Navigating Energy Choices in the 21st Century

What has been called the "oil century" is now history, and finding clean, affordable, 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

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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.

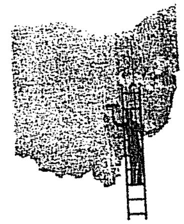
Moving Forward

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. ■

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.

'GREEN'  DREAMS

Clean-energy sources

Renewable-energy technologies

NATIONWIDE PRODUCTION, 2008. A million megawatt-hours is enough electricity to power about 90,000 homes for one year.

SOLAR .02%

0.3 MILLION MEGAWATT-HOURS

HOW IT WORKS: Photovoltaic cells convert the sun's rays into electricity. This has the potential for rapid growth, both for utility-scale projects and for smaller rooftop systems, though high costs are an impediment. A separate technology, known as solar thermal, uses solar collectors to transfer heat.

IN OHIO: Ohio has almost no utility-scale solar capacity, though several projects are in progress. Toledo has emerged as a center for making photovoltaic components.

WIND 14%

52 MILLION MEGAWATT-HOURS

HOW IT WORKS: Turbines create electricity by turning in the wind. Production has skyrocketed in recent years, making this the fastest-growing energy source, with a forecast for continued growth. The technology is most popular in states stretching from the Dakotas to Texas.

IN OHIO: Ohio's largest wind farm has only four turbines, though several larger projects are planned.

HYDROPOWER 67%

248.1 MILLION MEGAWATT-HOURS

HOW IT WORKS: The flow of water turns a turbine. This is the most common type of renewable energy in the country. It is also a somewhat mature technology, with less room for growth than other types of renewable energy.

IN OHIO: Ohio has 101 megawatts of hydropower capacity, by far the largest of any renewable source in the state.

GEOTHERMAL 4%

14.9 MILLION MEGAWATT-HOURS

HOW IT WORKS: Heat from the ground is converted into electricity, using a network of underground pipes filled with liquid. This is most viable in places with high underground temperatures, such as the western and southwestern United States.

IN OHIO: Ohio is not well-equipped for geothermal power.

BIOMASS 15%

55.9 MILLION MEGAWATT-HOURS

HOW IT WORKS: This is an umbrella term for the conversion of plant or animal matter into energy, which can include something as simple as burning wood or as complicated as turning animal waste into electricity.

IN OHIO: Ohio has many projects involving non-wood biomass, representing a little less than 41 megawatts of capacity in 2008.

Technologies in development

FUEL CELLS

HOW IT WORKS: A fuel, often hydrogen or natural gas, is converted to electricity using an electrochemical reaction. This is not necessarily renewable energy, but it is often regarded as environmentally friendly because it is much more efficient than more-common methods of producing electricity.

IN OHIO: Ohio has an emerging fuel-cell industry, looking at ways to power buildings and vehicles with the devices, though no company has as yet reached the point of mass production. This is a technology that could fundamentally *alter power production, and Ohio is poised to be a beneficiary.*

'CLEAN COAL'

HOW IT WORKS: Refers to several technologies that would reduce the pollutants released from burning coal. The very term "clean coal" is controversial, with many environmentalists arguing that there is no way to adequately reduce the harm of carbon emissions. Ultimately, the viability of this technology will depend on whether the cost cancels out the relative affordability of coal as a fuel source. This remains an open question.

IN OHIO: Ohio, one of the leading users of coal in the country, has invested heavily in "clean coal," and the state government regards this as clean-energy *research.*

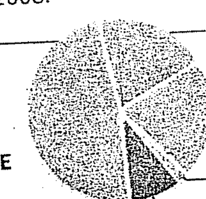
ADVANCED NUCLEAR

HOW IT WORKS: Much like "clean coal," this refers to attempts to mitigate the environmental concerns surrounding an existing power source. Also like "clean coal," this is controversial. Researchers are looking at ways to build nuclear-power plants that are less expensive and that use less fuel, leading to less waste from spent fuel. The Obama administration has pledged to support the construction of "safe, clean nuclear-power plants," though it is too early to know whether this will lead to the construction of more plants.

IN OHIO: There is talk of expanding Ohio's nuclear power, but no projects have been approved.

Fuel sources for electricity

Nationwide, 2008:



Figures are based on share of megawatt-hours.
Sources: *Dispatch* research, Energy Information Administration

THE COLUMBUS DISPATCH