NATIONAL PETROLEUM COUNCIL

Draft Report

Facing the Hard Truths about Energy

A comprehensive view to 2030 of global oil and natural gas

EXECUTIVE SUMMARY

July 18, 2007

This is the working draft reviewed and approved on July 18 by the members of the National Petroleum Council, subject to final editing. The Executive Summary includes all such edits as of August 31. A final report and accompanying CD will be published and available to the public in September.

Facing the Hard Truths about Energy

A comprehensive view to 2030 of global oil and natural gas by the National Petroleum Council

Executive Summary

The American people are very concerned about energy—its availability, reliability, cost, and environmental impact. Energy also has become a subject of urgent policy discussions. But energy is a complex subject, touching every part of daily life and the overall economy, involving a wide variety of technologies, and deeply affecting many aspects of our foreign relations. The United States is the largest participant in the global energy system—the largest consumer, the second largest producer of coal and natural gas, and the largest importer and third largest producer of oil. Developing a framework for considering America's oil and natural gas position now and for the future requires a broad view and a long-term perspective; both are provided in this study.

During the last quarter-century, world energy demand has increased about 60 percent, supported by a global infrastructure that has expanded to a massive scale. Most forecasts for the next quarter-century project a similar percentage increase in energy demand from a much larger base. Oil and natural gas have played a significant role in supporting economic activity in the past, and will likely continue to do so in combination with other energy types. Over the coming decades, the world will need better energy efficiency and all economic, environmentally responsible energy sources available to support and sustain future growth.

Fortunately, the world is not running out of energy resources. But many complex challenges could keep these diverse energy resources from becoming the sufficient, reliable, and economic energy supplies upon which people depend. These challenges are compounded by emerging uncertainties: geopolitical influences on energy development, trade, and security; and increasing constraints on carbon dioxide (CO_2) emissions that could impose changes in future energy use. While risks have always typified the energy business, they are now accumulating and converging in new ways.

The National Petroleum Council (NPC) examined a broad range of global energy supply, demand, and technology projections through 2030. The Council identified risks and challenges to a reliable and secure energy future, and developed strategies and recommendations aimed at balancing future economic, security, and environmental goals.

The United States and the world face hard truths about the global energy future over the next 25 years:

- Coal, oil, and natural gas will remain indispensable to meeting total projected energy demand growth.

- The world is not running out of energy resources, but there are accumulating risks to continuing expansion of oil and natural gas production from the conventional sources relied upon historically. These risks create significant challenges to meeting projected energy demand.

- To mitigate these risks, expansion of all economic energy sources will be required, including coal, nuclear, renewables, and unconventional oil and natural gas. Each of these sources faces significant challenges—including safety, environmental, political, or economic hurdles—and imposes infrastructure requirements for development and delivery.

- "Energy Independence" should not be confused with strengthening energy security. The concept of energy independence is not realistic in the foreseeable future, whereas U.S. energy security can be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. There can be no U.S. energy security without global energy security.

- A majority of the U.S. energy sector workforce, including skilled scientists and engineers, is eligible to retire within the next decade. The workforce must be replenished and trained.

- Policies aimed at curbing CO_2 emissions will alter the energy mix, increase energy-related costs, and require reductions in demand growth.

Free and open markets should be relied upon wherever possible to produce efficient solutions. Where markets need to be bolstered, policies should be implemented with care and consideration of possible unintended consequences. The Council proposes five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. All five strategies are essential—there is no single, easy solution to the multiple challenges we face. However, the Council is confident that the prompt adoption of these strategies, along with a sustained commitment to implementation, will promote U.S. competitiveness by balancing economic, security, and environmental goals. The United States must:

- Moderate the growing demand for energy by increasing efficiency of transportation, residential, commercial, and industrial uses.

- Expand and diversify production from clean coal, nuclear, biomass, other renewables, and unconventional oil and natural gas; moderate the decline of conventional domestic oil and natural gas production; and increase access for development of new resources.

- Integrate energy policy into trade, economic, environmental, security, and foreign policies; strengthen global energy trade and investment; and broaden dialogue with both producing and consuming nations to improve global energy security.

- Enhance science and engineering capabilities and create long-term opportunities for research and development in all phases of the energy supply and demand system.

- Develop the legal and regulatory framework to enable carbon capture and sequestration (CCS). In addition, as policymakers consider options to reduce CO_2 emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economy-wide cost for CO_2 emissions.

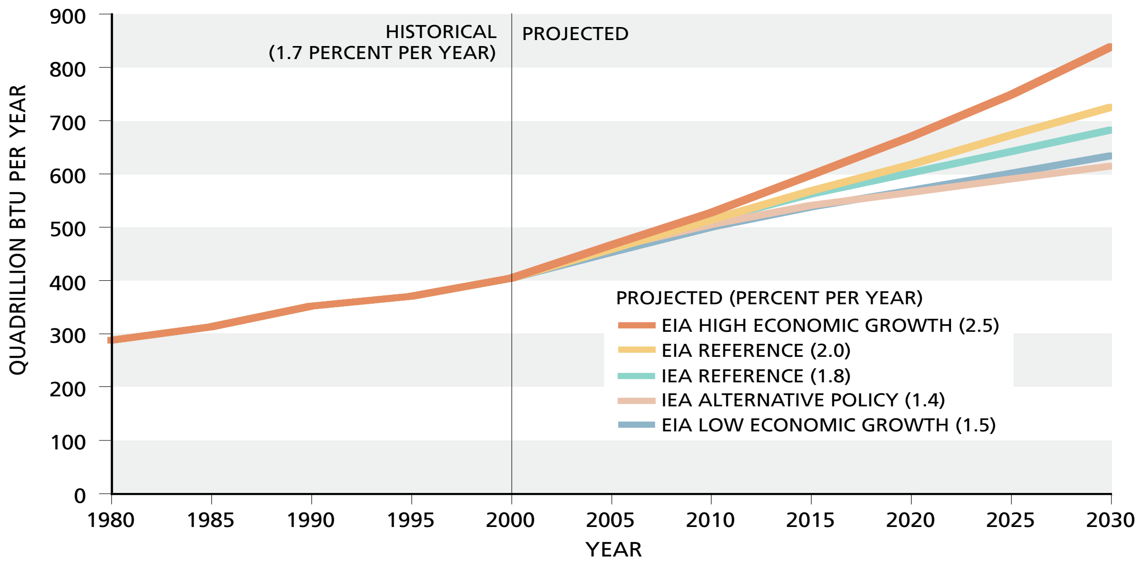
The Council identified these strategies by drawing upon more than 350 expert participants with wide-ranging backgrounds to provide analysis, information, and insight. Additionally, extensive outreach efforts involved more than 1,000 people actively involved in energy. Task Groups for this study reviewed a broad range of public and aggregated proprietary studies in order to understand and evaluate the many assumptions and forces behind recent global energy projections.

Given the massive scale of the global energy system and the long lead times necessary to make significant changes, concerted actions must be taken now, and sustained over the long term, to promote U.S. competitiveness by balancing economic, security, and environmental goals. The Council's findings and recommendations are summarized below and explained in detail in the report chapters.

I. THE GROWING DEMAND FOR ENERGY

Over the coming decades, energy demand will grow to increasingly higher levels as economies and populations expand. This will pressure the supply system and require increased emphasis on energy-use efficiency.

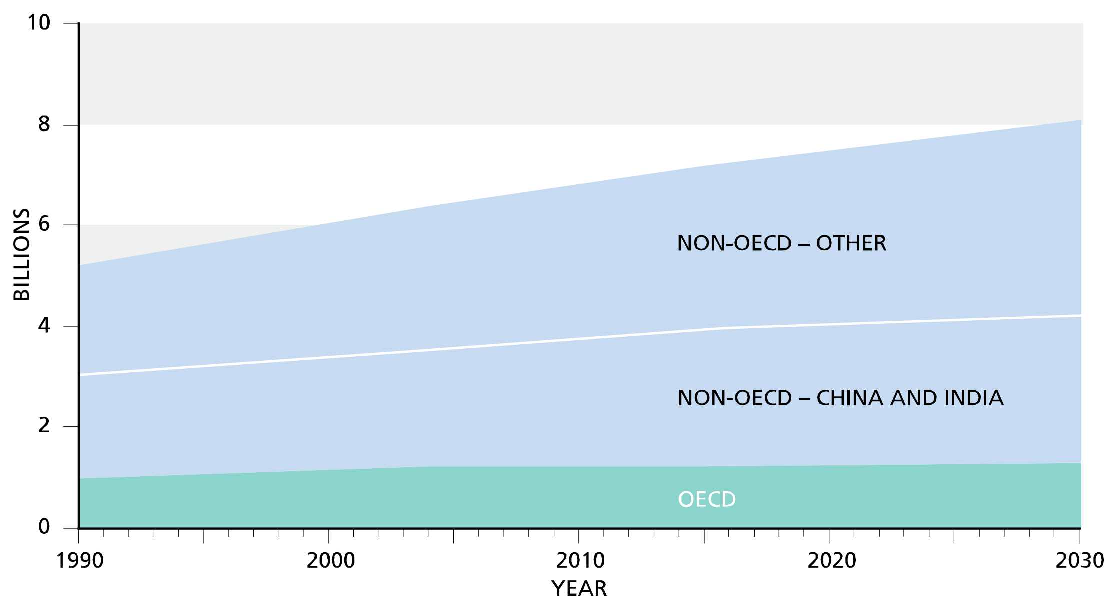
Energy is essential to the economic activity that sustains and improves the quality of life. Projections for future energy needs generally assume expanding economies and populations, which drive continued energy demand growth. Over time, the efficiency of energy use has improved, thanks to the combined effects of technological advancement, education of consumers, and policy initiatives. These developments have allowed growth in economic activity to outpace growth in energy use. Differing assumptions for the world's population, economic activity, and energy efficiency result in varying projections for future energy demand, as shown in Figure ES-1.



Note: A quadrillion Btu is one million million British thermal units. A Btu is the amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit.
Sources: EIA: U.S. Energy Information Administration, *International Energy Outlook 2006.*
IEA: International Energy Agency, *World Energy Outlook 2006.*

Figure ES-1. World Energy Demand – Growth Projections

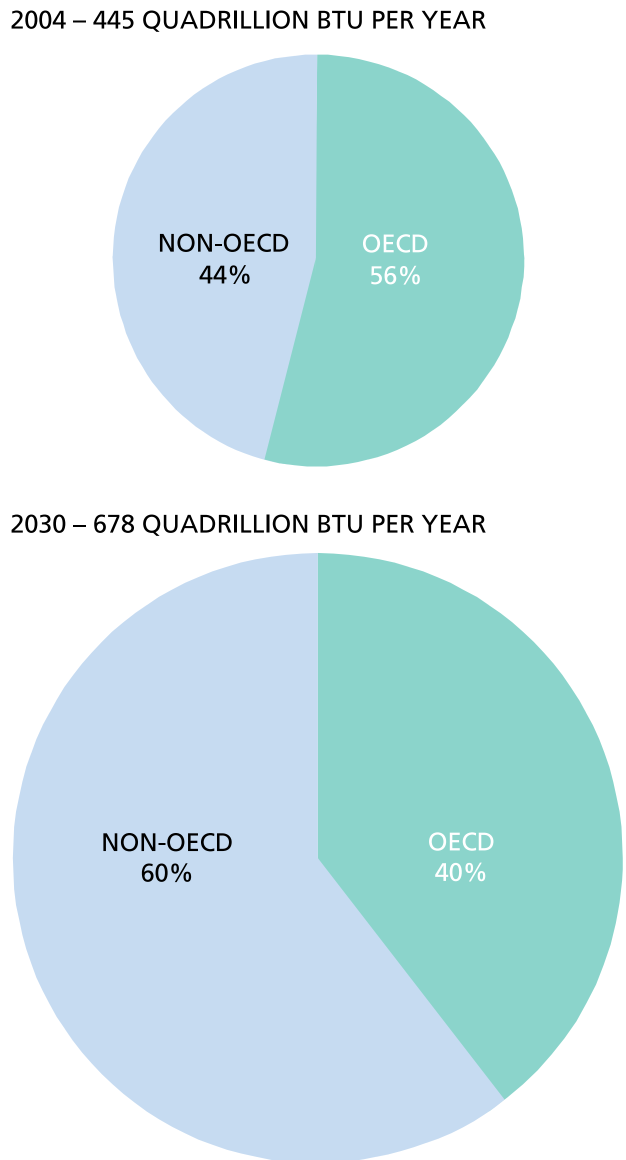
Historically, energy consumption has been concentrated in the developed world, where economic activity has been centered. Today, the developed world, represented by the Organisation for Economic Co-operation and Development (OECD),[1] uses half of the world's total energy to produce half of the world's Gross Domestic Product.[2] However, over 80 percent of the world's population is projected to live in developing countries by 2030, as shown in Figure ES-2.



