed for the circulating pumps is relatively small so it cannot maintain a high discharge rate for very long. An electric or plug-in hybrid car would provide useful support. The PV panels would recharge the batteries and they in turn could provide power for an inverter that would provide general electricity for the

house. Potentially such a combination could enable all of the functions of the house to function normally, including the heat pumps. Large buildings would need standby power generators for full capacity operation.

Six kW may be an inadequate amount of power in many cases so it would desirable to eventually use a plug-in hybrid car that could add up to 15 kW to the available emergency power.

It should be borne in mind that the efficiency of solar cells is improving steadily. The following graph shows the progress that has been made to date:



It is reasonable to expect that the improvements that are currently being seen in laboratory samples will be incorporated into future volume production cells. That will in time double the power and energy production capacity of solar PV rooftop panels. Moreover, cooling the panels also increases their electrical output and as the cells are modified to become part of the building material (BIPV) rather than being rooftop attachments the areas they cover will increase. These factors will bring the average annual electricity output per house to more than 16,000 kWh per year (if 2 out of every 3 homes have PV panels), which is greater than the average home's power consumption. The excess is more than enough to power the family's electric car.

In terms of meeting both the thermal and the electrical energy needs of our cities the City Block design provides an almost complete answer. The missing element is a means of storing the electricity for use when it is needed, for which there are presently only partial solutions.

The City Block concept should be of even greater interest in the US where about half of the power is presently being generated by coal-fired generators. The rate of insolation is higher in the US (LA receives 1485 kWh/m2 vs. 1161 kWh/m2 in Toronto) and the US has a comparatively small hydro

contribution to its generation capacity.