RESOURCES

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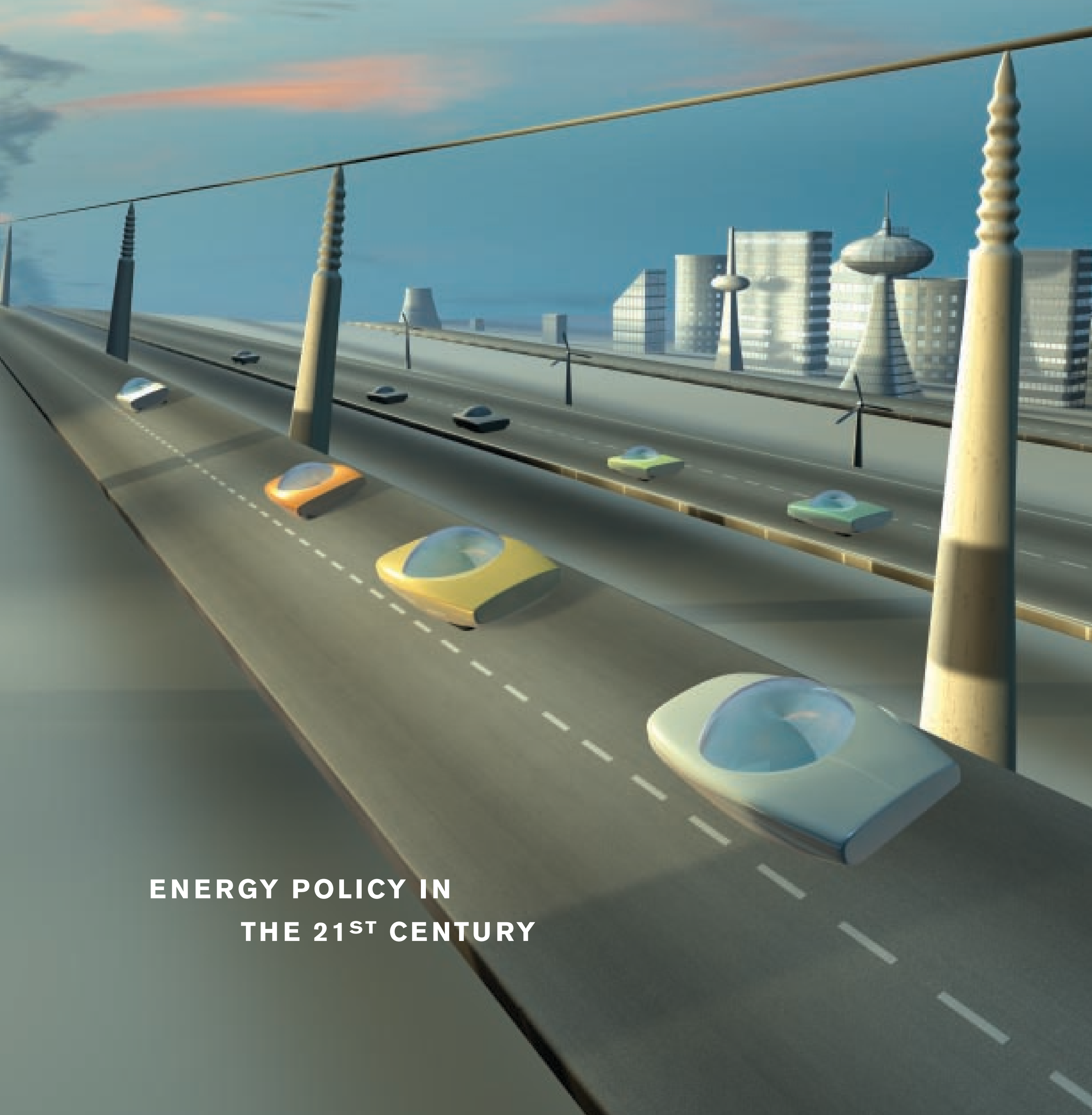

ENERGY POLICY IN THE 21ST CENTURY

Contents




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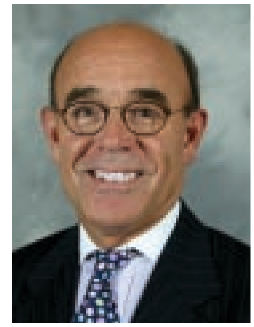


PAUL R. PORTNEY

Energy Choices and Challenges

Congress is making noises once again about comprehensive energy legislation—and claiming that the process will be more bipartisan this time around to avoid the stalemates that doomed efforts in the previous two Congresses. We should all hope this is the case.

For a variety of reasons, it is in this country's interest for the House and Senate agree on measures that would both increase America's energy production and slow the rate of growth of our energy demand. First, recent and steep increases in energy prices, especially for oil and natural gas, have acted as a drag on the economy as a whole and have hit certain sectors of the economy especially hard—transportation and chemical production to name but two. Second, our country's energy choices have important implications for the quality of the environment here in the United States. It's impossible to understand why air quality has improved so dramatically across the country over the past 30 years, for example, without acknowledging changes in the types and amounts of energy we use and the efforts we have made to burn fuels more cleanly. Energy exploration, production, and use also affect water quality, as well as the management of public lands, principally in the West.

There are also sound foreign policy reasons for altering the way we use energy. The most obvious of these is our country's increasing dependence on foreign oil. Nearly 60 percent of our oil supply is now imported—including a growing share from a socially and militarily turbulent Middle East. All signs indicate that our dependence on this part of the world for oil will only increase with time. However, in the international arena, this is not the only reason to act on our energy use. The decisions the United States makes today will affect energy choices made by China, India, Brazil, and dozens of other rapidly developing countries. Not only do other countries often look to the United States for technological leadership (or have in the past, at least), but the choices we make here will also affect the cost and availability of the technologies others will choose from in the years ahead. Since these countries will account for an increasingly larger share of energy use and global economic growth in the future, the energy forms they use to power their growth are of critical importance to the future of all of our economies and environments.

For all these reasons, we dedicate most of this issue of *Resources* to energy matters. We've chosen to do so by focusing on the United States and its varying sources of *primary* energy. Although electricity is vital to this country's energy future, it is generated using several primary energy forms we discuss and so is not treated separately. To be sure, we might have written separate articles on the environment, energy security, technology, and public policy issues, and then talked about each primary energy form along those dimensions. But that would have raised the same kinds of difficulties that attend a fuel-by-fuel organizing arrangement. Instead, we settled on a schematic and narrative presentation of the U.S. energy situation that we believe captures the major alternatives available to policymakers.

It is our hope that you find these brief articles a useful primer on America's energy options, and that they spur you to learn more and perhaps even encourage your elected representatives to become seriously engaged in this critical area of policymaking. As always, thanks for your interest in and support for RFF's work!

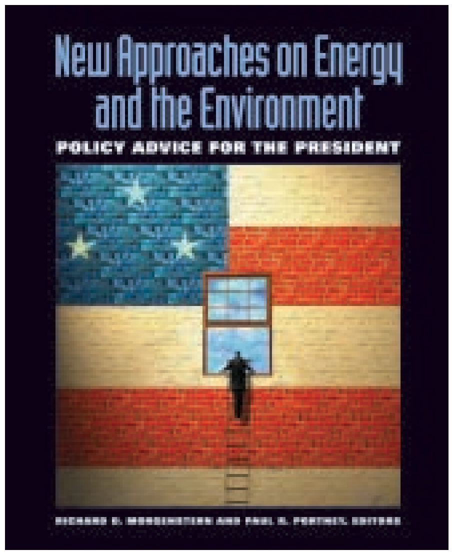
Goings On

RFF Scholars Offer President Sound Advice on Solving Major Energy and Environmental Problems

Just after the election, RFF released a comprehensive set of detailed policy recommend–ations for the Bush administration and Congress, laying out an energy and environmental blueprint for the nation. *New Approaches on Energy and the Environment: Policy Advice for the President* was launched at a Washington Press Club briefing, and the book has since been distributed to all congressional offices, key DOE and EPA staffers, and media across the country.

New Approaches on Energy and the Environment, a collection of 25 analytical, stand-alone "memos to the President," encompasses topics ranging from global warming, oil dependency, electricity regulation, brownfields revitalization, and forest management, to environmental health issues, such as water quality, food safety, and the growing threat of antibiotic resistance. It was published by RFF Press.

"We believe that Americans want actionable solutions to such concerns as energy independence, climate change, air and water quality, and stewardship of land and forest," said Paul Portney, president of RFF and coeditor of the new book. "Although many of these issues were not central to the debates of the 2004 election, the re-election of George Bush signals a prime opportunity to push forward on a range of environmental and energy issues that have languished in gridlock and stalemate."



The re-election of George Bush signals a prime opportunity to push forward on a range of environmental and energy issues that has languished in gridlock and stalemate.

RFF scholars chose policy subjects for the book based on their areas of expertise. Each contributor addressed the question, "Based on your own research and knowledge, what policy recommendation would you like to make to the next U.S. president?" Writing in advance of the 2004 election to keep their essays free of partisan interpretation, authors were asked not to confine their suggestions to what prevailing wisdom says is politically possible. They also took pains to make their ideas accessible to a busy president—as well as a wide range of readers interested in a concise and authoritative overview of energy and environmental policy choices.

"The fact is, Americans want cleaner air and water and healthy and attractive surroundings, but they also want inexpensive fuel, comfortable cars and houses, and continued economic growth," noted Richard Morgenstern, RFF senior fellow and coeditor of the book. "This collection of policy advice is intended to refocus public attention on how we can achieve those goals."

"As our colleagues point out in their recommendations, President Bush will confront competing perspectives about the priorities and approaches that should apply to energy and environmental policy," Portney says. In the aftermath of the 2004 campaign, *New Approaches on Energy and the Environment* seeks to provide thought-provoking, commonsense contributions—and needed course corrections—to the critical energy and environmental issues confronting the United States today. ■

New Approaches on Energy and the Environment is available from RFF Press. Please visit www.rffpress.org or call 800.537.5487. Each chapter of the book may be downloaded on a complimentary basis—see www.rff.org/newapproaches for more information.

RFF Policy Conference Tackles Challenges to U.S. Auto Industry

Few other industries have shaped economic and social growth in the United States as the auto industry has. Yet increased competition from overseas, technological challenges, calls for increased fuel economy, and environmental concerns now threaten the future of this pivotal part of the American economy. These concerns brought together auto and fuel industry leaders, technological experts, environmental experts, and others in November for RFF's Policy Conference, titled "Autos, Energy, and the Environment: Challenges for the 21st Century." The seminar was cohosted by New York University's Leonard N. Stern School of Business, and was held on the NYU campus.

The event kicked off with a dinner and keynote address by Allan D. Gilmour, retired vice chairman of the Ford Motor Company. Panel participants the next day included Thomas Sidlik, executive vice president of global procurement and supply, DaimlerChrysler Corporation; Donald Paul, vice president and chief technology officer of the Chevron Texaco Corporation; Charles Shulock, vehicle program specialist with the California Air Resources Board; and Christopher Grundler, deputy director of the Office of Transportation and Air Quality at EPA.

Discussions over the course of the three panels centered on two topics: financial concerns within the industry, and the challenges of meeting the environmental requirements of policymakers and consumers. Auto executives touched on the pressures they feel from stagnant volume sales, competition from foreign manufacturers, steeply rising health care costs, and pension issues as large numbers of employees reach retirement age. Maryann Keller, president of Maryann Keller & Associates, noted that after accounting for unprofitable sales to rental car fleets or friends and family discounts, U.S. auto manufacturers aren't really selling more cars in the United States than their foreign counterparts.

Declining market share means that production costs per unit are rising, making it more difficult for auto manufacturers to invest in alternative technologies. Meanwhile, fuel industry experts acknowledge an increased demand for energy security and "zero impact" environmental performance. Grundler believes that at this stage, winners and losers in future fuel and technology sources cannot be predicted. RFF Senior Fellow Raymond Kopp noted that there are currently no viable fuel alternatives to petroleum. Despite this, said Dennis Cuneo, senior vice president of Toyota Motor North America and Toyota Motor Manufacturing North America, there is a waiting list for hybrid vehicles, such as the Toyota Prius. Cuneo believes a viable hydrogen market is going to require competition within the auto industry and help from the government, to truly be successful.

While answers to these issues will not be easy to find, conference participants did clearly convey that the challenges facing U.S. automakers in the future are sizable and are being felt throughout the industry. Energy efficiency, alternative fuel sources, and the future of American carmakers depend upon their ability to meet economic and research challenges at home and abroad in the years ahead. ■

Regional Greenhouse Gas Initiative: Prelude to a National Program?

Joseph Kruger and William A. Pizer

Over the past few years, state programs addressing climate change in general and emissions from greenhouse gases more specifically have proliferated. They run the gamut from renewable energy portfolio standards in about 20 states to a proposed carbon dioxide (CO_2) emissions standard for automobiles in California. Perhaps the most significant of these programs is the joining together of nine northeastern states to develop a regional cap-and-trade program known as the Regional Greenhouse Gas Initiative (RGGI). It was launched in April 2003 when New York Governor George Pataki sent letters to fellow governors in the region proposing an emissions trading program. Initially, RGGI seeks to address CO_2 emissions from the electric power sector. Ultimately, the program may be expanded to include additional sectors and other greenhouse gases (GHGs). RGGI advocates argue that the program could serve as a model for a future national GHG cap-and-trade program.

