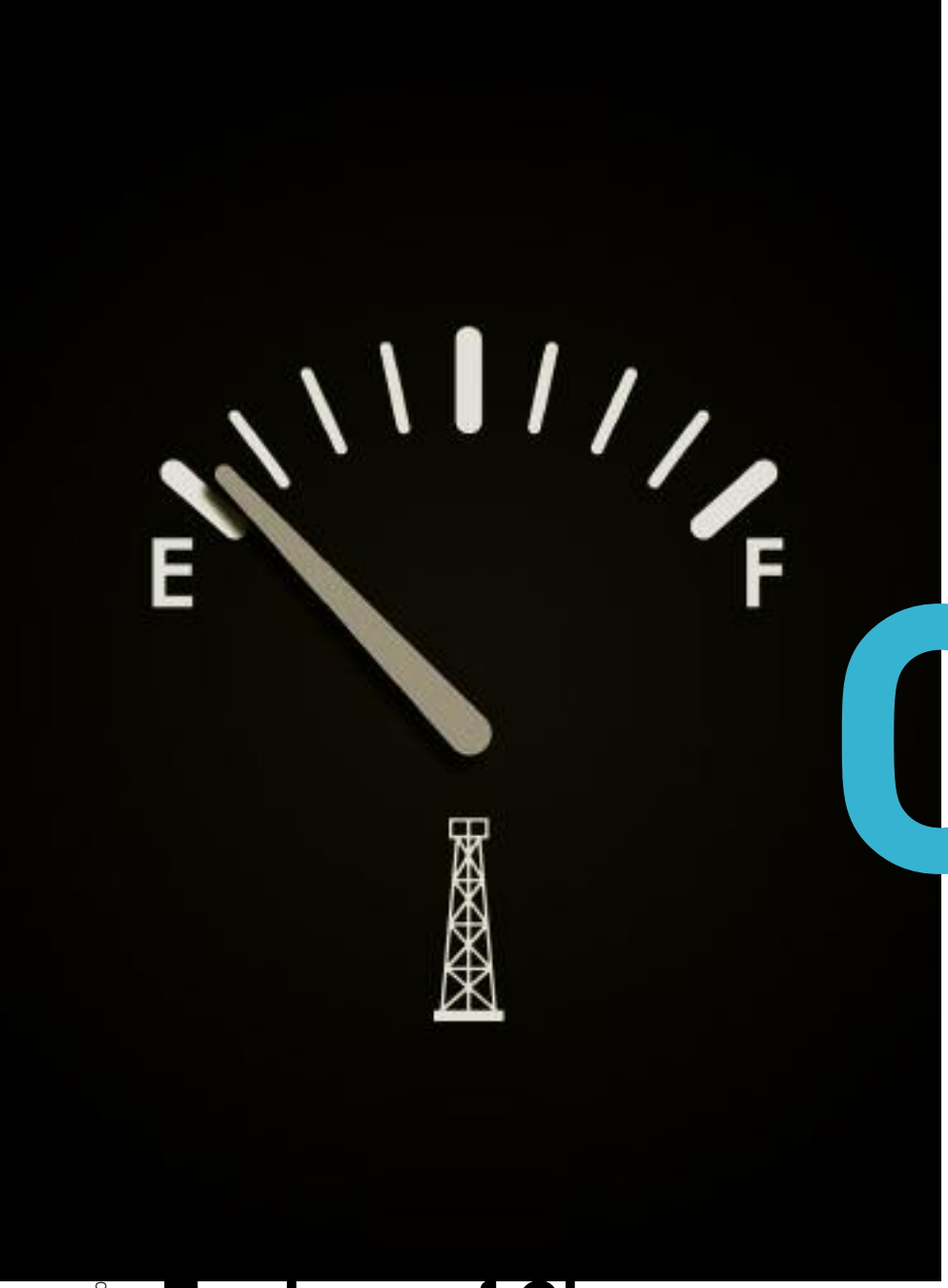

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Engines of Change

Sources for making sense of fossil fuel scarcity, the oil endgame, and the automotive future.

by John Wormald

Oil is on the front burner again. The political tensions of the Middle East, the economic development of China and India, the volatility of energy prices, and concerns about global climate change have brought attention back to the energy source upon which our automotive society most depends. With the supply of oil uncertain and no clear consensus about alternative energy sources, the continued viability of carbon-fueled economic development — and thus the future of our highly mobile industrial society — is being questioned. Anyone trying to make sense of developments since, say, 2001, will find that information is plentiful, but reliable perspective and judgment are harder than ever to come by. It's as if the depth of the issues at stake makes it harder to step back dispassionately and look at the state of the petroleum industry today, and the real availability and cost of energy tomorrow.