Source: *UN World Population Prospects.*

Figure ES-2. World Population

Many developing countries are just reaching the point where individual wealth and energy consumption start to accelerate. For example, while the number of cars in China more than doubled between 2000 and 2006, there remains just one car for every 40 people[3] whereas the United States has one car for every two people.[4] Thus, dramatic further growth in vehicle sales and demand for fuel in China are very likely. As this accelerating consumption combines with large and growing populations, it becomes likely that most new energy demand growth will occur in the developing world, with one projection shown in Figure ES-3.



Source: IEA *World Energy Outlook 2006.*

Figure ES-3. World Energy Demand Growth from 2004 to 2030

II. THE ENERGY SUPPLY LANDSCAPE

The world uses a wide variety of energy sources today. Oil and natural gas now provide nearly 60 percent of world primary energy,[5] as shown in Figure ES-4, and it is a hard truth that oil and natural gas will remain indispensable to meeting the projected growth in energy demand.

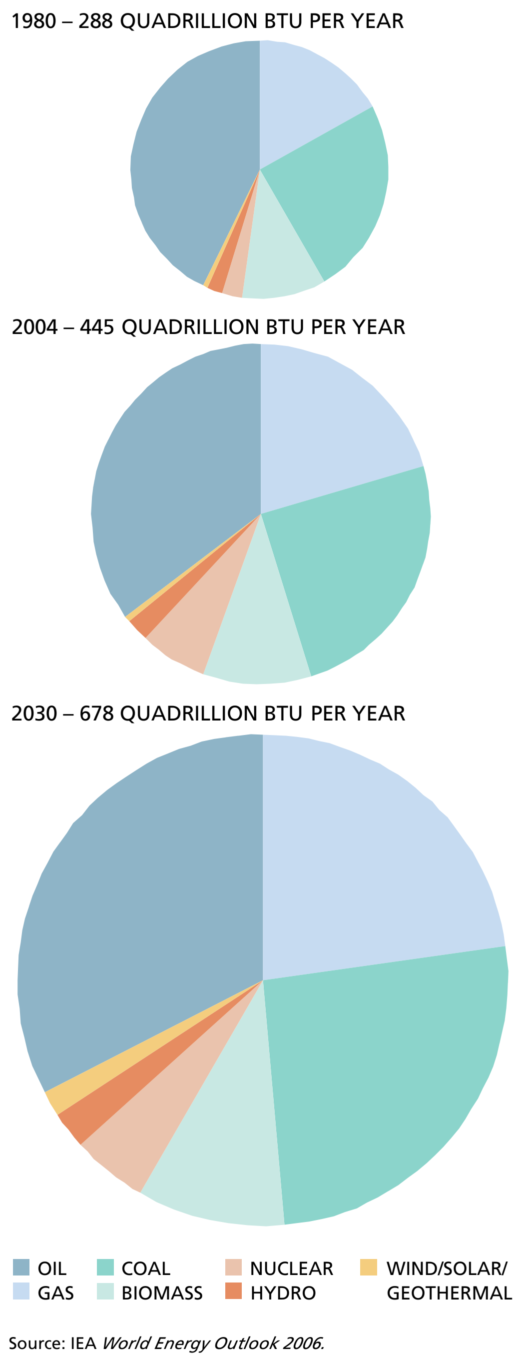
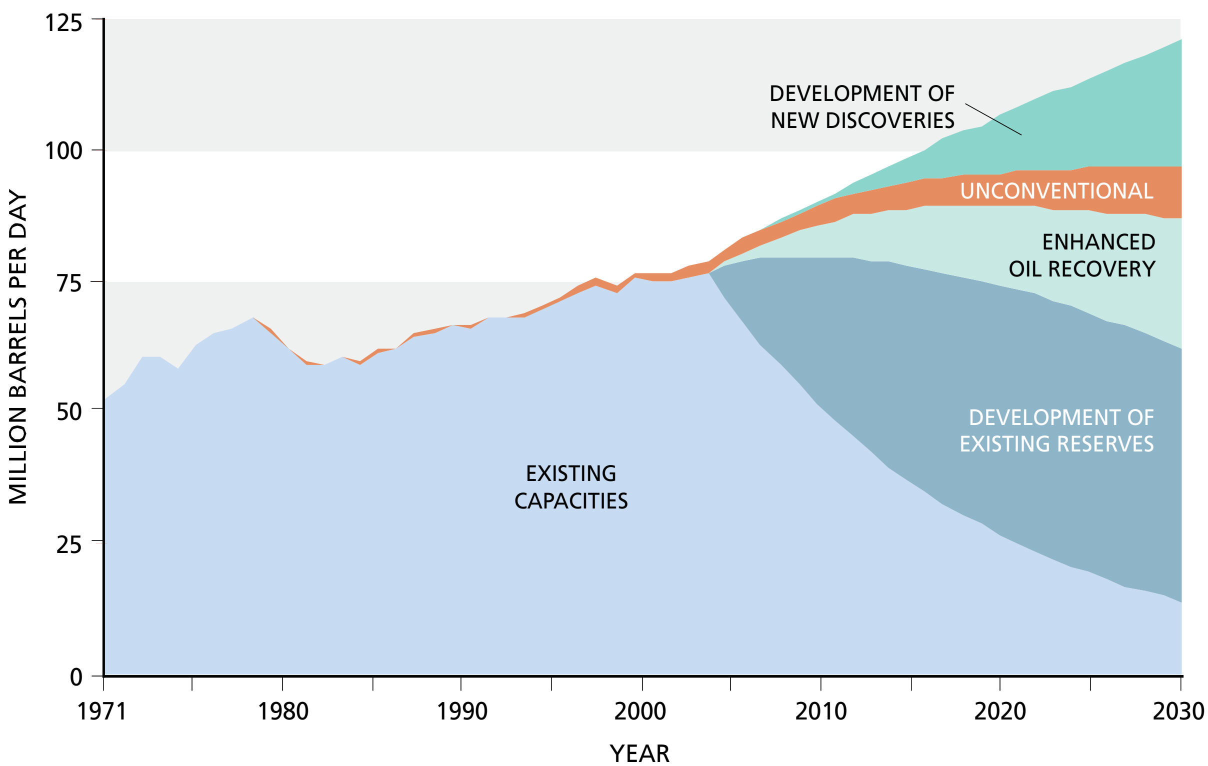


Figure ES-4. World Energy Supply – Historical and Projected

It is another hard truth that a rapidly growing world economy will require large increases in energy supplies over the next quarter-century. Expansion of all economic energy sources will be required to meet demand reliably, including coal, nuclear, renewables, and unconventional oil and natural gas. All energy sources have their own challenges that must be overcome to be produced, delivered, and used on an ever-increasing scale.

Current assessments for both oil and natural gas indicate large in-place volumes of resource. The natural gas resource appears more than adequate to meet the increased natural gas production typically anticipated by energy outlooks over the study period.

Future oil supply will come from a variety of sources, including existing production capacities, development of existing reserves, application of enhanced oil recovery, expansion of unconventional liquids, and development of new discoveries. Figure ES-5 is an illustrative example of these sources as depicted by the IEA in its *World Energy Outlook 2004*. There is uncertainty about the potential of the oil resource base to sustain growing oil production rates. Additional uncertainty surrounds the industry's potential to overcome multiple increasing risks, including access to promising areas for development, and the rate and timing of investment, technology development, and infrastructure expansion. This study observed a range of oil projections from less than 80 to 120 million barrels per day in 2030. This wide range results from differing assumptions about these uncertainties.



Source: IEA, *World Energy Outlook 2004*.

Figure ES-5. Illustrative Total Liquids Supply

Biomass, mainly wood and dung burned for heat, is today's largest non-fossil energy source. Liquid fuels from biomass, such as ethanol from corn and sugarcane, have grown rapidly in recent years, but given the scale of total oil consumption, liquids from biomass contribute only about 1 percent of the energy provided by oil. Potential cellulosic biomass resources, from wood, energy crops, and food crop waste, are large in the United States; the U.S. Departments of Agriculture and Energy estimate that the United States could generate sufficient biomass to produce up to 4 million barrels per day of oil-equivalent liquids.[6] As with the expansion of any energy source, challenges must be overcome before biofuels production can achieve significant volumes. For example, technology does not yet exist to convert cellulosic material economically at scale to liquid fuels. Ethanol expansion in the United States faces compound challenges: increasing rail, waterway, and pipeline transport capacity; scaling up distribution systems; and balancing food uses and water requirements.

Wind and solar energy have also grown rapidly, now contributing about 1 percent to the world's energy mix. Wind and solar energy are expected to continue their rapid expansion, with associated challenges that include economics, intermittent availability, land-use considerations, and the need for grid interconnection and long distance transmission lines.

Hydroelectric power supplies about 2 percent of today's energy. It is not generally expected to grow significantly, except in developing Asia-Pacific areas, since the most suitable locations in developed countries are already in use.

Nuclear power contributes about 6 percent of world energy today, and its use is generally expected to increase outside the United States. Nuclear power expansion faces concerns about safety and security, the management and disposal of radioactive waste, and weapons proliferation. Further expansion of nuclear power could be promoted to limit CO_2 emissions or bolster energy security through diversification. On the other hand, additional restrictions on the nuclear industry, such as early plant retirements or limits on projected new installations, would raise demand for alternatives to generate electricity, such as natural gas, coal, wind, and solar.

Coal supplies the second largest share of world energy today, after oil. In forecasts where CO_2 emissions are not constrained, coal is generally expected to increase its share. Projected increases in coal use are driven mainly by growing electricity demand in developing countries. Remaining coal resources are far larger than for oil and natural gas; at current consumption rates, the United States has economically recoverable resources for at least another 100 years.[7] China also has large coal resources, although major deposits are far from consuming areas, and transportation infrastructure is limiting. In addition to the logistical challenges of rail, water, and power lines, coal combustion also produces more CO_2 per unit of energy than natural gas or oil from conventional sources. The combination of coal, natural gas, and oil is generally expected to provide over 80 percent of global energy needs in 2030, exacerbating the challenge of constraining CO_2 emissions.

III. THE CHANGING WORLD ENERGY MAP

Growth in energy production has been supported by global trade and open markets, combined with capital investment to produce and deliver energy. Energy consumption in the developing world is projected to increase dramatically, while oil and natural gas production in the United States and Europe declines. This combination will require a substantial increase in international oil and natural gas trade, profoundly redrawing the world energy map.

Forecasts for growth in oil and liquefied natural gas (LNG) shipments place greater emphasis on reliable transport, trade, and delivery systems while raising geopolitical, environmental, and security concerns. Today, more than half the world's inter-regional oil movements pass through a handful of potential "choke points," including the Suez Canal, the Bosporus, and the Straits of Hormuz and Malacca.[8]

Figure ES-6 shows one projection of significant changes in regional oil imports and exports between now and 2030. Natural gas supply and demand are projected to make similar shifts.

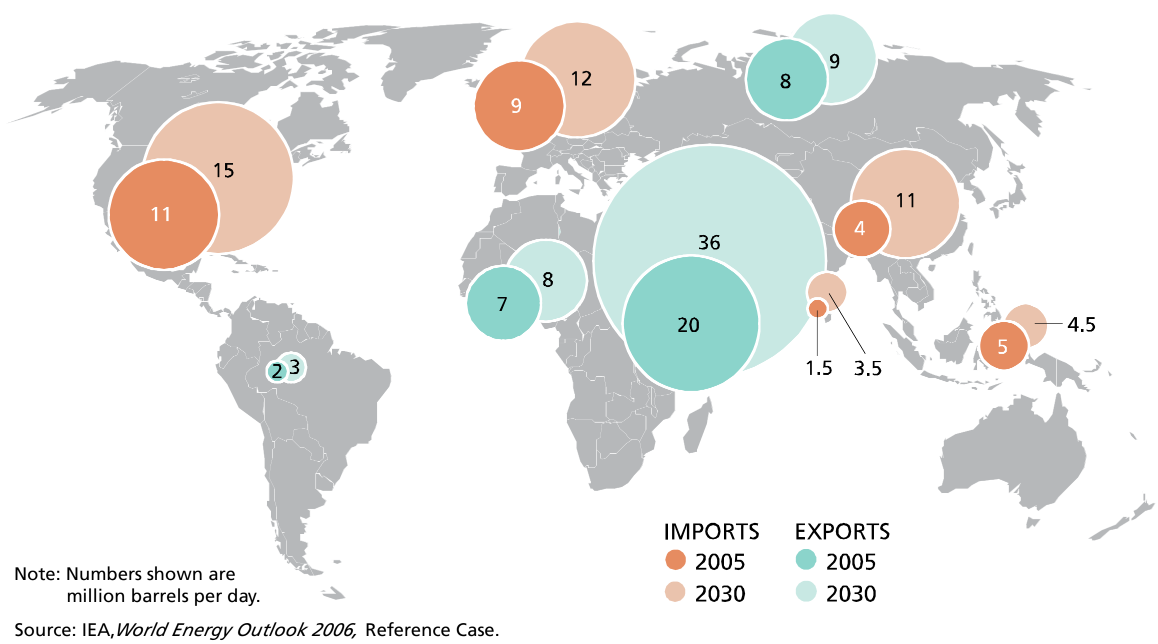


Figure ES-6. Net Regional Oil Imports and Exports

In addition to increases in the international trade of oil and natural gas, the world energy map is changing in another dimension. Conventional oil and natural gas resources are increasingly concentrated in a handful of non-OECD countries. The national oil companies and energy ministries in these countries play central roles in policy decisions about how to develop and produce their resources. Producers may increasingly leverage their assets when dealing with oil companies and consumer nations, either to gain commercial benefits or to further national or foreign policy objectives. The trend of market liberalization that expanded global energy trade and investment in the 1990s has come under renewed pressure.