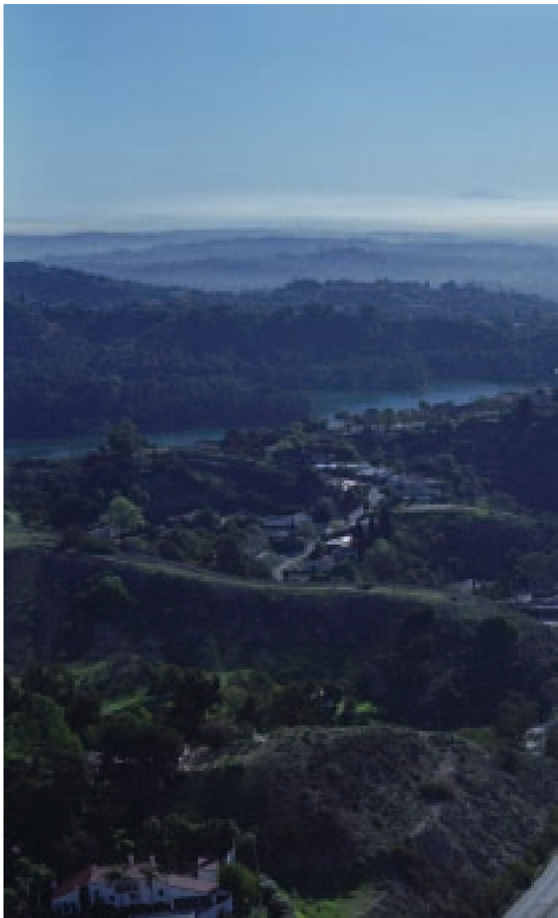
Programs such as RGGI have engaged state policymakers and stakeholders in the important task of reducing greenhouse gas emissions. However, they also raise a number of questions, including what the role of state governments should be in climate change, which is essentially a global problem. Also, given the need for a national if not international solution, will state programs help or hinder the development of effective national institutions for emissions trading? In particular, can states pioneer innovative approaches to some of the unique issues associated with emissions trading of greenhouse gases?

Our answer to these questions is that despite some significant challenges, efforts like RGGI can offer the chance to experiment with some of the features and institutions that will be needed for future national efforts to address greenhouse gases.

Does State Action Make Sense?

Unlike many of the pollutants we are used to dealing with, greenhouse gas emissions are a global phenomenon. Ton for ton, CO_2 emitted in the northeastern United States matters no more for climate change in the region than CO_2 emitted in China; emissions from cars and power plants are the same as emissions from residential furnaces. If state actions do not lead to longer-term, comprehensive federal and international action, they will not make a significant impact on climate change. This differs dramatically from smog, particulates, and acid rain: the emissions that cause these problems are created locally from smokestacks and traffic and have mostly local and regional impacts.

A regional greenhouse gas cap-and-trade program like RGGI poses additional challenges because companies can simply shift emissions to unregulated emissions sources outside the region, causing what is known as leakage. For example, limits on power plant emissions in the RGGI region may simply shift power generation to other parts of the country. In theory, total emissions could even increase, if regulated gas generation in the Northeast, for example, is shifted to unregulated coal generation in the Midwest. This problem is considerably less important under a national pro-



gram, where the flexibility to move economic activity out from under the cap is lower.

Ultimately, whether leakage is a small or large problem for RGGI will be determined by a number of factors, including the level of the emissions cap and constraints on the electricity transmission system that may mitigate leakage. Stakeholders have suggested several solutions, including regulating distribution rather than generation of electricity within the region or regulating regional electricity imports as well as generation.

Although such solutions are feasible if leakage is deemed a significant problem, we believe that care should be taken to avoid complex design features that would complicate implementation, particularly because these features would become obsolete if the United States adopted a national program. Instead, RGGI could focus on innovative solutions to problems more relevant to a national program and address leakage by implementing a more modest cap level.

Efforts like RGGI can be constructive ways to experiment with some of the features and institutions that will be needed for future national efforts to address greenhouse gases.

Experimenting with Innovations Necessary for Greenhouse Gas Trading

Although a state approach to greenhouse gas trading presents challenges such as leakage, RGGI policymakers also have an opportunity to experiment with several innovative features that could be useful for a potential future national cap-and-trade program to address greenhouse gases. Several of these features are discussed below.

Testing Emissions Allowance Approaches

Allowance distribution is one of the most contentious issues policymakers face in designing a cap-and-trade program. Allowances are a valuable asset, created alongside an equally large liability for future emissions, and the distribution of this asset has important implications. Even with a modest target, the value of allowances in a national GHG trading program could be 10 (or more) times larger than those in the sulfur dioxide trading program (currently the largest and most successful emissions trading program in the country). As a result, allowance distribution for a national program will raise significant issues of fairness.

Under RGGI, innovative allocation approaches at the state level could be tested, such as auctioning portions of the annual allocations or allocating some allowances (or the revenues from the sale of allowances) directly to groups that are adversely affected by the costs of a cap-and-trade program. State governments could also experiment with alternative formulas for allocating to existing sources and addressing new source needs. These approaches could be helpful to developing a strong national program in the future.

Developing an Effective GHG Offset Program

Offsets could be a particularly cost-effective way to reduce the costs of a mandatory greenhouse gas program. Unfortunately, there are no functional models for offset programs to draw upon. Although project-based emissions offset programs for conventional pollutants have been around for many years, many have had limited effectiveness because of high transaction costs and uncertain environmental integrity. More recently, the Clean Development Mechanism (CDM), an effort to incorporate offsets from developing countries used under the Kyoto Protocol, has been costly and cumbersome.

If RGGI states advance an environmentally credible program with low transaction costs, they would make an enormous contribution to a future national program. To this end, RGGI policymakers and stakeholders have discussed developing performance standards and other transparent, objective criteria that would provide clear signals to investors about the types of projects that would be acceptable and the volume of credits that would be generated.

Exploring International Linkages

RGGI's launch has sparked great interest in Europe, where an even larger experiment with GHG trading began on January 1, 2005. There have already been informal contacts between state officials and officials of the European Commission and European member states to share information on how the new European Emissions Trading System (EU ETS) is developing. These informal contacts may provide opportunities to explore linking issues that will be useful for any future greenhouse gas program seeking to trade with the EU ETS. A consensus is growing that if or when the United States adopts mandatory GHG reductions, the most likely approach to international trading would be to first develop the national program and then negotiate trading agreements with other countries. Questions on linking that might be explored in the RGGI effort include:

- What metrics will be used to determine whether cap levels are compatible in linked systems?
- What are the implications of using offset credits from the Clean Development Mechanism or allowances from the EU ETS in the RGGI program?
- What enforcement and compliance issues arise when there are trades that cross national boundaries?

The Keys to Success

Ultimately, we believe that RGGI can be a valuable building block for a national climate policy if it is designed in ways that allow it to be successfully scaled up to a federal, multisector cap-and-trade program. Policymakers and stakeholders should focus on keeping the design as simple as possible. An emphasis on creating the right institutions is more important than pushing for an overly stringent short-term emissions cap that might place the region at an economic disadvantage, require special mechanisms to combat leakage, and prove to be politically untenable.

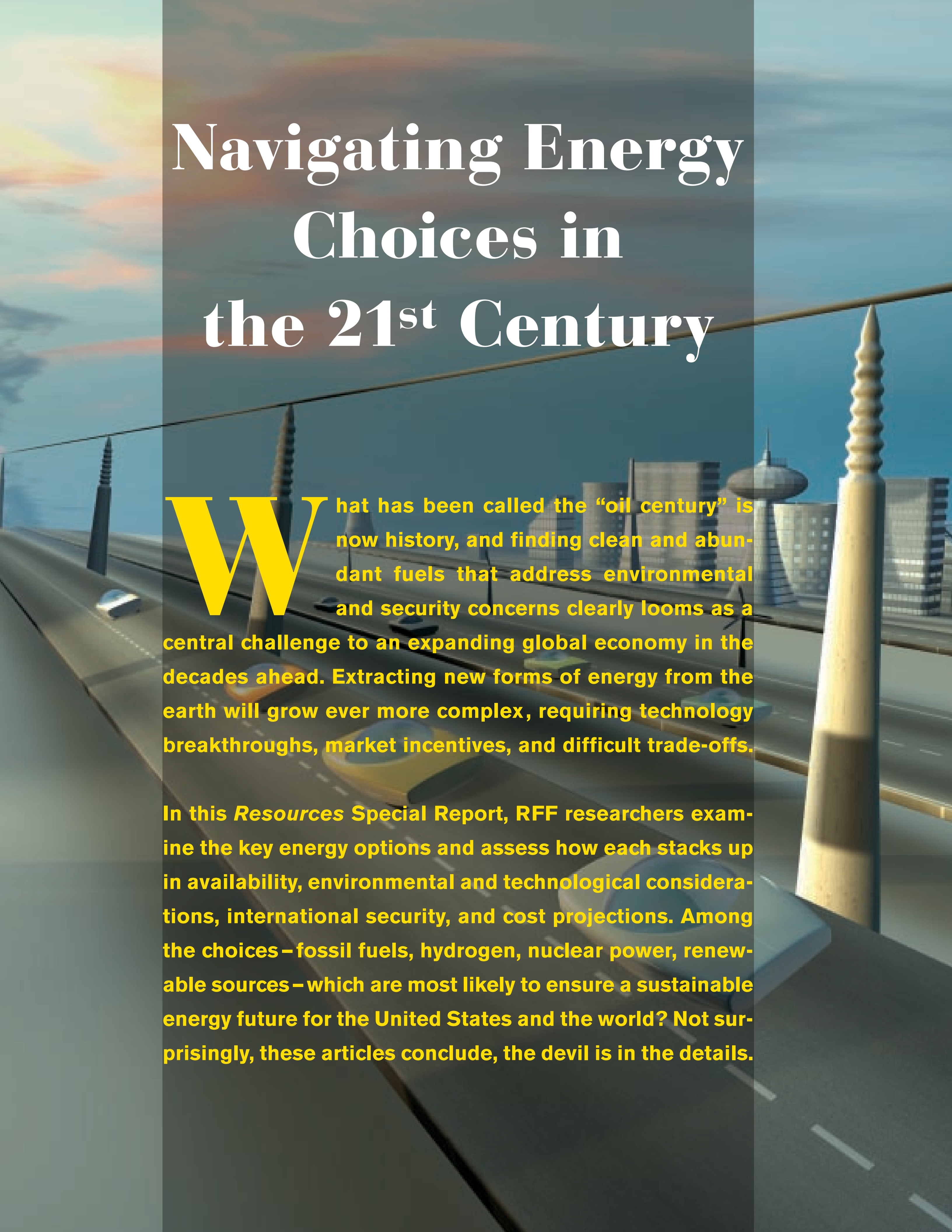
Specifically, we believe RGGI should experiment with new approaches on allocation, offsets, and other features that could develop useful experience and set positive precedents for a future national effort. ■

Joseph Kruger is a visiting scholar at RFF. William A. Pizer is an RFF fellow and a senior economist at the National Center on Energy Policy.

In Memoriam: Pierre Crosson 1926–2004

Pierre Crosson, a member of the RFF staff for 38 years and one of the country's leading agricultural economists, passed away in November 2004. A prolific scholar, he wrote or edited more than 100 articles and books on the economics of agriculture in the United States and developing countries. In recent years, he focused particularly on problems associated with sustainability, soil erosion, and environmental aspects of farming.

"Pierre was uncomfortable with the sense of despair associated with the neo-Malthusian, limits-to-growth model that asserts that unchecked population growth is bound to outstrip the world's carrying capacity," said his long-time RFF colleague Joel Darmstadter. "Still, he recognized that meeting the food needs of a world inhabited by many millions of poor and malnourished people confronted agricultural policy and practice with a formidable challenge. But it was a challenge, Pierre believed, that serious scholarship and enlightened policymaking could successfully help meet." ■



Navigating Energy Choices in the 21st Century

What has been called the "oil century" is now history, and finding clean and abundant fuels that address environmental and security concerns clearly looms as a central challenge to an expanding global economy in the decades ahead. Extracting new forms of energy from the earth will grow ever more complex, requiring technology breakthroughs, market incentives, and difficult trade-offs.

In this *Resources* Special Report, RFF researchers examine the key energy options and assess how each stacks up in availability, environmental and technological considerations, international security, and cost projections. Among the choices – fossil fuels, hydrogen, nuclear power, renewable sources – which are most likely to ensure a sustainable energy future for the United States and the world? Not surprisingly, these articles conclude, the devil is in the details.

Setting Energy in the

William A. Pizer

More than 50 years ago, when RFF was founded, there was widespread concern about potential shortages of crucial energy and natural resources that might jeopardize economic well-being in the United States. RFF scholars, among others, helped to disprove that myth, showing that free markets, free trade, and technological innovation would alleviate pressure on resource constraints, an idea that seems almost clairvoyant today. The United States has experienced remarkable economic growth since then, with the real gross domestic product increasing by more than 400 percent. Our domestic reserves of natural gas and petroleum are virtually unchanged over the same period, and global reserves have roughly doubled in the past 25 years alone.

Today, the United States finds itself facing a very different set of issues over energy supplies, focusing mainly on security and the environment. We currently spend more than half a billion dollars *a day* on imported oil, overwhelmingly from the Middle East, even as we fight a war on terrorism centered in that region. We are increasingly concerned about the reliability and resiliency of the electricity grid to both unintentional and intentional disruptions. We are also the largest emitter of greenhouse gases, primarily from the burning of coal, oil, and natural gas, which are believed to cause changes in the earth's climate.

The perceived problem 50 years ago, resource scarcity, is one best solved by letting free markets work out how to efficiently extract and allocate limited supplies, simultaneously signaling both conservation and innovation, and the development of new technologies. But the new problems of energy security and environmental challenges result from a fundamental failure of energy markets to address issues that fall outside the market framework. This time, government clearly must intervene to correct these problems.

The government's role should be to intercede in ways that allow the private sector the most flexibility to trade off equally effective actions in the face of incentives that promote security and environmental protection. Such interventions could include an emissions trading program for greenhouse gases, a petroleum tax to address concerns about oil use, or clear rules for cost recovery associated with new electricity transmission infrastructure.

Energy "Problem" or Functioning Marketplace?

Popular discussions of energy problems today tend to focus either on increases in consumer energy prices or on high-profile news events, such as the Northeast blackout in 2003 and the California energy crisis in 2000. Natural gas prices, which stayed consistently in the range of $2 per million British thermal units (MBtu) for virtually all of the 1980s and 1990s, have been above $4 since January 2003. Crude oil, which similarly hovered in the $20 per barrel range from the mid-1980s until 2002, has been above $40 since July 2004. Adjusting for inflation, crude oil prices are still lower than the levels experienced during the early 1980s, but both the suddenness of the runup and the gut-level reaction to gasoline prices above $2 per gallon have propelled concern over energy policy to higher levels.

