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ESSENTIALS OF ENERGY STORAGE

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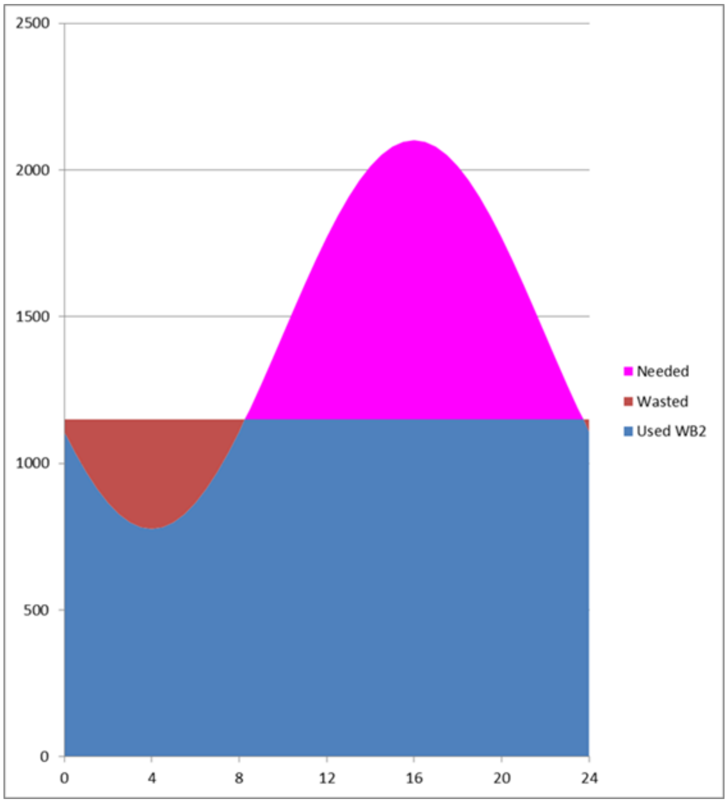

Figure 1. Continental US Load Profile

The typical Hawaii load profile is similar, but has differences based on the details of the Hawaiian economy, as shown in Figure 2.

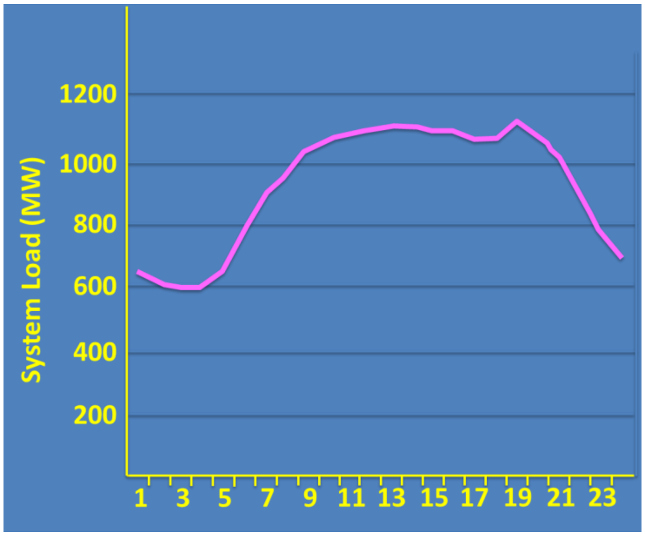

Figure 2. Hawaii Load Profile

Meeting the 2045 goal for Hawaii will require energy storage to match availability to demand, as will be discussed next.

