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Transportation Research at the University of California

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The University of California Transportation Center, founded in 1988, facilitates research, education, and public service for the entire UC system. Activities have centered on the Berkeley, Davis, Irvine, Los Angeles, Riverside, and Santa Barbara campuses.

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Cover image: Computer circuit board

Transportation Technologies for the 21st Century

NEW TECHNOLOGIES are transforming the way we plan, design, build, and operate transportation systems. Transport agencies use them to count traffic, detect crashes, collect tolls and fares, and manage transit operations and traffic signal systems. Travelers depend on traffic condition reports, electronic maps, on-board vehicle performance monitors, real-time transit arrival information, and a host of other services that did not exist a generation ago. Some of us are already driving hybrid vehicles or commuting in buses powered by hydrogen or biofuels. For the future, we all are counting on additional advances in transportation technology, not just to get us where we want to go, but also to reduce greenhouse gases, improve air quality, and support economic development.

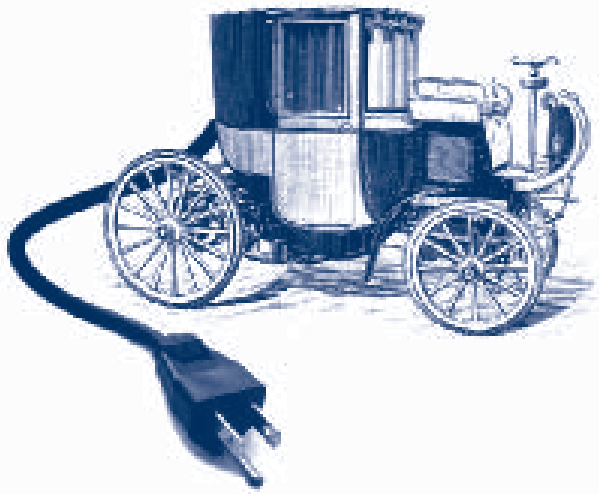
As these examples suggest, technologies for transportation often involve the application of new materials or tools, such as emissions control devices or a long-lived pavements. Many research and development efforts are focused on these physical artifacts. However, technology also extends to the broad set of methods, procedures, and organizational arrangements for delivering transportation facilities and services, as well as to the user applications that a new device or method finds in the marketplace. These “soft” elements are often key to a technology’s success, or the lack of it. For example, if a variety of technologies are vying for a market, it’s important to know whether that market is large enough to be shared, or so small and specialized that only a few providers (if any) can succeed. Factors such as design standards and product specifications can enable technologies or

block them, as can rules about competitive bids and product liability. And the political acceptability of a new technology’s impacts, including its social and environmental consequences, may be as important as—or more important than—the technology’s effects on mobility or its cost-effectiveness. Planners and engineers need to understand a new technology’s potential, as well as its limitations, in order to effectively build it into new project proposals. Decision-makers need evidence on benefits and costs, including social, economic, and environmental effects, to weigh whether to invest in a new technology or stick with traditional approaches. New technologies can disrupt established ways of doing things, and so technology development may need to be complemented by institutional analyses that allow leaders to remove barriers and support innovations. Research on this full range of issues can help inform these decision processes as well as advance the technologies themselves.

The papers in this issue of ACCESS examine several technologies that are of key interest to transportation today: motor vehicle fuels, fuel efficiency standards, electric vehicles, and new technologies for transit and highways. The papers were written in honor of Professor Charles Lave of UC Irvine and Professor Alex Farrell of Berkeley, both of whom passed away in Spring 2008. Charlie and Alex are fondly remembered by their colleagues and students, and much missed.

The issue also marks my departure as director of UCTC, at the end of my second five-year term. I’ll be on sabbatical, but reading ACCESS.

—Elizabeth Deakin



Saving Fuel, Reducing Emissions

Making Plug-In Hybrid Electric Vehicles Cost-Effective

BY DANIEL M. KAMMEN,
SAMUEL M. ARONS,
DEREK M. LEMOINE,
AND HOLMES HUMMEL

CARS AND LIGHT TRUCKS IN THE US CONSUME ABOUT eight million barrels of gasoline per day, more than total US petroleum production. They account for eighteen percent of national greenhouse gas emissions. Both motor vehicle gasoline consumption and emissions have been rising at about 1.5 percent per year.

Plug-in hybrid electric vehicles (PHEVs) could alter these trends. On a vehicle technology spectrum that stretches from fossil-fueled conventional vehicles through hybrid electric vehicles to all-electric vehicles, PHEVs fall between hybrids and all-electrics. They have both gas tanks and batteries, like hybrids, and can run either in gasoline-fueled mode or in electric mode. Their batteries are much larger than batteries in other hybrids, and they can store electricity directly from the grid as well as electricity derived from regenerative braking, as do conventional hybrid vehicles. PHEVs combine the best aspects of conventional vehicles (long range and easy refueling) with the best attributes of all-electric vehicles (low tailpipe emissions and reduced petroleum use). Widespread use of PHEVs could reduce transportation-related GHG emissions, improve urban air quality, reduce petroleum consumption, and expand competition in the transportation fuels sector. Several companies now offer to convert hybrid vehicles to PHEVs, and several automakers have announced PHEV development projects.

However, there's a downside: cost. Because of their large batteries, PHEVs currently are much more expensive than either conventional vehicles or hybrids. Under today's market and policy conditions, the expected savings in fuel costs are not enough to compensate consumers for their high prices. Therefore, PHEVs could be consigned to a small or non-existent market share unless something changes.

In the following pages, we compare costs, energy consumption, and emissions of these different vehicle types. We look at a conventional vehicle, a hybrid-electric vehicle, and two different PHEVs—one that can travel twenty miles on grid-supplied electricity (called a PHEV20) and one that can travel sixty miles (a PHEV60) without recharging or using gasoline mode. We consider both compact and full-size SUV models. We assume that the PHEVs require batteries that can store and deliver large amounts of energy for distances and for the high-power driving needed in urban areas, but that they are otherwise similar to conventional vehicles. >

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GASOLINE OR ELECTRIC POWER?

While PHEVs are much more efficient at using gasoline than conventional vehicles, they are only slightly more efficient than hybrids. Thus almost all of the benefits of converting from hybrids to PHEVs would depend on whether they can be driven on cheaper and cleaner electricity.

Figure 1 shows electricity rates that provide the same cost per mile as various gasoline prices. Lower electricity rates than the ones shown would encourage PHEV owners to drive in electric mode, while higher rates would favor gasoline-fueled hybrid-electric mode. The equivalent cost per mile of \$3-per-gallon gasoline is 22 to 24 cents per kilowatt hour (kWh). For comparison, in 2006 US residential electricity rates averaged about \$0.083 per kWh, and US gasoline prices averaged about \$2.75 a gallon. Thus, under current prices, electric operation would save money.

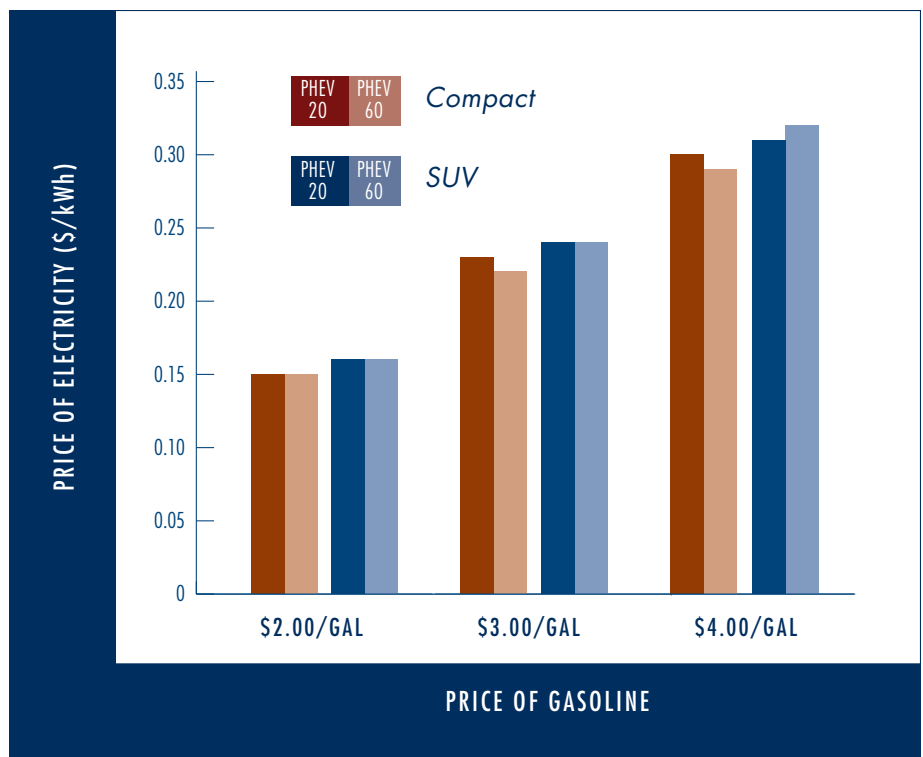
The question is whether the fuel cost savings over the lifetime of the vehicles are enough to offset PHEVs' higher capital cost and provide an incentive for their purchase.

BATTERY COSTS

Currently, electric vehicles cost more than conventional vehicles because batteries are expensive. Their price must fall substantially for consumers to be able to recoup costs by saving fuel. To compare the very different modes, we assume that batteries represent the entire difference in cost between PHEVs and conventional vehicles, and that they will last the entire twelve-year vehicle lifetime. We also assume that the vehicles are driven 11,000 miles annually, that PHEV20s drive 39 percent of their miles in all-electric mode, and PHEV60s drive in all-electric mode for 74 percent of their miles.

FIGURE 1

Equivalent cost per mile:
electricity vs. gasoline



We show the resulting break-even costs for the purchase of hybrids and PHEVs at various gasoline prices in Figure 2. Battery prices would have to fall substantially from their current price of about \$1300 per kWh, or gasoline prices would have to be substantially higher than the upper range of \$4 a gallon shown in the graph, for consumers to recoup the costs through fuel savings. Consumers' break-even costs are far lower than hybrid or PHEV battery prices, so fuel savings alone would not offset the vehicles' increased capital cost and thus justify their purchase.

The US Advanced Battery Coalition is aiming for a target battery price of \$150 per kWh, which would bring it in line with the break-even cost for hybrids and PHEV20 vehicles, but PHEV60s would still be too expensive unless gasoline were above \$5 a gallon. Thus, fuel savings alone are not likely to be sufficient to attract a cost-conscious consumer to hybrids or PHEVs unless gas prices rise or battery costs drop faster than anticipated.

GHG EMISSION REDUCTIONS

Hybrids and PHEVs offer prospects for considerably lower greenhouse gas emissions. The efficiency gains achievable from simply replacing a conventional vehicle with a hybrid are significant: 23 percent lower GHG emissions for compact hybrids and 34 percent lower emissions for SUV hybrids compared to their conventional counterparts. For PHEVs, however, the extent of the emissions reduction depends on how the electricity used to charge the battery is produced.