But what kind of energy policy do we need? The reliability and performance of electricity markets (as well as related demand for natural gas) are clearly something that needs to be addressed cooperatively by both federal and state agen-

Policy

TOUGH CHALLENGES LIE AHEAD

Modern Era

cies. Higher prices, on the other hand, may be part of a new balancing of supply and demand and something that energy policy can do little to relieve. In 2000, the Energy Information Administration (EIA) forecasted prices of $2.50–3.00 per cubic foot (pcf) of natural gas and $20 per barrel of crude oil by 2020. These estimates have clearly been exceeded, and the higher prices are expected to continue. Government has little room to intervene here.

Although many people express concern about national security and environmental issues, few see the connection to national energy policy and especially to their own patterns of energy use. The historical trend in new vehicle sales toward less fuel-efficient pickup trucks, minivans, and SUVs and away from more fuel-efficient cars has continued unabated despite the events of 9/11 and hoopla surrounding the Kyoto Protocol. (One promising trend is the 89 percent annual growth in hybrid sales since 2000, though they are still a tiny fraction of the new-vehicle market.)

Security

Our ongoing national debate over energy security has so far focused on the steady growth in oil use in the transportation sector, the consequent rise in imports of oil from the Middle East, and the threat of economic calamity should our oil supplies be disrupted. But there are emerging concerns that deserve equal attention, namely the resilience of the domestic energy infrastructure—oil and gas terminals and pipelines, nuclear power plants, and the electricity grid—to terrorist attacks and, in the future, the same problems for natural gas imports as there are for oil. The former requires somewhat conventional security policies—building stockpiles, fortifying installations and control networks, and creating redundant back-up systems. The latter requires thinking about how various policies will affect natural gas supply and demand in the future.

In this vein, electricity generation accounts for about half the forecast growth in natural gas use over the next 20 years, with about two-thirds of that supply coming in the form of imported liquefied natural gas. Policies that emphasize coal, renewables, and nuclear power generation—three energy sources with abundant, secure domestic supplies—will reduce pressure on natural gas imports. Similarly, efforts to encourage and diversify natural gas supplies can diminish the kinds of security concerns that are associated with oil imports.

Our large and increasing dependence on oil—supplied in growing part from the Middle East—to fuel the transportation sector nonetheless remains the 900-pound gorilla seated at the policy table. As economists struggle to put a dollar value on the risks posed by oil imports from the Middle East, two broad categories of consequences often emerge: economic dislocation from actual or threatened supply disruptions, and the diplomatic and military costs associated with safeguarding access to Middle East oil supplies. With the ongoing war on terrorism, another concern has arisen: some of the oil revenue flowing into the Middle East makes its way into the hands of the very terrorists we are fighting.

The global nature of oil markets makes it impossible for the United States to discriminate against oil from particular sources. The idea of completely isolating ourselves from these markets is also unappealing: despite costly fluctuations, international markets still provide us with much cheaper oil supplies than we could ever access domestically. The solution, then, is for the government to encourage broad-based reductions in petroleum use, reducing our exposure to supply disruptions, our need to intervene diplomatically or militarily, and the flow of funds into the Middle East. A particularly simple (but politically unlikely) approach is to set a petroleum tax at a level that reflects the estimated consequences—risk and cost of a oil shock, diplomatic and military expense to maintain global market access, and indirect support of terrorism—associated with additional oil consumption.

A broad tax has the advantage of both encouraging less fuel use and encouraging the development of energy-saving technologies, which are now more valuable. A second-best alternative might be to focus solely on energy-saving technologies through a broad, market-based performance standard for all vehicles or other incentives. In this scenario, the new-vehicle fleet is forced to meet a miles-per-gallon standard on average but can offset production of less-efficient vehicles with credits gained from producing more-efficient vehicles. Under such a standard, the new vehicle fleet is forced to meet a miles-per-gallon standard on average, but production of more fuel-efficient vehicles generates credits that can be used to offset production of less fuel-efficient vehicles by any manufacturer. This approach focuses on the "technology" margin of reducing fuel use per vehicle mile travelled, rather than the "behavioural" margin of encouraging people to drive fewer miles.

Climate Change

Global awareness and acceptance of the problems associated with carbon dioxide emissions are growing, but considerable disagreement remains over what to do about it. Many nations have embraced the idea of national caps for greenhouse gas emissions embodied in the Kyoto Protocol, and most notably, Europe has implemented an emissions trading scheme for carbon dioxide. Other countries, including the United States, have instead focused on voluntary programs and federal spending on technology—even as emissions trading proposals sporadically appear in Congress and some states attempt to implement regional programs.

U.S. technology programs center on nuclear, renewables, coal with carbon capture and sequestration, and hydrogen as a future energy carrier. Meaningful government efforts to push these technologies will go only so far, however; government also needs to provide incentives to encourage private-sector investment in them. A flexible emissions trading program or emissions tax sends a clear signal to the market about the value of emissions reductions both now and in the future. In a competitive environment, firms cannot invest significantly in emissions-reducing activities or R&D designed to lower the cost of these activities in the future if their competitors do not; that reality will confound effective voluntary programs. Most analysis also suggests that technology policy alone is unlikely to displace entrenched carbon-emitting technologies.

Markets and Innovation

Maintaining and expanding the efficiency of underlying energy markets poses a different set of challenges. Electricity markets in particular exist somewhere between regulation and competition with a great deal of uncertainty about their future. Because electricity generation constitutes a large source of natural gas demand, gas markets are also affected by this uncertainty. Federal and state governments need to work out a clearer roadmap for the future of these and other energy markets.

Government support for technological innovation is just as important now as it was 50 years ago. Investment in research and development tends to be undervalued because many of the economic benefits of new discoveries are not captured by those who discover them, but instead accrue to firms that imitate successful innovations. In the case of research into oil-saving and greenhouse gas–reducing technologies, it is likely that these innovations are further undervalued because policies to directly address those problems (such as petroleum taxes and emission caps) may be weaker than security and environmental concerns justify.

Moving Forward

Part of the guidance we need to tackle today's energy problems lies in the suggestions put forward by RFF researchers decades ago. Then, as now, concern over scarcity and price will be best addressed through well-functioning energy markets and government support for technological innovation. However, concern over newer issues, where the market fails to incorporate broader societal concerns over security and the environment, requires government intervention, ideally through flexible, market-based approaches. But the devil is often in the details. Energy markets and particular fuel choices are complicated by a variety of features. Market-based approaches, because they raise prices, often face political resistance.

There is no magic bullet for our energy problems, no single way to address our security and environmental concerns. Effective intervention and market reform requires attention both to the peculiar features of energy markets and fuel choices, as well as to broad incentives that promote society's security and environmental goals. ■

Petroleum

ENERGY INDEPENDENCE IS UNREALISTIC

Ian W.H. Parry and J.W. Anderson

With heightened concerns about energy security and global warming, governments and businesses around the world are beginning to think seriously about a transition away from oil as the crucial fuel for transportation. The central policy question is how to push this transition forward without slowing or destabilizing the growth of economies to which rapid and convenient transportation has become essential.

Crude oil prices have tripled over the past three years and this has sparked predictions of ever-rising prices in coming decades and exhaustion of the world's oil reserves. We heard these predictions before, during the energy crises of the 1970s; however, the subsequent two decades in fact saw falling prices, increasing world oil production, and expanding reserves as the market responded to higher prices. On the demand side, energy conservation and fuel-switching measures reduced the amount of oil used per unit of gross domestic product (GDP), in the U.S. case, by half over the last three decades (see Figure 1). And on the supply side, higher prices encouraged oil exploration and development of known but previously uneconomic fields, through improved technologies for locating and extracting reserves.

It is possible that we will see some reversal of recent price rises as these types of economic forces come into play again; for example, breakthroughs in converting oil shales and tar sands could significantly add to global supply. However, other factors appearing on the horizon suggest that things may turn out rather different, this time around. Most importantly, is large developing countries, particularly China but also India, are beginning to embark on the path of wider automobile ownership that nearly all countries experience as they get richer. With four times the population of the United States, China currently has eight vehicles per thousand people compared with the United States's 780 vehicles per thousand—a ratio suggesting relentless pressure on oil markets in coming decades.

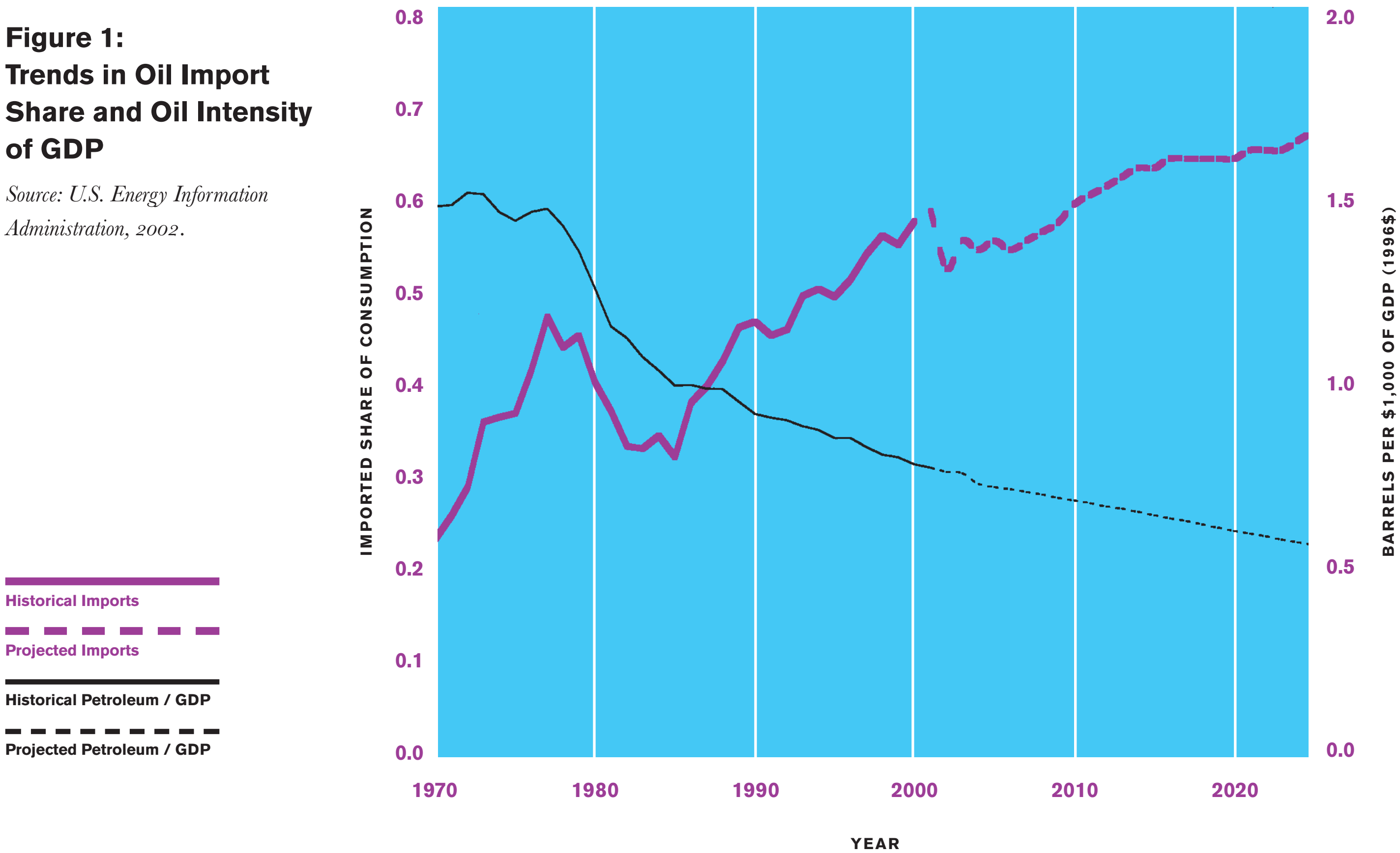
And now that U.S. electricity generators have more or less dispensed with oil, further reductions in oil intensity are harder to come by. Two-thirds of American oil consumption is now in transportation—highways, air routes, and long-distance railroads—and there is no other fuel that is currently viable (see page 14 for a discussion of ethanol's potential).

Growing Dependence on Foreign Oil

Concerns about the economy's dependence on oil are compounded by three trends. First is the steadily rising volume of imports, which currently account for well over half of the 20 million barrels a day that we consume (see Figure 1). Domestic American production is falling as long-worked fields are exhausted, but demand keeps rising relentlessly.

Figure 1: Trends in Oil Import Share and Oil Intensity of GDP

Source: U.S. Energy Information Administration, 2002.



The problem of dependence on foreign oil is frequently misunderstood and overstated: for a given amount of domestic oil consumption, the increase in cost of producing goods in the economy following an oil price shock depends on the amount of oil used per dollar of production, and not the share of oil consumption that is imported. And given that the world oil market is fully integrated, the price we pay for imports is the same whether imports come from the Persian Gulf or from reliable sources such as Canada and Mexico. But import dependence does exacerbate the macroeconomic disruptions caused by oil price shocks: because extra dollar payments for imports go out of the economy to OPEC and other foreign suppliers, rather than being recycled within the economy to domestic oil companies, oil dependence leads to a further reduction in aggregate demand for U.S. goods.

The second trend is that production is expected to become increasingly concentrated in the Persian Gulf region, where an estimated two-thirds of global reserves are located; by contrast, estimated reserves for the United States are only about 2 percent of the global total. Intense concentration of supply in any one region would be cause for concern, but that concern is intensified by the history of political upheaval and violence in the Middle East.

A third trend is the growing U.S. trade deficit, which many economists consider unsustainable. For 2004 it will come to about $650 billion dollars, well over 5 percent of GDP. At the current price—at this writing, over $40 a barrel—U.S. oil imports total about $175 billion a year, more than one-fourth of the total trade deficit. Pressure on the exchange rate of the U.S. dollar is rapidly becoming another prominent reason for Americans to look for ways to reduce oil use.

Calls for energy independence are unrealistic, to put it mildly, for the foreseeable future; cutting oil consumption to current domestic production would severely derail an economy in which cheap and rapid transportation is taken for granted. Like it or not, Americans must confront the reality that oil prices are set by worldwide markets that respond to many economic and political factors beyond the U.S. government's control. Of all the reasons that make policymakers uneasy about dependence on oil, the most immediate is the impact of sudden and prolonged price swings on economic growth, particularly given evidence that price increases harm the U.S. economy more than price reductions benefit it.

