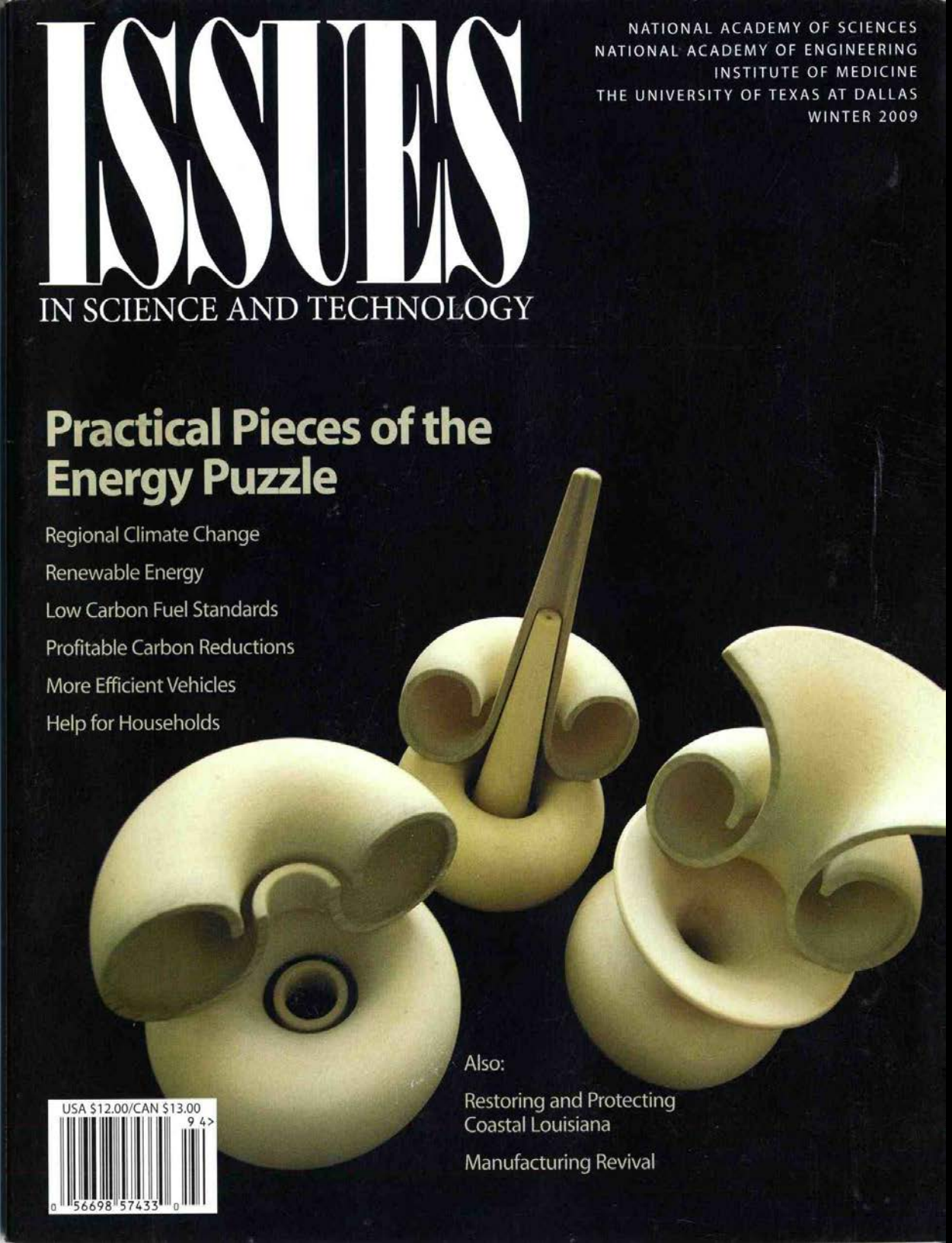

In Winter 2009, the culobocca family was featured by the National Academy of Sciences in a special issue on energy.

National Academy of Sciences
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Above: Geoffrey Thün and Kathy Velikov, The Post-Carbon Highway. *Image courtesy of RVTR (www.rvtr.com).*

Cover: Robert Kirkbride, Culobocca.

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Getting More Miles per Gallon

The answer may require looking beyond CAFE standards and implementing other consumer-oriented policy options to wean drivers away from past habits.

In December 2007, concerns over energy security and human-induced climate change prompted Congress to increase Corporate Average Fuel Economy (CAFE) standards for the first time in 20 years. The new standards aim to reduce petroleum consumption and greenhouse gas (GHG) emissions in the United States by regulating the fuel economy of new cars and light trucks, including pickups, SUVs, and minivans. The standards will require these vehicles to achieve a combined average of 35 miles per gallon (mpg) by 2020, up 40% from the current new-vehicle average of 25 mpg.

Since Congress acted, the nation witnessed a dramatic rise in the prices of petroleum and gasoline, which reached record levels during the summer of 2008, increasing pressure on policymakers to reduce transportation's dependence on petroleum. Prices have since fallen markedly with the arrival of an economic crisis. But few observers expect prices to stay low when the economy recovers, and many see a future of steadily rising prices, driven by global economic expansion. Thus, the goal of reducing the nation's thirst for gasoline remains an important goal. And although striving to meet the CAFE standards will be an important part of the mix, other policy initiatives will be necessary to make timely progress.