To determine greenhouse gas emissions savings from hybrids and PHEVs, we combined a well-to-wheels assessment of the transportation fuel sector with GHG emission data for the full fuel lifecycles of a number of different power plant types. Then we calculated >

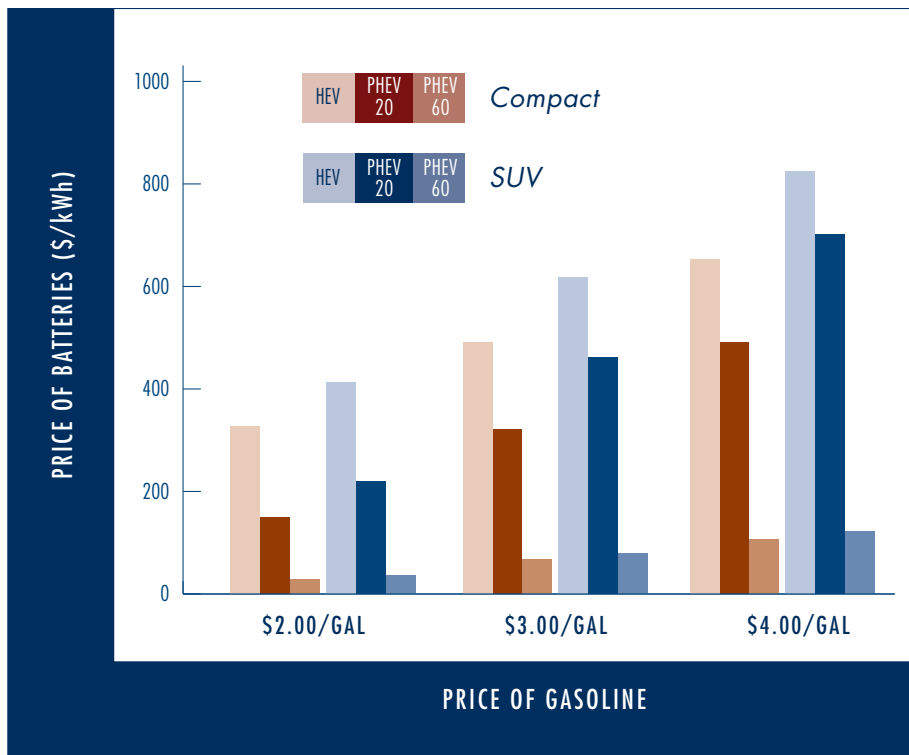


FIGURE 2

Break-even costs for PHEV batteries: what batteries must cost to justify PHEV purchase (current price \$1,300/kWh)

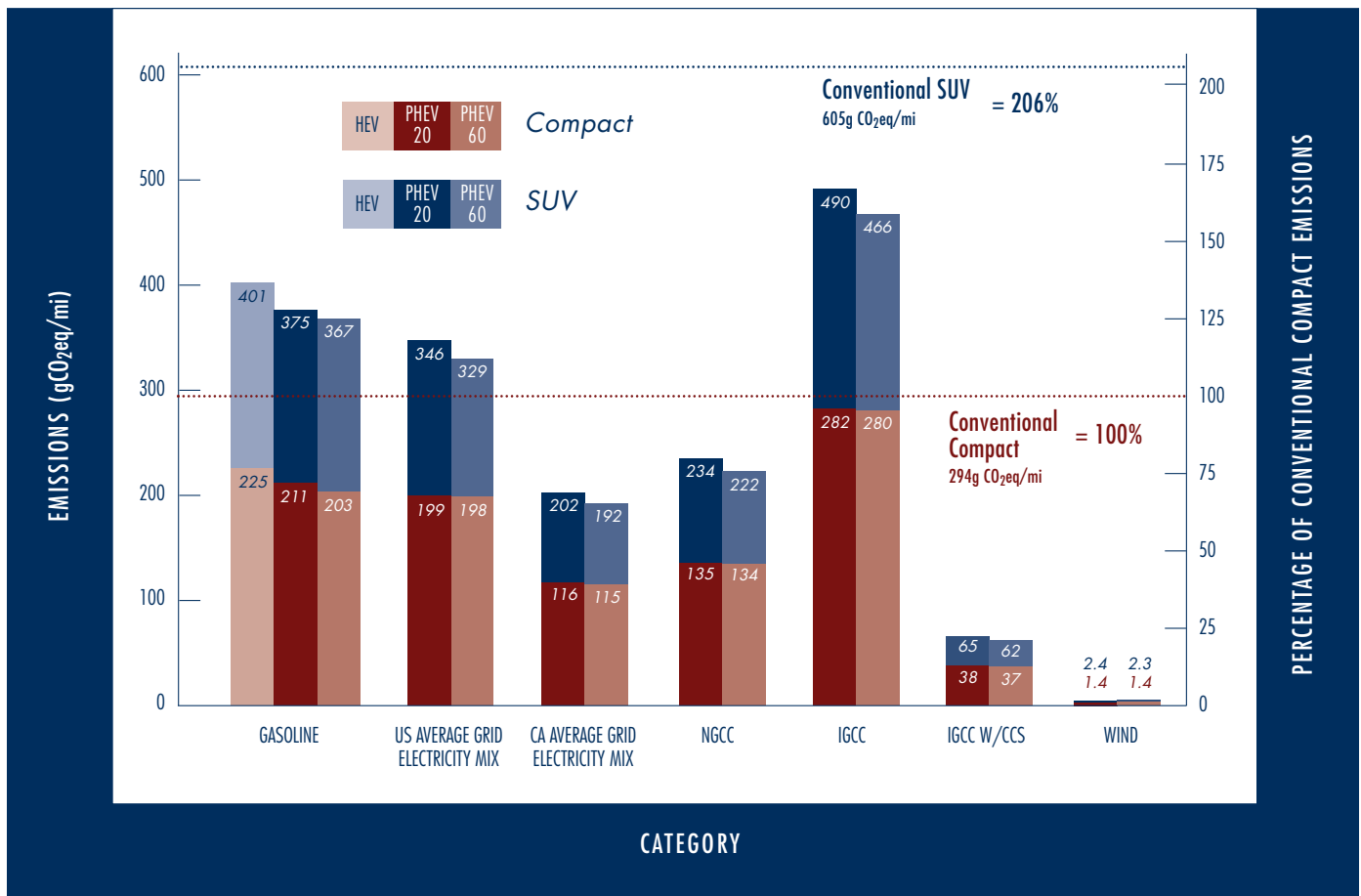
the emissions of each vehicle type when operating in gasoline mode and, when applicable, in electric mode. Figure 3 shows our results.

If the electricity comes from very low-GHG plants, such as wind turbines, nuclear plants, or integrated gasification combined-cycle (IGCC) plants with carbon capture and sequestration, PHEVs could reduce GHG emissions by as much as 85 percent relative to conventional vehicles under average driving conditions, and by nearly 100 percent when driven only in electric mode. However, a more accurate analysis must recognize that PHEVs would create new electricity demand and thus would be responsible for electricity produced by “marginal” power plants, those needed to meet this additional demand. In the US, marginal plants are often thermal plants burning natural gas (NGCC in Figure 4). If PHEVs are operated with electricity from natural gas, compact and SUV PHEVs reduce emissions by 54 and 61 percent relative to their conventional vehicle counterparts.

In some US regions, however, the marginal power plant is a coal plant. If PHEVs are operated on IGCC coal electricity without carbon capture and sequestration, compact and SUV PHEVs reduce greenhouse gas emissions by only four to nineteen percent relative to comparable conventional vehicles. In this case GHG reductions are actually *less* than those achieved by hybrids running on gasoline (23 and 34 percent, respectively). Thus, when the

FIGURE 3

GHG emissions from gasoline use and from electricity use with different generation mixes



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marginal power plant is a coal plant, it is *always* better from a GHG perspective to drive a hybrid or a PHEV in gasoline-fueled hybrid electric mode rather than in grid-supplied all-electric mode.

In the long run, if PHEVs become numerous enough to lead to new investment in electricity generation, an analysis using average emissions from all power plants would be reasonable. We include the current US average and California average electricity grid mixes in Figure 3 for purposes of comparison. PHEVs would perform better in California because California power uses relatively little coal, but in other cases emissions savings would not be as good as our NGCC example. However, high market penetration of PHEVs is likely to take ten years or more, and over that time period power plant regulations also could change significantly, presumably toward lower emissions from power production and hence better emissions gains from switching to PHEVs. >

SUBSIDIES AND INCENTIVES

If fuel savings alone don't justify the purchase, how big must a subsidy or monetary incentive be to induce a cost-conscious consumer to buy a PHEV? Would the greenhouse gas benefits of PHEVs justify such a subsidy? To address these questions, we calculated the necessary subsidy as the difference between the marginal vehicle cost and the marginal fuel savings (assuming a base case of ten cents per kWh electricity, \$2 a gallon gasoline, \$1,000 batteries, and a sixteen percent discount rate on future fuel savings). We then separately tested the effects of a \$200 battery, lower emissions from electricity production (using wind instead of NGCC), and a higher gasoline price (\$4 a gallon instead of \$2). Finally, we tested what would happen if regulatory agencies charged \$100 per metric ton for carbon emissions (currently most such carbon emissions prices range from \$20 to \$50 per metric ton).

Figures 4 and 5 show the results. The analyses illustrate the critical importance of low battery prices: with expensive batteries, emission reductions from PHEVs cost well over \$100 per metric ton of CO₂—making this strategy a costly way to reduce greenhouse gases. The analyses for low-GHG electricity and for gasoline price reinforce this conclusion. And a carbon price of \$100 per metric ton of CO₂ does not have much of an effect. Thus, we conclude that a carbon tax or economy-wide GHG cap-and-trade system would not be particularly helpful in making PHEVs a cost-effective greenhouse gas mitigation option.

Figures 4 and 5 additionally show that it is more cost-effective to replace conventional SUVs with hybrid or PHEV SUVs than to replace conventional compact cars. This is simply because the same percentage increase in fuel efficiency (e.g., in miles/gallon) saves more fuel when the initial fuel efficiency is lower. An even better and more cost-effective way to reduce GHGs, of course, would be to replace conventional SUVs with *compact* hybrids or PHEVs. This suggests that any automotive GHG-mitigation strategy should focus on reducing emissions from larger vehicles both by shifting purchases towards smaller vehicles and by improving the efficiency of larger vehicles.

FIGURE 4

GHG abatement cost of subsidizing replacement purchases of HEVs and PHEVs (in dollars per ton of carbon dioxide)

	COMPACT CARS			SUVS		
	CV → HEV	HEV → PHEV20	PHEV20 → PHEV60	CV → HEV	HEV → PHEV20	PHEV20 → PHEV60
Base case*	\$163	\$429	\$2,498	\$113	\$270	\$1,994
Wind-generated electricity	\$163	\$196	\$982	\$113	\$128	\$904
\$200/kWh batteries	\$0	\$26	\$440	\$0	\$0	\$338
Wind and \$200/kWh batteries	\$0	\$12	\$173	\$0	\$0	\$153
\$4/gal gasoline	\$84	\$258	\$2,298	\$34	\$103	\$1,820
\$100/tCO₂-eq carbon tax	\$120	\$373	\$2,441	\$70	\$215	\$1,940

*10¢/kWh electricity, \$2/gal gasoline, \$1,000 batteries, 16% discount on future fuel savings

