CHAPTER 6

You Can Get There from Here: Transportation

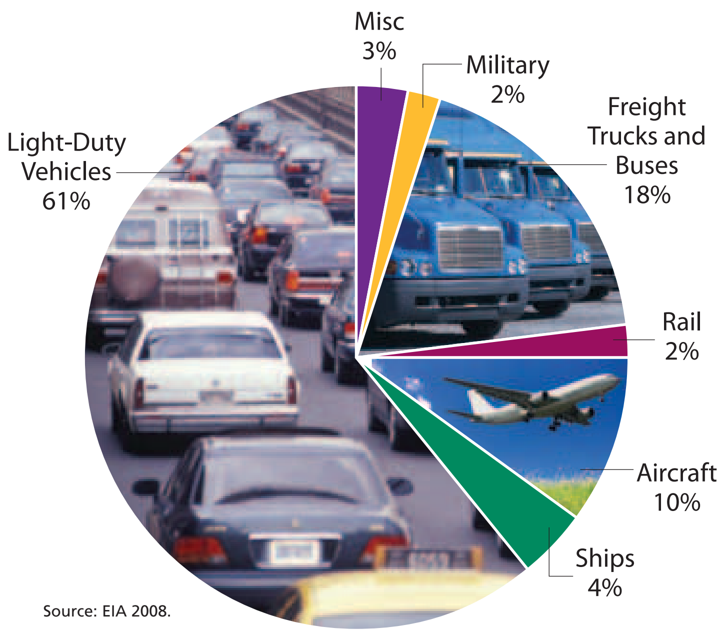
America's transportation system is intricately woven into our daily lives. The most obvious examples are the light-duty vehicles (cars, SUVs, pickups, and minivans) we use to get to work, do errands, or visit family and friends. We rely on trucks, trains, and ships to move goods as well, and on garbage trucks to haul our waste. We also spend a lot of time on airplanes, while some people use public transit, walk, or bike.

All this travel and shipping add up when it comes to global warming. The production and use of fuel for transportation in the United States is directly responsible for more than 2 billion metric tons of carbon dioxide and other heat-trapping emissions annually.[45] That puts the U.S. transportation system second to power plants as the biggest contributors to the nation's global warming emissions—producing about 30 percent of the total, and more than one-third (36 percent) of all carbon dioxide emissions.

The biggest transportation sources of heat-trapping emissions are light-duty vehicles, which account for more than 60 percent of transportation's total, and about one-fifth of the nation's total (see Figure 6.1). Next in line are medium- and heavy-duty vehicles at 18 percent, followed by air at 10 pcercent, and then shipping, rail, military, and other uses.

The impact of these vehicles also adds up when it comes to America's addiction to oil. Transportation depends on petroleum for 98 percent of its fuel, and accounts for more than two-thirds of all petroleum products used in the United States (CTA 2008). In 2007, with average gasoline prices at more than $2.75 per gallon, Americans spent more than $575 billion on transportation fuels such as gasoline, diesel, and jet fuel (EIA 2008a).

FIGURE 6.1. The Sources of Transportation Heat-Trapping Emissions (2005)



Source: EIA 2008.

Much of the oil used to make those fuels is imported, so transportation demand shipped nearly $200 billion out of our economy and into the hands of oil-exporting nations (EIA 2008a).

The impact of transportation's near-exclusive use of petroleum products goes beyond carbon emissions and the cost of fuel. The past 40 years have brought five significant spikes in oil prices—every one soon followed by an economic recession (CTA 2008). Although analysts have tied the most recent recession to problems with the housing and credit markets, spiking oil and gasoline prices likely had a significant impact, given these historical trends.

45 That is more than the amount produced from burning fossil fuels in all sectors in every nation except China and the United States (Marland, Boden, and Andres 2008).

A surprisingly small percentage of the fuel in your car's gas tank is actually used to move you down the road—most of the energy contained in fuel is wasted on inefficiencies in the engine and transmission, or lost while idling in stop-and-go traffic. Increasing fuel economy will help reduce these inefficiencies and decrease heat-trapping carbon emissions (which currently average about 1.25 pounds per mile driven, based on an average fuel economy of 20 miles per gallon for new cars and light trucks).

Three key ingredients for a more stable transportation system. The transportation sector is so large that no single solution will end our oil addiction and cut global warming emissions as much as we need. But the lack of a silver bullet does not mean there are no solutions. It simply means we need to take advantage of a variety of options to address these challenges.

The easiest way to think of this opportunity is to break it into three parts:

- Tapping technology to improve the efficiency of vehicles and their air conditioning systems.
- Shifting away from oil toward cleaner alternatives.
- Providing smarter transportation options to cut down on the number of miles we spend stuck in traffic in our cars.

As with a table or a stool, strengthening these three legs can provide both a stable climate and a secure energy future.

6.1. Driving Change: Technologies to Improve Fuel Efficiency and Air Conditioning

Only 15–20 percent of the energy in our fuel tanks actually goes to propelling today's cars and light trucks down the road. Most is effectively thrown away because of inefficiencies in the engine and transmission systems, or is wasted when we are stuck at a traffic light with the engine running or in stop-and-go traffic. Some of this energy also powers air conditioning, fans, lights, and the growing use of onboard electronics. Of the fuel that is not simply wasted, most is needed to push air out of the way, keep tires rolling, and speed up the 1.5 to 3 tons of metal, plastic, and glass in our cars and trucks.

That, in a nutshell, is why new cars and light trucks sold in 2005 averaged only about 25 miles per gallon on government tests and about 20 mpg on the road—about the same as they did two decades ago (OTAQ 2008). As a result, the average new vehicle is responsible for nearly one and a quarter pounds of carbon dioxide and other heat-trapping emissions for every mile it is driven (one pound from the tailpipe, and another quarter-pound from making and delivering the fuel) (ANL 2008). The average auto—driven about 11,500 miles annually—is responsible for about 6.5 metric tons of global warming emissions every year.

The bigger trucks used to ship goods and haul garbage waste less fuel because they tend to have more efficient engines and transmissions. However, these vehicles carry a lot more weight, and their boxy shapes mean they must push much more air out of the way. Bigger trucks also use heavy-duty tires, which also waste more energy when they roll.

As a result, medium-duty trucks, such as those used to deliver packages, average 8–8.5 mpg of gasoline equivalent, while the heaviest trucks, such as 18-wheelers, average only about 6 mpg of gasoline equivalent (EIA 2008a). This low fuel economy means that medium-duty trucks are responsible for about three pounds of global warming emissions per mile, while heavy-duty trucks release about four pounds per mile (ANL 2008).

The typical medium-duty truck also travels about 11,500 miles annually, so it is responsible for more than 15 metric tons of global warming emissions each year. With more annual mileage (about 36,000 miles) and lower fuel economy, the average heavy-duty vehicle is responsible for more than 65 metric tons of carbon dioxide and other heat-trapping emissions each year. And cross-country 18-wheelers put on 130,000 miles annually, so they average more than 240 metric tons of global warming emissions each year.

Potential Costs

6.1.1. Potential and Costs of Vehicle Technologies

6.1.1.1. Efficient Choices in the Showrooms

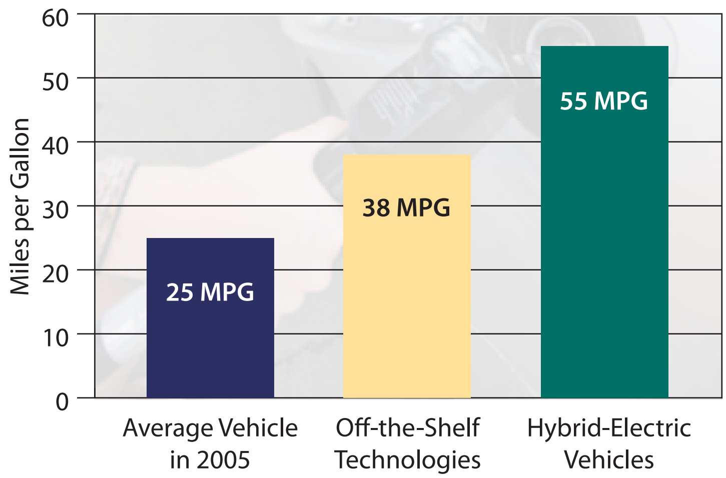
For decades the automotive industry has been developing technologies that can safely and economically help consumers get more miles to the gallon while driving cars, minivans, pickups, and SUVs of all shapes and sizes. These off-the-shelf technologies include turbocharged direct-injection gasoline engines, high-efficiency automatic-manual transmissions, engines that shut off instead of wasting fuel while idling, improved aerodynamics, and better tires (among many others). More advanced vehicles, such as hybrids, can push fuel economy even further (see Figure 6.2).

These technologies will deliver vehicles with the same safety, utility, and performance consumers enjoy today (Gordon et al. 2007; Friedman, Nash, and Ditlow 2003). Other technologies, such as high-strength steel and aluminum and unibody construction, can boost fuel economy while actually making highways safer (Gordon et al. 2007; Friedman, Nash, and Ditlow 2003).

Automakers are already including many of these technologies on vehicles individually (see Appendix F online for examples). But not until they are packaged together can they deliver a substantial boost in fuel economy.

A variety of studies have looked at this potential and the associated costs (Kliesch 2008). For example, a 2002 study from the National Academies of Science pointed to a potential for passenger vehicles to average about 37 mpg, at a cost of about $3,000. However, this study did not include the potential benefits of using high-strength steel to reduce the weight of vehicles (NRC 2002).

FIGURE 6.2. Fuel Economy Potential for Cars, Minivans, SUVs, and Pickups



While the average vehicle in 2005 reached only 25 miles per gallon on government tests, tapping into off-the-shelf technologies already in the hands of automakers could boost the fuel economy of our cars and light trucks to 38 mpg. Adding hybrid electric vehicle technology on top of that could bring our fleet to more than 50 mpg. These values all assume a mix of 54 percent cars and 46 percent light trucks, which may change over time.

The average 18-wheel tractor trailer, or "big rig," is responsible for 65 metric tons of carbon emissions each year. Existing and emerging technologies can boost truck fuel economy by nearly 60 percent and significantly reduce emissions. To help guide this process, the Department of Energy developed the 21st Century Truck Partnership, a collaboration between government agencies and manufacturers of heavy-duty engines, trucks, buses, and hybrid powertrains.

A more recent MIT study points to the potential for these conventional technologies to deliver a fleet of new cars and trucks that achieves 42–48 mpg while offering today's size and acceleration. These vehicles would cost about $2,200–$2,950 more than today's average vehicle (Bandivadekar et al. 2008).

A recent UCS study showed that a similar package of technologies could bring the fleet of new cars and trucks to about 38 mpg, at an extra cost of $1,700 (Kliesch 2008). That report found that even at fuel prices of just $2.50 per gallon—a conservative estimate, given that the *2008 Annual Energy Outlook* predicts notably higher fuel prices—owners would save almost $5,100 on gasoline over the average vehicle's lifetime, for a net savings of almost $3,400.[46] In other words, consumers would save thousands of

46 That figure assumes that a vehicle's real-world fuel economy is 20 percent lower than achieved on federal tests. It also assumes that the owner drives the vehicle 15,600 miles during the first year, declining by 4.5 percent per year (as an approximation of data from CTA 2008d on the decline in vehicle mileage with age), and a 7 percent discount rate. For more on modeled cost assumptions, see Table 6.1 and Appendix E online.

dollars while cutting carbon emissions by more than one-third.

Advanced technologies such as hybrid-electric drive trains hold even greater promise. In such a hybrid, an electric motor and a battery pack work together to provide supplemental power to the vehicle, which allows it to use a smaller engine that operates more efficiently. The electric motor/battery combination also allows the engine to shut off at stoplights, rather than wasting fuel while idling. Hybrids also employ "regenerative braking," which recovers some of the energy normally lost in braking and feeds it back into the battery. These technologies work together to improve fuel economy while maintaining vehicle performance.

If 25 percent of cars and light trucks were hybrids in 2020, with the remainder using the best conventional fuel economy technologies, the fleet could average 42 mpg.

