Energy Storage

Horace Heffner April, 2005

Energy is sometimes stored in thermal form, i.e. in cold form via liquified gas storage, or in hot form via thermal wells or salt phase change heat storage. These storage methods may depend on later heat exchange with the environment to recover some of the energy. This recovery is usually limited by the Carnot efficiency, (deltaT)/(T_hot), and thus is sensitive to environmental conditions.

Simultaneous storage of *both* heat and cold (e.g. heat and cold generated by air liquefaction) is a more sensible way to go. Liquid air is easy to store at high efficiency, and heat from the compression process can be stored in thermal wells or by using salt phase exchange, though a low melting point salt would have to be used to directly obtain the heat from the compression. Otherwise heat pumps are required in addition. Thermal wells should be cheaper than salt tanks, and if drilled deep enough, they produce geothermal heat also.

The choice of combinations would depend on local economics and geology. High temperature salt melting can clearly be achieved by resistance heating. Lower temperature salt phase change can be achieved using post compressor gas temperatures and heat pumps, by using special low temperature salts. The use of thermal wells depends on local geology and regulations.

The important point with regard to thermal energy storage is the notion of storing *both* heat and cold simultaneously so as to maximize the carnot efficiency when the energy is recovered by Sterling engine or turbine. For some reason one just does not see this concept in much use. Typically the approach is storing cold in the form of liquid nitrogen or air, or otherwise storing heat in the form of thermal mass or phase change, and then later doing an exchange with the ambient environment to effect the recovery. Liquefaction produces both waste heat and cold products. Both should be stored to maximize later energy recovery. This can work well for a home sized energy storage system, but it should be workable for a large wind or solar system as well.

Wind power could be used to mechanically and directly drive first stage gas compression. Liquified air, used in combination with a combustible fuel, in a sterling engine, provides a new kind of triply hybrid vehicle - one which can run in the following three modes:

1. Hot/Ambient
2. Cold/Ambient
3. Hot/Cold

depending on the fuel available. The Hot/Cold mode theoretically provides a phenomenal Carnot efficiency and a good power to weight ratio. Hydrogen could be used for the hot fuel.

For home energy storage systems salt phase change may be the best means of storing energy in hot form.

The heat of fusion of NaCl is 124 cal/g at 804.3 C, density 2.165 g/cm^3. NaNO3 is only 45.3 Cal/g but melts at only 333 C, has density of about 2.168 g/cm^3. NaF puts out 186 Cal/g but melts at 992.2 C, density 2.79 g/cm^3. These look like the best candidates in the CRC.

Looking at NaCl the storage density is (124 cal/g)(2.165 g/cm^3) = 268 cal/cm^3 = (2.68x10^8 cal/m^3)/(0.239 cal/J) = 1.121x10^9 J/m^3. A 10 m^3 storage facility could hold (1.121x10^10 J). 1 kwh = (3600 s)(1000 J/s) = 3.6x10^6 J. A 10 m^3 storage thus can hold (1.121x10^10 J)/(3.6x10^6 J/kwh) = 3113 kwh. Pretty good.

Looking at NaNO3 the storage density is (45.3 cal/g)(2.168 g/cm^3) = 98.2 cal/cm^3 = (9.82x10^7 cal/m^3)/(0.239 cal/J) = 4.11x10^8 J/m^3. A 10 m^3 storage facility could hold (4.11x10^9 J). A 10 m^3 storage thus can hold (4.11x10^9 J)/(3.6x10^6 J/kwh) = 1141 kwh. Assuming a good house can be heated and run with 10 kw, that's about 114 hours of total storage capacity, or about 11.4 hours per m^3 of storage volume.

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Cold storage for use with small or home energy systems can be achieved using the ice/water phase change. This can be achieved, even by amateurs, using only ordinary refrigeration means.

Direct electrical energy storage bulk by use of flow batteries is now both economically feasible and commercially available. See:

http://www.vrbpower.com/

Advances continue to be made in hydrogen storage. For exampe see:

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http://www.sciencedaily.com/releases/2006/12/061209083951.htm