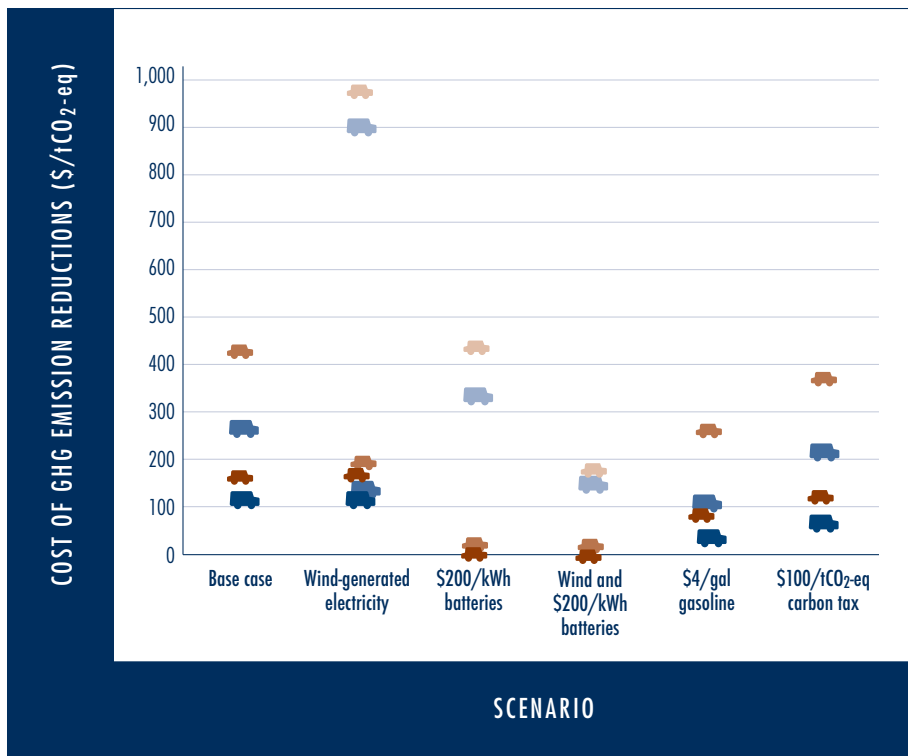


FIGURE 5

GHG abatement cost of subsidizing replacement purchases of HEVs and PHEVs (in dollars per ton of carbon dioxide)

Compacts

- CV → HEV
- HEV → PHEV20
- PHEV20 → PHEV60

SUVs

- CV → HEV
- HEV → PHEV20
- PHEV20 → PHEV60

Under most market conditions, replacing conventional cars with hybrids is the least costly GHG mitigation step. However, with cheap enough batteries, replacing hybrids with PHEV20s can be cost-effective in its own right, aside from emission abatement benefits. Replacing PHEV20s with PHEV60s, however, is an expensive GHG control strategy under every scenario we consider here. These findings suggest that automotive emission reduction strategies should initially focus on vehicles with smaller and cheaper batteries. Nonetheless, vehicles with large batteries and all-electric vehicles may have more value for longer-term abatement strategies.

We conclude that for cost-conscious consumers to want to buy PHEVs, battery prices must decline to about forty percent of their current prices, or US gasoline prices must be roughly \$5 a gallon.

POLICY INNOVATIONS

Policies to improve battery costs and lifetimes, to decrease greenhouse gas emissions from electricity production, and to raise gasoline prices relative to electricity prices can make the significant direct GHG emission reductions from PHEVs cost-effective. Legislators might enact policies supporting a broad program of battery research and development, with the goal of increasing battery lifetimes and bringing down prices. Policymakers might also encourage PHEV adoption by reducing vehicle costs or increasing vehicle benefits such as loans, rebates, feebates, tax incentives, or non-monetary incentives (e.g., preferred parking spaces or access to carpool lanes) to consumers who purchase PHEVs, and by raising the price of gasoline disproportionately more than the price of electricity. All of these policy options would require further analyses of their own costs and benefits. >

FURTHER READING

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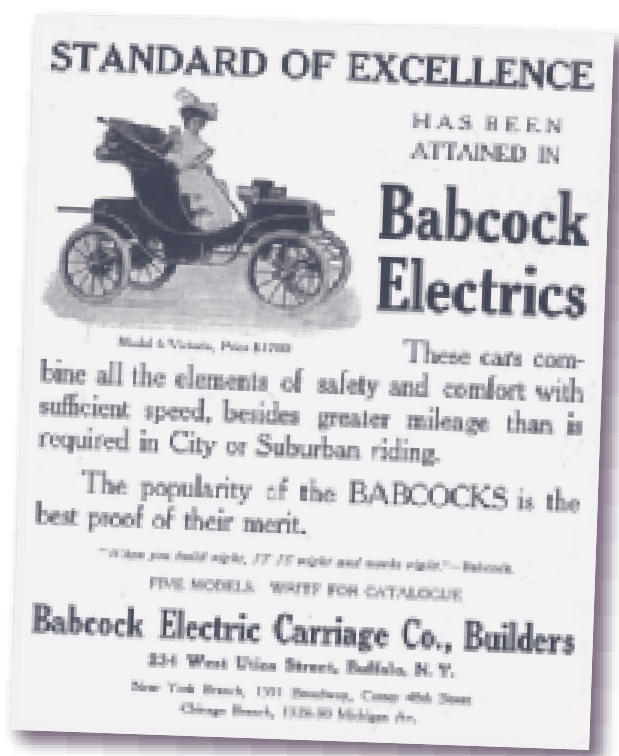
A second goal policymakers might pursue is to adopt policies (such as a renewable portfolio standard) that lower greenhouse gas emissions from electricity production and especially from marginal generators. Such strategies would in turn lower PHEV fuel costs and make them more attractive to consumers.

Importantly, it is unlikely that in the near term a moderate carbon price alone would make PHEVs' direct abatement economical. Given current technologies and prices, replacing full-sized conventional sport utility vehicles with hybrid electric sport utility vehicles is a highly cost-effective GHG mitigation strategy. However, a large-scale shift to PHEVs could enable much greater greenhouse gas abatement in the future by encouraging battery research and electric power policies that would bring even further savings. ♦

Acknowledgments

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We dedicate this paper to Dr. Alex Farrell, collaborator, colleague, and friend, who passed away in April 2008 during work on an earlier version of this project.



Moving Forward With Fuel Economy Standards

BY LEE SCHIPPER

IN THE EARLY 1970S, the American Petroleum Institute had a slogan: “A nation that runs on oil can’t afford to run short.” Yet at the beginning of 1973, the US relied on oil for 46 percent of its energy supply, of which 32 percent was imported. Today we import about two thirds of the oil we consume. The price of crude oil in early 1973 was around \$3 a barrel, and gasoline cost 39 cents a gallon. In 2009 dollars, those figures are close to \$15 a barrel and \$1.85 a gallon. Crude oil prices in early 2009 were still almost three times higher than in 1973. However, the fuel cost for driving a mile is less today than in 1973, because cars are more fuel-efficient and it takes thirty percent less fuel to go a distance today than in 1973.

When oil supplies were interrupted by the OPEC embargo, the US Congress and President Ford decided that the government should mandate higher fuel economy for cars. American policy makers and drivers understood how vulnerable the nation’s transport system was to even a partial fuel supply cut-off. Fuel prices had jumped, and fuel availability was uncertain. In 1975, Congress enacted the Corporate Average Fuel Economy law, or CAFE, for motor vehicles. In 2007 lawmakers raised the CAFE standards for vehicles sold in 2012 and later. But in light of fluctuating oil prices and concerns about greenhouse gas emissions, many today think even stronger standards will make both America and the faltering car industry more robust when the inevitable rise in oil prices occurs with economic recovery. >



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A BRIEF HISTORY OF CAFE

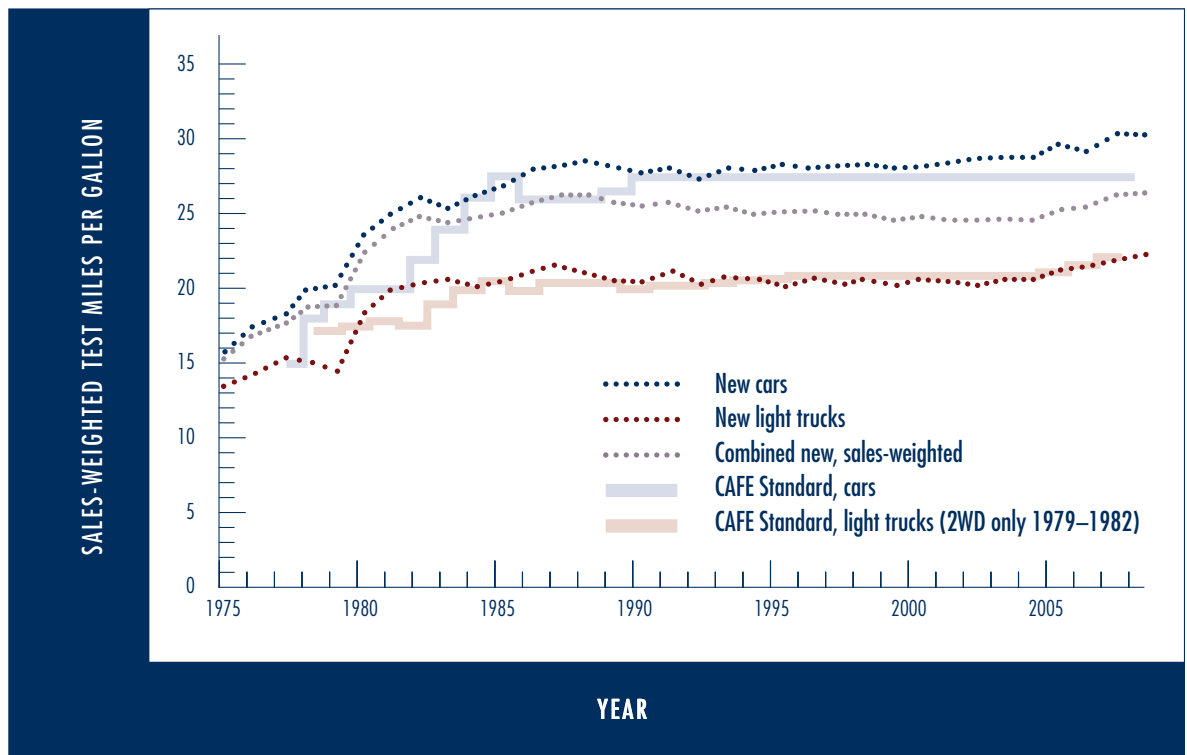
CAFE was timed to take effect in summer 1977. The standards were to be phased in over time, reaching their maximum for cars, 27.5 mpg, by model year 1985. New cars carried labels showing energy use under “typical” urban and non-urban driving conditions. CAFE standards applied to each producer’s sales-weighted fleetwide average fuel economy, and car companies had to pay fines if their fleet average failed to meet the standard. Manufacturers whose averages exceeded standards could earn credits to use against years when they fell below mandated levels. Additionally, a “gas guzzler” tax was applied to cars and trucks that did not meet a minimum mpg level. Figure 1 shows the historical mpg levels of cars and light trucks as well as mandated levels. Note that in 1986–1988 standards were relaxed somewhat in response to manufacturer claims that they could not sell cars that met the required average fuel economy.

When CAFE was passed, the fuel price increases of 1973 had already had some effect on automobile fuel efficiency. Consumers had begun buying somewhat smaller and less powerful cars, and automakers had announced plans to make lighter cars and use technologies that would save fuel. Thus CAFE reinforced behavior that was already being driven by prices.

Then in 1979, a new political crisis (in Iran) set off an even greater run-up in oil prices. At the peak, in 1980-81, a gallon of gasoline cost around \$2.50 in 2009 terms. At that time it still took almost 25 percent more gallons per mile to run an average car, so the fuel cost of driving was higher than in the spring of 2009.

FIGURE 1

MPG: CAFE standards for cars and light trucks, the actual sales-weighted averages, and the combined average of each year’s new cars and light trucks sold.



Source: US EPA

Gasoline prices in real terms started to slide down in 1982, and in 1986 crashed to only slightly above their real pre-1973 values. Supported by the CAFE standards, however, new vehicle efficiency did not sink back to values seen in the 1970s; instead it slowly increased through the late '80s and then stayed close to CAFE values, all during a time when energy prices were low.