IV. UNITED STATES AND GLOBAL ENERGY SECURITY

U.S. and global energy security depend upon reliable, sufficient energy supplies freely traded among nations. This dependence will rise with the growth required in international oil and natural gas trade, and may be increasingly influenced by political goals and tensions. These trends are prompting renewed concerns about U.S. energy security.

These energy security concerns have spurred calls for the United States to become totally self-sufficient in energy supply, often referred to as "energy independence." This concept is unrealistic in the foreseeable future and incompatible with broader foreign policy objectives and treaty obligations. Policies espousing "energy independence" may create considerable uncertainty among international trading partners and hinder investment in international energy supply development.[9]

It is a hard truth that energy independence is not necessary for energy security. Rather than pursuing energy independence, the United States should enhance its energy security by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. Indeed, even if the United States could become physically self-sufficient in energy, it could not disengage from global energy activity, trade, and finance. There can be no U.S. energy security without global energy security.

V. INVESTMENT IN GLOBAL ENERGY DEVELOPMENT

The projected increase in energy demand through 2030 will require massive new investments in large-scale projects to develop and deliver energy. The International Energy Agency's (IEA) *World Energy Outlook 2006* estimates that $20 trillion will be required over the next 25 years—$3,000 per person alive today. Over half of this amount is for electricity generation and distribution.

Building new, multi-billion-dollar oil platforms in water thousands of feet deep, laying pipelines in difficult terrain and across country borders, expanding refineries, constructing vessels and terminals to ship and store liquefied natural gas, building railroads to transport coal and biomass, and stringing new high-voltage transmission lines from remote wind farms—all will require large investments over decades. Higher investment in real terms will be needed to grow production capacity. Future projects are likely to be more complex and remote, resulting in higher costs per unit of energy produced.[10] A stable and attractive investment climate will be necessary to attract adequate capital for evolution and expansion of the energy infrastructure.

The United States should actively engage energy suppliers, encouraging open trade and investment to expand international energy production and infrastructure. International trade and diplomatic negotiations should routinely incorporate energy issues to promote the rule-of-law, fiscal stability, equitable access, and the environmentally responsible development of all energy resources.

VI. TECHNOLOGY ADVANCEMENTS

Human ingenuity and technological advances create the potential to develop new energy sources, to further develop existing resources, and to use energy in more efficient and environmentally friendly ways. The oil and natural gas industry has a long history of technological advancement, and today it operates using materials, chemistry, engineering, computing, and sensing techniques well beyond anything envisioned several decades ago. Technology has led to large savings in energy demand and additions to supply while reducing the industry's environmental "footprint." Technology advances are expected to continue, although broad-ranging technology impact can take over a decade from initial concept to large-scale implementation.[11]

There is no single technology capable of ensuring that the world's future energy needs will be met in an economical and environmentally responsible way. Many advances and breakthroughs will be required on numerous fronts. To do this, significant financial and human resources must be engaged over a sustained period. Meanwhile, the U.S. energy industry faces a dramatic human resource shortage that could undermine the future development of technological advances needed to meet the demand for increasingly diversified energy sources. A majority of the industry's technical workforce is nearing retirement eligibility, and the number of American graduates in engineering and geosciences has dropped substantially during the last quarter century, compromising future delivery of technology advances.

The Council's findings echo many in the National Academy of Sciences report "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," which calls for a focus on mathematics and science education, long-term basic research, and ensuring that the United States is the premier place in the world for research and technological innovation.

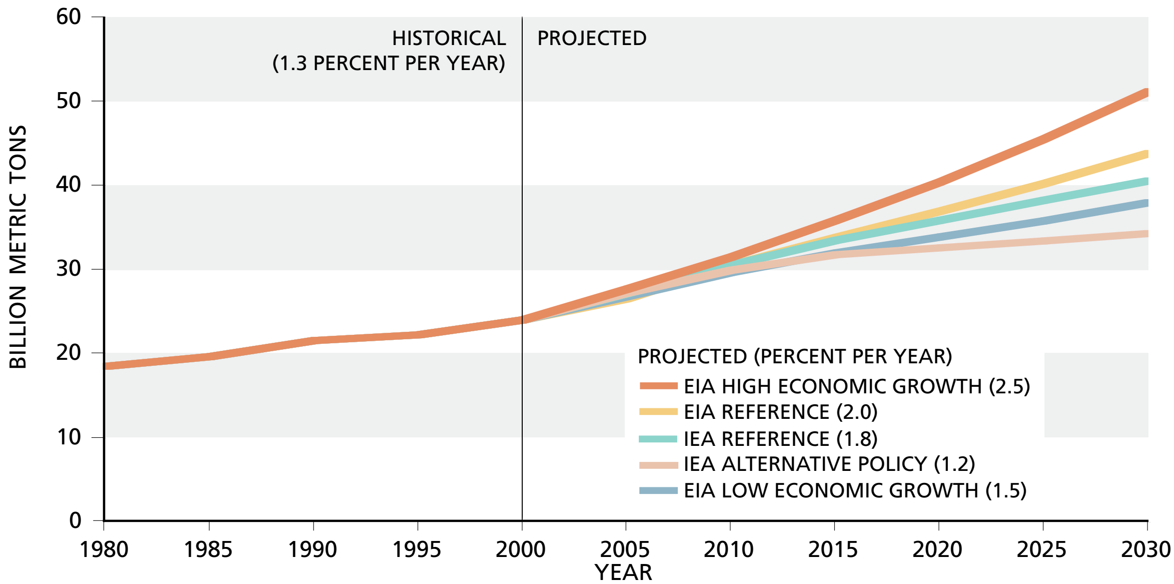
Energy Systems Scale and Timeline

The scale of the world energy system and the time required to make significant changes, both on the demand and on the supply sides, are frequently underestimated. A few examples:

- The world currently uses about 86 million barrels per day of oil—40,000 gallons every second.
- New, large oil discoveries can take 15-20 years from exploration until production actually begins, and production can continue for 50 years or more.
- A major new oil platform can cost billions and take a decade or more to complete. The Hibernia platform off the east coast of Canada cost $5 billion, took 19 years from discovery to production, and produces only 0.2 percent of world oil demand.[12] The Thunder Horse platform in the U.S. Gulf of Mexico cost $4 billion, is not yet operating eight years after discovery, and has a capacity of 0.3 percent of world oil demand.[13]
- A new average-sized U.S. refinery (120,000 barrels per day of crude oil distillation capacity) would cost $3 billion or more[14] and would increase U.S. refining capacity less than 1 percent.
- The United States has about 200,000 miles of oil[15] and about 280,000[16] miles of natural gas pipeline, built up over the last century.
- It can take over two decades for a newly commercialized technology to be broadly applied in the vehicle fleet actually on the road—examples include fuel injection and front-wheel drive.
- Buildings typically last for decades. Many of the attributes that affect energy consumption are costly and difficult to retrofit after initial installation, for example wall thickness, insulation, structural tightness, and windows.
- Commercializing new technology in the oil and gas market takes an average of 16 years to progress from concept to widespread commercial adoption.

VII. ADDRESSING CARBON CONSTRAINTS

Constraints on CO_2 emissions are emerging, with profound implications for energy supply and demand. Worldwide CO_2 emissions from energy use are generally predicted to grow, as shown in Figure ES-7. Rising concerns about climate change may lead to further limits on these emissions. It is a hard truth that policies aimed at curbing carbon emissions will alter the energy mix, increase energy-related costs, and require reductions in demand growth.



Sources: EIA: U.S. Energy Information Administration, *International Energy Outlook 2006.*
IEA: International Energy Agency, *World Energy Outlook 2006.*

Figure ES-7. World Carbon Dioxide Emissions – Growth Projections

Significantly reducing CO_2 emissions will require major changes in energy production, infrastructure, and use: reducing demand, substituting low-carbon or carbon-neutral fuels, and capturing and sequestering the emissions from burning coal, oil, and natural gas. Implementing effective changes on a sufficient scale will require time, money, and technology. It can take over two decades for newly commercialized vehicle technology to be incorporated into the vehicle fleet actually on the road. Improvements in building efficiency are made slowly—because buildings can stand for many decades, and retrofitting efficiency steps such as increased insulation and better windows can be difficult and costly. Power plants and industrial facilities often last fifty years or more, limiting the rate of capital turnover in these sectors. Achieving any significant increase in efficiency, shift in fuels used, and capture of CO_2 emissions for storage will require major changes over decades to vehicles, buildings, industrial plants, electric generation facilities, and infrastructure.

VIII. STRATEGIES FOR U.S. ENERGY POLICY

No single, easy solution can solve the world's energy challenges. The world will need all the economic, environmentally responsible energy sources that can be found to support and sustain prosperity in the coming decades. To assure this, actions on multiple fronts must be taken now and sustained over the long term. The NPC study participants developed recommendations to achieve the following five strategic goals:

- Moderate demand by increasing energy efficiency
- Expand and diversify U.S. energy supply
- Strengthen global and U.S. energy security
- Reinforce capabilities to meet new challenges
- Address carbon constraints.

While the focus of this report has been concentrated on identifying key findings and relevant and effective recommendations, it is prudent to be mindful of the lessons of the past. The prospect of unintended consequences or the adverse impacts of poor policy choices should not be underestimated.[17] Policies aimed at penalizing industry segments may have political appeal but often undermine security goals and broader national objectives.

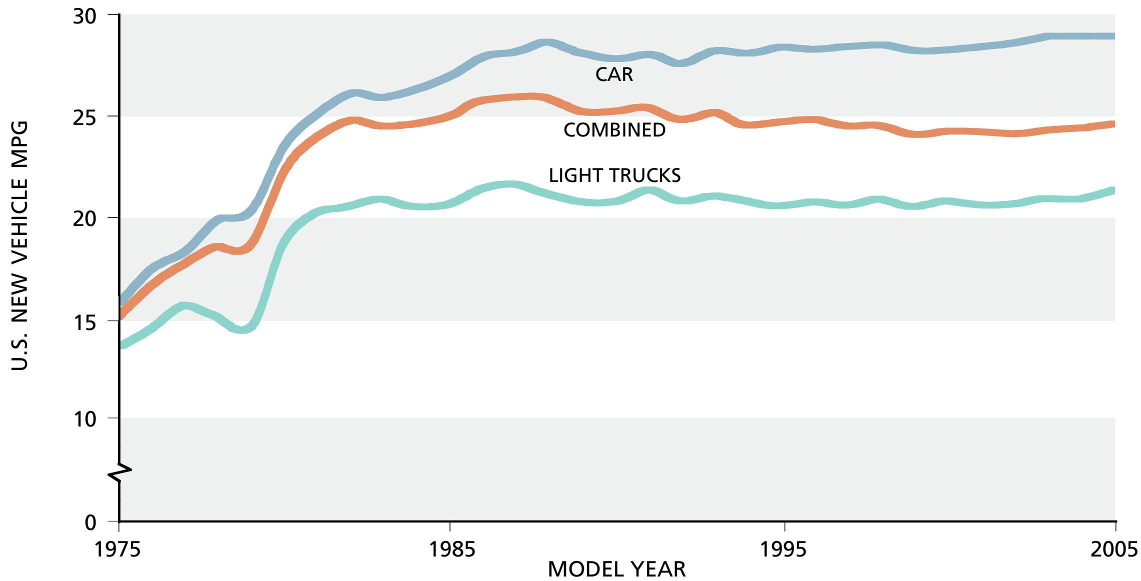
A. Moderate Demand by Increasing Energy Efficiency

1. Improve Vehicle Fuel Economy

Nearly half of the 21 million barrels of oil products that the United States consumes each day is gasoline used for cars and light-trucks. The Reference Case in the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2007* projects that gasoline consumption will increase by an average of 1.3 percent per year, totaling an increase of 3 million barrels per day between 2005 and 2030.

