

Shell Eco-Marathon Project Proposal

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Project Overview

Background information on the Eco-Marathon Competition

- **1939 - Competition started from wager between two Shell engineers**
- **1977 - First international competition in UK**
- **2004 - Record for highest fuel economy (8000 mpg)**
- **2007 - First competition in the Americas**
- **2010 - First competition in Asia**

Client & Need Statement

- **Client**
 - **Dr. John Tester and NAU SAE Student Chapter**
- **Need Statement**
 - **The increase in pollution is a result from the amount of greenhouse gases. The amount of these gases can be decreased by making vehicles more fuel efficient. The more efficient the vehicle, the less amount of gases that are emitted.**

Objectives & Goal

- **Objectives:**

Table 1: Project Objectives

Objective	Benchmark	Unit of Measurement
Start-up to desired RPM	Time	Seconds
Achieve max speed of 17mph	Velocity	MPH
Shut down systems in 1 second	Time	Seconds

- **Goal: Design, build, and compete with a car prototype that maximizes high fuel efficiency. The car needs to follow all rules and regulations provided by Shell.**

Operating Environment

- **Tuning Environment**
 - **The initial tuning will be done in Flagstaff for engine break in and preliminary testing**
 - **The vehicle will also be tuned and tested in Phoenix before the competition to obtain a better idea of potential results due to the lower elevation (1200 ft above sea level)**
- **Competition Environment**
 - **The competition will take place in downtown Houston, TX from April 25th to the 27th**
 - **Practice, tuning, competition, and presentation will take place in Houston.**

Engine Constraints

- **The engine must be fueled by gasoline.**
- **The engine must not combine fuel and oil (no 2-stroke engines).**
- **The starter must not provide forward propulsion.**

Engine Selection

- **Small Honda engines compared**
 - **GY6-QMB 50cc**
 - **GX25 25cc**
 - **GX35 35cc**
- **Honda engines offer best power band among small displacement engines.**

Engine Selection

- **Engines are compared by the weighted criteria:**
 - **Power Output (5%)**
 - **Compression Ratio (25%)**
 - **Aftermarket Support (20%)**
 - **Starter Type (10%)**
 - **Clutch Type (10%)**
 - **Fuel Consumption (10%)**
 - **Cost (20%)**

Engine Selection

Table 2: Engine Decision Matrix

	Weighted Percentage	Honda GY6-QMB	Honda GX25 25cc	Honda GX35 35cc
Power Output	5%	1	10	5
Compression Ratio	25%	10	1	1
Aftermarket Support	20%	10	1	1
Starter Type	10%	10	1	1
Clutch Type	10%	10	1	1
Initial Fuel Consumption	10%	1	10	5
Cost	20%	1	5	10
Total	100%	6.85	3.15	3.4

Engine Engineering Analysis

- **The 3 engines were compared using**
 - **Air standard Otto Cycle efficiency**
 - **Brake Specific Fuel Consumption (BSFC)**

Engine Engineering Analysis

Table 3: Engine Properties

	<u>Units</u>	<u>Honda GX25</u>	<u>Honda GX35</u>	<u>Honda GY6</u>
Displacement	cc	25.00	35.00	50.00
Comp. Ratio	unitless	8.00	8.00	10.50
Power Output	kW	0.72	1.00	2.10
Torque Output	N-m	1.00	1.60	3.10
Initial Fuel Consumption	L/hr	0.54	0.71	1.04
Fuel Consumption Engine Speed	RPM	7000	7000	6500

Engine Selection Analysis

Air Standard Otto Cycle

- **Otto Cycle Efficiency Equation:**

$$\eta = 1 - \frac{1}{r^{k-1}}$$

- **r is the engine compression ratio**
- **k is the specific heat ratio**
 - **For ambient air, k=1.4**

