# MIDEAST OIL FOREVER?

## JOSEPH J. ROMM AND CHARLES B. CURTIS

Congressional budget-cutters threaten to end America's leadership in new energy technologies that could generate hundreds of thousands of high-wage jobs, reduce damage to the environment, and limit our costly, dangerous dependency on oil from the unstable Persian Gulf region.

Imagine a world in which the Persian Gulf controlled two-thirds of the world's oil for export, with $200 billion a year in oil revenues streaming into that unstable and politically troubled region, and America was importing nearly 60 percent of its oil, resulting in a $100-billion-a-year outflow that undermined efforts to reduce our trade deficit. That's a scenario out of the 1970s which can never happen again, right? NO, that's the "reference case" projection for ten years from now from the federal Energy Information Administration.

Imagine another world in which fossil-fuel use had begun a slow, steady decline; more than a third of the market for new electricity generation was supplied from renewable sources; the renewables industry had annual sales of $150 billion; and the fastest-growing new source of power was solar energy. An environmentalist's fantasy, right? NO, that's one of two planning scenarios for three to four decades from now, developed by Royal Dutch/Shell Group, the world's most profitable oil company, which is widely viewed as a bench mark for strategic planning.

A decade's worth of little-heralded technological advances funded by the Department of Energy have helped to bring such a renewables revolution within our grasp. Yet budget cuts already proposed by Congress would ensure that when renewable energy becomes a source of hundreds of thousands—if not millions—of new high-wage jobs in the next century, America will have lost its leadership in the relevant technologies and will once again be importing products originally developed by U. S. scientists. Moreover, Congress's present and planned cuts in advanced transportation and fossil-fuel research and development impede efforts to maximize the nation's conventional energy resource base.

Although little can be done to change the first scenario, Congress's actions all but guarantee that if an oil crisis comes, our national response will be reactive, uninformed, and unduly burdensome. Having abandoned the technological means to minimize the crisis, the nation will be left in the next century with little more than its usual responses to energy crises: price controls or other rigid regulations, or unplanned, ineffective attempts to deal with the effects of sharp price or supply fluctuations.

**Today, we are so dependent on oil, and oil is so embedded in our daily doings, that we hardly stop to comprehend its pervasive significance. It is oil that makes possible where we live, how we live, how we commute to work, how we travel -- even where we conduct our courtships. It is the lifeblood of suburban communities. Oil (and natural gas) are the essential components in the fertilizer on which world griculture depends; oil makes it possible to transport food to the totally non-self-sufficient megacities of the world. Oil also provides the plastics and chemicals that are the bricks and mortar of contemporary civilization, a civilization that would collapse if the world's oil wells suddenly went dry. ~**

What's more, cuts in research on clean-energy technologies represent a statement by Congress—conscious on the part of some members, unintentional on the part of others—that global climate change is of little or no concern, and that domestic environmental problems, such as urban air quality and industrial waste, require nothing more than existing strategies. Yet the nation's "tools" for dealing with pollution are similar to those for dealing with an oil crisis, and new technology usually provides the most cost-effective solution. One example: A relatively small amount of money spent today to develop, test, and deploy highly reflective roofing and road material and plant shade trees could help cool the Los Angeles area by five degrees, reducing annual air-conditioning bills by more than $150 million. Since smog formation is very temperature-sensitive, such cooling would reduce smog concentrations by 10 percent, which would be comparable to removing three quarters of the cars on the road. The health-related benefits of that smog reduction would be worth $300 million a year. Applied nationally, the energy savings alone could exceed $10 billion a year by 2015.

Although news coverage of the environment has focused on congressional efforts to roll back environmental regulations, cuts in environmental technology programs will have as significant an impact on our quality of life in the long run. And by turning a blind eye to the technological solutions to environmental problems, we limit ourselves to far-more-onerous alternatives. The environmental regulations that Congress is rolling back today may become all the more necessary in the not too distant future.

The programs being cut are not those failures of the past that are often mentioned by critics of federal energy research—for example, the synfuels program of a decade and a half ago. They are instead programs that have been delivering results for years. A report released last June by a blue-ribbon panel of independent energy analysts, led by the energy expert Daniel Yergin, the Pulitzer-winning author of The Prize, cited dozens of federally funded technological advances that "are generating billions of dollars worth of annual consumer energy savings and new business opportunities, and playing an important role in job creation." This is what will be lost.

Government and the people it represents cannot expect that the best-case scenario will play out. Rather, government should in behalf of the people try to prevent plausible worst-case scenarios or take advantage of likely trends and opportunities through long-term investments that the private sector will not make (either because they are too risky or because the reward is too far off). Both of us work for the Department of Energy, and in this article we examine some likely scenarios concerning petroleum, power generation, and pollution to help focus attention on a quiet revolution in energy markets and energy technologies which will have a profound impact on U.S. economic strength, environmental health, and national security in the next century. The impact will probably equal that of the much-ballyhooed information revolution, which receives far more attention from policymakers and the

**~ The twentieth century rightly deserves the title "the century of oil." Yet for all its conflict and complexity, there has often been a "oneness" to the story of oil, a contemporary feel even to events that happened long ago and, simultaneously, prond echoes of the past in recent events. At one and the same time, this is a story of individual people, of powerful economic forces, of technological change, of political struggles, of international conflict and, indeed, or epic change. It is the author's hope that this exploration of the economic, social, political, and strategic consequences of our world's reliance on oil will illuminate the past, enable us better to understand the present, and help to anticipate the future.**

DANIEL YERGIN, THE PRIZE, P. 14-15

media. Yet if we don't focus on energy today, our quality of life tomorrow will be permanently diminished.