The Corporate Average Fuel Economy (CAFE) standards have been the primary policy used to promote improved car and light-truck fuel economy in the United States over the last three decades. The original standards created one economy requirement for cars, and another less stringent one for light-trucks to avoid penalizing users of work trucks. At the time, light-truck sales were about one-quarter of car sales. Since then, sport utility vehicles and minivans classified as light-trucks have increased their share of the market. Now, these light-truck sales exceed car sales, and the increase at the lower truck fuel economy standard has limited overall fuel economy improvement.

Cars and trucks sold today are more technically efficient than those sold two decades ago. However, the fuel economy improvements that could have been gained from this technology over the last two decades have been used to increase vehicle weight, horsepower, and to add amenities. Consequently, car and truck fuel economy levels have been about flat for two decades, as shown in Figure ES-8.



Source: U.S. EPA, *Light Duty Automotive Technology and Fuel Economy Trends: 1975 through 2006.*

Figure ES-8. U.S. Car and Light-Truck Fuel Economy

Based on a detailed review of technological potential, a doubling of fuel economy of new cars and light-trucks by 2030 is possible through the use of existing and anticipated technologies, assuming vehicle performance and other attributes remain the same as today.[18] This economy improvement will entail higher vehicle cost. The 4 percent annual gain in CAFE standards starting in 2010 that President George W. Bush suggested in his 2007 State of the Union speech is not inconsistent with a potential doubling of fuel economy for new light duty vehicles by 2030. Depending upon how quickly new vehicle improvements are incorporated in the on-road light duty vehicle fleet, U.S. oil demand would be reduced by about 3-5 million barrels per day in 2030.[19] Additional fuel economy improvements would be possible by reducing vehicle weight, horsepower, and amenities, or by developing more expensive, step-out technologies.

The NPC makes the following recommendations to increase vehicle fuel economy:

- Improve car and light-truck fuel economy standards at the maximum rate possible by applying economic, available technology.
  - Update the standards on a regular basis.
  - Avoid further erosion of fuel economy standards resulting from increased sales of light-trucks, or, alternatively, adjust light-truck standards to reflect changes in relative light-truck and car market shares.

Potential Effect: 3-5 million barrels of oil per day in the United States from the increased base in 2030.

2. Reduce Energy Consumption in the Residential and Commercial Sectors

Forty percent of U.S. energy is consumed in the residential and commercial sectors, including the energy lost while generating and distributing the electricity used. The EIA projects that U.S. residential and commercial energy use will increase almost one-third by 2030.

Significant efficiency improvements have been made in buildings over the last several decades. Improvement areas include the building structure itself; heating, cooling, and lighting systems; and appliances. However, these improvements have been partly offset by increased building sizes and by use of larger and multiple appliances. Cost-effective energy efficiency building technologies have outpaced current U.S. federal, state, and local policies. If applied, currently available efficiency technology would reduce energy use an additional 15-20 percent.[20]

Buildings typically last for decades. Many of the features of buildings that affect their energy consumption, such as wall thickness, insulation, structural tightness, and windows, will go largely unchanged throughout the life of the building. Technologies and practices affecting these long-lived systems will be slow to penetrate the building stock and affect their overall efficiency, making it important to implement policies early to achieve significant long-term savings.

Major barriers to energy efficiency investments include initial costs, insufficient energy price signals, split incentives—where the consumer is different from the facility provider, and individual consumer's limited information. To reduce energy consumption significantly below the projected baseline will require policy-driven improvements in energy efficiency.

a. Building Energy Codes

Building energy codes have proved to be a significant policy tool to encourage increased energy efficiency in new buildings, and in buildings undergoing major renovations. Building codes are administered by the 50 states and by thousands of local authorities. To help state and local governments, national model energy codes are developed and updated every few years. Under federal law, states are not obligated to impose energy codes for buildings, although at least 41 states have adopted some form of building energy code.

Adopting a building code does not guarantee energy savings. Code enforcement and compliance are also essential. Some jurisdictions have reported that one-third or more of new buildings do not comply with critical energy code requirements for windows and air conditioning equipment, which are among the easiest energy saving features to verify.[21]

Building energy codes typically target only new buildings and major renovations. Additional policies are needed to encourage incremental, significant savings in existing buildings.

b. Appliance and Equipment Standards

Standards for appliances and other equipment are major policy measures that reduce energy use in existing buildings. These products may not consume much energy individually, but collectively they represent a significant portion of the nation's energy use.[22]

Energy efficiency standards currently do not apply to many increasingly common products, including those based on expanded digital technologies. Product coverage must be continuously evaluated and expanded when appropriate to assure inclusion of all significant energy consuming devices. In addition, industry and other stakeholders have negotiated standards for other products, such as residential furnaces and boilers. Implementing and enforcing expanded and strengthened standards would reduce energy consumption below the levels that will result from current Department of Energy requirements.[23]

Residential and commercial efficiency gains are partially consumed by increased use of the services and products that become more efficient. For example, U.S. house sizes have increased steadily over the years, offsetting much of the energy efficiency improvements that would have resulted had house sizes not swelled. Similarly, household refrigerators have increased in number and size, consuming much of the reduced energy use per refrigerator gained by efficiency standards. Energy efficiency programs should consider steps to avoid increasing the demand for energy services.

The NPC makes the following recommendations to improve efficiency in the residential and commercial sectors:

- Encourage states to implement and enforce more aggressive energy efficiency building codes, updated on a regular basis.
- Establish appliance standards for new products.
- Update federal appliance standards on a regular basis.

Potential Effect: 7-9 quadrillion Btu per year by 2030 in the United States, including 2-3 quadrillion Btu per year of natural gas (5-8 billion cubic feet per day), 4-5 quadrillion Btu per year of coal, and ~1 quadrillion Btu per year (0.5 million barrels per day) of oil.

3. Increase Industrial Sector Efficiency

The industrial sector consumes about one-third of U.S. energy, and contributes to a large share of the projected growth in both oil and natural gas use globally and in the United States. Worldwide, industrial demand for natural gas is expected to double by 2030. Worldwide, industrial sector demand for oil is expected to increase by 5 million barrels per day, or 15 percent of total oil demand growth through 2030.

The industrial sector is a price-responsive energy consumer. U.S. energy-intensive industries and manufacturers rely on internationally competitive energy supplies to remain globally competitive. In recent years, U.S. natural gas prices have risen faster than those in the rest of the world. As a result, U.S. energy-intensive manufacturers using natural gas as a fuel or feedstock have responded by increasing the efficiency of their operations and/or by shifting more of their operations to lower energy cost regions outside the United States.

Across the industrial sector, there are opportunities to increase energy efficiency by about 15 percent.[24] Areas for energy savings include waste-heat recovery, separation processes, and combined heat and power.[25] While 40 percent of that opportunity could be implemented now, further research, development, demonstration, and deployment are required before the remaining savings can be achieved. Providing programs that encourage deployment of energy efficiency technologies and practices will hasten their implementation. Making the federal research and development tax credit permanent is one way to encourage private investment in these areas. However, a lack of technically trained workers can impede the implementation of efficiency projects while the uncertainty from price volatility can make justifying those projects difficult.

The NPC makes the following recommendations to improve efficiency in the industrial sector:

- The Department of Energy should conduct and promote research, development, demonstration, and deployment of industrial energy efficiency technologies and best practices.
- The research and development tax credit should be permanently extended to spur private research and development investments.

Potential Effect: 4-7 quadrillion Btu per year by 2030 in the United States, about equal parts coal, gas, and oil.

Generation of electricity uses a significant amount of energy. In the United States, about 30 percent of primary energy is used by the electric power generating sector. Only modest generation efficiency improvements appear economically feasible in existing plants (2 to 6 percent), as efficiency improvements are incorporated during routine maintenance. The major potential for efficiency improvement comes when existing generation plants are replaced with facilities using updated technology and designs. Retirement of existing facilities and selection of replacement technology and design is driven by economics affected by fuel cost, plant reliability, and electricity dispatching considerations.

B. Expand and Diversify U.S. Energy Supply

Oil, natural gas, and coal—the fossil fuels used for transportation, heating, power, and industrial uses—are by far the largest energy sources in industrial economies. While alternative sources, particularly fuel from biomass and other renewables, are likely to contribute increasingly to total energy supply, these three fossil fuels are projected to dominate through at least 2030.

The prospects for oil and natural gas production raise complex questions. It is a hard truth that the global supply of oil and natural gas from the conventional sources relied upon historically is unlikely to meet projected 50-60 percent growth in demand over the next 25 years. There are accumulating risks to replacing current production and increasing supplies of conventional oil and natural gas. They involve a growing set of global uncertainties ranging from production capabilities through environmental constraints, infrastructure needs, and geopolitical complications.

While risks have always typified the energy business, they are now accumulating and converging in new ways. Geopolitical changes coincide with increasingly large and complex technical challenges. Environmental concerns that limit access to some U.S. resources may compete with security concerns that would promote expanded access. Carbon issues challenge coal use while energy security considerations may encourage it. Carbon constraints would require huge capital investments to maintain energy production. These uncertainties, and the risks they generate, describe the background for understanding energy supply prospects during the next few decades.

Endowment and recoverable resources are fundamental concepts in any discussion of fossil fuel supplies. *Endowment* refers to the earth's physical store of potential energy sources: barrels of oil, cubic feet of natural gas, and tons of coal. The endowment of fossil fuels is fixed: it can be depleted but not replenished. *Recoverable resources* are a subset of the endowment—the portion that can be produced and converted to fuel and power.

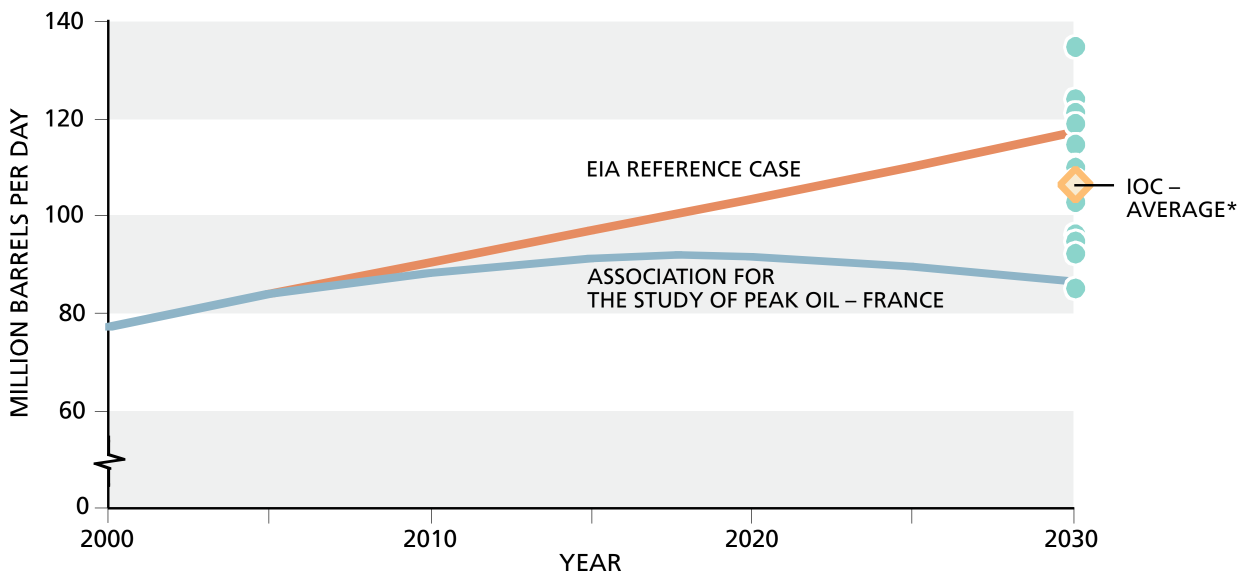
The total global fossil endowment estimates appear huge, but only a fraction of these estimated volumes can be technically produced. The total endowment of oil is estimated at 13-15 trillion barrels, natural gas at 50 quadrillion cubic feet, and coal at 14 trillion tons.

Renewable resources such as biomass, wind, and solar represent huge additional energy endowments that are continuously replenished, unlike fossil fuels.

1. Understanding the Range of Production Forecasts

This study examined a comprehensive range of oil production forecasts including integrated supply/demand studies from EIA and IEA; publicly available projections from a diverse range of other sources; and a unique set of aggregated proprietary forecasts from international oil companies (IOCs) and energy consulting groups. The diversity of this range of projections is shown in Figure ES-9, which highlights the EIA reference, the Association for the Study of Peak Oil (ASPO) France, and the average of the IOC forecasts for 2030. The distribution of production forecasts, spanning a range from less than 80 million to more than 120 million barrels per day, highlights the effect of assigning different levels of risk and uncertainty to both resource and above-ground factors. This distribution of outcomes, along with evaluation of assessments of the total resource base, indicates that the key consideration for energy supplies is not endowment but "producibility." Over the next 25 years, risks above ground—geopolitical, technical, and infrastructure—are more likely to affect oil and natural gas production rates than are limitations of the below-ground endowment. This range of outcomes emphasizes the need for proactive strategies to manage the accumulating risks to liquids delivery in 2030.