A half dozen books and publications have appeared to help people comprehend the linked oil, automotive, and national security enigmas. All of these publications are perceptive enough to recognize

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the conflicting beliefs held by various opinion makers in the field. But each book, because it is limited by its own perspective, does not even attempt to reconcile the contradictions among those beliefs. Thus, to understand the future of transportation and energy, even on as simple a matter as the speed with which fossil fuels are "running out," a reader needs to consider these sources together. A forced transition away from fossil fuel dependence is almost certain, and sooner than many people expect; but on the details and impact of that transition, there are still many uncertainties.

A good place to start making sense of them is with one of the oil industry's (and the world's) most enduring myths: that Saudi Arabia has only to open the tap a bit more and any oil supply crisis will end. *Twilight in the Desert* subjects this myth to critical analysis. Matthew R. Simmons, an investment banker specializing in the oil industry, has gone back to primary sources: more than 200 technical papers published by Saudi Aramco (the huge, Saudi Arabia–based company that conducts most of the exploration and extraction of that country's oil) under the professional auspices of the Society of Petroleum Engineers. For the lay reader, Mr. Simmons has produced an admirable primer of petroleum geology, exploration, extraction, and processing techniques. It's all a lot more complex, difficult, and expensive than it was in the days of Colonel Edwin Drake (who drilled the first successful petroleum well in 1859 near Titusville, Penn., and collected the oil in a bathtub).

Mr. Simmons drills down — the term is indeed appropriate — into the Saudi oil fields in which we have placed our greatest trust, particularly the mega-giant Ghawar complex near Dhahran. He explodes what George Orwell might have identified as a fine example of doublespeak: Aramco clearly acknowledging (in its arcane technical papers) the aging and depletion of its oil fields, while publicly claiming that reserves and production capacity are more than adequate.

In passing, Mr. Simmons documents the sorry "progress" of the Saudi leaders themselves, from ascetic princes of the desert to "oil welfare" dependents unable to conceive of supporting their lavish lifestyles and overpopulated cities without a stream of money from renting their lands as oil fields. His meticulous scholarship would befit any academic institution. The only criticism to be made of the book is that it is often repetitive — and even that does not detract from its inherent value. The publisher appropriately fast-tracked it and seemingly had to sacrifice thorough editing.

Anticipating Global Shortages

Beyond Oil, by energy consultant and emeritus Princeton professor Kenneth S. Deffeyes, builds on the author's previous book, *Hubbert's Peak.* In 1956, the statistician M. King Hubbert predicted that American oil supplies would reach a peak of production between 1965 and 1970 — in other words, a point after which the supply of oil from the U.S. would be increasingly expensive and scarce. Mr. Hubbert was only one year off (the peak occurred in 1971), which suggested his methodology was indeed robust. Then, in 1979, he predicted a *global* oil production peak in 2000. Few took notice. Was the reality too hard to contemplate?

The tone of Mr. Deffeyes's book is warm, with interesting and amusing anecdotes from his long career in the oil industry, which he

loves. Yet his prediction is somber enough. He takes the view that the world is indeed close to a peak of production for conventionally recoverable fossil fuel oil. The clash with rising oil demand, notably from China and India, will push market prices up rapidly — to which add the discomfiting politics of a world where an increasing proportion of reserves lies in politically sensitive regions. Industrial societies have already made a significant shift toward natural gas for fuel. But the amount of natural gas extracted from each new well is growing steadily smaller, and much of the remaining supply is in places remote from the main centers of consumption, requiring substantial liquefaction and transportation costs.

