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COMPARING THE ENVIRONMENTAL COSTS

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Diesels versus Hybrids

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BY CORINNA KESTER

High fuel prices and concerns about climate change are boosting the popularity of gasoline/electric hybrid cars in the United States and abroad. However, environmentally minded motorists have another choice—diesels—which account for 45 percent of new passenger-car sales in European markets. Besides fuel economy concerns, the reasons include lower taxes on diesel fuel and greater tolerance of higher air emissions. Enthusiasm for diesels is relatively muted in the United States, with sales of approximately 30,000 diesels per year, mostly Volkswagens. Compare this to the sales of hybrid cars: more than 180,000 have been sold in the United States to date, 85,000 of them in the last year.

Americans generally think diesels are noisy, dirty, and underperforming. In a 2002 diesel vehicle survey by J.D. Power and Associates, 32 percent of Americans were concerned about engine noise, 27 percent about exhaust odor, and 31 percent about lower performance. However, these concerns are largely misplaced; most Americans remember the dirty diesels of decades past and are not aware of the advances incorporated into modern diesel vehicles. For example, in the last 15 years, diesel engines have reduced noise by 60 percent, emissions by 90 percent, and fuel consumption by 30 percent, while increasing torque by 100 percent. Modern diesels can be as desirable to consumers as gasoline automobiles, but how does their environmental performance measure up?

To answer this question, we must examine the entire lifecycle of the vehicle, including extracting raw materials, manufacturing and assembling automobile components, producing and combusting fuel, and maintaining and disposing of vehicles. Several differences between diesels and hybrids are undeniable: diesel engines are inherently more efficient than gasoline engines, diesel fuel contains approximately 10 percent more energy per volume than gasoline, and diesels produce significantly more air pollution. A closer look at the models offered today highlights these differences.

Three hybrid and three diesel passenger cars are currently offered in the United States (excluding the two-passenger Honda Insight and the luxury Mercedes-Benz E320 CDI). Table 1 provides basic size, weight, price, and performance data for these cars. The Honda Accord is the most expensive and the best performing; the other cars closely match each other in cost and performance. Overall, the diesel vehicles have a smaller cost differential than the hybrids.*

Materials Use and Waste Production

Nearly all vehicle energy consumption (more than 85 percent) and pollutant emissions occur during vehicle usage, which includes the vehicle emissions themselves as well as the impacts associated with the fuel cycle: the extraction, refining, transport, and use of diesel and gasoline. The large environmental impact during vehicle use means that materials use for manufacturing is not a primary concern, though it is worth some consideration. The vehicle lifecycle includes the production of about 6,700 kilograms (14,740 pounds) of hazardous waste per vehicle; half of that is produced during materials extraction and vehicle manufacture and half during fuel refining. Hybrid-car batteries are an additional source of hazardous waste, but the impacts are difficult to quantify. The potential longer lifetime of diesel vehicles also reduces materials use, though this may be offset by the extended usage of older vehicles with worse-than-average air emissions. Overall, there is no clear preference for either vehicle based on materials use.

Table 1. Basic Vehicle Information

Vehicle*	EPA Vehicle Class*	Curb Weight (lb)	Base Price	Additional Cost (over pure gasoline version)	Zero to 60 MPH (seconds)
Prius	Midsize	2,890	$21,415	N/A	11.3
Civic	Compact	2,736	$20,315	$2,390	10.9
Accord	Midsize	3,501	$30,505	$3,290	6.7
Golf	Compact	3,051	$18,025	$1,620	11.3
Jetta	Compact	3,115	$21,315	$1,020	11.3
Passat	Midsize	3,442	$23,935	$215	10.2

** As defined by the EPA; compact = 100–109 ft^3, midsize = 100–119 ft^3 of passenger and luggage space*

Energy Use and Greenhouse Gases

The U.S. transportation sector produces 26 percent of the nation's greenhouse gas (GHG) emissions and consumes 27

* Most data in this article are presented in their original English or avoirdupois form to avoid confusion and the introduction of conversion errors.

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Table 2. Fuel Economy and Greenhouse Gas Emissions

Vehicle	Transmission	City MPG	Highway MPG	Combined MPG*	GHG Emissions (CO_2 equivalents, lb/mi)†
Prius	automatic	60	51	55	0.47
Civic	automatic	48	47	48	0.53
Civic	manual	46	51	48	0.55
Accord	automatic	29	37	32	0.80
Golf/Jetta‡	automatic	29	39	32	0.77
Golf/Jetta	manual	34	41	37	0.68
Passat	automatic	24	34	28	0.91

** The EPA defines the combined MPG as 1/[(0.55/city MPG) + (0.45/highway MPG)]*

† Includes emissions in fuel production, refining, distribution, etc. Obtained using DOE GREET model.