Environmental Concerns and Technological Challenges

Many of the traditional environmental concerns associated with oil use have been alleviated through a combination of regulation and technological improvements; for example, new passenger vehicles are more than 90 percent cleaner than 20 years ago and will become cleaner still with more stringent emissions standards.

The big environmental issue is the carbon dioxide emissions that form during fuel combustion and remain in the globe's atmosphere as a heat-trapping gas for hundreds of years. As consensus has solidified among most scientists that human-induced climate change is now occurring, calls for policies to slow down and eventually stop further increases in atmospheric greenhouse gas concentrations have intensified. But the challenges are immense: reductions in global emissions of 70 percent or more below current levels would ultimately be required if atmospheric greenhouse gas concentrations were ever to be stabilized before a doubling of atmospheric concentrations over preindustrial levels is reached.

No sector faces a tougher challenge for drastically reducing carbon dioxide emissions than the transportation sector,

Like it or not, Americans must confront the reality that oil prices are set by worldwide markets that respond to many economic and political factors beyond the U.S. government's control.

Ethanol at Every Pump? Not Quite Yet . . .

Consumption of ethanol has been rising fast in recent years, pushed by subsidies – currently set at 52 cents a gallon from the federal government, plus additional help in several states – and federal requirements for oxygenation of gasoline. Ethanol's only competitor as an oxygenating agent is MTBE (methyl tertiary butyl ether), which has been banned in some states and may soon be banned nationally as a carcinogen that finds its way into drinking water supplies.

Ethanol represents only a tiny fraction, 2.4 percent, of the total automotive fuel used last year. However, it enjoys powerful political support from farm lobbies because nearly all of it is made from corn, using one-tenth of the corn crop and lifting corn prices. Developing technologies may soon make it possible to make ethanol more cheaply from cellulosic biomass, such as cornstalks, sawdust, and waste paper. One question for the future of ethanol is whether its political support will continue if the industry moves away from grain toward less expensive raw materials.

where, unlike power generation, the possibility of substituting existing low-carbon fuels or capturing exhaust gases for underground or deep-ocean storage is simply infeasible.

As documented in a 2002 National Academy of Sciences report, there appears to be a wide range of emerging technological possibilities for raising the fuel economy of new passenger vehicles through improvements in engine efficiency, reduced rolling resistance, and so on. Better fuel economy for conventional gasoline engines would be a significant, though not dramatic, help in reducing oil consumption and carbon emissions. So would a shift toward diesel passenger vehicles that use less fuel per mile driven. Although widespread in European countries, diesels have been held back in the United States for two reasons: they would complicate auto manufacturers' compliance with stringent federal emissions standards for their vehicle fleets, and unlike in most European countries, diesel fuel is not taxed at a lower rate than gasoline.

Hybrid vehicles, which supplement a conventional gasoline engine with an electric drive train, promise a significant increase in gasoline mileage, particularly when the vehicle is used in urban stop-and-start driving. Toyota led the way with its hybrid Prius, and within the next few months, several major manufacturers will have hybrids in their showrooms. However, whether hybrids will achieve substantial market penetration in the foreseeable future is unclear; unless gasoline prices reach unusually high levels, their cost, including fuel costs over vehicle lifetime, is likely to exceed that of equivalent all-gasoline models.

General Motors has put several experimental automobiles powered by fuel cells on the streets of Washington, D.C. However before the fuel cell becomes a standard source of power on the highway, chemists and engineers will have to resolve a number of formidable technological challenges.

Policy Responses

In an ideal world, the instrument of choice to reduce the country's use of oil would be a modest tax on all oil uses, perhaps $5 a barrel to begin with and increasing gradually thereafter, to accelerate energy conservation measures and remind people of the full costs to society from oil use. The potential costs of global warming are not currently reflected in U.S. oil prices. Neither are the full costs of oil dependence: although businesses may try to account for risks to themselves from oil price volatility in their investment and inventory strategies, they may not consider other risks, such as the cost of temporarily idled labor and capital following energy price shocks. An oil tax would have implications for productivity in an economy that depends on rapid and flexible transportation. Still, society would benefit overall, so long as the tax were appropriately scaled and revenues were used productively—for example, in other tax reductions or deficit reduction.

The Bush administration wants to expand domestic oil production, particularly through legislation to open the Arctic National Wildlife Refuge to drilling. The oil reserves there could produce, at peak, some 1 million to 1.3 million barrels a day, according to administration data. That would be a substantial contribution to correcting this country's foreign trade deficit. But since that new production would represent slightly over 1 percent of world oil consumption and 5 percent of American consumption, it would be unlikely to have a significant effect on oil prices.

Furthermore, unlike an oil tax, increased domestic production does nothing to reduce the overall oil intensity of GDP, and hence our exposure to oil price shocks. A broad oil tax would also be much more effective at reducing oil use than a hike in the federal gasoline tax or higher fuel economy standards for new passenger vehicles, since the broader tax would encourage energy conservation measures and innovation throughout the economy, rather than just in motor vehicles. Although the chance of new energy taxes in the next few years appears very remote, it is conceivable that this situation may change down the road, given continuing pressures to "do something" about U.S. greenhouse gas emissions and our looming deficit problems. There is strong opposition to raising any tax in the United States; however, unlike for income taxes, there is at least some support for in favor of higher energy taxes because of the security and environmental benefits.

But over the long haul, the problem is really a technological one: developing transportation vehicles with low or zero conventional fuel requirements that can be manufactured for prices consumers are willing to pay. Although the market is engaging in some early R&D efforts on its own, in response to higher oil prices and future anticipations of a carbon-constrained world, a case can be made for strengthening and expanding grants and tax breaks for the development and adoption of clean vehicles. Without such incentives, manufacturers are likely to underinvest in innovative efforts, as they are not fully compensated for the environmental and energy security benefits from cleaner vehicles, and the benefits to other firms in the United States that may adapt their innovations, let alone potential benefits to vehicle manufacturers in China and other parts of the world. ■

Oil Prices and Foreign Policy

When oil prices rise or fall, there's an impact on both world politics as well as on country economies.

In 2002, Russia was working to attract foreign investment and appeared to be concerned about its reputation in the West. Net direct foreign investment in Russia that year was a little over $3 billion. But when oil prices rose by 50 percent in 2004, increasing Russian oil export earnings at a rate of perhaps $30 billion a year, one consequence was to diminish Russian need for foreign capital. Last year, President Vladimir Putin renationalized the major part of the country's largest oil company, tightened the government's grip on the press, and accelerated the trend toward centralized authority in Russia.

Several European governments have been urgently negotiating with Iran to dissuade it from pursuing nuclear weapons. One of the most attractive incentives they could offer has been investment capital. But Iran suddenly needs it much less: since early 2005, Iran's oil export earnings are now projected to run about $15 billion a year higher than the year before.

Throughout the Middle East, this wave of unexpected new revenue has flooded into countries not all of which are well equipped to keep it from reaching violent political factions and terrorists. The routes and magnitudes are unknown. But it is evident that the insurgency against the U.S. presence in Iraq is not suffering from inadequate financial support.

To the extent that Americans have contributed to the rise in oil prices through their steadily rising demand for oil, they appear to have undercut their own foreign policy goals and their own national security interests.

–J.W.A.

Natural Gas

SUPPLY PROBLEMS ARE KEY

Raymond J. Kopp

Natural gas is the fossil fuel *du jour.* It is less polluting than either coal or petroleum in conventional uses, including residential, commercial, and industrial applications, as well as in electricity generation, where it has displaced coal as the premier fuel for new power plants. Moreover, natural gas is a vital feedstock (that is, raw material) to the petrochemical industry and in the near term will be a driver for the evolving hydrogen economy of the future.

Right now, petroleum accounts for the lion's share of total U.S. energy consumption, with coal and natural gas tied for second (see Figure 1). But that's comparing apples and oranges—petroleum is predominantly used in the transportation sector. Natural gas is now widely used in industry, accounting for almost a third of industrial applications, with electricity generation and residential use close behind (see Figure 2).

What's the Problem?

Until the summer of 2003, when Federal Reserve Chairman Alan Greenspan began sounding the alarm over high natural gas prices, few policymakers and even fewer members of the public worried about such things as gas storage levels, drilling rates, and liquefied natural gas (LNG). Spot market prices for natural gas edged lower toward the close of 2004 from their record highs of over $9 per million British thermal units (MBtu) in October. However, as recently as late winter 2002, the price was a mere $2.50/MBtu. After the Fed chairman spoke on these issues in Capitol Hill appearances and gas prices rose to unprecedented levels, the heretofore quiet world of federal natural gas policy became a lot noisier. High natural gas prices hurt the competitiveness of many segments of the economy, including the hard-hit domestic petrochemicals industry, which relies heavily on natural gas as a feedstock. Moreover, higher gas prices may even now be tipping the balance back toward using coal, which is more polluting, in generating electricity.

Natural Gas Reserves

It is natural to ask what forces are causing gas prices in the United States to rise and what the prospect is for lower prices in the future. Like petroleum and coal, natural gas is an exhaustible resource, and at some point the world may run short of it and prices will naturally rise. But are we at that point?

The U.S. Energy Information Administration (EIA) reports global estimates of proven reserves of natural gas are 70 times the size of current world annual consumption. Moreover, while consumption will rise in the future, the size of proven reserves has increased every year since 1970. Therefore, one can reasonably conclude that recent high U.S. prices are not due to the world's running out of gas.

More important than aggregate global reserves, however, is their distribution. Natural gas reserves are not as concentrated as crude oil (with over 60 percent of all reserves located in the Middle East), but the United States is not heavily endowed with gas deposits (see Figure 3). The largest gas suppliers are located in the Middle East, Eastern Europe, and countries of the former Soviet Union, which together have over 70 percent of known reserves. The large gas consumers—North America and Western Europe—have only 7 percent. At current rates, U.S. reserves are about eight to nine times greater than annual consumption, which is considerably less than the world reserve-to-consumption ratio.

All things being equal, lower domestic reserves suggest that exploration and extraction costs will be greater in the United States and, so too will be delivered natural gas prices. However, to the extent there are integrated competitive world markets for gas, as there are for crude oil, gas prices should not differ from one county to another by more than the cost of transport. Unless gas pipelines link supplying and consuming countries, however, transport of natural gas becomes challenging, requiring specialized tankers and port facilities that are quite different from petroleum tankers and ports. At the present time, the United States has only four ports capable of importing natural gas from the countries with the greatest reserves. These and other factors contribute to large price discrepancies from country to country.

Natural gas is now widely used in industry, accounting for almost a third of industrial applications, with electricity generation and residential use close behind.

Production

Reserves are only an estimate of what is in the ground. Annual production data describe how much gas is actually being extracted. EIA forecasts U.S. production to grow at an annual rate of 0.7 percent over the next 20 years, with consumption to grow at 1.6 percent. Herein lies the problem. EIA cautions that regulatory and investment uncertainty exists in making those natural gas supplies available. Failure of investments to materialize or approvals to be granted will lead to upward price pressure on gas. And even with the anticipated added domestic production, a significant shortfall will still have to be augmented with imports, which are expected to grow by 4.5 percent over the coming two decades.

Prices and Increased Supply

Natural gas prices are determined by the interplay of supply and demand. The overall level of economic activity, continued use of gas to fire new electric power plants, and efforts at conservation are all factors affecting the long-term demand for natural gas. However, it is the factors affecting supply that are drawing the greatest attention from policymakers and analysts.

The most straightforward way to increase U.S. supply is to drill more gas wells, but with prices at all-time highs, the economics of natural gas suggests there is likely as much drilling going on now in the United States as the available industry infrastructure can support. Increasing the rate of domestic exploration is problematic for two reasons: drilling is taking place in the same, mostly depleted fields, and governmental restrictions currently do not allow additional drilling in new fields offshore (California and Florida) and in the intermountain West. As might be predicted, many are opposed to drilling in these environmentally sensitive areas, including the president's brother, Florida Governor Jeb Bush.

Others argue for more drilling and extraction of natural gas from the oil fields in Alaska. But getting the gas from Alaska to the lower 48 will require a large and expensive pipeline project. Language in a military construction appropriations bill passed in October 2004 smoothed the federal regulatory hurdles for the pipeline construction and provided some $18 billion in loan guarantees but did not include federal guarantees on the price of natural gas once the pipeline is operating. It remains to be seen if these "sweeteners" will bring forth the needed private investment.

Sources of renewable energy, such as wind power, are important components of the country's energy portfolio going forward, but the questions now are how much natural gas can we expect renewables to displace, how fast, and at what cost?

A third enhancement to supply is imported liquefied natural gas (LNG), which becomes economically competitive to domestic gas supply when the price of domestic gas rises above $3.50/MBtu. This is well below the current spot and futures prices—indicating that the economic climate for LNG is right. Although the troubled Middle East has large natural gas reserves, Venezuela and several Caribbean countries do as well, suggesting that increased LNG imports might not carry the added international political burdens associated with oil.

But ports accepting LNG tankers are large, capital-intensive industrial facilities that are expensive to build and must be operated for long periods to provide suitable rates of return to investors. Moreover, there are those who believe such coastal facilities will have negative effects on the local environment and might make tempting targets for terrorists as well.

Another option to consider is using renewable energy to stretch existing natural gas supplies instead of increasing them. Sources of renewable energy, such as wind power, are important components of the country's energy portfolio going forward, but the questions now are how much natural gas can we expect renewables to displace, how fast, and at what cost? Of course, gas supplies can be stretched through straightforward energy conservation as well.

In March 2003, then Energy Secretary Spencer Abraham asked the National Petroleum Council (a federally chartered advisory committee) to undertake a major study of natural gas supply and demand through 2025. In addition to increased efficiency and conservation, the council report recommended increased access to domestic gas deposits and reduced permitting impediments to development of natural gas resources in the lower 48 states. The council also argued in favor of legislation enabling the construction of a new Alaska gas pipeline and rapid, one-year processing of LNG project permit applications.

The recommended legislation has now passed, and it's up to private investors to make their move. Opening up more lands to exploration and extraction, whether onshore or offshore, will require a heavy political fight and even if successful, will have only near-term benefits because domestic gas reserves in the lower 48 are limited and unlikely to increase by much. So perhaps the greatest emphasis should be placed on imports and LNG.

