Shaping the Energy Technology Transition

Moving to a Low-Carbon, Renewable-Energy Economy

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
Policy Research Project Report

167

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Project directed by

Charles G. Groat, Ph.D.

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List of Acronyms

ACEE	American Council for Energy Efficient Economy
ANWR	Arctic National Wildlife Refuge
CAFE	Corporate Average Fuel Economy
CHP	Combined Heat and Power
CSP	Concentrating Solar Power
CRS	Congressional Research Service
DER	Distributed Energy Resources
DG	Distributed Generation
DOD	Department of Defense
DOE	Department of Energy
DSM	Demand Side Management
EERE	Energy Efficiency & Renewable Energy
EIA	Energy Information Administration
EIEA 2008	Energy Improvement & Extension Act of 2008
EISA 2007	Energy Independence and Security Act of 2007
EPA	Environmental Protection Agency
EPAct 2005	Energy Policy Act of 2005
EPCA	Energy Policy and Conservation Act
EU	European Union
FBR	Fast Breeder Reactor
FERC	Federal Energy Regulatory Commission
GEA	Geothermal Energy Association

GDP	Gross Domestic Product
GHG	Greenhouse Gases
GHP	Geothermal Heat Pump
GJ	Gigajoule
GTP	Geothermal Technologies Program
GW	Gigawatt
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
ITC	Investment Tax Credit
JET	Joint European Torus
kW	Kilowatt
kWh	Kilowatt Hour
MES	Minimum Efficiency Standards
MeV	Mega Electron Volt
MicroCHP	Micro-Combined Heat and Power
MIT	Massachusetts Institute of Technology
MSW	Municipal Solid Waste
MTBE	Methyl-Tertiary-Butyl Ether
MW	Megawatt
MWe	Megawatt Electron
MWh	Megawatt Hour
NECPA	National Energy and Conservation Policy Act
NELHA	National Energy Laboratory of Hawaii Authority
NETL	National Energy Technology Laboratory

NO_x	Nitrogen Oxides
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
OAPEC	Organization of Arab Petroleum Exporting Countries
OE	Office of Electric Delivery & Energy Reliability
OECD	Organisation for Economic Co-operation & Development
ORC	Organic Rankine Cycle
OTEC	Ocean Thermal Energy Conversion
PTC	Production Tax Credit
PURPA	Public Utility Regulatory Policies Act
RCSP	Regional Carbon Sequestration Partnerships
RPS	Renewable Portfolio Standard
REHC	Renewable Energy Heating and Cooling
RFS	Renewable Fuels Standard
SAP	Statement of Administration Policy
SECO	State Energy Conservation Office
SO_2	Sulfur Dioxide
Tcf	Trillion Cubic Feet
TIPS	Texas Interactive Power Stimulator
TWh	Terawatt-hour
UN	United Nations
USGS	United States Geological Survey
V2G	Vehicle to Grid
VIVACE	Vortex Induced Vibrations Aquatic Clean Energy

Foreword

The transition from a carbon-fuels-based energy economy to one more reliant on alternative and renewable energy technologies has been viewed in several contexts. The most prominent focus has been on the reduction of greenhouse gases, principally carbon dioxide, and the positive effects a transition would have on reducing global warming. The transition is also beneficial in that it moves society away from a dependence on non-renewable resources, most notably oil and natural gas, that have a limited reserve base and whose global distribution patterns pose security issues for much of the developed world. There has also been an interest in new energy technologies from an economic development perspective, with new jobs seen as a significant benefit.

The energy technology transition has posed many challenges, including a lack of understanding of the potential of some technologies, a failure to consider significant unintended economic and environmental consequences of some alternative technologies, assumptions that the technology transition can be accomplished quickly by political action and a failure to appreciate the role carbon-based fuels will continue to play in the next several decades. This study, undertaken as a Policy Research Project by graduate students in the Lyndon B. Johnson School of Public Affairs at The University of Texas at Austin, examines the emerging technologies, considers options, and presents recommendations based on their findings. The findings and recommendations are current as of May 2009.

Completing a Policy Research Project is an important requirement for students seeking a Master of Public Affairs degree in the LBJ School of Public Affairs. This core element in their degree plan is a nine-month effort during which the graduate students organize the project, gather information, analyze data, develop findings, and prepare recommendations. They gain not only a body of knowledge, but skills in teamwork and project organization and implementation. I am pleased to salute the effort they have put forth and the report that has resulted. Please note that neither the LBJ School of Public Affairs nor The University of Texas at Austin endorses the findings and recommendations included in the report.

Bobby R. Inman

Admiral, USN (Ret.)

Interim Dean

Acknowledgments and Disclaimer

This project would not have been possible without the support of the Center for International Energy and Environmental Policy at The University of Texas at Austin, the New Energy Foundation, and the law firm of Hamilton and Terrile. This report was drafted as a group effort by students in a Policy Research Project (PRP) on Shaping the U.S. Energy Technology Transition. Participants included Jose Chavez, Axel Gerdau, Linhong Kang, Martin Kareithi, Kymberlie Koch, Desiree Ledet, Melissa Lott, James Ovelmen, Emily Owens, Patrick Tyler, Rachel Veron, Jonathan Wang, and Lei Wu. Co-instructors Charles Groat and Thomas Grimshaw, along with Gary Hamilton, provided guidance and supervision to the class. Lana Morris helped prepare the class to create an effective survey and conduct interviews. Tom Gerrow, a professional writer, edited the final report.

Speakers from private businesses, state agencies, and congressional staffers conveyed background information on energy policy and energy technologies to the PRP class. The class thanks Perry Been, of Texas State Energy Conservation Office, and Ed Clark, of Austin Energy, for their discussions on energy conservation and efficiency; Ian Duncan, of UT Bureau of Economic Geology, for his explanation of carbon capture and sequestration; Russell Smith, of Texas Renewable Energy Industries Association, and Pam Groce, of Texas State Energy Conservation Office, for their presentations on biofuels; Cary Ferchill, venture capitalist, for his insights on energy storage; Gary Hamilton, J.D., of Hamilton & Terrile, for his explanation of intellectual property; Ed Storms, PhD., of Kiva Energy, and Dennis Letts, independent researcher, for their presentations on Cold Fusion; and Tom Weimer, Staff Director for the Select Committee on Energy Independence and Global Warming, for his explanation of energy policy and the current political climate.

We also wish to express our appreciation to all those interviewed during the preparation of this PRP.

None of the sponsoring units, including the LBJ School, the Jackson School or The University of Texas at Austin endorses the views or findings of this report. Any omissions or errors are the sole responsibility of the authors and editors of this report.

Executive Summary

A transition of the U.S. energy economy from hydrocarbon dependence to one that is based on sustainable energy technologies will strengthen the U.S. economy, enhance national security, and minimize the environmental impact of energy consumption. Failure to make this transition could be devastating to the future security of the United States.

