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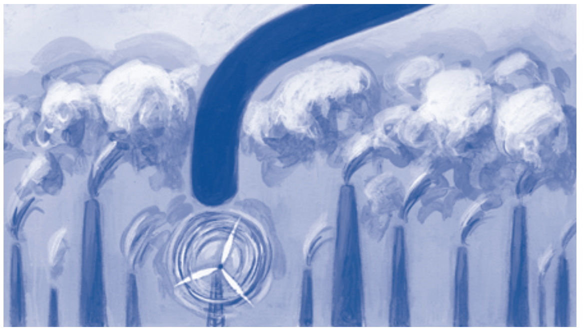

Understanding the Global Energy Industry Is Key to Meeting Maine's Energy Challenge

by Elizabeth A. Wilson

Dependence on petroleum has global consequences with regard to supply constraints, energy security, and economic impacts, along with major consequences for climate change and other environmental problems. Maine is at a particular disadvantage due to our reliance on home heating oil and transportation fuels in our rural state. In this article, Elizabeth Wilson analyzes the global petroleum industry and the challenges and solutions ahead for the U.S. and Maine as we seek to reduce dependence on fossil fuels and develop other cleaner and cost-effective energy sources.

INTRODUCTION

We are in the midst of yet another energy crisis, and this one is, indeed, of global significance. As world population increases and as economies grow in developing countries, more pressure is placed on energy resources of all types. In the U.S., we now must face the reality and consequences of our dependency on petroleum (particularly imports) and the resulting economic, environmental, and supply concerns. We face more challenges in moving new and cleaner energy technologies into the market place, encouraging efficiency and conservation, and implementing public policy and performance-based regulations to achieve these goals.

Maine is at a particular disadvantage because of our dependency on home heating oil and transportation fuels and our higher-than-average utility costs. Many of our citizens, especially those who live in rural communities where there are fewer choices, can ill afford the higher prices. The impact is compounded as higher energy prices move through the economy, raising the cost of goods and services for everyone. It is also compounded as the global economy weakens and oil prices drop, creating additional economic uncertainty.

These are not new issues, but it is imperative that we find real solutions now. We need a rigorous approach with involvement by everyone from all walks of life in a truly global effort.

What we do in Maine does matter. We can create opportunities from the current energy crisis and economic downturn that will benefit Maine's economy and protect our environment while making positive contributions to the global community through innovation, invention, and demonstration of effective use of technology and ideas. To do this, we need to look at the real causes of this energy crisis and understand the global energy industry.

CAUSES OF OUR ENERGY CRISIS

Increasing Global Demand, Growing Population

More than 80 percent of the energy the world consumes comes from fossil fuels (oil, gas, and coal), and forecasts suggest we will be dependent on these fuels for the foreseeable future (Figure 1). Natural gas and coal are important, but oil is our energy of choice. In 2000, the world used 77 million barrels of oil per day (mmbopd). In 2005, consumption rose to 84 mmbopd, and in 2007 it was 85 mmbopd. The trend is clear. Both the Energy Information

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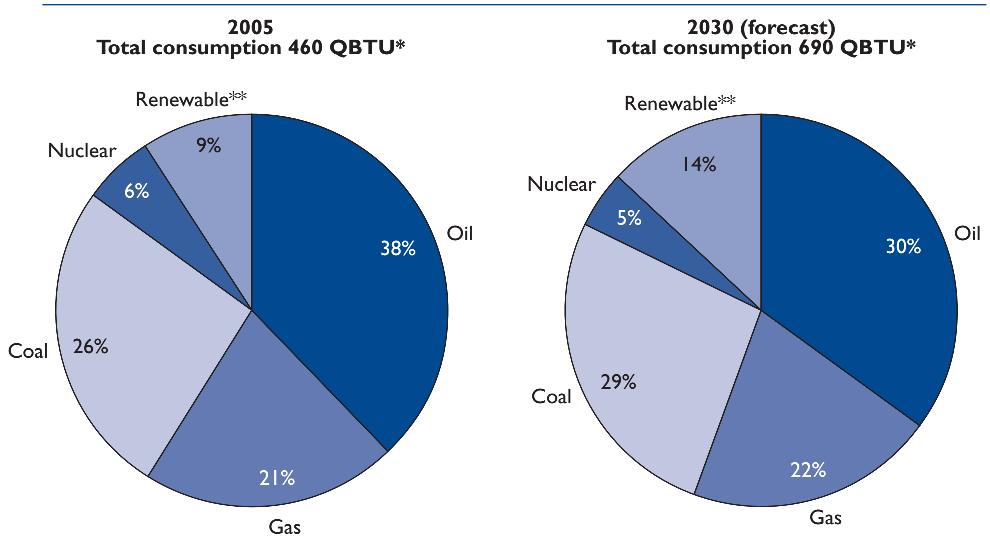
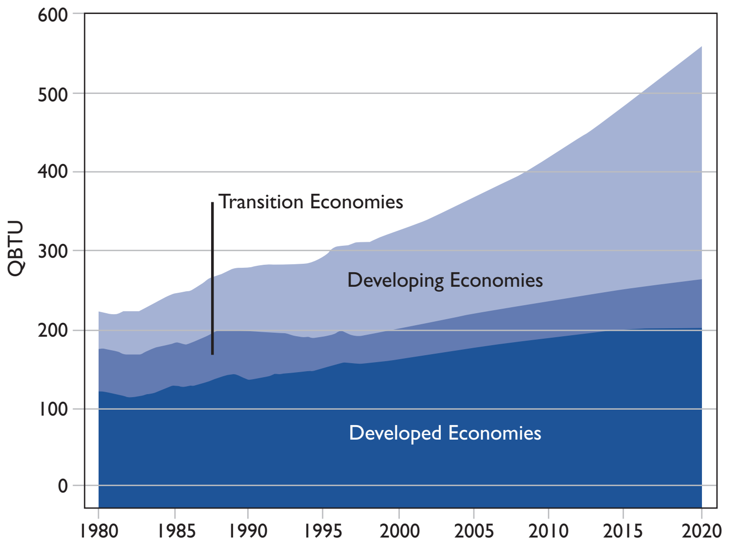
FIGURE 1: **World Energy Consumption**



*Quadrillion British thermal units.
**Renewables include both traditional and new renewable energy.
Source: International Energy Agency (IEA) and the Energy Information Administration (EIA), including October 2008 forecast demand reductions.