CAFE standards for cars and SUVs were separate. Those affecting cars were administered by the US Environmental Protection Agency, while those affecting light trucks (principally pickups and vans in the 1970s) were under the control of the US Department of Transportation. Wary of a political backlash from people who traditionally bought pickups—farmers and builders—Congress required less stringent standards on light trucks than cars. At the same time, more light trucks were being bought by ordinary consumers. The share of light trucks and vans in the overall mix of vehicles continued to rise, and combined new vehicle sales-weighted fuel economy worsened slowly. It fell from its 1989 peak of 26.8 mpg to around 25.4 mpg in 1999, as gasoline prices hit bottom in 1998.

From that point, new vehicle fuel economy started inching upward again. Among the cars sold in model year 2007–2008, the average new car achieved over 30 mpg in tests, slightly better than required by CAFE, in part because of pressure from higher fuel prices. The mpg of new trucks and SUVs rose, partly due to tightened standards, reaching 24.2 mpg in both 2007 and 2008. The combined average was rising as well because the share of SUVs sold peaked in 2004. These changes gave Americans some comfort as gasoline prices hit a fifty-year high in the summer of 2008.

Of course gasoline use depends on what level of fuel economy vehicles attain on the road, not in tests, and on how far they are driven. Actual fuel economy for the entire fleet of cars and household light trucks on the road approached 21 mpg by 2006, according to DOT estimates, and around 19 mpg when commercial light trucks are included. The estimated “on road” fuel efficiencies of each year’s new models, as calculated by the EPA, as well as of the entire fleet of cars and light trucks, are given in Figure 2.

Figure 3 summarizes the changes in fuel economy and fuel use that have occurred since 1973, given 1990 and 2007 results. All values are compared to their 1973 level, which lies on the central line at 100 percent. The first bar shows the most important result: oil use for cars and household light trucks fell through 1990 and rose again only weakly, reaching marginally above its 1973 level in 2007. Since VMT per capita had increased almost forty percent over its 1973 level by 1990 and nearly sixty percent by 2007, and GDP per capita—a driver >



of both VMT and oil use—increased even more, the lack of growth in oil use per capita through 2007 is a sign that CAFE standards had a strong effect. This can be seen in the bar showing fuel use per mile, which fell to around 65 percent of its 1973 level by 2007. The fact that oil use per capita in 2007 approached its 1973 value is explained by the large increase in the number of vehicles per capita, a consequence of 34 years of economic growth. That VMT per vehicle was slightly higher in 2007 than in 1973 should not be discouraging; it is well below what an extrapolation of the trends of the years before 2000 would have given.

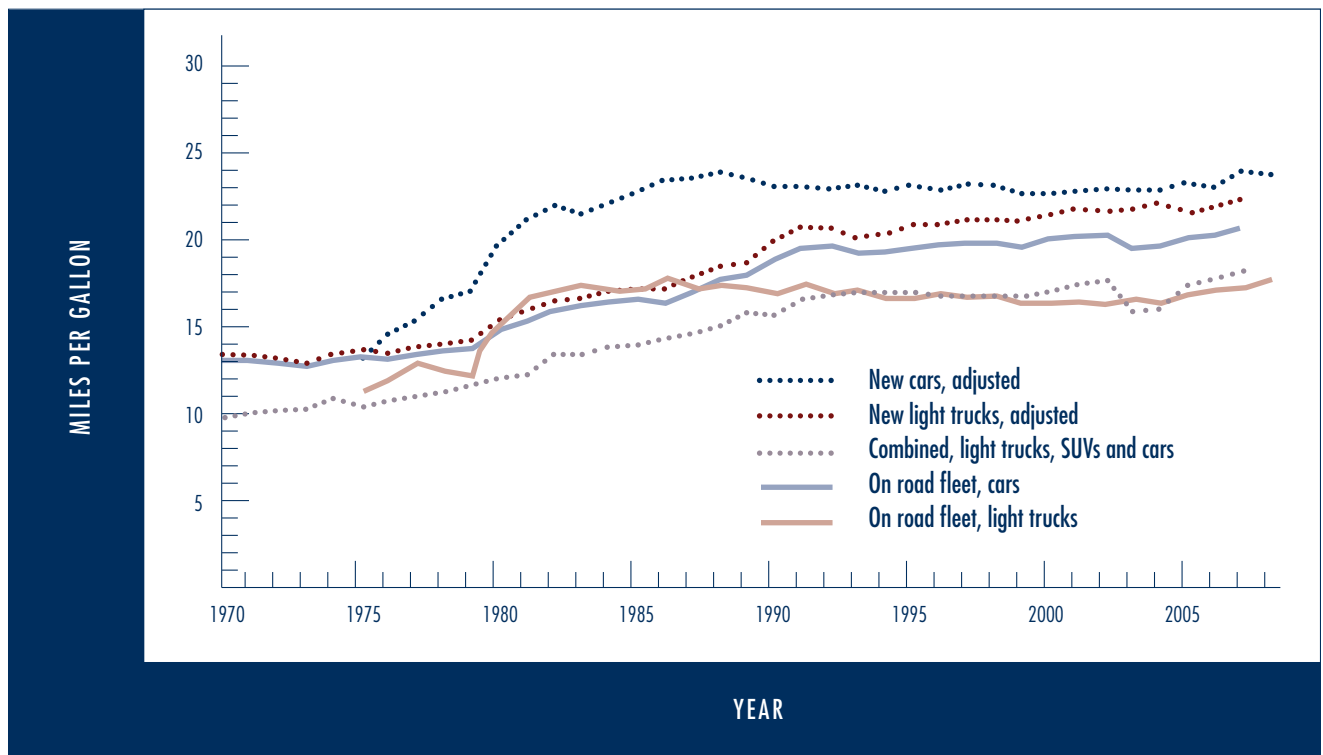
THE NEW CAFE STANDARD

Figure 3 also shows that in 2007 new vehicles weighed almost as much as they did in 1973, and their horsepower was 25 percent greater. Vehicle technology has improved continuously since the 1970s—but instead of using it to make vehicles a lot more efficient, manufacturers developed larger and more powerful vehicles while barely meeting the CAFE requirements.

There had been spirited Congressional debates about tightening the CAFE standards in 1991 and again in 2002, but no major action took place until late 2007, when concerns again arose about oil imports, rising oil prices, and to some extent the CO₂ emissions from car use. While many energy experts saw tighter CAFE standards as an important move, the issue of

FIGURE 2

New-car mpg levels translated to their approximate on-road averages (EPA 2008), on-road averages of the entire car and light truck fleets, and the on-road average of the entire fleet calculated using non-commercial light trucks and SUVs and all cars, based on DOT and US Dept of Commerce estimates



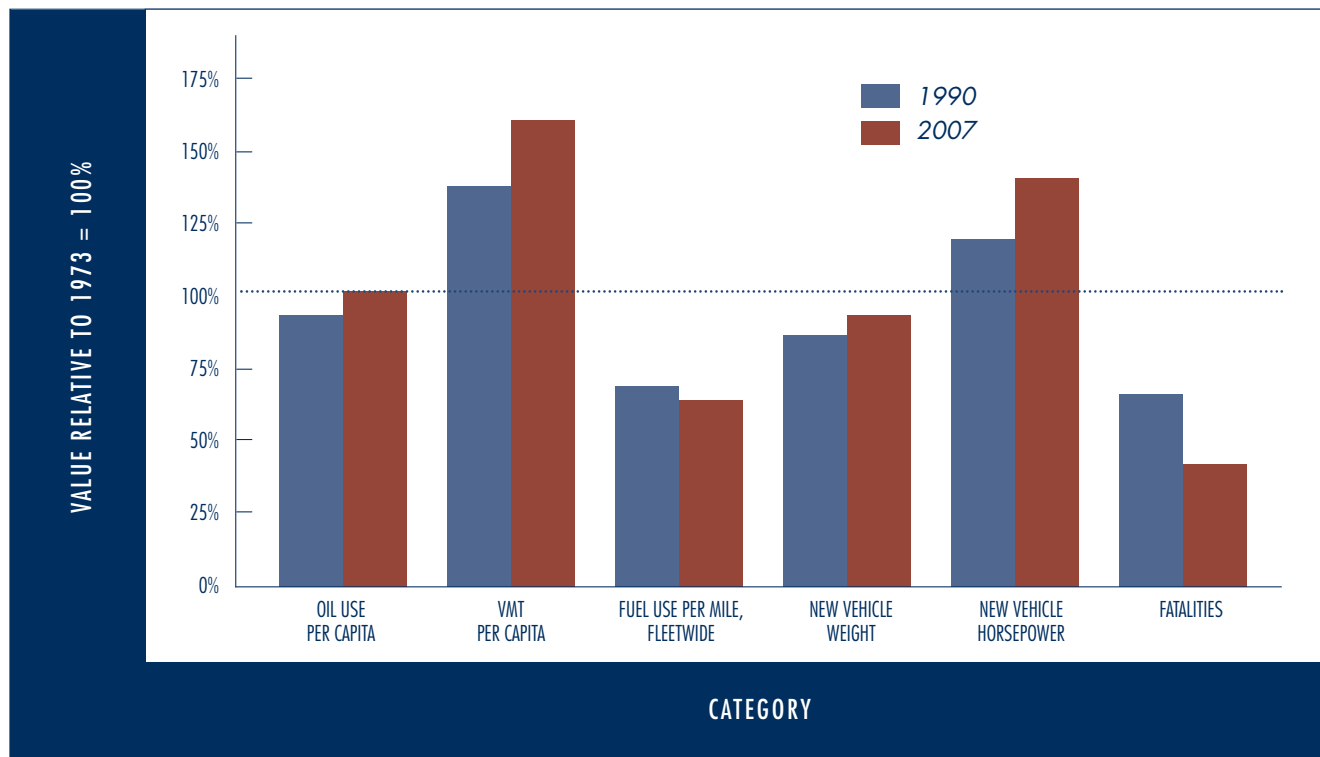
their efficacy and overall results remained hotly debated. Two important National Academy of Sciences studies and a stakeholder project initiated by President Clinton in 1993 (“Car Talk”) left a great deal of dissent on the record. In the end Congress enacted a significant increase in CAFE in 2007, and President Obama gave the EPA the go-ahead to implement the new standards. Still, the discussion over tighter fuel economy standards continues.

THE CONTINUING DEBATE

Why has there been such a protracted dispute over light-duty-vehicle fuel economy standards? David Greene has summarized the arguments in two important articles. One early analysis asserted that while cars had become more efficient, drivers were using them more, in part because fuel cost them less. This “rebound effect” offset part of the gains. Another critique estimated that there were two to four thousand extra traffic deaths every year because CAFE standards forced automakers to make lighter—and therefore less safe—cars. Others maintained that the new technology was simply too expensive. The US auto industry itself has seemed to adhere to the viewpoint that small cars make small profits.