Effective public policies to implement this transition must be incorporated into a comprehensive National Energy Plan that fosters innovation in sustainable energy generation, distribution, and energy conservation. Technological innovation, and supporting public policies, will entail a two-pronged approach – implementing conservation policies and substitution of sustainable energy sources in place of conventional hydrocarbon energy sources. Several sustainable energy sources are well developed technologically (e.g. wind, solar, geothermal) but will require supportive policies to become economically competitive with hydrocarbon fuels. Other sustainable energy sources (e.g. hydrogen, wave, tidal, ocean current) will require aggressive policies to support further development and implementation. Reduction in energy consumption may be realized through policies that support conservation and efficiency, infrastructure technologies such as smart grid and distributed generation, energy storage, and renewable energy heating/cooling systems.

Under almost all transition scenarios, hydrocarbon fuels will continue to be essential in the near term. As conventional fossil fuels (oil, gas, coal) become scarcer, development of other hydrocarbon sources, such as oil shale or tar sands, may become economically feasible. Regardless of the source of hydrocarbon-based energy, technologies such as carbon sequestration must be implemented in concert with the transition to these sources in order to abate their adverse environmental effects.

Two case studies in this report—biofuels and cold fusion—demonstrate that current energy policymaking has not always led to an optimal solution for maximum public welfare benefit. The biofuels case is viewed by many as an example of energy policy that did not necessarily take into account all relevant economic and environmental factors, such as water supply, soil erosion, and increased use of fertilizers and pesticides. Cold fusion represents a case in which negative public policies, despite a continuing possibility that the phenomenon may eventually be found to be "real," may not necessarily serve the long-term public interest.

Independent interviews of more than two dozen energy experts from industry, academia, and government agencies confirmed the findings of background research and presentations by outside speakers: 1) energy policy is at least as important as any other policy area; 2) the United States should transition away from hydrocarbon-based energy sources; 3) continued dependence on hydrocarbons may threaten national security and negatively impact the environment; 4) an energy transition may create economic problems or opportunities for the United States; 5) the United States should incorporate increasing amounts of renewable energy technology into its energy portfolio.

These findings, along with results from the same interviews regarding the continuing role of hydrocarbons, new energy technologies, energy conservation and efficiency, and energy policy, strengthen the case for a need for change in energy policy direction. Policy recommendations emerging from this investigation are summarized as follows:

National Energy Plan, 2010-2050. Replace current energy policies, an agglomeration of uncoordinated standards and programs, with an integrated set of policies to guide the United States through a transition from depletable and polluting hydrocarbon energy sources to an energy economy that relies on nuclear, renewable, and clean hydrocarbon sources of energy. Ensure that the National Energy Plan addresses three critical areas: energy independence and security, economic impact and feasibility, and environmental impact.

Hydrocarbon Transition. Establish a national carbon emissions reduction goal of 80 percent by 2050. Establish a national carbon tax of $35 per ton emitted after 2014. Continue the Department of Energy Loan Guarantee Program for low-carbon solutions to coal-based power generation. Continue Clean Coal Initiative, FutureGen, and other federal initiatives to reduce emissions of existing coal and natural gas power facilities.

Transportation Innovation. Increase research and development grants for battery and hydrogen fuel cell technology. Maintain current fuel efficiency standards and proposed increases. Repeal the current Renewable Fuels Standard, reinstating it when next-generation biofuels become available. Extend tax credits for purchases of hybrids, plug-in hybrids, pure electric, and hydrogen fuel cell vehicles until these vehicles comprise 50 percent of the U.S. auto fleet. Extend consumer tax credits for converting older vehicles to improved efficiency technologies. Increase research and development to ensure the use of next-generation biofuels, electric batteries, and/or hydrogen fuel cells in heavy trucks, ships, and airplanes.

Energy Conservation and Efficiency. Expand minimum efficiency standards to more electric appliances and commercial equipment. Expand and continue financial incentives for renewable energy heating and cooling. Increase investment in energy storage technology. Promote implementation of smart grid technologies. Enhance research and development for more energy efficient products and services.

Renewable Electricity Development. Enforce achievement of a national Renewable Portfolio Standard of 15 percent renewable electricity by 2030. Approve tax credits and investment tax credits for renewables. Rapidly deploy and extend new DOE loans for renewable electricity. Continue to support basic and applied research in renewable energy technologies.

Nuclear Energy Development. Expand nuclear energy research, development, and deployment efforts with a focus on central storage, and the reprocessing and disposal of spent fuel. Continue government guaranteed loans for new advanced nuclear power plants. Continue nuclear energy production tax credits.

Public Awareness of the Energy Technology Transition. Educate the public about the need for the energy transition to ease misgivings about higher prices. Address the importance of energy efficiency in households and businesses. Enable citizens to make the best energy decisions themselves.

If these policy recommendations are implemented, the costs and consequences of reliance on hydrocarbon energy will be reduced, greenhouse gas emissions will be ameliorated, new "green" domestic industries and jobs will be created, a diverse energy portfolio will be created that is more robust and resistant to market volatility, and consumer choice in energy consumption will be better informed.

Chapter 1. Introduction

Recent developments in economic, political and natural phenomena have created a situation of the utmost urgency for U.S. policymakers. Dependence on depletable hydrocarbons[1] to meet the nation's energy needs has led to significant economic costs, environmental consequences, and geopolitical risks. These factors require a transition of the national energy economy from hydrocarbons to renewable energy sources and other alternative energy technologies. Not making this energy transition threatens the future peace and prosperity of the United States. Technological innovation in energy generation, distribution, and use will provide the solution to this problem.

Current U.S. dependence on hydrocarbon energy resources is extensive. The United States relies upon these resources for the vast majority of its energy needs: currently, 98 percent of transportation fuels and more than 75 percent of fuels used for electricity generation are hydrocarbon-based.[2] This high level of dependence makes an abrupt switch to renewable energy technologies highly improbable and inadvisable, necessitating a transition period to successfully lead the United States to a renewable energy economy. To facilitate this transition period, a comprehensive National Energy Plan must be designed and implemented. This plan must recognize that government should not select which technologies will succeed in a transition, but rather establish a system where the market decides which technologies will ultimately be incorporated into the energy landscape. The plan should also include measures to optimize hydrocarbon use (including effective use of low greenhouse gas emitting hydrocarbon fuel sources), educate energy consumers, and enhance energy conservation.

In designing and implementing an energy transition plan that addressed these key items, the following research questions emerged:

- What are the consequences of continued U.S. reliance on hydrocarbons? What should the continued role of hydrocarbons be?
- What energy alternatives are available to meet growing energy demand? Do they achieve U.S. goals for cleaner energy, economic growth, and national security?
- Which federal policies are most effective in facilitating/encouraging an energy technology transition?
- What lessons should be drawn from the rejection of cold fusion by the mainstream science community in the United States?
- What lessons should be drawn from the consequences of biofuels mandates in the United States?

- Which energy policies are needed to accelerate an energy technology transition in the United States, when should they be implemented, and why are they needed?

To explore these questions, a team consisting of 13 student researchers aided by two instructors was established. Over a period of eight months, the team attended guest lectures, performed extensive literature reviews, evaluated previous energy policies, examined two case studies, and surveyed technology and policy experts in the energy field.