Engine Selection Analysis

Table 4: Otto Cycle Efficiencies for Selected Engines

<u>Engine:</u>	<u>Efficiency:</u>
GX25	57%
GX35	57%
GY6-QMB	62%

Engine Selection Analysis

Brake Specific Fuel Consumption

- **Measure fuel consumption without considering driving habits**

$$BSFC = \frac{r}{T \times \omega}$$

- **r = fuel consumption in g/s**
- **T = engine torque in N-m**
- **ω = engine speed in radians/s**
- **Smaller number means less fuel consumed**

Engine Selection Analysis

Table 5: BSFC for Selected Engines

<u>Engine:</u>	<u>Efficiency: (g/J)</u>
GX25	0.00072
GX35	0.00059
GY6-QMB	0.00048

Engine Selection Analysis

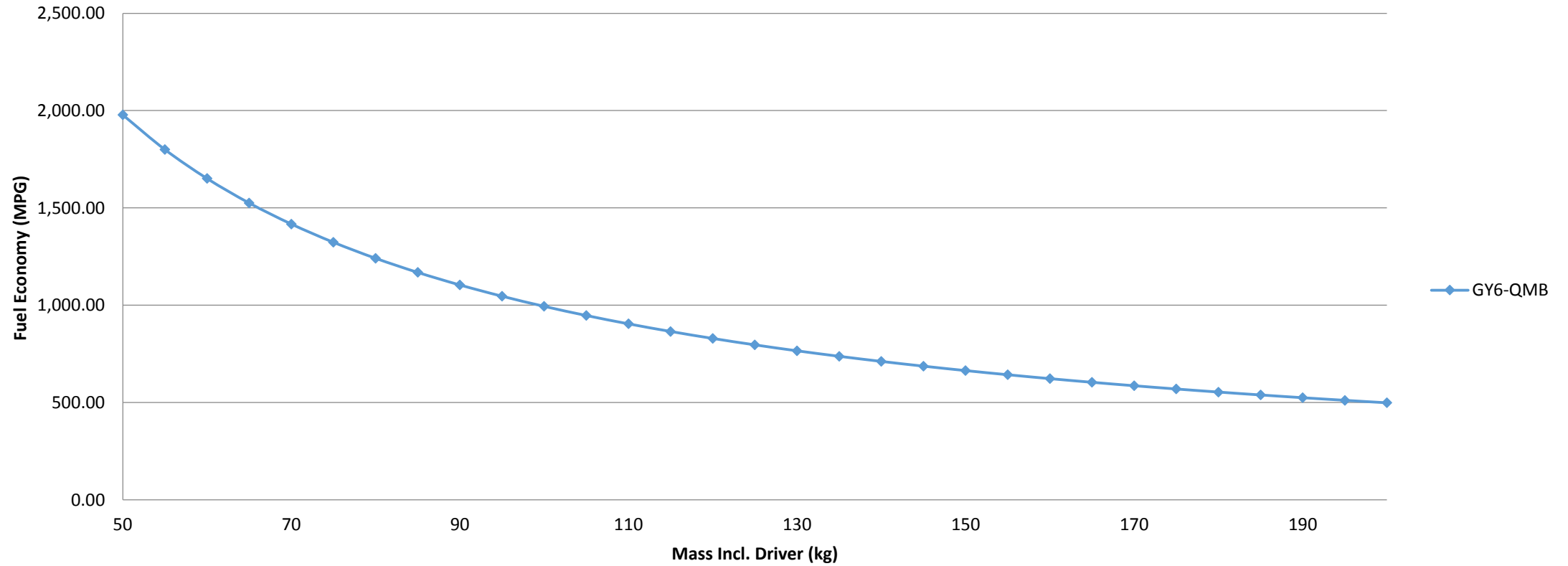
- **GY6-QMB engine to be used because of superior efficiencies**
- **Fuel Injection will be used on GY6 with programmable engine control unit (ECU) in order to come closer to meeting projected efficiencies and improve consistency**

Engine Selection Analysis

- $$\text{Fuel Efficiency}(mpg) = \frac{2.351215 \frac{mpg}{km/L} * 1000 \frac{g}{L} * BSFC(g/J)}{M_{car} * (A_f * C_D + C_{rr} * M_{car} * 9.81 \frac{m}{s^2}) * 1000m}$$
- **Based on an assumed weight of 150kg for the entire vehicle, we expect to achieve a fuel efficiency near 550mpg**