Explanations for the variance in projections for both conventional oil and natural gas production are widely discussed as part of the "peak oil" debate. As a result, this study sees the need for a new assessment of the global oil and natural gas endowment and resources to provide more current data for the continuing debate.



* Average of aggregated proprietary forecasts from international oil companies (IOC) responding to NPC survey. See Chapter Two (Energy Supply), Analysis of Energy Outlooks, GlobalTotal Liquids Production, for identification of other aggregations and outlooks shown here.
Source: EIA, *International Energy Outlook 2006*, and NPC survey.

Figure ES-9. Understanding the Range of Global Oil Forecasts

The Peak Oil Debate

Concerns about the reliability of production forecasts and estimates of recoverable oil resources raise questions about future oil supply and deliverability. These concerns are strongly expressed in "peak oil" forecasts in which (1) oil production does not grow significantly beyond current levels and (2) an inevitable decline in oil production is increasingly near at hand. Views about oil supply tend to diverge after 2015, with peak oil forecasts providing the lower bound. These forecasts generally consider oil supply independently of demand and point to supply shortfalls. Such views contrast with forecasts and economic models that expect market forces to provide incentives for developing global hydrocarbon and other resources to meet energy needs through at least 2030.

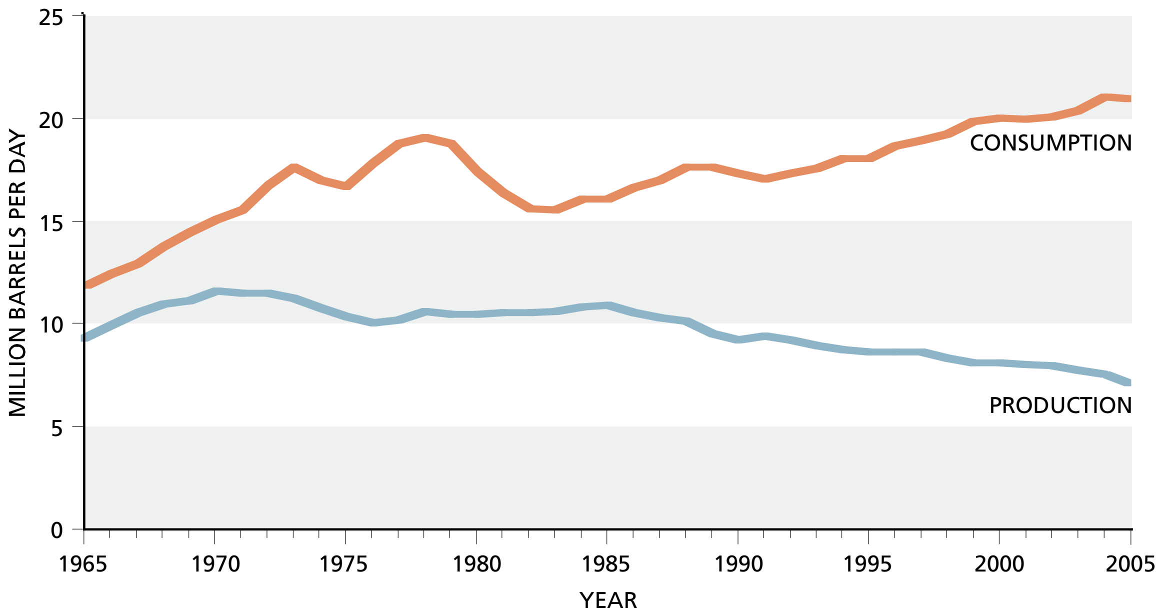
Forecasts that see an imminent peak in oil production use several indicators to support their case, including: historical peaks in production for individual countries; extrapolations of the production cycle from individual wells to fields, basins, and the world; and the historical dominance of large reservoirs in supplying the world's oil. These historical indicators for production of conventional oil are countered by expectations for new discoveries, enhanced recovery techniques, advancing technology for producing oil from unconventional sources, and reassessments and revisions of known resources. The economic and investment climate, as well as access to resources, will also affect the production base.

For further discussion of peak oil forecasts and related issues, please see Chapter 2, "Energy Supply," in this report.

2. Reduce Declines in U.S. Conventional Oil and Natural Gas Production

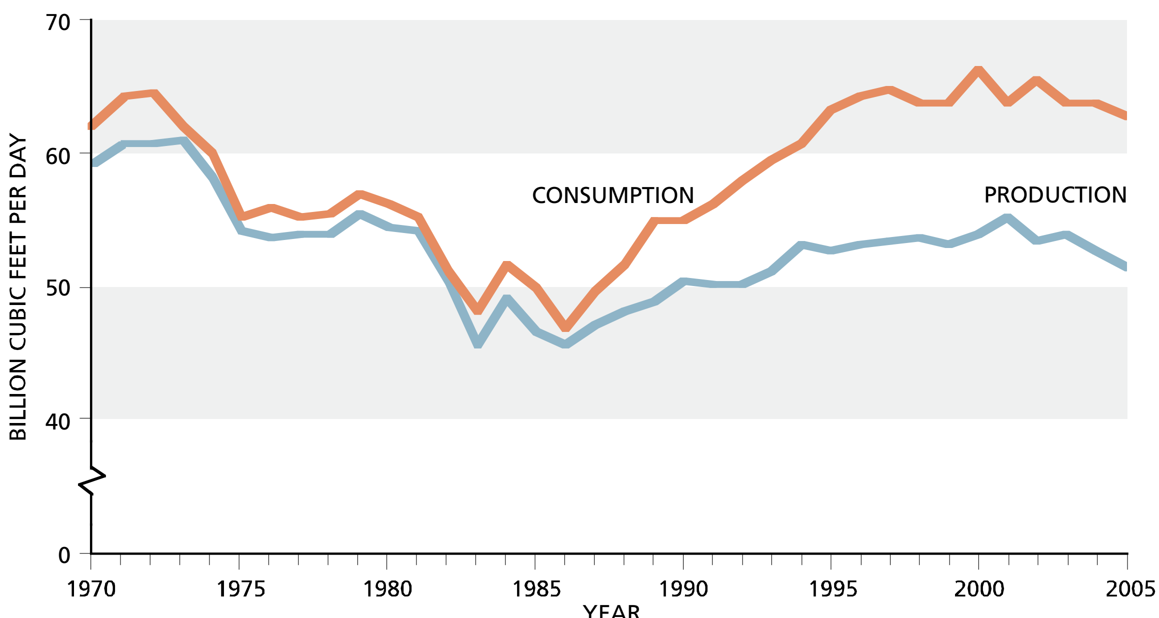
The United States was once the largest oil producer in the world, but is now the third largest daily producer, after Russia and Saudi Arabia. U.S. oil production has declined steadily over the past 35 years, as shown by Figure ES-10. U.S. natural gas production has been more stable, as shown by Figure ES-11, but demand for both oil and natural gas has increased steadily, creating a gap that is filled by imports. Many forecasts project that the gap between supply and demand for domestic oil and natural gas will widen over the next 25 years and beyond. Historically, technology advances have increased the recovery from existing wells and reservoirs. Technology such as enhanced oil recovery (EOR) has the potential to improve recovery factors and reduce declining production.[26]

In 2005, over 17 percent of oil and 9 percent of natural gas produced onshore in the United States came from marginal oil wells. The nation has more than 400,000 marginal oil wells[27] each producing on average 2.2 barrels per day. Without these wells, U.S. imports would increase by nearly 7 percent to make up for the shortage. Increasing operational and regulatory costs, and diminishing access to markets via pipelines, are all key factors that can contribute to the premature abandonment of marginal wells. When wells and fields are prematurely abandoned, the associated oil and gas resources may never be recovered due to economics, lease termination and related issues. Access to existing fields provides the opportunity to deploy new technologies to enhance the ultimate recovery of oil and natural gas from these fields.



Source: *BP Statistical Review of Energy 2006.*

Figure ES-10. U.S. Oil Production and Consumption



Source: *BP Statistical Review of Energy 2006.*

Figure ES-11. U.S. Natural Gas Production and Consumption

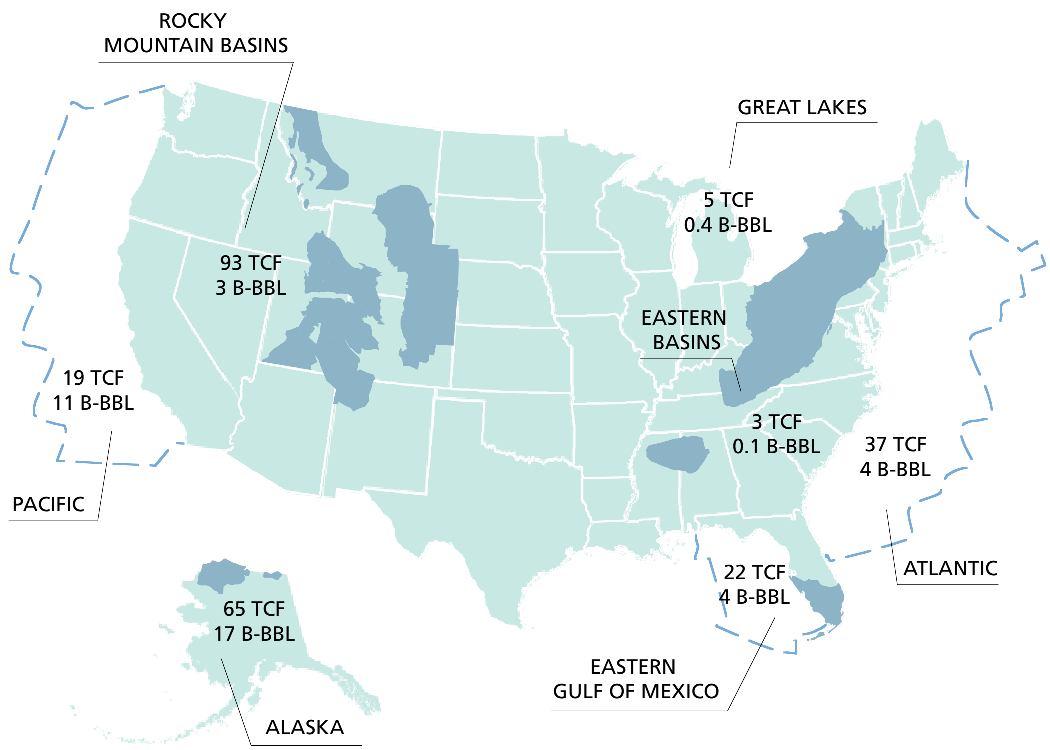
The NPC makes the following recommendations to promote enhanced oil recovery (EOR) from existing reservoirs:

- Support regulatory streamlining and research and development programs for marginal wells.
- Expedite permitting of EOR projects, pipelines, and associated infrastructure.

Potential Effect: An additional 90 to 200 billion barrels of recoverable oil in the United States alone, which could help slow the current decline in production

3. Increase Access for New Energy Development

For various reasons, access to some domestic energy resources has become restricted. In the United States, an estimated 40 billion barrels of technically recoverable oil resources are either completely off-limits or are subject to significant lease restrictions. These resources are evenly split between onshore and offshore locations, as shown in Figure ES-12. Similar restrictions apply to more than 250 trillion cubic feet of natural gas. Another estimated 11 billion barrels of oil resources and 51 trillion cubic feet of natural gas resources are restricted in Canada. Advancements in technology and operating practices may now be able to alleviate the environmental concerns that originally contributed to some of these access restrictions.



Note: TCF = Trillion Cubic Feet; B-BBL = Billion Barrels.
Source: U.S. Department of the Interior.

Figure ES-12. U.S. Oil and Natural Gas Resources Affected by Access Restrictions

The NPC makes the following recommendations to expand access to the most favorable U.S. oil and natural gas basins:

- Conduct national and regional basin-oriented resource and market assessments to identify opportunities for increasing oil and natural gas supply.
- Use technology and operational advancements to allow environmentally responsible development of high potential onshore and offshore areas currently restricted by moratoria or access limitations.

Potential Effect: Material increases to current reserves within 5 to 10 years from currently inaccessible areas could approach 40 billion barrels of oil and 250 trillion cubic feet of natural gas with current technology.