Guest Lectures

Researchers attended lectures presented by both the project instructors and invited speakers from government, academia, and industry. These lectures had three main goals: to help the research team develop an understanding of the problems associated with a hydrocarbon-based energy economy, report on alternative technologies which could play a role in a more sustainable energy future, and discuss the policy mechanisms that have been used and are being proposed to establish a comprehensive national energy policy.

Literature Review

During the research process, the team conducted an extensive literature review with three primary areas of interest. The first was developing an understanding of energy technologies. Emphasis was placed on both currently available alternative energy technologies as well as those in the research and development stage that demonstrate significant future potential. This area included both energy production and demand reduction technologies.

Second, the research team carefully conducted an analysis of past and current energy policy proposals, including those most recently announced by President Obama and his team. This analysis included the vital step of developing an understanding of the implications of these energy policies. Finally, two thorough case studies, exploring cold fusion and biofuels technology, were evaluated to extract general lessons that might inform future political decisions to fund or implement new alternative energy technologies.

Original Survey of Experts

The core of this report's original work was gathered via interviews with technology and policy experts. Of 156 interview requests sent by the research team, 27 interviews were completed for a response rate of 17 percent. Each interviewee received a set of pre-determined questions targeted at answering the research questions and customized for each expert area: technology and policy. Responses gathered in this portion of the research process revealed key messages and lessons that helped to shape the policy recommendations.

Findings and Recommendations

After establishing a foundation of knowledge, the research team designed a cohesive set of policy recommendations. These recommendations, if implemented as a National Energy Plan, could successfully facilitate an energy technology transition in the United States. A presentation of findings and recommendations from this research project was released in a preliminary research document at a Center for International Energy and Environmental Policy conference "Shaping the Energy Technology Transition" on April 30, 2009. Also, members of the research team participated in a radio show aired by KVRX 91.7FM on April 6, 2009, to present the team's findings.

PRP Document

Details of the findings from the guest lectures, literature review, case studies, and expert interviews are provided in subsequent sections. These findings form the basis for a National Energy Plan with several key components designed to successfully facilitate an energy technology transition. Specifically, the report adheres to the following progression:

- The case for the energy transition
- Alternative energy resources and technologies evaluated according to environmental impact, economic development potential, and national security implications
- Energy efficiency, conservation, and abatement technologies
- Hydrocarbons and their future role
- The evolution of energy policy in the United States
- Energy policy: case studies
- The viewpoints of energy experts
- Final findings and analysis
- Recommendations for a comprehensive National Energy Plan

Notes

[1] The term hydrocarbon refers to organic compounds that consist of hydrogen and carbon. This term is used interchangeably with fossil fuels. Common examples include petroleum, coal, and natural gas.

[2] EIA, *Annual Energy Outlook 2009 Preliminary Release.* Online. Available: http://www.eia.doe.gov/oiaf/aeo/overview.html. Accessed: April 12, 2009.

Chapter 2. The Case for an Energy Technology Transition

As its energy needs have grown, the United States has continuously expanded its use of hydrocarbon sources of energy. Today, the United States is almost completely dependent on coal, petroleum and natural gas to meet its energy needs and is expected to remain so into the future. For economic, geopolitical, and environmental reasons, however, hydrocarbon energy resources are becoming inadequate, more costly, and unreliable. Hydrocarbon supplies will eventually be exhausted; meanwhile, price volatility makes them costly to use. Geo-strategic factors make them unreliable and impose additional costs and constraints on the United States. Finally, the environmental consequences associated with the emissions of carbon dioxide and other greenhouse gases pose a long-term threat to the climatic and ecological stability of the earth's natural and biological systems. Together, these issues make an energy technology transition imperative to the future prosperity and security of the United States.

U.S. Energy History

U.S. economic prosperity over the past century has been closely linked to the large quantities of oil, coal, and natural gas available domestically. By not constraining production capacity, the availability of energy enabled the growth of U.S. industrialization without impediment. Until recent fears of energy shortages and other consequences associated with dependence on hydrocarbons, the United States has not been concerned about the adequacy and reliability of its energy supply.

Coal

Coal was the first hydrocarbon widely used after the beginning of industrialization and the rapid depletion of timber resources. Heavy use of coal for energy began with the industrial revolution and the invention of the steam engine. Ultimately, it was the development of the railroads in the mid-19th century that inaugurated a period of growing production and consumption that continues today. From 1885 to 1951, coal was the leading source of energy produced in the United States, and, after crude oil and natural gas vied for the top position until 1982, it regained the spot for good in 1984.[1] Its continued importance to the U.S. energy economy is explained in part by its price, which has historically been low, and its changing role in meeting energy demand. Originally, Americans used coal to heat their homes and fire factory furnaces. Today, coal power plants supply nearly half of the country's electricity.

Coal continues to be an abundant resource in the United States. In fact, the nation produces more coal than it consumes. In 2000, exports totaled 58 million short tons, approximately 37 percent of all energy sales to foreign countries. Overall, the United States produces nearly 1.15 billion short tons a year and holds more than 25 percent of the world's coal reserves.

Although coal remains an abundant energy source, there are significant environmental and health costs associated with its use, including emissions of toxins such as mercury, sulfur dioxide, nitrogen oxide, and particulate matter. Only since public awareness of anthropogenic global warming increased during the past ten years has coal been universally branded a "dirty" fuel. Coal is the leading emitter of carbon dioxide and other greenhouse gases amongst all fuels, and its use, primarily for electricity generation, now accounts for roughly 20 percent of global greenhouse gas emissions worldwide.[2]

Petroleum

The modern U.S. petroleum age began in 1859 with the discovery of oil in Pennsylvania. This find ignited a petroleum exploration boom that would extend from California to Texas over the following decades, fed by a rising demand for lighting fuel and lubricants. While overproduction drove market prices down temporarily, the rapid adoption and spread of the internal combustion engine created vast new markets at the turn of the century. National petroleum consumption has increased ever since.[3]

Until the 1950s, the United States was able to produce enough oil to meet its own demand. At that point the gap between production and consumption began to widen, and starting in 1994 the nation imported more petroleum than it produced. National oil exploration had already reached its peak decades earlier—crude oil production in the lower 48 states was at its highest level in 1970 at 9.4 million barrels per day[4]—yet the national appetite for petroleum continued to grow largely due to economic expansion, the rise of the automobile, and population growth. Today the United States consumes 20.6 million barrels of petroleum a day, nearly 60 percent of which is imported.[5]

In 1973, U.S. policymakers and citizens first came to realize the negative consequences of their oil dependence, and the unreliability of their supply. The Organization of Arab Petroleum Exporting Countries, consisting of the Arab members of OPEC, proclaimed an oil embargo in response to U.S. support of Israel during the Yom Kippur War. Consequently, the world market price of oil quadrupled and gasoline had to be strictly rationed across the United States. Even though this prompted President Nixon to declare independence from foreign oil a federal energy policy goal, U.S. imports of petroleum are higher today than they were 35 years ago.