But other research has countered most of these challenges. Greene and Maryanne Keller, writing in the 2001–2002 NAS study on fuel economy, pointed out that the difference in weight between colliding cars is what causes most damage, and that other safety >

FIGURE 3
Indicators of CAFE impact

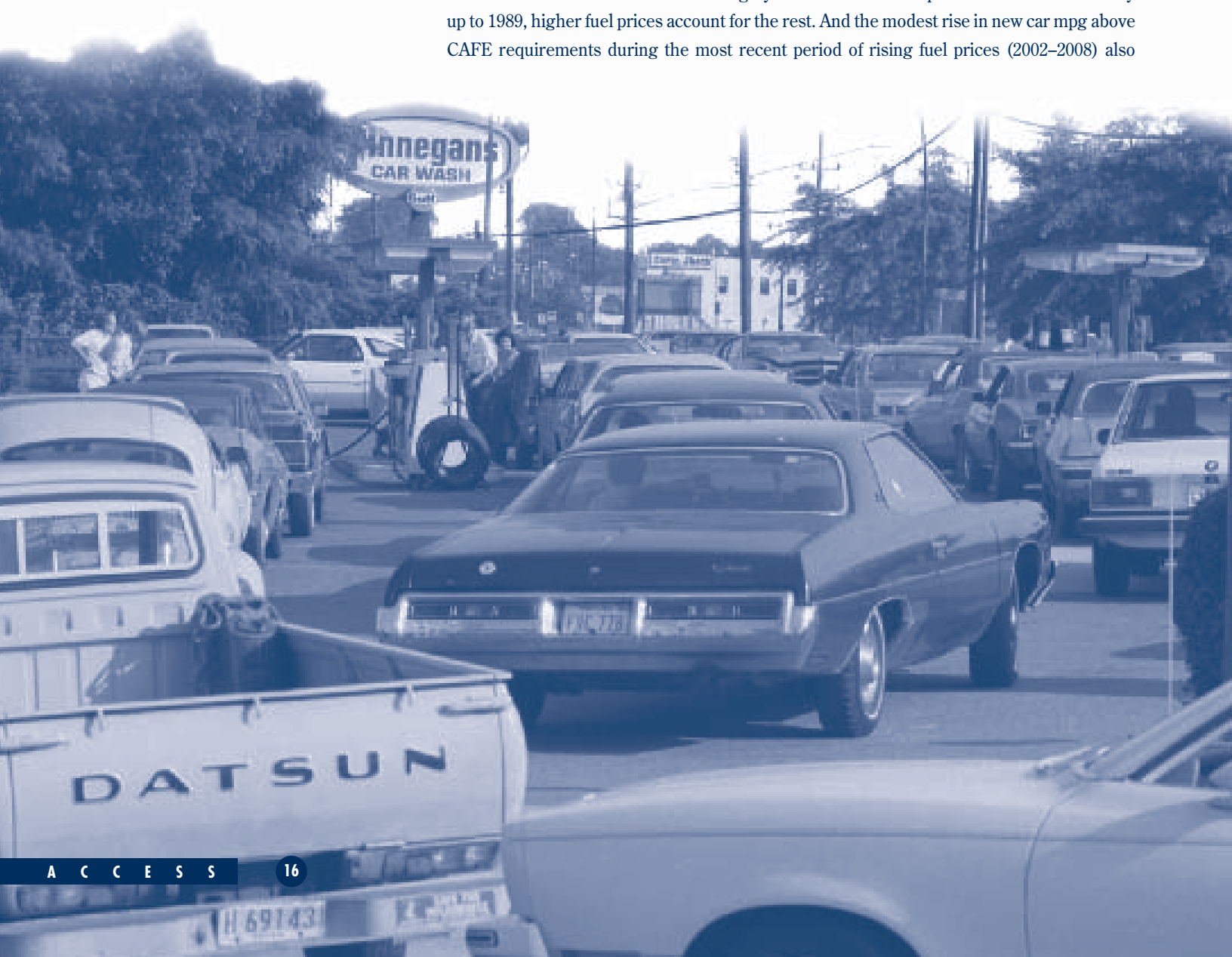


measures offset risks from lighter weight cars. Indeed, the rate of traffic deaths per mile driven has fallen steadily throughout the period that CAFE standards have been applied.

Most researchers acknowledge the existence of the rebound effect but have found it to be small, on the order of two to five percent. While even a small rebound effect will increase congestion somewhat, placing a cost on that increase depends on when and where the increased car use occurs, and additional travel is most likely to be for discretionary trips that occur outside of congested periods.

Exactly how much more a car meeting CAFE standards costs relative to one not meeting standards is difficult to estimate because it's never been possible to choose between the two. Moreover, there is a wide range in the fuel economy of cars with roughly the same acceleration, weight, power, etc. The 2002 National Academy of Sciences Study estimated that taking a mid-sized car from a baseline of 26 mpg to almost 40 mpg would cost slightly over \$3000, while getting a subcompact from a baseline of 30 mpg to slightly over 41 mpg would cost \$2000. By calculating average annual fuel use and including the small rebound effect, one can project substantial fuel savings. Would buyers be willing to pay these initial extra costs to save fuel over three to five years? That depends on gasoline prices, on how consumers discount future savings, and on whether consumers trust the projected returns.

Gasoline prices do have an important role in this evolution. Greene concludes that, while CAFE standards account for roughly two-thirds of the improvement in fuel economy up to 1989, higher fuel prices account for the rest. And the modest rise in new car mpg above CAFE requirements during the most recent period of rising fuel prices (2002–2008) also



point to the role of fuel prices. But CAFE provoked producers to develop and incorporate more fuel economy technology than they otherwise would have in response to short-term price swings. CAFE thus helped compensate for consumer myopia about tradeoffs between vehicle price and fuel-saving technologies or future fuel savings. Greene points out that without the standards, buyers might find more immediate satisfaction in better floor mats and a fancier car stereo than in a future stream of fuel savings.

OVERALL ASSESSMENT AND THE FUTURE

The tightening of CAFE standards in 2007 was welcomed by many observers. New vehicles must achieve 35 mpg in tests by 2020, and manufacturers' cars and light trucks are counted together. Accounting for somewhat less favorable on-road performance, the new standards imply that the fleet will eventually achieve 28 mpg, about forty percent higher than today. Put another way, our cars will use almost thirty percent fewer gallons per mile when the standards finally work their way through the fleet, some time in the 2030s. Are these strong enough standards?

One way of judging the strength of the new standards is by comparison with Europe and Japan. Auto manufacturers in those areas entered into voluntary agreements to increase fuel efficiency, with a target of about 37 mpg in tests. In 2006 all European cars averaged about 29 mpg—a level of on-road performance that the new US standards won't bring to new cars until 2020—and in Japan the car fleet averaged about 23.5 mpg, compared to 21 mpg in the US. European and Japanese new car fuel efficiency has improved steadily, and new vehicles sold in Europe in 2006 averaged about 32 mpg on the road, in Japan about 33 mpg. The European and Japanese experience suggests that even voluntary agreements can make a difference. That the European voluntary agreements did not achieve their targets led to even tighter mandatory standards, although the final level and deadline is still being debated in Brussels.

Cars in Europe and Japan use less fuel than those in the US almost entirely due to differences in power and weight. In the EU, the average new car weighs about 550 kg less than a new US car; new European cars have about 115 HP, while new US cars average over 200 HP. Fully one third of new Japanese cars are mini-cars, which helped the Japanese market exceed its voluntary targets. A key unknown is whether Americans will buy smaller, less powerful cars in the next few years while US manufacturers (if there are any left) develop more fuel efficient technologies. The dramatic decline in gasoline prices—November 2008 levels fell back to where prices were in 2005—certainly removed the pressure for Americans to think smaller. At the same time, present economic uncertainties are having a devastating effect on the new car market. While this means fewer expensive large cars will be sold, a slow market also inhibits the entrance of more efficient vehicles into the stock and squeezes investment and development plans of cash-strapped manufacturers.

It is hard to expect significant improvements in new US vehicles, even with an increased share of hybrids, if car size and weight remain where they are. But if the nation's drivers accept more modest vehicles than they drive today, a CAFE average above 40 mpg probably could be achieved. Indeed, meeting California's hoped-for greenhouse gas emission standard would require a test CAFE average of approximately 43 mpg. The Bush administration opposed this standard in a long series of administrative and court battles. Although President Obama reversed that opposition, the California standard is unlikely to be implemented on the original time table, which called for improvements by 2009. ➤



One way or another, one expects the US eventually to meet the new CAFE standards. However, increases in population between 2008 and 2037 alone are likely to offset greater efficiency. Some combination of even more efficient vehicles, fewer cars per capita, and fewer miles per car per year must also occur just to hold fuel use steady. And if the price of gasoline remains at the relatively low level of early 2009 after economic recovery, auto manufacturers may have problems meeting the standard if consumers turn back to larger cars.

This is where one of Charlie Lave's important ideas enters. He felt that most forecasts of car use were too high, both because of the saturation of ownership and because of a number of effects that would limit or even reduce VMT. One was congestion, which would slow us down and to some extent reduce how much we drive. Another was the aging of the driving population itself—older people, particularly retirees, tend to drive less than younger or economically active people. If the increase in driving were to slow, as Lave suggested, then there would be less upward pressure on oil demand and imports, and therefore a stronger CAFE might not be needed. But Lave believed that even with a possible slowdown in VMT growth, CAFE standards were important.

Both oil and climate concerns suggest that even the current level of US oil use for light duty vehicles is too high. Initial enthusiasm for biofuels has dampened because of concern about costs and wider environmental impacts, and in the case of corn-based ethanol, whether that fuel even saves greenhouse gas emissions at all. Efforts to make gasoline or diesel fuel from natural gas, coal, or shale also face severe cost and environmental constraints. Experts



have little real expectation of significant increases in conventional US oil and gas production. With the plummeting of crude prices in November to less than a third of what they were in July, the International Energy Agency warned of a supply crunch once the current recession ends. In short, both conventional fuels and other hydrocarbon-based fuels will cost more. And significant quantities of truly low-impact, low-carbon biofuels are not available nor expected in the next ten to twenty years.

With these prospects for the future of fuels driving US mobility, the US seems to have only one choice, namely to both push for even greater fuel economy and pursue policies that will reduce car use, increase the use of other modes, and reshape communities to be less dependent on cars. These alternatives will not be easy to realize if fuel prices remain low for a long period of time. They require increased attention to land use planning and appropriate pricing of car use, both in proportion to distances driven and to economic, social, and environmental costs. These measures can be justified both to raise money for transport infrastructure and to assure that where capacity is limited, i.e. on bridges or in congested areas, it is better used. Unfortunately Charlie Lave is not with us to apply his skills to this problem.

In retrospect, the CAFE standards enacted in the 1970s were a good legacy that can serve us even better. Tighter standards, resulting in greater fuel efficiency and more modest, more efficient vehicles, perhaps augmented by a gradual increase in the fuel tax, would reduce the risks of instability in world oil markets as well as US emissions of CO₂ from our transportation system. ♦



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Transforming the Oil Industry into the Energy Industry

BY DANIEL SPERLING AND SONIA YEH



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HEN IT COMES TO ENERGY SECURITY AND CLIMATE CHANGE concerns, transportation is the principal culprit. It consumes half the oil used in the world and accounts for almost one fourth of all greenhouse gas (GHG) emissions. In the United States, it plays an even larger role, consuming two thirds of the oil and causing about one third of the GHG emissions in the country. Vehicles, planes, and ships remain almost entirely dependent on petroleum. Efforts to replace petroleum, usually for energy security reasons but also to reduce local air pollution, have continued episodically for years—and largely failed.

The United States and the world have caromed from one alternative to another, some gaining more attention than others but each one eventually faltering. These have included methanol, compressed and liquefied natural gas, battery electric vehicles, coal liquids, and hydrogen. In the United States, the *fuel du jour* four years ago was hydrogen; two years ago it was corn ethanol; now it is electricity for use in plug-in hybrid electric vehicles. Worldwide, the only non-petroleum fuels that have gained significant market share are corn ethanol in the US and sugar ethanol in Brazil. With the exception of the latter, petroleum's dominance has never been seriously threatened anywhere since taking root nearly a century ago.