There is vast potential for oil and natural gas from "unconventional" resources that could be significant contributors to U.S. oil and natural gas production over the next 25 years. Unconventional natural gas exists in formations of "tight" or physically constrained deposits, in coalbeds, and in shale formations. This represents a significant and growing segment of U.S. natural gas production, estimated to be 20-25 percent of current U.S. natural gas production. Typically, unconventional natural gas wells are productive longer than conventional wells, and they can contribute to sustaining supply over a longer period. Similarly, there are large deposits of crude oil in unconventional formations where production is currently increasing with recent technology innovations.

Vast hydrocarbon deposits exist in the oil shales in the Rocky Mountain region of the United States. Until recently, technology has been unavailable to produce these oil shale deposits at a competitive cost and with acceptable environmental impact. Research, development, and demonstration programs are increasing to advance the technologies required to expand economically and environmentally sustainable resource production. However, successful production at scale may still be several decades away.

The NPC makes the following recommendations to increase unconventional oil and natural gas production:

- Accelerate U.S. oil shale and oil sands research and development and leasing.
- Accelerate U.S. unconventional natural gas leasing and development.

Potential Effect: Double U.S. unconventional natural gas production to more than 10 billion cubic feet per day, increasing total U.S. natural gas production by about 10 percent.

Implementing these strategies can slow the inevitable decline in U.S. oil and natural gas production, but is unlikely to reverse it. The gap between U.S. production and demand will continue to widen, particularly for oil. Long lead-times and higher capital requirements to develop economical energy from new or remote locales, and from unconventional oil and natural gas resources, all contribute to the challenge of moderating the U.S. production decline.

4. Diversify Long-Term Energy Production

a. Accelerate the Development of Energy from Biomass

As total U.S. energy demand grows, there will be an increasing need to supplement energy supplies with diversified domestic energy sources that are economically and environmentally viable and can be developed at commercial scale. Coal and nuclear power already play a significant role, and biomass is emerging as an option, primarily for conversion to transportation fuels. Wind and solar energy are forecast to grow faster than overall energy demand, although their total projected contribution will remain small over this study period. Taken together, all these energy sources can contribute to reducing risks posed to energy supply security.

Biomass includes wood, cultivated crops, and naturally growing vegetation that potentially can be converted to energy sources. First-generation biomass conversion to fuels has been based on crops like corn, sugarcane, soybeans, and palm oil. Developing second-generation biomass conversion technologies, such as cellulosic ethanol, which would use trees, energy crops, and plant waste as a feedstock, could allow non-food vegetation to become a significant resource for fuel production.

As with any newly developed energy sources, certain technical, logistical, and market requirements must be met for biofuels to achieve significant scale. Challenges include: expanding rail, waterway and pipeline transportation; scaling up ethanol production plants and distribution systems; developing successful cellulosic ethanol conversion technology; and maximizing the potential of arable land.

The NPC makes the following recommendations to accelerate development of biomass energy sources at large commercial scale:

- Support research into second-generation biofuel crops that have lower input requirements or are suited to more marginal lands.
- Promote agricultural policies that enhance global production of both food crops and biomass for fuel.
- Support policies that promote the development of the infrastructure for harvesting, storing, and transporting energy crops, and facilitate the integration of biofuels into the national transportation fuel supply.

Potential Effect: Increase U.S. production by up to 4 million barrels per day of oil-equivalent liquids.[29]

b. Enable the Long-Term Environmental Viability of Coal for Power, Fuel, and Feedstock

Given the vast coal resource base in the United States—by some estimates, the world's largest—and the major contribution that coal makes to electricity generation today, coal needs to remain a viable long-term component of U.S. energy supply. Many studies forecast growth in coal use for power, plus additional growth for direct conversion of coal to liquids to diversify the fuel supply. However, coal combustion is also the largest source of CO_2 emissions from energy production. Adding coal-to-liquids production at scale, as with conversion of most heavy unconventional hydrocarbons, would generate large additional CO_2 volumes. Therefore, addressing carbon constraints at scale will likely be an essential requirement for retaining coal as a viable part of the energy supply system. Recommendations for maintaining coal's long-term viability are discussed specifically in the section entitled "Address Carbon Constraints" later in this Executive Summary.

c. Expand Domestic Nuclear Capability

Energy projections generally show a continuing role for nuclear energy, notwithstanding concerns about safety, security, radioactive waste, and weapons proliferation. In a carbon constrained environment, nuclear energy may need to become a much larger part of the energy mix. Nuclear energy must remain viable over the 25 years considered in this study—both to meet projected demand and to provide expanded capacity, if necessary, to reduce CO_2 emissions.

The NPC makes the following recommendations to expand the domestic technical and industrial capabilities of the nuclear energy/power industry:

- Implement the recommendation by the National Commission on Energy Policy[30] to provide $2 billion over ten years from federal energy research, development, demonstration, and deployment budgets for demonstration of one to two new advanced nuclear facilities.
- Fulfill existing federal commitments on nuclear waste management.

Potential Effect: Reestablish U.S. leadership capability. Maintaining a viable nuclear energy option will increase policy choices in future carbon constrained circumstances.

C. Strengthen Global and U.S. Energy Security

Besides expanding U.S. oil and natural gas production and developing additional domestic energy types at commercial scale, it will be necessary to enlarge and diversify oil and natural gas supplies from global markets. The long lead-times needed to build domestic energy alternatives at commercial scale will require the United States to remain engaged in international energy markets beyond the time frame considered in this study. Moreover, oil and natural gas supplies from major resource-holding countries often bear lower production and development costs than do U.S. domestic sources. Maintaining U.S. access to these sources will contribute to an affordable U.S. energy supply and promote U.S. competitiveness in the global marketplace.

The world is entering a period in which international energy development and trade are likely to be influenced more by geopolitical considerations and less by the free play of open markets and traditional commercial interactions among international energy companies. Global competition for oil and natural gas will likely intensify as demand grows, as new parties enter the market, as some suppliers seek to exploit their resources for political ends, and as consumers explore new ways to guarantee their sources of supply.

These shifts pose profound implications for U.S. interests, strategies, and policy making as well as for the ways that energy companies conduct business. Many of the expected changes could heighten risks to U.S. energy security in a world where U.S. influence is likely to decline as economic power shifts to other nations. In years to come, security threats to the world's main sources of oil and natural gas may worsen.

In geoeconomic terms, the biggest impact will come from increasing demand for oil and natural gas from developing countries. This demand may outpace timely development of new supply sources, thereby pressuring prices to rise. In geopolitical terms, the consequences of shifting the balance between developed and developing countries will be magnified by the accelerating demand coming most strongly from China, India, and other emerging economies.

These developments are taking place against a background of rising hostility to globalization in large parts of the world, including in many industrialized countries that benefit from it. This hostility could possibly fracture the global trading system. The political will to complete multilateral trade negotiations may be ebbing as major producers and consumers seek bilateral or regional preferential agreements that can fragment world trade, increase costs, and diminish market efficiency.

The NPC makes the following recommendations to promote global and U.S. energy security:

- Integrate energy policy into trade, economic, environmental, security, and foreign policies by having the Department of Energy share an equal role with the Departments of Defense, State, Treasury, and Commerce on policy issues relating to energy and energy security.
- Continue to develop the international energy marketplace by expanding the energy dialogue with major consuming and producing nations, including China, India, Canada, Mexico, Russia, and Saudi Arabia.
- Promote an effective global energy marketplace by sustaining and intensifying efforts to encourage global adoption of transparent, market-based approaches to energy through multilateral and international institutions—including the World Trade Organization, G8, Asia-Pacific Economic Cooperation (APEC), IEA, International Energy Forum, and the Joint Oil Data Initiative (JODI).
- Assist and encourage global adoption of energy efficiency technologies through technology transfer programs and lend-lease arrangements.

Potential Effect: Restricted resource access and curtailed production could put potential 2030 global liquid (25-35+ million barrels per day) and gas (150-200+ billion cubic feet per day) incremental growth at risk.

Energy Security and Strategic Petroleum Stocks

This study examined the long-term energy future and focused on fundamental supply and demand, since a robust supply/demand balance is necessary for global energy security. In the short term, there is another aspect to energy security—the availability of strategic stocks to respond to a short-term disruption in supplies.

Following the oil supply shocks of 1973-74, the OECD countries agreed to maintain strategic petroleum stocks and created the International Energy Agency to coordinate measures in times of oil supply emergencies. Today, OECD countries are committed to individually hold oil stocks equal to 90 days of their imports.

This strategic stockholding proved its worth in the aftermath of Hurricanes Katrina and Rita in the U.S. Gulf of Mexico in the fall of 2005. At one point, the hurricanes shut down all Gulf Coast crude oil production and nearly 30 percent of U.S. refining capacity. The IEA coordinated a release of oil from stockpiles worldwide, and the global market quickly rebalanced, with the United States receiving petroleum product supplies from around the world including Europe and Japan.

In total, the OECD countries currently hold about 1.4 billion barrels of strategic oil stocks. The U.S. Strategic Petroleum Reserve (SPR) alone holds nearly 700 million barrels of crude oil today. To put the U.S. SPR in perspective, its volume currently represents sixteen months of United States oil imports from Venezuela.

The total OECD strategic stockpile volume represents almost 19 months of the entire volume of Iranian crude oil exports[31] (none of which are currently imported into the United States).

D. Reinforce Capabilities to Meet New Challenges

To meet the world's growing energy needs, critical capabilities for delivering energy supplies will need to be improved. These critical capabilities include:

- Assessing future infrastructure requirements
- Developing human resources
- Encouraging technology advancement
- Enhancing the quality of energy data and information, including expanding knowledge of resource endowments.

1. Develop a Comprehensive Forecast of U.S. Infrastructure Requirements

Transportation infrastructure plays a vital role in delivering energy and other commodities from resource locations to shipping centers, to manufacturing plants for processing, and ultimately to demand centers for consumption. The transportation system as a whole is an immense network of pipelines, railways, waterways, ports, terminals, and roadways that has evolved over the past two centuries. The system today is a highly complex, robust delivery network that operates in a safe, reliable manner and serves as the foundation for the country's economic activity.

Shipments of goods have increased substantially using all modes of transport. The spare capacity and redundancies in the various infrastructure systems that existed 25 to 30 years ago have diminished. Continuing growth will require additions to infrastructure.

New infrastructure investments will also be required as nontraditional energy sources grow. Infrastructure requirements for many alternative energy sources, such as biofuels and unconventional oil and natural gas, will be significant and yet are often underestimated. The potential scale of CCS activities would also require significant new infrastructure.

Energy supply and demand projections to 2030 generally assume infrastructure will be built if it is economic to do so. These forecasts generally assume no constraints on the ability to finance, permit, and build the infrastructure required to supply increasing kinds and amounts of energy. In practice, however, social, environmental, and land-use constraints do affect infrastructure planning and development. Complex permitting processes lengthen the time and cost of infrastructure construction and maintenance or may entirely preclude the infrastructure needed for certain energy options. Additional information is needed to understand the full requirements for energy infrastructure additions and the potential limitations to timely investment.

The NPC makes the following recommendations to improve understanding of infrastructure needs to meet future U.S. energy system growth:

- The Department of Energy (DOE) should develop an integrated study of the energy infrastructure needs to 2030.
- The EIA should incorporate infrastructure-related data into its energy information collection system.

2. Rebuild U.S. Science and Engineering Capabilities

As the post-World-War-II baby-boom generation begins to retire, the energy industry faces a severe human resource challenge. Nearly half of personnel in the U.S. energy industries will be eligible for retirement within the next 10 years, and fewer people have entered the workforce over the past generation. A "demographic cliff" is looming in all areas of energy industry employment.[32] A hard truth is that the U.S. energy workforce must be replenished and trained, although too few young people are preparing for the opportunities.

An American Petroleum Institute survey in 2004 indicated that by 2009 there will be a 38-percent shortage of engineers and geoscientists and a 28-percent shortage of instrumentation and electrical workers in the U.S. oil and gas industry. Statistics for other science, engineering and technology professions specifically within the energy industry are not available, but the problem extends to those areas as well. One of the more important predictors for the future supply of potential employees in oil and natural gas is the number of students earning university degrees in petroleum engineering and geosciences. Enrollment in these petrotechnical programs has dropped about 75 percent over the last quarter century.

The United States has traditionally been a leader in the global energy industry, but that position is threatened by the anticipated loss of experience through retirements, without adequate replacements. The U.S. government and the energy industry should work actively to renew this vital workforce through education, recruitment, development, and retention—much as companies strive to develop and renew energy supplies.

Federal and state governments can play an important role by funding university research and development in science and technology. Consistent support for university research programs relating to the energy industry will signal prospective students that these subjects are vital to the country. For example, several universities have recently increased petrotechnical enrollment by active recruiting aimed at high school seniors, their parents, and their counselors. These results indicate that vigorous recruiting can yield positive results, but efforts need to be more widespread.

