Fueling Our Transportation Fu

What are the options for decreasing demand for oil and lowering greenhouse gas emissions in cars and light trucks? **BY JOHN B. HEYWOOD**

If we are honest, most of us in the world's richer countries would concede that we like our transportation systems. They allow us to travel when we want to, usually door-to-door, alone or with family and friends, and with our baggage. The mostly unseen freight distribution network delivers our goods and supports our lifestyle. So why worry about the future and especially about how the energy that drives our transportation might be affecting our environment?

The reason is the size of these systems and their seemingly inexorable growth. They use petroleum-based fuels (gasoline and diesel) on an unimaginable scale. The carbon in these fuels is oxidized to the greenhouse gas carbon dioxide during combustion, and their massive use means that the amount of carbon dioxide entering the atmosphere is likewise immense. Transportation accounts for 25 percent of worldwide greenhouse gas emissions. As the countries in the developing world rapidly motorize, the increasing global demand for fuel will pose one of the biggest challenges to controlling the concentration of greenhouse gases in the atmosphere. The U.S. light-duty vehicle fleet (automobiles, pickup trucks, SUVs, vans and small trucks) currently consumes 150 billion gallons (550 billion liters) of gasoline a year, or 1.3 gallons of gasoline per person a day. If other nations burned gasoline at the same rate, world consumption would rise by a factor of almost 10.

As we look ahead, what possibilities do we have for making transportation much more sustainable, at an acceptable cost?

Our Options

SEVERAL OPTIONS could make a substantial difference. We could improve or change vehicle technology; we could change how we use our vehicles; we could reduce the size of our vehicles; we could use different fuels. We will most likely have to do all of these to drastically reduce energy consumption and greenhouse gas emissions.

In examining these alternatives, we have to keep in mind several aspects of the existing transportation system. First, it is well suited to its primary context, the developed world. Over decades, it has had time to evolve so that it balances economic costs with users' needs and wants. Second, this vast optimized system relies completely on one convenient source of energy—petroleum. And it has evolved technologies—internal-combustion engines on land and jet engines (gas turbines) for air—that well match vehicle operation with this energy-dense liquid fuel. Finally, these vehicles last a long time. Thus, rapid change is doubly difficult. Constraining and then reducing the local and global impacts of transportation energy will take decades.

We also need to keep in mind that efficiency ratings can be misleading; what counts is the fuel

OVERVIEW

* The massive use of petroleum-based fuels for transportation releases immense amounts of carbon dioxide into the atmosphere—25 percent of the total worldwide.
* Options for constraining and eventually reducing these emissions include improving vehicle technology, reducing vehicle size, developing different fuels, and changing the way vehicles are used.
* To succeed, we will most likely have to follow through on all of these choices.

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▲ Concept car from Volkswagen was designed to carry two people around cities and suburbs. Weighing 640 pounds (290 kilograms), the vehicle, which at present exists only as a prototype, gets some 240 miles to the gallon.

consumed in actual driving. Today's gasoline spark-ignition engine is about 20 percent efficient in urban driving and 35 percent efficient at its best operating point. But many short trips with a cold engine and transmission, amplified by cold weather and aggressive driving, significantly worsen fuel consumption, as do substantial time spent with the engine idling and losses in the transmission. These real-world driving phenomena reduce the engine's average efficiency so that only about 10 percent of the chemical energy stored in the fuel tank actually drives the wheels. Amory Lovins, a strong advocate for much lighter, more efficient vehicles, has stated it this way: with a 10 percent efficient vehicle and with the driver, a passenger and luggage—a payload of some 300 pounds, about 10 percent of the vehicle weight—"only 1 percent of the fuel's energy in the vehicle tank actually moves the payload."

We must include in our accounting what it takes to produce and distribute the fuel, to drive the vehicle through its lifetime of 150,000 miles (240,000 kilometers) and to manufacture, maintain and dispose of the vehicle. These three phases of vehicle operation are often called well-to-tank (this phase accounts for about 15 percent of the total lifetime energy use and greenhouse gas emissions), tank-to-wheels (75 percent), and cradle-to-grave (10 percent). Surprisingly, the energy required to produce the fuel and the vehicle is not negligible. This total life-cycle accounting becomes especially important as we consider fuels that do not come from petroleum and new types of vehicle technologies. It is what gets used and emitted in this *total sense* that matters.

Improving existing light-duty vehicle technology can do a lot. By investing more money in increasing the efficiency of the engine and transmission, decreasing weight, improving tires and reducing drag, we can bring down fuel consumption by about one third over the next 20 or so years—an annual 1 to 2 percent improvement, on average. (This reduction would cost between $500 and $1,000 per vehicle; at likely future fuel prices, this amount would not increase the lifetime cost of ownership.) These types of improvements have occurred steadily over the past 25 years, but we have bought larger, heavier, faster cars and light trucks and thus have effectively traded the benefits we could have realized for these other attributes. Though most obvious in the U.S., this shift to larger, more powerful vehicles has occurred elsewhere as well.