The *fuel du jour* phenomenon is fed by oil market failures, overblown promises, the inertia of oil industry investments, and the short attention spans of government, the mass media, and the public. Alternatives emerge when oil prices are high, but wither when prices fall. They rise when public attention is focused on the environmental shortcomings of petroleum fuels, but dissipate when oil and auto companies marshal their considerable resources to improve their environmental performance. When George H. Bush advocated methanol fuel in 1989 as a way of reducing vehicular pollution, oil companies responded by offering cleaner-burning reformulated gasoline (and later, cleaner diesel). And when air regulators in California and the US adopted aggressive emission standards for engines, vehicle manufacturers diverted resources to improve combustion and emission control technologies.

Another problem is the ad hoc approach of governments to petroleum substitution. The US government provided loan and purchase guarantees for coal and oil shale “synfuels” in the early 1980s when oil prices were high, passed a law in 1988 offering fuel economy credits for flexible-fuel cars, launched the Advanced Battery Consortium and Partnership for a New Generation of Vehicles in the early '90s to accelerate development of advanced vehicles, promoted hydrogen cars in the early years of this decade, provided tens of billions of dollars in federal and state subsidies for corn ethanol, and now is providing incentives for plug-in hybrids. State initiatives included California's purchases of methanol cars in the 1980s and its zero emission vehicle requirement of 1990. These many alternative fuel initiatives have failed to move us away from petroleum-based transportation in part because the government did not adopt supporting incentives and plans. More durable policies are needed—ones that are based on performance, that stimulate innovation, and that reduce consumer and industry risk and uncertainty. >

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A low-carbon fuel standard provides a durable framework, doesn't pick winners, encourages innovation, and sends an unambiguous signal to fuel providers that alternatives are welcome.

POLICY SOLUTION

To reduce oil dependence and emissions from transportation we must improve vehicle efficiency, reduce vehicle use, and decarbonize fuels. A new policy approach, we have learned from the past, will be most successful if it embraces certain principles. It must inspire industry to pursue innovation aggressively, and it must be flexible, performance-based, and inclusive so that industry picks the winners, not government. Importantly, any new policy approach should also take account of all greenhouse gas emissions associated with the production, distribution, and use of the fuel, from the source to the vehicle.

We believe a Low-Carbon Fuel Standard (LCFS) is an important and compelling policy instrument for shifting away from petroleum and decarbonizing our transportation fuels. It meets all the criteria listed above. The LCFS is a performance standard that measures CO₂ equivalent grams per unit of fuel energy. An important feature of LCFS is that it takes account of emissions along the entire energy pathway, from source to vehicle. This lifecycle approach is important because it assures that all emissions associated with a fuel are included, from the vehicle that consumes the fuel all the way upstream to the cornfields and oil wells. While upstream emissions account for a small portion of total greenhouse gas emissions from petroleum (about twenty percent), they represent almost the total lifecycle emissions for fuels such as electricity and hydrogen. The new types of fossil energy that companies are using to supplement dwindling sources of conventional crude oil, especially very heavy oils and tar sands, also emit a larger share of their lifecycle emissions in upstream extraction, production, and refining.

The LCFS is the first major public initiative to codify lifecycle concepts into law. The point of regulation could occur anywhere along the energy chain, from the individual user all the way upstream to the fuel producers. To ease administration, it is best placed as far upstream as practical—meaning on oil refiners, importers, and fuel producers. An important feature of the LCFS should be the ability to buy and sell credits, which would help reduce the cost of achieving the reductions. A tradable credit market would give companies a strong incentive to invest in new and better ways to produce lower carbon fuels. An oil refiner could,

for instance, buy credits (or the fuels themselves) from biofuel producers or from an electric utility that sells power to electric vehicles. Those companies that are most innovative and best able to produce low-cost, low-carbon alternative fuels would thrive, and overall emissions would be lowered at less cost for everyone.

The idea of imposing a low-carbon fuel standard is highly attractive because it provides a durable framework, doesn't pick winners, encourages innovation, and sends a direct, unambiguous signal to fuel providers that alternatives are welcome. It's a hybrid of regulatory and market approaches, which makes it more politically palatable (and economically efficient) than a purely regulatory approach.

The concepts underlying the LCFS are not unique, but the intellectual and programmatic antecedents of the LCFS are remarkably sparse. The intellectual origin of the LCFS might be traced to Jonathan Rubin's 1993 PhD dissertation at the University of California, Davis, evaluating the use of tradable credits and emission performance standards in transitioning to alternative transportation fuels. Surprisingly,





the scholarly literature is otherwise largely quiet on the concept of carbon standards for fuels. John DeCicco and Jason Mark suggested it in various publications in the 1990s, but not until Bob Epstein, a former Silicon Valley entrepreneur, began promoting the concept in 2005 did it gain prominent attention. He and others, especially Roland Hwang of Natural Resources Defense Council, an advocacy group, pitched the concept to California Governor Arnold Schwarzenegger in fall 2006. In January 2007, Governor Schwarzenegger directed the California Air Resources Board (CARB) to develop and implement a low-carbon fuel standard to spur technological innovation and investment in alternative fuels. The California Air Resources Board adopted the LCFS on April 23, 2009, with a nine-to-one vote. This revolutionary new requirement calls for at least a ten percent reduction in greenhouse gas emissions (per unit of energy) by 2020.

The European Union unveiled a similar proposal just two weeks after Governor Schwarzenegger, and in December 2008 its Parliament adopted an amended “fuel quality directive” that is very similar to the California LCFS—with EU leaders publicly indicating it was their intent to closely imitate the California standard. In January 2009, eleven Northeastern and mid-Atlantic states signed a letter committing to cooperate in developing a regional LCFS. >



WHY LCFS?

Instead of the LCFS, why not use a volumetric standard like the renewable fuels standard (RFS) adopted by the US Congress? The RFS requires 36 billion gallons of biofuels to be sold annually by 2022, of which 21 billion must be advanced biofuels, while 15 billion can be corn ethanol. The advanced biofuels must achieve at least fifty percent reduction in lifecycle GHG emissions, and a subcategory must meet a sixty percent reduction target. These targets take account of lifecycle GHG emissions, including indirect emissions from changes in land use around the world in response to the changing fuel market. While the renewable fuels standard is a step in the right direction, it has three shortcomings. First, it targets only biofuels. Second, the fifty and sixty percent greenhouse gas reductions are an admirable but clumsy effort that forces biofuels into a small number of fixed categories, which could stifle innovation. And third, the RFS exempts existing and planned corn ethanol production facilities from the greenhouse gas requirements, essentially mandating a massive unfettered expansion of corn ethanol. Rapid expansion of corn ethanol not only stresses food markets and requires vast amounts of water, but also pulls large quantities of prairie lands, pastures, rainforests, and other lands into intensive agricultural production—to replace corn acreage that has been diverted to ethanol production—which means some corn ethanol will likely have higher overall GHG emissions than gasoline or diesel fuels.

Many argue that a carbon tax or cap-and-trade program would improve the RFS. Economists argue that carbon taxes—taxes on energy sources that emit carbon dioxide—would be a more economically efficient way to introduce low-carbon alternative fuels. Former Federal Reserve chairman Alan Greenspan, car companies, and economists on the left and the right all have supported carbon and fuel taxes as the principal cure for both oil insecurity and climate change. But carbon taxes have shortcomings. Not only do they attract political opposition and public ire, they are of limited effectiveness, and they work better in some situations than others. They work well with electricity generation, for example, because electricity suppliers can choose among a wide variety of commercially available low-carbon energy sources. Given the many energy choices available, a tax of as little as \$25 per ton of carbon dioxide would increase the retail price of electricity made from coal by seventeen percent; this increase would effectively motivate electricity producers to seek lower-carbon alternatives. Carbon taxes could transform the electricity industry.

But transportation is a different story. Producers and consumers would barely respond to even a \$50-a-ton tax, well above what US politicians have been considering. Oil producers wouldn't respond because they've become almost completely dependent on petroleum to supply transportation fuels and can't easily find or develop low-carbon alternatives within a short time frame. Equally important, a transition away from oil depends on automakers and drivers changing their behavior—and they also would be unmotivated by a carbon tax. A tax of \$50 a ton would raise the price of gasoline only about 45 cents a gallon. This would barely reduce gas consumption, let alone induce drivers to switch to low-carbon alternative fuels when virtually none are available.

Carbon cap-and-trade programs suffer the same shortcomings as carbon taxes. This policy, as usually conceived, involves placing a cap on the carbon dioxide emissions of large industrial sources and granting or selling emission allowances to individual companies for use in meeting their caps. Emission allowances, once awarded, can be bought and sold. In the transportation sector, a cap would be placed on oil refineries' emissions, requiring them to reduce carbon dioxide emissions associated with the fuels they produce. The refineries would be able to trade credits among themselves and with others. As the cap is tightened over time, pressure would build to improve the efficiency of refineries and introduce low-carbon fuels. Refiners are likely to increase the prices of gasoline and diesel to subsidize low-carbon fuels—creating a market signal for consumers to drive less and for producers of cars to make them more energy efficient. But if the cap is not very stringent, this signal would likely be relatively weak for the transportation sector.

Given the huge barriers to alternative fuels and the limited impact of increased taxes and prices on transportation fuel demand, a low-carbon fuel standard seems to be the most effective instrument available to orchestrate the transition to alternative fuels. Some day, when innovation results in advanced biofuels and electric and hydrogen vehicles become commercially viable, cap-and-trade and carbon taxes will become effective policies with the transport sector. But until then, we need more direct forcing mechanisms like the low-carbon fuel standard for refiners to stimulate innovation and overcome the many barriers to change. The LCFS cannot stand alone, however. It must be coupled with other policies, including fuel efficiency and greenhouse gas emission standards for vehicle suppliers, infrastructure to support alternative fuel distribution, and incentives and rules to reduce driving and enhance transportation alternatives. That, indeed, is California's approach and one that might be embraced by the US and others. ➤





DETAILS OF THE LCFS

California's proposal would impose a ten percent reduction in lifecycle GHG emissions by 2020 on all transport fuel providers, including refiners, blenders, producers, and importers. Aviation and certain maritime fuels are excluded because California either has limited authority over them or cannot overcome logistical challenges.

There are several ways that regulated parties can comply with an LCFS. Refiners can blend low-GHG fuels, such as biofuels made from cellulose or wastes, into gasoline and diesel. Or they can buy low-GHG fuels such as natural gas, biofuels, electricity, and hydrogen. They can also buy credits from other refiners or use banked credits from previous years. In the EU, producers may also earn credit by improving energy efficiency at oil refineries or by reducing upstream CO₂ emissions from petroleum and natural gas production.

A major challenge for the LCFS is avoiding "shuffling." Companies will seek the easiest way of responding to the new requirements, which might involve shuffling production and sales in ways that meet requirements without actually creating a net change in emissions. For instance, a producer in Iowa could divert its low-GHG cellulosic biofuels to California markets, and send its high-carbon corn ethanol elsewhere. The same could happen with gasoline made from tar sands and conventional oil. Environmental regulators will need to account for shuffling in their rules. This problem will eventually disappear as more states and nations adopt the same regulatory standards and requirements.

Perhaps the most controversial and challenging issue is land use changes. When biofuel production increases, land is diverted from food and fiber production to energy production. The displaced agriculture is replaced elsewhere, which for the most part brings new land into intensive agricultural production. This newly farmed land might have been pasture or, because markets are international, perhaps even rainforest. Because soils sequester a vast amount of carbon in roots and organic material—effectively storing more than twice the carbon contained in the entire atmosphere—any change in land usage can have a large effect on carbon releases. Large amounts of carbon are also released when above-ground vegetation is removed, especially from forests.

