Bulldogs Racing BR16 Sustainability Report

Resource	Impact
CO_2 generated per MJ of natural gas burned at Yale University's Central Power Plant (CPP)	0.056 kg CO_2 per MJ[1]
Delivery efficiency of unit electrical energy stored in the vehicle's battery per unit thermal energy dissipated at the CPP:	~40%[2]
Electricity consumption of the vehicle: Battery capacity: 5.7 kWh[3] (20.5 MJ); battery range ~ 35 mi (56 km) in racing environment[4]; efficiency $\frac{20.5\ \text{MJ}}{56\ \text{km}} = 0.36$ MJ/km	0.36 MJ/km
Total CO_2 generated is $0.056\ \text{kg}\ CO_2$ per MJ of natural gas $*$ $\frac{1}{0.4}$ efficiency $* 0.36 \frac{\text{MJ}}{\text{km}} = 0.0504\ \text{kg}\ CO_2$ per km	0.0504 kg/km

Notes:
Fuel production (i.e., electricity in our case) is accomplished at Yale University's Central Power Plant, which is an 18 MW cogeneration facility using gas turbines powered by natural gas.

Sources:

1) Government of Canada. "Canadian Industry Program for Energy Conservation (CIPEC) Appendix B – CO2 Emission Factors." *Natural Resources Canada*, 15.05.13. Web. 12.03.16.
2) EPA. "Methods for Calculating Efficiency." *Combined Heat and Power (CHP) Partnership*. US Environmental Protection Agency, 10.12.15. Web. 12.03.16.
3) 5.2 kWh de-rated (0.8 * 5.7 kWh)
4) From test data based off battery capacity, power, weight, and estimated stress on the vehicle in race environment

Fuel consumption during the endurance event:
Length: 44 km; 44 km x 0.36 MJ/km = 15.8 MJ of electricity

CO_2 generated during the endurance event:
Length: 44 km; 44 km x 0.0504 kg/km = 2.22 kg of CO_2

Our performance and efficiency targets had us to use 86 A123 AMP20 prismatic pouch cell batteries with a chemistry of lithium, phosphate, and iron due to their nature of providing a combination of high energy and high power density, since every cell has a capacity of 20 Ah and a peak discharge current of 600 A. The AMP20 delivers high usable energy over a wide state of charge (SOC) range to minimize pack oversizing and offer very low cost per watt-hour with 1.35 $/W.
(source: http://www.a123systems.com/prismatic-cell-amp20.htm)

In addition, we strove to maximize efficiency by minimizing our use of raw materials and our vehicle weight, as evidenced by the reduced weight and size of our car (approximately 500 lbs. without driver) compared to last year; in the chassis alone we saved about 25 lbs. with more compact packaging. Furthermore, we worked to eliminate complex manufacturing processes that tend to be resource-intensive by moving to injection molding for the plastic battery tab covers rather than using 3D printing or machining.

Lastly, we managed to make our car 95-96% efficient when run at the correct speed and torque levels, a product of our commitment to performance and efficiency.