## The Coming Oil Crisis

Given that the most recent war America fought was in the Persian Gulf, let's start by examining the likelihood that an oil crisis will occur in the coming decade. Forecasting is always risky, especially where oil is concerned, but consider what a variety of experienced energy hands from every point on the political spectrum have said in the past year alone. Donald Hodel, who was a Secretary of Energy under Ronald Reagan, has said that we are "sleepwalking into a disaster," and predicts a major oil crisis within a few years. Irwin Stelzer, of the American Enterprise Institute, says that the next oil shock "will make those of the 1970s seem trivial by comparison." Daniel Yergin says, "People seem to have forgotten that oil prices, like those of all commodities, are cyclical and will go up again." James Schlesinger, who was the Secretary of Energy under Jimmy Carter, has said, "By the end of this decade we are likely to see substantial price increases." In March of last year Robert Dole, the Senate majority leader, said in a speech at the Nixon Center for Peace and Freedom, "The second inescapable reality of the post-twentieth-century world is that the security of the world's oil and gas supplies will remain a vital national interest of the United States and of the other industrial powers. The Persian Gulf ... is still a region of many uncertainties.... In this 'new energy order' many of the most important geopolitical decisions—ones on which a nation's sovereignty can depend—will deal with the location and routes for oil and gas pipelines. In response, our strategy, our diplomacy, and our forward military presence need readjusting." The chairman of the Federal Reserve, Alan Greenspan, not known for being an alarmist, in testimony before Congress last July raised concerns that a rising trade deficit in oil "tends to create questions about the security of our oil resources."

Concerns about a coming oil crisis have surfaced in the financial markets as well. Last October, in an article titled "Your Last Big Play in Oil," Fortune magazine listed several billionaires and "big mutual fund managers" who were betting heavily that oil prices would rise significantly. The magazine went on to suggest an investment portfolio of "companies that are best positioned to profit from the coming boom."

Fundamental trends in oil demand and supply underlie this emerging consensus. First, the world will probably need another 20 million barrels of oil a day by the year 2010, according to the Energy Information Administration (EIA). The International Energy Agency projects an even greater growth in demand, following the inexorable tide of population growth, urbanization, and industrialization.

Second, the world's population is expected to increase by 50 percent by 202O, with more than half those additional people born in Asia and Latin America. And as farm workers move to the city, much more energy and oil will be needed. The fundamentals of urbanization—

**Harmony with land is like harmony with a friend. You cannot cherish his right hand and chop off his left.**

ALDO LEOPOLD

commuting, transporting raw materials, constructing infrastructure, powering commercial buildings—all consume large amounts of oil and electricity. At the same time, fewer farms will have to feed more people, and so the use of mechanization, transportation, and fertilizer will increase, entailing the consumption of still more energy and oil. An analysis by one of the Department of Energy's national laboratories found that a doubling of the proportion of China's and India's populations that lives in cities could increase per capita energy consumption by 45 percent—even if industrialization and income per capita remained unchanged.

Finally, industrialization has an even greater impact on energy use. As countries develop industries, they use more energy per unit of gross national product and per worker. Crucial industries for development are also the most energy-intensive: primary metals; stone, clay, and glass; pulp and paper; petroleum refining; and chemicals. In the United States these industries account for more than 80 percent of manufacturing energy consumption (and more than 80 percent of industrial waste).

As Fortune has noted, if the per capita energy consumption of China and India rises to that of South Korea, and the Chinese and Indian populations increase at currently projected rates, "these two countries alone will need a total of 119 million barrels of oil a day. That's almost double the world's entire demand today."

Barring a major and long-lasting worldwide economic depression, global energy demand will be rising inexorably for the foreseeable future. The Persian Gulf, with two thirds of the world's oil reserves, is expected to supply the vast majority of that increased demand—as much as 80 percent, according to the EIA. Within ten to fifteen years the Persian Gulf's share of the world export market may surpass its highest level to date, 67 percent, which was attained in 1974. The EIA predicts that in the face of increased demand, oil prices will rise slowly to $24 a barrel (1994 dollars) in 2010. If, instead, they remain low, the Gulf's share of the world export market may rise as high as 75 percent in 2010.

Although non-OPEC nations did increase production by almost 15 percent from 1980 to l99O, they increased proven reserves of oil by only 10 percent. The net result is that the remaining years of production for non-OPEC reserves has actually fallen from eighteen years to seventeen years. On the other hand, while OPEC increased production by 20 percent in the 1980s, it increased its proven reserves by 75 percent. As a result, OPEC's reserves-to-production ratio doubled to ninety years.

The growing dependence on imported oil in general and Persian Gulf oil in particular has several potentially serious implications for the nation's economic and national security. First, the United States is expected to be importing nearly 60 percent of its oil by ten years from now, with roughly a third of that oil coming from the Persian Gulf. Our trade deficit in oil is expected to double, to $100 billion a year, by that time—a large and continual drag on our economic health. To the extent that the Gulf's recapture of the dominant share of the global oil market will make price increases more likely, the U. S. economy is at risk. Although oil imports as a percent of gross domestic product have

**There are secrets and mysteries surrounding magnets and collapsing field energies, and only after exhaustive studies of these two phenomena inpractive, do these mysteries unravel themselves and emerge in their glory.**

DR ROLF SCHAFFRANKE

**By putting all of our talents together, not only America but the whole world will gain, for pollution is an international enemy of progress and the dependence on oil has often had dangerous economic and military consequences.**

S.R. OVSHINSKY, PRESIDENT AND CEO OF ECD, USABC PRESS CONFERENCE, MAY 19, 1992

decreased significantly in the past decade, our economic vulnerability to rapid increases in the price of oil persists. Since 1970 sharp increases in the price of oil have always been followed by economic recessions in the United States.