‡ The Golf and Jetta have the same engine and are rated at the same fuel economy. Diesel MPG expressed in gasoline-equivalents to aid comparison.

percent of the energy, making fuel economy particularly important in this analysis. Table 2 shows the fuel economy and full fuel cycle greenhouse gas emissions of each automobile; the Prius has the highest MPG (miles per gallon), followed by the Civic and manual Golf and Jetta. These data are estimates made by the U.S. Environmental Protection Agency (EPA), and many vehicle owners point out that the numbers overestimate the actual mileage. Nevertheless, the numbers are a good starting point for comparison, and it is clear that the gasoline hybrids have a significant advantage.

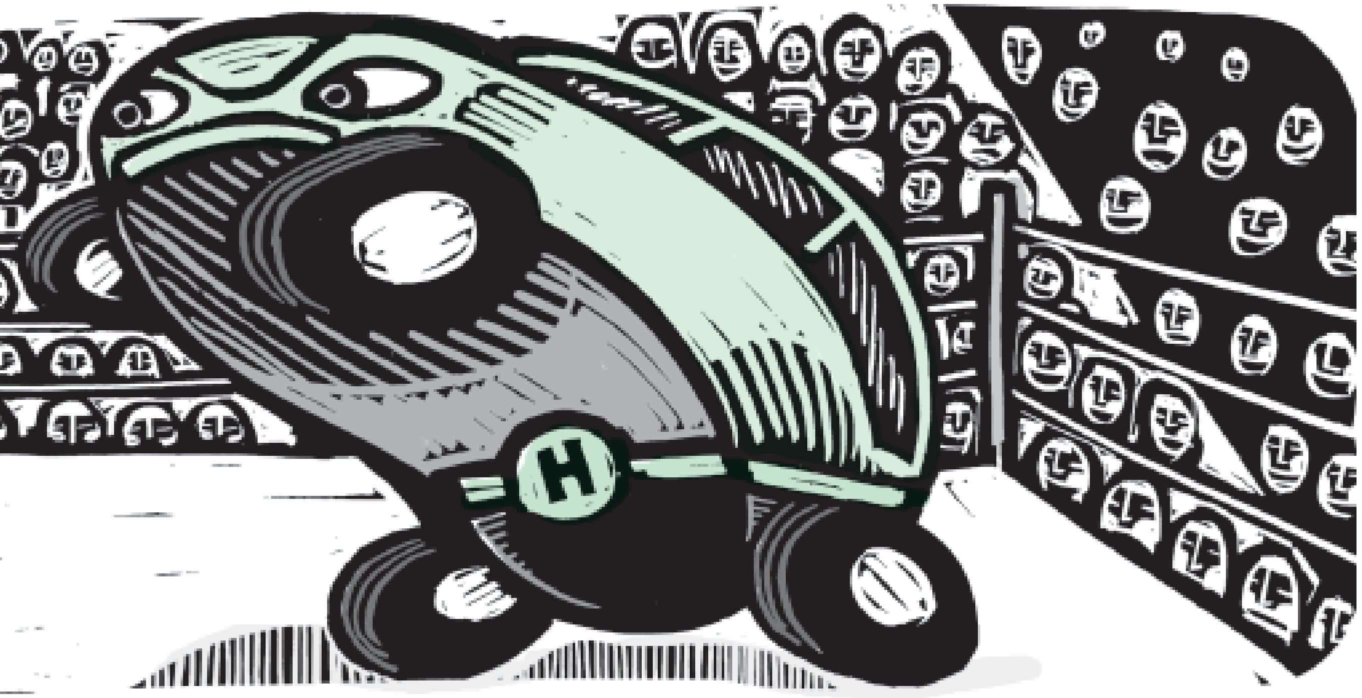
Air Pollutants

The U.S. transportation sector produces significant amounts of air pollution, including 40 percent of volatile organic compounds, 77 percent of carbon monoxide, and 49 percent of nitrogen oxide emissions. Vehicle use produces five key regulated air pollutants: nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOCs), and particulate matter (PM). NO_x and hydrocarbons combine to form ground-level ozone, which damages the lungs and increases the vulnerability of plant life to disease. Carbon monoxide causes cardiovascular damage, and sulfur dioxide leads to acid rain. Particulate matter can contribute to lung cancer and respiratory problems at any ambient concentration; the World Health Organization estimates that it leads to 100,000 deaths per year in Europe. Approximately 10 percent by weight of the VOCs emitted are known or suspected to cause cancer; these include benzene, 1,3-butadiene, acetaldehyde, and formaldehyde.