The MIT study says that such hybrids have the potential to reach more than 70 mpg for about $5,100 more than the cost of today's conventional vehicles. The 2008 UCS analysis points to a more modest 55 mpg for advanced hybrids, at a cost of about $4,400 more than today's conventional vehicles. At a conservative $2.50 per gallon, owners of these vehicles would therefore save nearly $8,100 on fuel, or about $3,700 above the cost of the technology—while cutting carbon emissions in half.

6.1.1.2. Improving Air Conditioning to Cut Heat-Trapping Emissions

While fuel combustion in vehicles produces a host of heat-trapping emissions—including carbon dioxide, nitrous oxide (N_2O), unburned hydrocarbons (HC), and methane (CH_4)— burning fuel is not the only way cars and light trucks produce heat-trapping emissions. The air conditioning systems they use to keep drivers cool leak refrigerant and require extra power.

While the amount of refrigerant that vehicles leak is small compared with the amount of carbon they emit, the heat-trapping impact of today's refrigerants is more than 1,400 times that of carbon dioxide. Replacing those refrigerants with alternatives such as

Hybrids combine an electric motor and battery pack with a combustion engine to improve fuel economy, cut carbon emissions, and save drivers money at the pump. These savings are achieved through features including "idle-off" technology, which shuts off the engine when idling so that no fuel is wasted; power assist, in which the motor boosts acceleration to allow for a smaller gasoline engine; and regenerative braking, which captures some of the energy normally lost when braking and uses it to recharge the battery.

HFC-152a, which is only 120 times as powerful as carbon dioxide in trapping heat—and taking steps to reduce leaks and improve the efficiency of the air conditioning system—can cut global warming emissions by about 8 grams per mile. And the newer refrigerant system would cost just $50 per vehicle (Hill 2003).

Scientists are continuing to develop new refrigerants. The refrigerant HFO1234yf, for example, has a remarkably low heat-trapping potential of just four times that of carbon dioxide. And that refrigerant still allows compressors in air conditioners to operate efficiently (SAE 2008).

6.1.1.3. Boosting the Efficiency of Medium-Duty and Heavy-Duty Vehicles

Long-distance, heavy-duty tractor-trailers are the largest consumers of fuel in the truck category. According

TABLE 6.1. Fuel Economy Potential and Costs Used in the Climate 2030 Blueprint

	Cars and Light-Duty Trucks	Medium-Duty Trucks	Heavy-Duty Trucks
2005 Baseline Fuel Economy (mi/gallon gasoline eq)	26	8.6	6
2020 Fuel Economy for New Vehicles (mi/gallon gasoline eq)	42	11	8
2020 Incremental Cost vs. 2005 (2006 dollars)	$2,900	$6,000	$15,800
2030 Fuel Economy for New Vehicles (mi/gallon gasoline eq)	55	16	9.5
2030 Incremental Cost vs. 2005 (2006 dollars)	$5,200	$14,900	$40,500

Notes: These potentials and costs are based on assumptions in the AEO 2008 NEMS high technology case, as modified by the authors, and modeling runs of UCS-NEMS. The values in our Blueprint case model runs may not match these levels because of limitations in the model. See Appendix E online for details.

to the U.S. Census Bureau's Vehicle and In-Use Survey Microdata, the average new tractor-trailer travels 130,000 miles per year while consuming more than 20,000 gallons of diesel (U.S. Census Bureau 2002).

Using technology available today, owners can improve the fuel efficiency of these trucks more than 10 percent

Medium-duty vehicles, such as those used to deliver packages, could average 16 mpg by 2030, while heavy-duty trucks could average 9.5 mpg.

by purchasing equipment to make trailers and tractors more aerodynamic, and by choosing fuel-efficient tires. The resulting savings in fuel costs—after accounting for the cost of the upgrades—can top $20,000 over the life of a truck (Anair 2008). However, despite these savings, the trucking industry has been slow to adopt many of these technologies.

What's more, studies from Argonne National Laboratory and the Department of Energy (DOE) show that better engines and transmissions—plus advanced aerodynamics, better tires, and weight reduction—could improve the fuel efficiency of heavy-duty trucks by about 60 percent, at a cost of about $40,000 (Cooper et al. forthcoming; Vyas, Saricks, and Stodolsky 2003). That would raise the gasoline-equivalent fuel economy of the average heavy-duty truck from six miles per gallon today to more than 9.5 mpg—and reduce global warming emissions per truck by more than 36 percent (see Table 6.1).

Hydraulic hybrid vehicle (HHV) technology combines a highly-efficient diesel engine with a hydraulic propulsion system, which stores energy more efficiently than a battery. This advanced technology can improve fuel economy up to 50 percent compared with conventional diesel engines, while reducing carbon emissions by as much as one-third. UPS was the first company in the package delivery industry to purchase HHVs, and currently has seven in its fleet.

For a typical medium-duty truck, hybridization alone—by adding a battery and an electric motor or a hydraulic motor and storage system—could improve fuel economy 40 percent.[47] That improvement could

47 Performance of these vehicles varies based on how and where they are used, with some estimates showing a 100 percent improvement in fuel economy for use in urban stop-and-go driving (An et al. 2000). Under typical driving conditions, analysts at Argonne National Laboratory estimate that hybrids would improve the fuel economy of such vehicles 40–71 percent (Vyas, Saricks, and Stodolsky 2003).

save 1,000 gallons of fuel per vehicle each year, with the more advanced systems paying for themselves in as little as four years.[48]

By 2030, the average medium-duty truck with a combination of conventional and hybrid technologies could raise its fuel economy by more than 80 percent, at a cost of about $15,000.[49] That would boost the gasoline-equivalent fuel economy from an average of 8.6 mpg to about 16 mpg, and reduce carbon emissions per truck by 44 percent.

6.1.1.4. Trains, Ships, and Planes

Trucks are not the only mode of freight transport that can benefit from improvements in efficiency. Better vehicle and engine technology for rail, ship, and air—along with more efficient use of these modes—can also deliver cuts in emissions between now and 2030. Trains and ships can take advantage of engine improvements similar to those for heavy-duty trucks, and can also reduce engine idling.[50] Improvements aimed at maximizing loads and optimizing routes can deliver even more gains (Stodolsky 2002).

Passenger aircraft can save fuel by using lighter-weight materials and improved engine technology. And efforts to ensure that planes fly full can provide immediate benefits from existing aircraft. These incremental improvements can boost efficiency in rail, ship, and air by 10–15 percent. Shifting freight from one mode to another and tapping alternative fuels (see below) can also reduce emissions from freight transportation.

Challenges

6.1.2. Key Challenges for New Vehicle Technologies

All the technologies and other options for travel and shipping in this chapter point to a 2030 where consumers and companies can do their part to cut heat-trapping emissions while also reducing America's oil addiction and saving money. But if past is prologue, the needed changes simply won't happen on their own. Each of the technologies and other options faces barriers to becoming mainstream.

One barrier has been low gas prices. Between 1990 and 2003, annual average gasoline prices ranged from about $1 to $1.50 per gallon (EIA 2009c). The average vehicle achieved only about 25 mpg on government tests, as automakers devoted new technology to boosting vehicle size and power instead of fuel economy (OTAQ 2008).

Gasoline would have to rise to $5–$10 per gallon just to encourage consumers to purchase vehicles that reach about 40 mpg, according to estimates of people's responses to price.[51] And the upper end of that range may be the most realistic. A recent study indicates that consumers are becoming less responsive to gas prices as household incomes rise (Small and Van Dender 2006).

A second, related, barrier is that consumers appear to be averse to risk. Purchasing a vehicle with higher fuel economy means making an investment today that will yield benefits in fuel savings over time. Yet consumers lack information on future fuel prices, and are unsure about how long they will own the vehicle and other factors—and that creates uncertainty about whether their investment in fuel economy will pay off. Recent research indicates that the result is a market failure: consumers choose fuel economy lower than what makes sense given the costs and benefits (Greene, German, and Delucchi 2009). That is, consumers are sensitive to sticker prices, placing a greater emphasis on up-front costs despite potential longer-term benefits.

A final barrier has been a lack of options for consumers. They have historically had to shift to smaller or less powerful vehicles if they wanted much better fuel economy. Only with the recent introduction of hybrids have consumers been able to choose a vehicle with better fuel economy that also has the size and acceleration of the vehicle they already own.

Other automakers were caught off guard by the success of the Prius when Toyota first introduced it in

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48 This figure is based on 30,000 annual miles driven, a 40 percent improvement in fuel economy, an incremental cost of $10,000, a fuel price of $2.50 per gallon, and a 7 percent discount rate.

49 This figure is based on improvements in conventional and hybrid technologies described in Vyas, Saricks, and Stodolsky 2003. Even greater improvements may be available, as indicated by the goal of the DOE's 21st Century Truck program: to improve the fuel efficiency of medium-duty (Class 6) trucks by a factor of three (DOE 2000).

50 Hybrid tugboats and switcher locomotives designed to reduce or eliminate idling are two examples of where these technologies are already gaining traction.

51 This figure assumes that the long-run price elasticity of demand for lower fuel intensity (fewer gallons per mile) ranges from 0.2 to 0.4 (based on Brons et al. 2006; Small and Van Dender 2006; Espey 2004; Goodwin, Dargay, and Hanly 2004; Dahl 1993). The figure also assumes fixed household income. Note that consumers would purchase fewer vehicles and drive less because of the higher prices.

Japan in 1997 and in the United States in 2000, when gas prices were still quite low (Sperling and Gordon 2009). It is difficult for consumers to show demand for a product with high fuel economy if it is not on the market.[52]

Policies

6.1.3. Key Policies for Putting Better Vehicle Technology to Work

If the main barrier to better fuel economy and less global warming emissions is simply low gas prices, then the policy solution could be to raise those prices. But as the previous section showed, gas prices might have to rise to $10 per gallon to encourage consumers to move just to 40 mpg vehicles. Even higher gas prices would be needed to spur a wider move to the better fuel economy offered by hybrids. That suggests another barrier to the use of technologies to improve fuel economy: the political difficulty of creating policies that will raise gas prices enough to deliver the benefits of those technologies.

That political barrier does not mean we should abandon attempts to create policies that influence gas prices. Instead, it means that we cannot rely on them on exclusively. Indeed, accurately pricing gasoline is essential to capture the costs of smog, global warming, the U.S. military presence in the Middle East, and other externalities that gas prices do not now reflect.

An economywide cap-and-trade policy that includes the Blueprint's complementary policies for energy and transportation will gradually add up to $0.55 per gallon to the price of gasoline. Such a policy will provide modest cuts in carbon emissions by spurring people to reduce the number of miles they drive and encouraging automakers to increase fuel economy somewhat. Such a policy will also help internalize the costs of the impact of gasoline consumption on our climate. However, that policy alone will not deliver the full potential benefits of better technologies for both conventional and hybrid vehicles.[53]

Instead, policies that require or reward better vehicle performance—whether higher fuel economy or lower carbon emissions—can deliver on this potential and overcome all three barriers. As Greene, German, and Delucchi (2009) note, such policies remove or reduce the uncertainty associated with the benefits of more efficient vehicles. Such policies also guarantee that consumers will be able to choose higher-fuel-economy or lower-polluting vehicles in all types and sizes, not just small cars.

Over the past 30 years, Corporate Average Fuel Economy (CAFE) standards have made America's cars and trucks go farther on a gallon of gas, saving consumers hundreds of billions of dollars in gas costs. Under a proposal announced by President Obama in May 2009, CAFE standards would be coordinated with the nation's first system to regulate carbon emissions from cars and light trucks—helping to further reduce global warming emissions, consumer costs, and America's oil dependence.

The federal government has relied on performance-based standards for about 40 years to reduce smog-forming and toxic pollution from cars and trucks (such as grams per mile for Tier 1 and Tier 2 vehicles). Such standards have cut these pollutants by well over 90 percent compared with emissions from cars and trucks in the 1960s. Federal performance standards have also cut gasoline use in cars and trucks.