Second, the Persian Gulf nations' oil revenues are likely to almost triple, from $90 billion a year today to $250 billion a year in 2010--a huge geopolitical power shift of great concern, especially since some analysts predict increasing internal and regional pressure on Saudi Arabia to alter its pro-Western stance. This represents a $1.5 trillion increase in wealth for Persian Gulf producers over the next decade and a half. That money could buy a tremendous amount of weaponry, influence, and mischief in a chronically unstable region. And the breakup of the Soviet Union, coupled with Russia's difficulty in earning hard currency, means that for the next decade and beyond, pressure will build to make Russia's most advanced military hardware and technical expertise available to well-heeled buyers.

The final piece in the geopolitical puzzle is that during the oil crisis of the 1970s the countries competing with us for oil were our NATO allies, but during the next oil crisis a new, important complication will arise: the competition for oil will increasingly come from the rapidly growing countries of Asia. Indeed, in the early 1970s East Asia consumed well under half as much oil as the United States, but by the time of the next crisis East Asian nations will probably be consuming more oil than we do.

**Energy drives the economies of all prosperous nations. It also separates the rich from the poor.**

**This world is desperately crying out for a clean, cheap, renewable energy source.**

RAY A DALE

## Abandoning the Solution

What is the appropriate national response to the reemerging energy-security threat? Abroad the Department of Energy has been working hard to expand sources of oil outside the Persian Gulf region—in the former Soviet Union, for example—and to encourage the privatization of the oil companies in Mexico and other Latin American countries.

At home the DOE is encouraging greater production by providing royalty relief in the deep waters of the Gulf of Mexico and similar incentives, so that the industry can drill wells that otherwise would not be cost-effective. The DOE is working to reduce the cost for the industry to comply with federal regulations. Finally, the department is spending tens of millions of dollars a year to develop new technologies that will lower the cost of finding and extracting oil—for example, using advanced computing to model oil fields. Still, few expect to reverse the decade-long decline in U.S. oil production. Some would open the Arctic National Wildlife Refuge to drilling, a plan the Clinton Administration has opposed on environmental grounds, but not even that would change our forecasted oil dependency much. This is true even using earlier, more optimistic estimates that the refuge could provide 300,000 barrels of oil a day for thirty years. The EIA projects that within ten to fifteen years the United States will probably be importing thirty times as much—some 10 million barrels of crude oil a day, even if the decline in other domestic production levels off in the next few years.

**There is a better way. Find it.**

THOMAS EDISON

Increasing domestic supply, although it may help to slow the rising tide of imports, cannot itself reverse the major trend. And reversing the nation's ever-increasing demand for oil would be difficult. The country is in no mood to enact higher energy taxes in order to bring our energy markets into better balance. To most people, an increase in gasoline taxes of even a few cents a gallon—let alone the amount needed to have a noticeable impact on consumption—is anathema. Similarly, Congress is in no mood for a regulatory approach, such as mandating increased fuel efficiency for cars.

That leaves one solution for reducing consumption: the technological approach, which draws on America's traditional leadership in research and development. Here tremendous progress has been made. Given the uncertain nature of long-term, high-risk R&D in leapfrog technologies, the prudent approach is to explore a number of possibilities. The DOE has invested in the development of cars and trucks that are highly fuel-efficient, along with cars that run on electricity, on liquid biofuels from crops, crop waste, and municipal solid waste, or on natural gas.

Consider biofuels. In 1994 research sponsored by the DOE created a genetically engineered organism that enhances the fermentation of cellulose, increasing the rate of conversion and the yield of ethanol. This achievement, described in the journal Science, was named one of the hundred most significant technological advances of the year by R&D magazine. This and other federally supported research has brought the cost of making ethanol from $3.60 a gallon fifteen years ago to about $1.00 a gallon today. If biofuels R&D were funded at current levels for five to ten years, ethanol from fast-growing dedicated crops, crop waste, and wastepaper could be produced for as little as sixty to seventy cents a gallon by 2005. In a country with excess cropland, such as the United States, the potential for biofuels is enormous. Rather than paying some farmers not to grow anything, we might in the future pay the same farmers to grow dedicated bioenergy crops. In a country where cropland is scarce, such as China, bioenergy could come from municipal and agricultural wastes.

Technologies are also being developed to make possible a super-efficient hybrid vehicle that has both an internal-combustion engine and some kind of energy-storage device, such as a battery or a flywheel. A very advanced hybrid has been described by Amory B. Lovins and L. Hunter Lovins (see "Reinventing the Wheels," January, 1995, Atlantic). Supporting technologies include lightweight, super-strong materials and advanced engines, among other things. This research has been undertaken by the Partnership for a New Generation of Vehicles, a collaboration among several federal agencies, the DOE's national laboratories, and the auto industry. The goal of the partnership is to design and construct by 2004 a prototype clean car that has three times the fuel efficiency of existing cars and very low emissions, and also comparable or improved performance, safety, and cost. Such a car would allow domestically produced advanced technologies to replace oil imports.

Another direction that research is taking is toward advanced batteries for use in electric cars—among them the nickel metal-hydride battery—which promise to double the range achievable with existing lead-acid batteries. In conjunction with advances in clean power generation, described below, these batteries hold the prospect of replacing imported oil with domestically produced electricity.

The technology that most experts would agree has the best chance over the long term of replacing petroleum use in the transportation sector is fuel cells. These are compact modular devices that generate electricity and heat with high efficiency and virtually no pollution. They run on hydrogen converted from natural gas and other fuels. The National Aeronautics and Space Administration developed early versions of fuel cells for use on space missions. Over the past two decades the DOE has spent tens of millions of dollars on several types of fuel cells that will soon be used to power cars, trucks, utilities, commercial buildings, and industries. The Japanese government has been increasing its fuel-cell budget by an average of 20 percent a year for the past five years, and Japanese companies are less than five years behind U.S. companies in this technology. The Europeans are considering significantly increasing their fuel-cell funding. Sustained federal support might well give America the lion's share of a multibillion-dollar global market.