While LNG fleets and facilities are costly investments, the economics of large-scale LNG importation suggests investment funds will be forthcoming. The real obstacle is siting the port facilities. Safety and environmental concerns are raised everywhere a new LNG port is proposed, and increased fear of terrorist attacks on LNG tankers as they enter ports has only heightened fears and opposition.

These facilities are too large, too expensive, and too politically vulnerable to ram down the throats of reluctant communities. Some rational process by which the safety, security, and environmental threats are credibly assessed, standards for acceptable risks established, and siting decisions made without years of bureaucratic wrangling must be found—and found quickly—for natural gas to be a viable option in the U.S. energy future. ■

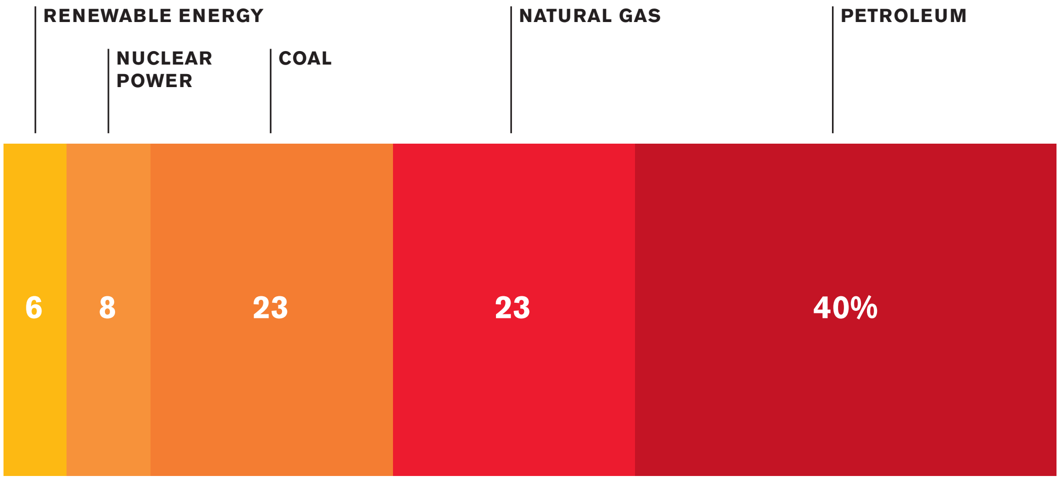


Figure 1: Projected Composition of U.S. Energy Demand in 2005

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION, 2005

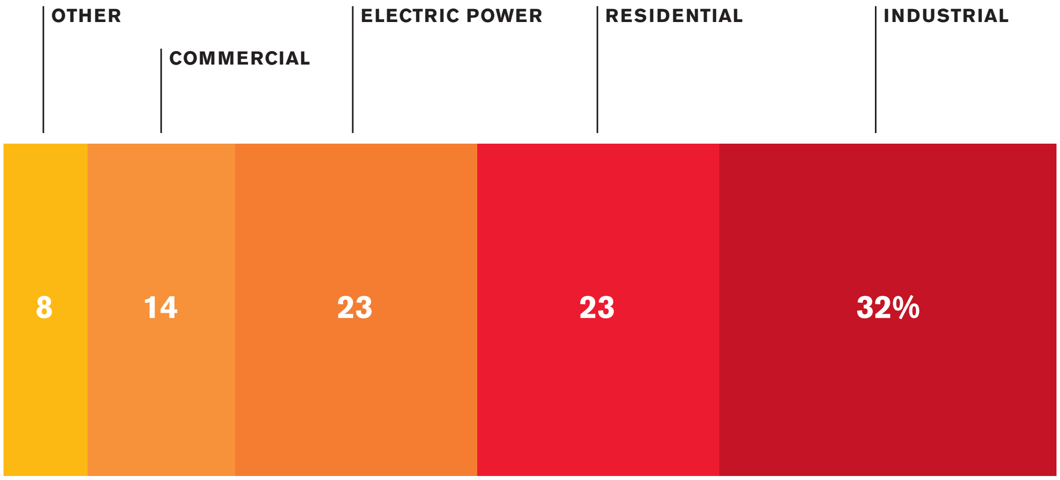


Figure 2: Projected Composition of U.S. Natural Gas Demand in 2005

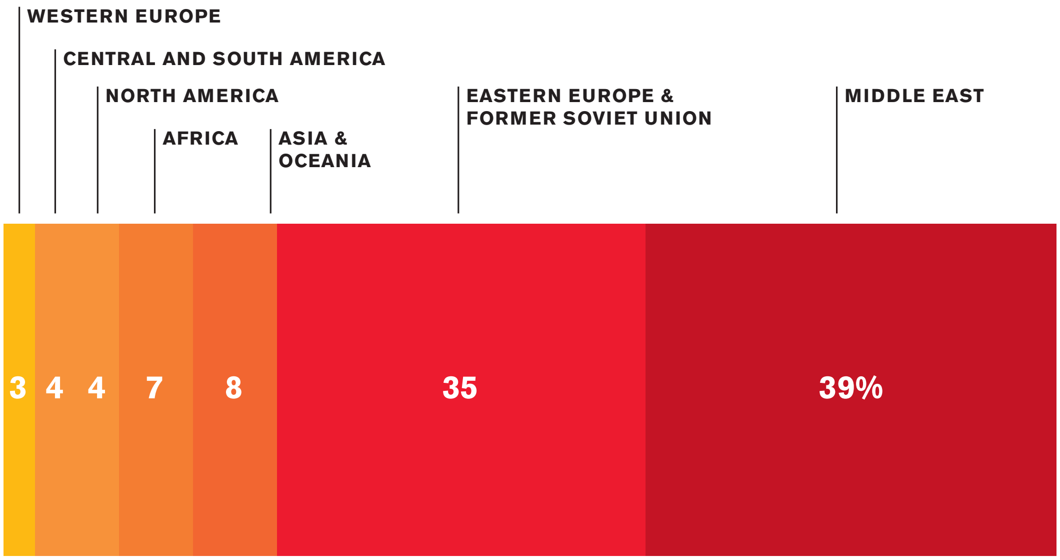


Figure 3: Current Distribution of World Natural Gas Reserves

The Hydrogen

LAYING OUT THE GROUNDWORK

Richard G. Newell

In the 1970s, several studies predicted a hydrogen fuel economy might emerge as early as the year 2000. Flash to the present—where, in his 2003 State of the Union address, President Bush put forward the Hydrogen Initiative, which would involve spending $1.2 billion over five years to develop hydrogen, fuel cell, and infrastructure technologies to reduce our dependence on foreign oil. His goal is to make it possible for enough Americans to choose hydrogen fuel cell vehicles by 2020, so that, as the president put it, "the first car driven by a child born today could be powered by hydrogen."

More recently, California Governor Schwarzenegger set out his Hydrogen Highway goal of building, by 2010, a network of 150–200 hydrogen fueling stations throughout the state, making hydrogen fuel available to a majority of Californians. Meanwhile, hydrogen-fueled demonstration vehicles and related filling stations are making news in the nation's capital.

So what's all the buzz about? In addition to being a potential substitute for oil, hydrogen use in fuel cells is pollution-free, thereby eliminating emissions that cause air quality problems. The impact on carbon dioxide emissions and global climate change depends on how the hydrogen itself is produced—whether it is from nuclear or renewable energy sources or from fossil fuels—and what is done with the emissions generated by its production. Potentially, a "hydrogen economy" could evolve that addresses both the energy security and environmental concerns associated with our current "carbon economy."

Significant scientific and practical hurdles must be surmounted before hydrogen becomes a cost-effective part of the energy system, however. These hurdles extend from the initial production of hydrogen, to its distribution and storage, and through to the final conversion of hydrogen into energy through fuel cells or other means. A reasonable person might ask, "In 20 years, will we be reading again that the hydrogen economy is only 20 years away?" To shed some light on this question, this essay briefly reviews the challenges to the widespread hydrogen use in light-duty vehicles and offers some perspective on the likely timeframe in which they might be overcome.

Hydrogen production

About nine million tons of hydrogen are produced per year in the United States, with about one-third used in the manufacture of ammonia and most of the remainder in petroleum refining. A recent National Research Council (NRC) report suggested that under an optimistic timetable, hydrogen-fueled vehicles could replace light-duty vehicles by 2050. But that would require about 111 million tons of hydrogen per year—more than 12 times current production levels. For this to be a plausible and desirable future, at least two major production challenges must be met: cost and climate friendliness.

Economy

Hydrogen gas does not exist naturally on earth as an isolated element. Rather, it must be produced by chemically separating it from other elements, particularly carbon and oxygen. One way to do this is through electrolysis, whereby hydrogen is separated from the oxygen in water, producing water vapor and heat as the only by-products. This process is simple, but it is also very expensive because the electricity that drives the process must itself be generated. At current electricity prices, producing hydrogen through electrolysis costs about seven times more than gasoline per unit of usable energy. Hydrogen production using electricity generated from renewable sources, such as wind, solar, and biomass, faces the same cost disadvantage of those options in producing electricity but emits little or no carbon dioxide.

If hydrogen-fueled cars are ever going to make it, hydrogen must at some point be widely available to consumers—this quintessential chicken-and-egg problem is what has gotten policymakers' attention.

Currently, fossil fuels containing both carbon and hydrogen are used to produce hydrogen. Natural gas is the most common feedstock, through a relatively cost-effective process known as catalytic steam reforming. Hydrogen produced from natural gas is much cheaper than electrolysis-based hydrogen but still presents a significant cost barrier, being about two to four times the price of gasoline per unit of usable energy. Also, if the price and amount of natural gas imported continues to increase, its desirability as a method of producing hydrogen will decrease.

Another concern about hydrogen from fossil fuels is the stream of carbon dioxide released as a by-product. While the NRC hydrogen report finds that many of the possible future supply chains would release significantly less carbon dioxide than hybrid gasoline-electric vehicles, the least expensive options based on natural gas and coal still emit significant amounts. Therefore, if hydrogen is to be produced from fossil fuels in a climate-friendly manner, it will need to be coupled with carbon emissions capture and storage. This is technically feasible but currently very expensive (at least $50 per ton of carbon dioxide) and faces its own technical, political, and environmental challenges if it is to help mitigate the climate problem.

Coal is also used in much smaller amounts for current hydrogen production but it could be a key feedstock in the future, given its widespread domestic availability. But coal contains the most carbon dioxide per unit of energy. In response to this environmental challenge, the Department of Energy set up a 10-year, $1 billion program (known as FutureGen) to research producing hydrogen cost-effectively through integrated gasification combined-cycle (IGCC) plants for electricity production and other uses, and storing the resulting carbon dioxide emissions underground.

Nuclear-based hydrogen production is also a possibility, through either electrolysis or more speculative high-temperature thermochemical processes. Nuclear-based hydrogen has the advantage of generating no carbon dioxide emissions but also the usual safety, security, and cost disadvantages of nuclear power. Other innovative (but currently very expensive) approaches include photochemically producing hydrogen using algae, sunlight, and catalysts to split water molecules directly.

Hydrogen distribution

The next link in the hydrogen economy chain is developing the necessary infrastructure for distributing hydrogen from production sites to fueling stations and storing it there. Because of its very low density and high flammability, hydrogen presents unique cost, safety, and convenience challenges at every step. But if hydrogen-fueled cars are ever going to make it, hydrogen must at some point be widely available to consumers. This quintessential chicken-and-egg problem is what has gotten the attention of policymakers, including the president and the governor of California.

> **A major technical challenge of widespread hydrogen use is safely storing adequate quantities onboard vehicles. As the lightest element, it takes up far more space than other fuels, even when compressed.**

A big question is whether hydrogen should be produced at central facilities and distributed as molecular hydrogen for end use or at smaller facilities located directly at filling stations. This involves a trade-off between economies of scale in centralized production and the cost and safety of a transportation infrastructure, which would be less necessary with distributed generation of hydrogen. In the long term, the NRC report predicts that the most economic approach will likely be large-scale centralized generation with pipeline distribution.

Under this scenario, the cost of distributing the hydrogen is expected to be approximately equal to the cost of producing it. In the interim, however, distributed generation using small-scale natural gas reformers or electrolysis is more feasible and is likely to be a necessary part of any transition. Transport of low-temperature liquid hydrogen via trucks or rail could also play a significant role. If hydrogen were distributed as part of a chemical compound, a whole different system would be required. All of these options face significant technical and economic hurdles.

Onboard hydrogen storage

Perhaps the biggest technical challenge facing widespread use of hydrogen is safely storing adequate quantities onboard vehicles. As the lightest element, hydrogen takes up far more space than other fuels, even when compressed. With current technology, enough compressed hydrogen gas to move a car about 300 miles takes up about four times as much space as a typical gas tank. Liquefying hydrogen can reduce its volume several times, but that requires chilling it to minus 253°C, taking up to 30 percent of the hydrogen's energy to do so and using larger insulated tanks to maintain this low temperature. Currently, most experts are skeptical that onboard hydrogen storage in a gas or liquid form can meet the capacity, size, and safety requirements of the automotive industry.

Advanced materials for "solid-state" storage are also under investigation, including metal hydrides and carbon nanotubes. These options typically involve adsorbing—or coating materials with a thin layer of a substance—the hydrogen into the advanced materials and later releasing it when needed for driving. Each of these options faces serious technical obstacles, however, requiring further research and development. In addition to these concerns, an acceptable storage system must be capable of being refueled within just a few minutes, be safe, and be reliable over the decade-plus lifetime of a car. Even if technical problems can be met, there is still the issue of cost.

Hydrogen use

The final piece of the hydrogen puzzle is the conversion of hydrogen into useful energy through fuel cells or advanced internal-combustion engines. While fuel cells were invented well over a century ago and have been successful on spacecraft for decades, the current cost of power from them is about 100 times higher than from internal-combustion engines. Some estimates place the potential price of a fuel-cell vehicle at over $1 million, with the fuel cell and storage tank contributing most of the cost. Other challenges include durability of fuel cells under continuous vibration and consistency of operation under different conditions. It took about 20 years for wind and solar power to see tenfold declines in cost, and current penetration of these technologies is still under 1 percent of electricity generation.

