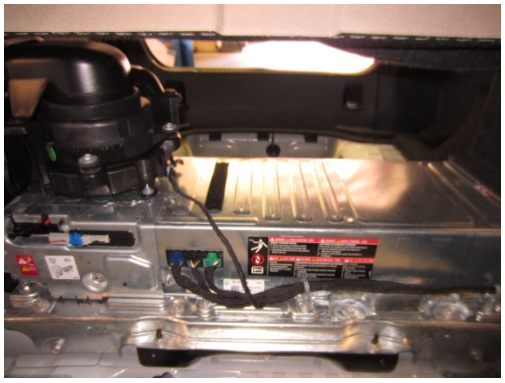
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

VEHICLE TECHNOLOGIES PROGRAM

2013 Chevrolet Malibu ECO Hybrid – VIN 6791

Advanced Vehicle Testing – Beginning-of-Test Battery Testing Results



VEHICLE DETAILS AND BATTERY SPECIFICATIONS[1]

Vehicle Details

Base Vehicle: 2013 Chevrolet Malibu ECO Hybrid
VIN: 1G11D5RR0DF106791
Hybrid Propulsion System: Mild Parallel Belt-Alternator Starter (BAS)
Number of Electric Machines: 1
Motor: 15 kW (peak), AC induction

Battery Specifications

Manufacturer: Hitachi
Type: Cylindrical Lithium-ion
Number of Cells: 32
Nominal Cell Voltage: 3.6 V
Nominal System Voltage: 115.2 V
Rated Pack Capacity: 4.4 Ah
Maximum Cell Charge Voltage[2]: 4.10 V
Minimum Cell Discharge Voltage[2]: 3.00 V
Thermal Management: Active – Forced air
Pack Weight: 65 lb

BEGINNING-OF-TEST: BATTERY LABORATORY TEST RESULTS SUMMARY

Vehicle Mileage and Testing Date

Vehicle Odometer: 5,715 mi
Date of Test: January 8, 2013

Static Capacity Test

Measured Average Capacity: 3.98 Ah
Measured Average Energy Capacity: 460 Wh

HPPC Test

Pulse Discharge Power @ 50% DOD[3]: 14.1 kW
Pulse Charge Power @ 50% DOD[3]: 14.5 kW

NOTES:

1. Vehicle details and battery specifications were either supplied by the manufacturer or derived from a literature review.
2. Maximum cell charge voltage and minimum cell discharge voltage are based on similar battery chemistries. No manufacturer suggested rating was available.
3. Calculated discharge and charge power values based on battery charge and discharge voltage limits (see Note 2) at 50% depth of discharge (DOD).

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Test Results Analysis

Test results for the beginning-of-testing (BOT) battery testing are provided herein. Battery test results include those from the Static Capacity Test and the Hybrid Pulse Power Characterization (HPPC) Test, based on recommended test procedures for hybrid electric vehicles (HEVs) from the United States Advanced Battery Consortium at the time of testing.

These tests were performed for the Department of Energy's (DOE's) Advanced Vehicle Testing and Evaluation (AVTE). The AVTE, part of DOE's Vehicle Technology Program, is conducted by the Idaho National Laboratory and Electric Transportation Engineering Corporation dba ECOtality North America.

Static Capacity Test Results

Static capacity test results are summarized in the fact sheet on the previous page. The test was performed on January 8, 2013 with a vehicle odometer reading of 5,715 miles. The average measured C_1-rate capacity was 3.98 Ah compared with the manufacturer's rated capacity of 4.4 Ah. The average measured energy capacity was 460 Wh.

Figure 1 is a graph of battery voltage versus energy discharged. This graph illustrates the voltage values versus the cumulative energy discharged from the battery at a constant-current C_1 discharge rate.

