# Two Billion Cars

## Transforming a Culture

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More than one billion motorized vehicles are driven on the earth today. The United States, birthplace of the car industry and car culture, leads in the numbers of vehicles.[1] In the next two decades, vehicle ownership is expected to double worldwide (Figure 1, next page).

Can the planet sustain two billion vehicles? No—at least not as they exist today. Today's billion vehicles are pumping extraordinary quantities of greenhouse gases into the atmosphere, are draining the world's conventional petroleum supplies, are inciting political skirmishes over oil, and are overwhelming city roads. Even in the most conservative view, conventional motorization, vehicles, and fuels threaten an economic and environmental cataclysm.

Cars will not disappear. The desire for personal vehicles is powerful and pervasive. Cars offer unprecedented freedom, flexibility, convenience, and comfort. Cars bestow untold benefits on their owners. Cars have transformed modern life and are one of the great industrial success stories of the 20th century (Figure 2, next page).

***Editor's Note:*** *The spotlight theme for the TRB 2009 Annual Meeting is Transportation, Energy, and Climate Change. The 70 sessions and workshops addressing this theme offer a myriad of research results and perspectives; this feature article serves as a preview.* TR News *invites articles and letters to the editor about research and perspectives on energy and climate change to continue the focus on these issues.*

[1] The term cars often is used here to represent all conventional motor vehicles—cars, sport utility vehicles, minivans, trucks, buses, motorcycles, scooters, or three-wheeled motorized vehicles.

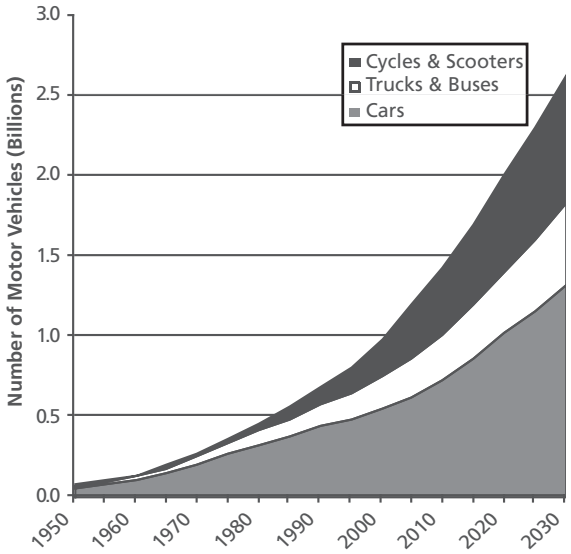


**FIGURE 1 Historical and projected increases in global motor vehicle population, 1950–2030 (*1*).**

## Troublesome Trends

### *Vehicle Ownership*

Despite the rhetoric about energy independence and climate stabilization, vehicle sales, oil consumption, and carbon dioxide emissions are soaring globally. The number of motorized vehicles around the world is expected to increase by 3 percent annually. The slowest rate of car growth is expected in Europe, at less than 1 percent per year; in the United States, the rate will be likely 1 to 2 percent; but in China and India, growth rates of more than 7 or 8 percent per year are expected (2).

Ever-cheaper cars are whetting the powerful desire for personal vehicles. The Indian conglomerate Tata plans to unveil the $2,500 Nano soon. Most international automakers will follow, manufacturing cheap cars not only for the developing world but also for richer countries.

Increasing vehicle ownership translates into increasing oil use. The world consumes 85 million barrels of oil per day, and demand is expected to reach 120 million barrels by 2030. One-fourth of all the oil consumed by humans throughout history will be consumed during the next 10 years.

With oil production outside of the Organization of Petroleum Exporting Countries (OPEC) already near peak, the United States and other countries will rely increasingly on OPEC supplies, creating stress as countries compete for ever scarcer petroleum resources. With transportation accounting for one-half of all oil consumption in the world and for two-thirds in the United States, the oil problem is largely a transportation problem.

| | | |
|---|---|---|
| 1859 | | First U.S. oil well discovered |
| First internal combustion engine car built by Karl Benz | | 1885 |
| 1908 | | Model T, with internal combustion engine, debuts |
| U.S. transit ridership reaches highest peacetime levels | | 1926 |
| 1930 | | Car ownership reaches 200 for every 1,000 Americans |
| Suburban building boom begins after World War II | | 1947 |
| 1956 | | U.S. Interstate Highway System launched |
| Arab oil embargo constricts supply | | 1973 |
| 1979 | | Iran-Iraq war doubles oil prices |
| First hybrid-electric cars sold in U.S. | | 2000 |
| 2003 | | Car ownership reaches 1.15 vehicles per American driver |
| Motor vehicle numbers worldwide exceed 1 billion | | 2005 |
| 2008 | | Crude oil priced at $140 a barrel |