The NPC makes the following recommendation to enhance U.S. science and technical education programs:

- Provide support to those seeking engineering and other technical degrees, both undergraduate and graduate, by increasing scholarships and research funding at universities and support for technical schools.

There is insufficient time to train enough young professionals to fill the positions opening over the next decade. Accelerating competencies through knowledge sharing, coaching, and mentoring will become critical. Many retirees might prefer to phase-in retirement, but face regulatory barriers that restrict their part-time work. These individuals' expertise should be harnessed to prepare the next generation in both professional and vocational training programs.

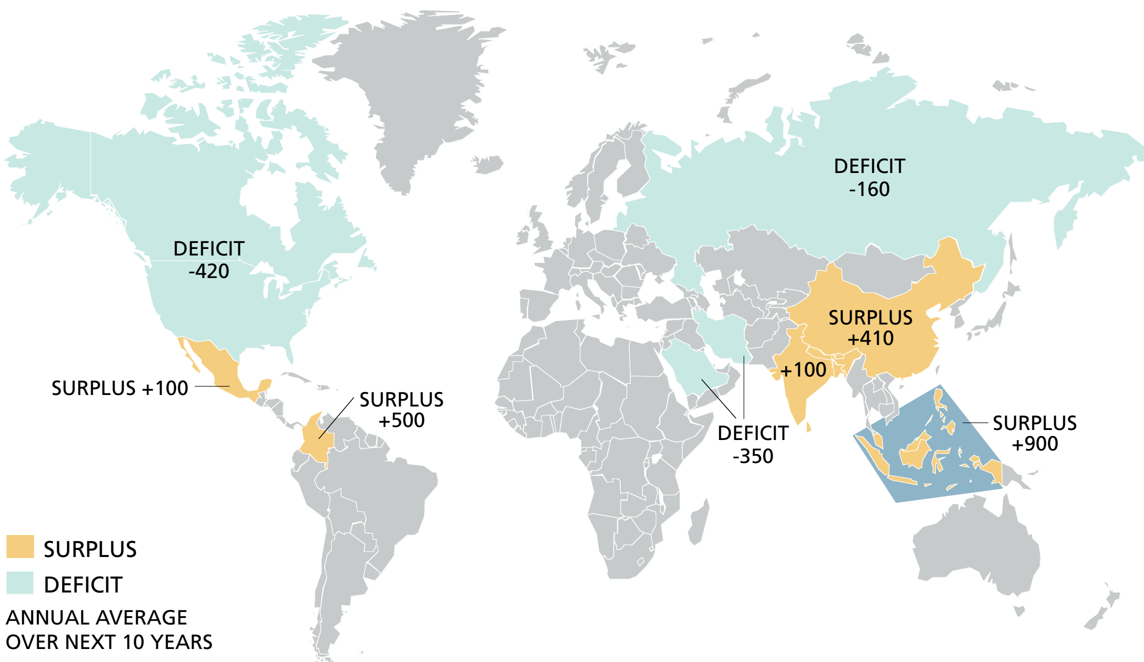
The NPC makes the following recommendation to make it easier for retirees to continue working as consultants, teachers, and coaches:

- Modify the U.S. tax code and retirement plan regulations to allow part-time work after retirement without penalty.

Across continents, there is a geographical disparity in the supply of new graduates for some energy related fields (Figure ES-13). Over the next ten years, the number of foreign nationals allowed to work in the United States will be restricted by the number of work permits issued each year. Increasing the quotas on work and study permits can help alleviate this geographical imbalance, and support U.S. energy productivity.

The NPC makes the following recommendation to increase the supply of trained energy professionals in the United States:

- Increase student and immigration quotas for trained professionals in energy and technical fields.



Source: Schlumberger Business Consulting study, 2005.

Figure ES-13. The Regional Imbalance of Petrotechnical Graduates

3. Create Research and Development Opportunities

The oil and natural gas industry uses advanced, state-of-the-art technology. Exploration specialists interpret geologic structures miles beneath the earth's surface. Drilling engineers access the resources found at extreme depths, at high temperature and pressure, and often in remote and physically challenging places. Production engineers bring the oil and natural gas to the surface through miles of pipeline, also under sometimes extreme conditions, and deliver them to refineries. Once there, increasingly heavy and sulfurous crude oils are refined into useful products. All these accomplishments are achieved today with a smaller environmental "footprint" than even a decade ago, and are conducted more economically than ever before.

Most energy technology is developed by industry in response to a resource opportunity, such as opening exploration in the deepwater Gulf of Mexico. Fewer investments are being directed to researching possibilities for energy production in the continental United States, where accessible conventional opportunities are maturing. Government has a role in creating new opportunities and developing the regulatory framework and infrastructure needed to extract new resources. Enhanced oil recovery is an activity for which funding by the DOE for research could pay significant dividends through increased domestic production. Coal-bed methane and oil shale present additional opportunities.

The decline in DOE-funded oil and natural gas-related research and development in the past two years has affected both universities and the National Laboratories. Government funding in engineering and science, when distributed to universities and National Laboratories, sustains these important institutions. It is vital that this funding is accompanied by contracts that call for spending accountability and research delivery.

The national interest is also well served when the government supports large-scale demonstration projects, such as the FutureGen program to integrate large-scale electricity generation with carbon capture and sequestration. In addition, government and industry would benefit from collaborating in several critical areas, including advanced materials, bioprocess, and meteorological and oceanic (metocean) research.

The NPC makes the following recommendations to expand research and development opportunities to support long-term study goals:

- Review the current DOE research and development portfolio to refocus spending on innovative, applied research in areas such as EOR, unconventional oil and natural gas, biofuels, nuclear energy, coal-to-fuels, and CCS.
- Maintain a fundamental research budget in the DOE Office of Science to support novel technologies.
- Focus and enhance research in the U.S. universities and National Laboratories.
- Encourage DOE, Department of Defense, and industry cooperation in innovative areas of development, such as advanced materials and metocean information and analyses.

4. Improve the Quality of Energy Data and Information

As the study teams examined multiple forecasts, they observed that some of the important basic data and information were incomplete, inconsistent, dated, or oversimplified. Investment and policy decisions are increasingly informed by such uncertain data. For example, some disparities in predictions for future oil and natural gas supplies result from divergent estimates of the underlying resources and their deliverability. Additionally, little or no quantitative data are available to clearly understand the need for additional infrastructure capacity.

The NPC makes the following recommendations to enhance the quality of energy data and information:

- Expand data collected by EIA and IEA to provide additional sources of production and consumption data for inclusion in annually prepared public domain energy outlooks.
- Expand funding for data collection and analysis of energy transportation systems to enable informed infrastructure decisions.

There are many energy outlooks, but most base their projections for future fossil-fuel production on a few publicly available resource estimates, most notably the U.S. Geological Survey (USGS) assessments. Since these assessments are comprehensively updated only every decade or so, the fundamental data for energy policy decisions may not reflect the most current perspectives. In addition, the many organizations involved in energy forecasting and analysis often apply different methodologies and assumptions to the assessments, which can create misunderstandings about future production capabilities.

This study's results confirm the primary importance of maintaining comprehensive, up-to-date, fundamental assessments of the global oil, natural gas, and coal endowment and resources. Although each such assessment produces inherent uncertainties based on the state of geological knowledge and observational information, a new, comprehensive assessment would more accurately frame the condition of the fossil resource base for policy decision making and strategy. Additionally, given the growing contribution expected from biomass-based energy sources by 2030, a global assessment of this renewable resource would provide a more complete outlook for the available energy endowment.

In order to increase the reliability and timeliness of fundamental endowment and resource data, the United States should collaborate with other global stakeholders to improve the collection, management, interpretation, and communication of data and estimates for energy endowments and recoverable resources.

The NPC makes the following recommendations to update publicly available global endowment and resource estimates:

- The USGS should conduct a comprehensive geological assessment of U.S. and global oil and natural gas endowment and recoverable resources.
  - Incorporate wider participation of industry and international experts and current data.
- The USGS should conduct a new, comprehensive survey of U.S. and global recoverable coal resources and reserves using common analysis and reporting methodologies.
- The U.S. Departments of Energy and Agriculture should conduct a global biomass resource assessment.

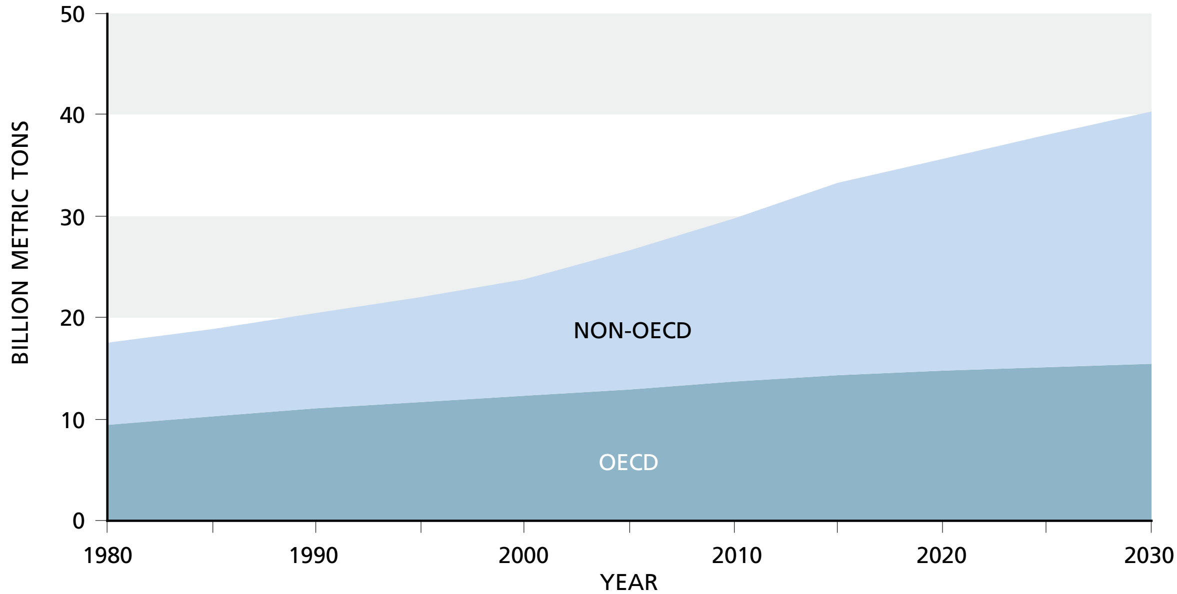
Potential Effect: Timely and better informed policy decisions based on shared understanding of critical resource data

E. Address Carbon Constraints

There is growing concern that the global climate is warming, and that CO_2 emissions from human activity play a role. The NPC did not examine the science of climate change. But recognizing that an increasing number of initiatives to reduce these emissions are emerging, the NPC considered the potential effect of CO_2 emissions constraints on energy and opportunities for technology application. Limits on CO_2 emissions could restrict fossil fuel use, which currently provides more than 80 percent of the world's energy. Therefore, it is increasingly important to plan for potential constraints on CO_2 emissions as part of any overall energy strategy.

By its nature, climate change is global. CO_2 emissions from burning fossil fuels contribute to the overall flux of carbon between the atmosphere, the land, and the oceans. By mixing in the atmosphere, CO_2 emitted anywhere in the world is distributed around the globe.

The United States was the world's largest CO_2 emitter from energy use as of 2005,[33] both in total emissions and on a per-capita basis, but most projected growth of CO_2 emissions is in the developing world, as illustrated in Figure ES-14. Significantly reducing CO_2 emissions would require global, broad-based actions over decades, with major and sustained investment.



Source: IEA, *World Energy Outlook 2006,* Reference Case.

Figure ES-14. World Carbon Dioxide Emissions

1. Enable Carbon Capture and Sequestration

Coal combustion is the largest source of CO_2 emissions from energy use, and coal is projected to remain a major fuel for electricity generation in most forecasts. The resource base for coal is much larger than that for oil and natural gas, and the United States has the world's largest coal resource by some estimates.[34] One opportunity for reducing CO_2 emissions is carbon capture and sequestration, which traps CO_2 and stores it underground. Extensive, commercial scale deployment of this technology could allow continued coal use in a carbon constrained future. Additionally, some unconventional oil production requires substantial energy, increasing CO_2 emissions per unit of delivered energy, and future development could be influenced by the availability of CCS. An initial suite of technologies for large-scale CCS implementation already exists within the oil and natural gas industry, although such technologies have yet to be demonstrated in combination and at commercial scale. More importantly, a legal and regulatory framework for long-term CO_2 storage is still lacking.

Scale is also a major consideration for CCS. In the United States, if all the CO_2 from today's coal-fired electricity generation were collected and compressed, it would total 50 million barrels per day.[35] This amounts to 2½ times the volume of oil handled daily in the United States. To accommodate such volumes, potential storage sites need to be mapped and assessed.