FIGURE 2: **Global Energy Consumption and Forecast**



Source: International Energy Agency (2000)

Administration (EIA) in Washington, D.C., and the International Energy Agency (IEA) in Paris estimate global oil demand will reach more than 100 mmbopd by 2030, even as more renewable energy enters the market and as some analysts question whether such production is attainable.[1]

Analysts have predicted for many years that the greatest increase in demand will occur in developing countries and that time has come (Figure 2). A little more than a decade ago, China was an oil exporter, now it is second only to the U.S. in oil imports. India's energy consumption is also rising rapidly, but is still far below that of China. Growing economies consume more energy as do growing populations. World population is projected to increase from 6.6 billion to 9 billion by 2050, and it is inevitable that this will increase energy demand.

Even after adjusting for recent reductions in demand, total world energy, including all forms of energy, is expected to increase by 50 percent from 2005 to 2030 and double by 2050. According to the most optimistic forecasts and scenarios, as found on the Shell Energy Scenarios Web site (www.shell.com/scenarios/), we will still need as much as 60 percent of our energy from fossil fuels by 2050.

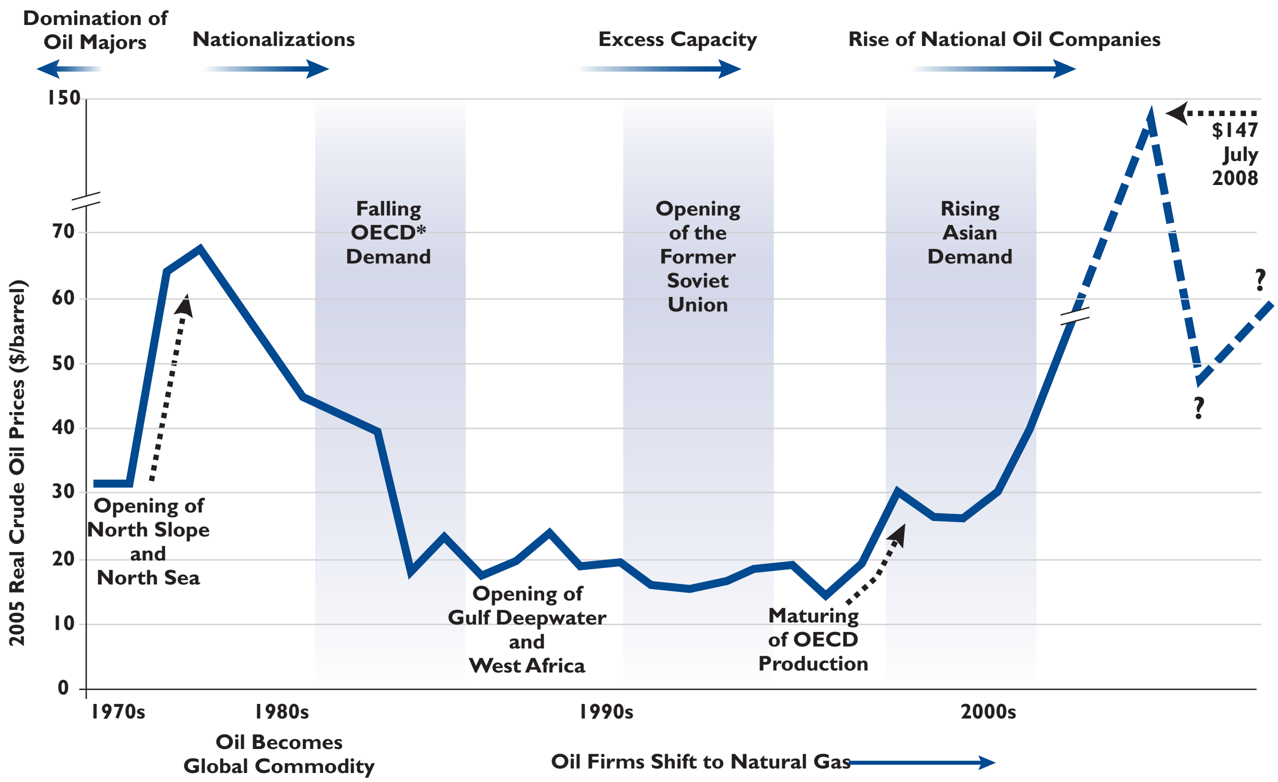
Energy Security, Interdependency and Climate Change Nexus

Since World War II and perhaps earlier, petroleum has been a strategic interest to developed countries in Western Europe, North America, and Asia. Approximately 50 countries in the world produce oil and gas, and all countries consume these products. Hundreds of thousands of miles of pipelines crisscross the continents around the world, and tankers carry crude oil, oil products, and liquid natural gas (LNG) across oceans. Moving these commodities globally is expensive and complicated, but it has been done for the most part well, efficiently, and safely for a long time. But energy resources are not distributed evenly around the world. Not only is most of the world's oil found in the Middle East, most of the oil yet to be discovered is likely there. Other parts of the world are gaining greater significance in oil production, particularly Africa and Central Asia, but they also pose serious risks in terms of political stability and exploitation.

Energy security issues are of increasing concern for countries that rely heavily on imports, particularly in Western Europe, the U.S., Japan, and more recently, China. These countries are under pressure to diversify not only regional sources of oil, but also suppliers within regions. Exporting countries also face challenges as they try to maximize natural resource assets for the benefit of their citizens. Global interdependency and self-interest of exporting and importing countries are critical issues that require new strategies for cooperation and diplomacy if future conflicts are to be averted.

At the same time we must consider the negative impact that consumption of fossil fuels has on our global environment. A report from the Intergovernmental Panel on Climate Change (IPCC 2007) provides the strongest evidence yet of the influence of human activities on climate change, and the risks we face as a consequence. Fossil fuel consumption is a major source of the abundant greenhouse gas, carbon dioxide (CO_2), and thus contributes to global warming. All of this is even more critical in light of the Stern report for the British government, which links market economics to climate, predicting that the economic benefits to society will be greater if we act now to control carbon emission rather than wait until conditions worsen and costs increase (Stern 2006).