Fuel cells are one of many advances that may increase the use of natural gas as a transportation fuel over the long term. Since 1992 the DOE has significantly increased its budget for research and development related to enhancing the supply and the efficient use of natural gas. It is seeking to encourage a wider use of natural-gas vehicles, to establish a nationwide infrastructure for fueling those vehicles, and to develop gas-turbine engines for light-duty vehicles.

Current DOE programs—unlike those of the late 1970s, which required oil to cost $80 a barrel if they were to be competitive—are aimed at making alternatives competitive even if oil prices decline. The likely outcome of all the programs mentioned above should not be overstated: we will not achieve energy independence in the next fifteen years. What this investment portfolio does offer is a chance in the years thereafter to blunt any foreign threat to raise oil prices dramatically and to limit the economic and geopolitical impact of Persian Gulf oil in particular. At the same time, domestic jobs will be created if money that might have gone overseas to buy foreign oil goes instead to manufacturing super-efficient cars and trucks or domestic biofuels.

What's more, the rapid population growth and urbanization of developing nations, coupled with the harsh pollution that characterizes most major urban centers in those nations, ensure a tremendous market for low-emission, super-efficient automotive technology. Our industrialized competitors have one inherent advantage in the race to develop the super-car: gas prices of $3.00 or $4.00 a gallon. Fuel efficiency matters more in their economies, and vehicles that use alternative fuels will be cost-competitive in their markets sooner. The primary counterbalance to that advantage is U.S. technological

**Wars are fought over mineral rights. The line between North and South Korea bisects the world's largest tungsten deposit. The Vietnam war was really about the oil fields in the South China Sea. Hitler sought to expand Germany into the oil fields of southeast Europe and to obtain other natural resources. The latest, the Persian Gulf War was to protect U.S. interests in the oil imports from the Middle East.**

**The best way to prevent nuclear war, or any other kind of war, is to make enegy and scarce elements available to everyone. That objective is now in sight.**

HAL FOX, NEW ENERGY NEWS

leadership in most relevant areas, stemming in part from historically higher levels of R&D spending.

That counterbalance is about to disappear. Congress has cut the proposed fiscal year 1996 allocations for the DOE's advanced-transportation-technology budget by 30 percent. Moreover, the multiyear balanced-budget plan approved by the House and Senate would cut the budget for such technology by 60-80 percent in real terms.

The fact that the DOE has been collaborating with the auto industry in the Partnership for a New Generation of Vehicles gives some in Congress a thin excuse to label the partnership's programs "corporate welfare." Yet Detroit's car makers agreed to match federal spending while coordinating their corporate research with the DOE's national laboratories in order to address the pressing national problems of oil imports and urban air quality. The last time America ignored the warning signs of growing dependence on imported oil, the Japanese were able to seize a significant share of the U. S. auto market with fuel- efficient cars.

Congress's own Office of Technology Assessment released a report last September acknowledging that the DOE's "strategy of pursuing several different [vehicle] technology options is advantageous for a variety of reasons." Congress is ignoring the advice of the office it set up, staffed, and funded to provide independent advice on technological issues of national importance. Indeed, it apparently no longer wants to hear any advice on such issues. Late last year Congress closed the Office of Technology Assessment for good.

That the nation's and the world's dependence on Persian Gulf oil will grow over the next decade seems inevitable. This is particularly true since most projections assume continuing significant technological progress in bringing down the cost of domestic production, in developing alternatives, and in using energy and oil more efficiently. But those projections have not factored in the federal government's plans to withdraw from its role in fostering the development and deployment of those technologies.

## The Renewables Revolution

Predicting our energy future beyond 2010 is chancy, but here we have an opportunity to rely on perhaps the most successful predictor in the energy business: Royal Dutch/Shell Group. According to The Economist, "The only oil company to anticipate both 1973's oil-price boom and 1986's bust was Royal Dutch/Shell." Anticipating the oil shocks of the 1970s helped Shell to move from being the weakest of the seven largest oil companies in 1970 to being one of the two strongest only ten years later. Anticipating the oil bust was apparently even more lucrative. According to Fortune's ranking of the 500 largest corporations, Royal Dutch/Shell is now not only the most profitable oil company in the world but the most profitable corporation of any kind.

When such a company envisions a fundamental transition in power generation from fossil fuels to renewable energy beginning in two decades, a transition that will have a significant impact on every aspect

of our lives, the prediction is worth examining in some detail. Chris Fay, the chairman and CEO of Shell UK Ltd., said in a speech in Scotland last year, "There is clearly a limit to fossil fuel.... Shell analysis suggests that resources and supplies are likely to peak around 2030 before declining slowly.... But what about the growing gap between demand and fossil fuel supplies? Some will obviously be filled by hydroelectric and nuclear power. Far more important will be the contribution of alternative renewable energy supplies."

Fay presented a detailed analysis of future trends in energy supply and demand, noting that the fossil-fuel peak in 2030 would occur at a usage level half again as high as today's. Shell's analysis does not rely exclusively on supply limits—after all, for decades people have been worried about such limits, and the supply has continued to expand—but also incorporates a recognition of the tremendous advances that have been made in renewable-energy technologies over the past two decades and that are expected to be made over the next two decades.