DAILY USE OF PETROLEUM WORLDWIDE

At present, consumers use 80 million barrels a day (MBD) of petroleum (a barrel contains 42 U.S. gallons). Two thirds of this goes to transportation.

53	29	19	5
MBD for transportation overall	MBD for land transport for people	MBD for land transport for freight	MBD for air transport for people and freight

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We need to find ways to motivate buyers to use the potential for reducing fuel consumption and greenhouse gas emissions to actually save fuel and contain emissions.

In the near term, if vehicle weight and size can be reduced and if both buyers and manufacturers can step off the ever increasing horsepower/performance path, then in the developed world we may be able to slow the rate of petroleum demand, level it off in 15 to 20 years at about 20 percent above current demand, and start on a slow downward path. This projection may not seem nearly aggressive enough. It is, however, both challenging to achieve and very different from our current trajectory of steady growth in petroleum consumption at about 2 percent a year.

In the longer term, we have additional options. We could develop alternative fuels that would displace at least some petroleum. We could turn to new propulsion systems that use hydrogen or electricity. And we could go much further in designing and encouraging acceptance of smaller, lighter vehicles.

The alternative fuels option may be difficult to implement unless the alternatives are compatible with the existing distribution system. Also, our current fuels are liquids with a high-energy density: lower-density fuels will require larger fuel tanks or provide less range than today's roughly 400 miles. From this perspective, one alternative that stands out is nonconventional petroleum (oil or tar sands, heavy oil, oil shale, coal). Processing these sources to yield "oil," however, requires large amounts of other forms of energy, such as natural gas and electricity. Thus, the processes used emit substantial amounts of greenhouse gases and have other environmental impacts. Further, such processing calls for big capital investments. Nevertheless, despite the broader environmental consequences, nonconventional petroleum sources are already starting to be exploited; they are expected to provide some 10 percent of transportation fuels within the next 20 years.

Biomass-based fuels such as ethanol and biodiesel, which are often considered to emit less carbon dioxide per unit of energy, are also already being produced. In Brazil ethanol made from sugarcane constitutes some 40 percent of transport fuel. In the U.S. roughly 20 percent of the corn crop is being converted to ethanol. Much of this is blended with gasoline at the 10 percent level in so-called reformulated (cleaner-burning) gasolines. The recent U.S. national energy policy act plans to double ethanol production from the current 2 percent of transportation fuel by 2012. But the fertilizer, water, and natural gas and electricity currently expended in ethanol production from corn will need to be substantially decreased. Production of ethanol from cellulosic biomass (residues and wastes from plants not generally used as a food source) promises to be more efficient and to lower greenhouse gas emissions. It is not yet a commercially viable process, although it may well become so. Biodiesel can be made from various crops (rapeseed, sunflower, soybean oils) and waste animal fats. The small amounts now being made are blended with standard diesel fuel.

It is likely that the use of biomass-based fuels will steadily grow. But given the uncertainty about the environmental impacts of large-scale conversion of biomass crops to fuel (on soil quality, water resources and overall greenhouse gas emissions), this source will contribute but is unlikely to dominate the future fuel supply anytime soon.

Use of natural gas in transportation varies around the world from less than 1 percent to 10 to 15 percent in a few countries where tax policies make it economical. In the 1990s natural gas made inroads into U.S. municipal bus fleets to achieve lower emissions; diesels with effective exhaust cleanup are now proving a cheaper option.

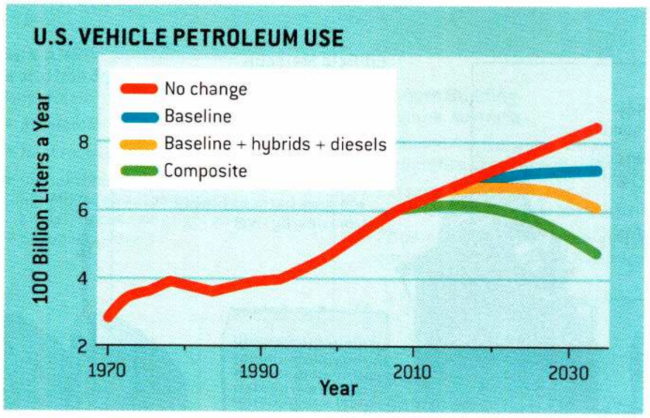
What about new propulsion system technology? Likely innovations would include significantly improved gasoline engines (using a turbocharger with direct fuel injection, for ex-

TIMESCALES FOR NEW TECHNOLOGIES

New designs for vehicles may eventually bring down overall energy consumption for transportation in the U.S., but they do not offer a quick fix. Estimates from M.I.T.'s Laboratory for Energy and the Environment indicate how long it might take for new technologies to have a significant impact.