Engine Selection Analysis

GY6-QMB



Engine Cost Analysis

Table 6: Engine Cost Analysis for GY6

<u>Component</u>	<u>Cost</u>
Engine	\$309.95
Total	\$309.95

Engine Conclusions

- **GY6-QMB selected because of highest efficiency of engines compared**
- **Electronic fuel injection (EFI) selected to give best consistency of fuel consumption**
 - **Programmable ECU makes changes between altitudes easier (Houston vs. Flagstaff)**

Engine Conclusions

Picture of selected GY6-QMB engine



(image from www.mbe-motorsports.com)

Drivetrain Constraints

- **Effective transmission chain or belt guards:**
 - **To protect driver or technician**
 - **Made of metal or composite material**
 - **Rigid enough to withstand a break**
- **Clutch system must be equipped, with the internal combustion engines**
- **Manual Clutch:**
 - **Must have starter motor inoperable with the clutch engaged**
- **Automatic clutch:**
 - **Motor starting speed must be below engagement speed of the clutch**

Drivetrain Selection

There are three types of possible drivetrain systems:

- **Shaft & gearbox drivetrain**
- **CVT belt system**
- **Roller chain & sprocket drivetrain**

Drivetrain Selection

- **Engines are compared by the weighted criteria:**
 - **Weight (30%)**
 - **Reliability (30%)**
 - **Simplicity (10%)**
 - **Cost (30%)**

Drivetrain Decision Matrix

Table 7: Drivetrain Decision Matrix

	Low Weight	High Reliability	High Simplicity	Low Cost	Total
Relative Weight	30%	30%	10%	30%	100%
Shaft & Gearbox	1	5	2	3	2.9/5
CVT Belt	4	3	3	3	3.3/5
Roller Chain & Sprocket	5	3	5	5	4.4/5

Drivetrain Selection Analysis

- **2 stage Chain and Sprocket drivetrain**
 - **24:1 Gear ratio**
 - **20:1 Gear ratio**
- **The team's methodology for the analysis is to compare each drivetrain's respective velocity output.**

Drivetrain Selection Analysis

The selected GY6 engine has a power 2.8 HP(2.1kW) @ 6500 RPM, torque of 3.1 N-m @ 5500 RPM. Using the equation below, solve for wanted speed to gain the overall speed of the vehicle.

$$\text{Gear Ratio} = \frac{\left(\frac{\text{RPM}}{60 \frac{\text{sec.}}{\text{min.}}}\right) (\text{Wheel Diameter (meter)} * \pi)}{\left(\text{wanted speed} \left(\frac{\text{meters}}{\text{sec.}}\right)\right)}$$

Drivetrain Selection Analysis

Table 8: Final Wheel Velocities

Ratio	Rear Hub Torque (ft-lbs)	RPM	Velocity (mph)
24:1	54.29	270.9	17.74
20:1	45.24	325	21.3