The federal government created the corporate average fuel economy (CAFE) standards more than 30 years ago, to boost the fuel economy of cars and trucks in response to an oil embargo. If car companies do not meet those standards, they are subject to a fine.[54] Had these standards not been around, and had consumers been stuck with the same fuel economy choices from the 1970s—when vehicles averaged about 15 mpg on government tests, versus about 25 mpg in 2007—they would have needed to purchase another 40 billion

52 This resembles the experience with airbags. Automakers fought a federal requirement that they install airbags, but now compete based on the number onboard in response to consumer interest in safety.

53 This analysis assumes base gas prices of $2.50–$3.50 per gallon. Adding even $0.55 per gallon would not raise the price enough to exhaust conventional technology, let alone hybrids, based on elasticity values for gasoline demand of 0.2–0.4.

54 The fine is $5.50 per 0.1 mpg below the standard, multiplied by the manufacturer's sales volume (40 CFR 32912).

gallons of gasoline in 2007, at a cost of more than $100 billion.[55]

While CAFE standards are clearly saving consumers money today, they have been nearly stagnant for the past 20 years. That changed at the end of 2007, when Congress required that America's cars and trucks average at least 35 mpg by 2020.[56]

BOX 6.1.

The Advantages of Regulating Vehicle Emissions versus Fuel Economy

Today the National Highway Traffic Safety Administration (NHTSA) regulates the fuel economy of vehicles through its CAFE (Corporate Average Fuel Economy) standards, but those do not directly cap heat-trapping emissions from vehicles. Having the Environmental Protection Agency (EPA) regulate carbon emissions directly would offer several advantages:

- The EPA can set long-term standards, while NHTSA can set standards for only five years at a time. This limits NHTSA to technologies that are available today, and robs automakers of the regulatory certainty that would help them direct their long-term investments.
- The EPA can consider the potential of all technologies to reduce the emissions of vehicles and fuels, while the law forbids NHTSA from accounting for the impact of alternative fuels on fuel economy standards.
- An EPA-based standard for global warming emissions would guarantee a shift away from oil, one of the most carbon-intensive fuels on the market. NHTSA's fuel economy standards, in contrast, do not guarantee cuts in carbon emissions, because the agency must use complicated formulas that reward displacement of oil alone. For example, NHTSA assumes that natural gas will reduce the use of petroleum-based fuels by more than 80 percent. However, such a substitution would reduce carbon emissions by only about 15 percent. NHTSA's process also overstates the impact on oil consumption and carbon emissions of a shift to diesel by at least 10 percent.
- The EPA would regulate global warming gases beyond CO_2, such as the refrigerants used in vehicle air conditioning systems, as well as nitrous oxide and methane. NHTSA's regulations ignore those emissions.

An alternative to CAFE standards is to target heat-trapping emissions from cars and trucks directly. Such standards can tap a broader set of solutions than fuel economy, including better air conditioning systems and fuels, while also saving consumers money and cutting the use of gasoline.

California and 14 other states have already adopted standards requiring new cars and trucks to cut global warming emissions by about 30 percent in 2016, and California is considering stronger standards for 2020.[57] These state standards represent a more aggressive attempt to address global warming emissions, but they still fall short of the potential for the technologies outlined earlier in this chapter. As of 2009, the U.S. Environmental Protection Agency (EPA) was also considering adopting standards on global warming emissions for cars and trucks nationwide (see Box 6.1).

If we are to reap the benefits of technologies that are available now—including low-carbon fuel (see below)—national standards would have to require new cars and light trucks to average no more than 200 grams of global warming emissions per mile in 2020, and no more than 140 grams per mile in 2030 (see Table 6.2).[58]

The 2020 level is based on enabling conventional passenger vehicles to achieve 38 mpg, and spurring hybrids to account for 25 percent of the car and light-truck market. The combination would produce an average fuel economy for passenger vehicles of 42 mpg. The 2020 level also assumes that all automakers would install better air conditioning, which would cut 8 grams per mile by 2015, and that the federal government would create a 3.5 percent low-carbon fuel standard (see below). The 2020 standard also accounts for the fact that today's vehicles emit about 1.9 grams per mile of heat-trapping gases other than carbon dioxide.

The 2030 standard is based on near-complete market penetration of hybrids, 20 percent penetration of plug-ins (see below), full adoption of air conditioning improvements, a 10 percent low-carbon fuel standard, and the same 1.9 grams per mile in other heat-trapping emissions.[59]

States and the EPA can establish similar standards to reduce emissions from medium- and heavy-duty vehicles. Those standards would have to account for the

55 This figure is based on 2.67 trillion miles traveled in cars and trucks in 2007, gasoline at an average of $2.843 per gallon (EIA 2009d), a rebound effect of 10 percent, and estimated on-road fuel economies of 13.1 mpg (OTAQ 2008) versus 20.2 mpg (EIA 2008a).

TABLE 6.2. **Standards for Vehicle Global Warming Emissions**

	Cars and Light-Duty Trucks	Medium-Duty Trucks	Heavy-Duty Trucks
2005 Baseline Global Warming Emissions (g/mi CO_2 eq)[a]	**372**	**1,038**	**1,489**
Fuel Economy (mi/gallon gasoline eq)	24	8.6	6
Non-CO_2 Emissions Estimate (g/mi CO_2eq)	2	5	8
2020 Standard for Global Warming Emissions (g/mi CO_2eq)[a]	**198**	**777**	**1,072**
Fuel Economy (mi/gallon gasoline eq)	42	11	8
CO_2 Emissions with Current Gasoline (g/mi CO_2eq)[b]	212	808	1,111
Non-CO_2 Emissions Estimate (g/mi CO_2eq)[c]	2	5	8
Credit for Improved A/C (g/mi CO_2 eq)[d]	-8	-8	-8
Credit for Low-Carbon Fuel Standard (g/mi CO_2eq)[e]	-7	-28	-39
2030 Standard for Global Warming Emissions (g/mi CO_2eq)[a]	**139**	**497**	**842**
Fuel Economy (mi/gallon gasoline eq)	55	16	9.5
CO_2 Emissions with Current Gasoline (g/mi CO_2eq)[b]	162	555	935
Non-CO_2 Emissions Estimate (g/mi CO_2eq)[c]	2	5	8
Credit for Improved A/C (g/mi CO_2 eq)[d]	-8	-8	-8
Credit for Low-Carbon Fuel Standard (g/mi CO_2eq)[e]	-16	-56	-94

Note: Values may not sum properly because of rounding.

a We calculated global warming emissions as the sum of CO_2 and non-CO_2 emissions from today's gasoline, minus cuts in emissions from the use of better air conditioning and low-carbon fuels.

b In converting fuel economy into CO_2 equivalent, we assumed 8,887 grams of CO_2 per gallon of today's gasoline burned.

c We scaled up estimates of non-CO_2 heat-trapping emissions for medium- and heavy-duty trucks from those for light-duty vehicles based on relative fuel consumption. We expect to update these numbers as more accurate data become available. These estimates do not include black carbon.

d Note that 8 grams per mile is a conservative estimate for cars and light trucks based on Bedsworth 2004 and CARB 2008. We have no data for medium- and heavy-duty vehicles. However, given that they have larger air conditioning systems (and thus greater potential for absolute savings) but travel farther (reducing the per-mile benefit), we used 8 grams per mile as a rough value pending more information.

e All fuels achieve the average low-carbon standard in Table 6.4.

56 As required by the 2007 Energy Independence and Security Act, online at *http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h6enr.txt.pdf*. Our Reference case includes this policy, which delivers significant cuts in carbon emissions. Reductions in emissions from the transportation sector under the Blueprint are therefore notably lower than they would otherwise be.

57 Under the Clean Air Act, California can adopt its own vehicle standards. Other states must choose between California's standards or those of the federal government. However, the latter has yet to regulate global warming emissions from vehicles. California's proposed stronger standards would reduce heat-trapping emissions from vehicles by more than 40 percent, according to estimates. For more information, see Tables 4 and 6 at *http://www.climatechange.ca.gov/publications/arb/ARB-1000-2008-012/ARB-1000-2008-012.PDF*.

58 Under this approach, automakers would receive credit for selling vehicles that use ethanol, hydrogen, or electricity, if they reduce global warming emissions from the production and delivery of the fuel.

59 The factors used for air conditioning and non-CO_2 emissions for the 2020 and 2030 standards are consistent with those used by the California Air Resources Board (CARB 2008), and are conservative in the case of air conditioning, given that newer refrigerants with very low potential for trapping heat are likely to enter the market soon.

BOX 6.2.

Promising Policies the Blueprint Case Did Not Include

Feebates and the California Clean Car Discount. Besides vehicle performance standards, a system of financial carrots and sticks can encourage automakers to make better vehicles, and consumers to purchase them. Feebates create surcharges on vehicles with more heat-trapping emissions, and use the proceeds to pay for rebates on cleaner vehicles. California is considering adopting such a system. A 2007 study suggests this approach could encourage greater use of technology to cut carbon emissions while saving consumers money (McManus 2007).

Air, rail, marine, and off-road standards. Limits on global warming emissions can also apply to planes, trains, ships, and off-road vehicles—all of which can benefit from technologies to improve efficiency, including hybridization in some cases, and can tap into cleaner fuels and improved air conditioning systems.

The aviation sector is responsible for 10 percent of heat-trapping emissions from transportation, so regulators should not ignore it. And construction and other off-road equipment present an important opportunity for further emissions cuts, as that equipment uses about 7 percent of all diesel fuel.

Without such policies, however, baseline improvements are still likely. The efficiency of rail transport (ton miles per Btu) is likely to rise by a modest 10 percent between 2005 and 2030, marine transport (ton miles per Btu) by 12 percent, and passenger aircraft (passenger miles per gallon) by 16 percent.

Lower speed limits. When cars and trucks travel at highway speeds, they use a lot of fuel to overcome aerodynamic drag. Lowering maximum speeds can save fuel and reduce carbon emissions.

For example, reducing vehicle speeds from 70 to 65 mph could cut highway fuel use and carbon emissions by 8–10 percent per mile (CTA 2008). A forthcoming study by the North East States Center for a Clean Air Future similarly finds that lowering the maximum speed of a tractor-trailer on a typical long-haul trip to 60 miles per hour could reduce carbon emissions by 4 percent. Such a vehicle can require 5–10 percent more fuel traveling at 70 mph than at 65 (DOE 2000).

Freight transport standards. California is considering a suite of regulatory and voluntary measures aimed at reducing carbon emissions from the use of planes, trains, and ships to transport freight. Those measures could cut emissions from the movement of goods by 3.5 million metric tons of carbon dioxide equivalent by 2020—a 20 percent reduction.

Efforts that could help meet that goal include reducing the speeds of oceangoing vessels, connecting docked ships to the electricity grid, using better hull and propeller maintenance practices, reducing idling of cargo-handling equipment and relying on electricity to power it, setting energy efficiency standards for refrigerated trailers and containers, and using zero-emission rail technologies (CARB 2008a).

many different uses of such vehicles, as well as the numerous manufacturers of engines, truck chassis, and trailers (Lowell and Balon 2009).[60]

Today's medium-duty vehicles produce more than 1 kilogram of global warming emissions per mile, not counting upstream emissions. Based on the vehicle technologies noted above and the potential for cleaner fuels, state and federal standards should allow such vehicles to release no more than 780 grams of heat-trapping emissions per mile in 2020, and no more than 500 grams per mile in 2030—representing cuts of 25 percent and 50 percent, respectively.

For heavy-duty vehicles, standards should be no more than 1,075 grams per mile in 2020, and no more than 840 grams per mile in 2030. Those standards would cut carbon emissions more than 25 percent and 40 percent, compared with today's emissions of about 1,500 grams per mile.