	IMPLEMENTATION PHASE			
VEHICLE TECHNOLOGY	Market competitive vehicle	Penetration across new vehicle production*	Major fleet penetration†	Total time for impact
Turbocharged gasoline engine	5 years	10 years	10 years	20 years
Low-emissions diesel	5 years	15 years	10–15 years	30 years
Gasoline hybrid	5 years	20 years	10–15 years	35 years
Hydrogen fuel-cell hybrid	15 years	25 years	20 years	55 years

** More than one third of new vehicle production* *† More than one third of mileage driven*



▲ Four scenarios project petroleum use over the next quarter of a century. "No change" assumes that fuel consumption per vehicle remains steady at 2008 levels. "Baseline" adds evolutionary improvements in technology, whereas "baseline + hybrids + diesels" assumes the gradual addition of gasoline-electric hybrid and diesel vehicles into the fleet, and "composite" adds to the mix a slowing in the growth of vehicles sold and vehicle-kilometers traveled.

ample), more efficient transmissions, and low-emission diesels with catalysts and particulate traps in the exhaust, and perhaps new approaches to how the fuel is combusted might be included as well. Hybrids, which combine a small gasoline engine and a battery-powered electric motor, are already on the road, and production volumes are growing. These vehicles use significantly less gasoline in urban driving, have lower benefits at highway speeds and cost a few thousand dollars extra to buy.

Researchers are exploring more radical propulsion systems and fuels, especially those that have the potential for low life-cycle carbon dioxide emissions. Several organizations are developing hydrogen-powered fuel cell vehicles in hybrid form with a battery and an electric motor. Such systems could increase vehicle efficiency by a factor of two, but much of that benefit is offset by the energy consumed and the emissions produced in making and distributing hydrogen. If the hydrogen can be produced through low-carbon-emitting processes and if a practical distribution system could be set up, it has low-greenhouse-emissions potential. But it would take technological breakthroughs and many decades before hydrogen-based transportation could become a reality and have widespread impact.

Hydrogen is, of course, an energy carrier rather than an energy source. Electricity is an alternative energy carrier with promise of producing energy without releasing carbon dioxide, and various research teams are looking at its use in transportation. The major challenge is coming up with a battery that can store enough energy for a reasonable driving range, at an acceptable cost. One technical barrier is the long battery recharging time. Those of us used to filling a 20-gallon tank in four minutes might have to wait for several hours to charge a battery. One way around the range limitation of electric vehicles is the plug-in hybrid, which has a small engine on-board to recharge the battery when needed. The energy used could thus be largely electricity and only part engine fuel. We do not yet know whether this plug-in hybrid technology will prove to be broadly attractive in the marketplace.

Beyond adopting improved propulsion systems, a switch to lighter-weight materials and different vehicle structures could reduce weight and improve fuel consumption without downsizing. Obviously, though, combining lighter materials and smaller vehicle size would produce an even greater effect. Maybe the way we use vehicles in the future will differ radically from our "general purpose vehicle" expectations of today. In the future, a car specifically designed for urban driving may make sense. Volkswagen, for example, has a small two-person concept car prototype that weighs 640 pounds (290 kilograms) and consumes one liter of gasoline per 100 kilometers (some 240 miles per gallon—existing average U.S. light-duty vehicles use 10 liters per 100 kilometers, or just under 25 miles per gallon). Some argue that downsizing reduces safety, but these issues can be minimized.

Promoting Change

BETTER TECHNOLOGY will undoubtedly improve fuel efficiency. In the developed world, markets may even adopt enough of these improvements to offset the expected increases in the number of vehicles. And gasoline prices will almost certainly rise over the next decade and beyond, prompting changes in the way consumers purchase and use their vehicles. But market forces alone are unlikely to curb our ever growing appetite for petroleum.

A coordinated package of fiscal and regulatory policies will need to come into play for fuel-reduction benefits to be realized from these future improvements. Effective policies would include a "feebate" scheme, in which customers pay an extra fee to buy big fuel-consumers but get a rebate if they buy small, fuel-efficient models. The feebate combines well with stricter Corporate Average Fuel Economy (CAFE) standards—in other words, with regulations that require automobile makers to produce products that consume less fuel. Adding higher fuel taxes to the package would further induce people to buy fuel-efficient models. And tax incentives could spur more rapid changes in the production facilities for new technologies. All these measures may be needed to keep us moving forward. SA

MORE TO EXPLORE

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