Drivetrain Cost Analysis

Table 9: Engine Cost Analysis for GY6

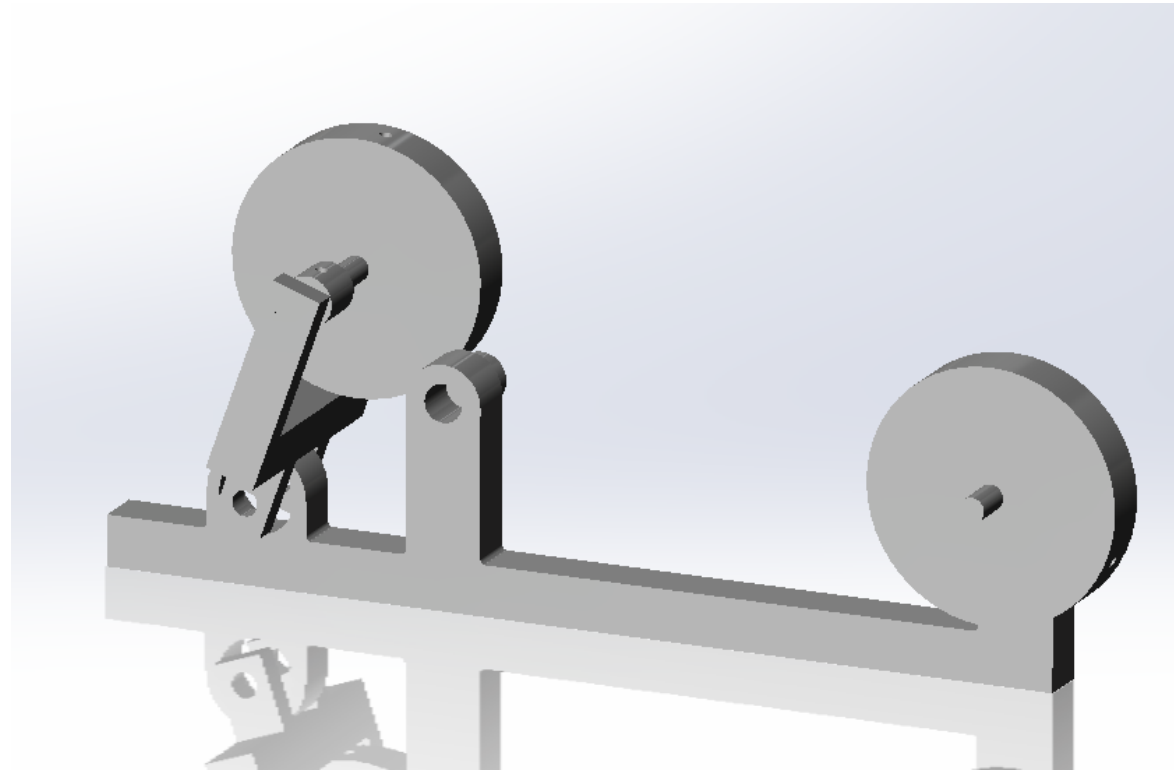
<u>Component</u>	<u>Cost</u>
Sprockets	\$150.00
Chains	\$30.00
Clutch System (apparatus)	\$100.00
Shafts	\$30.00
Bearings	\$50.00
Rear Hub	\$50.00
Total	\$410.00

Drivetrain Conclusions

The gear ratio of 20:1 was selected because it allows the vehicle the ability to reach a higher speed, turn the motor off and coast, giving an average speed of ~17 mph while cycling the engine. Cycling the engine will give the vehicle the highest fuel efficiency.

Drivetrain Conclusions

Picture of selected drivetrain



(image created from NAU Shell Eco-Marathon 2013-2014 Team)

Fuel System Constraints

- **Fuel must be Shell Regular Gasoline (87) or E100 (100% Ethanol)**
- **Fuel tank must be APAVE certified and a volume of either 30,100, or 250 cc**
- **Fuel tank must be mounted in a zero degree position and at least 5cm below the roll bar**
- **Air Intake must not contain any fuel or blow-by gas**
- **Internal and external emergency shut-down systems must shutdown the ignition and fuel supply**
- **External system must be permanently mounted to body**
- **External system must have a latching red push button and be labeled with a 10cm by 3cm wide red arrow on a white background**
- **Fuel line between tank and engine may not contain any other elements**

Fuel System Constraints

- **Fuel lines must be flexible and clear in color and not prone to expansion**
- **Teams cannot increase or decrease the fuel temperature**
- **Float chambers must include a drain valve at the bottom of the carburetor to ensure fuel level goes down in the fuel tank**

Fuel System Selection

The team came up with three different concepts related to the fuel system:

- **Carburetor**
- **Fuel Injection**
- **Forced Induction**

Fuel System Selection

- **Fuel Systems are compared by the weighted criteria:**
 - **Fuel Efficiency (40%)**
 - **Ease of Implementation (10%)**
 - **Precise Tuning (20%)**
 - **Reliability (15%)**
 - **Maintenance (10%)**
 - **Cost (10%)**