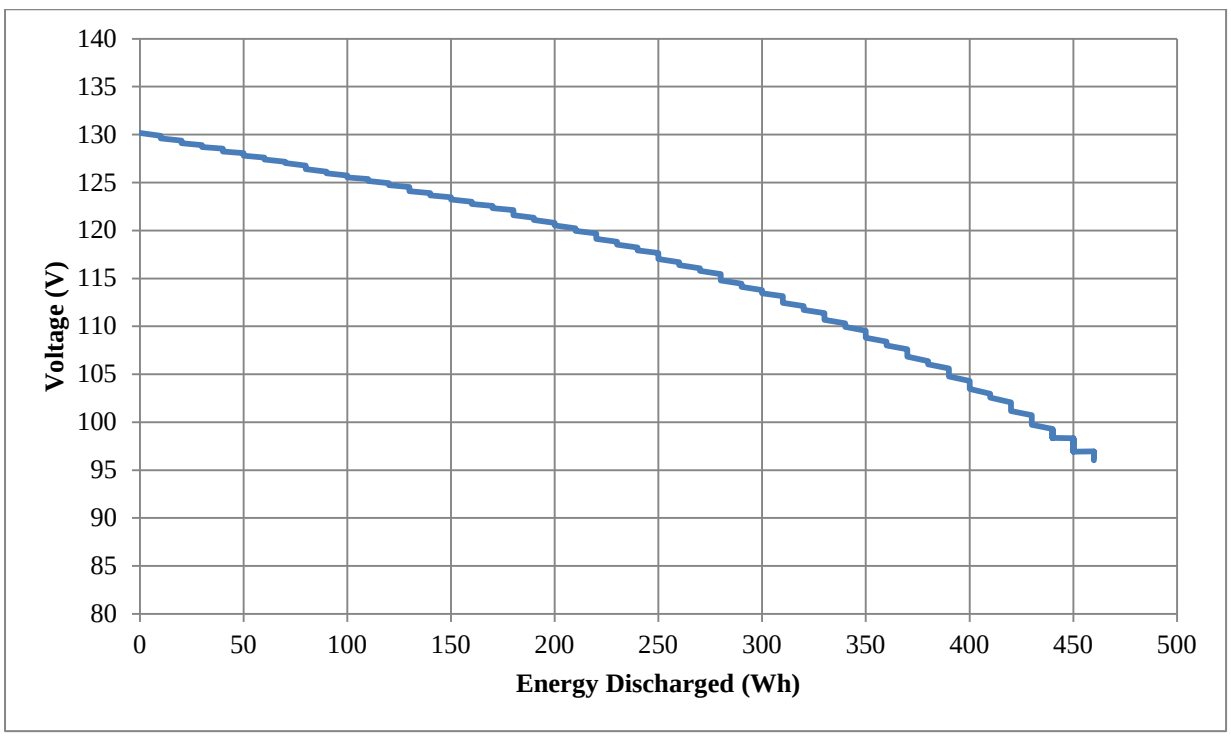

Figure 1. Voltage versus energy discharged during the static capacity test.

HPPC Test Results

HPPC test results are summarized in the fact sheet on the first page. The peak pulse discharge power is 14.1 kW at 50% depth of discharge (DOD). The peak pulse charge power is 14.5 kW at 50% DOD. The maximum and minimum cell voltages used for this analysis were 4.10 V and 3.00 V, respectively. Results are shown on the next page.

Figures 2 and 3 illustrate the battery's charge and discharge pulse resistance graphs which show internal resistance at various values of energy discharge. Each curve represents the resistance calculated at the end of the specified pulse interval.