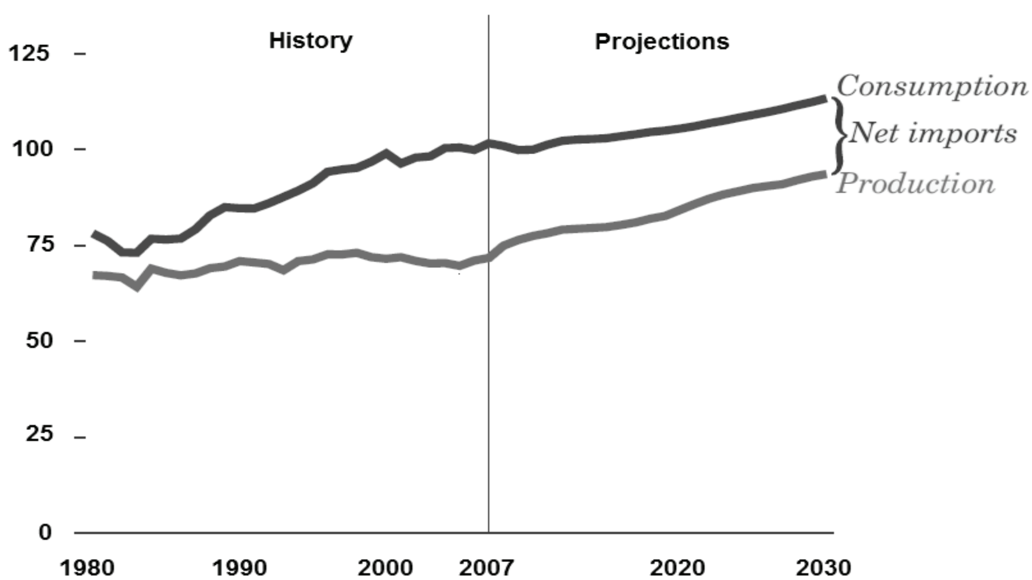
Natural Gas

Natural gas has become an indispensable part of the U.S. energy economy since the development of steel pipelines and related equipment allowed large volumes to be transported over hundreds of miles. While residential demand for the fuel grew 50 fold between 1906 and 1970, the United States had large natural gas reserves and was essentially self-sufficient until the late 1980s. At this point consumption, partially pushed by increasing electricity generation needs and industrial uses, began to outpace production. Today, natural gas is the second leading fuel in the United States in terms of consumption (totaling more than 23 percent of all energy consumed), and the country imports approximately 16 percent of its gas, most of it from Canada. In the long-term, price volatility combined with the fact that the vast majority of all natural gas reserves are located in Russia and the Middle East poses economic and political challenges.[6]

U.S. Energy Production and Consumption

Although Americans consist of only 4.5 percent of the world population, they consume approximately 23 percent of the world's energy annually[7] – 101.9 quadrillion British thermal units (Btu) in 2007.[8] Despite producing approximately 73 quadrillion Btu of energy annually, domestic production only represents 71 percent of the total energy supply. The remaining 29 percent is imported from foreign countries in different forms and portions, mostly imported oil.[9] Past and projected U.S. energy production and consumption are shown in Figure 2.1.

Figure 2.1
Total U.S. Energy Production and Consumption



The sustainability of continued dependence on hydrocarbons is also a concern, as increasing demand for hydrocarbons globally presents the United States with challenges to the adequacy of its energy supply. This supply problem is compounded by a high level of demand for, and inefficient use of, energy. The United States currently requires more energy than it produces domestically, and is extremely wasteful in how it generates, distributes, and uses energy.

Future projections for national energy supply and demand assume continued population growth, higher prices for crude oil and natural gas, growth in the use of renewables, reduced economic growth, and slower than expected growth in energy demand.[10] Although energy use has recently declined as a result of global economic recession, this is expected to be temporary.[11] Long-term forecasts predict that energy demand will be dependent on the level of economic growth but will continue to increase with population growth. Since energy use is closely correlated with population size, projected growth in the U.S. population will be the primary cause of future increases in total demand.[12]

Supply Analysis

The United States is endowed with numerous energy resources, including vast interior coal deposits, offshore and arctic oil fields, natural gas deposits, a large central wind corridor, numerous waterways, and plenty of sunlit land. A breakdown of the overall U.S. energy supply (101.6 quadrillion Btu) can be found in Figure 2.2. Figure 2.3 shows the breakdown of the renewable energy component (6.7 percent, 6.8 quadrillion Btu) of the total energy supply. Despite the diversity of its domestic energy resource supply, the United States is highly dependent on hydrocarbons for energy. Petroleum, natural gas, and coal comprise 85 percent of the national energy supply; nuclear and renewable energy sources make up the remaining 15 percent.[13]

Used for generating electricity, nuclear energy provides 8 percent of the primary total energy supply and could supply more but has not been expanded in the United States for several economic and political reasons. First, nuclear plants are expensive to build and require significant long term investments. Second, there is significant political opposition to the location of proposed facilities. In contrast to depletable hydrocarbons and nuclear projects, "renewable" sources of energy are inexhaustible and have the potential to reduce the need for hydrocarbons in the future. Renewable sources of energy presently comprise 6.8 percent of the total national energy supply.[14]

Numerous economic, environmental, and political reasons have prevented the development of additional domestic energy resources, primarily the large amounts of capital necessary to fund new projects.[15] Since energy production is a capital-intensive industry, domestic energy production has stagnated and little has been done to expand national energy infrastructure over the past decades. The mixture of energy supply sources is not predicted to change much over the next 20 years. The Energy Information Agency (EIA) predicts that the United States will remain dependent on hydrocarbons well into the future. There is great uncertainty about the future of world petroleum markets, however, and the future use of oil will depend on price. In turn, the future price of oil will depend on geopolitical factors and the future availability of the resource. Higher prices are projected to reduce the demand for oil and lead to the use of other liquid fuels.[16] Liquefied coal and natural gas are predicted to supplement the energy that would otherwise come from oil.

The use of coal and natural gas has expanded to meet the nation's ever-increasing demand for electricity. Given the abundance of U.S. coal deposits, it will likely remain a significant contributor to the domestic energy supply for some time. By 2030, coal is still expected to fuel 44 to 47 percent of the nation's electricity generation.[17] Natural gas is also predicted to supplement decreasing oil stocks. Yet the share of hydrocarbons as a portion of the total primary energy supply is predicted to decline in the future as constraints on their use increase renewable and nuclear energy production. Anticipated changes in public policy incentives and technological advances will also make renewable energy technologies more competitive and lead to greater use. By 2030, total renewable energy generation is projected to be 12.5 percent of total domestic power production.[18]