Fuel System Selection

Table 10: Fuel System Decision Matrix

	Weighted Percentage	Carburetor	Fuel Injection	Forced Induction
Fuel Efficiency (%)	40%	10	50	100
Ease of Implementation (mins)	10%	100	50	10
Precise Tuning	20%	10	100	50
Reliability (days)	15%	10	100	50
Maintenance (mins)	10%	50	100	10
Cost (\$)	10%	100	50	10
Total	100%	27.5	72.5	60

Fuel System Selection

Fuel Injection selected because

- **High fuel efficiency**
- **Best tuning precision**
- **Best reliability**
- **Least amount of maintenance**

Ecotrons Programable ECU fuel injection kit will be used because:

- **Made specifically for the GY6-QMB**
- **Programable spark controlled ECU**

Fuel System Selection Analysis

A experimental procedure on the fuel system will be performed once the fuel injection and engine are combined. The experimental procedure will include:

- **Numerous trial runs based upon different tuning characteristics when final design vehicle construction is completed**
- **Possibility of the use of a small scale dyno machine to plot power curves of the engine at various tuning characteristics**

Fuel System Cost Analysis

Table 11: Engine Cost Analysis for GY6

<u>Component</u>	<u>Cost</u>
Fuel Injection System (Ecotrons)	\$399.99
Shell Fuel Tank	\$200.00
Fuel Lines	\$10.00
Pressure System (valves, relief valve, tank, etc.)	\$80.00
Fittings	\$50.00
Total	\$739.99

Fuel System Conclusions

- **Fuel Injection selected because of very fuel efficient, best tuning precision, best reliability, and requires the least amount of maintenance.**
- **Ecotrons electronic fuel injection (EFI) system is selected to give best consistency of fuel consumption**
- **Ecotrons EFI made specifically for the engine selected**
- **Programmable spark controlled ECU makes changes between altitudes easier (Houston vs. Flagstaff) versus fuel controlled ECU**
- **Fine Tuning Analysis will be completed once vehicle is finished. Possibility use small engine of dyno machine.**

Fuel System Conclusions

Picture of Ecotrons Fuel Injection Components



(image from www.mbe-motorsports.com)

Electrical System Constraints

- **Maximum on-board voltage must not exceed 48V nominal**
- **Only one on-board battery and the battery must maintain a constant ground**
- **Electrical circuits must be protected from short circuit and overload**
- **Electric horn must be 85 dBa and pitch of 420 Hz**
- **Electrical starter can only operate when ignition and fuel systems are activated**
- **Electrical starter must not provide propulsion**
- **A red starter light must be installed on the rear of the vehicle with a luminescence of 21W and be clearly visible from both sides**
- **Starter and starter light must be extinguished by the time the rear wheel crosses the start line**

Electrical System Selection

The electrical system will be composed of:

- **12V Battery Source**
- **2-independent kill switches**
- **Depression kill switches**
- **Circuit Protection (fuses, relays, connectors, etc.)**
- **Starter Light (21 W)**
- **Horn**
- **Driver Accessories (speedometer, interior lighting, etc.)**

Due to the strict rules and specific design, the only component to analyze the the battery source.

Electrical System Selection

Since the only difference in concept designs is the battery source, the team chose three different batteries for the vehicle:

- **Deka ETX-9 Battery**
- **Duralast Lawn & Garden**
- **Optima Yellow Top**

Electrical System Selection

Electrical Systems are compared by the weighted criteria:

- **Weight (20%)**
- **Scale (15%)**
- **Capacity (40%)**
- **Costs (25%)**

Electrical System Selection

Table 12: Battery Source Decision Matrix

	Weighted Percentage	Deka ETX-9	Duralast Lawn & Garden	Optima Yellow Top
Weight (N)	20%	20	10	2
Scale (cm³)	15%	15	7.5	1.5
Capacity (Ahr)	40%	20	4	40
Cost (\$)	25%	12.5	25	2.5
Total	100%	67.5	46.5	46