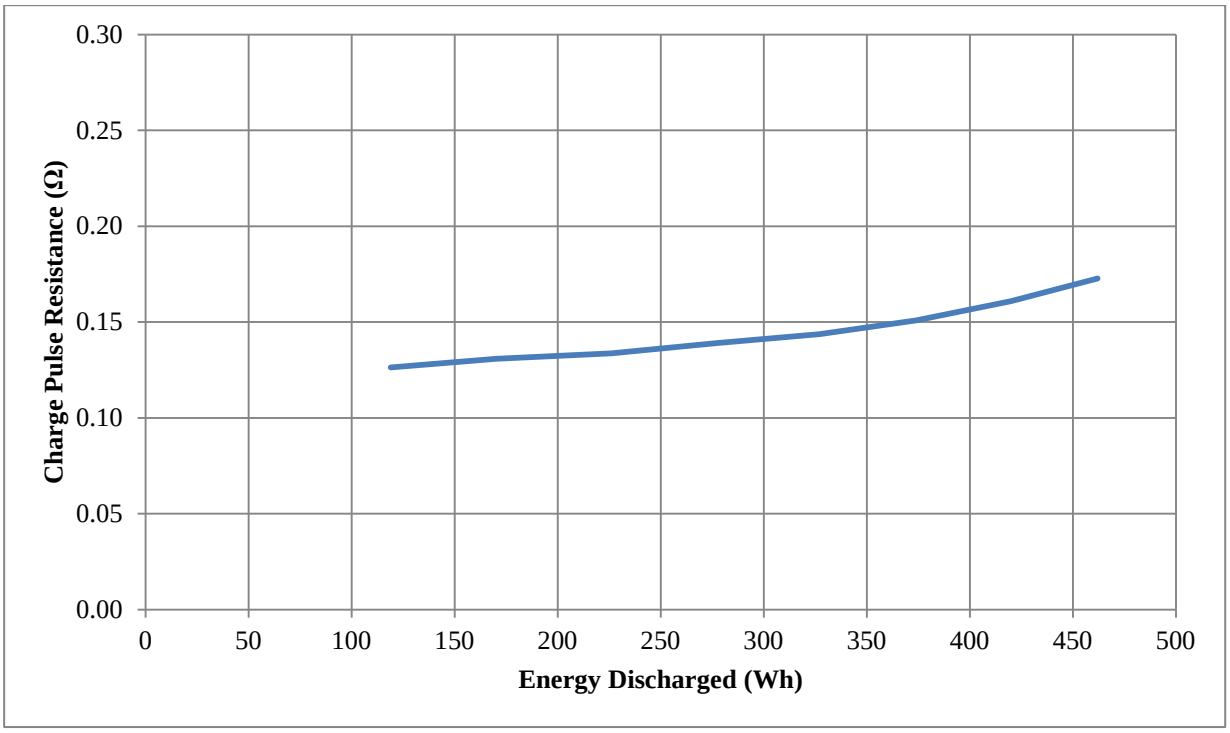

Figure 2. Ten-second charge pulse resistance versus energy discharged.

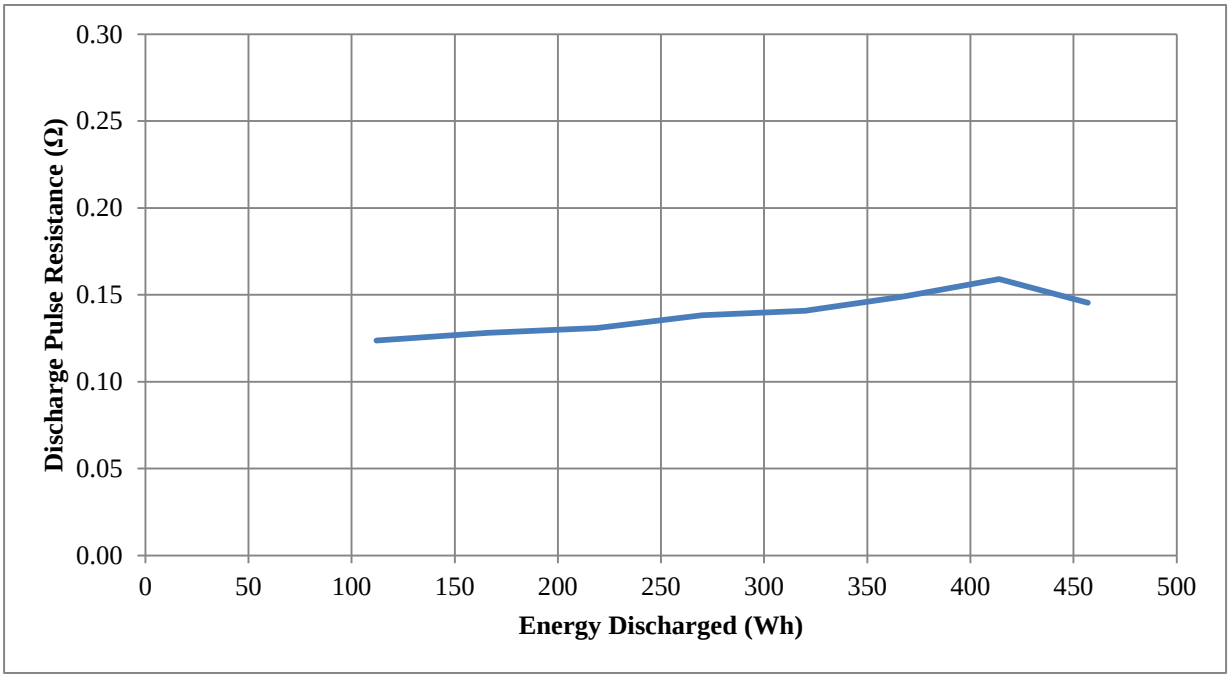

Figure 3. Ten-second discharge pulse resistance versus energy discharged.