Figure 2.2
Total Energy Supply Breakdown

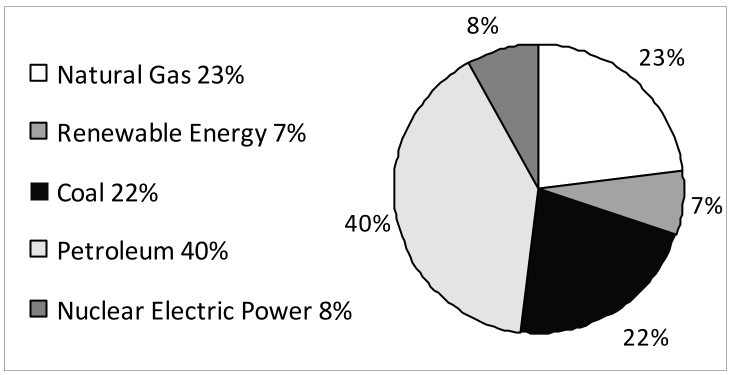
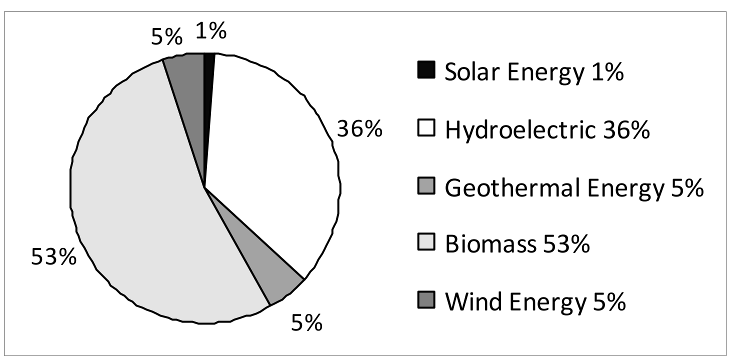


Figure 2.3
Renewable Energy Supply Breakdown



Source: EIA, Renewable Energy Consumption and Electricity Preliminary 2007 Statistics, Table 1: U.S. Energy Consumption by Energy Source, 2003-2007 (May 2008)

Consumption Analysis

Energy consumption is classified according to four broad sectors: residential, commercial, industrial, and transportation usage. By increasing the demand for housing, transportation, and consumer goods/services, population growth will increase energy demand by 0.5 percent per year.[19] The EIA estimates that total energy consumption will be 113.6 quadrillion Btu in 2030.[20] Low economic growth for the near future, however, is likely to reduce the rate of growth in total energy demand. Although average energy use per person is projected to remain stable through 2030, growth in total energy consumption is predicted across all sectors.

Residential energy use is expected to increase due to population growth and expanding household uses for electricity[21] from 11.4 quadrillion to 12.4 quadrillion Btu by 2030.[22] Commercial and industrial energy consumption is highly dependent on rates of economic growth and will vary widely across industries depending on the energy intensity of the industry. By 2030, commercial energy use is expected to grow by 20 percent, from 8.5 quadrillion to 10.6 quadrillion Btu, as the commercial sector requires more space, and therefore more electricity, for their operations. The industrial sector is the second largest consumer of energy and presently requires 25.3 quadrillion Btu. This sector is expected to need 0.2 percent more energy annually, requiring an additional 1 quadrillion Btu by 2030. The transportation sector consumes the largest amounts of energy of every year and the growth in demand for this sector is expected to increase from 28.8 quadrillion to 31.9 quadrillion Btu by 2030.[23]

If nothing is done to reduce the amount of energy consumed annually, or to develop new sources of energy, then increased demand for energy will continue to be met with hydrocarbons. Since coal and natural gas generate the nation's electricity and petroleum propels the nation's transportation, and the composition of the U.S. energy supply is not expected to dramatically change, then growth in energy demand means greater use of hydrocarbons. There are significant economic, geopolitical, and environmental reasons, however, that will make it difficult to fulfill these growing requirements for energy if the United States remains dependent on hydrocarbon energy sources.

Economic Issues of Dependence on Hydrocarbons

Energy is a critical production factor for all goods and services, and its cost affects the entire economy. Energy is necessary for producing food, manufacturing and transporting goods, and providing services throughout the economy, and also has numerous household applications. Since its cost affects the price of everything that requires energy, an increase in energy costs will negatively impact the economy by raising prices and/or reducing demand for many other goods and services.

There are several economic costs associated with dependence on hydrocarbons that create an incentive for an energy technology transition. The finite nature and expected increase in the price of hydrocarbons will make them an inadequate and costly energy source in the future. The trade imbalance resulting from dependence on hydrocarbon imports presents additional costs for the U.S. economy. The prior abundance and affordability of hydrocarbons enabled the creation of an inefficient energy infrastructure, and prevented the technological innovation that could replace these resources. Finally, there are negative externalities, such as climate change, associated with the use of hydrocarbons that are not incorporated into the price.

Energy expenditures represent a significant portion of the national gross domestic product (GDP). In 2007, energy expenditures cost the United States $1.2 trillion, representing 8.8 percent of GDP. Dependence on hydrocarbons makes the economy susceptible to supply shortages and dramatic price increases. The sharp increase in the price of oil during 2008 raised energy expenditures as a share of GDP to 9.8 percent, its highest level in more than twenty years.[24] The proportion of energy expenditures to GDP has since lessened with the rapid decline in energy prices and the onset of global economic recession. Although the current volatility of the world oil market may increase the short term cost of energy expenditures relative to GDP, total energy expenditures are predicted to range between $1.5 trillion to $2 trillion (2007 dollars) by 2030, representing 5.6 percent of GDP.[25] This reduction in relative energy expenditures is attributed to continued advances in energy efficiency that will lower the energy intensity of the U.S. economy.[26]

Finite/Exhaustible Resource

One of the primary economic reasons for an energy transition is the finite nature of hydrocarbon sources of energy. As hydrocarbon resources are depleted they will become more expensive, eventually reaching a point where continued use becomes impractical or impossible. Exhaustible resources will cease to be used when substitutes reach cost parity with the resource. Since hydrocarbon energy prices are expected to increase in the future and the cost of renewable energy technologies are expected to continually decrease, renewable energy conversion technology will eventually become more cost effective than hydrocarbon based methods, making the transition from hydrocarbons to renewables essential to future cost savings.

Although hydrocarbons are being depleted, they remain an abundant source of energy; it is primarily the supply of oil that is a matter of concern. Hydrocarbons are, however, depleted much faster than supplies are replenished. If substitutes are not developed and hydrocarbon use continues at current levels, it does not matter how much coal or natural gas there is to supplement dwindling oil supplies – eventually these resources will also be exhausted. This makes an eventual transition away from hydrocarbons an immutable necessity. The question is when the transition should begin and how quickly it should proceed. While it is imperative that the United States find new sources and methods of generating energy to replace unsustainable hydrocarbon dependence, the other costs of dependence on hydrocarbons make the energy transition a priority now.

Higher Prices

The volatility and expected increase in the price of hydrocarbons will make them an unreliable and costly source of energy in the future. With the amount of remaining hydrocarbon supplies in question, there is great uncertainty surrounding hydrocarbon prices. The EIA reference case for the price for a barrel of oil in 2030 is $130. The EIA, however, recognizes the uncertainty of this projection and includes alternative cases in their analysis in which the price ranges from $50 to $200 per barrel.[27] The cost of electricity is also expected to increase in the long-term future due to higher prices for hydrocarbon fuels, as well as capital expenditures to expand capacity with new projects.[28]

The growth of demand for hydrocarbons in China, India and other developing countries is exacerbating the problem and contributing to expectations of future oil price increases. Yet the depletion of hydrocarbons is only one of several factors that contribute to the expectation of future price increases. It is also likely that governments will raise the price of hydrocarbons in an attempt to reduce greenhouse gas emissions by internalizing the negative external costs of hydrocarbon use. This could be done by taxing the emission of these gases directly or installing a system of emission cap-and-trade programs.