FIGURE 3: **Industry Forces Behind Global Oil and Gas Production**



Source: Adapted from Petroleum Finance Corporation (PFC Energy) (2006), with permission.

*Organization for Economic Cooperation and Development. The OECD includes 30 member countries committed to market economies, sustainable growth and financial stability. http://www.oecd.org.

THE GLOBAL PETROLEUM INDUSTRY

A Brief History

The modern petroleum industry began in 1859 in Titusville, Pennsylvania, when Edwin Drake struck oil at a depth of 69 feet. It was not until oil was discovered at Spindletop in southeastern Texas in 1901, however, that oil began to fuel the industrialized world. From that point, Texas became both the real and storybook center of the oil industry, and the Texas Railroad Commission officially set the price of oil. The U.S. exported oil to other countries during the first half of the 20th century. It was a time of big oil companies, money, and power (Yergin 1991).

During the second half of the 20th century, the energy industry changed significantly (Figure 3). Before 1961, oil companies ("majors" such as Exxon, Shell and Texaco) could invest anywhere in the world, except Mexico and the Soviet Union. Then in 1960 the Organization of Petroleum Exporting Countries (OPEC) was established in Baghdad. The founders Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela were later joined by nine other oil-producing countries. OPEC quickly assumed a major role in the international oil market. In the 1970s, nationalization of oil companies increased and the 1973–74 Arab oil embargo shocked the world. By 1980 the Shah of Iran had been deposed, and the Iran/Iraq war had begun. Oil prices increased, the first major wave of solar and other renewable energies came on the U.S. market, and global economies weakened under the pressure of higher energy prices. Then, as new oil and gas deposits were discovered on the North Slope of Alaska and in the North Sea, oil supply exceeded demand and oil prices fell in the mid-1980s, and OPEC lost market share. The economic benefits were significant for developed economies, but many oil companies either merged or went out of business, and the industry lost half of its professionals.

It took 20 years for demand to increase to supply levels, and during that time the global oil industry had less capital and less incentive to invest in infrastructure, particularly refineries, and in drilling, resulting in fewer discoveries. Now pipelines, refineries, and other facilities around the world are at maximum capacity, and there are shortages of trained personnel, equipment, and raw materials. Almost any increase (or decrease) in demand or disruption in supply can have a major effect on price. Price is no longer set by the Texas Railroad Commission or controlled by large oil companies or even by OPEC, but determined daily in the global commodities market.

National oil companies (NOCs), both inside and outside OPEC, control more than 80 percent of world oil reserves.

What Controls Price or Who Can We Blame?

The overriding control on oil price is the basic economic principle of supply and demand. Increasing price reduces demand and also encourages investment to increase supply. When supply increases, price falls, infrastructure investments drop, and demand increases as the cycle continues. Yet markets are driven by more than simple supply and demand. Other factors come into play such as weather (exceptionally cold winters or hot summers, or hurricanes), geopolitics, war, terrorism, changes in inventories of gasoline, heating oil, and other refined products, global crude oil stockpiles, refinery capacity, currency valuation (oil is traded in U.S. dollars), market speculation, and/or market manipulation. Perceived as well as actual crises influence price on almost a daily basis and contribute to price volatility. Unanticipated events can cause the most dramatic swings in price. Information technology means everything is shared worldwide 24 hours a day and is factored into the price of a barrel of oil nearly instantaneously. This complexity is compounded by the longer lag in demand response to price changes.

In recent years OPEC has attempted, with varying degrees of success, to keep oil prices relatively high by controlling production and investment in order to maximize revenue that flows directly to its central governments, but not so high that they lose market share or the global economy destabilizes. OPEC's ability to do this has been questioned not only as prices rose dramatically during the past few years, but also as they have fallen precipitously.[2] It remains to be seen if OPEC can maintain price within the October 2008 target of $70 to $90 a barrel as global demand decreases.

In addition to all these factors, longer-term uncertainties in government policies and future economic growth, environmental and climate issues, and new energy technologies affect the amount and type of energy investments made in all parts of the industry. This in turn affects current and future prices. Thus, although stable, predictable energy prices help nearly everyone—industries, governments, institutions, businesses, and individuals—they are difficult to achieve in today's market economy.

Where Is Most of the Oil?

National oil companies (NOCs), both inside and outside OPEC, control more than 80 percent of world oil reserves (Figure 4). Perhaps more importantly, they control areas with the best exploration potential, where future reserves may be discovered. NOCs such as Aramco (Saudi Arabia), PdVSA (Venezuela), and Petronas (Malaysia) are state-owned and have the exclusive right to resource development. They generally do not allow foreign companies to explore for, or produce, oil within their borders. The international oil companies (IOCs) such as Exxon, Shell, and British Petroleum (BP) now have access to fewer areas of the world for exploration and development and find it increasingly difficult to replace reserves. In the not-so-distant future, IOCs will need to find new sources of oil and/or focus on other areas of energy. Major changes are occurring within the energy industry and, as described in *The Economist* magazine, we have replaced "Big Oil" with "Really Big Oil" (*The Economist* 2006).

The Middle East, where many of the NOCs are located, has the largest known concentration of oil in the world. Saudi Arabian oil reserves are estimated at 260 billion barrels (BBO) or 20 percent of the current global proven reserves of 1.2 to 1.3 trillion barrels. The largest oil field in the world, Ghawar, was discovered here in 1948. Ghawar has already produced more than 55 BBO and continues to produce five million barrels of oil per day. According to the American Association of Petroleum Geologists' Web site, this one field is 174 miles long, 16 miles wide, and covers 1.3 million acres (www.aapg.org/explorer/2005/01jan/ghawar.cfm). The oil comes from 6,000 to 7,000 feet below the surface. Try to imagine burying the Green Mountains in Vermont and adding oil. There is very little chance of finding another field as large as Ghawar, but there is high probability that there is much more oil in the region and many more fields to be discovered.

