Kinetic energy (KE) is:

$$KE = \frac{mass * velocity^2}{2}$$

Thus, the kinetic energy of a 50,900 kg object moving at 5,600 meters/seconds is:

$$KE = \frac{50900 * 5600 * 5600}{2} = 7.98E + 11Joules = 798Gigajoules$$

One must account for the fact that the conversion of energy, from stored magnetic potential energy to that of inertial kinetic energy, will not be 100%. Not only do these losses directly increase the total energy requirement for a launch, it is the indirect effect of these losses that have an outsized effect, depending on where they occur in the system.

For those losses that occur within the cryostat (therefore within the HTSC stator windings), these losses must be removed by the cryocooling system. This not only has implications when sizing the cryocoolers, it also has significant consequences when it comes to overall energy consumption. This is because this waste heat must be moved from a compartment at approximately 20K, and rejected to the ambient environment at ~300 K.

To understand the implication of moving heat between two such reservoirs, we look at the Carnot Cycle, which is an application of the 2nd Law of thermodynamics. The Carnot Cycle is an ideal cycle that is perfectly reversible and is therefore the limiting (best) case to which one can aspire. One finds that the Coefficient of Performance, or the ratio of heat moved to that of work input, is equal to:

$$COP_{CARNOT} = \frac{Q_{LOW}}{W_{NET}} = \frac{1}{\left[\frac{T_{HIGH}}{T_{LOW}} - 1\right]} \approx \frac{1}{14}$$

Thus, what one finds is that in best/ideal case, we would have to input 14 Joules of work to remove 1 Joule of waste heat. However, in the practical world, one finds that the efficiency of even the best made/most efficient cryocooling systems can only reach about 35% of Carnot efficiency at 20 Kelvin, and thus we are penalized at whopping ratio of about 40:1 (COP = 1/40). This is to say that it takes 40 Joules of input work to move every 1 Joule of waste heat out of such a system! It is therefore imperative that the energy conversion within the HTSC stator windings be very high. Fortunately, theoretical work suggests this to be the case for a quench launcher.

For the sake of simplicity, let us assume that the energy conversion losses occur only within the stator, and that there are no additional losses (switching losses, etc.). One can calculate the total energy requirement as:

$$InputEnergy = KE * \left[\frac{1}{\eta} + \frac{(1-\eta)}{COP}\right]$$

Thus, in this instance, given an assumed 95% HTSC winding efficiency, and no other losses, and a cryocooling COP of 1/40, we find that the energy requirement becomes:

$$798GJ * \left[\frac{1}{0.95} + \frac{(1-0.95)}{(1/40)}\right] = 798GJ * (1.053 + 2) = 2.44TJ$$

With these assumptions our input energy requirement has more than tripled (to 2.44 Terajoules), almost entirely a result of removing heat out of the cryogenic stator coil environment (whereas the direct penalty itself was a mere 5.3% increase in required energy). The very low temperature (30 K) used for the stators is well below the operating temperature of HTS ribbons but was used as these materials perform at their highest level at temperatures well below their initiation of super conductivity temperature. We used this very low temperature requirement to be conservative in our cost estimating.

We now look at the question of power generation requirements. That is to say we know what the required energy is, and now we wish to understand the size of the required powerplant.

The average delivered power is just the input energy for each launch, times the number of launches per day, divided by the number of seconds per day:

$$Requiredaveragepower = \frac{(PerLaunchInputEnergy * LaunchesPerDay)}{(24 * 3600)}$$

Following our previous example, if we assume 3 launches per day, and the same per-launch energy requirement, we find the average power requirement to be 84.7 MW (Megawatts). At 8 launches per day this average requirement becomes 226 MW.

A power generation source is characterized by an availability factor. For nuclear systems (arguably the highest availability factor), this is around 0.95 (95%). For solar it is around 0.18 (18%). The nameplate power requirement is:

$$Nameplatepower = \frac{(RequiredAveragePower)}{(AvailabilityFactor)}$$

Again, following our example, the nameplate power requirement for 8 launches per day using nuclear and solar would be 238 MW and 1.26 GW, respectively.