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ECOCAR: THE NEXT CHALLENGE

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EcoCAR Challenge

The University of Waterloo Alternative Fuels Team, UWAFT, has a mission to design, build, and market fuel efficient vehicles of the future. UWAFT is one of 16 university student teams participating in *EcoCAR: The NeXt Challenge* [1]. The challenge was established by the USA Department of Energy and General Motors (GM), recognizing the need to devise solutions to reduce the environmental impact of gasoline-fueled vehicles. Students are challenged with re-engineering a GM-donated vehicle, a 2008 dual-mode hybrid Saturn VUE. The overall objective is to significantly reduce fuel consumption and emissions by exploring advanced technological solutions, while increasing energy efficiency and maintaining vehicle performance, safety and utility. Vehicle configurations considered by the various teams include electric drive, hybrid, plug-in hybrid and fuel cell technologies. Alternate fuels range from ethanol, biodiesel and hydrogen. All teams explored alternative lightweight materials [2].

Figure 1: The original Saturn Vue vehicle in the UWAFT garage

Saturn VUE Specifications

The 2008 production Saturn VUE XE provided by GM to UWAFT and other student teams has the following major driveline components:

- All aluminum 2.4L I-4 EcoTEC engine with peak power of 160hp @ 6200rpm and peak torque of 161 lb-ft @ 5100rpm
- Four-speed electronically controlled front-wheel-drive Hydra-Matic Transaxle (4T45) with automatic overdrive, and electronically controlled torque converter clutch.

In addition to providing a production vehicle, the teams were also provided with the Saturn VUE PSAT model and test data. PSAT – Powertrain Systems Analysis toolkit© – is an advanced vehicle simulation software developed by Argonne National Laboratory, USA. Test data was used to evaluate the accuracy of the PSAT model in terms of fuel economy and performance. PSAT was also used by the teams to design their electric hybrid vehicles [2].

Competition Background

The competition runs over three years starting in 2008. In the first year, the teams designed their vehicle using vehicle modeling software such as PSAT, to select and compare advanced vehicle powertrain configurations. The focus was on vehicle architecture in the first year, and performance modeling for vehicle development and refinement in later years. In the second year, students built the vehicle based on their design. The final year was devoted to iterative testing to improve vehicle efficiency. At the end of each academic year, student teams participated in a weeklong competition to demonstrate their vehicle performance [2].

Objectives

The primary goal of the competition is to minimize fuel consumption, petroleum use, and emissions. The vehicle performance was compared against the stock production vehicle. The vehicle must meet or exceed the stock vehicle in the following criteria:

- Incorporate technologies that reduce petroleum energy consumption on the basis of a total fuel cycle well-to-wheel (WTW) analysis;
- Increase vehicle energy efficiency;
- Reduce WTW greenhouse gas (GHG) emissions; and
- Maintain consumer acceptability in the areas of performance, utility and safety [2].

Some of the original vehicle performance requirements, aside from fuel economy, were relaxed, Tables 1 and 2.

Table 1: Vehicle metrics for EcoCAR [2]

Metric	Production VUE	EcoCAR Requirements
Mass	1758	≤ 2268
Coefficient of Aerodynamic Drag	0.33	N/A
Vehicle Frontal Area (m^2)	2.2	N/A
Tire Rolling Resistance Coefficient	0.0056	N/A
0 - 60 mph time (s)	10.6	≤ 14.0
50 - 70 mph time (s)	5.0	≤ 10.0
0 - 45 mph time (s)(Towing 680kg, 3.5%)	N/A	≤ 30.0
Combined fuel economy (mpg-ge)	28.3	32

Table 2: Vehicle Technical Requirements for EcoCAR [2]

Specification		
EcoCAR	**Production VUE**	**Competition Requirement**
Towing Capacity	680 kg (1500 lb)	≥680 kg @ 3.5%, 20 min @ 72 kph (45 mph)
Cargo Capacity	0.83 m^3	Height: 457 mm (18”) Depth: 686 mm (27”) Width: 762 mm (30”)
Passenger Capacity	5	≥4
Braking 60 - 0	38 m- 43 m (123 -140 ft)	< 51.8 m (170 ft)
Mass	1758 kg (3875 lb)	≤ 2268 kg* (5000 lb)
Starting Time	≤ 2 s	≤ 15 s
Ground Clearance	198 mm (7.8 in)	≥178 mm (7 in)
Range	> 580 km (360 mi)	≥ 320 km (200 mi)

UW in EcoCAR Challenge

Fuel Selection

Fuel was selected based on well-to-wheel GHG (greenhouse gas) and PEU (petroleum energy use). The possible energy sources included electricity, hydrogen, biodiesel, 10%-ethanol-gasoline-blend, and 85%-ethanol-gasoline-blend. To determine the well-to-wheel GHG and PEU influence on architecture selection, each fuel was compared assuming 1 BTU of energy is required at the wheels of the vehicle. Then approximate efficiencies of each power plant were used to determine how much energy (Btu’s) was required at the tank. This value was then used to calculate the upstream GHG and PEU, using the WTW factors provided for EcoCAR.

Table 3: GHG and PEU well-to-wheel factors for energy carriers [2]

	Energy Source				
CRITERIA	**E10**	**E85**	**B20**	**Electric**	**H2**
Total WTW PEU(g/btu)	0.55	0.45	0.25	0.09	0.03
Total WTW GHG (g/btu)	0.17	0.16	0.21	0.23	0.23
Range MJ/L	34.2	26.7	33	2	2.7

Based on the ratings in Table 3, UWAFT determined that hydrogen and electricity were the most promising, followed by biodiesel.