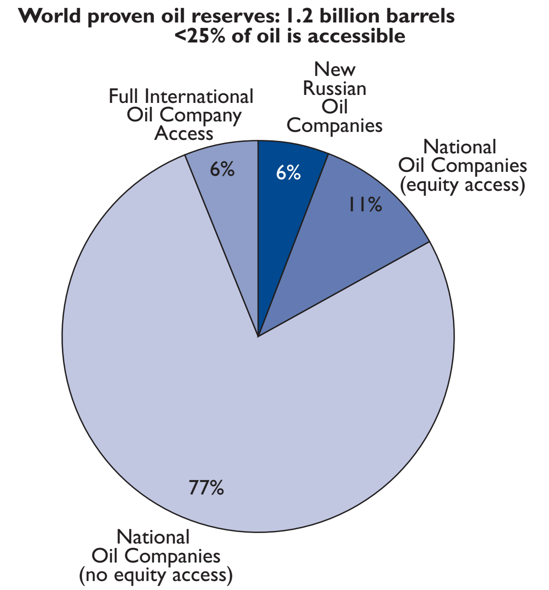
Iran and Iraq hold the most significant conventional proven reserves after Saudi Arabia. Exploration and production infrastructure is weak in Iran and Iraq due to years of economic sanctions and war. Although Middle Eastern companies have dramatically increased energy investments during the past five years, it will take many years before oil and gas production can be significantly increased. In addition, most new fields will be smaller and more expensive to develop. Lifting costs, or the costs required to get one barrel of oil out of the ground, have risen from some of the lowest in the world to some of the highest. Producing countries and their national oil companies have huge profits to invest in energy projects, both fossil fuel and renewable, but like all countries they have other revenue demands as well.

What about Natural Gas?

During the past 20 years, natural gas has gone from an unwanted by-product of oil production to an important global commodity. Natural gas is an environmentally cleaner fossil fuel and emits far less CO_2 than either oil or coal because it is the smallest hydrocarbon molecule. Most new power generation and heating systems in the developed world use natural gas. Natural gas is transported by pipeline and increasingly by tanker in liquid form (LNG). LNG transport has opened large, previously inaccessible natural gas resources to the world market. As a result, global demand for natural gas is increasing.

The largest proven gas reserves are in Siberia and the Middle East. Russia, Qatar, and Iran together control 60 percent of world gas reserves and according to the *International Herald Tribune*, they have taken steps towards establishing an OPEC-style organization for natural gas (www.iht.com/articles/ap/2008/10/21/business/ML-Iran-Gas-Cartel.php). This has caused increased concern about future supplies in countries that import natural gas. Russia, through state-owned Gazprom, supplies the European Union by pipeline with approximately 50 percent of its gas imports. Indeed, disputes in recent years, notably in Ukraine and Georgia, have interrupted pipeline shipments to Europe for short periods of time. Gazprom's influence may soon extend to other regions of the world in the form of LNG. Russian gas from Sahkalin Island in the Pacific has been contracted not only to Japan, Korea, and China, but also to the U.S. Middle Eastern LNG is exported to Europe and increasingly to Asia, the fastest-growing market. The amount of Middle Eastern gas available for export, however, is affected by

FIGURE 4: **Control of Oil Reserves**



Source: Adapted from PFC Energy (2006), with permission.

domestic demand in petrochemical, power generation, and water desalination sectors as well as other needs.

Natural gas exploration, production, and infrastructure have challenges and opportunities independent from oil, but world resources of proven and estimated undiscovered gas are comparable to those of oil. Natural gas will be an important energy source for many years to come. LNG trade especially, which now controls about 25 percent of the global gas market, is expected to grow in importance despite various risks and uncertainties.

When Will We Run Out of Oil and Gas?

There is no doubt that oil and other fossil fuels are finite resources. Ever since M. King Hubbert of Shell Oil Company accurately predicted in 1956 that oil production would peak in the U.S. by 1970, many industry experts have attempted to use similar statistical methods to predict global peak production. The results have been varied and conflicting, and hotly debated. Some ascribe to imminent peak models (Deffeyes 2002; Simmons 2005) that indicate oil production is already in decline or near decline. Others support the broad or undulating plateau models of Jackson (2006) and Lynch (2004), suggesting a less dramatic decline in production in decades to come.

What we do know is that the world has already consumed 1.1 trillion barrels of oil and that we have 1.2 to 1.3 trillion barrels in proven conventional reserves (twice the 1980 figure) (Figure 5). The U.S. Geological Survey, according to their Web site, estimates there are at least two trillion barrels of future technically recoverable conventional oil (www.usgs.gov/newsroom/article.asp?ID=636). The IEA takes their projections even further into the future and with much greater uncertainty. They estimate total long-term (including not now economically and/or technically) potentially recoverable conventional and unconventional (including liquids from coal) oil-resource base to be about nine trillion barrels (www.iea.org). What do these numbers really mean?

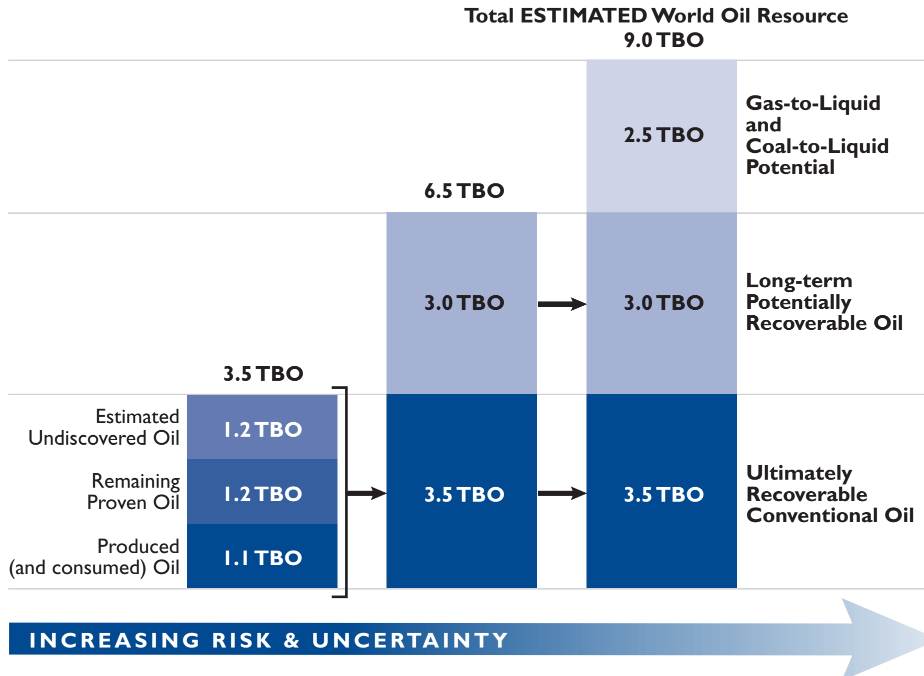
The factors that influence production, consumption, and discovery of additional reserves are hard to quantify and predict. Improved technology continues to reduce drilling risks, to open new areas of exploration, and to increase recovery rates in both new and old fields. Although we may not be running out of oil soon in geologic terms, the oil that does exist is often found in politically unstable parts of the world, in areas not accessible to most oil companies, in smaller fields and more difficult regions to drill, and in unconventional resources. These fields require increasingly complex and expensive infrastructure to produce, refine and deliver oil—and gas—to end users. In addition, future global supply depends largely on the exploration and production programs of the NOCs—and how much and when their governments are willing to reinvest. As many others have said, the real challenges may well be aboveground, rather than belowground. There is little doubt, though, that future oil will be more expensive to produce and deliver. And much of it will always remain beyond reach.