Mr. Deffeyes makes the reasonable case that other fossil fuels, or, for that matter, renewables like hydro, solar, and wind power, will probably not cushion the descent, as we can't bring them online fast enough. Rising petroleum prices will enable the tapping of alternative sources, such as nonconventional oil (shale oil, the Athabasca tar sands in Western Canada, heavy oil in Venezuela's Orinoco basin) and coal, of which there is still plenty. But their direct and environmental costs will be considerable, so the switchover can occur only at much higher energy prices than we have become used to. Coal is a concentrated energy form, but the investment and environmental costs of synthesizing hydrocarbons from it are high. Hydrogen, touted as the wholly nonpolluting fuel, is not in fact a primary fuel but only an energy carrier. It is only as clean or as cheap as the process by which it is generated. Widespread use of it will require a complete new distribution infrastructure. Through failure to recognize the oil problem early enough, we may face an awkward and expensive transition.

If Mr. Deffeyes disappoints at all, it is because, having led us to the edge of the precipice, he stops short of describing the economic thrills and spills of the impending fall. This is perhaps wise, as he makes his own argument skillfully and has chosen not to stray into speculation about its implications, noting that he is not an economist.

Virtues of Development

Peter W. Huber and Mark P. Mills, the authors of *The Bottomless Well,* do not share Mr. Deffeyes's view of imminent disaster. Rather, they are what he would call "cornucopians," advocates of the idea that there will always be enough energy to go around, at least for those who matter. Mr. Huber and Mr. Mills begin plausibly enough by characterizing all life and economic development as a fight against entropy — the measure of disorder, which inescapably increases as energy degrades. All ordering, all upgrading of energy, requires the input of high-grade heat and the throwing off of degraded heat, as stated in the Second Law of Thermodynamics, enunciated 182 years ago by Sadi Carnot.

Mr. Huber and Mr. Mills see themselves in an increasingly ordered and virtuous world. They note that the energy consumed per unit of gross domestic product (GDP) declines with rising prosperity — and has notably done so in the U.S. in recent decades. At the same time, fuel-using devices are becoming more numerous, sophisticated, and power-hungry. This requires a steadier and more reliable supply of electricity, which in turn requires more energy in absolute terms. In the end, the continued increase in GDP per capita and our propensity for using more electrically powered devices will outpace the gains in energy efficiency. Thus, the U.S. (and other Western countries) will continue to see an overall increase in energy consumption.

The authors make a virtue out of this continued increase. They believe it to be an inevitable concomitant of human development. There isn't enough evidence, they say, to confirm or deny the scarcity of energy sources, or the consequences of consuming more energy — notably greenhouse gas emissions and global warming. Nor do they think these are serious problems. Never mind if rising ocean levels cause Bangladesh to be flooded, no American president will allow the lights to go out. Whatever happens, "we" (in the United States, at least) have unrivaled military technology that other nations have not. The book ends on a slightly peculiar and sentimental suggestion that breeding more children will solve all problems. There is also an unpleasantly supremacist ring to its implication that those with political

power will get the energy. *The Bottomless Well* is based on the idea that even if oil supplies run out in the Middle East, human ingenuity, abetted by technological innovation, will always find more somewhere. This may be true — but how and at what cost, and whether this bounty is to be extended to all or reserved for the privileged few, are not explained.

Taken together, *Twilight in the Desert, Beyond Oil,* and even *The Bottomless Well* (albeit unintentionally) add up to a convincing case: no more lakes of oil to be tapped by simply drilling holes. Should we wail and gnash our teeth as energy prices rise and the darkness and cold envelop us? Not at all, argues Mark Jaccard in *Sustainable Fossil Fuels.*

Don't be put off by the cover illustration of someone, perhaps Mr. Jaccard, dressed up as a dinosaur and riding a trail bike. The author is not a prehistoric creature, but an economist (they are distinguishable) with considerable experience in energy research and policy formulation. His approach is disciplined and rigorous, and the book is well structured, logical, and eminently readable. No mental entropy here, but a systems view of global energy supply.

Mr. Jaccard sorts energy sources into primary, secondary, and tertiary forms. There are only two primary energy forms continually accessible on earth: nuclear fusion, taking place in our sun and reaching us as its radiation; and the gravitational pull of the moon, which drives the ocean tides. From these come the renewables: hydro (from falling water and the tides), wind, solar heat, and photoelectricity. The secondary energies are the accumulated derivative forms of the primaries: the heavy elements used in nuclear energy generation, created at the time of the earth's formation; geothermal energy from the same source; and the carbon-based fuels (coal, oil, and natural gas). The tertiary forms are the carriers, which we use to deliver usable heat, light, and power to our homes, places of work, factories, and vehicles. Electricity and hydrogen are carriers; neither occurs naturally in usable form.