**FIGURE 2 Brief history of car-centric transportation (*1*).**

### *Climate Change*

Climate change poses another problem. The scientific community believes that greenhouse gas emissions, especially carbon dioxide ($CO_2$), need to be reduced by 50 to 80 percent by 2050 to stabilize the climate and to avert economic and environmental cataclysm (3). Transportation-related $CO_2$ emissions have more than doubled since 1970, a faster rate of growth than emissions from any other sector. In the United States, transportation contributes one-third of $CO_2$ emissions.

In 2008, for the first time, greenhouse gas emissions from transportation did not increase in the United States, after annual increases of approximately 2 percent during the preceding decades. Transportation-related petroleum use and greenhouse gas emissions likely will level off and slowly begin to decrease in the next few years—because of improvements in vehicle fuel economy—but U.S. oil imports still will be extraordinarily high, and greenhouse gas emissions will not approach the stabilization goal of a 50 to 80 percent reduction.

Car companies are evolving quickly, prodded by high oil prices, aggressive energy and climate policies, and shifts in consumer preferences. The era of large sport utility vehicles is receding, with smaller and more efficient vehicles moving to the fore, and electric-drive propulsion slowly gaining adoption. Policies to improve fuel economy and reduce carbon emissions face resistance from many, but change is at hand.

PHOTO: TIM BERENS

Air pollution over Hong Kong, China. The city's roads are among the most crowded in the world, with approximately 280 vehicles per road kilometer. Diesel commercial vehicles produce 90 percent of particulate matter and 80 percent of nitrogen oxide emissions from the road sector. The dense population, factories, power stations, and construction also contribute.

### *Fuel Supply*

Fuel supply is more problematic. Prices in global oil markets have little relationship to production costs, and national oil companies in the Middle East, Venezuela, and elsewhere control more than 80 percent of all oil reserves. ExxonMobil, the largest investor-owned Western oil company, ranks 12th in the oil reserves it controls, far behind Saudi Aramco and many others. Many of the politicized national oil companies in OPEC provide more than half their governments' revenue and are more responsive to domestic priorities than to market prices.

As a result, the market is not working. High oil prices are not stimulating investments in oil production or in alternative fuels. With carbon emissions still largely ignored, the Western oil companies are turning to high-carbon unconventional oil—such as tar sands, heavy oil, and even shale oil and coal liquids—investments that may be rational in the market but are not in the public interest.

### *Traffic Congestion*

Vehicle travel has outpaced population growth, even in the United States (Figure 3, page 6). More cars mean more traffic—road construction cannot keep pace with growing mobility demands. In 2008, after five years of steadily increasing gasoline prices, vehicle travel finally did not increase for the first time in decades. Yet car use worldwide is booming, as incomes increase and vehicle costs shrink.

Despite a few innovative alternatives—such as carsharing, pioneered in Switzerland; telecommuting and carpooling, in the United States; and bus rapid transit, in Curitiba, Brazil—cars dominate the transportation system. This hegemony of cars encourages low-density suburban development. With growth, the suburbs become too dense for cars but not dense enough for mass transit.

Cities that developed with autos—for example, Los Angeles, Houston, and Phoenix—consist of suburbs with small commercial districts. They are not easily served by conventional bus and rail transit with fixed routes and schedules and have difficulty shifting citizens out of cars. Transit accounts for only 2 percent of passenger miles traveled in the United States.

Yet the solutions to oil security and climate change also can resolve local air pollution, traffic congestion, and urban livability. Some traffic congestion is desirable—the absence of congestion would indicate a depressed economy, a somnolent society, or an overinvestment in infrastructure. But congestion levels in most large cities of the world are severe enough to harm economic and social activity. The need to address traffic congestion and escalating infrastructure costs could engage the transportation community in reducing oil use and greenhouse gas emissions.

## Road Map to Survival

The world can accommodate two billion or more vehicles, but a transformation of the auto and oil industries—and eventually, of transportation systems—will be required.

### *Transforming Vehicles*

The year 2008 likely will be seen as a turning point in vehicle energy use. Although the energy efficiency of vehicles has been improving steadily, in terms of work per unit of energy, the gains have been applied for more than two decades to increasing vehicle size and power. In other words, the efficiency innovations

Tata Motors factory in Singur, West Bengal, India, was set to produce the inexpensive Nano (*above*); the site was moved late in 2008 to the state of Gujarat after massive opposition from displaced farmers.