Trade Imbalance

U.S. dependence on hydrocarbons is problematic because many of these energy sources are imported. Dependence on imported oil, primarily to sustain domestic transportation needs, presents an economic loss to society by creating a trade imbalance of U.S. energy exports over imports. Imported oil represents 26 percent of the total primary energy supply.[29] In 2005, oil imports cost the United States $231 billion, representing 30 percent of the trade deficit that year.[30] Reducing dependence on imported oil would decrease this trade imbalance and contribute to the future economic prosperity of the United States.

Inefficiency Losses

The previous abundance and affordability of hydrocarbons has damaged the nation's energy assets by enabling an inefficient energy infrastructure. The United States is extremely wasteful in how it generates, distributes, and uses its energy. For every three units of energy that are converted to generate electricity, only one unit of energy reaches the consumer.[31] The EIA reports that "approximately 67 percent of total energy input is lost in conversion; of electricity generated, approximately 5 percent is lost in plant use and 9 percent is lost in transmission and distribution."[32] These efficiency losses represent large economic costs for the United States. The Environmental Protection Agency (EPA) *National Action Plan for Energy Efficiency* has identified $500 billion in potential net savings from more efficient energy use that could be implemented by 2025.[33]

Hydrocarbons have been a cheap and reliable source of energy but its low cost and availability has, until recently, inhibited the development of new energy conversion technology. As long as the costs of using hydrocarbons have been low and known reserves have been sufficient to meet demand, there has been no incentive to innovate. Methods of propulsion and electricity generation based on the combustion of hydrocarbons basically use the same processes to produce energy that were developed a century ago. While the technology that discovers and uses hydrocarbons has continued to improve, different methods of generating and using energy that could substitute for hydrocarbons have not been adequately developed.

Technological Stagnation

Unfortunately, the energy system is difficult to transform. The nature of energy production, the creation of entrenched interests, and a lack of research and development have prevented innovation in energy technology. Energy projects require large amounts of financial capital and have long time scales for operation. Estimates suggest that complete replacement of all current global energy infrastructure would cost approximately $12 trillion.[34] There are also powerful economic and political actors whose power derives from the current pattern of energy supply. With large investments in energy resources, these actors have an interest in preserving the status quo.[35]

There has not been nearly enough research and development in innovative energy technologies to overcome these other obstacles. Until recently, total public and private energy research and development expenditures have ranged from just $5 billion to $6 billion per year, only 1 percent of what the United States was spending on electricity and fuels.[36] The failure to adequately develop alternative technologies, which could have resulted in significant savings, is a lost economic opportunity. The need for an energy transition would not be so urgent if this issue had been addressed earlier.

Negative Externalities

Many of the costs associated with hydrocarbon use are not borne by either the producer or consumer, which creates negative externalities in the U.S. economy. For example, security and environmental costs, such as military expenditures and climate change, are not incorporated into the price. These costs drain the economic vitality of the United States and present an obstacle to long-term economic growth. Allowing these externalities to continue has also led to unfettered growth in demand for hydrocarbons. Since demand for hydrocarbons is responsive to changes in price, the United States must internalize these externalities into the price of hydrocarbons to reflect the true costs of their continued use.

Geopolitical Issues of Dependence on Hydrocarbons

Continued reliance on hydrocarbon-based sources of energy has serious geopolitical implications for the United States. Not only could it weaken the country's leadership role in the world, but it would continue to compromise foreign policy objectives and threaten national security. The U.S. military is completely dependent on petroleum and there are several geo-strategic implications of this dependence. Continued dependence on hydrocarbons also puts unneeded constraints on U.S. foreign policy. Finally, the effects of climate change and resource scarcity associated with hydrocarbon use are recognized as additional security threats.

Military Dependence on Hydrocarbons

The U.S. military is dependent on large amounts of oil to maintain its operational capabilities. The Department of Defense (DOD) is the single largest consumer of energy in the United States, using 4.6 billion gallons of fuel annually. That is equivalent to 12.6 million gallons of fuel per day or 93 percent of fuel used by the U.S. government.[37] Fuel energy from petroleum is key to U.S. military combat power, propelling Navy ships, Army tanks, and Air Force jets.[38]

Directly linked to those high consumption rates—which, according to the 2005 CIA *World Fact Book*, would rank the DOD 34th in the world in average daily fuel use, just behind Iraq and ahead of Sweden—are significant costs. In 2006 alone, the Defense Department spent $10 billion on mobility fuels and $3.5 billion on related facilities and infrastructure.[39] While present DOD fuel costs represent less than 5 percent of the national defense budget, a spike or gradual increase in oil prices could well double that number over the short or long term.

This in turn would require redirecting financial resources from other budgetary items, which is not only a financial management challenge in a fiscally constrained wartime environment but could also compromise the combat effectiveness of U.S. troops. For example, a $10 per barrel increase in the cost of fuel increases DOD operating costs by approximately $1.3 billion annually, roughly the entire 2007 procurement budget for the U.S. Marine Corps.[40]

Enemies of the United States understand the importance of oil to both the country's economic strength and the operational capabilities of its armed forces. A Congressional Research Service report highlighted terrorists' emphasis on exploiting this vulnerability: "Statements by Bin Laden and Al Zawahiri urging attacks on oil infrastructure and military supply lines could indicate a shift in Al Qaeda's strategic and tactical planning in favor of a more protracted attritional conflict characterized by disruptive attacks on economic and critical energy production infrastructure."[41]

Foreign Policy Constraints

While potentially compromising the strength of the U.S. military, continued dependence on hydrocarbon imports also undermines U.S. foreign policy objectives. Energy suppliers such as Russia, Iran, and Venezuela have been increasingly willing and able to use their resource endowment to achieve political objectives. This presents a challenge to the United States on at least three levels.[42]

First, nations that depend on foreign oil are reluctant to join efforts to combat weapons proliferation, terrorism, or aggression. One example is the French, Russian, and Chinese resistance to sanctions against Iran. Second, high energy revenues in the hands of oil exporting nations allow governments to act against their neighbors and the United States. For example, Venezuelan President Hugo Chavez has built support for his economic vision by subsidizing oil for neighboring countries and "gained leverage over them by purchasing bonds to finance their debt."[43]

The third problem is the fact that the oil market is not a free market. Governments of oil-rich states do not allow free market access to develop, exploit, and expand supply, and thereby effectively control the world's major oil reserves. As world demand for oil rises, these states are even less dependent on foreign investment for the development and exploitation of their resources, causing prices to increase even further since supply does not necessarily increase.