Potential for New Supplies: Conventional and Unconventional

In addition to proven reserves that have yet to be produced and consumed, an estimated additional 1.2 trillion barrels of conventional oil remains to be discovered (Figure 5). Conventional petroleum exploration continues all over the world in North and South America, the Middle East, Europe, Asia, and Africa. Even in the U.S. where 3.5 million wells have been drilled (compared to approximately two million in the rest of the world), discoveries are still being made. But these discoveries take greater and greater effort. IOCs and NOCs are especially interested in Central Asia, Africa, and Australia because, unlike most of the oil- and gas-rich regions of the world, these governments allow foreign companies to participate in exploration programs and hold ownership (equity) positions. Opportunities exist to transfer clean technologies and the best practices of the international petroleum industry, but it will take responsible leadership on the part of many to ensure that oil and other resource exploitation benefits developing countries in these regions, and their citizens.

Unconventional oil is produced from areas considered more difficult to develop and/or from areas using non-traditional drilling and/or completion techniques. Some of this is already happening today. For example, large oil resources are now being produced in deep

FIGURE 5: **IEA 2008 World Oil Resource Estimates (in Trillion Barrels of Oil)**



Source: International Energy Agency, World Energy Outlook 2008 released November 12, 2008. http://www.iea.org [Accessed November 12, 2008]

water in the Gulf of Mexico and offshore Brazil, areas that were uneconomic and technically impossible to develop just a few years ago. Heavy oil, another unconventional resource, is found in oil sands containing bitumen (oxidized oil) that are mined both on the surface and at depth. More than 60 percent of the world's heavy oil is found in North and South America, primarily in Venezuela and Canada. Environmental concerns in terms of extraction, particularly water use and CO_2 emissions, along with increased energy needs during mining, transportation, and complex refining of synthetic crude ("syncrude") make this a controversial energy source. Canadian government policy supports development of the Alberta oil sands and the U.S. imports oil from these sands, but as signatory to the international climate change treaty, the Kyoto Protocol, the Canadian government is also under pressure to reduce CO_2 emissions. It remains to be seen whether the energy benefit of developing this unconventional oil resource is worth the environmental cost.

Production from other unconventional sources of fossil fuels such as natural gas from coal beds, from deeply buried shales, and from other low-permeability rocks already supplies significant amounts of energy, particularly in the U.S. These projects often depend on high oil and gas prices to remain economically viable.

The importance of these resources and some others still way beyond reach, as shown in the estimates in Figure 5, will increase worldwide as additional technological, environmental, and economic challenges are overcome. But the risks and uncertainties are huge, and no one suggests that all the potential petroleum resources can or will be developed, even in the far distant future. Some argue that these non-traditional sources provide energy security while others argue they create more pollution. Both opinions are valid and the issues need to be addressed carefully and constructively. Programs such as carbon trading and possible solutions such as carbon capture and storage (CCS) may help to reduce greenhouse gas emissions, but many questions still remain unanswered. In reality, we cannot drill our way out of this, either in the U.S. or elsewhere. We need other sources of energy.

OTHER FORMS OF ENERGY

Nuclear, coal, and renewable energy (traditional sources such as hydropower and new technologies) are used mostly for power generation. With future technological advances and policy incentives, some of these energy sources also may provide better transportation and heating solutions. They also help increase energy security by diversifying types of energy and thus reducing our dependency on petroleum.

Nuclear

The pros and cons of nuclear energy are being intensely debated for the first time since the nuclear accidents at Three Mile Island in 1979 and Chernobyl in 1986. On the positive side, nuclear plants do not produce greenhouse gas emissions during operation. Major advances have been made in plant safety and new technologies. Yet continued concerns over plant safety, large initial capital costs, waste disposal, and the potential for nuclear proliferation have deterred the development of new nuclear plants. In addition, nuclear plants use uranium, another ultimately limited resource, as fuel. Mining of uranium generates greenhouse gases and other environmental concerns.

Higher oil prices and concerns about energy security and supply along with climate change make the renewable energy industry more attractive and more competitive in the market place.

Policy decisions vary from country to country and continue to evolve. France generates 80 percent of its electricity from nuclear power and exports it to neighboring countries. Other European countries such as Germany and Denmark are reconsidering past decisions to decommission nuclear plants as they try to meet Kyoto greenhouse gas targets. Global electricity generation from nuclear power is increasing as existing plants are expanded and re-licensed both in the U.S., where there are 103 operating facilities, and worldwide. The EIA and the IEA predict that most new nuclear facilities in the next two decades will be built in countries outside Europe and North America, particularly China, India, and Russia, and that nuclear power will still provide approximately five percent of total energy consumption by 2030 (Figure 1).

Coal

Coal is used to produce heat and electricity and is the largest global source of CO_2. It is the dominant fuel for power generation around the world, and half of the electricity in the U.S. is generated from coal. The U.S. has the largest reserves in the world, more than 250 years' worth at our current consumption rate, and there is pressure to increase its use here. There is pressure to use more coal globally, especially in China, Russia, and India where there are also large coal reserves. Coal is relatively inexpensive to mine, but it has high environmental and health costs that need to be factored into its true cost.