Although the nation's collective gas-pump shock has lessened, the lessons from recent experiences are telling. In June 2008, the average price of crude oil doubled from a year earlier, and gasoline prices rose by one third. High fuel costs sharpened the public's awareness of fuel use in light-duty vehicles, causing them to seek alternatives to gas-guzzling private vehicles. Sales of light trucks during the first half of 2008 were down by 18% relative to the previous year, and total light-duty vehicle sales dropped by 10%. The total distance traveled by motor vehicles fell by 2.1% in the first quarter of 2008 relative to the same period in 2007. At the same time, ridership on public transportation systems showed rapid growth in the first quarter of 2008, with light-rail ridership increasing by 7 to 16% over 2007 in Minneapolis-St. Paul, Miami, and Denver.

These changes marked major changes from trends of the past two decades, when fuel prices were low and relatively stable. During this period, fuel economy standards remained unchanged for cars and largely constant for light trucks. Proponents of more demanding CAFE requirements argue that the standards stagnated during this period, allowing automakers to direct efficiency improvements toward offsetting increases in vehicle size, power, and performance rather than improving fuel economy. On the other hand, critics of

ROBERT KIRKBRIDE, *Culobocca*.

retail price increase that could be expected, although the price arrived at in a competitive auto market would be subject to various pricing strategies that may increase or decrease the final price tag. With a strong emphasis on reducing fuel consumption over the next 25 years, the average price of a conventional gasoline vehicle could increase by around 10% relative to today's mid-sized sedan such as the Toyota Camry or light truck such as the Ford F-150.

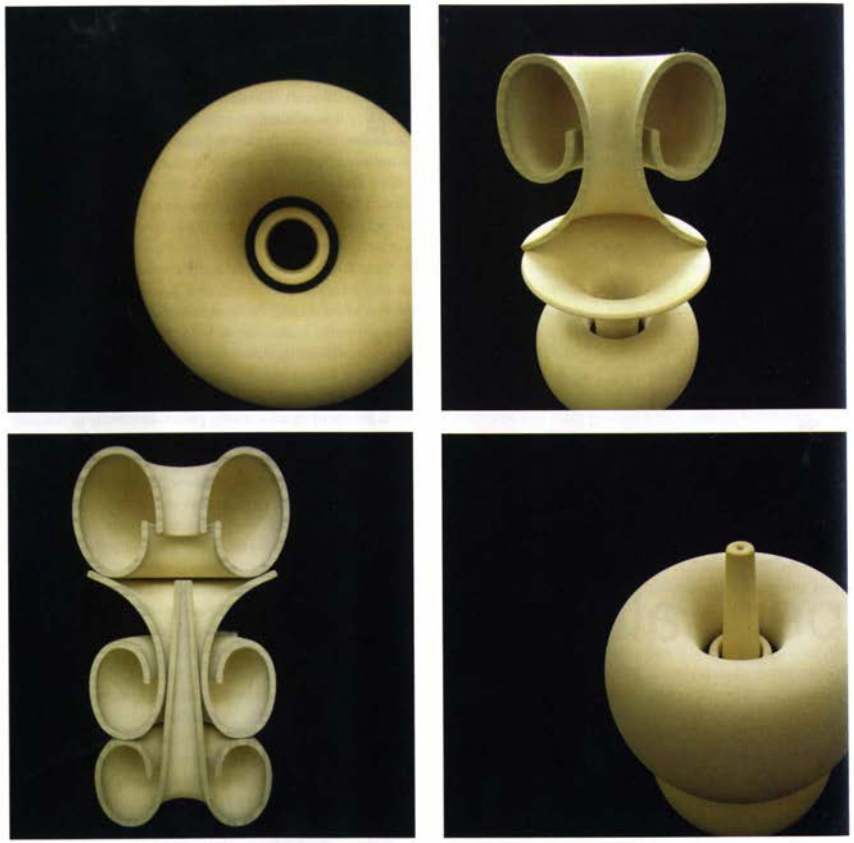
Shifting from a conventional gasoline engine to an alternative powertrain would further increase the cost of manufacturing a vehicle. In 2035, the retail price of a vehicle could increase by $700 to $800 for a turbocharged gasoline engine and by $1,700 to $2,100 for a diesel engine. Future hybrid-electric powertrains could increase the manufacturing cost of a conventional gasoline vehicle by $2,500 to $3,200 in 2035. These costs correspond to a retail price increase of 5 to 15% above the price of today's gasoline vehicle. Achieving a 35% reduction in vehicle weight by 2035 would add roughly $2 to the cost of manufacturing a vehicle for every kilogram of weight removed. This would increase the retail price of a conventional gasoline vehicle in 2035 by roughly 10% compared to today.