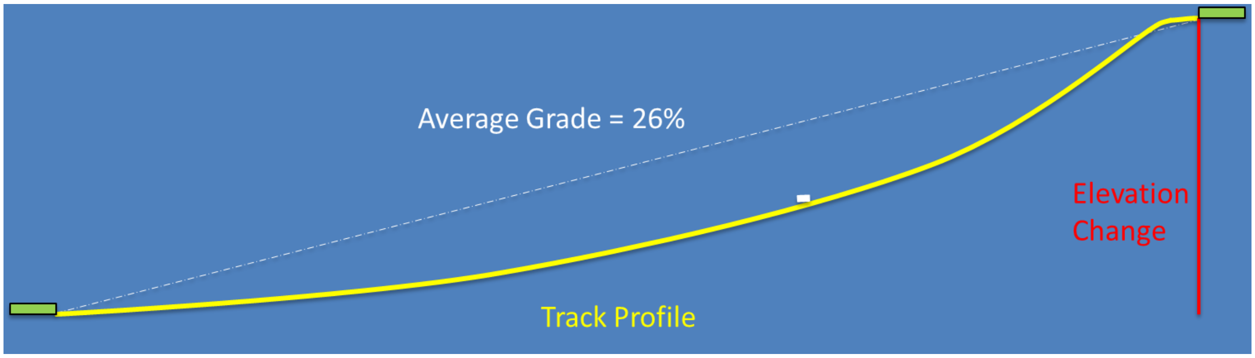

Figure 8. Sisyphus Energy Storage

The reason for the high efficiency is the use of superconducting magnetic levitation. Superconducting magnets are lossless and the levitation means that there is no friction to cause energy losses. The primary reason for energy losses is wind resistance, as the vehicles carrying the blocks move at 60+ miles per hour.

Sisyphus System Details

Figure 9 illustrates the parts of the vehicle and block. The vehicle weighs 10 tons and the block weighs 100 metric tons (220,000 pounds). Together, they are about the same size and weight as a loaded coal hopper car on a conventional railroad. The superconducting magnets are mounted on the vehicle and react against non-superconducting aluminum coils on the sides of a guideway beam (monorail).

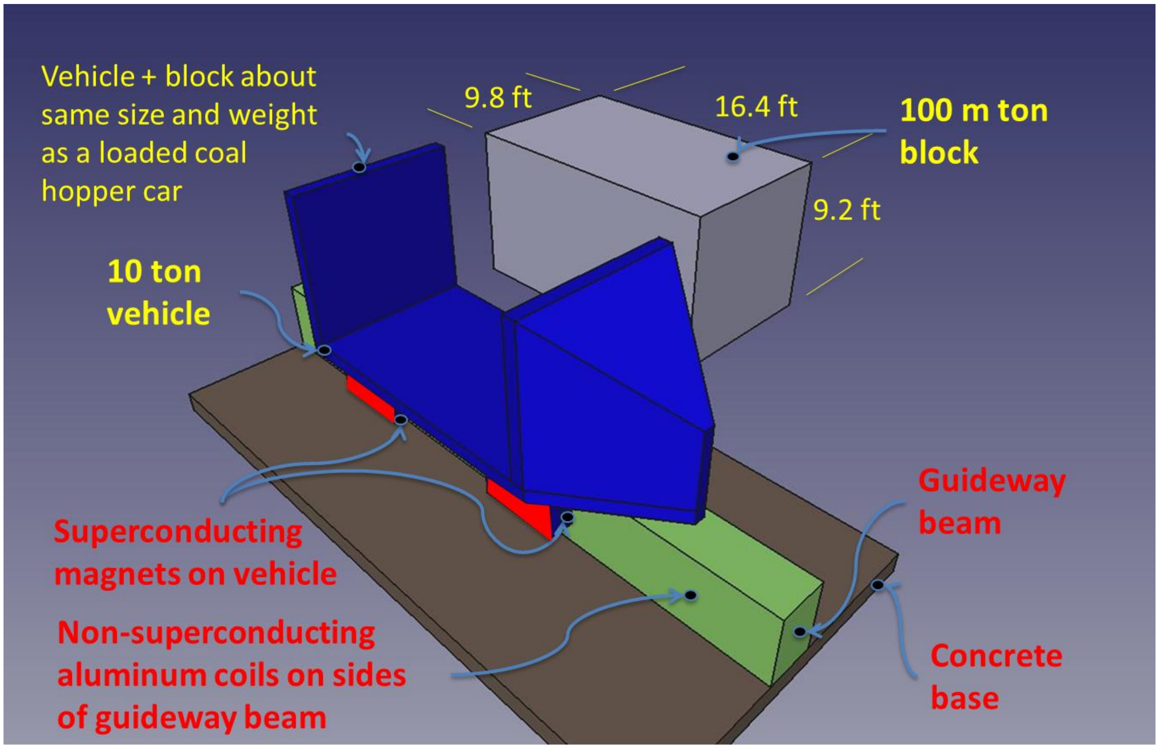

Figure 9. Sisyphus Vehicle and Block

The magnet/guideway coil systems provide four functions:

- They react against each other, levitating the vehicle.
- They provide automatic level maintenance (anti-tilt) and horizontal centering.
- In motor mode (going uphill), locally energized coils provide vehicle acceleration (a linear induction motor).
- In generator mode (going downhill), local coils recover energy by decelerating the vehicle (a linear induction generator).