If biomass production does not cause the removal of large amounts of soil carbon or competition for land via direct or indirect land conversion—for instance when its sources are crop residues or urban trash—then indirect land use effects are small or even zero. But if rainforests are destroyed or peat burned, as is occurring in southeast Asia to accommodate growing demand for palm oil to supply biodiesel for the European market, then the carbon releases are huge. In extreme cases, these land use shifts result in each gallon of palm oil releasing several times as much carbon as the diesel fuel it replaces. In the case of corn ethanol, the indirect land use effects are smaller, but still significant. Cellulosic fuels would have a much smaller effect, and waste biomass, such as crop and forestry residues and urban waste, would not compete for land and result in no land use changes.

The problem is that few scientific studies have attempted to quantify the indirect land use effect. The prudent approach for regulators is to use available science to assign a conservative value to the effect, and then provide a mechanism to update these assigned values as science improves. Meanwhile, companies should focus on biofuels with low greenhouse gas emissions and minimal indirect land use effects—fuels created from wastes and residues and from biomass grown on degraded or marginal land or with very high yields per unit of land (e.g., grasses, some tree species, and algae). Those feedstock materials and lands should be the heart of a future biofuels industry, instead of intensively farmed food crops like corn.



GOING NATIONAL AND INTERNATIONAL WITH A LOW-CARBON FUEL STANDARD

The principle of performance-based standards lends itself to adoption of a national or even international LCFS. The California program is designed to be compatible with a broader program and in fact will be much more effective if the entire US as well as other countries also adopt it. Existing volumetric biofuel requirements could be readily converted into an LCFS by converting them to greenhouse gas requirements. In the US that would not be difficult, since GHG requirements are already imposed on required biofuels. The European biofuels programs could also be converted similarly. Indeed, in Europe and the UK the Renewable Transport Fuel Obligation's evolving carbon and sustainability reporting and certification schemes are already gravitating away from a pure volumetric requirement and toward an LCFS.

An important innovation of the California LCFS is its embrace of all transportation fuels. The US renewable fuels standard and the European programs, in contrast, include only biofuels, not gaseous fuels or electricity (although biogas is eligible for credits in the EU, and the December 2008 revisions of the EU fuel quality directive envision a future role for electric vehicles). While it is desirable to cast the net as wide as possible, there is no reason why all states and nations must target identical fuels.

Broader LCFS programs are attractive for three reasons. First, it would be easier to include fuels used in international transport modes, especially jets and ships. California is excluding these fuels initially because it has limited jurisdiction over international modes of travel. Second, a broader low-carbon fuel standard would facilitate standardization of measurement protocols. California is currently working with fuel-exporting nations to develop common greenhouse gas emissions specifications for their fuels. And third, the broader the pool, the greater the options available to regulated entities. More choice means lower overall cost, since there will be greater chance of finding low-cost options to meet targets. ➤

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CONCLUSION

The ad hoc policy approach to alternative fuels has largely failed. A more durable and comprehensive approach is needed that encourages innovation and lets industry pick winning technologies. The LCFS does that. It provides a single greenhouse gas performance standard for all transport fuel providers, and uses credit trading to ensure the transition is accomplished in an economically efficient manner. It encourages investments in low-carbon fuels and provides strong incentives to produce high-carbon fossil fuels more energy efficiently and with low-carbon energy inputs.

While one might prefer more theoretically elegant policies such as carbon taxes and cap-and-trade, those instruments are not likely to be effective with transport fuels in the foreseeable future. Though they would be attractive complementary measures, by themselves they are not sufficient to induce large investments in electric vehicles, plug-in hybrids, hydrogen fuel cell vehicles, and advanced biofuels.

Ideally, the US and other nations will eventually adopt a low-carbon fuel standard. This will probably require some political accommodations, such as variation in targets across nations and possibly states. One unacceptable accommodation, however, would be a failure to require standardized measurement protocols. The prospect of an international LCFS that guides the transformation of transportation fuels and oil companies is a very real possibility. Indeed, the low-carbon fuel standard promises to play a central role in creating a low-carbon energy future. ♦

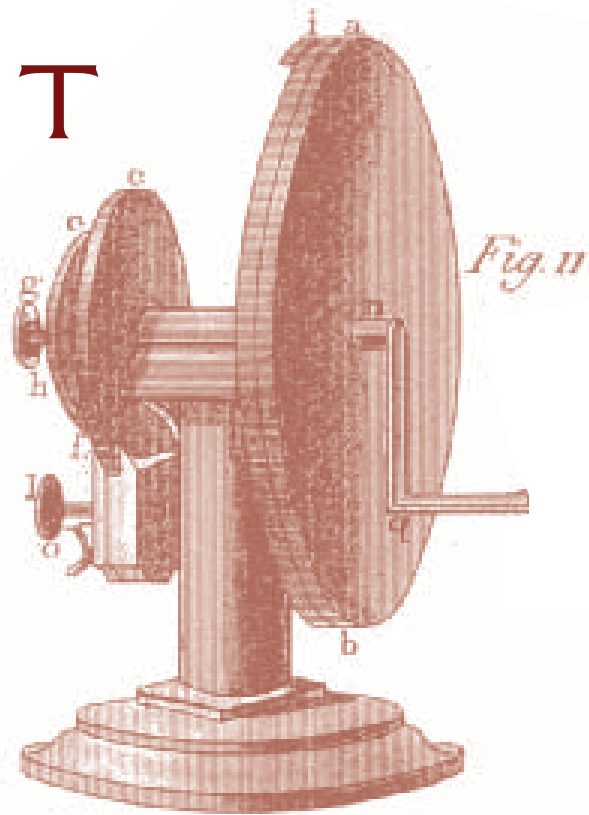
Acknowledgments

We honor our colleague, Professor Alex Farrell, for his leadership and intellectual contributions in developing the initial design of California's LCFS. Along with Daniel Sperling, he co-directed the initial study design of the Low Carbon Fuel Standard in California and helped conceptualize this paper before his untimely death in April 2008. This paper is adapted from and similar to Daniel Sperling and Sonia Yeh's article, "Low Carbon Fuel Standard," in Issues in Science and Technology, Winter 2009, pp. 57–66.

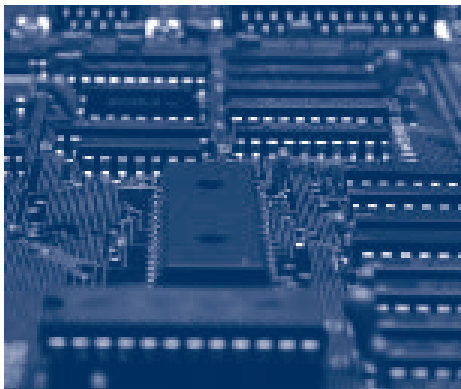
INTELLIGENT TRANSPORT SYSTEMS

LINKING TECHNOLOGY AND TRANSPORT
POLICY TO HELP STEER THE FUTURE

BY ELIZABETH DEAKIN, KAREN TRAPENBERG FRICK,
AND ALEXANDER SKABARDONIS



IF YOU'VE SEEN AN ELECTRONIC MESSAGE SIGN along the highway that tells you how long it will take to get downtown or to the airport, or paid your toll or your parking fees with an electronic tag, or ridden a bus that triggered the traffic lights to turn green as it approached them, then you have experienced some of the benefits of Intelligent Transportation Systems (ITS)—an umbrella term for a variety of new technologies and operations methods for highways and transit. Other on-the-ground ITS applications are less visible to the average traveler, but every bit as useful: they help traffic managers detect and respond to accidents promptly, handle the extra traffic that special events generate, and help state workers safely plow snow on mountain roads in blinding snowstorms.



ITS proponents see an even bigger future for new technologies in transportation—applications that could transform the way transportation systems are designed, operated, and used. To paraphrase one expert: Imagine that car crashes are rare events, traffic flows smoothly even in rush hour, travel times are reliable, up-to-the-minute travel information is ubiquitous, and pollution and wasted fuel from traffic jams are a thing of the past. This vision of Intelligent Transportation Systems has >

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attracted billions of dollars of R&D funding and some of the best minds in the field, both in university research groups and in the private sector, over the past two decades.

Yet Intelligent Transportation Systems also face a host of barriers, only some of which are technological. Deployment costs, funding restrictions, liability concerns, uncertain demand, institutional inertia, and political challenges have limited ITS implementation in a number of cases.

To document the key accomplishments of ITS, find out what is on the horizon, and uncover the challenges to broader implementation of technology-based transportation improvements, we conducted a series of interviews with more than two dozen technical experts and policy makers, including academics and industry experts in California and elsewhere in the US. Here we present the highlights of our findings.

KEY ACCOMPLISHMENTS OF ITS

Technological improvements that emerged from ITS research are now so ubiquitous that we take them for granted. They include objects like electronic tags on car windshields for paying tolls and parking charges and “smart cards” for paying transit fares. Travelers also benefit from ITS innovations such as real-time traffic and transit information systems, from

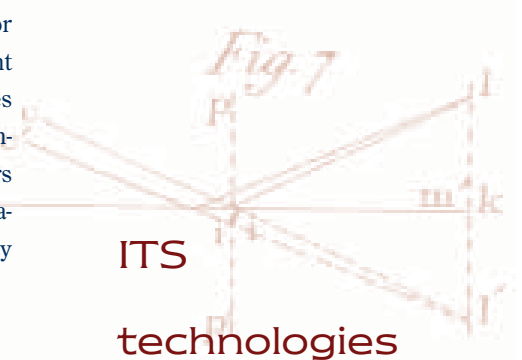
the national phone number 511 to map and directions applications for dashboard displays, cell phones, and PDAs. We barely notice that many traffic signal systems are coordinated along corridors and in grid networks, adjusting signals based on the actual numbers of vehicles present, both for daily traffic and for special events. Other ITS improvements we have come to rely on include safety technologies such as vehicle collision warning and avoidance systems and on-board driver monitoring systems for commercial vehicles, as well as freight identification and routing information systems that get baggage to the right airport and packages to the right address.

Technologies like these make travel easier and more convenient. Many of them also make the transportation system more efficient by increasing the number of people and vehicles that can be comfortably accommodated in a travel corridor. In addition, these technologies provide operators with information about the transport system that can be used for better planning, operations, and management. For example, the PeMS data management system, developed with Caltrans funding at California PATH, allows transportation agencies to store and process massive quantities of data from roadway sensors quickly and inexpensively. The resulting data sets measure traffic volumes and congestion levels, which planners use to analyze system performance and develop improvements. New sensors also instantaneously detect unusual delays and stoppages, allowing managers to dispatch emergency service vehicles far faster than previous methods of monitoring could do.

EMERGING APPLICATIONS

As computer and wireless technologies continue to improve, ITS researchers are finding new applications for them in transportation. Recent examples include smart parking applications that direct drivers to empty parking spaces so they don't have to cruise around looking for parking. Travelers can use their cell phones and PDAs to find transit routes and schedules from their current location or from a proposed departure point to a planned destination, and to check the arrival time of the next bus or train. Detector systems are growing more sophisticated, and can now warn motorists of ice on the pavement, pedestrians in the crosswalk, and debris in the lane ahead. Dashboard displays can now tell drivers how much fuel they are using so that they can improve their driving efficiency.

