

LETTERS

Reducing CO₂ Emissions: Turn Down the Heat, Crank Up Efficiency

In a splendid survey of new technologies and new thinking about ways to save fossil fuel (PHYSICS TODAY, November 2000, page 29), Arthur H. Rosenfeld, Tina M. Kaarsberg, and Joseph Romm included the building sector. However, they did not make the obvious (to me) suggestion that buildings be less heated in the winter, perhaps to 70°F instead of 72°F, and especially that they be less refrigerated in the summer, perhaps no colder than 78°F or 80°F.

In France, it is a rule of thumb that setting your thermostat 1°C higher in the winter leads to a 7% increase in your fuel bill (3.9% per degree Fahrenheit). The cost per degree of air-conditioning must be about the same. In winter, Americans might learn to put on a sweater instead of turning up the thermostat—that's what I did when I moved to France.

BEROL ROBINSON
(berol@ecolo.org)
Meudon, France

The article by Rosenfeld, Kaarsberg, and Romm deals with essentially marginal methods for reducing CO₂ emissions. It ignores nuclear power, which is capable of a major effect. According to the International Atomic Energy Agency,¹ US electric power is 20% nuclear generated, but that percentage is likely to shrink rather than grow in coming years unless steps are taken to encourage new nuclear facilities. No nuclear power plants have been licensed since 1978; the costs of nuclear plants are at least doubled by delays caused by licensing, inspections, reviews, and intervenor hearings. Moreover, in the 12 years that it is estimated to get a nuclear plant on line, the cost is doubled by inflation and interest charges.

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Many of the nations that agreed to the Kyoto Protocol get a major share of their electric power from nuclear plants: France, 75%; Sweden, 47%; UK, 29%; and Japan, 36%. Moreover, in most countries, power plants are government operated; several countries have plans to convert more of their power generation to nuclear: France, for example, has a stated goal of 95%. I have no doubt that conversion to nuclear power will be a factor in their strategy to comply with Kyoto.

An interesting possibility would be siting a nuclear power plant in Mexico near the California border for the express purpose of selling power to the US grid. Freed from US red tape, a plant might be on line in five years or less, would cost about half as much, and would be near a power-hungry market, already suffering from high costs for power. That would make a real contribution to lowering CO₂ emissions.

Reference

1. J. Johnson, *Chemical Engineering News*, 2 October 2000, p. 39.
D. G. KARRAKER
(david.karraker@srs.gov)
Aiken, South Carolina

The authors confined their discussion of reducing carbon dioxide emissions to end uses, and therefore did not discuss energy generation. However, they should have mentioned the possibility of operating the railroads, and perhaps automobiles, with electricity generated by nonpolluting methods, such as nuclear, wind, or solar power, instead of burning fossil fuels in internal combustion engines. Already a major part of the electricity running the railroads in western Europe is nuclear generated. In France it amounts to 75%.¹

Reference

1. Nuclear News Staff, *World Directory of Nuclear Utility Management*, 12th ed., American Nuclear Society Inc., La Grange Park, Ill. (2000).
JOHN E. TANNER
(pust@srv.net)
Idaho Falls, Idaho

Kudos indeed to the "three US automakers—DaimlerChrysler, Ford, and General Motors" for producing prototype hybrid electric-gas cars that emit less carbon dioxide.

It might have made a more complete article if the authors had also mentioned two non-US automakers that are already in full production with such vehicles. The Honda Insight and Toyota Prius have been available to consumers in Japan for more than three years and in North America and Europe for several months.

JOHN WALMSLEY
(john.walmsley@ca.jdsuniphase.com)
JDS Uniphase
Victoria, British Columbia, Canada

Several small ground transportation manufacturers have gone beyond the technology discussed in the box "A Doubly Efficient Electric Hybrid" on page 33. The cars discussed require the alternator-motor to rotate the gasoline or diesel engine crankshaft in battery-operated mode, reducing efficiency. That problem can be eliminated.

Magnet-Motor GmbH of Starnberg, Germany, replaces the conventional drive train with two "hub motors"—inside-out permanent-magnet DC motors with the magnets rotating and connected directly to the wheel hubs without gears. The engine drives a large alternator, and the design offers state-of-the-art speed control, rectification, and regenerative braking with battery storage. This technology is applied in hundreds of Swiss trolley buses and in nearly all diesel European airport buses; the technology is available for all power sources.

Lockheed Martin Control Systems of Johnson City, New York, uses a similar arrangement that has an alternator, state-of-the-art control, and regenerative braking with battery storage, but one large DC motor delivers power through a drive shaft, differential, and rear axle, or through double drive shafts and planetary gears. The New York City Transit Authority is apparently pleased with
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the performance of these vehicles and now has a large fleet.

G. G. S. Engineering/Stored Energy Technology in Derby, UK, has taken the magnet-motor concept and placed it in a standard resilient wheel (for a light-rail car or street-car), reducing weight and complexity. The concept should have even greater advantages for automobile applications.