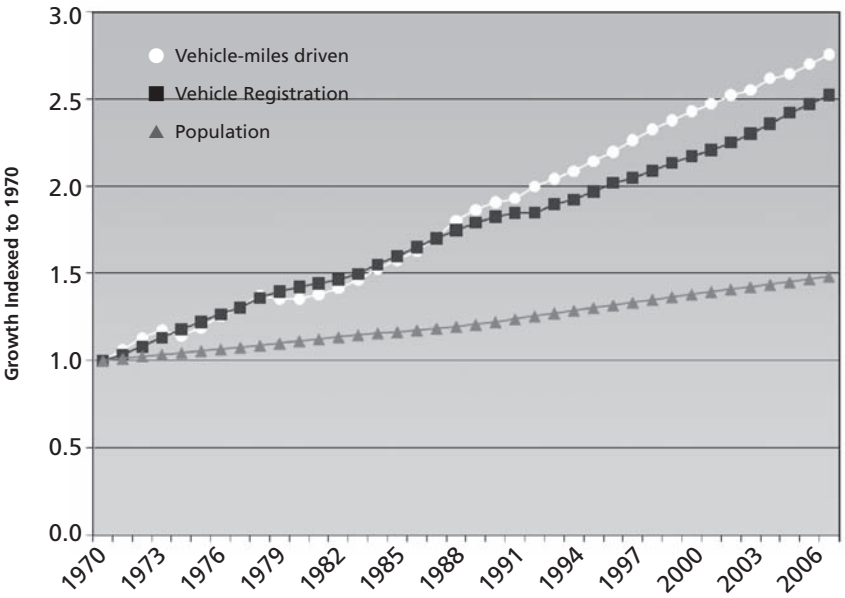


**FIGURE 3 Growth of vehicle miles traveled, vehicle registration, and population in the United States since 1970 (2, Tables 3.3, 3.4, and 8.1).**

have served private desires for larger and more powerful vehicles, not the public interests of energy security and climate stabilization.

Change is on the way. In December 2007, Congress passed a law to improve the fuel economy of new cars and light trucks by 40 percent by 2020. California has a pending law to reduce greenhouse gases and fuel consumption still further, and 12 other states are ready to follow. Near-term reductions in energy use and in greenhouse gas emissions will result mainly from improvements in conventional technology—in engines, transmissions, aerodynamics, and materials.

The more profound change is to electric-drive technology. Although 97 percent of the vehicles in the world burn petroleum fuels in combustion engines, electric motors will propel an increasing proportion of vehicles. Hybrid electric vehicles, like the Toyota Prius, are the vanguard of this revolution.

How the electricity will be provided to these vehicles remains uncertain. The two likeliest options are fuel cells that convert hydrogen to electricity and batteries that store electricity from the grid. The transformation of vehicles to electric-drive propulsion is under way, with several automakers planning to release next-generation plug-in hybrids and battery electric vehicles in 2010.

### *Transforming Fuels*

Fuel suppliers and fuels are the next focus for transformation. Except for ethanol in Brazil, alternative fuels have not dislodged or even competed with petroleum fuels, although alternative fuels have spurred improvements indirectly in conventional fuels and engines. In the late 1980s and early 1990s, the anticipated introduction of alternative fuels played a central role in the development of cleaner gasoline and diesel fuels and cleaner-burning engines. The demonstrated viability of methanol and natural gas vehicles—and their lower emissions—provided air quality regulators with a sound basis for tightening fuel and vehicle standards.

More profound changes are under consideration. The dominant transportation fuels of the future will be a mix of biofuels, electricity, and hydrogen. Electricity and hydrogen will fuel electric-drive vehicles, with biofuels gradually replacing petroleum fuels in combustion engines—probably including jet engines.

The debate over biofuels has focused on ethanol made from corn. But corn ethanol is not an attractive option for the long term—nor, according to many, for the short term—for a variety of economic and envi-

Open pit mining of tar sands—or bituminous sands—in Alberta, Canada; the complex recovery processes include extracting and separating the bitumen from clay, sand, and water (*see photo, lower right*); upgrading before refining, and then diluting with lighter hydrocarbons to make the oil transportable by pipelines.

PHOTO: SUNCOR ENERGY, INC.

A separation cell is one step in the extraction of bitumen from tar sands mixed with water.