Figure 10 illustrates the other major component of the Sisyphus system, one of the two storage yards. In the energy storage mode, the vehicles pick up blocks from the lower storage yard and carry them up to the upper storage yard. In the energy recovery mode, the vehicles pick up blocks from the upper storage yard and carry them down to the lower storage yard.

Table 2. 2045 Energy Storage Requirements

Energy Costs

We have said that CAES is unsuitable for Hawaii (and possibly for any commercial large-scale use). We have also said that the use of pumped hydro in Hawaii is unlikely for siting reasons. That leaves Sisyphus as the only option, if the 2045 goal is to be met. What will it cost?

We can divide energy cost considerations into two components as follows:

- Indirect
    - Air pollution from burning fossil fuel,
    - Greenhouse gas production from burning fossil fuel, and
    - Environmental pollution from mining or drilling.
    - These are parts of the reason for Hawaii going totally renewable by 2045.
- Direct
    - Plant capital costs,
    - Plant operating and maintenance (O&M) costs, and
    - Fuel costs.
    - Comparing among alternatives is difficult.

The energy experts have devised a way for comparing the direct costs of energy, called Levelized Cost of Energy (LCOE). Figure 11 presents the formula and a simplified explanation. The first term calculates the contribution of plant capital cost, based on its operating lifetime (discounted), stated in cost per kilowatt hour (kWh). The next two terms calculate the O&M cost contribution per kWh. The final term calculates the fuel cost per kWh. These are added together to produce the LCOE.

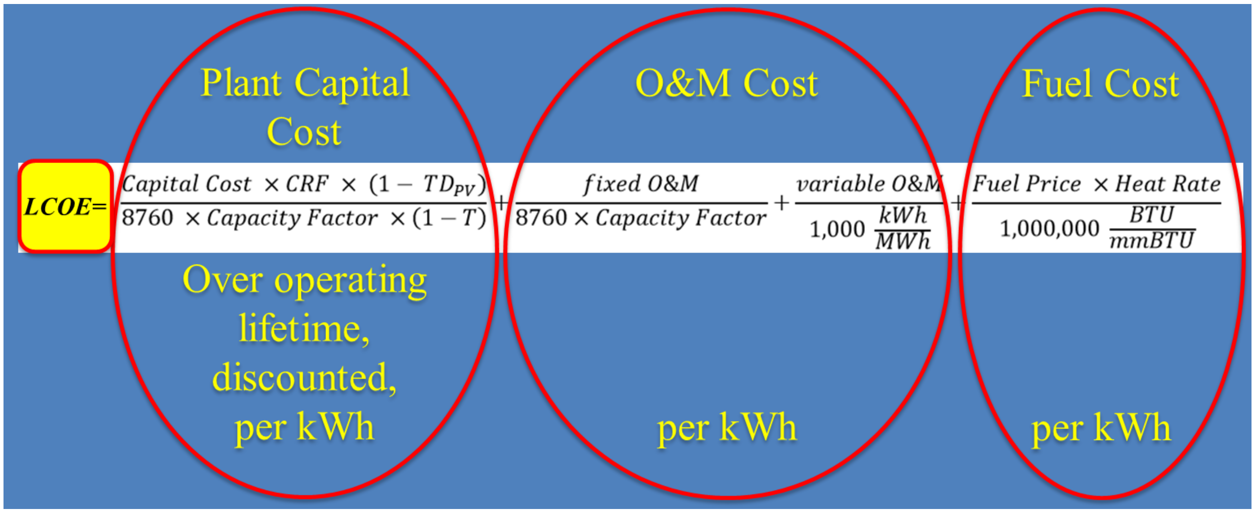

Figure 11. LCOE Formula

Figure 12 presents the LCOE values for a number of technologies that might be used to generate electricity (or store energy) in Hawaii. These costs may be read as fractional dollars per kWh or fractions of millions of dollars per GWH. The latter yields the levelized cost of a 1 GWH/day system. Because the costs of actual power plants vary, several cost points are given, a minimum, a maximum, an average, one standard deviation below the average, and one standard deviation above the average. The take-away point is that the average cost for a Sisyphus system is lower than the average cost of any other system, except for a natural gas combined cycle plant, which is a fossil fuel plant. And even that system's cost and the Sisyphus cost are probably within the margin of error of being the same. This says that Sisyphus will cost Hawaii less than the cost of adding generating capacity.