Also in the UK, J. P. M. Parry & Associates of Cradley Heath has several low-floor, lightweight, flywheel-storage tramcars in trial operation for low-cost public transit, but has not yet used the hub- or wheel-motor concepts.

I suggest taking the hub- and wheel-motor concepts and reducing weight and complexity by replacing the rotating permanent magnets with rotating slanted copper or aluminum bars to form an inside-out hysteresis-nonsynchronous AC motor, that is, one with slanted rotating conducting bars allowing efficient operation below synchronous speed; the bars would be shaped to ensure efficient air cooling by fan action. US transit engineering expert William Vigrass has suggested possible all-wheel steering, "crab" berthing when standing, and the ability to follow a slightly modified rail right-of-way with automatic guidance and rear wheels following front wheel paths.

An experimental bus line in Trieste, Italy, designed by Breda of Italy, is all electric, using rails in the street that are powered only when the bus is over them. The bus has battery storage for limited off-rail capability, and does not require the rail for steering. Why not place power rails at specific bus stops and use battery power between? And why not extend the concept to an all-electric personal car system with the driver positioning his car on power rails at "filling stations" to charge the battery for, say, 500 km to the next charge? A similar French system is on trial on the Marseilles, France, tram line. Perhaps my "wheel motor" suggestion can make such a system even more practical for personal vehicles.

DAVID LLOYD KLEPPER
Jerusalem, Israel

ROSENFELD, KAARSBERG, AND ROMM REPLY: We are pleased to

receive letters with excellent suggestions for more technologies that could substantially reduce carbon dioxide emissions. For the article, however, we had limited our detailed discussions to those technologies that were included in the 1997 five-labs study.

We disagree with David G. Karaker's suggestion that any single technology will be the silver bullet for the climate-change problem. Our experience from the comprehensive, multisector five-labs study, in which various technologies competed against each other, is that a broad portfolio of technologies in all sectors is needed for a credible strategy to reduce carbon dioxide emissions. In addition, we explicitly excluded the utility sector in our article, because the five-labs study on which the article was based predated the implementation of any utility deregulation plan. The report from that study also included nuclear power (extending the lives of existing plants) as an option accounting for up to 5% of the utility sector's carbon reductions.

Although we omitted discussion of the power sector because of policy uncertainties, the power sector is the single largest contributor to US CO₂ emissions. In fact, all three of us are now working on power technology issues. The electric power industry probably has the greatest efficiency backlog! Since the late 1950s, the fossil-fuel efficiency of electric utilities has been stagnant at about 30%. This lag in efficiency, however, cannot be blamed on a lack of innovation in power technologies. The regulated monopolies have had no incentive to take advantage of numerous advances in combustion, renewable, and nuclear power technologies. For example, efficiencies for natural gas-fired combustion turbines already have risen from 20% in the mid-1970s to nearly 60% for today's utility-sized (several hundred megawatt), combined-cycle units.

As for John Walmsley's criticism that we neglected the two commercial hybrid cars, that omission was unintentional. For brevity, specific vehicle names were edited out of the sentence "Technologies to double vehicle miles per gallon are available today." We are big fans of these hybrids; in fact, one of us (Kaarsberg) just bought a Prius. The vehicles were not mentioned in the Partnership for a New Generation of Vehicles box on page 33 because neither Honda nor Toyota is a member

of that collaboration. We described a simplified hybrid because it was the quickest, most straightforward way to briefly highlight the energy savings. We also appreciate David Lloyd Klepper's detailed explanation of more sophisticated commercially available hybrids.

ARTHUR H. ROSENFELD

*(Arosenfe@energy.state.ca.us)
California Energy Commission
Sacramento, California*

TINA M. KAARSBERG

(Tina.Kaarsberg@ee.doe.gov)

US Department of Energy

Washington, DC

JOSEPH ROMM

(jromm@getf.org)

*Center for Energy and Climate Solutions
Annandale, Virginia*

Quantum Theory Comes in Waves and Particles

Certainly there is no unique answer to Frank Wilczek's question, "What Is Quantum Theory?" (PHYSICS TODAY, June 2000, page 11). I was not certain that a pragmatic answer, which I proposed for a course in applied quantum mechanics,¹ would be sustainable for the entire course, but it seems that it was. That answer was the assertion that everything is both a particle and a wave, and that everything else would follow from that one assertion. Planck's constant arose when the velocity of a wave (the derivative of the frequency with respect to wavenumber) was equated to the velocity of a particle (the derivative of the energy with respect to momentum), so that energy is proportional to frequency and momentum to wavenumber, with the same proportionality constant $\hbar$.

When Hamiltonian mechanics was introduced, "everything" became anything that can be described by such mechanics, or anything that satisfies a wave equation. Quantum theory does not say what nature gives, only how to predict the behavior of what is given. If nature serves up particles with half-integral angular momentum, the wavefunction that describes them must go into its negative when they are interchanged, and they therefore obey the Pauli principle.

Such principles, which historically arose as independent conjectures, now follow from the one assertion. It is a matter of seeing how this