Although these advances in renewables have received very little media attention, they have persuaded Shell planners that renewables may make up a third of the supply of new electricity within three decades even if electricity from fossil fuels continues to decline in cost. An "Energy in Transition" scenario that they have prepared does not assume price increases in fossil fuels—also, as we have seen, a plausible hypothesis. Nor does Shell assume any attempt by governments to incorporate environmental costs into the price of energy, even though every single independent analysis has found that fossil-fuel generation has much higher environmental costs than non-fossil-fuel generation has. According to Shell's strategic-planning group, "The Energy in Transition future can claim to be a genuine 'Business as Usual' scenario, since its energy demand is a continuation of a long historical trend, and the energy is supplied in a way which continues the pattern."

Indeed, in the past fifteen years the Department of Energy, working with the private sector, has reduced the costs of electricity from biomass (such as crops and crop waste) and wind, bringing them into the current range of wholesale costs for coal and other traditional sources of electricity: three to five cents per kilowatt-hour.

A quiet revolution has already brought the United States almost eight gigawatts of biomass electrical capacity. Gasifying biomass and using advanced turbines could bring biomass power to 4.5 cents per kilowatt-hour within a decade, according to the DOE's National Renewable Energy Laboratory. Shell projects that by 2010 commercial energy from biomass could provide five percent of the world's power; using Shell's projections, we estimate that the value of that power generation could exceed $20 billion.

Over the past fifteen years electricity from wind power has declined in cost by 10 percent a year. The problems of the windmills that were rushed to market in the 1970s, such as noise and TV interference, have largely been solved. With the DOE's help the old wind-turbine blades, borrowed almost directly from aircraft-propeller design, have been

**The key to paradigm shifts is the collapse of formerly pivotal scarcities, the rise of new forms of abundance, and the onset of new scarcities. Successful innovators use these new forms of abundance to redress the emergent shortages.**

GEORGE GILDER

replaced with sophisticated blades designed to capture wind energy efficiently over a broad range of wind speeds and direction. Utilities are already receiving long-term bids for electricity from wind at 4.5 cents per kilowatt-hour in the best wind sites in the country. With a continued public-private partnership in technology advancement, wind could hit three cents per kilowatt-hour by 202O, and soon after that wind-power plants' annual sales could reach $50 billion.

Photovoltaic (PV) cells, which convert sunlight into electricity, now cost one tenth what they did in 1975. The DOE has invested heavily in new thin-film PV panels, which take advantage of U. S. expertise in semiconductor fabrication. Shell expects that PVs, along with fuel cells and small gas-fired power plants, will permit the growth of distributed power systems. In developing nations distributed sources can obviate the need for huge power lines and other costly elements of an enormous electric-power grid (much as personal computers replace large mainframe computers). PV modules sold worldwide totaled less than four megawatts in 1980 and now exceed 80 megawatts a year; sales continue to grow. The Energy in Transition scenario predicts that photovoltaics and other direct conversions of sunlight will be the most rapidly growing form of commercial energy after 2030. Sales could quickly exceed $100 billion. Shell itself has bought two photovoltaics companies.

This scenario, a highly credible one given Shell's reputation, is tantalizing, because it holds out the possibility that the world could within a few decades begin to realize the dream of nearly pollution-free energy. Consider also that the United States, which is now the leader in most areas of renewables technology, could simultaneously reduce its dependence on foreign energy supplies, reverse the trend toward an ever-increasing energy trade deficit, and capture a large share of what promises to be perhaps the largest new job-creating sector of the international economy.

This is only a scenario; our actions today can have an impact, either positive or negative. According to Chris Fay, of Shell, "New technologies cannot leap from laboratory to mass market overnight. They must first be tested in niche markets, where some succeed but many fail. Costs fall as they progress down the 'learning curve' with increasing application." The long-term nature of research, and the real potential for failure, are why many options must be pursued at once and why many private-sector companies have been reluctant to invest. Fay observes, "Renewables will have to progress very quickly if they are to supply a major proportion of the world's energy in the first half of the next century....They can only emerge through the process of widespread commercial experimentation and competitive optimization."

Federal investments clearly make a difference in technology development and global market share. Consider the case of photovoltaics. In 1955 Bell Laboratories invented the first practical PV cell. Through the 1960s and 1970s investments and purchases by NASA, the Pentagon, and the National Science Foundation helped to sustain the PV industry and gave America leadership in world sales. In 1982

federal support for renewable energy was cut deeply, and within three years Japan became the world leader in PV sales. The Bush Administration began to increase funding for solar energy and, in 1990, collaborated with the American PV industry in efforts to improve manufacturing technology; three years later the United States regained the lead in sales in this rapidly growing industry. The Clinton Administration has accelerated funding for PVs.

Sadly, however, the cuts of the 1980s have taken their toll: in the past decade German and Japanese companies snapped up several major American PV companies, which accounted for 63 percent of the PVs manufactured in the United States. Such purchases represent huge savings for our foreign competitors. They don't have to spend hundreds of millions of dollars to determine which technologies succeed. They need only let the United States do the basic research, and then spend a few tens of millions of dollars plucking the winners when the federal government abandons funding for applied research.

Although many members of Congress argue that the cuts in federal R&D will be made up for by the private sector, historically this hasn't happened. When the government pulls out of an area of technology, it sends a signal to the industrial and financial communities that the area has no long-term promise and that the federal government is not a reliable partner. The situation is especially bad today, because recent studies make clear that private-sector R&D has been fairly flat since 1991, and because U. S. companies have been shifting away from basic and applied research toward incremental product and process improvement—a shift that has been exacerbated by increased international competition and the downsizing of corporate laboratories.

In addition, whereas the federal government only recently, and temporarily, increased funding for renewable energy, reversing the deep cuts of the 1980s, our foreign competitors have been steadily increasing such funding for a decade and a half. Whereas we once spent several times as much as the rest of the world combined, the rest of the world now significantly outspends us. Moreover, countries such as Germany, Japan, Denmark, and the Netherlands have far greater financial incentives for renewable energy. And their prices for electricity are typically much higher: in 1991 electricity cost Germany's industrial sector 8.8 cents per kilowatt-hour, whereas in the United States it cost 4.9 cents per kilowatt hour. That means renewable energy will be cost- effective in foreign countries before it is in America.