The NPC makes the following recommendations to enable long-term environmental viability of coal for both power and fuel:

- Establish a legal and regulatory framework which is conducive to CCS.
  - Provide regulatory clarity for land use and liability policies.
  - Provide access to federal lands for storage.
- Enable full scale CCS and clean coal technology demonstration.
  - Organize efforts between the power and oil/natural gas industries.
- Undertake a national CO_2 sequestration capacity assessment.
  - Build on the existing efforts being undertaken by the DOE Regional Partnerships.
  - Encourage global application.
- Continue federal research and development support for advanced coal-to-fuel technologies.

Potential Effect: Maintaining coal's projected 30 percent contribution (54 quadrillion Btu per year in 2005) to the future U.S. energy mix, including potential coal-to-liquids production, even in carbon-constrained circumstances.

A comprehensive approach to carbon management would include measures to: boost energy efficiency and reduce demand; increase use of power that is not carbon based (nuclear, wind, solar, tidal, ocean-thermal, and geo-thermal); shift to lower carbon fuels, including renewables; and deploy CCS. Putting a cost on carbon emissions across all economic sectors, whether through a carbon tax or a carbon cap-and-trade mechanism, would allow the marketplace to find the lowest cost combination of steps to achieve carbon reduction. Any cost should be imposed in a predictable manner over the long term, since regulatory uncertainty weakens the investment climate and has the potential to disrupt economic activity. Any cost imposed should also consider the actions of other countries and the resulting effect on U.S. competitiveness.

As policymakers consider actions to reduce CO_2 emissions, the NPC recommends including:

- An effective global framework for carbon management incorporating all major emitters of CO_2 and focusing particularly on opportunities for U.S.–China cooperation.
- A U.S. mechanism for setting an effective cost for emitting CO_2 that is:
  - Economy-wide, market-based, visible, transparent, applicable to all fuels.
  - Predictable over the long term for a stable investment climate.
- A credit for CO_2 used in enhanced oil and natural gas recovery.

Policy Avenues to Limit Carbon Dioxide Emissions

Direct regulation: CO_2 emissions could be constrained by imposing limits on emissions from individual sources, such as power plants and industrial facilities. Economists generally regard this sort of regulation as inefficient, because it does not allow for the likelihood that some sources may be able to achieve emissions reductions more economically than others. Encouraging greater emissions reductions by the sources that can do so most economically would yield a larger total reduction for a given total cost, but this can be difficult to accomplish with fixed regulatory targets.

Cap-and-trade regulation: Cap-and-trade systems seek to overcome the inefficiency of direct regulation by providing a market-based mechanism to encourage those who can reduce CO_2 emissions most economically to do so. Regulators must determine which sources will be covered by the system and the total amount of emissions that will be allowed within a specified period of time. Permits to emit a given amount, such as one metric ton of CO_2, are then allocated or auctioned. The permits can be traded, encouraging sources that can eliminate emissions for less than the market price of a permit to do so, while sources for whom emissions control is more costly can buy permits from others.

Creating a cap-and-trade system involves important policy choices:

- Which sectors to include.
- What level of emissions should be permitted and whether any "safety valve" is provided to limit the volatility or price of permits.
- Whether permits should be allocated at no cost or auctioned.
- Whether there should be a single permitting system covering all affected sectors or multiple systems for different sectors.

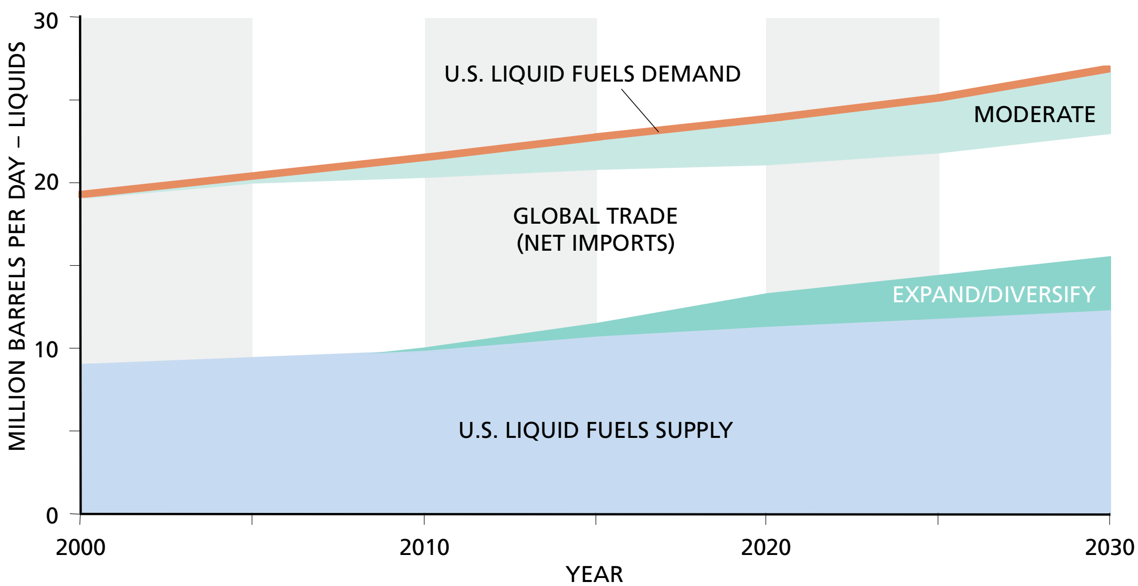
Fundamentally, a cap-and-trade system establishes a level of emissions, and the marketplace then establishes the cost.

Carbon taxes or fees: A tax or fee could be levied on CO_2 emissions, establishing the cost of emissions while letting the market then establish the emissions level. In principle, any level of emissions reduction that could be achieved with a cap-and-trade scheme could also be achieved with taxes or fees. For CO_2 emissions from combustion, the simplest method would levy the fee on the primary fuel, with a credit system for any use that doesn't emit CO_2 such as production of petrochemicals.

A tax or fee system has the advantages of establishing a predictable cost, thus encouraging long-term planning and investment, and not requiring the regulatory complexity of determining the equitable emissions allowance levels by sector and facility. A tax or fee system has the disadvantage that the level of resulting emissions is not established in advance. A tax or fee system also poses the challenge of how to equitably return the revenues to the economy.

F. Potential Effect of Recommended Strategies

The Council proposes five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. An illustration of the potential effect of implementing all the recommended strategies is shown in Figure ES-15. Starting with the EIA Reference Case for U.S. liquid fuel demand, the potential effect of the recommended demand reduction strategies is shown in light green. The potential effects of recommended strategies to moderate the decline of conventional supplies, and strategies to further expand and diversify supplies are shown in dark green. The combined effect of the recommended strategies would reduce the gap between domestic demand and supply by about one-third from 2006 to 2030 in this illustration—improving the outlook for energy availability, reliability, cost, and environmental impact.



Source: EIA, *International Energy Outlook 2006*, Reference Case / NPC Global Oil and Gas study estimates.

Figure ES-15. Illustrative Effect of Recommended Strategies for the United States

Given the massive scale of the global energy system and the long lead-times necessary to make significant changes, concerted actions to implement these recommendations must be taken now, and sustained over the long term, to promote U.S. competitiveness by balancing economic, security, and environmental goals. The following report chapters detail more fully the challenges posed by the complexity of the world's integrated energy system and the opportunities to secure a more reliable energy future.

□

1 The OECD (Organisation for Economic Co-operation and Development) includes Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States of America.

2 For 2003, per the IEA's *World Energy Outlook 2005* and the EIA's *International Energy Outlook 2006*.

3 As of year-end 2005, 31.6 million cars and 1.3 billion people, as reported by the China National Statistics Bureau.

4 Per the U.S Bureau of Transportation Statistics, the United States had 137 million cars in 2004; population was 281 million. But the U.S. also has a large number of trucks/SUVs used as passenger vehicles, which are unfortunately not reported separately. A close approximation would be the category of "other vehicles—two axle, four wheel," which would add 92 million vehicles and bring the total for U.S. "passenger vehicles" to 228 million, for a ratio of 8 passenger vehicles for 10 people.

5 "Primary Energy" refers to first use of an energy source. For example, coal can be burned to produce electricity. There are losses of energy in the process of generating and transmitting the electricity to the end user, such that the energy value of electricity finally used is less than the energy value of the coal initially burned. In this example, coal is the primary energy, not the final electricity used.

6 The "Billion Ton Study" – *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, USDA and USDOE, April 2005, available at http://www.osti.gov/bridge

7 About 240 years based on the most recent study by USGS in 1974. Just prior to publication of this NPC study, the National Academy of Sciences issued a report suggesting that economically recoverable coal reserves in the U.S. might be lower than the 1974 USGS study □ approximately 100 years of current consumption.

8 See in this report, "New Patterns of Trade" section in Chapter 4, Geopolitics.

9 See *World Oil Outlook 2007*, OPEC Secretariat, especially pages 2, 7, and 8

10 IEA *World Energy Outlook 2006*, Chapter 12, page 315

11 Refer to the *Technology Development Topic Report* accompanying this Report, Section F

12 The Hibernia platform □ discovery in 1979, first production in 1997, producing 180,000 barrels per day. *http://www.hibernia.ca*

13 The Thunder Horse Platform □ discovery in 1999, design capacity 250,000 barrels per day. *http://www.bp.com*

14 Per reported estimates for a proposed new refinery by the Arizona Refining Company, *http://www.arizonacleanfuels.com*

15 American Association of Oil Pipelines

16 National Petroleum Council, *Balancing Natural Gas Policy*, 2003.

17 For example, see *The Crude Oil Windfall Profit Tax of the 1980s - Implications for Current Energy Policy*, Congressional Research Service, 2006 available at http://nationaljournal.com/policycouncil/energy/legnar/031406CRS_Crude.pdf,

18 See in this report, "Transportation Efficiency" section of Chapter 3, Technology. The extent to which technologies translate into reductions in fuel consumption depends on several factors, including costs, consumer preferences, availability, deployment, and timing.

19 The potential fuel savings of 3 to 5 million barrels per day in 2030 is relative to a scenario where current fuel economy standards remain unchanged through 2030.

[20] Baseline projections taken from Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030*, Table 2, February 2007, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls; savings estimates taken from several studies including *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005. "Achievable" used here means that the measures are currently available and the savings can be realized with a reasonable level of effort and with acceptable reductions, if any, in perceived amenity value.

For additional discussion, see the *National Action Plan for Energy Efficiency*, which is available at: http://www.epa.gov/cleanrgy/actionplan/eeactionplan.htm

[21] From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, pp. 18-19. For a compilation of compliance studies, see U.S. Department of Energy, *Baseline Studies*, on web site (http://www.energycodes.gov/implement/baseline_studies.stm). Arkansas reports 36 of 100 homes in the study sample did not meet the HVAC requirements of the state energy code.

[22] From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, p. 24

[23] For additional savings potential see Steven Nadel, Andrew deLaski, Maggie Eldridge, & Jim Kleisch, *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*, March 2006, http://www.standardsasap.org/a062.pdf.

[24] From the *Chemical Bandwidth Study*, DOE, 2004, *Energy Bandwidth for Petroleum Refining Processes*, DOE, 2006, *Pulp and Paper Industry Energy Bandwidth Study*, AIChE. 2006

See also *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*, McKinsey Global Institute, May 2007

[25] "Combined heat and power" refers to using the excess heat from generating electricity to meet processing or building heat needs. This combination is frequently called "cogeneration" and results in a substantial increase in efficiency versus generating electricity and heat separately.

[26] See in this report "Conventional Oil" section in Chapter 3, Technology, for a full discussion of potential technologies that may increase conventional oil and gas recovery.

[27] A "marginal well" is one that produces less than 10 barrels of oil per day.

[29] The "Billion Ton Study" - *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, USDA and USDOE, April 2005, available at http://www.osti.gov/bridge

[30] See www.energycommission.org/files/contentFiles/report_noninteractive_44566feaabc5d.pdf, page IV

[31] Iranian oil exports were 2.5 million barrels per day in 2006 per the EIA

[32] U.S. Department of Labor: "Identifying and Addressing Workforce Challenges in America's Energy Industry," President's High Growth Job Training Initiative, U.S. DOL Employment Training Administration (March 2007)

[33] According to a preliminary estimate by the Netherlands Environmental Assessment Agency, China overtook the United States in total CO_2 emissions for the year 2006. More info at http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html

[34] Based on the 1974 USGS assessment. A very recent study by the National Academy of Science suggests that the U.S. economically recoverable coal resource my only be ~40% of the USGS estimate.

[35] Based on 150,000 barrels per day of supercritical CO_2 from a one-gigawatt coal-fired power plant and 2,090 TWhr of coal-fired electricity generation in the United States in 2004 per the EIA.