The enormous revenues governments generate in this way allow them, in some cases, to stifle democratic movements and suppress civil rights – a pattern which has been proven by policy experts time and again and in which the United States, as the world's leading oil consumer, has been a participant for many years. Governments in such states tend, for example, to use their revenues to relieve social pressures that might otherwise lead to demands for greater accountability from and representation in government. Or they spend excessively on police, internal security, and intelligence forces that can be used to contain opposition.[44]

Climate Change and Security

In order to remain a world leader, the United States must address the issue of manmade global warming and its root cause, the consumption of hydrocarbon-based fuels. After all, the international community has identified climate change as a threat to human life, ecological and political stability, and economic growth. At the same time, mitigation policy can provide an important avenue of engagement with both China and India—the other two large CO_2 emitters and emerging superpowers—and promises to strengthen U.S. national security at home and abroad.[45]

Hurricane Katrina demonstrated how an extreme weather event could kill and endanger large numbers of people, cause civil disorder, and damage critical infrastructure within the borders of the United States. And it may not remain an isolated incident. The 2007 report of the Intergovernmental Panel on Climate Change explicitly warns that coastal populations in North America, including 50 percent of U.S. citizens, will be increasingly vulnerable to climate change related events. A National Aeronautics and Space Administration simulation that includes a forty-centimeter sea-level rise over the next forty years and a category three hurricane found, for example, that large parts of New York City would be inundated under these conditions.[46]

Yet such severe weather events could strike sooner rather than later, and possibly have a direct impact on national security by damaging critical military assets today. A

University of South Florida simulation found that MacDill Air Force Base and U.S. Central Command (CENTCOM), the center of strategic operations in Iraq, would likely be inundated if a category three hurricane were to hit the region around Tampa Bay, Florida.[47]

Abroad, increasingly frequent extreme weather events could contribute to humanitarian disasters and create the possibility of large-scale refugee flows. Or they could contribute to state failures in destabilized regions of the world such as Indonesia and Africa. In China, a country marked by rapid social change and widening economic inequality, future instability is a realistic possibility – especially if rising sea-levels or storms threaten metropolises on the Chinese seaboard.[48]

Environmental Issues of Dependence on Hydrocarbons

The negative environmental impact of hydrocarbon use provides further incentives to reduce dependence on hydrocarbons. The effect of greenhouse gas emissions on climatic stability and air quality is of particular concern. Naturally occurring greenhouse gases (GHG) like carbon dioxide, methane, and nitrogen oxides, are entering the atmosphere in larger quantities due to human industrial and agricultural activities. Though GHG play a vital role in keeping the planet's surface warm by trapping heat from solar radiation, as the atmospheric concentration of these gases increases, warming will accelerate and the Earth's temperature will follow.[49]

This process has been accelerating for decades; global anthropogenic (human-caused) GHG emissions grew 70 percent between 1970 and 2004.[50] Increased levels of deforestation also compound the problem as trees, natural carbon dioxide consumers, are destroyed, thereby reducing the planet's ability to absorb the gas. While questions remain as to the rate at which the Earth's climate will change and the severity of those changes, evidence increasingly suggests that bold action will be required. According to the EPA, "if greenhouse gases continue to increase, climate models predict that the average temperature at the Earth's surface could increase from 3.2 to 7.2°F above 1990 levels by the end of this century."[51]

Hydrocarbons and the Greenhouse Effect

The three dominant hydrocarbon-based energy sources include natural gas, petroleum, and coal. Natural gas emits the least amount of carbon dioxide at 117 pounds per million Btu of energy. Petroleum and coal release different amounts of carbon dioxide depending on their chemistry. Liquefied petroleum gas emits less carbon dioxide than petroleum coke (139 and 225 pounds per million Btu respectively). Emissions related to coal vary from 205 pounds of carbon dioxide per million Btu for bituminous coal to 227 pounds for anthracite coal.[52] While carbon dioxide emissions resulting from the combustion of liquids (gasoline) and other petroleum products have slightly decreased since 1990 (42 to 39 percent), natural gas emissions are expected to stabilize at the current level of approximately 20 to 21 percent of all hydrocarbon emissions. Carbon dioxide emissions from coal, the most carbon-intensive of the hydrocarbons, are expected to increase from 39 percent of the world's carbon dioxide emissions in 1990 to 44 percent by 2030.[53]

The Intergovernmental Panel on Climate Change (IPCC) referenced a number of threats related to the increased warming of the Earth's climate system in its Fourth Assessment Report (2007). Short-term impacts like rising air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level will have major repercussions. Those near-term impacts, however, may pale in comparison to the longer term effects like weather change, water and food shortages, increased incidence of tropical diseases, ecosystem and species loss, and coastal changes whose likelihood increases with even small global temperature increases (Figure 2.4).

The IPCC goes further, stating that there is high agreement and much evidence that with current climate change mitigation policies and sustainable development practices, global GHG emissions will continue to grow over the next few decades, increasing by 25 to 90 percent between 2000 and 2030 if hydrocarbons maintain their dominant position in the global energy mix. Tundra biomes, mountainous regions, and Mediterranean-type ecosystems are likely to be particularly effected by climate change. Human health, in populations with low adaptive capacity, is also expected to be negatively effected, along with water resources in dry mid- and semi-arid low latitudes, agriculture in low latitudes, and low-lying coastal systems. Additionally, the world's oceans are becoming increasingly acidic as they absorb rising levels of carbon. Growing levels of ocean acidification are expected to negatively impact shell-forming organisms such as corals, as well as their diverse and numerous dependent species. Recent observations have shown the process already underway, and this loss of such a foundational element in the ocean's ecosystem has many scientists alarmed.[54]