The primary competitive advantage the United States has had in renewables is technological leadership driven by long-term federal spending prior to the early 1980s and then the spending in the early 1990s. Recently Congress cut renewable-energy funding by 30 percent, and its multi-year budget plan calls for overall cuts of 60 percent or more by the year 2002. The cuts will have two effects.

First, the transition to renewables that Shell envisions will probably be slowed somewhat, since America remains the leader in many relevant renewables technologies and U.S. government funding remains a sizable fraction of R&D funding worldwide. The transition, however,

even if slowed, seems inevitable at some point in the middle of the next century.

Second, when the transition occurs, the United States will miss what may well be the single largest new source of jobs in the next century. Mature areas like automobile manufacturing and aerospace haven't been significant net job producers for the country in two decades. The most highly promoted new area—the information revolution—is unlikely to provide as many jobs as manufacturing can, because making duplicate pieces of information generates many fewer new jobs than manufacturing duplicate pieces of hardware. Yet according to Shell's numbers, annual sales in renewable-energy technologies may hit $50 billion in 2020 and almost $400 billion in 2040. In the later year such an industry would support several million jobs.

Moreover, as said above, the United States will be importing $100 billion worth of oil annually ten years from now. With prudent federal investment today, that might be the peak, and we might then see a gradual decline as U.S. technology and domestic fuels, including homegrown biomass, replace imported oil. With Congress's cuts, however, we may be only augmenting our debilitating trade deficit in oil with an equally debilitating trade deficit in oil-replacing technologies.

## Preventing Pollution

The renewables revolution, inevitable or not, won't spell the end of the nation's or the world's environmental problems. In Shell's scenario overall fossil fuel use will increase steadily for decades, peaking in 2030 at a level half again as high as today's, and will not dip below current levels until 2100. If we are to achieve genuine prosperity—higher living standards accompanied by improved environmental quality—we will need to do better.

Consider one of the nagging environmental problems around the world: urban air quality. Most cities have dark surfaces and less vegetation than their surroundings, creating a "heat island" that affects climate, increases energy use, and decreases habitability. Buildings' dark roofs and inadequate shade in summertime raise the demand for air-conditioning, so more power and pollution are generated. Heat islands raise the temperature of many cities by as much as five degrees, increasing the production of smog, which is typically created in hot weather. Finally, urban heat islands exacerbate all heat waves, contributing to summer fatalities.

We know the basics of how to cool a city: Buildings need shade trees, and buildings, roads, and parking lots require light-colored surfaces. Cooler roads might cost slightly more initially, but they would probably last 20-50 percent longer because they reduce thermal wear and reduce ultraviolet damage. Over a twenty-year period trees could be planted cheaply, and roads, roofs, and parking lots could be resurfaced during the course of normal maintenance, saving the country billions of dollars a year.

Clearly, the mitigation of urban heat islands is an important effort. The federal government has a crucial role to play in research and testing

to help identify and develop the best roofing and paving materials, in funding computer models for determining the optimal approach to cooling a city, and in disseminating information in the nation and the world.

This energy-saving, pollution-avoiding approach would be part of a much broader shift in the nation's environmental policy, which is vital if we are to be a prosperous country in the next century. The environmental paradigm that has predominated since the 1960s has been based on the notion that pollution is an inevitable by-product of business and that public- and private-sector efforts should be aimed at cleaning up that pollution after the fact or safely disposing of it in land, water, or the atmosphere. This so-called end-of-pipe approach is increasingly being challenged not only on environmental grounds but also on economic ones.

Michael Porter, a professor at the Harvard Business School, wrote in the September-October, 1995, issue of the Harvard Business Review, "When scrap, harmful substances, or energy forms are discharged into the environment as pollution, it is a sign that resources have been used incompletely, inefficiently, ineffectively. Moreover, companies then have to perform additional activities that add cost but create no value for customers: for example, handling, storage, and disposal of discharges."

The traditional end-of-pipe approach involves three kinds of economic waste: two identified by Porter (using resource inputs and pollution outputs inefficiently) and the societal costs associated with the myriad harmful side effects of resource overuse (for example, dependence on foreign oil) and of pollution (such as human illness and agricultural loss).

Because of the close connection between energy production and consumption on the one hand and pollution on the other, the Department of Energy provides a substantial majority--70 percent—of all federally funded pollution-prevention R&D.

Pollution-prevention technologies take a variety of forms. Renewable energy prevents pollution in the production of electricity. Fuel cells offer the hope of preventing pollution in the transportation sector. Many other sectors of the economy have equally great prevention opportunities.

As Yergin's task force noted, in the past two decades a DOE investment totaling about $1.1 billion in energy-efficient industrial technologies has yielded "approximately $2.5 billion in documented energy savings and net productivity gains, and the accumulation of these savings continues to grow at increasing rates." By 2000 these investments will be generating savings of about $10 billion a year. Very few other federal investments produce as great a societal return on taxpayers' dollars.

One technology, a process for dezincing (removing the galvanized coating from) scrap steel, provided the breakthrough that industry needed in order to recycle up to 10 million tons of scrap metal annually. By 2005 electrochemical dezincing could reduce raw-materials costs by $150 million a year, saving 50 trillion BTUs in the process, and reduce the

need to import at least 7O,000 tons of zinc, for further savings of at least $70 million annually. Another government-funded technology, vacuum-pressure swing adsorption, which is now used in manufacturing 15 percent of the glass made in the United States, reduces glass-making emissions of nitrogen oxide by 90 percent and cuts furnace energy use by 25 percent.