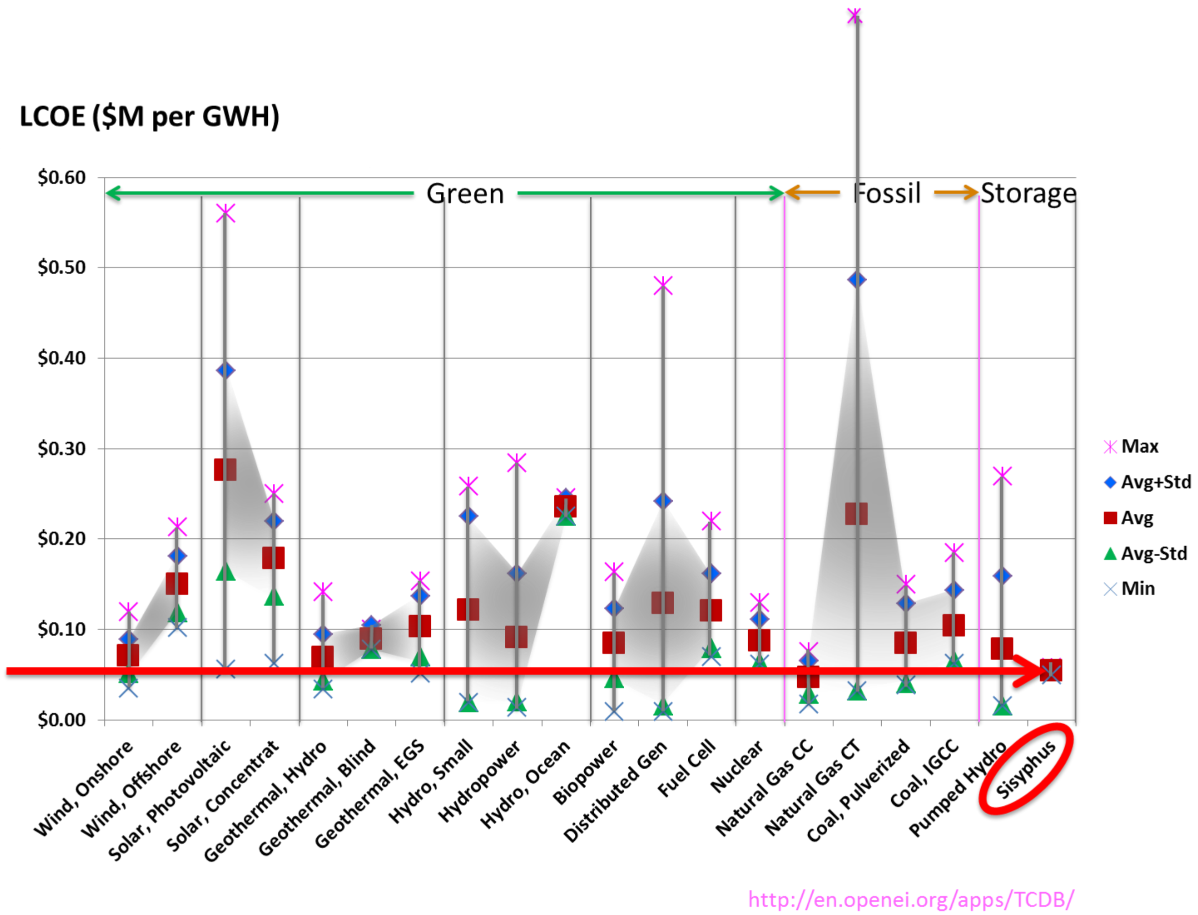

Figure 12. LCOE Comparisons for Various Energy Technologies

Conclusion

Except for geothermal and waste-to-energy, renewable electricity production is intermittent. Going green by 2045 will require bulk energy storage to store energy when it is available and supply it when it is needed. Sisyphus is the only viable storage system for Hawaii and it is cost effective.

For more information, visit http://SisyphusEnergy.com.