Traffic congestion in Hyderabad, India—"Traffic Jams a Way of Life Now," according to an Indian newspaper headline.

ronmental reasons. The other prominent biofuel, ethanol made from sugarcane in Brazil, is more attractive, but Brazil's circumstances are unique and are not likely to be replicated elsewhere. The future of biofuels is promising, but the principal fuel produced from biomass will not be ethanol, and the principal feedstock will not be corn.

Most biofuels of the future probably will be made from cellulosic waste materials—grasses, trees, crop and forestry residues, and municipal waste—and converted into fuels that resemble gasoline and diesel. Ethanol will be phased out, because it has lower energy densities and is not compatible with the gasoline distribution system already in place—ethanol distribution is expensive and inefficient, relying mostly on rail cars instead of pipelines.

The imperative for alternative fuels is not that the world is running out of oil, but that it is running out of conventional oil. Tomorrow's oil resources will be different from today's. The 20th century was fueled by easily accessible, relatively cheap, conventional oil. Most of the remaining conventional oil comes from the Persian Gulf countries of OPEC. Those supplies not only are insecure but are inadequate. Oil companies therefore are developing unconventional fossil resources—such as tar sands, oil shale, tarlike heavy oil, and coal. The unconventional oil is dirtier, requires more energy to extract, and is more carbon-intense than conventional oil.

The oil industry excels at assembling capital to build and operate complex facilities and therefore favors high-carbon fuels. Unless the risk and cost of low-carbon alternative fuels are reduced, the fuels of the future will be predominantly high-carbon unconventional oil.

The question is whether oil companies will invest their profits to deliver a new array of low-carbon transportation fuels. For this to occur, the oil companies would have to transform themselves into broader energy companies that supply not only petroleum fuels but also biofuels, hydrogen, and possibly electricity.

### *Transforming Mobility*

Relying solely on auto technology and fuels to reduce oil use and greenhouse gas emissions dramatically would be hugely expensive—in part because of continuing growth in vehicle use. If the historical growth in vehicle miles traveled were to prevail, today's 3 trillion vehicle miles in the United States would more than double by 2050. Slowing or stopping this growth in vehicle use while still meeting the desire for accessibility is a tremendous challenge that will necessitate changes in the transportation culture.

The key to change is greater choice for travelers. Wide-scale use of information and wireless technologies in the transportation sector is imperative. These are needed to facilitate innovations such as smart paratransit, intelligent carsharing, dynamic ridesharing, and the use of telecommunications to rationalize and even replace tripmaking. Choices can be expanded through better land use management,


Hybrid powertrain in a Mercedes Benz Vision GLK, a four-cylinder diesel engine with an electric motor module that acts as a generator and starter. The manufacturer claims that the "luxury class" vehicle achieves "the world's lowest $CO_2$ emissions in the SUV segment."

neighborhood cars, and enhanced mass transit. The availability of these choices will reduce vehicle use and create a lower carbon transportation system.

Traditional solutions will not suffice. The old trains and buses of half a century ago will not solve energy and climate problems, at least in affluent nations. With their low ridership, transit buses in the United States are actually less energy efficient than car travel on a passenger-mile basis.[2] Conventional rail transit is somewhat more energy efficient but is not well suited to the suburban development patterns prevalent in the United States and therefore is unlikely to account for much more than 1 percent of passenger travel in the future. To reduce high-carbon vehicle travel, policies must encourage better choices and more effective integration of land use, conventional mass transit, and transportation planning.

A new culture of innovation is needed in the transport sector. Hints of change are emerging in the United States—for example, increased carsharing and bus rapid transit, a new law in California linking land use and vehicle miles traveled, and interest in conditioning transportation funds on environmental performance. The result could be a higher quality and less costly transportation system that consumes less energy and emits fewer amounts of greenhouse gases.

[2] Transit buses used far less energy per passenger-mile than autos 30 years ago, but the numbers have since flipped, as performance improvements and air conditioning were added, and ridership failed to keep pace with expanding bus service (2, Table 2.13).

In early 2008, Chevrolet began testing a fleet of more than 100 hydrogen-powered Equinox Fuel Cell vehicles in New York City, Washington, D.C., and Southern California. A communication cable from the refueling pump connects to an onboard computer that determines fuel temperature and pressure and how much hydrogen to dispense. The fuel cell adds about 500 pounds to the vehicle's weight; aluminum doors and a carbon fiber hood compensate.