Something that is not widely understood is that most industrial pollution in the United States comes from the country's seven most energy-intensive industries: steel, aluminum, petroleum refining, chemicals, pulp and paper products, glass, and metal casting. These industries account for about 80 percent of the energy consumed in U.S. manufacturing and for more than 90 percent of the hazardous waste. They represent the greatest opportunities for increasing energy and resource efficiency while reducing pollution. That's why the DOE has been forming partnerships with these industries to develop clean technologies.

Funding for pollution prevention is the best way for the nation to avoid the need for costly environmental regulations. The government has a role in encouraging pollution prevention for several reasons. First, pollution-prevention technologies often benefit each of many companies only a little bit, so no one company has an incentive to spend the necessary money by itself. Second, prevention has many societal benefits: it reduces energy and other resource consumption and improves the environment, among other advantages. Third, and most important, pollution prevention and resource efficiency help companies to shift money from consuming energy and resources to investing in technology and capital equipment, thus creating jobs and economic growth. Indeed, a shift from consumption to investment may be the single most important transformation the U. S. economy must undergo if we are to remain prosperous in the next century.

A 1993 analysis for the DOE attempted to quantify the macroeconomic benefits of pollution prevention. The study found that a 10-20 percent reduction in waste by American industry would generate a cumulative increase of $ 1.94 trillion in the gross domestic product from 1996 to 2010. By 2010 the improvements would be generating two million new jobs, or roughly 1.5 percent of employment in that year. According to the study, this is "a relatively large impact considering that the investments driving it were assumed to be made for purposes other than increasing employment."

Moreover, this analysis does not include the jobs to be gained from capturing the large and growing export market for clean technologies and processes. Resource inefficiency and environmental degradation are very real limitations on the attempts of developing nations to raise the living standards of their people, especially since most of those nations do not have the abundance of resources with which America is endowed. The World Bank estimates that by 2000 the countries of Asia alone will need to spend about $40 billion a year on clean technologies. By then the global market for environmental services and technologies is expected to exceed $400 billion. The resource, environmental, and

capital constraints on the developing world guarantee a rich export market for the nation that leads the world in developing clean technologies.

As Michael Porter wrote in the Harvard Business Review, We are now in a transitional phase of industrial history in which companies are still inexperienced in handling environmental issues creatively.... The early movers—the companies that can see the opportunity first and embrace innovation-based solutions—will reap major competitive benefits, just as the German and Japanese car makers did [with fuel-efficient cars in the early 1970s].

That's why foreign governments are forming partnerships with their nations' companies to develop clean technologies: to overcome inexperience and ensure that they reap the benefits of early strength in the field.

The Japanese government is betting heavily on clean technologies and renewable energy. It is vigorously pursuing the Asian environmental market through the Green Aid Plan, which is designed to help Asian countries prevent water and air pollution, recycle waste, conserve energy, and develop alternative energy sources. In 1993 Japan quadrupled funding for the Green Aid Plan, to $120 million.

Germany, too, is moving in this direction, with regulations that increasingly push industry toward prevention, recycling, and life-cycle analysis. Proposed or pending regulations throughout Western Europe have implications for U.S. companies, as noted in a 1993 report prepared for the Saturn Corporation by the University of Tennessee Center for Clean Products and Clean Technologies: "European auto manufacturers are the current world leaders in car recycling and the use of life-cycle assessment to design environmentally superior cars."

One of the countries most attentive to prevention is the Netherlands, which spends about $500 million a year on environmental technologies—equivalent on a per capita basis to $9 billion in the United States. More than a third of that money is spent on pollution prevention. The Netherlands also uses its tax code to promote clean technologies by allowing firms that practice innovative pollution prevention to depreciate their investment in one year instead of over ten years.

Congress, in contrast, has cut by a third the Department of Energy's proposed budget for the development and deployment of energy-efficient and pollution- prevention technologies—a step that threatens U. S. leadership in this crucial area. Congress has proposed still deeper cuts in its multi-year budget plans—cuts that would deny U. S. companies a great many opportunities to compete and the nation as a whole the opportunity to capture a big piece of a market whose potential is equal to that of renewable energy: several hundred billion dollars a year.

Even the vitally important urban-heat-island-mitigation program described above has gone un-funded. For the 1995 and 1996 budgets the DOE asked for $2 million—a tiny sum by federal-government standards—for a Cool Communities program, to take the idea beyond the realm of small-scale testing. Like many programs that save energy in

a cost-effective way, the program would also reduce emissions of carbon dioxide, whose increasing prevalence in the atmosphere may be changing the earth's climate. The department included the Cool Communities program in its Climate Change Action Plan, to meet the nation's international commitment to try to limit greenhouse gases.

In both years Congress zeroed out the Cool Communities program. Why? Whereas the pre-1994 Congress was skeptical of global climate change, the new one is downright hostile to the concept, with some labeling it "trendy" and "scientific nonsense."

Yet at a meeting last December of the Intergovernmental Panel on Climate Change, representatives of 120 governments agreed that "the balance of evidence . . . suggests a discernible human influence on global climate." In a 1995 study scientists examined detailed records of weather over the past hundred years and concluded that weather extremes—heat, drought, excessive rain, or the kind of blizzard that the Northeast experienced in January—are becoming more common and that the extreme weather is almost certainly due to human-generated emissions of greenhouse gases.

The Economist concluded last October, "Climate change is a legitimate worry. Although still riddled with uncertainties, the science of climate change is becoming firmer: put too much carbon in the atmosphere and you might end up cooking the earth, with possibly catastrophic results."