Carbon capture and storage (CCS) and other new technologies might make coal more attractive in the long term, particularly if utilities and carbon storage are located near coal fields. Large-scale applications of coal-to-liquid (CTL) processes for power generation, heating and/or transportation are still in pilot or demonstration phases and are not proven solutions. These technology and associated economic issues all point to the critical need for major R&D funding, particularly at the federal level. Indeed, the cost to our society, to our health and environment, of not funding this research may be greater if we decide to build more conventional coal-fired utilities in the future. And without access to cleaner affordable technologies, the developing world will continue to build conventional coal-fired plants resulting in increased global consumption (Figure 1) and increased CO_2 emissions.

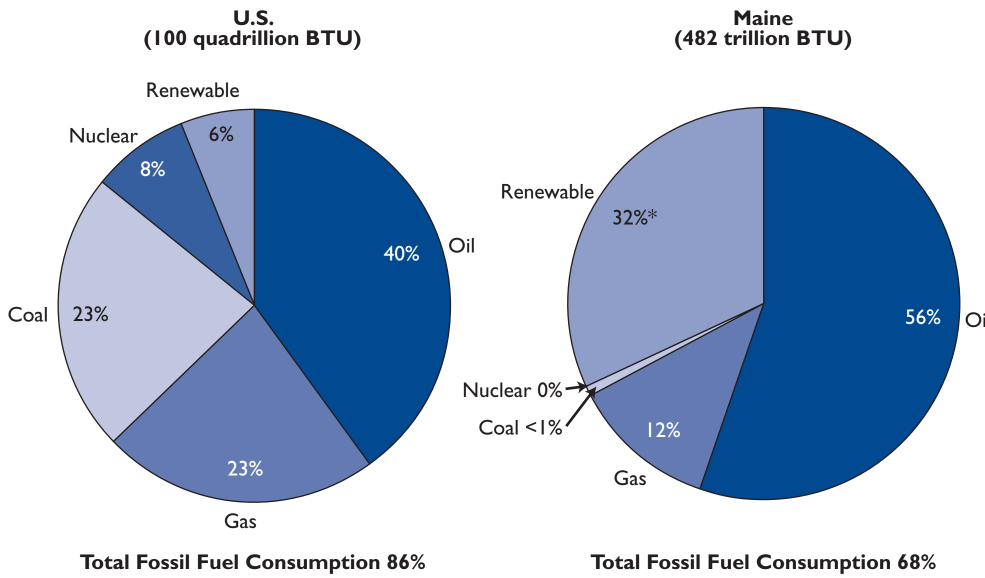
Renewables

Higher oil prices and concerns about energy security and supply along with climate change make the renewable energy industry more attractive and more competitive in the market place. Wind, solar, biofuels, geothermal, hydrogen fuel cells, and other advanced-battery technologies all have strengths and weaknesses and are in various stages of development. Wind is competitive with more traditional energy in many areas, but wind (and solar) energy is intermittent and advanced storage systems are essential for large-scale displacement of fossil fuels. In the short term, innovative programs such as those in California allowing for rental of solar panels may help make solar power more affordable. Indeed solar applications are in many products we use already, from calculators to outdoor lighting and road signs, and are increasingly incorporated into building products. Biofuels hold great promise, but they need to be developed carefully to avoid competing with food production and/or to avoid causing habitat destruction. Private sector investment, including venture capital, is critical and growing significantly. Oil companies are diversifying their energy programs to include renewables, although perhaps not as fast as many would like. Public/private partnerships are more common. Government leadership at all levels is important. But all of this is very confusing, even for those of us in the energy field. Which fuel is best to use? The cheapest? The cleanest? The most convenient? The most efficient? The most reliable supply?

Much more work needs to be done in research and development before renewable energies can replace fossil fuels and achieve true economies of scale in the market place. They need to be affordable, convenient, reliable, and in sufficient supply for the consumer. As Andrew Revkin points out in a *New York Times* article on October 30, 2006, U.S. federal spending on energy research is half of what it was in real dollars in 1979 (www.nytimes.com/2006/10/30/business/worldbusiness/30energy.html). The need for investment in all kinds of energy research in industry, at universities and independent research institutions, and in government laboratories such as National Renewable Energy Laboratory (NREL) is urgent.

Twenty years ago NASA scientist and noted climatologist James Hansen suggested a "common sense" approach to reducing greenhouse gas emissions and energy consumption, including conservation, efficiency, and new technologies that produce little or no carbon dioxide, but few seemed to hear him. Perhaps his message is better received today. The importance of conservation and efficiency cannot be overestimated. As many have said: The cheapest energy is the one that is not used. Conservation and efficiency are some of the easiest methods we can use and continue to improve upon, as both short- and long-term goals to reduce energy consumption.

FIGURE 6: **U. S. and Maine Energy Consumption**



Sources: Maine: http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=ME [Accessed November 18, 2008] http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_tot.html [Accessed November 18, 2008]

U.S.: http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/ [Accessed July 15, 2008]

*Maine renewables include hydro (24 percent), biomass from pulp and paper industry (69 percent) and other (7 percent).

CHALLENGES AHEAD—AND SOLUTIONS—FOR THE U.S. AND MAINE

The U.S. uses around 100 quadrillion BTUs of energy each year (Figure 6), nearly 25 percent of world consumption shown in Figure 1. Each American uses about six times the world average. About 70 percent of our energy is produced in the U.S., with 86 percent of the total coming from fossil fuels. The U.S. imports 15 percent of natural gas and 60 percent of oil consumed.[3] Our country is the world's largest consumer of oil and the third largest producer after Saudi Arabia and Russia.

Maine is even more dependent on oil than the rest of the country (Figure 6). In addition, our high consumption of renewable energy is based largely on the traditional pulp and paper industry and does not reflect new technologies. These two factors represent in a nutshell the challenges and opportunities facing us. As we consider how to reduce our dependency on fossil fuels, expand clean technologies, and reduce greenhouse gas emissions and environmental impact, it is convenient to look at three areas of energy consumption: power generation, transportation, and heating.

Power Generation

Electricity can be transported long distances relatively easily, but not efficiently, and it cannot be stored. More than 60 percent of the energy used during conventional electricity generation and distribution is lost as heat. Utilities are the single largest (40 percent) emitter of greenhouse gases worldwide and in the U.S., although in New England power generation is second to transportation in emissions. This is largely because there are fewer coal-fired plants in New England. Yet, even though we do not burn coal in Maine, we receive air pollution from coal-fired plants in the Midwest and from easterly winds from as far away as China. Nuclear plants generate 20 percent of electricity in the U.S., but not in Maine since the closure of Maine Yankee in 1997.