Electrical System Selection

Deka ETX-9 selected because:

- **Lightest**
- **Smallest**
- **More than needed capacity**
- **Not too expensive**

Electrical System Cost Analysis

Table 13: Engine Cost Analysis for GY6

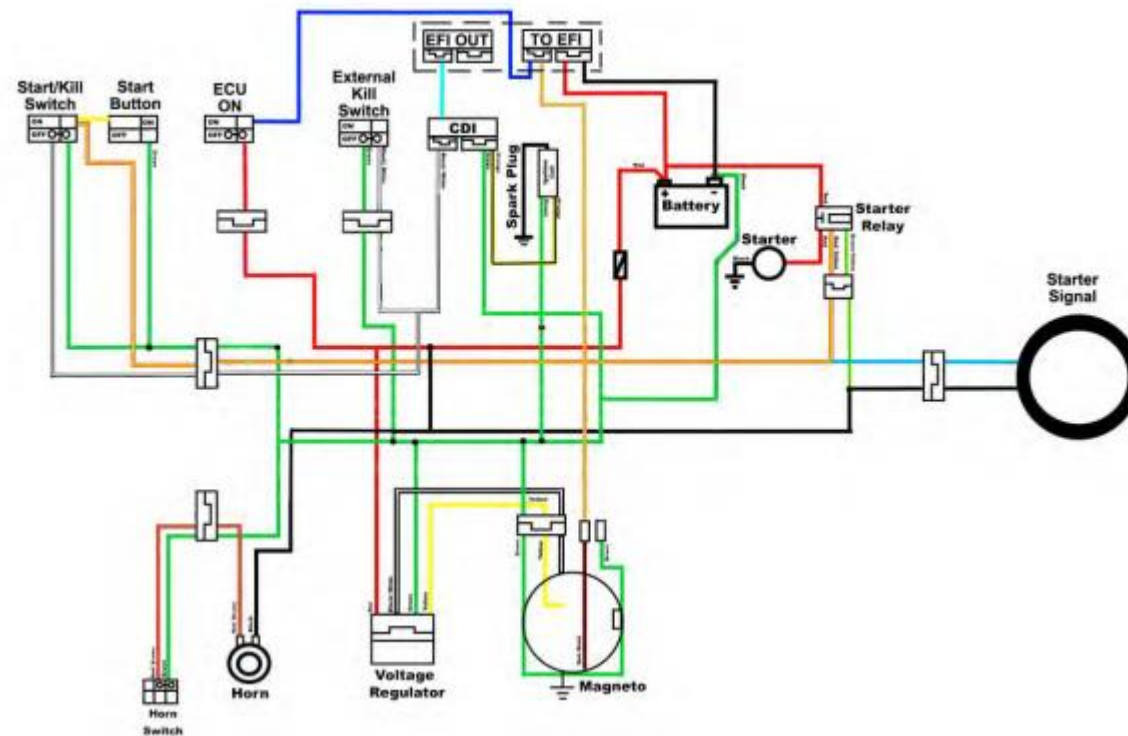
<u>Component</u>	<u>Cost</u>
Deka ETX-9	\$64.00
Wiring	\$20.00
Fuses, quick connectors, etc.	\$20.00
Horn	\$0.00* (taken from old car)
Kill Switches	\$40.00
Depression Switches	\$20.00
Total	\$164.00

Electrical System Conclusions

- **The Deka ETX-9 battery selected selected because it is the lightest and smallest while still having good capacity and a low cost.**
- **All other electrical system components will be common mass produced vehicle components.**

Electrical System Conclusions

Approximate Circuit Diagram



(Image from <http://www.mme.fiu.edu/wp-content/uploads/2013/04/R-T1-ShellEcoMarathon.pdf>)