## Moving Forward

The desire for personal mobility can be accommodated even while reducing the environmental and geopolitical impacts. Two overarching principles are suggested. First, develop consistent incentives to empower and motivate people and organizations. Second, advance a broad portfolio of energy-efficient, low-carbon technologies. This vision requires pervasive changes over a long period of time.

These transformations require leadership. The adoption of fuel economy and renewable fuel requirements in the Energy Independence and Security Act of 2007 was a positive step—although boosting corn ethanol may prove problematic.

### *Cues from California*

Leadership may emerge at the local and state levels. For example, California is in the vanguard of climate and energy policy. A hotbed of environmentalism and entrepreneurialism, California adopted the world's first air pollution regulations and monitoring systems and the first requirements to develop cleaner gasoline and zero-emission vehicles. Now it is leading with climate policy. If these initiatives are successful, California can lead America and the world away from petroleum and toward climate stabilization.

In fall 2006, the California legislature passed the Global Warming Solutions Act, which calls for reducing the state's total greenhouse gas emissions to 1990 levels by 2020—roughly a 28 percent reduction from forecasted levels. A comprehensive set of rules and policies is being put in place as a follow-up to this law—including aggressive greenhouse gas emissions standards for vehicles, low-carbon fuel standards, and initiatives to reduce sprawl and reduce driving.

The vehicle standards would require an improvement of roughly 20 percent above the federal fuel economy standards adopted in December 2007. But the proposed California standards have become ensnared in legal battles over states' rights.

California's low-carbon fuel initiative may be even more instrumental in bringing about change. The standards require a 10 percent reduction in life-cycle greenhouse gas emissions from fuels by 2020 and


Advances in biofuels—including marketing and distribution—can produce key options for a transition to performance-based, low-carbon fuels.

provide a durable, performance-based framework for transitioning to low-carbon fuel alternatives. The California Air Resources Board is scheduled to adopt the standard in early 2009. Many other states are moving toward adopting California's fuel standards, as is the European Union.

The conversion of the national ethanol program into a performance-based, low-carbon fuel system would stimulate innovation in the entire range of alternative fuels—from biofuels to hydrogen—allowing industry to pick winners and to reduce carbon emissions from all options, including unconventional petroleum fuels.

The third thrust of the California program is to reduce vehicle travel. An enabling law was passed in September 2008 directing metropolitan regions to apply land use regulations and other means to reduce vehicle miles traveled. The law provides for funding to reward local governments, including adjustments to transportation funding.

If these new vehicle, fuel, and land use initiatives are successful, California can lead the United States and the world away from petroleum and toward climate stabilization.

### *National Policy Questions*

The new Congress and president will debate energy security, climate policy, and transportation funding in the coming session. Will they embrace some of the policy innovations of California and others? Will they allow California and other states to proceed with more aggressive greenhouse gas standards for vehicles? Will they restructure and enhance the renewable fuels subsidies and mandates to be performance-based and to encompass promising alternative fuels? Will they reform transportation funding to empower state and local governments to reduce greenhouse gas emissions? Will local and state governments reform their taxation rules and transportation financing practices to support innovative mobility services and more efficient land use and transportation patterns?

## Hard Work Ahead

Human society faces a dilemma. People want cheap and easy mobility, and they want to travel in comfort and style. But giving free rein to these desires means more oil consumption and more greenhouse gas emissions; global tensions over scarce oil supplies and a rapidly altering climate; and potential devastation for many regions, many businesses, and many people. The challenge is to reconcile the tensions between private desires and the public interest.

America tends to embrace the desires of individuals in the name of freedom and consumer sovereignty and to place faith in technology and the marketplace to rescue society from its excesses. But how can the conflicts between private desires and the public interest be resolved?

Even according to the most conservative scenarios, dramatic reductions in oil use and carbon emissions are necessary. Sweeping transformations are in order and are slowly taking root. These transformations will only come about through an upsurge in innovation, entrepreneurship, and leadership.

Instead of bigger and more powerful vehicles, smarter vehicles are needed. Instead of demanding cheap oil, consumers need to embrace low-carbon alternatives. Government needs to invoke the public interest and spur new, cutting-edge enterprises. Leaders need to send consistent messages that encourage better choices. Instead of overlooking or decrying the growing demand for motorization in China, India, and elsewhere, global action is needed to encourage innovative solutions.

The transportation community needs to summon its ingenuity and take a big step forward. Intelligence, leadership, and a moral vision can transform the economy and society. Vehicles and fuels can be improved, new mobility options can be introduced, and unsustainable travel behaviors can be altered—and the planet eventually will be able to accommodate two billion cars.

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