Figures 4 and 5 illustrate the battery's charge and discharge pulse power graphs which show the power capability at various DOD. Each curve represents the pulse power calculated at the end of the specified pulse interval at the cell voltage limits.

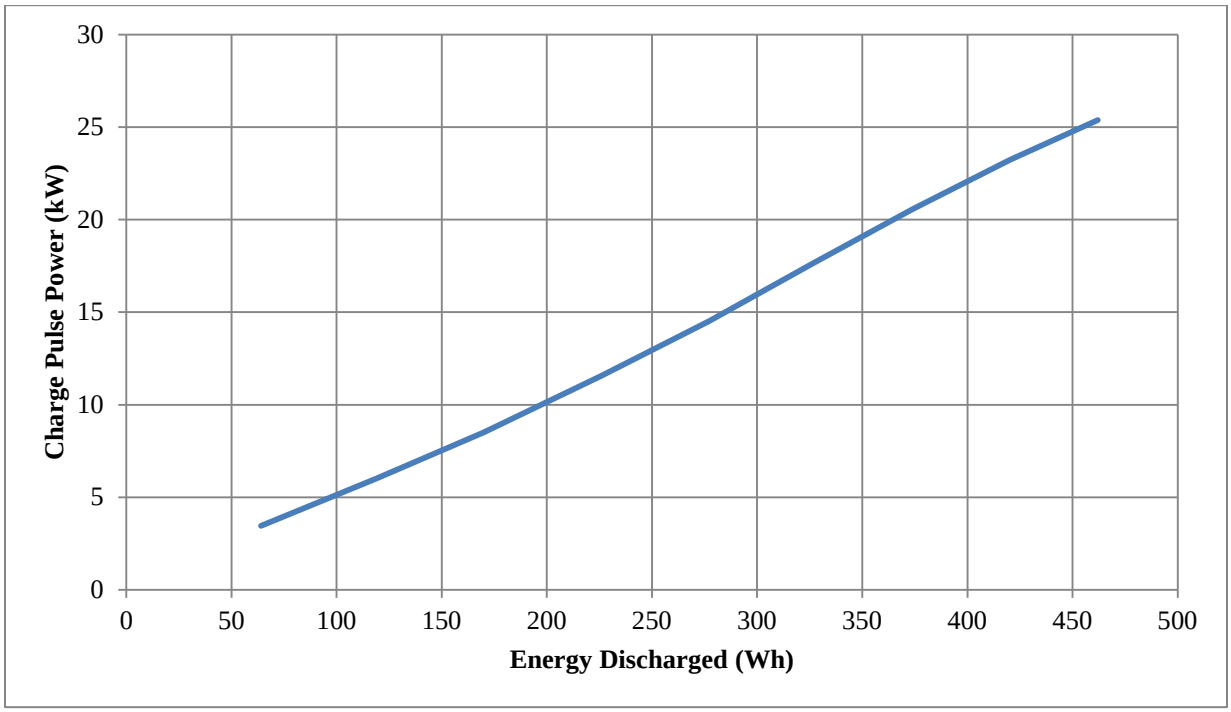

Figure 4. Ten-second charge pulse power capability versus energy discharged.

