Power Delivery Systems: Energy Consumption Comparison

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Overview

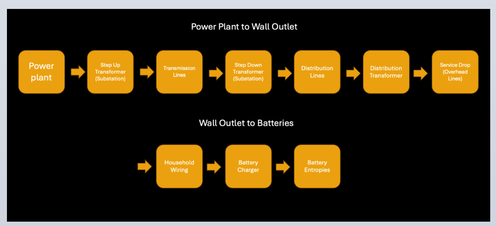
Problem Statement: Perform a comparative analysis of power delivery systems in terms of carbon-based fuel consumption.

Background

It is widely believed that electric powertrains are better at converting potential energy in a battery into mechanical energy when compared to traditional Internal Combustion Engine (ICE) powertrains. Often both powertrains consume carbon-based fuel at some point to ultimately create kinetic energy. The meaning of carbon-based fuel consumption references gasoline burned in the ICE and natural gas burned at a power plant to provide electrical power.

Motivations

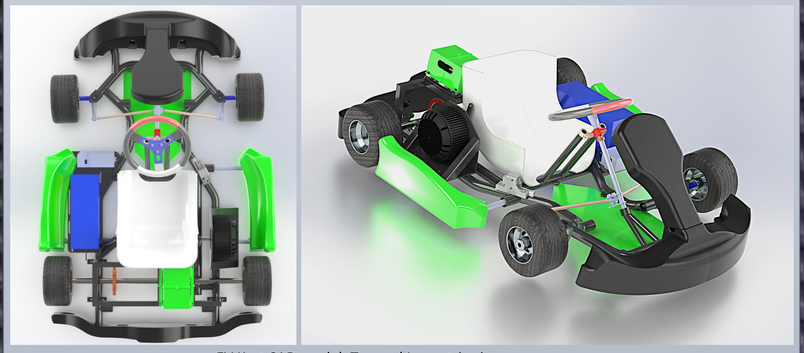
The project sponsor, RTX, has an interest in alternate fuel technologies and their respective efficiencies. To better understand the consumption of energy from carbon-based fuels between power delivery systems (ICE and Electric) we must consider all the energy losses from source to application. These losses must be accounted for and combined to contribute to calculating energy usage rates.



Block Diagram: Losses from power source to application

Design Process

Important design and project requirements/constraints were considered. Go kart powertrain systems were chosen as the platform for comparison between ICE and Electric. Predator Pro class standards were used and adapted to develop ICE and EV karts. Through careful consideration and implementation of various selection methods the EV kart components and layout were chosen and modeled to ensure design verification.

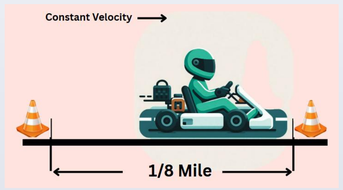


EV Kart CAD model: Top and Isometric views

Method

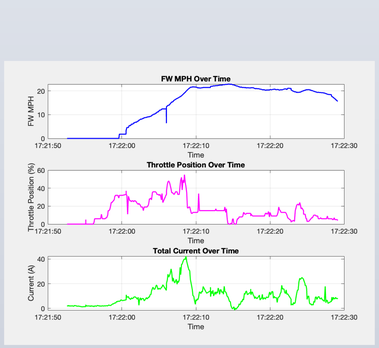
Testing Procedure

Each kart performed three test runs at 10, 20 and 30 mph. The driver was tasked with maintaining the target speed of each run as closely as possible over an 1/8-mile straight.

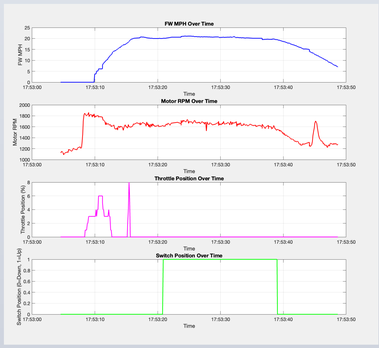


Data Collection

Data was collected for each run via sensors connected to a microcontroller (ESP32). Data was then plotted in MATLAB to display key factors of fuel consumption and other relevant data. This empirical data would then be used in conjunction with research to perform an energy consumption analysis.