> Finding ways to reduce or displace our use of oil in transportation is a daunting task and there is no single solution.

Is it better to use natural gas? Natural gas generates approximately 20 percent of U.S. electricity, and most new power plants use natural gas as their primary fuel. This increased demand of gas for electricity competes with gas for heating almost everywhere except in Maine. Combined heat and power units (CHP) and combined cycle gas turbines (CCGT) capture "waste" heat during electricity generation and re-use it. Improving these efficiencies reduces the amount of energy used and thus reduces CO_2 emissions. Performance-based regulations and policy incentives to encourage CHP and CCGT investments and to replace old coal-fired plants could significantly reduce emissions. Increased use of natural gas for power generation, heating, and to some extent transportation will require long-term planning and government policy that encourages more exploration and production activity in the U.S., more imports by pipeline from Canada, and/or transportation as LNG from other countries.

The expansion of wind power in the U.S. has added more renewable energy to traditional sources such as hydropower and geothermal and holds significant potential both onshore and offshore Maine. (See Parker, this issue.) According to the American Wind Energy Association, wind is second only to natural gas for new power generation in the U.S. (www.awea.org). There are many technological, permitting, cost, and operational challenges, particularly for offshore operations. Distribution costs are usually higher than generation costs and connection to the grid is more difficult. Some solutions may involve establishing separate distribution networks and expanding distributed generation.

Distributed energy refers to small-scale generation near the consumer of electricity or, better yet, electricity and heat. These systems may be powered by fossil fuels and/or renewables and may be on the grid, off the grid, or on-and-off the grid. This is still a niche market and is used more for back-up power, "green," and/or high-tech applications such as in Silicon Valley. One significant advantage is the reduction in energy loss compared to large centralized plants that transmit over great distances. As technology improves, standards are adopted, infrastructure is upgraded, and regulatory barriers are removed, there should be more choices for all consumers. Distributed generation is not viewed as a replacement for or as being in competition with central power stations at this point, but would complement existing facilities. This may change as new power markets and technologies develop. Programs such as "net metering," the ability to sell back excess electricity to the utility at market rates, and "green pricing," the voluntary program for consumers to pay more for electricity generated from renewable energy, exist in many states with varying degrees of success. More aggressive government "feed-in tariff" policies in other parts of the world, such as Germany and Spain, encourage renewable energy use by requiring utilities to buy energy from renewable sources at above market rates for many years.

The complex regulatory framework of power markets is changing and new models are evolving although it is not clear what they will look like in Europe, the U.S., or here in Maine. Electricity generation from hydropower, particularly from Canada, has long been important, but Maine's utilities rely most heavily on natural gas, particularly the Portland natural gas system from Quebec and the Maritimes and Northeast Pipeline from New Brunswick. Natural gas supply into Canada as LNG and then by pipeline to Maine is important not only for electricity generation, but could be used to displace heating oil over more of the state. Proposals in New Brunswick to renovate the Point Lepreau nuclear plant and/or build a new nuclear plant to displace coal-fired utilities further indicate how closely tied our energy future is to that of Canada.

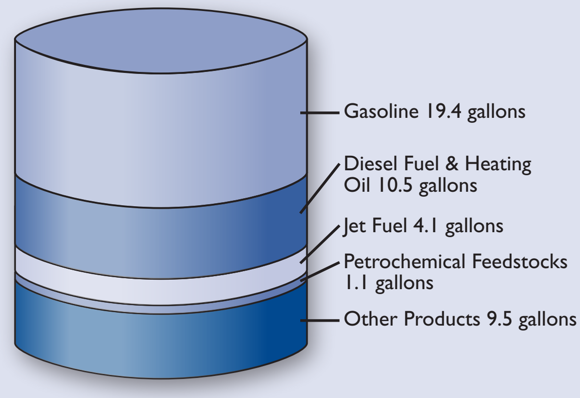
Renewable energy, perhaps including offshore wind in the Gulf of Maine, could play an increasing role in electricity generation in Maine and neighboring states and provinces if grid connections are made to major population centers. There could be more opportunities for distributed generation in island communities and in rural areas from a combination of wind, biomass, geothermal, solar, and perhaps tidal. Maine is currently an exporter of electricity and could assume a larger role in the future. As we transition to new mixes of power generation, utility regulations should encourage conservation and efficiency and rates should reflect that behavior throughout the system. The power sector is beginning to play an important role in providing market mechanisms for reducing greenhouse gas emissions in Europe and here in Maine where we are part of the Regional Greenhouse Gas Initiative (RGGI).[4] Other market mechanisms are under development, and it remains to be seen what system of carbon taxes, cap-and-trade policies, sanctions, incentives, and other regulations work best.

Transportation

The transportation sector is the most heavily dependent on fossil fuels. Two-thirds of an average barrel of oil is refined into gasoline, diesel, or jet fuel (see sidebar). According to the U.S. Energy Information Administration, 97 percent of our transport fuels come from crude oil. Maine is very dependent on New Brunswick for refined products, particularly diesel. Although there are no refineries in Maine, oil pipelines cross the state, and Portland Harbor is one of the largest oil receiving terminals on the East Coast. It might also become a significant export terminal if Canadian syncrude from oil sands is transported east by pipeline from Alberta. (See Hastings, this issue.)

Finding ways to reduce or displace our use of oil in transportation is a daunting task and there is no single solution. Fleet vehicles for both public and private transit companies such as buses and delivery

What's in an Average Barrel of Oil?