Table 3 summarizes the air pollution associated with vehicle use, including actual vehicle emissions and emissions from fuel production. The Accord produces twice the carbon monoxide and VOCs as the other cars, while the diesel automobiles have approximately six times more NO_x and eight times more particulate matter than the Prius and Civic. Notably, the diesel vehicles do not currently meet some state air standards and cannot be sold in California or several northeastern states. The hybrids lead the diesel vehicles by far in terms of air emissions. One caveat, however: these data are from EPA tests and may not correspond exactly with real-world emissions, as driving conditions vary.

Advanced Fuels

Because the vehicle-use portion of the life-cycle has the biggest environmental impact, the choice of fuel is very important. Low-sulfur fuel, which is being phased in through 2006 in the United States, will enable significant reductions in air pollution from vehicles. Because sulfur damages emissions control equipment, the low-sulfur fuel will enable



development of a variety of new emissions control technologies. These will allow diesel vehicles to meet EPA's new emissions standards. In 2009, the maximum vehicle emissions will be 0.02 grams per mile (g/mi) of particulate matter and 0.2 g/mi of NO_x, about 30–45 percent of current Volkswagen diesel emission levels. However, even with stricter EPA standards, diesel engines will still exceed the air emissions of most gasoline engines.

Another fuel option is biodiesel, which can be produced from plant oils and used in diesel engines with no modifications. Most biodiesel in the United States is produced from soybeans; its life-cycle includes soybean production, transport, and crushing, conversion of soybean oil to biodiesel, distribution of biodiesel, and finally the use of the fuel. Biodiesel is the clear choice for climate protection; it uses 0.3 megajoules (MJ) of fossil energy for each MJ of fuel energy, while petroleum diesel requires 1.2 MJ of fossil energy for each MJ of fuel energy. Biodiesel produces only one-quarter of the greenhouse gas emissions of regular diesel. The most common blend, with 20 percent biodiesel and 80 percent diesel, reduces particulate matter emissions by 10 percent, volatile organic compounds by 21 percent, and carbon monoxide by 11 percent. It also leads to a 2 percent increase in NO_x emissions and a 1–2 percent decrease in fuel economy. Unfortunately, it seems unlikely that biodiesel can fully replace fossil fuels. Converting all U.S. cropland to soybean production for biodiesel would meet only 62 percent of current U.S. on-road diesel fuel use, which tops 37 billion gallons per year. Cost may be an even more significant barrier, as pure biodiesel costs 20–30 cents more per gallon than diesel fuel.

Table 3. Full Fuel Cycle Air Pollution, grams/mile

Vehicle*	Carbon Monoxide	Volatile Organic Compounds	Nitrogen Oxides	Particulate Matter	Sulfur Oxides
Prius	0.16	0.05	0.09	0.01	0.07
Civic	0.16	0.05	0.10	0.01	0.08
Accord	0.40	0.10	0.19	0.01	0.12
Golf	0.20	0.05	0.66	0.08	0.11
Jetta	0.20	0.05	0.66	0.08	0.11
Passat	0.20	0.07	0.58	0.07	0.12

** Emissions listed are for automatic transmission vehicles.*

Conclusion

In general, due to the higher air emissions and lower fuel economy of diesel cars, a hybrid is a more environmentally sound choice, given current options. A diesel purchase today could be justified if the vehicle were to be run on 50 percent or more biodiesel, as this would produces GHG emissions equivalent to a gasoline hybrid. However, when new air pollution rules come into effect in 2007, there is no clear winner on environmental merits; hybrids will maintain a lead in air pollution, but not enough to justify avoiding diesels running on high blends of climate-friendly biodiesel. It will come down to an individual decision on whether air pollution or climate impacts of vehicles are more important. However, the higher cost of biodiesel might tip the scale toward hybrids for those on a budget. Of course, within the next five years we could also see the introduction of hybrid diesel/electric vehicles, and when that happens the dominance of gasoline vehicles in the United States could be threatened.

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