Not accounting for fuel savings, the total extra manufacturing cost to double fuel economy in the average vehicle by 2035 would be between $55 billion and $65 billion in constant 2007 dollars in the 2035 model year alone, or an additional 15% to 20% of the estimated baseline manufacturing cost in 2035 if fuel economy were to remain unchanged from today. Over 15 years of vehicle operation, this corresponds to a cost of $65 to $75 to reduce one ton of greenhouse gas emissions.

For the average consumer, this translates into a retail price increase of $3,400 for a car with doubled fuel economy in 2035, and an increase of $4,000 for a light truck. If the fuel savings provided by doubling fuel economy are taken into account, the undiscounted payback period (that is, the length of time required for the extra cost to pay for itself) is rroughly five years for both cars and light trucks at the Energy Information Administration's long-term gasoline price forecast of $2.50 per gallon. At $4.50 per gallon—a price that didn't seem out of the question in mid-2008—the undiscounted payback period shortens to only three years.

Engaging the policy gear

Although it is technically possible to double the fuel economy of new vehicles by 2035, major changes would be required from the status quo. Tough trade-offs will need to be made among improvements in vehicle performance, cost, and fuel economy. Although CAFE is a powerful pol-



ROBERT KIRKBRIDE, *Culobocca*, Plaster, water, epoxy, Z-Corp Spectrum ZS10 3D printer, 7.75" x 6" diameter. Special thanks to Veronica Choi.

icy tool, it is also a blunt instrument for grappling with the magnitude and cost of these required changes for two reasons: It has to overcome the market forces of the past two decades that have shown a strong preference for larger, heavier, and more powerful vehicles; and in attempting to reverse this trend, CAFE places the burden of improving fuel economy solely on the auto industry.

As buyers have grown accustomed to current levels of vehicle size and performance, domestic manufacturers have profited from providing such vehicles. In contrast, increasing CAFE standards may require abrupt changes in vehicle attributes from automakers whose ability to comply is constrained by the high cost of rapid changes in technology. More consistent signals that buyers are willing to pay for improved fuel economy would justify the investments needed for compliance.

Such signals can be provided by policy measures that influence consumer behavior and purchase decisions. First, providing financial incentives for vehicles based on their fuel economy would strengthen the market forces pulling efficiency improvements toward improving fuel economy. Second, raising the cost of driving with a predictable long-term price signal would further reduce the popularity of gas-guzzlers, encouraging the adoption of fuel-sipping vehicles over time. These complementary measures can sharpen the bluntness of CAFE by providing clear incentives to consumers that directly influence market demand for fuel economy.

Feebates are one such reinforcing policy that would reward buyers for choosing improved fuel economy when they purchase a new vehicle. Under a feebate system, cars or trucks that achieve better than average fuel economy would receive a rebate against their retail price. Cars or trucks that achieve worse than average fuel economy would pay an extra fee. Effectively, sales of gas-guzzling vehicles subsidize the purchases of models with high fuel economy.

Feebates have several advantages. They can be designed in a revenue-neutral manner so that the amount paid in rebates is equal to the revenue collected from fines. They do not discriminate between vehicles that employ different technologies but focus on improving fuel economy in a technology-neutral manner. And they provide a consistent price incentive that encourages manufacturers to adopt technologies in ways that improve vehicle fuel economy. A drawback is that feebates require administrative oversight in defining how the fees and rebates will be calculated and in setting an increasingly stringent schedule in order to balance revenue against disbursements.

Feebates have been proposed in France and Canada. France's scheme is aimed at achieving the European Commission's objective of reducing new vehicle carbon dioxide

ROBERT KIRKBRIDE, *Culobocca*.

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Based on our cost assessment, the feebate measure would be strong enough to neutralize the retail price increase of enhancements of conventional gasoline engines that improve fuel economy and most of the increased price from purchasing a more fuel-efficient turbocharged gasoline engine. It would offset roughly half of the price increase of a diesel engine and more than a third of the price of a hybrid-electric powertrain. By effectively subsidizing manufacturers to adopt technologies in ways that improve fuel economy, such feebates would ease the internal pricing strategies of automakers while sending consumers a clear price signal at the time of vehicle purchase.

The second measure, increased fuel taxes, would send a continuous signal to consumers each time they fill up at the pump. Under our suggested policy package, the federal government would increase its fuel tax by roughly 10 cents a gallon annually over five or more years. This would provide a moderate but consistent signal to consumers over the longer term. Such a policy alone could stimulate a 4 to 8% reduction in annual gasoline consumption over 10 to 15 years, given recent estimates of the sensitivity of gasoline demand to changes in price. Alongside CAFE, sustained fuel tax increases could match the public's desire for more miles per gallon to fuel economy regulations that the public might not otherwise prefer.

The combined effect of these two policies is consistent and reinforcing: Consumers respond to feebates and fuel prices in a way that aligns their desire for fuel economy with requirements placed on manufacturers. These demand-side measures would encourage consumers to choose vehicles that achieve more gallons per mile, an approach that harnesses market forces to pull efficiency gains in vehicles toward improved fuel economy alongside the regulatory push provided by CAFE. A sustained demand for better fuel economy from consumers would also assuage the fears of automakers that they will be stuck with CAFE's price tag.

Just as there is no silver bullet in the various technology options now available or just over the horizon, controversy