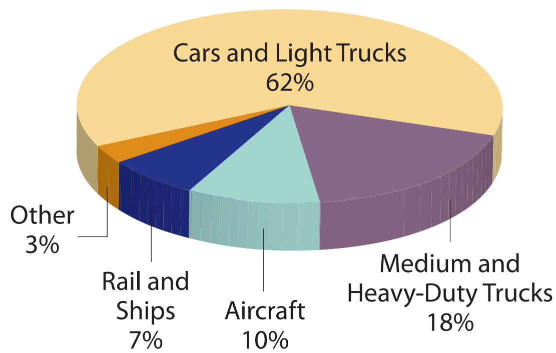
These standards assume full adoption of available technology for improving fuel economy by 2030, and

60 The EPA can regulate carbon emissions for medium- and heavy-duty vehicles under the Clean Air Act. The Energy Independence and Security Act of 2007 authorized the National Highway Traffic Safety Administration to establish fuel economy standards for medium- and heavy-duty vehicles, based on a National Academy of Sciences study now under way. Japan established fuel efficiency standards for heavy-duty vehicles in 2005.

3.5 percent and 10 percent low-carbon fuel standards for 2020 and 2030. The standards also assume that better air conditioning systems in medium- and heavy-duty trucks would reduce emissions 8 grams per mile, though we lack data on actual values. (The air conditioning systems in these vehicles are larger, so their emissions are higher than those from cars and light trucks. However, medium- and heavy-duty vehicles also travel more miles per year, so we assume that the per-mile emissions from all the vehicles are about the same.)

FIGURE 6.3. Petroleum Use in Transportation (2005)

218 billion gallons gasoline equivalent



Source: EIA 2008.

6.2. Smart Fill-Ups: Switching to Low-Carbon Fuel

Americans use the equivalent of nearly 220 billion gallons of gasoline every year (EIA 2008a). Cars and light trucks use the largest portion of that amount: 62 percent, or 140 billion gallons. Medium-duty and heavy-duty trucks are next, at 18 percent, followed by airplanes at 10 percent. Rail, shipping, military, and other uses account for the last 10 percent (see Figure 6.3).

Even if the nation takes aggressive measures to increase the efficiency of vehicles and reduce the number of miles we travel, we will still need the equivalent of about 200 billion gallons of gasoline by 2030 as the population and economy continue to grow. If transportation is to do its part in cutting U.S. carbon emissions close to 60 percent by 2030, we cannot continue to fill up almost exclusively on petroleum products as we do today.

To make these deep cuts while continuing to strengthen our economy, we must tap into transportation fuels that do not release significant amounts of carbon. Biofuels (fuels produced from plants), electricity, and hydrogen all have the potential—if produced in a sustainable manner and without significant impacts on land use—to both cut carbon emissions from transportation and curb our country's dependence on oil.

Potential Costs

6.2.1. Potential and Costs of Low-Carbon Fuel

6.2.1.1. Biofuels for Today and Tomorrow

You probably already use biofuels when you drive your car. To cut down on smog or substitute for gasoline, fuel makers now blend ethanol—an alcohol—into gasoline, where it accounts for 4–5 percent of what Americans buy (EIA 2008a).[61]

As noted, biofuels are made from plants: ethanol is made from corn or sugar cane, for example, and biodiesel from vegetable oil. Existing vehicles can use small amounts of ethanol and biodiesel, but must be modified to use larger amounts.[62] However, enabling cars to use up to 85 percent ethanol (E85) adds only \$50–\$100 to their price (DOT, DOE, and EPA 2002).

New technologies nearing commercialization will create fuel based on other types of plant material, such as wood, grass, and waste products from agriculture, forestry, and landfills. Some of these technologies can be used to make biofuels that are even more compatible with gasoline and diesel engines, potentially requiring no engine modifications at all.

Because the carbon in biofuels comes from plants rather than fossil fuels, they could theoretically provide carbon-free transportation—if regrown crops absorbed the CO_2 emitted from tailpipes. However, the true picture is not that simple. To get a complete understanding of the carbon and other heat-trapping emissions from fuel, we need to look at its full life cycle, which includes all the emissions caused directly or indirectly by its production, distribution, and use.

For ethanol based on corn, that means accounting for the fertilizer and pesticide used to grow it, the energy used to convert the corn to fuel, the tractors, trains, and tanker trucks used to move the fuel around, and

61 Ethanol is blended at 6–7 percent to cut down on smog, but is not used everywhere year-round.

62 Ethanol blended with gasoline up to 10 percent is sold as E10, or gasohol. Biodiesel can be blended up to 5 percent under today's warranties, although some vehicles use blends of up to 20 percent.

Biofuels made from food crops, especially corn and soybeans, require a lot of energy to produce and can actually create more global warming emissions than traditional gasoline. However, cellulosic biofuels—made from sugars in the plant walls of corn cobs and stalks, grasses, wheat straw, and other plants—have the potential to cut carbon emissions by 80 percent or more compared with gasoline. This South Dakota farmer is harvesting switch-grass, a prairie grass native to the Midwest that can be grown on land not typically used for agriculture.

finally the emissions from vehicles' tailpipes. We also need to account for heat-trapping emissions from indirect effects, such as the expansion of agricultural production to produce more biofuels and the resulting changes in land use. When we add up all of these sources of emissions, today's generation of biofuels—which are made from food crops, especially corn and soybeans—offer little opportunity to reduce carbon emissions, and may even increase them (Fargione et al. 2008; Searchinger et al. 2008; UCS 2008a).

To deliver biofuels that can provide significant cuts in carbon emissions, the industry is moving to second-generation technologies. Cellulosic biofuels, for example, are produced from the materials that compose the cell walls of all plant matter. That means corn cobs and corn stalks, grasses, wheat straw, and sawdust can all be used to make fuel. A closely related technology called biomass-to-liquids (BTL) can be used to make a replacement for diesel fuel from plants, wood, or even the carbon-containing portion of municipal garbage, such as lawn clippings and used plastic.

These next-generation biofuels could cut carbon emissions from transportation by 60–80 percent or more (ANL 2008). However, these cuts rely on using waste products, grasses, or other crops grown on land that does not directly or indirectly displace food crops. These restrictions mean that the amount of low-carbon biofuels we can make from domestic resources is significantly less than some analysts estimate (Perlack et al. 2005; Greene et al. 2004).

Further, some of those resources will be used in power plants to generate cleaner electricity. Based on the domestic potential given land-use restrictions and other exclusions outlined in Chapter 2, the transportation sector could tap about 280 million tons of biomass for conversion into biofuel.[63] At a conversion rate of 110 gallons of ethanol per ton of biomass, we estimate that the ethanol equivalent of about 30 billion

63 This is the combination of 158 million tons of agricultural residues and 121 million tons of biofuel crops grown without inducing direct or indirect changes in land use.

gallons of low-carbon biofuels could be available in 2030—enough to displace about 20 billion gallons of gasoline (see Table 6.3).[64]

Biofuels have historically been more expensive than gasoline. However, the next generation of biofuels has the potential to be cost-competitive with gasoline prices of $2.70–$3.00 per gallon (Anden et al. 2002), and some studies point to the potential for even lower costs (ASES 2007; Greene et al. 2004).

The nation could produce about 30 billion gallons of low-carbon biofuels in 2030, displacing 20 billion gallons of gasoline.

Biofuel makers can achieve cost-competitiveness through greater efficiency, lower production costs, and "biorefinery" approaches, which combine ethanol production with the production of electricity, heat, and animal feed. Such technologies can lead to true low-carbon biofuels that can deliver dramatic cuts in carbon emissions while allowing consumers to at least break even and possibly even save money compared with future gas prices.

The leaves and stalks left behind after the corn harvest—known as corn stover—have substantial potential as a biofuel. Increasing our use of biofuels in vehicles and power plants can help reduce our dependence on fossil fuels.

6.2.1.2. An Electrifying Transportation Future

There is a lot of excitement today about the potential for drivers to not only own a hybrid vehicle but to plug it in and recharge the battery pack from the electricity grid. Such "plug-in" hybrids would have the fuel efficiency and range of a conventional hybrid, but would rely on a larger battery pack to tap into electricity as another potentially low-carbon fuel.

The next step after plug-ins is to get rid of the engine and have an all-electric vehicle, which would require an even bigger battery pack. If based on most

TABLE 6.3. A Look at Cellulosic Ethanol in 2030

Resource, Yield, and Potential		Costs	
Biomass Resources Available for Transportation (million tons)	280	Fixed Production Costs (in 2006 dollars per gallon)	$0.128
Ethanol Yield (gallons per ton)	110	Non-Feedstock Variable Costs (in 2006 dollars per gallon)	$0.17
Maximum Biofuel Potential (billion gallons ethanol equivalent)	30	Initial Capital Cost (in 2006 dollars per gallon of capacity)	$1.99

Note: In our Blueprint analysis, actual production of cellulosic ethanol may be lower, as it competes with biomass-to-liquids technology for access to biomass resources. However, the total volume of low-carbon biofuels will be similar.

64 The 110 gallons of ethanol per ton of biomass is based on information in ASES 2007 (90 gallons per ton) and Greene et al. 2004 (100–126 gallons per ton). Ethanol and gasoline equivalents are used for convenience, and because the federal renewable fuel standard uses ethanol equivalence. The actual volume of the biofuel will vary with the density of the product.

Plug-in hybrids have real potential to reduce carbon emissions and fuel costs from passenger vehicles. A plug-in with an all-electric range of 30 miles could supply the average driver with about half of his or her driving needs using electricity alone. If that electricity comes from a battery charged from renewable electricity sources, carbon emissions will be at least 70 percent lower than today's vehicles.

battery technologies available today, such a vehicle would give up a significant amount of range. However, the electric power train in such a vehicle is more than four times as efficient as that in a conventional vehicle, and about two times as efficient as that of a hybrid.

Electric vehicles have not advanced past small-scale commercialization because of high battery costs, short lifetimes, and limited range. Advances in battery technology—such as lithium ion batteries similar to those used to run laptops—have brought battery-electric vehicles closer to commercial reality. However, plug-in hybrids are more likely to reach sales in the millions first (Kalhammer et al. 2007).

General Motors, Toyota, and Ford have all announced plans to put early-model plug-ins into small-scale production between 2010 and 2012, and companies that convert conventional hybrids into plug-ins are already making a few available (Ford Motor Company 2009; Toyota Motor Sales 2009; GM 2008). GM has noted that its first plug-in will be a car that can travel about 40 miles on the battery alone, and that it will cost around $40,000 in small volumes—about a $20,000 premium over the cost of a conventional car (Gonzales 2008). Toyota and Ford are targeting plug-ins with smaller all-electric ranges.

Given the variety of possible plug-in configurations, and their potential for an all-electric range of 5–10 miles to 40 miles or more, the Blueprint analysis assumes that the average plug-in will have an all-electric range of about 30 miles. That would allow the average driver to satisfy about half of his or her driving needs using electricity alone (Komatsu et al. 2008; Santini and Vyas 2008; Tate, Harpster, and Savagian 2008; EPRI 2007a).

A combination of fuel cell vehicles and plug-in hybrids could account for at least 20 percent of the car and light-truck market by 2030.

Based on recent studies, we expect a typical plug-in with an all-electric range of about 30 miles to cost about $8,650 more than today's conventional vehicles, when sold at high volume—or about $4,250 more than hybrids (Bandivadekar et al. 2008; Duvall 2002). If a driver can satisfy half of his or her driving on electricity at $0.10 per kilowatt-hour (equivalent to about $3.60 per gallon of gasoline), and gasoline is $2.50 per gallon, that driver will save more than $9,500 on fuel over the vehicle's lifetime compared with today's conventional vehicles, for a net lifetime savings of $850.[65]

As with biofuels, we must count all the emissions released during the life cycle of fuels used for plug-ins. For electricity, that means going back to the power plant. As a result, cuts in emissions from such vehicles can vary significantly, depending on where the electricity comes from. Given the average mix of fuels now used to produce electricity, a good plug-in will cut carbon emissions by about 55 percent compared with today's vehicles—if half the vehicle's miles come from the battery (ANL 2008). If the battery is recharged from a 2030 grid with 70–80 percent lower carbon emissions, the vehicle's emissions would be at least 70 percent lower than today.