As societies get richer, they both need and can afford more controllable forms of tertiary energy, which tend to consume yet more secondary energy (a point also made by Mr. Huber and Mr. Mills). Thus, human energy needs will increase in even the most energy-efficient future imaginable. Mr. Jaccard projects that both world population and energy consumption will level out over the next 100 years (his willingness to explore a long time frame is a major virtue), but not before humanity consumes three times as much energy per year as it did in 2000.

Mr. Jaccard has strong reservations about the value of energy-saving schemes, such as trying to persuade consumers to buy expensive low-energy lightbulbs. He says we can get much further by making proper use of the mix of energy resources available to us, notably the carbon-based fossil fuels. Some substitutions are highly desirable in themselves — for example, in poor countries, the use of bottled gas, instead of wood, for cooking and heating helps reduce the huge health hazard of indoor atmospheric pollution. Other substitutions will be forced upon us as conventional oil and gas run out. Some energy sources, notably nuclear fission, carry perceived or real elements of catastrophic risk that make them difficult to accept. Others are inhibited by physical factors, for example, the difficulty of compressing hydrogen enough to carry a sufficient supply on board automobiles. Over time, if we properly manage the transition from oil and gas to coal and biomass, he says, it can be smooth rather than abrupt and disruptive, with energy costs increasing for most people by a bearable 25 to 35 percent.

It all adds up to a masterly exposition of a highly complicated and contentious subject. The book includes a useful section about the different policy instruments available to government lawmakers and their relative efficacy in securing changes in consumption patterns. But Mr. Jaccard makes one crucial and unproven assumption: that sequestering carbon dioxide — removing it from the smokestacks of coal-processing plants and burying it in the ground — will be economically affordable, physically possible, and benign. Even if that works out, we will only postpone the lamenta-

World energy consumption will level out in 100 years, but not before humanity consumes three times as much as it did in 2000.

ble day when the coal starts to run out, and we will have to fall back increasingly on nuclear fission, with all its attendant challenges. (Perhaps by then the ultimate white knight of fusion, solar energy made copious and practical, will come to the rescue.)

Energy's Endgame

These issues find their most acute and popularly visible focus in automotive mobility. Motor vehicles and aviation are the largest and fastest-growing consumers of oil-based fuels. The automobile was the iconic product of the 20th century, driving economic development — and dependent in turn on its cheap and convenient hydrocarbon fuel. This is well put in context in *Children of the Sun,* a charming and readable book by Alfred W. Crosby, a retired professor of history, geography, and American studies. Perhaps it takes a historian to maintain a sufficiently long and broad view of our social, economic, and cultural dependence on energy. He takes us from the first cooking fires of the Paleolithic age to the perils of nuclear power in the 20th and 21st centuries. The paradigm breakers in this story are the invention of cooking; the sailing ship and firearms, which gave Europeans domination over the world (the Chinese could have had it but sent their fleets back to harbor); coal-based iron smelting (another Chinese miss); Thomas Newcomen's primitive steam engine of 1712 and James Watt's reengineering of it, financed by Matthew Boulton's venture capitalism; Colonel Drake's oil well, feeding the internal combustion engines of Karl Benz and Rudolf Diesel; and the harnessing of electricity. Professor Crosby's last paragraph before the coda is sobering: "We children of the sun may be standing on the peak of our energy achievements poised for the next quantum leap upwards…or we may be teetering there, destined to participate in nature's standard operational procedure of pairing a population explosion with a population crash."

How then can we maintain mobility in developed countries, extend its benefits to emerging economies, and do so at an acceptable environmental cost? A report called *Mobility 2030* attempts to address this dilemma. It is a highly informative primer on the social, economic, and environmental impact of automobiles, produced by the World Business Council for Sustainable Development at the behest of leading firms in the automotive, oil, and tire industries.

The first half of *Mobility 2030* is an admirably rich, complete, and readable account of what motor vehicles do for us and how many of their unpleasant side effects can be mitigated. Sophisticated technologies have already hugely improved air quality in many cities, through improved fuel and engine management and exhaust gas post-treatment. Techniques for modifying behavior can reduce unsafe driving. The immediate (and technically solvable) challenge is in emerging markets, where motor vehicle use is increasing, air pollution is rising, and (as a separate report from the World Health Organization notes), the incidence of road traffic injuries is rising steeply as well.