Some automakers are also pursuing the alternative course of developing internal-combustion engines that run on hydrogen instead of gasoline, at least as a transition technology to hydrogen fuel cells. This course would not require the parallel creation of an economic fuel-cell car and a hydrogen infrastructure, but still would require facing the hydrogen infrastructure as a major stumbling block. While such engines do face technical hurdles, they are not typically thought to be as great as for the fuel cell. On the other hand, these engines would still produce small amounts of nitrogen oxides and would not be as efficient in converting hydrogen to useful energy as are fuel cells.

Conclusion

Widespread, cost-effective use of hydrogen will come only when the very large cost and technical barriers that now exist are removed. Each aspect of the hydrogen system—from production, to distribution, storage, and use—faces a cost disadvantage several times that of competitive alternatives. But the negative security and environmental consequences of petroleum use, and the dearth of attractive alternatives, make further research into hydrogen's potential absolutely essential.

Many of the most pressing questions surrounding the hydrogen economy are still largely technical at this time. Economics will play an increasing role, however, if and when these questions get resolved and hydrogen moves toward a commercially viable fuel choice.

Given the magnitude and complexity of the challenges that lie ahead for hydrogen, successful resolution will probably take several decades, not 15 years as the president predicted. Now is not the time to close out options or focus too much on deployment due to near-term policy goals and political pressures, but rather to explore a wide range of options, many of which may not pay off in the end. And in the interim, more effort and more funding need to go toward reducing petroleum use by advancing the development of new gas-electric hybrids, advanced diesel-fueled vehicles, and the like. ■

Renewable of Electricity

SAFE BET OR TILTING AT WINDMILLS?

Joel Darmstadter
and
Karen Palmer

Excluding hydropower, renewable energy makes up a tiny portion of the nation's overall electricity supply—its roughly 2.2 percent share is dwarfed by fossil energy, nuclear power, and hydroelectric dams (see the table on age 27). But given all the environmental and safety caveats associated with more traditional energy sources, a lot of people are paying closer attention to how renewables can play a larger role in the domestic energy mix.

Hydropower continues to overwhelm all other renewable resources in magnitude, but even existing dams, much less newly built ones, are widely seen as unpopular because of their effect on commercial and recreational fishing and on ecosystems as a whole. Virtually no one expects any meaningful addition to the nation's current hydropower capacity.

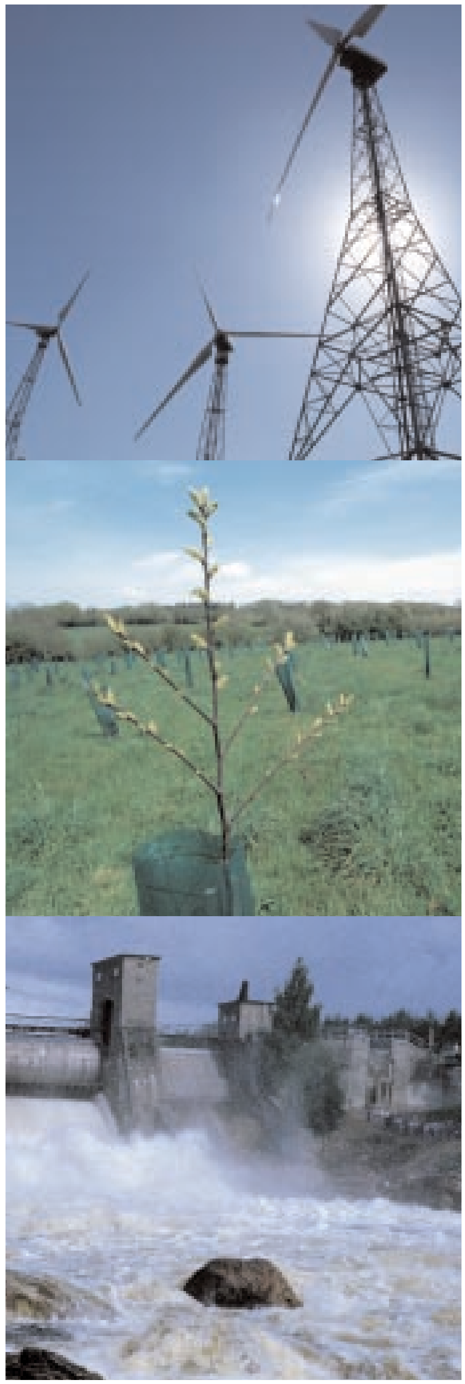
In the current marketplace, the dominant renewables are wind power, wood products (used mainly as a fuel source in manufacturing), municipal solid waste, and geothermal resources. Wind power has taken the lead in this race, with an 11 percent rate of growth since 1990, pushing it from 4 percent of total renewables generation (excluding hydropower) in 1990 to 13 percent in 2003. This trend of relatively strong growth for wind power is likely to continue.

Virtues

A useful way to appreciate the virtues of renewable energy resources is to look at some of the disadvantages associated with their conventional counterparts—fossil fuels and nuclear power—that dominate today's world energy scene. Coal is cheap and abundant but its combustion produces pollutants only partially controlled by prevailing regulations, while control of carbon dioxide emissions awaits sequestration technologies not yet at hand. As trade in liquefied natural gas increases, natural gas may in time present challenges similar to those currently associated with large dependence on oil imports. And even if the nuclear option could be revived on technological and economic grounds, the public remains divided about such problems as disposal of nuclear waste.

In all of these respects, renewables are attractive. Typically, though not invariably, their use produces far less environmental damage than conventional energy. Burning of biomass such as fuelwood does result in some air pollution. At some locations, wind farm opponents cite danger to wildlife and aesthetic affronts. But these environmental concerns pale in comparison with those associated with conventional fossil fuels. Even with current pollution controls,

Sources



coal-generated power still causes more pollution than that produced by wind turbines, and that's before considering greenhouse gas emissions from coal combustion. Also, renewables are largely insulated from the rising costs that, in time, may hit depletable resources like natural gas. Finally, in moderating the demand for fuels imported from unstable parts of the world, renewables indirectly provide an energy security benefit.

To be sure, these contrasting features are a bit overdrawn: some renewable energy sources might be limited while some nonrenewables are effectively inexhaustible. For instance, among renewables, geothermal resources are, strictly speaking, exhaustible because a given site may lose heat after a number of years of extraction. Among alternatives to renewables, one could cite nuclear power, whose underlying resource requirements are effectively limitless.

Drawbacks

Although renewable energy might be beneficial overall, it is no panacea. Renewables clearly do have some drawbacks. The most important is their high cost. To compare costs, we use each technology's "levelized" cost—that is, the real cost of generation, including capital cost, over the estimated life of the plant. For some technologies, such as solar photovoltaics, the levelized cost of producing a kilowatt-hour (kWh) can be three or four times as high as that for a new natural gas-fired combined-cycle plant, even at today's high natural gas prices. For other technologies, such as wind power, the cost differential from natural gas is smaller.

Except for biomass, renewable technologies have no fuel costs, and their other operating costs are typically low as well. So the bulk of their expense consists of the fixed costs of equipment and land. The translation of that fixed cost into a levelized cents per kilowatt-hour (kWh) of generation depends on how much electricity the facility generates. Because wind generation depends on when and how fast the wind blows, wind power installations typically operate at capacity factors of 10 to 35 percent, contributing to higher costs per kWh.

Renewables aren't on a level playing field with fossil energy. Competing coal- and gas-fired generators escape having to pay the full cost of the air pollution and other consequences they impose on society. Such externalities, though they certainly exist, are surely minimal for wind and solar generation.

The potential for renewable sources of energy to gain a larger share of the electricity market is further constrained by physical and political limits. Geothermal energy sources are limited primarily to southwestern states. Biomass generation requires conversion of large quantities of land from other uses. A relatively strong, steady wind and land that is amenable to construction of wind towers and reasonably accessible to the transmission grid are prerequisites for the development of commercial-scale wind projects. Many offshore sites can meet these criteria, but efforts to develop offshore windpower in the United States have met with substantial resistance from those—like residents of Cape Cod—whose coastal views would be affected. Meeting the demands of opponents could add to the cost of developing windpower resources in particular sites.

All that being said, the costs of renewables have come down over time. Research at RFF shows that over the course of the 1980s and 1990s, the *cost* of electricity from renewable sources typically fell faster than had been predicted. But despite achieving lower costs, renewables failed to meet prior expectations regarding trends in the *volume* of future generation. This is because a simultaneous decline in the cost of competing fossil fuels and generation continued to place renewables at a relative cost disadvantage. How renewables fare in the years ahead will, similarly, be at least partly determined by concurrent trends in fossil or nuclear generation costs.

Renewables aren't on a level playing field with fossil energy. Competing coal- and gas-fired generators escape having to pay the full cost of the air pollution and other consequences they impose on society. Such externalities, though they certainly exist, are surely minimal for wind and solar generation.

Policy Options

A totally hands-off governmental stance—subjecting renewables exclusively to market discipline—has abstract appeal. But fairness would dictate that other fuels would then no longer qualify for subsidies and also be subject to their full environmental costs, something that is not likely at the present time.

A number of different policies have been implemented in the United States to promote greater use of renewables in the electricity sector. One approach that gained currency with the introduction of competition in electricity markets in numerous states is "green power" marketing. Under this voluntary approach, renewable generators seek to appeal to households willing to pay a premium—ranging, in 2003, from 0.6 to 17.6 cents per kWh—to purchase power wholly or largely generated by renewables. Roughly 400,000 households participated in such green power programs by the end of 2003—an inconsequential 0.3 percent of nationwide residential power customers.

Another, far more significant trend is the evolution of renewable portfolio standards (RPS). As of early 2005, nearly 20 states had introduced requirements that a minimum amount of electricity distributed (as well as, in some cases, produced) in the state be generated using qualified renewable systems. These rules typically impose increasingly stringent requirements over the next several decades. An important feature of RPS programs in numerous states is a tradable-credit system. Such credits, created whenever renewables-based power is generated, allow for the fact that electricity distributors vary in the ease with which they can incorporate a renewables component in their sales. In a system somewhat analogous to tradable emissions rights in sulfur dioxide and nitrogen oxides to meet stipulated clean air targets, utilities overcomplying in their renewables requirement can sell excess credits to those utilities failing to meet their quotas. Some state programs have an important provision that effectively sets an upper limit to the cost of such credits.

Undoubtedly, a nationwide renewable credit trading system would be more efficient than one limited to intra- or multi-state transactions. Indeed, several proposals to adopt a federal RPS have been introduced in Congress. For example, Congress considered comprehensive energy legislation in 2002 in the form of the Energy Policy Act, which included a requirement that renewables account for 2.5 percent of electricity generation in 2005, increasing 0.5 percent per year until reaching a 10 percent target in 2020. This legislation, similar to some state programs, included a cap of 3 cents per kWh on the price of renewable credits, but recent analysis suggests that the credit price for a 10 percent federal RPS would fall well below this threshold. But thus far, such congressional initiatives have failed—in part because of strong opposition from traditional electricity providers.

A production tax credit (or subsidy) has so far been the main policy instrument to promote renewable generation at the federal level. In 1992, Congress authorized a renewable energy production credit (REPC) now amounting to 1.9 cents per kWh of electricity produced from wind and dedicated closed-loop biomass generators, later expanded to include electricity from geothermal, solar, and landfill gas resources. The REPC could be claimed by new generators for the first 10 years of their operation. The federal government also grants a tax credit equal to 10 percent of investment costs for new geothermal and solar generation facilities; this policy has no expiration date. Both credits make renewables more competitive than they would otherwise be.

Net metering is another renewables-promoting program at the state level. Under net metering, customers who generate electricity on site—for example, through fuel cell or solar photovoltaic systems—can sell any excess electricity back to the supplier at the retail price, essentially running the meter backward. Many states have special programs to fund R&D on renewables, and the U.S. Department of Energy has been devoting $300 million annually to R&D into renewable energy sources, though that level may be hard to sustain under the administration's latest budget. A variety of technological improvements, in part benefiting from such support, might bring about a substantially expanded volume of wind-generated power. Possibilities include continuing advances in the aerodynamics of wind turbines, electricity storage systems to provide power availability during poor wind-speed periods, and cost-reducing breakthroughs to reduce line losses in long-distance electricity transmission.

What's in Store for Renewables?

Although technological advances and unexpected steep price increases for conventional energy can contribute to expanded use of renewables, their prospective growth—as projected in the just-released *Annual Energy Outlook 2005* by DOE's Energy Information Administration (EIA)—remains modest. Absent major energy policy departures, non-hydropower renewables are projected to increase their share of total electricity generation only to about 3.2 percent by 2025, compared to 2.2 percent in 2003. This is in spite of the fact that the *absolute volume* of renewables, mostly in the form of wind, will likely grow substantially over that period.

A strategy for a stronger renewables role would have to be embedded in a broader national energy policy. Dealing with the problem of greenhouse gas emissions from fossil-fuel combustion is one component of such a policy. Well-designed R&D funding for both renewable and other innovative energy systems is another. To stimulate renewables more directly, one of the most cost-effective approaches would be a national RPS, providing for an efficient nationwide trading system and a mechanism to protect against high costs. It will be very challenging to integrate a federal renewables policy with the variety of existing state-level RPS policies. Nevertheless, the RPS provision of the Energy Policy Act of 2002 provides a feasible approach. Complementary to other elements of a more rational energy policy than either political party or its leaders have given us in recent years, the RPS would represent one creative step forward. ■

U.S. Electricity Capacity and Generation, 2003

Fuel Type	Capacity		Generation	
	1,000 MEGAWATTS	PERCENTAGE	BILLION KWH	PERCENTAGE
Fossil/nuclear	**823**	**89.4 %**	**3,493**	**90.7 %**
All renewables	**98**	**10.6**	**359**	**9.3**
Hydropower	**79**	**8.6**	**275**	**7.1**
Non-hydropower	**19**	**2.0**	**84**	**2.2**
Wind	7	0.7	11	0.3
Geothermal	2	0.2	13	0.3
Solar	0.5	0.1	1	0.0
Wood/MSW	9	1.0	59	1.5
Total	**920**	**100 %**	**3,852**	**100 %**

Notes: Capacity refers to summer availability. Because of rounding, numbers may not add to totals. MSW = municipal solid waste.

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION, 2005.