65 While electricity is more expensive in this case, driving on electricity alone is much more efficient, so costs are lower per mile. In this plug-in example, electricity costs $0.033 per mile, while gasoline costs $0.057 per mile. The analysis assumes that the plug-in uses 0.33 kilowatt-hour per mile when operating on battery electricity. The analysis also assumes that the federal test fuel economy is 55 miles per gallon when the vehicle runs as a conventional hybrid, but that on-road fuel economy is 20 percent lower. The analysis also assumes that the vehicle is driven 15,600 miles during the first year, declining at 4.5 percent per year, and a 7 percent discount rate. For more on modeled cost assumptions, see Table 6.1 and Appendix E online.

Significant uncertainties remain as to how quickly plug-ins will be ready to enter the market, and how quickly that market will grow. The first mass-market hybrid, the Prius, introduced in 1997, accounted for about 2 percent of the U.S. market in 2007, 10 years later (Ward's Auto Data n.d.). If we assume that plug-ins—which Toyota and GM expect to introduce in 2010—parallel the significant success of conventional hybrids, they could reach 2 percent of the U.S. market by 2020. From there, a 25 percent average annual growth rate would have plug-ins capturing 20 percent of the market by 2030, given the proper incentives.

6.2.1.3. Hoping for Hydrogen Transportation

The excitement expressed today about plug-ins belonged to hydrogen fuel cells about three to five years ago. Like batteries, fuel cells provide electricity, but instead of storing it directly, a fuel cell generates it from hydrogen and air. That enables fuel cell vehicles—unlike battery-electric vehicles—to have driving ranges that approach those of today's vehicles. For example, the Honda Clarify FCX fuel cell vehicle is rated as having a range of 280 miles (American Honda Motor Company 2009).

Hydrogen fuel cells lost some of their luster when the technology did not deliver as quickly as automakers had hoped (much like battery-electric vehicles in the early 1990s). Despite that, automakers have made significant progress in lowering the costs of fuel cells and increasing their durability, and they could see small-scale production as early as 2015 if given enough support (NRC 2008; Kalhammer et al. 2007).

The incremental cost of fuel cell vehicles is quite high today, but could come down significantly over time. Reports from the National Research Council and MIT indicate that the incremental cost of fuel cells produced in large volumes can be similar to the costs we have presented for plug-ins (Bandivadekar et al. 2008; NRC 2008). The MIT study shows that the carbon benefits will be similar as well.

As with plug-ins, many uncertainties remain around the future of mass-market fuel cell vehicles. The National Research Council study suggests that sales could account for slightly more than 20 percent of the market by 2030.

6.2.1.4. Cleaner Gasoline and Diesel

While alternatives to petroleum fuels have clear potential, we will undoubtedly be using gasoline and diesel for decades to come. Given that, the nation also needs to reduce the emissions associated with those fuels by improving the efficiency of refineries.

In 2000, the petroleum industry created a technological vision that pointed to the potential for a 10 percent improvement in refinery efficiency by 2020 (API 2000). A 2005 study from Lawrence Berkeley National Laboratory suggested paths to improve the efficiency of refineries across the country by 10–20 percent that would also cut costs (Worrel and Galitsky 2005). Based on today's efficiency levels for refineries of about 90 percent (Wang 2008), a 10–20 percent improvement in efficiency would lead to a 1–2 percent reduction in carbon emissions from gasoline.

6.2.1.5. Avoiding Dirty Fuels

While new low-carbon alternatives can reduce global warming emissions from fuel, new high-carbon fuels can easily wipe out these hard-won gains. Development of oil shale, tar sands, heavy crudes, and coal-to-liquid (CTL) fuels can all substantially increase the upstream emissions associated with gasoline and diesel fuels.

The life-cycle carbon emissions from liquid transportation fuel made from coal are double those of conventional petroleum (Bartis et al. 2008). In fact, displacing a gallon of petroleum fuel with a gallon of CTL more than cancels out the benefits of displacing a gallon of gasoline with low-carbon biofuel or electricity.

Emissions from crude oil recovered from tar sands and oil shale are also much higher than those from conventional crude—and would mean that we would backslide on our path to cleaner alternatives to oil. Projections of these sources producing more than 6 million barrels a day by 2035 (Task Force on Strategic Unconventional Fuels 2006) suggest that avoiding these dirty fuels is just as important as developing better alternatives, to ensure steady progress in cleaning up our fuel supply.

Oil and gas refineries could become at least 10 percent more efficient by 2030, according to Lawrence Berkeley National Laboratory.

6.2.1.6. All of the Above

The reality is that no one can predict which of the lower-carbon fuels will win out. In fact, the most likely outcome is a mix of different options. Electricity and hydrogen are not well-suited for use in planes, ships, or big trucks, but will work well for cars and light trucks, and for some medium-duty trucks that operate mostly on city streets. Biofuels will work well in all parts of the transportation sector, but are a more limited resource if they are to remain truly low-carbon, so we might best use them where neither electricity or hydrogen work best (such as in airplanes).

Further complicating matters, the next 10 years will probably see some trial and error, wherein every sector tries all the low-carbon options. Based on that competition, plug-ins, fuel cell vehicles, and battery-electric vehicles could all emerge successful. If so, these electric-drive vehicles could account for one-third or even more of the market by 2030.[66]

66 California has a different mix of vehicles and sources of electricity. However, an analysis by the California Energy Commission shows that plug-in, battery, and fuel cell vehicles together could capture about 33 percent of the state's market in 2030 (Bemis 2008).

BOX 6.3.

SUCCESS STORY

Jump-Starting Tomorrow's Biofuels

The sustainable harvesting of perennial grasses and forestry and agricultural waste products to make biofuels can be an important part of our low-carbon future.

Corn and soybeans, grasses and wood chips, even municipal waste dumps—what do they have in common? In a world seeking to trim its dependence on the fossil fuels that, when burned, overload our atmosphere with carbon, these items all have the potential to be turned into vehicle fuels. Unfortunately, biofuels are not all created equal, at least not when it comes to curbing carbon emissions. The future of biofuels depends on making the right choices today.

The basic technology to extract liquid fuel from plants like wood and grass and other forms of biomass has existed for decades, but has not been cost-effective compared with the cost of producing gasoline and diesel. Driven primarily by an influx of federal dollars, production of corn ethanol has grown to 3 percent of the fuel used in U.S. passenger cars and trucks (EIA 2008a). However, land, water, and other resource constraints limit the potential of food-based biofuels—such as corn ethanol and soy biodiesel—to reduce the carbon footprint of our transportation fuels (UCS 2008a; UCS 2008b). A brighter future for biofuels requires technologies for making fuel from wood chips, grasses, and waste products—and then developing sustainable sources of these feedstocks.

Recent breakthroughs in biological research, combined with government support, are bringing us closer to making fuel from plant leaves, stems, and stalks (cellulosic biofuels) a commercial reality. Several new companies are making the transition from laboratory testing to pilot manufacturing plants.

Mascoma, for example, has built a pilot plant in Rome, NY, that can make half a million gallons of biofuel a year from wood chips. Verenium has opened a 1.4-million-gallon-a-year plant in Jennings, LA, to make ethanol from crushed sugar cane stalks. Both these plants use biochemical processes to break down cellulose into ethanol (Verenium 2009; LaMonica 2008). Bluefire Ethanol in Southern California is using a different approach—breaking down cellulose in municipal waste to make sugar via acid hydrolysis—and will begin construction this year of a 3.7-million-gallon-a-year facility in Lancaster, CA (Bluefire Ethanol 2008).

However, while exciting, these pilot plants are far too small to meet the nation's demand for cellulosic biofuels. In comparison, corn ethanol facilities often produce 100 million gallons a year or more, and petroleum refineries

On the other hand, given the fact that putting the maximum feasible number of fuel cell vehicles on the road over the next decade will cost about $50 billion, success for all these options may be difficult. Still, together they should be able to account for 20 percent of the car and light-truck market, as the National Research Council noted was possible for fuel cell vehicles alone (NRC 2008).

To supply the energy that transportation needs, the nation will have to tap renewable electricity, clean hydrogen, and low-carbon biofuels while avoiding fuels from tar sands, oil shale, and coal. However, these cleaner resources will not appear overnight—nor will the vehicles that use them.

can be 20 times that size (EIA 2008g; RFA 2009). The next step is commercial-scale facilities for cellulosic ethanol.

Range Fuels in Soperton, GA, is the top contender in the race to produce such fuel at a scale of tens of millions of gallons a year. The company has broken ground on a facility, and expects to begin using high-temperature gasification to turn the cellulose in waste wood chips into liquid fuel in 2010. Range Fuels plans an initial capacity of 20 million gallons a year, eventually expanding to 100 million gallons a year (Range Fuels 2007).

A competing approach to large-scale production of cellulosic ethanol relies on microorganisms to break down the cellulose. Using this technology, Mascoma's facility in Kinross, MI, is scheduled to produce 20 million gallons a year of ethanol from wood waste by 2011 (Reidy 2008). And Verenium plans to build a commercial-scale cellulosic ethanol facility in Highlands County, FL, to convert grasses into perhaps 36 million gallons of ethanol a year.

The variety of technologies, feedstocks, and locations tapped by these promising projects improves the chances that one or more will produce the breakthroughs that move the approach from laboratory to market. Scaling up next-generation biofuels from less than a million gallons a year in 2008 to more than a billion is essential if biofuels are to be players in America's low-carbon future.

Challenges

6.2.2. Key Challenges for Low-Carbon Fuel

Making progress on producing new fuels for transportation has proved even more challenging than boosting vehicle efficiency—highlighted by the fact that oil and other petroleum products still account for 98 percent of fuel used for transportation. This hard road exists because new fuels face three barriers: technological, infrastructure-related, and behavioral.

6.2.2.1. Technology and Cost Hurdles

Whether the option is low-carbon biofuels, renewable electricity, or clean hydrogen, a transition to new fuels has stalled because either the fuel or the vehicle faces technological barriers to becoming widely available at a reasonable cost.

While creating vehicles that can run on biofuels is not a challenge, making the fuel at a competitive cost is. Producing cellulosic biofuels requires special enzymes that break down the walls of the plant cells. These enzymes are expensive today—both because they are still in development and because they are made on such a small scale. More research and development is needed to lower the cost, and demonstration programs are essential to start scaling up production to bring down costs. Similarly, the technology exists for biomass-to-liquid fuel, but demonstration projects are needed to scale up production to help bring down costs.

Tomorrow's plug-ins will be competing against conventional hybrids with fuel economy as high as 55 miles per gallon.

Unlike biofuels, making renewable electricity itself is less of a challenge. As Chapter 3 shows, electricity from wind can be cost-competitive with electricity from natural gas. Instead, the technological challenge of using electricity as a transportation fuel comes from the vehicle. Researchers have been trying for decades to develop batteries that are both durable and cost-effective, and several companies are working hard to reach this milestone. However, as evidenced by the projected

$40,000 price tag for GM's plug-in hybrid, more R&D is needed to cross the finish line.

As noted, the costs of plug-ins are expected to come down, making them less expensive to own than today's conventional vehicles. However, tomorrow's plug-ins won't be competing against today's cars. Instead, they will be competing against conventional hybrids with fuel economy as high as 55 miles per gallon.

A plug-in will cost an additional $2,800 over its lifetime compared with such a vehicle, assuming gasoline at $2.50 per gallon for half of all mileage, and electricity at $0.10 per kilowatt-hour for the other half. For the average plug-in owner to break even with the average hybrid owner, gasoline would have to reach $4.50 per gallon (or $3.50 per gallon for an owner with short commutes who can take advantage of all-electric operation three-quarters of the time). The high up-front cost of plug-ins—combined with the fact that they pay for themselves only at higher gas prices or for owners with short commutes—poses a significant challenge.

Shell Hydrogen and General Motors teamed up to build the first combined hydrogen and gasoline fueling station in North America, located in Washington, DC.

Hydrogen, on the other hand, faces challenges in making both the fuel and the vehicles. Fuel cell vehicles require more R&D to lower costs, because of their extensive use of platinum and the cost of onboard storage of hydrogen. And although hydrogen can be produced cost-effectively from natural gas, further research is needed to cost-effectively produce hydrogen from renewable electricity or directly from sunlight. Hydrogen can also be produced from coal, but making that an effective low-carbon option requires unproven technology, such as carbon capture and storage.