Such technologies are already making travel safer and more environmentally friendly as well as easier and more efficient, and new applications currently under development have the potential to provide significantly enhanced benefits. For example, researchers are developing vehicle-to-vehicle communication systems that would automatically warn motorists that a vehicle ahead of them is braking. These systems could also automatically slow or stop a vehicle following one that puts on the brakes. Improved information technologies and vehicle routing and scheduling algorithms will reduce how far in advance paratransit services must be reserved, for example, from 24 hours to perhaps only two or three hours in advance. Integrated weather forecasting, hazard identification, and traffic management systems will allow traffic managers to adjust speed limits and signal timings, deploy emergency services and maintenance personnel, close threatened facilities, reroute traffic, disseminate information about conditions to the public, and if necessary provide information and support for evacuations. Corridor management systems will include information on transit travel times as well as highway times. And advanced electronic freight management systems will be able to provide a single manifest for shipments being transported by several different modes. >



ITS
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THE IMPLEMENTATION CHALLENGE

Despite the proven success of many ITS applications and the promise of more to come, ITS continues to face a number of challenges. These range from communicating what new technologies can do, to expectations about the speed of implementation, to lack of funding for implementation and operations. We list several of the most common implementation challenges below.

Communicating the benefits of new technologies to decision-makers

Elected officials and agency leaders who must make decisions about whether to invest in new technology development and deployment complain about the jargon that technology developers often use—a host of abbreviations and details that busy decision-makers do not need to understand and do not want to learn. Policymakers are looking instead for a clear description of why the new or proposed technology would be beneficial: what outcomes it would produce and what it would cost compared to other ways of accomplishing the same results. Better communications would be aided by cost-benefit analyses comparing new technology to conventional approaches as well as independent evaluations of completed projects. This suggests there is a need for technology developers to partner with social scientists with expertise in evaluation methods.

Managing expectations for near-term results


Funders want to see results from their investments in ITS, but it can take years to move a technology from “proof of concept” to full deployment. In between these two stages, it’s typical to make many refinements to the technology to improve performance and reliability and to reduce costs. Realistically, not all research results are likely to be deployable in the short or even medium term, but this is not always understood by sponsors. Yet a push for quick results can undermine technology development and reduce the prospects for success: a focus on fast implementation could miss out on longer-term but much larger payoffs. A fine balance needs to be struck between the desire for results and the premature introduction of new technologies that need more development.

Finding an appropriate role for the private sector

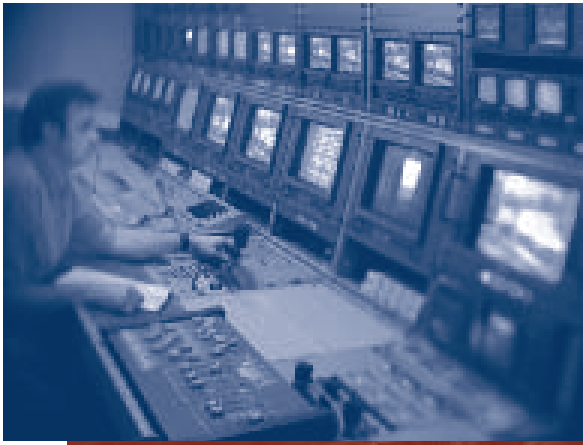
The private sector often plays a key role in moving technology from “proof of concept” through development and on to implementation. Private sector interest is, of course, one test of the market for a new technology, and private partners can be a major source of funding for technology development and testing. Industry and business leaders can also play important advisory roles, helping researchers identify possible markets and applications, understand the competition, and develop realistic cost and performance criteria. On the other hand, private sector involvement raises questions about intellectual property ownership, publication rights, competitive bidding obligations, and more. Case-by-case consideration of the roles that private companies can play needs to be a key part of ITS implementation planning.

Involving Users and Stakeholders

Understanding the perspectives of likely users of a new technology can improve the chances of implementation—or lead to a reconsideration of the technology project before too much money is spent on a product that will not find a sufficient market. Owners and operators of public facilities often include the state department of transportation as well as numer-



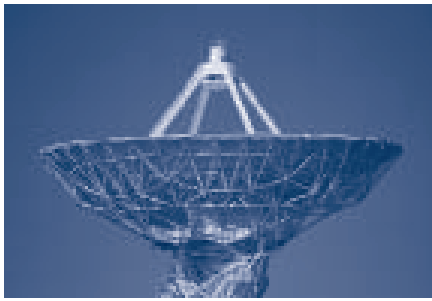
Policy makers
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ous local governments, transit agencies, delivery services, and freight transporters, as well as individual drivers. Businesses and residents also have a stake in changes that affect the transportation systems they rely upon, and often will have a say in those changes. Early involvement of these diverse stakeholders can help in at least three ways: identifying likely supporters and early adopters; understanding concerns early enough to address them in product designs and deployment plans; and introducing new concepts far enough in advance that stakeholders can develop a degree of familiarity with them. On the other hand, broad-based involvement requires skills in public outreach that are quite different from those most technology developers hold. Early stakeholder involvement also may be problematic in cases where the objective is to create for-profit applications.

Developing Workable Business Plans

In some cases, the business plan for transportation technologies has been underdeveloped; in other cases it has been overly rigid. Moving new technologies from the lab to real-world deployment requires a detailed yet flexible business plan. Business plans can help temper unrealistic expectations. For example, public agencies have sometimes assumed >



that there would be a market for new technologies they develop or for data their systems produce, only to discover that other agencies are uninterested in paying for the new technology or expect data generated on public facilities to be available without charge. Business plans can also help develop suitable contract provisions for anticipated applications. Many public agencies are accustomed to detailed specifications, but with new technologies with as-yet-unknown applications, flexibility is a desirable contract characteristic. Planning ahead for this can help reduce delays and conflicts.

In addition, for technologies that will remain in the public sector, a long-term funding plan is needed. Although new technology applications often can be paid for using standard funding sources, funding for even well-proven technologies like highway monitoring systems has been far from a sure thing. In a number of cases, monitoring systems have been dropped from projects when budgets tightened. Maintenance funding has also been a problem. In particular, underfunding of sensor maintenance has reduced the effectiveness of this large investment in street and highway instrumentation. Making the funding plan part of the technology assessment and business plan could help overcome these difficulties.

MEETING THE CHALLENGES

The challenges to ITS implementation are serious, but they need not be barriers. The non-technological challenges can be addressed by planning and policy researchers, social scientists, and law and business experts whose know-how would complement that of the engineers and scientists who are creating new technologies. The transportation problems that new technologies aim to address have strong legal, institutional, social, environmental, and economic dimensions; research should likewise cover the broader planning and policy context as a complement to technology development. Greater attention to these complementary research needs can help move ITS technologies from special initiatives to the mainstream. ♦

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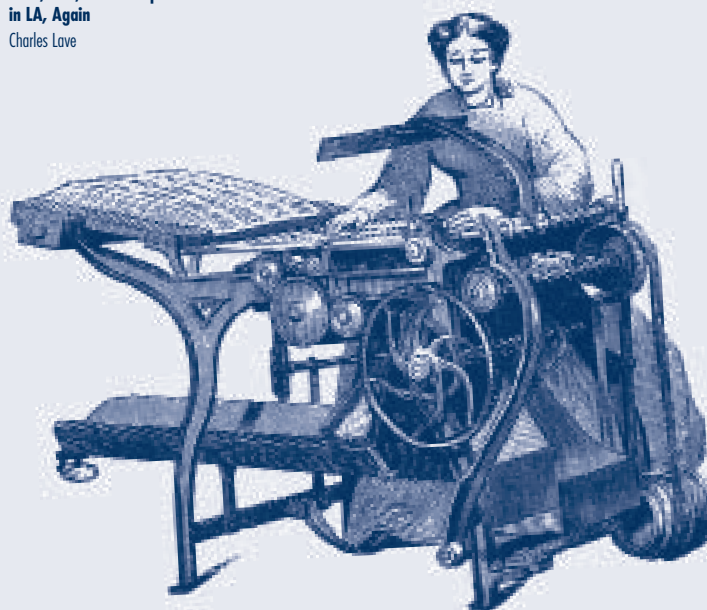
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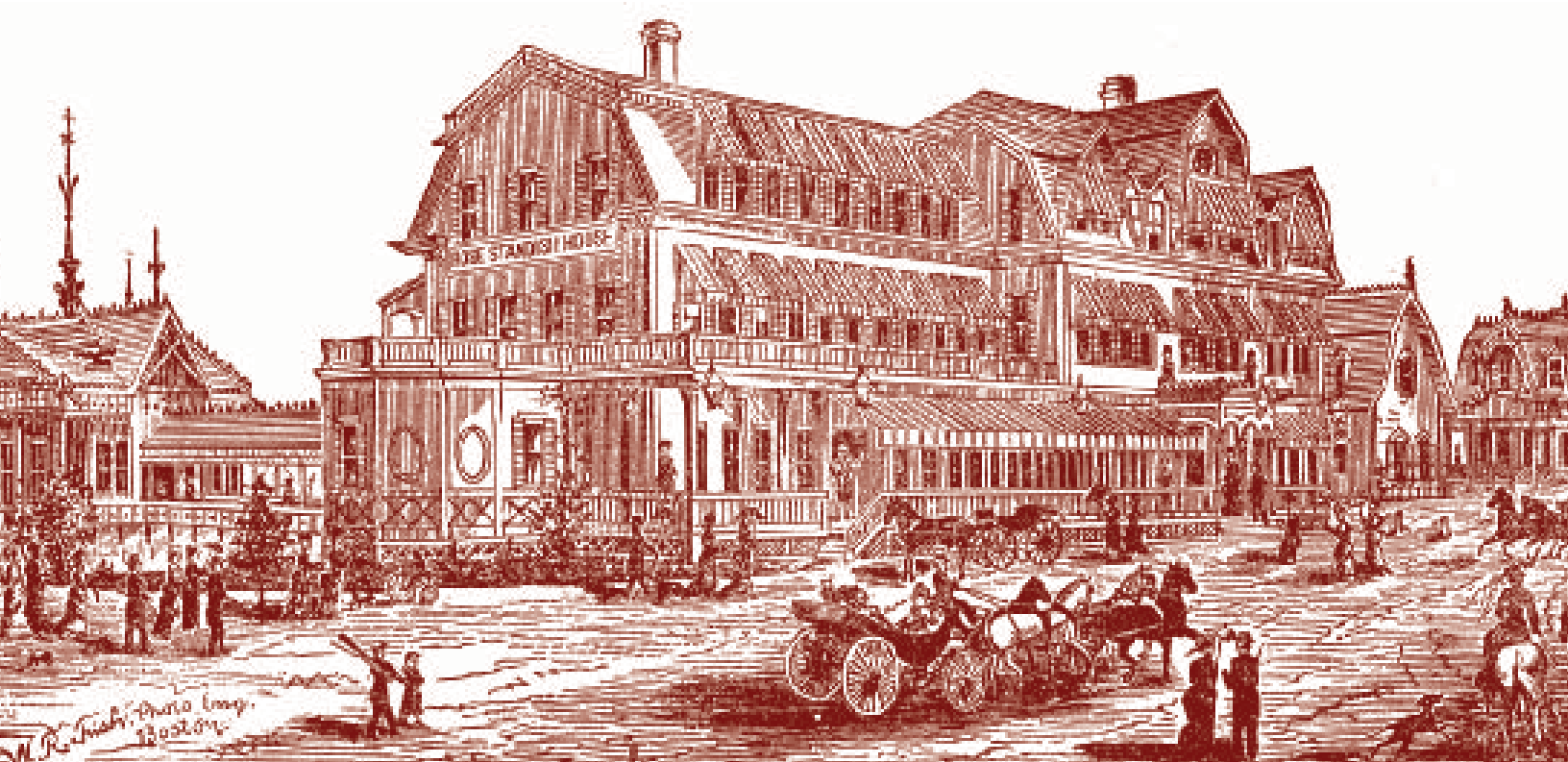
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