|  |  |
| --- | --- |
|  | This graph shows four estimates for the service life of Beckett battery modules in HyGen. The darkest curve, at the bottom, is the most conservative, and is based on Beckett’s spec for their modules, 3000 cycles at 80% depth of discharge (DOD) and 0.5C charge rate. End of Life (EOL) for the battery is defined when battery capacity has fallen to 80% of original nameplate capacity.  Next up, the red curve, is PPI’s estimate of 7500 cycles, achieved by limiting DOD to 50%, still using an 0.5C charge rate and 80% EOL. The 7500 cycle number is a guesstimate made by Michael Holder (7000) and Bill Marty (7500).  Beckett does not specify, or have data on the cycle life of their modules at 50% DOD. The darker pink curve is Boston Power’s estimate of 10,000 cycles at 50% DOD and 25C operation. Still at 80% EOL.  The light pink curve is an extrapolation of Boston Power’s 10,000 cycles if we run to 70% EOL. |

|  |  |
| --- | --- |
|  | Perkins specifies the engine to have a 15,000 hour service life. There are nearly 9,000 hours in a year, which is why non-hybrid generators tend to have around a 2 year service life.  Because the engine in HyGen cycles on and off, our service life is considerably longer than 2 years.  People in our industry tell us that the Perkins spec of 15,000 hours is pretty conservative. The lighter blue lines show our engine life if we assume longer than 15,000 hours of operation. |

|  |  |
| --- | --- |
|  | This plot shows shows battery and engine life superimposed on the same axes.  Pick the battery life estimate line and engine life estimate line that you are comfortable with. Where your two lines cross is theoretically the point where both engine and battery expire at the same time. To the left of the crossover point, HyGen life is battery-limited. To the right of the crossover point, HyGen is engine-limited. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Battery Parameters** |  |  | **4 sets of assumptions** |  | | Beckett module nominal energy, kWh | 1.0 | 1.0 | 1.0 | 1.1 | | Stack height | 11 | 11 | 11 | 11 | | Batt bank energy, kWh | 11 | 11 | 11 | 12.1 | | Batt end of life definition, capacity degradation | 80% | 80% | 80% | 70% | | Avg bank energy over lifetime | 90% | 90% | 90% | 85% | | Depth of Discharge, % | 80% | 50% | 50% | 50% | | Cycle energy, kWh | 7.92 | 4.95 | 4.95 | 5.14 | | Batt Cycles 80% DOD | 3000 | 3000 | 3000 | 3000 | | Batt Cycles 50% DOD, 0.5C charge, estimated by Boston Power | 7500 | 7500 | 10000 | 10000 | | Batt Cycles, projected based on end of life extension | 3000 | 7500 | 10000 | 15000 | |  |  |  |  |  | | **Engine Parameters** |  |  |  |  | | Engine spec'd life, h | 15000 | 15000 | 20000 | 25000 | | Hours in a year, h | 8760 | 8760 | 8760 | 8760 | | Engine service interval, h | 1000 | 1000 | 1000 | 1000 | | SFC, l/kWh | 0.38 | 0.38 | 0.38 | 0.38 | | Fuel Tank Capacity, l | 1000 | 1000 | 1000 | 1000 | | Diesel cost, $/l | 1.00 | 1.00 | 1.00 | 1.00 | | This table shows the variables and assumptions that produced the curves above.  Beige highlighted cells show where the assumptions changed.  The four columns of assumptions correspond to the four battery lines. The 3 engine lines were taken from the right 3 columns.  The rightmost column of assumptions is the most optimistic case for both battery and engine life. These are the assumptions required to get us to 5 year service life, barely, for customer loads 4kW and below.  Above 4kW average load, none of our assumptions will get us to 5 year life.  We could get to 5 year life by increasing the energy storage of our battery, thus reducing the number of battery cycles. This option is not cheap. It does offer an added benefit, though: If we had two BMS’s and two battery stacks, HyGen would survive the failure of one battery stack, so the design would be more fault tolerant. |