## Preparing for the Future

Some argue that energy forecasts are notoriously inaccurate and that for the Department of Energy to base decisions on them is risky. We cannot, of course, say with certainty that an oil crisis will occur in the next decade, that a transition to renewable energy will occur as Shell envisions, or that industry worldwide will shift to pollution prevention. But each of these things seems very plausible, if not likely.

Another criticism often leveled at the DOE is that it has had big, expensive failures, such as the synthetic-fuels program, but few successes. The department has learned from experience, however, and its R&D portfolio is diverse, emphasizing small-scale technologies that have in fact been remarkably successful in the past. The recently concluded independent review of the department's energy-research portfolio cited dozens of examples of such technologies, among them a $3 million investment in energy-efficient windows made in the late 1970s, which has already saved U.S. taxpayers more than $1 billion in lower energy bills; a polycrystalline diamond drill bit that has reduced the cost of drilling for oil by $1 million per well; and many of the advances described above, including photovoltaics.

Diversity is a key element of DOE policy today: diversify the world's oil supply, and diversify America's domestic supply and end-use options. Because no one can predict the future with certainty, or know the outcome of R&D in advance, the DOE must invest in many options. The sharp cuts that Congress is pursuing narrow the country's options and leave us far less flexibility to respond to future crises and opportunities.

**From time to time, the structure of nations and economies goes through a technological wringer. A new invention radically reduces the price of a key factor of production and precipitates an industrial revolution. Before long, every competitive business in the economy must wring out the residue of the old costs and customs from all its products and practices.**

**The steam engine, for example, drastically reduced the price of physical force. Power once wreaked at great expense from human and animal muscle pulsed cheaply and tirelessly from machines burning coal and oil. Throughout the world, dominance inexorably shifted to businesses and nations that reorganized themselves to exploit the suddenly cheap resource. Eventually every human industry and activity, from agriculture and seatransport to printing and war, had to centralize and capitalize itself to take advantage of the new technology.**

GEORGE GILDER

Finally, some argue that government investments are "corporate welfare," a term implying a giveaway with no societal benefits. But the DOE has formed partnerships with the private sector to develop leapfrog technologies—such as the fuel cell, solar energy, and clean industrial, building, and transportation technologies—that will benefit many segments of our society.

Americans today have a duty to eliminate the deficit, rooted in their obligation to future generations, but the country also needs to acknowledge that public investment in R&D, far from being corporate welfare, is an investment in America's own future. As the Yergin task force wrote, Americans have an obligation to "assure for future generations that our Nation's capacity to shape the future through scientific research and technological innovation is continually being renewed."

The cuts planned for the energy-efficiency-and-renewable-energy program--30 percent this year and 60-80 percent over the next several years—far exceed the cuts planned in overall domestic discretionary funding to balance the budget. The impact of such cuts will be enormous.

Perhaps the only way to begin to realize the loss to the future is to look at the past. Federal investment in research and development for national needs has been one of the great success stories in twentieth-century America. Why does the United States retain leadership and strong exports in vital industries like aerospace, computers, and biomedicine? American ingenuity and the private sector have certainly been instrumental in each of these industries. Yet these industries have also enjoyed government support for decades. Who can doubt that a sustained high level of federal funding—eight times as much money as America's leading competitor provides—is responsible for U. S. leadership in biomedical and biotechnological research?

As for computers and software, the Pentagon's Advanced Research Projects Agency "virtually single-handedly created the United States' position of world leadership in computer sciences," according to a Harvard Business School case study on ARPA. And of all R&D dollars spent in the aircraft industry from 1945 to 1984, some 85 percent came from the federal government. In an unexpected benefit of the kind that is common in federal R&D, much of the turbine technology that is today generating electricity and helping to keep down utility rates had its roots in government-funded work on jet engines.

John Preston, formerly the director of technology development for the Massachusetts Institute of Technology, told Congress in 1993, "It seems clear that when the government teams up with academia and industry, and participates throughout the spectrum of technology, the United States becomes dominant in that industry." America's technological lead in most kinds of fuel cells and photovoltaics stems from almost two decades of NASA, National Science Foundation, and Pentagon support, followed by almost two decades of DOE support.

Some of the most pressing national needs in the coming decades are to reduce the country's huge and growing trade deficit in oil, to

**The four successive stages of response to any new and revolutionary innovation:**

**1. It's crazy!**
**2. It may be possible -- so what?**
**3. I said it was a good idea all along.**
**4. I thought of it first.**

ARTHUR C CLARKE

minimize any economic or political threat that might arise from the growing world dependence on Persian Gulf oil, to prevent pollution, to avoid irreversibly changing the global climate, and to capture a large share of the enormous potential market for energy and environmental technologies. Remarkably, a great many of the same R&D investments can simultaneously achieve all these ends while cost-effectively reducing the energy bills of businesses and consumers. Equally remarkably, Congress demonstrates an overwhelming desire to gut the funding for investments by the energy-efficiency-and-renewable-energy program, although it costs Americans only $4.00 per person a year.

Nothing is clearer to those who study the matter than that the world is on the verge of a revolution in energy and environmental technologies—a revolution made possible by more than two decades of U. S. government investment. This revolution can be expected to create a number of industries that collectively will provide one of the largest international markets and one of the largest sources of new high-wage jobs in the next century, with annual sales in excess of $800 billion.

Yet just as our foreign competitors are starting to catch on to the major trends in this American-led revolution, Congress wants to pull the federal government out of every relevant technology, leaving America on the sidelines, perhaps for good. Only a misbegotten ideology could conceive a blunder of such potentially historic proportions.

**As Peter Drucker points out, a new technology cannot displace an old one unless it is proven at least 10 times better. Otherwise the billions of dollars worth of installed base and thousands of engineers committed to improving the old technology will suffice to block the new one.**

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