6.2.2.2. Infrastructure Barriers

A network of charging and alternative fueling stations is essential to the market success of low-carbon fuels and the vehicles that use them. As the number of vehicles that can run on low-carbon fuels grows, the infrastructure must grow as well.

Many biofuels, especially ethanol, require their own corrosion-resistant pumps and storage tanks at fueling stations, though regulations have already required such changes. Many of the nation's more than 160,000 gas stations already carry ethanol that has been blended into gasoline at low levels. However, fewer than 2,000 stations carry E85, a mixture of 85 percent ethanol blended with gasoline, which will be needed if ethanol is to grow to more than 10 percent of U.S. fuel use (EERE 2009c). Further, ethanol cannot be shipped in existing pipelines because of the risk of water contamination. Other biofuels will have to replace ethanol, or dedicated pipelines may be needed to supply larger amounts of biofuels.

Because plug-ins can operate on gasoline alone and have smaller battery packs than battery-electric vehicles, they will not require an extensive high-power charging infrastructure. Most overnight charging can occur at homes or businesses. However, such charging will require added equipment. A report from the U.S. Department of Energy (DOE) puts the cost of adding charging capabilities to a home at less than $900 (Morrow, Karner, and Francfort 2008).

Initially, battery-electric vehicles will be used by fleet operators or in urban locations, and will not require public charging stations. The cost of a charging system for such vehicles is higher than for plug-ins because quickly recharging the large battery pack requires more power. The DOE estimates that the cost of a residential charger is about $2,200 (Morrow, Karner, and Francfort 2008). If battery technology advances to a point where long-range electric vehicles do reach the market, the nation will need a public charging network.

As the numbers of plug-ins and battery-electric vehicles rise and they are integrated into the electricity grid, added costs and benefits will emerge. If large numbers of these vehicles increase electricity demand beyond today's levels, they will require investments by utilities and power producers.

The electricity grid will also need to tap into more renewable sources of power, or the environmental benefits of electric-drive vehicles will be limited. Standardized charging equipment and protocols, limits on charging during peak hours, and charging costs that vary with the time of day will also be critical to realizing benefits from widespread adoption of plug-ins or battery-electric vehicles.

Fuel cell vehicles will require the largest investment in infrastructure, because of the need to expand both the production and distribution of hydrogen. The National Research Council estimates that an aggressive goal of putting more than 60 million fuel cell vehicles on the road will require an investment of $8 billion from 2008 to 2023, and as much as $140 billion through 2035 (NRC 2008).

Regardless of the technology, widespread growth of clean vehicles will require both significant and intelligent investments in infrastructure.

6.2.2.3. Corporate and Consumer Behavior

Ensuring that the technologies for clean transportation fuels and vehicles work and that their costs are reasonable will probably still not be enough. The conventional gasoline car has been around for more than 100 years and is embedded in our way of life. Shifting to alternatives will require changes in the way we refuel our vehicles and changes in the vehicles themselves. For companies to invest in those changes, they need to believe that people will embrace them. But people will not do so unless they believe that the alternatives are viable.

The problem gets even worse when we consider petroleum prices. When they are low, the existing fuel supply industry resists competition, and consumers and the auto industry are less interested in alternatives. When petroleum prices are high, steering the fuel supply industry away from enormous short-term profits toward long-term alternatives will remain a challenge—just when consumers and the auto industry are most interested in those alternatives. And whether petroleum prices are high or low, almost everyone seems to resist fuel-pricing policies that support a shift to alternatives, despite their potential. All these challenges create a chicken-and-egg problem that can doom even cost-effective fuels.

Policies

6.2.3. Key Policies for Moving to Low-Carbon Alternatives

6.2.3.1. Making Them Available at the Pump

One approach is to put performance-based standards in place to make sure that low-carbon alternatives become available. The 2007 energy bill passed by Congress included the first federal policy requiring fewer heat-trapping emissions over the full life cycle of a fuel—including harvesting, production, delivery, and use, as well as direct and indirect emissions from the clearing of land for crops. This provision—the renewable fuel standard (RFS)—requires fuel providers to buy 36 billion gallons of biofuels by 2022, and sets low-carbon performance standards for at least 21 billion of those gallons. However, because the RFS does not regulate emissions from gasoline, biofuel production already in place, or other fuels, it covers only about 10 percent of the transportation fuel market. A more comprehensive approach—a low-carbon fuel standard that covers all transportation fuels—can protect and build on the benefits of the RFS.

A low-carbon fuel standard supports innovation in transportation fuels while ensuring that they contribute to both energy and climate security. Under such a standard, suppliers must reduce emissions from the fuels they sell on an average per-unit-of-energy (or energy intensity) basis. They can meet this requirement

Today, only about 4,000 out of the more than 160,000 U.S. gas stations carry biofuels, electricity, hydrogen, or natural gas. A strong policy push is needed to make these low-carbon fuels more widely available. A low-carbon fuel standard supports access to, and innovation in, transportation fuels while ensuring that these fuels contribute to both energy and climate security.

TABLE 6.4. Potential of Advanced Vehicles and Fuels

	2020	2030
Low-Carbon Fuel Standard: Reduction in Carbon Intensity for All Transportation Fuels vs. 2005[a]	3.5%	10%
Sales of Advanced Light-Duty Vehicles Spurred by Regulations[b]	2.0%	20%

a This standard would require a reduction in life-cycle grams of CO_2 equivalent per Btu of all fuel used for transportation, including cars and light trucks, medium- and heavy-duty vehicles, rail, air, shipping, and other miscellaneous uses. If the standard is restricted to highway vehicles (cars, light trucks, and medium- and heavy-duty vehicles), the figure for 2020 would be 4.5 percent, and that for 2030 would be 14 percent.

b This represents the fraction of light-duty vehicles that are plug-in hybrids, or pure battery and fuel cell vehicles delivering equivalent benefits.

by blending low-carbon biofuels, such as cellulosic ethanol, into a fuel, or by improving refinery efficiency. Suppliers can also sell clean hydrogen or renewable electricity, or purchase credits from those that do. A low-carbon fuel standard requires providers to account for emissions from high-carbon alternatives—such as liquid coal, which has double the carbon emissions of gasoline—by either avoiding them or offsetting them with cleaner fuels.

Based on the potential to produce about 30 billion gallons of low-carbon biofuels, the nation should be able to reduce carbon emissions from all transportation fuels 8 percent by 2030. A reasonable goal of a 10 percent improvement in refinery efficiency can add another 1 percent cut in emissions. And if plug-in hybrids or other electricity-based vehicles account for 20 percent of sales of new vehicles, and use electricity producing 70–80 percent fewer carbon emissions than today (see below), such vehicles should cut the carbon intensity of fuels by another 1–1.5 percent.

All told, those technologies could cut carbon emissions from transportation fuels by about 3.5 percent in 2020, and 10 percent in 2030 (see Table 6.4).[67] California—which is leading the nation with a low-carbon fuel standard that aims to reduce emissions from transportation fuels 10 percent by 2020—would play a key role in fulfilling such a national standard (CARB 2009). California consumes 11–12 percent of the nation's transportation fuel, so its requirement would cut the nation's carbon emissions from such fuel by about 1.2 percent in 2020, partly through importing biomass and low-carbon fuels from other parts of the country (EIA 2009e).

A nationwide low-carbon fuel standard is constrained by how quickly technologies such as cellulosic biofuels and biomass-to-liquids can scale up, and by the amount of land available to produce the needed biomass. Conservative assumptions in our Blueprint case about the availability of land for producing biomass for transportation fuel mean that such fuel would not have significant direct and indirect carbon emissions. More optimistic assumptions—such as those in a 2007 report from the DOE's Energy Information Agency—suggest that annual biofuel production could reach 45–60 billion gallons, which could support a 15 percent low-carbon fuel standard in 2030 (EIA 2007).

6.2.3.2. Moving Consumers to the Cleanest Fuels

All these challenges point to the need for significant research, development, and deployment programs to speed low-carbon fuels to market. While industry will bear much of the cost of such programs, and pass them on in the prices of vehicles and fuels, these technologies are both risky and important enough to suggest a clear role for government-funded programs. Those will need to support everything from basic research to grants for the pilot plants needed to prove the technology and begin the process of scaling up production.

But even R&D will not be enough to overcome the chicken-and-egg problem, especially when it comes to the more advanced vehicles like plug-ins, which will cost even more than conventional hybrids, and fuel cell vehicles. Even a low-carbon fuel standard is unlikely to spur early widespread use of the best technologies, if refiners find simpler alternatives. While that may be fine in the near term, it will further delay progress on these technologies, and may compromise their ability to bear fruit in the longer term.

Subsidies in the early years, when costs are high, can lead advanced fuels and vehicles to the market. One study put the incremental cost of bringing hydrogen fuel to market—and the number of fuel cell vehicles to about 5 million by 2023—at more than $50 billion (NRC 2008). Plug-ins may require a similar level of funding, to cover the extra up-front costs of more advanced vehicles. These resources could come from

67 If the low-carbon fuel standard applied only to highway vehicles—cars and light trucks, and medium- and heavy-duty vehicles—the equivalent values would be a 4.5 percent reduction in carbon emissions from highway fuels in 2020, and a 13.7 percent cut by 2030.

auctions of carbon allowances under the cap-and-trade program, or as part of a broader effort to create green jobs in the coming decade.

Another alternative is to create a performance-based version of California's Zero Emission Vehicle program. While that program has encountered delays, direct requirements for advanced vehicles have spurred the development of hybrids and significant progress on battery and fuel cell technology (Turrentine and Kurani 2000).

6.3. The Road Less Traveled: Reducing Vehicle Miles

The nation can make great strides in improving vehicle efficiency and producing cleaner fuels, but technology alone will not keep pace with growing demand for personal and freight travel if we continue on our current path. The classic suburban American lifestyle is predicated on driving a personal car a growing number of miles.

Since 1980, the number of vehicle miles traveled (VMT) in cars and light trucks has grown three times faster than the U.S. population, and nearly two times faster than vehicle registrations (Ewing et al. 2007). VMT is expected to grow at a slower pace than historical trends from 2005 to 2030 but continue its upward trajectory, growing nearly two times faster than the U.S. population (EIA 2008a).[68]

While today's fleet of cars and light trucks travels about 2.7 trillion miles a year, that number could easily reach 3.8 trillion miles by 2030—a 42 percent increase (1.4 percent per year) (CTA 2008; EIA 2008a). Freight travel could rise by a similar amount, while air travel could grow by as much as 60 percent (2.2 percent per year) (EIA 2008a).

To slow growth in vehicle miles traveled, the nation needs to promote compact development, provide drivers with market-based incentives to drive less (such as pay-as-you-drive insurance and congestion mitigation fees), and give freight operators tools to increase the number of tons they haul per mile. Better-planned and more compact development can shorten car trips, increase the use of public transit and light rail, and provide substantial health and other benefits. By co-locating housing with jobs, improving access to walking, biking, and public transit, and revitalizing city centers, the road less traveled can promote healthy, vibrant, and desirable communities while cutting carbon emissions.

Potential

6.3.1. Potential for Reducing Car and Truck Travel

Overturning today's car-centric culture will require us to overhaul how and where we live and work. The technical potential to reduce travel is vast, although more research is needed on the cost and effectiveness of various strategies.

The next sections explore the technical potential for building smarter cities, reducing VMT through personal choice, raising the number of people using each vehicle and public transit, and moving goods more efficiently. Our analysis does not include the technical potential to reduce air, marine, and off-road VMT, or to improve transit options, as in providing high-speed electric rail.

6.3.1.1. Smarter and More Compact Development

More compact and better-planned cities could reduce VMT by up to 30 percent (Ewing et al. 2007). One study found that residents of sprawling, suburban Atlanta and Raleigh drove more than 30 miles per person per day, while residents of compact cities such as Boston and Portland drove fewer than 24 miles per person

Growing in popularity, car sharing greatly reduces vehicle miles traveled simply by reducing the number of vehicles on the road. The car-sharing company Zipcar offers trucks, compacts, and hybrids for urban transport; members can reserve a car months or minutes in advance. Instead of purchasing a pickup truck and driving it year-round, members can rent trucks just for the times they need to transport heavy loads.