Nuclear

Paul R. Portney

The real policy question facing the United States is this: should the government take steps to facilitate the construction of at least some new nuclear plants in the United States, or should it leave this decision solely to the privately owned companies that build virtually all of the nation's electricity generating capacity? Some type of federal assistance would enable the companies building the first handful of plants to overcome the "first-of-a-kind" costs that can make them much more expensive than subsequent units.

For quite some time, nuclear power was the United States' most controversial energy source. While it is still not without its share of problems, some of them formidable, nuclear power has enjoyed a clear resurgence of late. For the first time in many, many years there is at least talk about beginning construction on a new nuclear power plant in the United States, something that hasn't happened here since the 1970s. Even some environmental advocates, once among the most implacable opponents of nuclear power, are casting a less jaundiced eye its way.

Nuclear power—harnessing the energy that results from the splitting of atoms—enters the energy mix in the United States in the form of electricity generation. Currently, slightly more than 100 operating nuclear power plants together provide about one-fifth of the electricity we use to power our factories, office buildings, homes, schools, and shopping malls. This makes nuclear power the second-largest source of electricity generation in the country; coal accounts for more than half of electricity generation, and natural gas (the fastest-growing source) for about one-sixth. Among all the developed countries in the world, nuclear power accounts for almost a quarter of electricity generation, a slightly larger share than in the United States.

The Case for Nuclear Power

What accounts for the second look that nuclear power is getting from energy experts and even some environmental advocates? First, it is free from some of the serious air pollution problems that can accompany coal-fired and, to a lesser extent, natural gas-fired electricity generation. This includes both conventional pollutants, such as sulfur dioxide, hydrocarbons, and nitrogen oxides—and mercury, cadmium, and other heavy metals present in coal. While emissions of all

Power

CLEAN, COSTLY, AND CONTROVERSIAL

these pollutants have been reduced significantly since the 1970 Clean Air Act took effect, electricity generation is still a major source of them all. Much more importantly, nuclear power is carbon-free. That is, unlike coal, natural gas, and petroleum, it does not release carbon dioxide into the atmosphere in the process of generating electricity. At a time when there is growing concern about the link between carbon dioxide and other greenhouses gases on the one hand and the warming of our planet on the other, this advantage of nuclear power has begun to loom larger.

A second advantage of nuclear power has to do with energy security. Concerns have existed since the early 1970s about the extent to which the United States is dependent upon petroleum imports to fuel our transportation sector, particularly from countries in the Middle East. For the first time, a concern about possible import dependence has begun to extend to the electricity generation sector. This is not because petroleum is used for electricity generation—its role there has almost disappeared. Rather, the concern is that natural gas production in the United States cannot keep pace with demand growth and that an ever-greater share of the natural gas we use for home heating and industrial production, as well as for electricity generation, will have to come from abroad (including from some of the same countries whose share of world oil reserves makes us nervous). Because of the likely adequacy of North American uranium reserves, this is not a concern for nuclear power (nor is it for coal, for which domestic reserves are ample).

There is a third attraction to nuclear power, though it currently pertains only to those plants that are already in operation—once built and paid for (a big qualification, as we'll see below), these plants are extremely inexpensive to operate. Indeed, the incremental cost of generating electricity from an existing nuclear plant is on the order of 1.5 cents for each kilowatt-hour (kWh) of electricity generated. This compares with about 2 cents/kWh for a conventional coal plant and, at current natural gas prices, about 3.5 cents/kWh for a natural gas plant. With the average retail cost of electricity in the United States currently standing at 7.5 cents/kWh, the 100 or so nuclear units in the country are quite profitable.

The Case Against

Despite those advantages, the last nuclear plant to commence operation in the United States began generating electricity in 1996, and no new plant has been started since 1973. Four liabilities have accounted for this disappointing record.

First and perhaps foremost, although nuclear plants are cheap to operate once they are up and running, they are by far the most expensive to build. Based on recent construction costs in Japan and Korea and on estimates from the vendors who would likely build plants in the United States, a new 1,000-megawatt (MW) nuclear power plant would cost on the order of $2 billion and take five years to build. By contrast, a new 1,000-MW pulverized coal plant would cost $1.2 billion and take three to four years to build, and a new clean coal plant (one in which the coal is first converted to cleaner-burning natural gas) would cost about $1.4 billion and take four years. Illustrating why natural gas has been the fuel of choice for most of the recent growth in electricity generation, a new 1,000-MW combined-cycle gas turbine can be built in less than two years at a cost of $500 million.

The longer construction time and higher capital cost of a new nuclear plant currently more than offset its operating cost advantage. According to a recent report by experts at the Massachusetts Institute of Technology, the "all-in" costs (capital plus operating) of electricity from a new nuclear plant operating for 40 years at 85 percent capacity would be 6.7 cents/kWh.

This compares with 4.2 cents/kWh for a coal plant and 4–5.6 cents/kWh for a new gas turbine, depending on the assumed price for natural gas. Even if it faced no other obstacles, then, nuclear power would have a formidable economic challenge to overcome.

Other obstacles exist, however. For one thing, there has long been concern in the United States about the safety of commercial nuclear reactors, concern that predated the accident at Three Mile Island in 1979, where the core of one of the reactors was damaged. The operating record of the U.S. nuclear industry has improved significantly over the past 20 years, with safety and other related downtime having been reduced to as little at 10 percent at many plants. However, problems still arise from time to time, such as those at the Davis-Besse reactor in Ohio, where shoddy maintenance could have led to a serious accident had it not been caught in an inspection. Unless plant safety continues to improve, not merely stay the same, nuclear power faces an uphill climb, economics aside.

Opponents of nuclear power also point to the risk that the spent fuel from nuclear plants could be stolen and diverted to the production of so-called dirty bombs or even thermonuclear weapons. While this is a risk that must be taken extraordinarily seriously everywhere, it is a much larger concern outside the United States—especially in countries that have no obvious need for nuclear power. One example is Iran, which has vast natural gas reserves that could be used for electricity generation, but which has elected not only to build nuclear power plants, but also to do so using a fuel cycle providing easier access to the plutonium required for nuclear weapons.

The final challenge associated with nuclear power has also to do with spent wastes—namely, where in the world they will be stored. Currently, almost all the wastes that result from nuclear-powered electricity generation are being stored on the grounds of the power plants. No one believes this is the best place for these wastes, and at some plants storage capacity has been or soon will be exceeded. For this reason, the federal government committed long ago to build and open a high-level nuclear waste repository. Yucca Mountain, Nevada, was chosen as its site, and the repository has now been completed, at an eventual cost to the public of $50 billion, perhaps more. There's just one problem. Nevadans have no interest in being home to these wastes and have been successful in preventing the first shipments to Yucca Mountain, aided by a recent U.S. Court of Appeals ruling that the Environmental Protection Agency erred in establishing a safety standard Congress had directed it to set. Until and unless this stalemate is resolved, the future of new nuclear plants—not to mention the continued viability of the existing ones—is uncertain.

Policy Issues

Yucca Mountain notwithstanding, the real policy question facing the United States is this: should the government take steps to facilitate the construction of at least some new nuclear plants in the United States, or should it leave this decision solely to the privately owned companies that build virtually all of the nation's electricity generating capacity? Some type of federal assistance would enable the companies building the first handful of plants (likely in consortia) to overcome the "first-of-a-kind" costs that can make them much more expensive than subsequent units. If these latter units then became as cheap as some vendors suggest, their upfront costs would be quite competitive with new clean coal and even pulverized coal units and perhaps even competitive with natural gas plants on an all-in basis if gas prices remain high. Not surprisingly, the industry is seeking such government assistance in the form of a contribution toward the cost of building the first new plants, like the production tax credit afforded to wind power and other emission-free sources, as well as possible loan guarantees and other protections.

Government subsidies are not the only way to ensure that nuclear power gets to compete as a clean and secure source of electricity generation, of course. In the same way that the conventional air pollution problems associated with coal-fired generation have been substantially internalized through federal emissions-control requirements, so too could the comparable externalities associated with climate change. This could be done through a carbon tax or through a mandatory cap-and-trade program that forced both coal- and gas-fired plants to reduce their carbon dioxide emissions. Similarly, the energy security costs associated with an increasingly international market for natural gas could be internalized through an appropriate tax. Once these external costs had been internalized, along with those associated with nuclear power and other sources of electricity generation, of course, the government could step aside and let nuclear battle with coal, natural gas, wind, biomass, solar, and any other means of power production one could think up.

Far from the "dead duck" nuclear power was once proclaimed to be, it has arisen phoenix-like from the ashes. Whether this revival will extend to a new fleet of commercial nuclear reactors in the United States depends in large part upon how the inherent problems are resolved and how a nuclear program would be implemented. ■

Coal

DIRTY CHEAP ENERGY

J.W. ANDERSON

Despite the pollution that it causes, coal will probably continue to meet nearly one-fourth of the world's steadily rising demands for energy in the coming decades. World consumption of coal, 5.3 billion tons in 2001, will go up to about 7.6 billion tons by 2025, the U.S. Energy Information Administration recently projected.

Almost all of that increase will come from three countries—in order, China, the United States, and India. All three have large and easily accessible deposits of coal, a major consideration for governments concerned about the instability of oil prices and the insecurity of oil imports. This increase is contrasted with Western Europe and other regions, where coal use is expected to decline, partly because of a greater availability of natural gas. See the table on page 33 for projected coal use worldwide.

The policy challenges of reconciling rapid economic growth with clean air and reduced risks of climate change will be met—or evaded—with the deepest consequences for the planet's richest country and the two biggest of its poor countries.

In the United States, where it is used almost exclusively to generate electricity, coal has been competing recently with a cleaner fuel, natural gas. Partly for environmental reasons, the electric power sector swung to increased use of gas in the 1990s. One result was a rapid rise in gas prices, which have more than doubled since 1999. And that, in turn, is currently causing the power companies to swing back toward greater reliance on coal.

This shift is not without consequences to human health and the environment. Coal smoke contains fine particulates — soot, ash, and gases such as oxides of sulfur and nitrogen—that threaten the health of those who breathe them. Coal is also a prolific source of carbon dioxide, which, of all the greenhouse gases generated by human activity, is the one that contributes by far the most to global warming.

Some writers have speculated that shortages of fossil fuels might soon push the world toward cleaner sources of energy. In the case of coal, that is highly unlikely. Current production amounts to 0.5 percent a year of the world's proven and economically recoverable coal reserves, and the United States is in no danger of running low in the future.

A shift to renewable energy or other cleaner sources would require strenuous pushing by governments. The necessary political will and financial support will emerge only when societies decide that the negative effects of coal smoke on health, human welfare, and the environment outweigh the benefits of power at the lowest possible price.

China is beginning to consider action against the air pollution that coal causes. It has chosen Taiyuan, a city notorious for its bad air, as the site of an experiment in cutting emissions of sulfur dioxide with a cap-and-trade program based on the highly successful American model. With support from the Asian Development Bank, the Chinese government proposes to cut emissions in Taiyuan by half, allowing the sources of these emissions to trade permits among themselves to hold the cost down. One question is whether this American concept can be transferred to a country with a very different economic and political system. The 50 percent goal is ambitious and the proposal is complex, but the fact that Taiyuan is thinking seriously about reducing emissions that dramatically is itself evidence of changing attitudes.

Here in the United States, energy policies sometimes work at cross-purposes with one another. Deregulation of electricity, for example, promises lower prices to consumers. But that leads to less use of natural gas, which is cleaner but more expensive, and more use of coal, which is cheaper but dirtier.

When utilities were regulated, state authorities were able to encourage electric companies to reduce pollution by guaranteeing them a return on their outlays. But under deregulation, the competitive pressure to push down prices is relentless. It is possible to combine deregulation with policies to curb emissions, possibly through a cap-and-trade program or a federal

One popular response to the rising emissions of carbon dioxide is the renewable portfolio standard, which typically requires a certain level or percentage of electricity to be produced from renewable sources.

COAL CONSUMPTION, 2001 TO 2025

(in millions of tons)

REGION	2001	2025 PROJECTED	PERCENT CHANGE
United States	1,060	1,567	47.8 %
Western Europe	574	463	-19.3
Japan	166	202	21.7
Former Soviet Union	446	436	-2.2
China	1,383	2,757	99.3
India	360	611	69.7
Rest of the world	1,274	1,538	20.7
Total world	**5,263**	**7,574**	**43.9**

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION, 2004.

carbon tax. But in either case, one effect would be to raise the price of electricity.

One popular response to rising carbon dioxide emissions is the renewable portfolio standard, which typically requires a certain level or percentage of electricity to be produced from renewable sources. In the United States, since the mid-1990s, about 20 states have imposed such standards on electricity producers or retailers. But policies to promote clean technologies such as renewables may not have a large effect on coal consumption. A renewable portfolio standard will decrease usage of natural gas more than coal, in part because of the price differential. For that reason, encouraging renewables will not have a large effect on coal use or carbon dioxide emissions from the electricity sector in the absence of other policy measures, such as a tax on carbon.

The cost of pollution reduction will be heavily influenced over the coming decades by technological developments. One promising avenue is the integrated gasification combined-cycle (IGCC) process, which chemically turns coal into a synthetic gas that can then be burned in a turbine. This method permits the segregation and capture of most of the pollutants, including carbon. In the form of carbon dioxide, it can be injected underground for permanent storage in geological formations that are common throughout most of the United States, without harming the environment.

The cost of pollution reduction will be heavily influenced over the coming decades by technological developments. One promising avenue is the integrated gasification combined cycle (IGCC) process.

But the IGCC technology has yet to be shown to work reliably at the scale of a large utility power plant. In a deregulated market, investors appear unwilling to risk the cost of a big plant based on an uncertain process. Experience so far indicates that substantial public subsidies will be required to put this concept into actual practice.

To demonstrate how this would all work, the Department of Energy is currently pursuing a project it calls FutureGen, a partnership between the federal government and industry to design and build an industrial-scale electric power plant with carbon emissions pushed close to zero. It is to run on gasified coal, with the carbon dioxide to be injected into permanent underground reservoirs. When the project was announced in early 2003, the department estimated that the investment in public and private funds would come to about $1 billion over a decade.