EV Kart Sensor Data: 20 mph run



ICE Kart Sensor Data: 20 mph run

Validation

To verify accurate data collection, key factors of fuel consumption and power used were averaged and analyzed. The constant velocity tests provided a comparable way to gather energy consumption rate data for both karts.

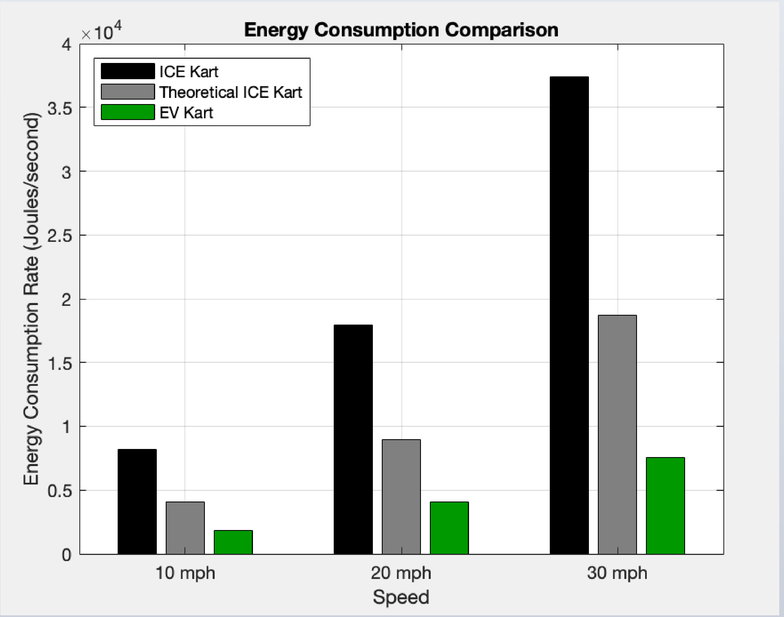
ICE Kart Tests			
Target Speed	**Actual Avg. Speed**	**Avg. Consumption Rate**	**Avg. mpg**
10 mph	11.26 mph	0.24 ml/s	59.24 mpg
20 mph	20.40 mph	0.56 ml/s	49.80 mpg
30 mph	30.51 mph	1.09 ml/s	36.74 mpg

EV Kart Tests			
Target Speed	**Actual Avg. Speed**	**Avg. Consumption Rate**	**Avg. mpge**
10 mph	10.73 mph	4.55 W	104.72 mpge
20 mph	21.12 mph	5.70 W	115.25 mpge
30 mph	31.41 mph	6.25 W	308.49 mpge

Findings

Results

Carbon-based fuel consumption was determined for the ICE and EV Karts. It was calculated that ~77.5% of energy was lost from the natural gas (power plant) to the EV kart batteries. These energy losses along with the battery discharge efficiencies and average power consumed were used to calculate the energy consumption rates of the EV kart. For the ICE kart, gasoline consumption and gasoline energy density were used to calculate the energy consumption rates. From source to application, the EV kart proved to be 6-8x more energy efficient than the ICE Kart.



Bar graph: Compares the difference in energy consumption for similar amounts of desired work.

To account for years of innovation, a comparable modern Inverter Generator Engine with EFI (electronic fuel injection) and smart load sensing is about 2x more efficient than the ICE kart's engine; thus, a theoretical modern high tech small engine is included in the graph ("Theoretical ICE Kart"). Overall, this analysis concludes that the current electrical infrastructure paired with the EV powertrain is more efficient at utilizing the energy in carbon-based fuels than the ICE powertrain.



Final Karts: EV Kart (left), ICE Kart (right)