68 This analysis of VMT is based on the EIA's high-gas-price scenario ($3.50 per gallon) versus its baseline scenario ($2.50 per gallon) in its *2008 Annual Energy Outlook*. Higher gas prices suppress VMT for light-duty vehicles from the baseline of 1.7 percent per year to 1.4 percent per year.

Over the next 20 years there are significant opportunities to shape new growth in ways that enable denser and more livable communities. As downtowns are revitalized, areas can be reserved for walking, biking, and public transit. New communities can have housing, shopping, parks, and jobs integrated with public transit.

per day—more than 25 percent less (Ewing, Pendall, and Chen 2002). Another study found that residents of compact regions drive up to one-third fewer miles than the U.S. average (Bartholomew 2005 and 2007 in Ewing et al. 2007).

Construction of new buildings and revitalization of existing neighborhoods provide the greatest opportunity to capitalize on smart growth to reduce VMT. According to one study, "By 2030, about half of the buildings in which Americans live, work, and shop will have been built after 2000" (AASHTO 2007). That means that the next 20 years will provide significant opportunities to shape new growth in ways that enable denser and more livable communities. As we revitalize our downtowns, we can reserve space for walking, biking, and public transit, while new communities can integrate housing, shopping, parks, and jobs with transit. These approaches would feed a smart-growth revolution that entails rethinking how we move people and goods.

6.3.1.2. Choosing to Drive Less

For discretionary trips, drivers can make a conscious choice to reduce VMT, spurred by good intentions, personal preferences (such as the desire to avoid time in traffic or trapped behind the wheel of a car), or market-based incentives. Given historical trends, good intentions and personal preferences alone are unlikely to provide much of a reduction. However, market-based incentives have proven successful.

The higher the cost per mile of driving, the more likely a consumer will be to drive less. A recent study of 84 U.S. urban areas from 1985 to 2005 found that for every 1 percent increase in the price of fuel, VMT fell by 0.17 percent (Ewing et al. 2007). A study by Cambridge Systematics found that pay-as-you-drive insurance—which charges drivers based on how many miles they drive—could reduce national VMT more than 7 percent (Cowart 2008).[69]

6.3.1.3. Bring a Friend: Raising the Occupancy of Personal Vehicles

One simple way to reduce travel is to increase the number of people riding in each vehicle, reversing historical trends. The average U.S. vehicle carries 1.6 people, and occupancy drops to barely more than one person (1.1) during trips to work (CTA 2008).

Carpooling is the key to increasing the occupancy of personal vehicles. If people who drive to work carpooled with just one other person (HOV-2) every other day, annual car and truck travel would drop by more than 5 percent, and average vehicle occupancy during work trips would rise to about 1.4.[70] If commuters carpooled with two other people (HOV-3) for about 60 percent of work trips, annual travel would fall about 10 percent, and average occupancy during work trips would rise to about 1.8.

6.3.1.4. Ride the Bus: Expanding Ridership on Public Transit and in Vanpools

Urban and suburban areas need greater access to public transportation and vanpools to help cut carbon emissions. As of 2001, less than one-third of the U.S. population lived within about a block of a bus line, and only about 40 percent lived within a half-mile (NCTR 2007). The situation is even worse for rail: only about 10 percent of the U.S. population lived within a mile of a rail stop, while only about one-quarter lived within five miles (NCTR 2007). As a result of low ridership, buses release more global warming emissions per passenger-mile than cars.

69 This figure does not account for induced demand from reduced congestion, which will offset some of the gains of pay-as-you-drive insurance.

70 Travel to work would shrink by about 25 percent. However, such travel represents only 27 percent of all VMT for cars and light trucks, so the overall impact of such a shift is much smaller (CTA 2008).

Public transportation advocates have pointed to the potential to at least double the capacity and ridership of bus and rail transit by 2030, at an annualized cost of about $21 billion (AASHTO 2007). That would represent an important start in satisfying Americans' awakening appetite for public transit (Sun 2008). Individual drivers who switch from a car or SUV to vanpools, bus, or electric rail cut their carbon footprint significantly, with the benefits rising as more people switch.

By carpooling with a co-worker every other day or shifting to a four-day work-week, Americans can reduce their personal travel by more than 5 percent.

The U.S. mass transit system is so small that doubling it will reduce VMT by only about 2 percent, given today's ridership levels. Expanding ridership could boost this impact significantly, especially in regions that use transit least effectively. The nation clearly needs to make major investments in public transit, but such investments will bear most of their fruit after 2030.

6.3.1.5. Working Up a Sweat or Working from Home: Near-Zero-Carbon Options

We can cut carbon emissions dramatically by replacing car trips with walking or biking. However, in 2000 fewer than 3 percent of Americans reported walking to work, while less than one-half of 1 percent reported bicycling to work (CTA 2008).

Flexible workplace policies that allow employees to work at home or shift to four days per week at 10 hours per day can also reduce car and truck use. In 2000, slightly more than 3 percent of Americans reported working from home (CTA 2008). By shifting to a four-day workweek or working from home one day per week, the typical American could cut his or her overall travel by about 5 percent. By working at home two days a week, he or she could cut annual travel by about 10 percent.

New technology and expanded transit service can increase ridership while dramatically cutting emissions and creating jobs. A number of Indiana cities, for example, have added hybrid buses to their transit fleets, including Indianapolis (pictured here), Muncie, Fort Wayne, Bloomington, greater Lafayette, Evansville, and Terre Haute. At least three Indiana-based companies manufacture hybrid bus drivetrains or components.

Changing our daily commutes by walking, biking, or telecommuting can dramatically cut carbon emissions. Unfortunately, less than 10 percent of Americans report taking advantage of these alternatives. This statistic highlights the need for policies and funding to make these commuting options safe and accessible—true alternatives to being stuck in traffic alone in a car.

Working from home is not quite carbon-free, because the use of lights, computers, heating, and cooling does grow. However, avoiding the use of those resources at the office should offset much of that use. Working longer hours but fewer days is not quite carbon-free for the same reason, and also because that practice could encourage people to take more leisure or shopping trips on their extra day off. However, those practices are a good start.

6.3.1.6. Car and Truck Travel: All of the Above

As with cleaner vehicles and fuels, no silver bullet can preserve the mobility we enjoy today while reducing overall travel. Instead, the nation will have to pursue a variety of approaches to ensure that people live productively while relying less on personal vehicles.

A recent analysis by Cambridge Systematics points to the potential for significant reductions in projected car and light-truck travel (Cowart 2008). That study evaluated a suite of policies to reduce VMT through more compact communities, per-mile pricing policies, and other smart-growth strategies. The study found that these approaches could reduce the annual growth rate in VMT for light-duty vehicles from 1.7 percent to 0.9 percent.[71] Part of that reduction could come from a doubling of transit.

6.3.1.7. Shifting Freight Back to Rail

Just as consumers can shift to more efficient transportation modes such as transit, biking, and walking, companies can also shift to rail as a more efficient mode for moving goods than trucks.

Moving goods by rail is about five times more efficient than doing so by truck, based on weight, primarily because rail transports dense, heavy cargo such as coal.[72] However, even for lighter-weight loads more typical of 18-wheelers, trucks emit two to three times more carbon emissions than trains (Mathews 2008). And rail is likely to retain that advantage over trucks during the coming decades, although it may erode if improvements in truck efficiency outpace those in rail.

Estimates from the American Association of State Highway and Transportation Officials (AASHTO) indicate that 1 percent of truck freight could shift to rail by 2020, and an analysis by two national laboratories points to the potential for a 2–5 percent shift (AASHTO 2003; IWG 2000). A conservative estimate is that about 1.5 percent of freight could move from trucks to rail by 2020, and at least 2.5 percent could shift by 2030.

71 The analysis showed an 18 percent reduction in projected light-duty travel in 2030 of more than 4 trillion miles, accounting for induced demand. The baseline projection of a growth rate of 1.7 percent per year is higher than that used in our study (1.4 percent per year). Our figure means that a reduction to 0.9 percent per year should be even easier to achieve.

72 The average value of five times is based on data from the *Transportation Energy Data Book* (CTA 2008), and assumes that freight trucks carry 11.8 tons per mile, based on statistics from the U.S. Department of Transportation (U.S. DOT 2000). Using the most common type of tractor-trailer (van trailers), we found the average payload to be 30,555 pounds. The loads of such combination vehicles are the most likely to shift to rail. Using the U.S. Census Bureau's 2002 Vehicle Inventory and Use Survey Microdata for Class 8 trucks, we determined that their "empty miles" averaged 23 percent.

Challenges

6.3.2. Key Challenges for Smarter Travel, Freight Transport, and Cities

6.3.2.1. Lack of Funding

There is no denying that expanding transit costs money, and that finding those funds is a challenge. Estimates show that annual funding for highways and transit falls about $10 billion short of what the nation needs just to maintain the existing system. Closing that gap would require a 6-cent-per-gallon increase in diesel and gasoline taxes, while doubling transit capacity would require another 12 cents per gallon. Together those increases would double today's 18-cent-per-gallon gasoline tax—a drop in the barrel compared with price swings in 2008, but likely still a significant political hurdle. Making matters ironically worse, rising fuel economy will cut projected gasoline and diesel use, expanding the funding shortfall.

If businesses shifted 2.5 percent of goods now shipped by truck to rail by 2030, carbon emissions from those shipments would drop by half or more.

6.3.2.2. The Impact of a Lower Cost of Driving

Blueprint policies that require new vehicles to reduce carbon emissions will help push fuel economy to 50–55 miles per gallon in 2030 and reduce the per-mile cost of driving—potentially giving consumers an incentive to drive even more. As the cost of driving falls, consumers have less incentive to carpool, take public transit, or explore near-zero-carbon options such as biking and walking. Increasing the efficiency of our car and truck fleets is essential. However, if doing so encourages people to drive more while still saving money, it could dilute some of the carbon benefits of more efficient vehicles.

A similar impact may result from reducing the number of vehicles on the road, as that will lower another cost: time wasted in congested traffic. That may encourage people who avoid congested routes to switch to those routes, again reversing some of the progress.

6.3.2.3. Weak Market Signals

Funding challenges are directly tied to the fact that consumers do not actually pay the full costs of driving. Given that Americans are not paying enough in gasoline taxes to maintain today's highway system, they are clearly not directly paying the full cost of the U.S. reliance on personal vehicles, including the national security costs of our dependence on oil, the health impacts from smog and toxic pollution, time lost owing to congestion, and the health and economic impacts of global warming, just to name a few. If we are not directly paying the full price of a resource, we are going to use too much of it, and will be less willing to switch to the many alternatives.

Transporting coal from where it is mined to where it is burned in a power plant takes up about 40 percent of our nation's rail capacity. Because rail is a more efficient and less carbon-intensive way to ship freight, one surprising benefit of phasing out coal-fired power plants is that rail capacity would be freed up to handle other kinds of freight currently transported in trucks, helping to reduce the global warming impact of the shipping sector.

BOX 6.4.

SUCCESS STORY

It Takes an Urban Village to Reduce Carbon Emissions

Arlington, VA, has won national awards for its "urban village" model of smart growth.

Chicago's Climate Action Plan includes a smarter, energy-efficient transportation mix.

The trolley carried its first passengers from Clarendon, VA, across the Potomac into Washington, DC, in 1896 (APA 2007). It served not only commuters but also shoppers, transporting them to stores along its lines. Today the "urban villages" along the old trolley lines—Clarendon, Courthouse, Ballston, and others—make Arlington County one of the most desirable communities in the metropolitan DC area.

Although there are no more streetcars, the spirit of the trolleys is alive in Arlington County. In contrast to its suburban cousins in Maryland and northern Virginia, the county used its rail and bus system as a foundation for smart growth, encouraging business development while preserving unique neighborhoods.

Under its General Land Use Plan, Arlington concentrated dense, mixed-use development around its Metro stations beginning in the mid-1980s. These urban villages emphasize pedestrian access, promote safety through traffic "calming," provide bike lanes, and create highly desirable living spaces by incorporating public art, pocket parks and street trees, wide sidewalks with restaurant seating, and street-level retail (EPA 2002).