According to one careful estimate, carbon capture and storage would become profitable at a price of roughly $200 to $250 a ton of carbon—that is, the point at which public policy, through regulatory limits or taxation, pushed the cost of emitting a ton of carbon into that range. That is approximately the price that would result from public action in this country to comply with the Kyoto treaty on climate change, which would have required the United States to cut its emissions of carbon dioxide by about 30 percent from the amount that it would otherwise reach in 2010. The United States has dropped out of the Kyoto treaty on grounds, among others, of the cost. But Kyoto continues to set a marker, in general terms, of the cost of a serious effort to protect the global climate from accumulating greenhouse gases.

At present there are no nationwide restrictions on carbon dioxide emissions in the United States, although most of the state governments have begun to move toward controlling them. To raise the cost to $200 per ton of carbon would require a very substantial change in national policy. But most studies indicate that the cost of carbon capture and storage is likely to come down significantly with technological improvements. The Energy Department announced in late 2004 that it would provide up to $100 million in federal subsidies over the next four years for field-testing promising carbon sequestration technologies.

Of all the fuels, coal poses the basic policy questions in their simplest form. The first choice is between dirty and cheap or clean and less cheap — possibly a good deal less cheap. Conservation is always highly desirable, but in a society in which the demand for electricity is growing steadily, voluntary conservation alone does not offer a way out of the hard choices. A serious effort to combat regional air pollution and global climate change will require the development of new technologies, probably with public financial support. It will also require forceful public action, through regulation, to ensure that power producers, if they burn coal, adopt these new technologies. ■

An Energy Options Matrix

Setting energy policy in the 21st century requires balancing competing factors and making tough choices. For example, framing an argument in favor of promoting coal over natural gas to produce electricity would involve weighing lower costs against greater environmental liabilities. The accompanying table (opposite) provides a framework of how various energy options stack up in terms of availability, costs, environmental and security concerns, and technological challenges. For more detailed information on RFF's work on energy issues, visit www.rff. org/energy.

Contributors to This Issue

J.W. Anderson is a former staff writer for *The Washington Post* who serves as RFF's journalist in residence.

In his recent work, Senior Fellow **Joel Darmstadter** addresses energy, climate change, and the economic viability of renewable sources of energy.

Senior Fellow **Raymond J. Kopp** studies the environmental aspects of energy policy and technological responses to environmental issues and geopolitical stability.

Richard G. Newell, an RFF fellow, analyzes the economics of technological change, looking at the influence of government programs and market incentives on energy technologies.

Senior Fellow **Karen Palmer** is an expert on the environmental and economic consequences of deregulation and restructuring of the electricity industry.

Senior Fellow **Ian W.H. Parry** looks at a wide range of policy approaches to address the social and political costs of motor vehicle use, including gasoline taxes, transportation financing, and fuel economy standards.

William A. Pizer, an RFF fellow, studies the design of policies to address climate change risks caused by man-made emissions of greenhouse gases. He also is a senior economist at the National Commission on Energy Policy.

RFF President and Senior Fellow **Paul Portney** is an expert on the role of economic analysis in energy and environmental regulation, especially the regulation of automobiles, power plants, and other industrial facilities.

A Framework for Understanding Energy Resources

ISSUE	PETROLEUM	NATURAL GAS	HYDROGEN	RENEWABLES	NUCLEAR	COAL
Fuel Supply Problems?	**Yes and no.** Many trillions of barrels are left, but perhaps several decades' worth is readily available at current prices.	**No.** Current estimates of proven reserves are 70 times present annual world consumption, and the size of proven reserves has increased every year since 1970.	**Yes and no.** The lightest gas, hydrogen does not exist naturally on earth. However, it can be produced using a wide variety of primary energy sources.	**Yes and no.** Most renewables occur in large but not inexhaustible, amounts. However, ancillary problems exist, such as the possibility of running out of wind farm sites.	**No.** By most accounts, the world has a sufficient supply of uranium to accommodate greatly increased nuclear power generation. Reprocessing spent fuel could stretch this even farther.	**No.** Proven reserves in the United States alone are huge. China and India also have large reserves.
Major Cost Concerns?	**Yes.** Unexpected rise in demand or decline in production can have a sharp effect on prices, with often dramatic economic consequences.	**Yes.** Although large quantities of gas can be found underground, they are not always located in places of high demand.	**Yes.** Every piece of the hydrogen puzzle (production, storage, use in vehicles) faces a cost disadvantage of several times relative to competing alternatives.	**Yes.** Costs have declined, and some windpower installations produce cost-competitive electricity. In spite of this, currently subsidies are essential.	**Yes.** Nuclear power is unlikely to be economically viable unless the cost of building a new plant can be reduced significantly.	**No.** Coal is by far the cheapest, per Btu of energy, of the fossil fuels, and its price has steadily declined.
Adverse Environmental Impact?	**Yes.** Although less damaging than coal, burning oil generates greenhouse gases, and spills affect marine life.	**Some.** Natural gas contains less carbon and is less of a problem than coal or petroleum, but it still emits pollutants, including nitrous oxides and solid particulates.	**Yes and no.** Combusting or using hydrogen in fuel cells produces very little, if any, direct pollution. But producing the hydrogen itself can harm the environment.	**No.** Environmental attributes are, on balance, highly positive, though with some caveats. Wind turbines and biomass use may present some environmental challenges.	**Yes and no.** Nuclear power does not emit conventional air pollutants when used to generate electricity. However, finding safe storage for spent fuel has been extraordinarily difficult.	**Yes.** Burning coal generates gases and airborne particles that threaten human health and, through acid rain, natural ecosystems.
Dependence on Unreliable Suppliers?	**Yes.** Ongoing wars and increasing terrorism in the Middle East, along with growing concerns about reliability of Russian oil, make this an important issue.	**Some.** The United States imports only 15% of its natural gas at this time, but this percentage is likely to increase in the future.	**Maybe.** Hydrogen can be produced using domestic sources, such as coal and renewables. However, the dominant current method uses natural gas, which is increasingly being imported.	**No.** Renewables, because they substitute for fuels subject to supply or price risks, enhance energy security.	**No.** Both the United States and Canada, as well as other friendly nations, have significant uranium deposits.	**No.** The biggest consumers, including the United States, are the biggest producers.
Serious Technical Challenges?	**Yes and no.** Major breakthoughs would be required to extract oil from new sources, such as tar sands. Improvements to cars and trucks can lessen pollution but may not greatly reduce oil dependence.	**No.** Normal improvements in exploration and extraction technology can be expected to continue.	**Yes.** Significant technical barriers apply to all facets of a hydrogen system. On-vehicle storage and fuel cell technology are the most daunting, but hydrogen production and distribution are challenging as well.	**Yes.** For some time to come, certain renewables, such as solar photovoltaics and nonethanol biofuels, will be critically dependent on R&D and technological progress.	**No.** There are no real R&D or technological challenges to producing nuclear energy. However, success will depend on keeping plant construction costs down and finding a politically acceptable way to dispose of wastes.	**Yes.** It is possible to hold emissions of noxious gases and particles to low levels, but this technology is rare in industrializing countries. Likewise, technology for capturing and storing carbon dioxide has yet to be fully developed.

Inside RFF

Fresh Perspectives on the Future of U.S. Energy Policy: Insights from RFF Board Member Vicky A. Bailey

Resources recently interviewed Vicky A. Bailey, who joined the RFF Board last year, about the ongoing evolution of U.S. energy policy. Now a partner at Johnston and Associates, a strategic legislative and public affairs consulting firm, Bailey was a primary adviser to Energy Secretary Spencer Abraham and senior DOE management on domestic and international energy policy during President Bush's first term. Previously, she was the president of PSI Energy Inc., Indiana's largest electricity supplier, which is part of Cinergy Corp. Before that, she was nominated by President Clinton to the Federal Energy Regulatory Commission and served two terms as a commissioner.

How did you first become aware of RFF's work?

Through my friendship with Paul Portney! I first met him many years ago, when I was serving as an Indiana state energy commissioner, and we have stayed in touch ever since. Paul's genuine sense of excitement and passion about RFF is contagious. He always made sure that I knew about upcoming events and new research going on at RFF.

Based on your experience in both the public and private sectors, are there things RFF could be doing to better communicate the results of its work?

RFF scholars have always been good at predicting the future of environmental policy but they could do more to influence how companies respond to new environmental, energy, and regulatory demands. Reality is starting to merge with theory: companies are now taking a much closer look at energy technologies that were once considered far-fetched, like cars being powered by hydrogen fuel cells. They are hungry for new ideas and the hard data to back them up, and this is where RFF could play a critical role.

Congressional passage of comprehensive energy legislation remains an elusive goal. Having served under both Clinton and Bush, do you think this situation will ever change?

Many things will have to happen for real change to come about—it will take a deeper and much more sustained effort than we've seen up until now. There needs to be one person in Congress who can get everyone to come to the table. Energy policy cannot be seen as a partisan issue—the need for affordable energy cuts across all demographic groups.

As a practical matter, do you think it is possible to lessen America's economic dependence on foreign oil? Shouldn't we just learn to live with it?

There's really no alternative. The United States is never going to become truly energy independent and it's naïve to think otherwise—demand is just too great. Oil is now a global commodity, with suppliers outside the Middle East—like Canada, Russia, and West Africa—starting to play a more dominant role.

Electricity deregulation appears to have stalled. Do you think this is a permanent state of affairs?

Given what happened in California a few years ago and ongoing price volatility in the power market, I think deregulation is possibly stalled, but not dead. You can't put the genie back in the bottle—this issue will return in a few years. The Federal Energy Regulatory Commission can do more to monitor and referee the inevitable fights over open access. I still believe that competition among power generators can work, if the right legislative checks and balances are in place. ■

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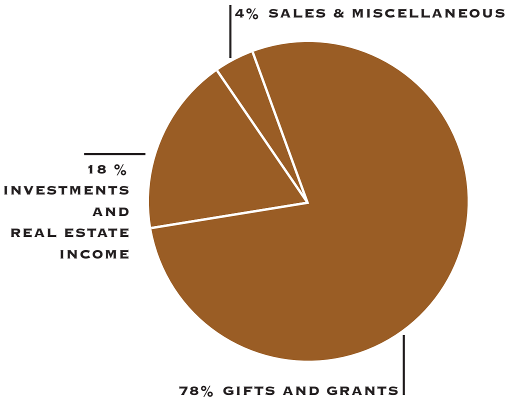

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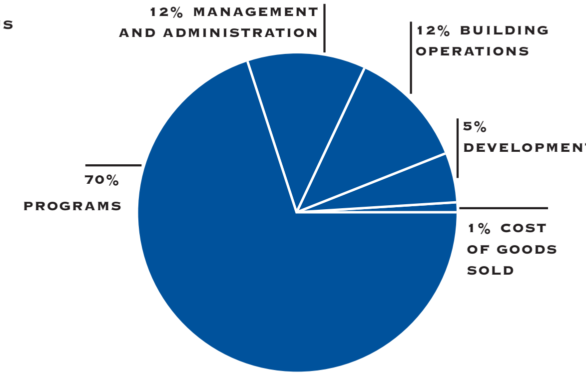

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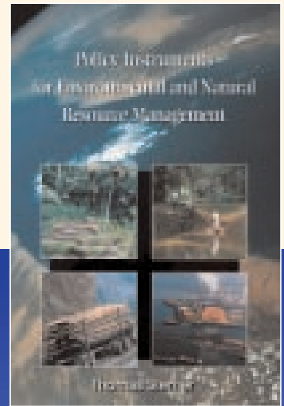

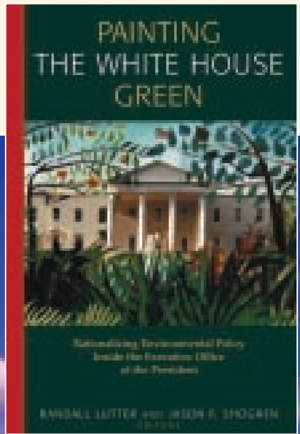

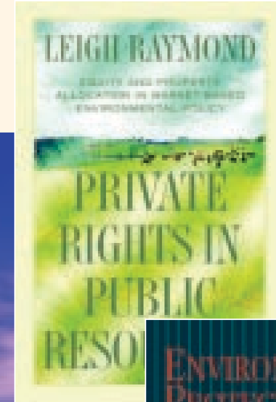

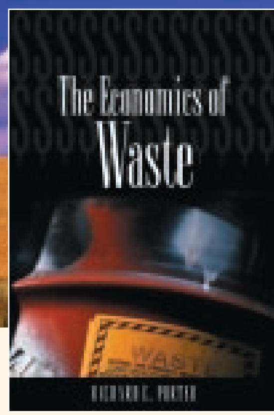

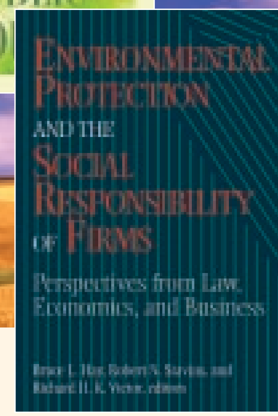

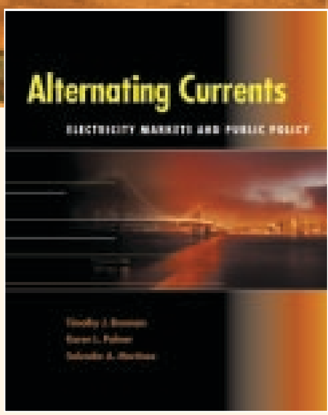

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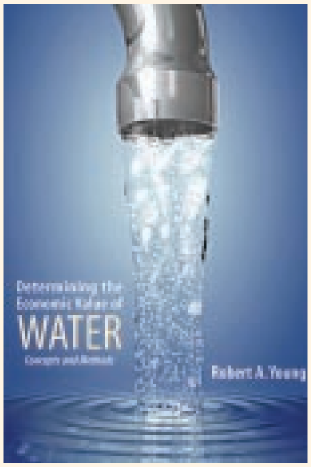

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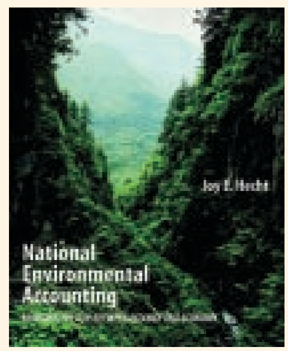

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