The second half of the book presents a long menu of technology options for propulsion systems, providing for each fuel system the "well-to-wheels" (complete) energy efficiency rating, which is the only proper way to compare them. The good old internal combustion piston engine remains in the running. Diesel fuel engines offer 20 percent

savings in energy and CO_2 emissions over conventional gasoline engines in light vehicles, but their emissions are more difficult to clean up. Hybrids (in which an electric motor–generator and battery complement the internal combustion engine) offer significant energy savings in urban driving but impose a weight and cost penalty on the highway. Fuel cells and hydrogen power are very attractive in theory, but their mass deployment remains firmly over the horizon because of on-board storage and fueling infrastructure barriers, on top of the continuing high cost and short life of fuel cells themselves.

In fact, there is no ipso facto miracle technology solution that will radically reduce the specific fuel consumption of motor vehicles (or airplanes). The lack of concise numbers-based arguments in the second half of the report is striking, compared to the first half of the report. There are almost indecipherable tables of scenarios. A diagram on aerodynamic drag suggests that an 80 km/hour (50 mph) limit could cut highway fuel consumption almost in half, but this obviously politically unpopular possibility is not pursued. Congestion gets

Resources for Understanding Energy and Automobiles

Works mentioned in this review.

Alfred W. Crosby, *Children of the Sun: A History of Humanity's Unappeasable Appetite for Energy* (W.W. Norton, 2006)

Kenneth S. Deffeyes, *Beyond Oil: The View from Hubbert's Peak* (Hill & Wang, 2005)

Kenneth S. Deffeyes, *Hubbert's Peak: The Impending World Oil Shortage* (Princeton University Press, 2001)

European Commission, *Cars 21: Competitive Automotive Regulatory System for the 21st Century. Final Report* (E.U. Directorate General for Enterprise and Industry, 2005)

Kelly Sims Gallagher, *China Shifts Gears: Automakers, Oil, Pollution, and Development* (forthcoming from MIT Press, July 2006)

Peter W. Huber and Mark P. Mills, *The Bottomless Well: The Twilight of Fuel, the Virtue of Waste, and Why We Will Never Run Out of Energy* (Basic Books, 2005)

Mark Jaccard, *Sustainable Fossil Fuels: The Unusual Suspect in the Quest for Clean and Enduring Energy* (Cambridge University Press, 2005)

Amory B. Lovins, E. Kyle Datta, Odd-Even Bustnes, and Jonathan G. Koomey, *Winning the Oil Endgame: Innovation for Profits, Jobs, and Security* (Rocky Mountain Institute, 2005), www.oilendgame.com

Matthew R. Simmons, *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy* (Wiley, 2005)

World Business Council for Sustainable Development, *Mobility 2030: Meeting the Challenges to Sustainability — The Sustainable Mobility Project,* Full Report 2004, www.wbcsd.org/web/publications/mobility/overview.pdf

World Health Organization, *World Report on Road Traffic Injury Prevention,* Geneva, 2004, www.who.int/world-health-day/2004/infomaterials/world_report/en/

a fairly superficial treatment — the report skirts the concepts of a different mix of individual and collective transport, and of the different patterns of living, working, and studying that this change would imply. The report ends on a note of seeming confusion and powerlessness in the face of greater events, and does not attempt to address the real question: If the energy intensity of physical transportation cannot be radically reduced, must it compete with other components of industrial society for an increasingly scarce fuel supply, or must we accept a reduction in mobility?

Composite Solutions

The long-standing forte of Amory B. Lovins and his Rocky Mountain Institute lies in boldly challenging conventional technological wisdom. Their latest report, *Winning the Oil Endgame,* seeks to identify the means of making such large decreases in energy consumption by road vehicles that the U.S. becomes independent of oil imports. Mr. Lovins dismisses nuclear-generated electricity as too costly. Instead, he argues for a massive development in biofuels — not just corn- or sugar-derived ethanol, but such novelties as fuels processed from cellulose by genetically modified bacteria. He takes cars and other vehicles to Weight Watchers, contending that far too much deadweight is hauled around in steel-structured designs, compared to their useful load of passengers and luggage. Stronger, lighter vehicles made from composite materials of plastic polymer and carbon fiber are, he says, more effective than extra mass in ensuring the safety of occupants, and will use as little as half as much fuel.