A barrel (42 gallons) of crude oil is refined into products such as gasoline, diesel fuel, jet fuel, heating oil, lubricating oil, wax, asphalt, plastics, biomedical materials, and feed stocks for nylon, polyester, and other polymers. (The volume increases during the refining process to 44.6 gallons.) Crude oils vary in character from field to field and region to region and often have exotic names such as West Texas Intermediate, Michigan Sour, or Nigeria Bonnie Light. When oil was first produced commercially in western Pennsylvania, the most convenient container available was the whiskey barrel, and the petroleum industry has been using barrels as a measure ever since. Now barrels of oil and other types of energy measures are often converted to British thermal units (BTUs) to more easily compare energy content, efficiency, and cost. This is particularly important when doing life-cycle analyses to assess environmental, heath, and economic costs and benefits as well as net energy production for different energy types.

vans use alternative fuels such as liquefied petroleum gas (LPG) and natural gas. There are other ways to reduce oil consumption such as improved mass transportation, lower speed limits, higher fuel efficiency standards, vehicle maintenance and engine efficiency, new engine technologies including flex-fuel vehicles, plug-ins, and better batteries. As Tom Vanderbilt describes in an article in the *New York Times* on June 29, 2008, in the short term, less-aggressive

In the past, lower oil prices have resulted in less investment in both fossil fuels and renewables. We should not repeat this mistake again.

driving behavior and common sense have the potential to significantly reduce consumption, up to 25 percent according to some calculations (www.nytimes.com/2008/06/29/opinion/29vanderbilt.html). Yet, in Maine the challenges are particularly daunting because of the rural nature of our state; the current practice of driving long distances in cars and trucks for work and pleasure; and the particular needs of the fishing industry and island communities. Maine's forest products industry and university research programs may help to provide some local solutions and help us to meet some of our fuel needs in the future (Dickerson, Rubin and Kavkewitz 2007; Dickerson and Rubin 2008).

We also need to invest in our infrastructure and make it flexible enough to accommodate new fuels over time. And, most importantly, a lesson learned from the "food vs fuel" biofuels debate is to watch for unintended consequences and to try to make sure policies create positive results, not larger problems.

Heating

Heating is one of Maine's biggest issues, not only because of our cold winters, but also because of our dependency on home heating oil. We are very susceptible to heating oil shortages and price increases. Less than eight percent of the country uses heating oil, yet more than 80 percent of Maine households do. It is a small market and getting smaller and more subject to price volatility and supply shortages. This is particularly true because heating oil competes with diesel fuel production in refineries and companies can make more profit from diesel production. Should we, or can we, switch to other fossil fuels such as propane (six percent current use) or natural gas (nine percent current use)? They are much cleaner than heating oil. When heating-oil systems need replacing, consider alternatives.

Biomass products such as wood pellets here in Maine provide some alternative heating solutions, but we need much more research and development, time and money, before these products reach the marketplace in a large way. Better building codes, improved insulation, recycling of materials, and other efforts to reduce energy consumption in manufacturing, construction, and operating phases of all buildings (industrial, commercial, and residential) are also critical.

CONCLUSION

The convergence of supply constraints, energy security, climate change, and other environmental and health issues all points in the same direction. We need to rethink how we use energy and what types of energy we consume. Diversity of source and supply is important. We need major R&D investments in all types of energy, particularly renewable energy and clean technologies, from both the public and private sector. In the past, lower oil prices have resulted in less investment in both fossil fuels and renewables. We should not repeat this mistake again. Periods of weaker demand and lower prices provide opportunities for significant research investment and planning in anticipation of stronger economic conditions and higher prices. We need policy initiatives at all levels of government and investment in infrastructure to accommodate new energy distribution systems and to encourage conservation and efficiency. We need to export and encourage clean technologies in developing countries to improve heath, environmental, and economic conditions for the entire world.

We can maximize our assets here in Maine and become a strong partner with our neighbors, particularly Canada. Effective leadership is required in all parts of state government to ensure that we participate in the regional decision-making that is now shaping our energy future. Many people in government, industry, academia, and the private sector both here in Maine and elsewhere have been working hard on these issues. Knowledge, education, and experience are important tools. There are lots of challenges, yes, but there are lots of opportunities as well. None of this will happen without careful thought, planning, and action, and the ideas and the commitment of many. The real challenge is recognizing that what we do in Maine is of global and regional significance. If we each take some small part, perhaps what we know best, and make a small contribution, we can make a difference.

Let's take responsibility for the energy we use and the pollution we create. As we do this I urge us all to remember we are part of a global community. Here are some final words of advice I have heard over my 35 years in the energy field and found to be true:

- The further away a technology is, the better it looks.
- The price of oil will go up as the world economy strengthens and down as it weakens.
- Every choice we make has a cost.
- Smart action takes the efforts and ideas of us all.

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ENDNOTES

1. The International Energy Agency (IEA) was founded in 1974 as a response to the Arab oil embargo with the initial objective of preventing oil supply disruptions to member nations (U.S., Canada, most of Europe, Japan, Australia, South Korea and New Zealand). It compiles and analyzes global energy statistics on all forms of energy and greenhouse gas emissions and also provides guidelines on energy policy and projections for future energy consumption (www.iea.org). The Energy Information Administration (EIA) in the U. S. Department of Energy provides detailed statistics, data, and analysis of energy supply, production and consumption for the U.S., and also for the rest of the world (www.eia.doe.gov). These two organizations are excellent sources of energy data and analyses and the major sources of statistics used in this article.
2. Oil price reached a record price of $147 per barrel in July 2008. Some forecasts suggested price might approach $200 per barrel by early 2009. Instead prices began to weaken in September and dropped below $50 a barrel by December 2008. It is tempting to think that the energy crisis is over, but it is not. Oil price will increase again (probably quickly and dramatically) when the global economy strengthens. Then our challenges to diversify energy sources and supplies may be even greater.
3. Natural gas is imported by pipeline from Canada and to a lesser extent as LNG, mostly from Trinidad and Tobago, but also from Nigeria, Qatar, and Equatorial Guinea. Approximately 12 million barrels (mmbo) of oil and refined products are imported daily with the top five sources from Canada, Mexico, Saudi Arabia, Venezuela, and Nigeria. Fifty percent of these imports come from North and South America.
4. The Regional Greenhouse Gas Initiative (RGGI) is an agreement to reduce carbon dioxide emissions from power plants in Northeast and Mid-Atlantic states using a market-based cap-and-trade system (Bogdonoff and Rubin 2007; see also Bogdonoff, this issue). The first auction of utility emission allowances (set by each state) took place on September 25, 2008. Although the auction

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price of $3.07 per ton was much lower than European prices of nearly $40 per ton, the government auction helps establish market mechanisms for pricing carbon emissions in the U.S. It may also encourage development of a global market for carbon. Auction proceeds are to be spent by states on renewable energy and energy efficiency projects.

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