Final Design

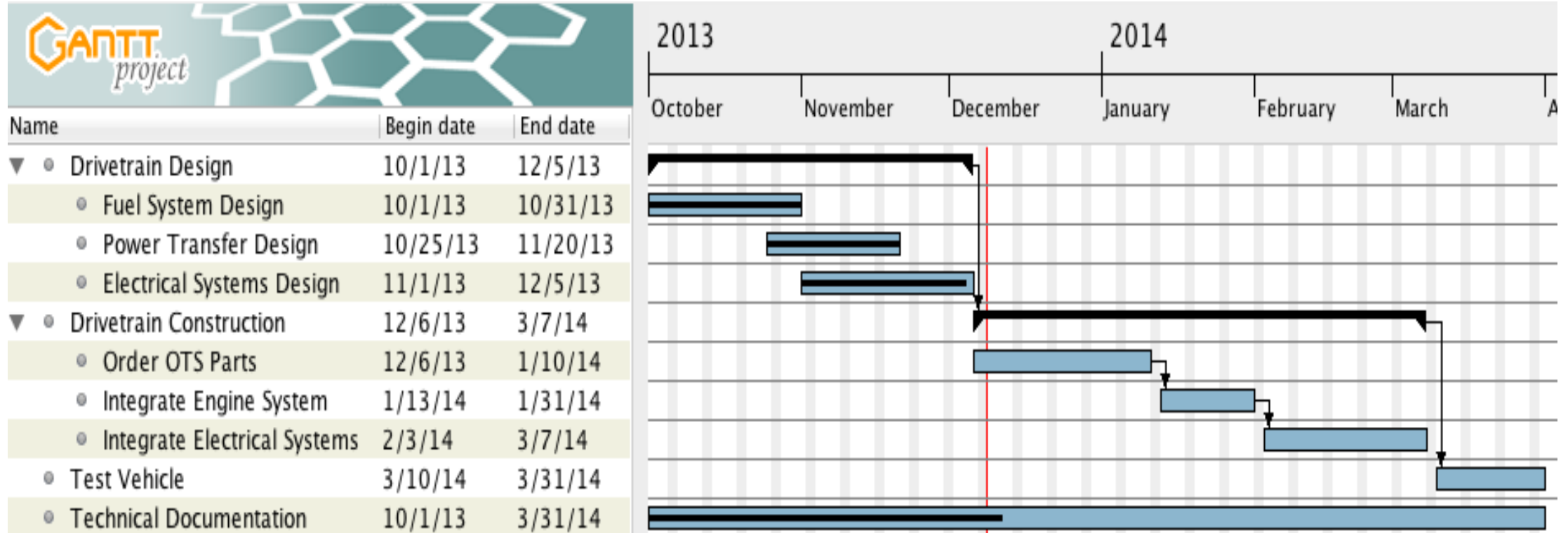
- **Engine & Fuel System: GY6-QMB 50cc engine with Ecotrons EFI fuel injection kit**
- **Drivetrain: 2 stage chain and sprocket drivetrain with custom integrated clutch**
- **Electrical: Deka ETX-9 battery supplying power source**

Final Design Costs

Table 14: Engine Cost Analysis for Final Design

<u>Component</u>	<u>Cost</u>
Engine Costs	\$309.95
Drivetrain Costs	\$410.00
Fuel Injection System	\$739.99
Electrical System	\$164.00
Total	\$1,622.94

Project Planning



Conclusion

- **The team created a final design for the specified systems through concept generations and engineering analysis methods.**
- **The vehicle will be powered by a GY6-QMB 50cc engine with Ecotrons EFI system with a target fuel efficiency of 550mpg.**
- **The vehicle will transmit this power by a 2 stage custom drivetrain with a 20:1 drive ratio.**
- **The battery chosen as a power source to run the electrical system is the Deka ETX-9.**
- **The estimated cost for these systems is \$1,622.95.**
- **The team is on schedule and will begin construction, testing, and competing in January 2014.**

References

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- **Honda Engines, “GX25 Motor Specs,” <http://engines.honda.com/models/model-detail/gx25>, Oct. 2013.**
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Questions?