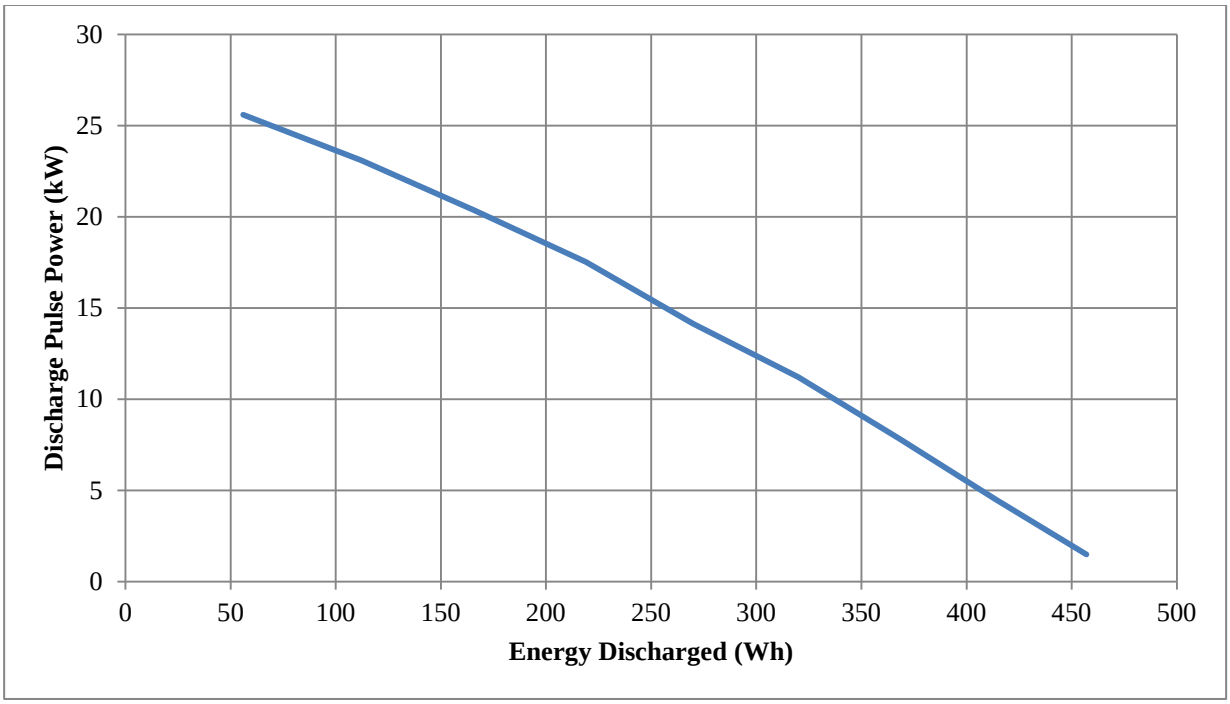

Figure 5. Ten-second discharge pulse power capability versus energy discharged.

Figure 6 is a plot of the battery's HPPC 10-second pulse power as a function of energy discharged. The graph shows the power values over the energy discharged range, as well as the DOE battery target performance goals of 25 kW discharge power and 20 kW regenerative power. Since there is no state of charge at which both curves are above the target performance goals, the Malibu battery does not meet the DOE power performance goals for any battery state of charge tested.

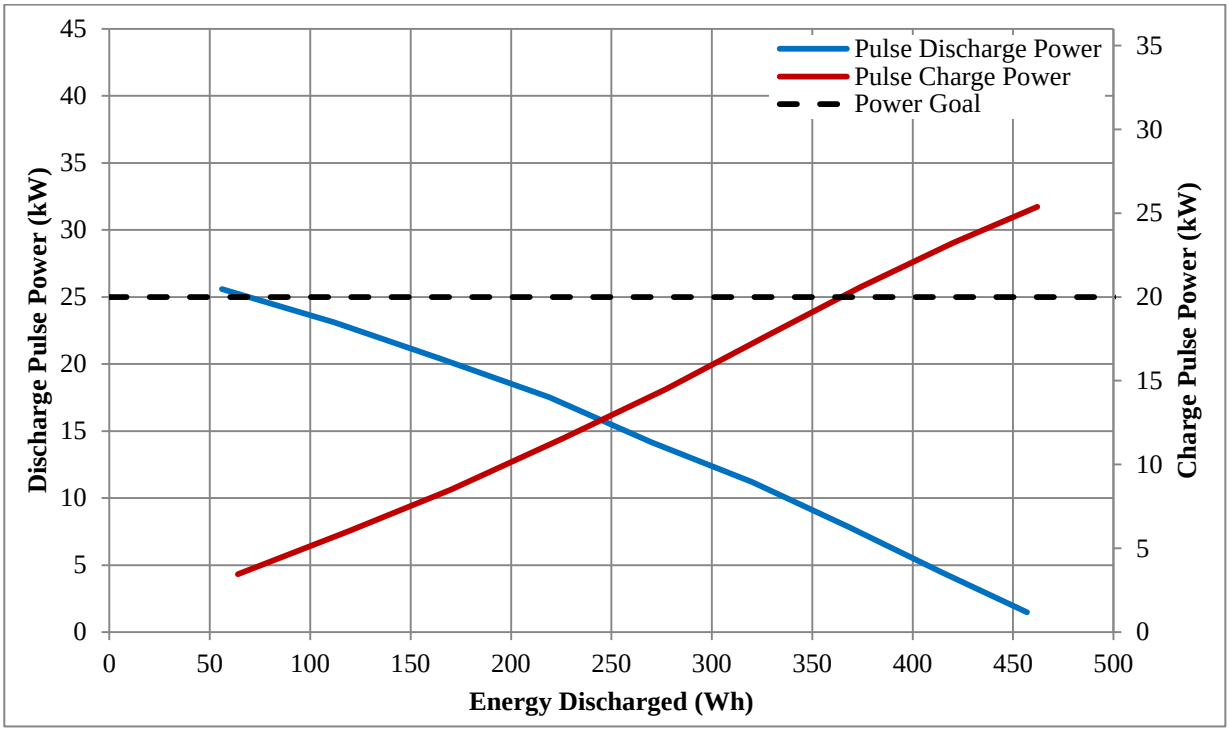

Figure 6. Peak discharge and charge power versus energy discharged.