Architecture Selection

A literature review of the following hybrid vehicle architectures was conducted: Hybrid Vehicle, Series Hybrid, Parallel Hybrid, Parallel Hybrids, Series-Parallel, Fuel Cell (FC), All Electric Vehicle (EV), and Energy Storage Systems (ESS) [3].

Series fuel cell hybrid and Biodiesel electric range-extended vehicle were selected for further review; the series fuel cell hybrid system was determined to be the best option.

Series fuel cell hybrids can entail many different configurations, depending on the energy storage systems chosen. All power electronics systems on the vehicle must be connected through a high voltage bus. The configuration of components on the high voltage bus can have a significant effect on component sizing and selection.

Figure 2 shows two out of eight possible configurations considered for a series fuel cell hybrid.

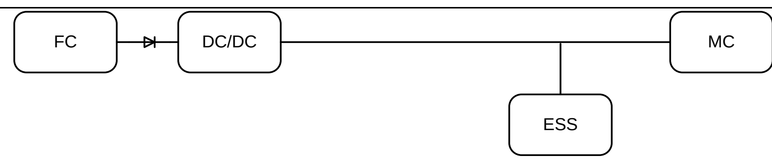
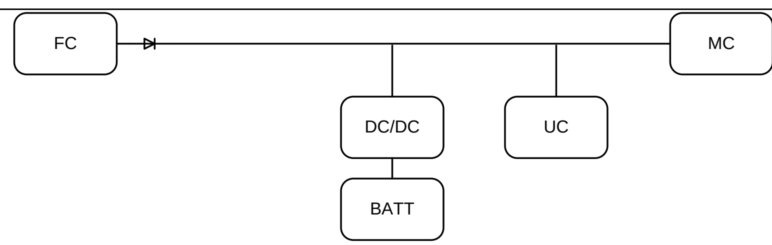
Configuration	**Flowchart**
#1. 1 ESS, 1 DC/DC on FC	
#2. 2 ESS, 1 DC/DC on Battery	
FC = fuel cell, MC = electric motor, ESS = energy storage system,BATT = battery, & UC = ultracapacitors	

Figure 2: Possible Series fuel cell hybrid configurations

The first configuration represents a conventional approach to power electronics configuration. The ESS could either be a battery pack or an ultracapacitor. The Challenge X vehicle, UWAFT's entry into the previous competition, used this configuration with a battery. The DC/DC boost converter facilitated control by decoupling the fuel cell voltage from the bus voltage, allowing the fuel cell to operate at higher efficiencies. The second configuration is a dual ESS architecture with only one DC/DC converter. Both the ultracapacitors and the fuel cell are directly connected to the electric motor through the high voltage bus, and the battery is the only component connected through a DC/DC converter.

UWAFT believed that the second configuration was better due to its higher efficiency power pathways, lower mass and lower number of components [3].

With the basic vehicle architecture selected, the team was required to size key components and design the detailed implementation for their prototype. Figure 3 presents a solid model illustrating the packaging of the chosen configuration.

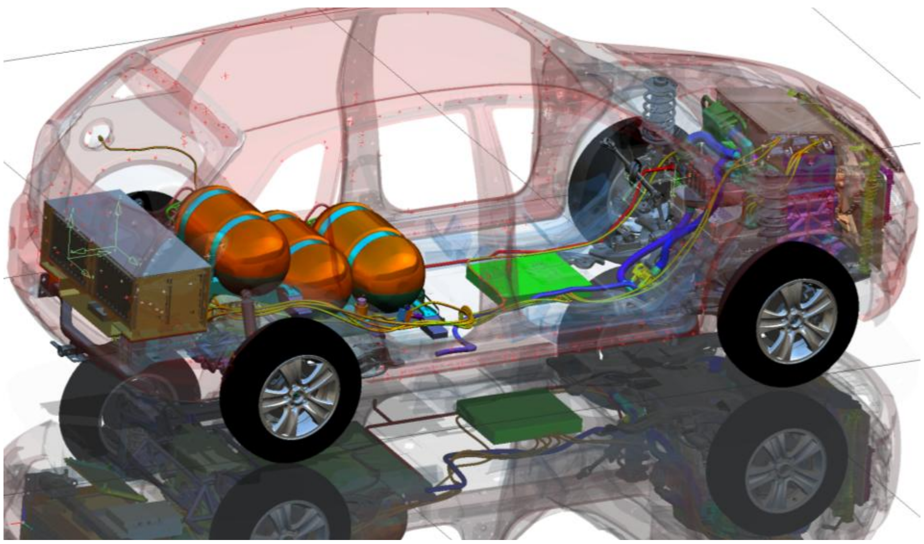


Figure 3: University of Waterloo Powertrain Configuration for the EcoCAR

References

[1] EcoCAR Challenge. (2009). *Meet The Teams* [Online]. Available: http://www.ecocarchallenge.org/meet_the_teams.html

[2] EcoCAR Challenge. (2009). *ABOUT EcoCAR* [Online]. Available: http://www.ecocarchallenge.org/about_ecocar.html

[3] University of Waterloo Alternative Fuels Team, “EcoCAR: The NeXt Challenge Architecture Selection Proposal” University of Waterloo, Waterloo, Ontario, 2008.