While much of the nation followed the trajectory of urban sprawl, Arlington County boasts 22,500 apartments and condos, townhouses, and single-family detached homes, as well as a thriving commercial base (EPA 2002). Mindful of the area's socioeconomic disparities, county government and civic groups worked to spread the benefits equitably among all residents. Affordable Housing Protection Districts, for example, help preserve low- and moderate-income apartment units (CPHD 2008a).

Metro ridership in the corridor doubled between 1991 and 2002. And to expand residents' access to public transportation, the county created the Arlington Rapid Transit

Arlington County's urban villages emphasize pedestrian access, promote safety through traffic "calming," provide bike lanes, and create highly desirable living spaces by incorporating public art, pocket parks and street trees, wide sidewalks with restaurant seating, and street-level retail.

system (ART)—a fleet of 30 smaller, handicapped-accessible buses that can navigate neighborhoods and are well integrated into the comprehensive network of bus and train lines in the nation's capital and the surrounding region (ART 2009).

The resulting health, environmental, and other quality-of-life benefits are equally impressive. Almost half of Arlington residents use transit to commute (APA 2007), while another 6 percent walk to work, compared with 2.5 percent nationwide (CPHD 2008b; Reuters 2007). Nearly 20 percent of county residents do not even own a car.

Heavily traveled Wilson Boulevard saw traffic drop nearly 16 percent from 1996 to 2006 (APA 2007). Commute time in Arlington County is the region's lowest, and both carbon and smog-forming emissions have fallen dramatically. The county has accomplished all this while maintaining a high level of municipal services and the lowest property tax rate of any jurisdiction near the nation's capital (CPHD 2008b).

The urban village model has won national awards for smart growth (EPA 2002), and the American Planning Association recently showcased Arlington's main corridor as one of the Great Streets of America (APA 2007).

Meanwhile other cities are forging their own smart-growth paths. Chicago's Climate Action Plan places strong emphasis on transit-oriented community growth. Atlanta has focused on urban renewal through its downtown Atlantic Station project (EPA 2005). And the outer-rim suburb of Buckeye, AZ, near Phoenix, is working to become its own bedroom and business community (Suarez 2008). Whatever the approach, a commitment to sustainable growth is one way to help us reach our lower-carbon future.

6.2.2.4. Incentives for Unrestricted Growth

A number of existing laws actually encourage sprawling development, which requires greater use of cars. For example, zoning requirements that do not allow commercial and residential uses to mix limit the potential to integrate transit, housing, and shopping. Local ordinances that require taxpayers to fund the expansion of utilities to new houses and businesses ensure that developers do not pass on the full costs of building outside existing communities. And formulas for distributing federal highway funds that focus on expanding roadways rather than mitigating traffic further encourage sprawl.

Policies

6.3.3. Key Policies That Provide New Options for Getting There from Here

As U.S. history shows, the barriers to reducing projected vehicle miles traveled are anything but trivial. However, several public policies could help overcome these barriers.

6.3.3.1. Smart-Growth Policies

The biggest job of all is rethinking and reinventing where we live. Much of this work has to happen at the local level, such as by changing zoning laws to allow more mixed use, and requiring developers to pay the full costs of extending utilities to their projects. However, the federal government can help move these approaches along through a variety of steps.

Agencies should tie existing and future highway funding to performance metrics—whether cuts in carbon emissions or vehicle miles, or more efficient use of infrastructure. Highway funds represent a significant transfer of taxpayer dollars, and their use should focus on delivering public benefits. The nation should also reform the home mortgage tax deduction, to allow higher deductions for homes near transit or in mixed-use developments.

6.3.3.2. Pay as You Drive

Another straightforward approach to overcoming barriers is to require that people pay the actual costs of their daily driving. The initial response to asking people to pay more for every mile they drive is resistance, as they see that approach as raising their expenses. However, that is just a misunderstanding.

Americans are already bearing those costs. For example, we pay higher hospital bills and health insurance rates because of asthma and lung disease stemming from smog. We also pay higher income taxes to help secure U.S. access to oil, and to cover the shortfall in road repair funds. And if we do not cover these costs elsewhere, we still pay them through spikes in gas prices, more costly car repairs, and time wasted owing to congestion, potholes, bridge collapses, and road closures. Consumers and businesses that pay driving fees will therefore see tax cuts elsewhere, lower health care costs, fewer price spikes, and less congestion.

We can start with two key measures: highway user fees and pay-as-you-drive insurance.

Highway user fees. As the fuel economy of vehicles rises, people will use less fuel, save money, and pollute less. But because they use less fuel, they will also pay fewer gasoline taxes, which are collected on a

TABLE 6.5. Potential for Reducing Vehicle Miles Traveled

Potential for Reducing Vehicle Miles Traveled	2020	2030
Assumed Policy Impact: Reduction in Annual Growth in Vehicle Miles Traveled (VMT)[a]		
Light-Duty Vehicles[b]	Reduce growth in VMT from baseline of 1.4% per year to 0.9% per year	
Trucks[c]	Reduce VMT by 0.1% per year, on top of all other policy effects	
Policies and Costs for Light-Duty Vehicles		
Transit[d]	Ramp up transit funding to reach $21 billion per year by 2030	
Pay as You Drive		
Highway User Fee 1: Maintain Existing Funding Levels[e]	$0.005 per mile	$0.011 per mile
Highway User Fee 2: Congestion Mitigation Fee Used to Fund Transit[d]	$0.004	$0.006
Total User Fees	$0.009 per mile	$0.017 per mile
Pay-as-You-Drive (PAYD) Insurance[e]	$0.07 per mile	$0.07 per mile
Federal Funding for PAYD Pilot Programs	$3 million per year for 5 years	
Tax Credit for PAYD Electronics	$100 million per year for 5 years	
Smart Growth[f]	$0.00	$0.00
Policies and Costs for Heavy-Duty Vehicles		
Switch from Truck to Rail[g]	$0.00	$0.00

Notes:

a NEMS is unable to model the full suite of policies needed to address vehicle travel. Instead, we inserted the total reductions in vehicle miles traveled that could result from such policies into UCS-NEMS.

b For the potential to reduce VMT from light-duty vehicles, we relied primarily on a recent analysis by Cambridge Systematics (Cowart 2008), which found that growth in light-duty VMT could be reduced to 0.9 percent per year.

c To evaluate the potential to reduce VMT from freight trucks, we assumed that policies can shift 2.5 percent of truck VMT to rail, based on potential highlighted in AASHTO 2007 and IWG 2000. This represents about a 0.1 percent annual reduction in freight truck travel. Actual freight truck travel will fall further as the economy shifts due to other policies, such as a cap-and-trade program and reduced oil use from higher vehicle efficiency.

d The congestion mitigation fee provides this funding, so we did not count it as a cost above that fee.

e Blueprint policies do not include these fees as a cost, because the Reference case would also need to raise the highway funding to pay for repair of existing roads, and would include the cost of insurance. Actual insurance costs would probably drop, because people would drive less under the Blueprint.

f Smart-growth policies could actually reduce costs, so we assumed that they are cost-neutral.

g Switching from truck to rail will likely entail some costs, but evaluating them was beyond the scope of our study.

Riding a bike to work is a healthy and affordable alternative to driving, and it saves time, too—no more wasting time stuck in traffic or circling parking lots.

per-gallon basis. Rather than raising those taxes to compensate, we should adopt a per-mile user fee that at least covers any resulting federal, state, and local shortfalls. We should also institute a congestion and air-quality mitigation fee that will at least cover the costs of doubling transit by 2030. The former would require at least a one-cent-per-mile road user fee by 2030. The latter would require a little more than a one-half-cent-per-mile fee—for a total of $0.009 per mile by 2020, and $0.017 per mile by 2030 (see Table 6.5).

Per-mile highway user fees do not represent a new cost to drivers, as the nation would need to raise the funds to maintain our roads in any case. And unlike income or sales taxes, such fees will have the added benefit of reducing the number of miles we drive. We therefore should not count these specific per-mile highway user fees as a "cost" of cutting carbon emissions.

Pay-as-you-drive insurance. Another cost that today's drivers already bear is car insurance. The price of that insurance is usually not tied to the number of miles we drive, despite the fact that the more we drive, the more we risk the accidents that insurance covers.

If insurance were tied to the number of miles we drive, the roughly $800 per year in insurance we pay would equal about $0.07 per mile—the equivalent of raising gas taxes by about $1.40 per gallon.[73] Two recent reports point to the potential of this approach to cut VMT by 7–9 percent (Bordoff and Noel 2008; Cowart 2008). The Blueprint analysis estimates an impact on the order of 5–6 percent (likely because of a higher per-mile baseline, reflecting higher gasoline costs).

Pay-as-you-drive (PAYD) insurance is more equitable, given that low-mileage drivers now subsidize high-mileage drivers, and consumers will save money

73 The cost of insurance is from Bordoff and Noel 2008. The per-mile figure is based on 11,500 miles per year. The per-gallon figure is based on 20 miles per gallon.

BOX 6.5.

Technologies and Other Options on the Horizon: Transportation

Breakthroughs in algae biofuels

High-speed rail

- **Dramatic expansion of all-electric cars and trucks.** If cost and other key hurdles are overcome, by 2050 most cars and light trucks could run on batteries or fuel cells supplied by renewable energy, effectively eliminating those vehicles as a significant source of carbon emissions. Many medium-duty and heavy-duty vehicles could also follow this path.
- **Advanced high-strength materials.** Carbon fiber, now used in aircraft, could become cost-effective for use in highway vehicles over the long term. Such uses would dramatically cut the weight—and thus the carbon emissions—of cars and trucks of all shapes and sizes while also increasing their safety.
- **Breakthroughs in third-generation biofuels.** From algae to efficient microbes that can digest almost anything, hoped-for breakthroughs could produce large volumes of liquid fuels with minimal land use.
- **High-speed and zero-emission rail.** Trains that can move rapidly between major cities while running on renewable electricity could replace airplanes for shorter trips, eliminating carbon emissions. Such a train system could also help shift freight from truck to rail, significantly reducing emissions from freight shipments.
- **Expanded transit-oriented development.** Cities do not expand overnight. With advanced planning, more and more cities could expand around transit, integrating homes, shopping, and transportation with parks and open areas across the country.

To double capacity and ridership for bus and rail transportation by 2030, more money must be set aside to expand and improve public transit. Chicago leads the way with an aggressive climate action plan (online at *www.chicagoclimateaction.org*) to reduce its emissions across various sectors including transportation (which currently comprises 21 percent of its total emissions). By investing in transportation alternatives such as public transit, bicycling, walking, car sharing, hybrid buses, and smart growth, Chicago can meet its goal of creating a convenient and energy-efficient transportation mix.

as reduced travel means fewer accidents and thus lower costs. Bordoff and Noel estimate that this approach could save the nation $32 billion just by reducing the number of accidents—or about $150 per vehicle, of which $34 per vehicle could accrue to insurers.

The way PAYD is implemented is also important. While it could be based on annual odometer readings, a once-per-year payment or rebate might not have the same impact as more immediate feedback. A better alternative is to install a GPS-based device to track mileage, which Bordoff and Noel estimate would cost $100 per vehicle, and to require periodic payment of insurance premiums. GPS technology could even allow us to pay for insurance along with a fuel purchase, combining pay-at-the-pump with PAYD.

Bordoff and Noel point to the cost of this device as a significant hurdle, because insurance companies would not save enough to cover it, so they might be unwilling to advocate for it. To overcome that hurdle, those analysts recommend a $100 tax credit per vehicle for insurance companies, for the first 5 million vehicles. That approach would put systems in place that could also support per-mile road user fees. Bordoff and Noel also recommend that the federal government spend $3 million per year for five years to establish pilot programs, and that states adopt laws clearing the way for PAYD insurance.

6.3.3.3. More Funding for Transit

If the nation is to double transit by 2030, we must set aside more money to expand and improve bus and rail transportation. Based on AASHTO recommendations, such a doubling would require additional dedicated funding that would reach $21 billion per year in 2030.