Mr. Lovins thereby takes a diametrically opposed stance to Mr. Jaccard's by proposing massive energy savings at the point of use — or tapping, as he puts it, "the 30-billion barrel per year fuel supply under Detroit." This would cut fuel consumption to the point where biomass can supplant the need for the U.S., or other countries, to import oil. The argument is powerful, although its applicability is limited to large-area, temperate-zone countries — plus special cases, such as Malaysia and Indonesia, with their massive palm oil plantations, or Brazil, with its massive sugar cane–based ethanol program. We are treated to a bewildering array of deployment scenarios, as though from a student who has just discovered simulation techniques. They don't really add to the force of Mr. Lovins's argument. And, of course, a key question is not addressed: If composite vehicles running on ethanol became commonplace, would society still have to constrain its fourth inalienable right, the right to unimpeded individual motorized mobility?

This is the fundamental dilemma. The challenge of energy supply cannot and should not be faced by automakers (or the energy industries) alone. Why should they be expected to manage the demand for mobility? Already, the automotive industry is among the most regulated on earth, in terms not only of safety and environmental protection but also of how its products are used. Only government has the regulatory responsibility and authority needed to manage the demand side and set environmental and safety standards. Only a governmental authority can set the technical standards for vehicles, provide most of the road infrastructure, regulate access to that infrastructure (more or less efficiently), and levy taxes on vehicles and their use, notably fuel taxes. Governments alone can insti-

The challenge of energy supply cannot be faced by automakers alone. Why should they have to manage the demand for mobility?

tute plans, standards, and means of persuasion and enforcement that can mediate among the public good, techno-economic feasibility, and political acceptability.

But for governments to help manage the transition to a post-oil world effectively, they need a long-term perspective, much longer than customary political cycles. The democratic governments of the past 10 years — whether in Europe, the United States, or Asia — have largely failed to rise to the challenge. One recent European Commission–sponsored report, *Cars 21,* was a tepid corporatist rehash of conventional wisdom, ducking an opportunity to spark an epoch-making shift in environmental and design practice for the European automotive industry, which might have given it a first-mover competitive advantage.

Might an authoritarian state do better? *China Shifts Gears* is billed as an analysis of technology transfer between U.S. automakers and China. The book follows the fortunes of three Sino-American joint ventures: Beijing Jeep, Shanghai GM, and Chang'An Ford. The People's Liberation Army never got its new Jeep, which was the original purpose of the first venture. Only the second became a major success, once GM transferred into it a European product better suited to the emerging Chinese mass market. The third venture appears stalled by cultural conflicts between its partners. Author Kelly Sims Gallagher somewhat naively wonders why the U.S. automakers initially transferred only their most conventional and not very energy-efficient vehicles and technologies. The answer: Mass-producing cars is complex, difficult, and driven by experience and know-how, so one would naturally transfer the simpler solutions to novice partners. Unlike telecommunications, the automobile industry is not an area in which technological leapfrogging is seen in nascent markets.

In the end, Dr. Gallagher correctly places the onus on the Chinese authorities. Only the Chinese government has the political power to impose order on its automotive industry, thereby managing the impact of changes in the fuel supply (and gaining a first-mover advantage for its own automotive industry). But, as Dr. Gallagher points out, because the Chinese government lacks the counterbalance of an informed and consulted public, its decisions probably won't be any more effective than those of its democratic rivals.

The ideas of Mr. Jaccard and Mr. Lovins may buy us time — a century, perhaps? But we will still have to face reality: The two successive ages of cheap coal and the steam engine, and then of cheaper and more convenient oil and of the all-conquering automobile, are over. How shall we deal with the new era of rising energy costs and tightening environmental constraints? Even with the highest possible level of technological acumen, clear vision, and honest analysis, we need a shared willingness to reconceive and redeploy our transportation and energy infrastructures. These works show how difficult that transition will probably be. They don't — and perhaps they could not — identify the solutions, or the institutional mechanisms through which we will achieve those solutions. But we as individuals, businesses, and nations must base our decisions on objective reality and a sufficiently long time frame, not on blind belief and short-term expediency. +

Reprint No. 06213