Figure 7 is a plot of the battery's useable energy as a function of discharge power. The x-axis indicates a desired discharge power level and the y-axis indicates the useable energy at that power. The dashed horizontal line shows the DOE energy performance goal of 300 Wh. The dashed vertical line shows the DOE HEV power performance goal of 25 kW. A portion of the battery's useable energy curve falls above the DOE useable energy goal; however, the entire curve falls to the left of the DOE power performance goal. The maximum power that can be delivered while meeting the DOE energy performance goal is 6.2 kW at 300 Wh. The battery from Malibu 6791 does not meet the DOE power performance goal for any energy value. These results indicate that at the time of BOT testing, the battery from Malibu 6791 was below the DOE HEV battery performance goals.

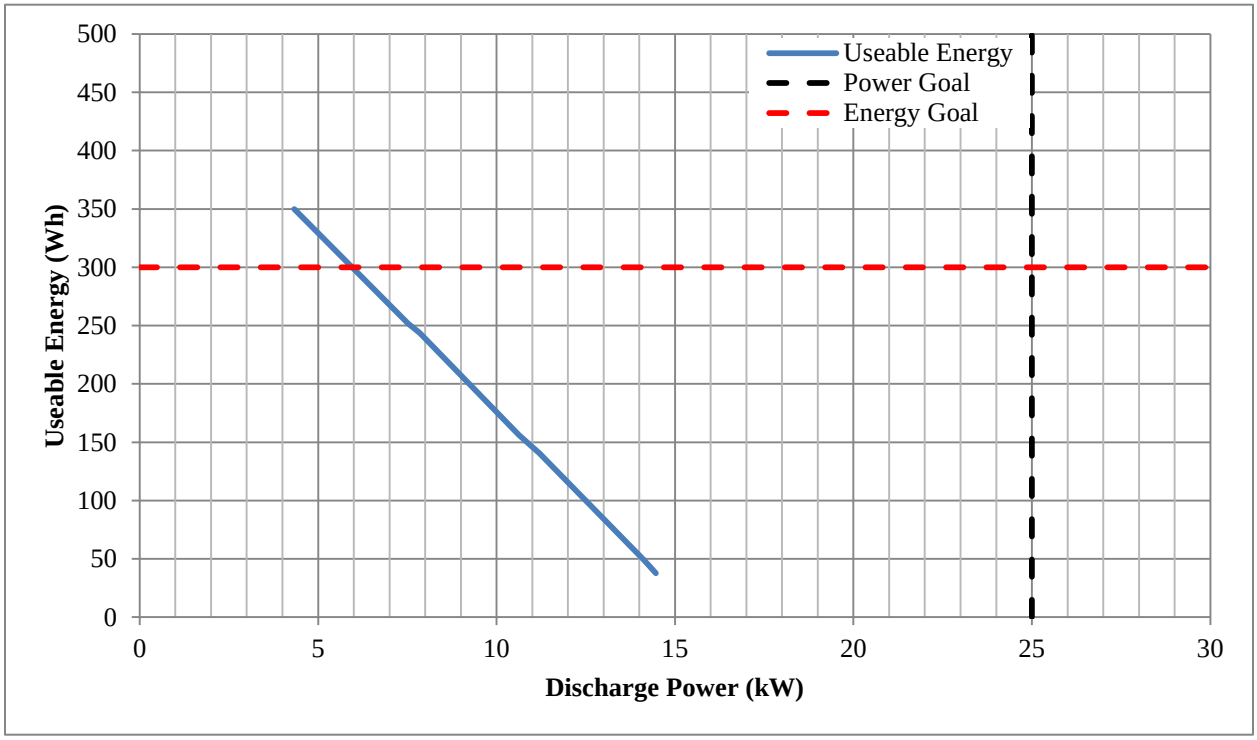

Figure 7. Useable energy versus discharge power.