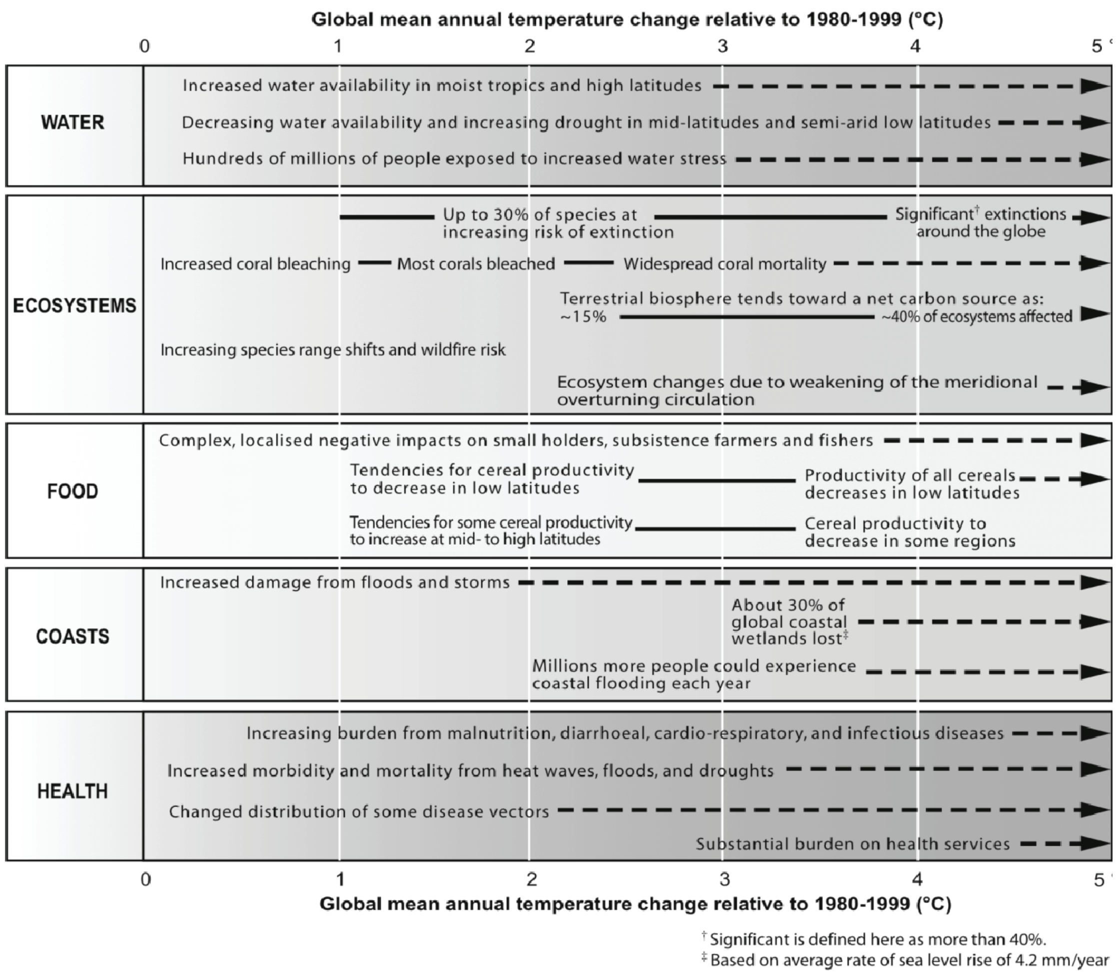
Other Environmental Risks of Hydrocarbons

Carbon dioxide emissions are just one of many threats to the environment from the continued reliance on hydrocarbons. The methods of extraction and chemical composition of hydrocarbons are also responsible for a variety of risks associated with hydrocarbon use.

Natural Gas: Even though natural gas emits lower levels of pollutants, its methane content and extraction procedures represent the main environmental hazards associated with its use. Methane (the main component of natural gas) is a potent greenhouse gas with an ability to trap heat almost 21 times more effectively than carbon dioxide. Though methane can leak from natural gas wells, pipelines, and storage facilities, it accounts for only 2.7 percent of total U.S. greenhouse gas emissions, a result of industry safety measures.[55] Potential harm to the environment from natural gas extraction is similar to that of petroleum in that extraction of the resource can involve the degradation of sizeable tracts of land with the additional concern of increased risks of gas leaks or explosions.

Petroleum: Exploration and drilling for oil does disturb land and ocean habitats, though new technologies have minimized the “footprints” associated with acquisition. Oil spills from ocean-going tankers, though infrequent, can cause significant harm to wildlife due to the large quantity of oil released. Leaking underground storage tanks or pipelines can contaminate local water supplies resulting in significant clean-up costs and health risks.

Figure 2.4
Impacts of Climate Change



Source: Intergovernmental Panel on Climate Change. *Climate Change 2007: Synthesis Report. Summary for Policymakers*. Online. Available: http://www.ipcc.ch/. Accessed: April 11, 2009.

Coal: Coal is widely considered the “dirtiest” energy source, and is the prevalent resource for many of the large industrialized countries such as United States, Russia, and China. The acquisition of coal through mining (by strip or mountain-top removal) poses its own environmental dangers. Both mining methods result in significant damage to the immediate land area, and the mandatory and stringent reclamation practices required to repair this damage have been lacking. The leakage of contaminated water, either highly acidic mine water or water from mine waste sludge ponds, into groundwater and rivers remains a significant health and environmental hazard. Acid rain, a little-understood phenomenon, is also believed to result from NO_x and SO_2 emissions released from coal-fired power plants. Acid rain is known to damage vegetation, lake ecosystems and marine animal life cycles, as well as manmade structures.[56]

The Scientific, Economic, and Political Consensus

Studies indicate that even after excess anthropogenic carbon dioxide emissions stop, the planet will continue warming for at least a thousand years, and the higher the atmospheric concentrations of carbon dioxide reached, the greater the level of irreversible consequences like species loss and sea level rise.[57] Since the combustion of hydrocarbons for energy is the primary source of human-caused emissions, world energy use remains at the center of debate.[58] Not only must the United States use different forms of energy like clean renewables, natural gas, and the co-firing of fossil fuels with biomass, but it is imperative that leadership and technology be provided for developing nations whose carbon dioxide emissions are expected to eclipse those of developed countries.

After the U.S. Supreme Court ordered a thorough scientific review of the potential threats due to GHG in 2007, the EPA issued their findings in April 2009. They stated, “in both magnitude and probability, climate change is an enormous problem. The greenhouse gases that are responsible for it endanger public health and welfare…” The review documented that concentrations of carbon dioxide, methane, nitrous oxide, and fluorinated gases are at unprecedented levels as a result of human emissions, and the high levels are very likely the cause of increasing average temperatures and other climate changes. Impacts like increasing drought, heavy downpours and flooding, more frequent and intense heat waves and wildfires, greater sea level rise, more intense storms, and harm to water resources, agriculture, wildlife and ecosystems are all likely to result from climate change.[59] The financial costs associated with mitigating and adapting to these negative effects will be enormous.

Although hydrocarbons have provided the dominant source of critical power and electricity for decades, noticeable changes in weather and the environment provide powerful evidence that a change is needed to preserve the quality of life for humans and the ecosystems on which we depend. Previous policymakers have understood this, yet have chosen not to act. The window of opportunity to enact legislation and begin a cultural shift that will minimize the impact of climate change is quickly closing. Innovative and bold vision is required to power the United States and the world with cleaner, sustainable energy.

Conclusion: The Case for Alternative Energy Technology

Hydrocarbons may have once been abundant and affordable, but are now recognized to have significant economic, geopolitical and environmental costs for the United States. U.S. dependence on depletable hydrocarbons is not sustainable indefinitely and, when combined with expectations of higher prices in the future, requires that the United States develop new energy technologies. Greenhouse gas emissions from hydrocarbons also threaten the United States with significant long-term costs, since mitigating and adapting to the negative effects of climate change will be extremely expensive. The present and future costs of hydrocarbon dependence provide a strong incentive to transform the national energy economy as soon as possible. Moving to a diverse mixture of alternative energy generation and distribution technologies will save the United States trillions of dollars in the long run by reducing both the economic and geopolitical costs of hydrocarbon dependence and the significant future costs associated with climate change.

Summary

- The United States requires large amounts of energy to sustain itself and lacks the ability to satisfy its own energy needs. Despite being endowed with an abundant and diverse energy supply, the United States is completely dependent on hydrocarbons to meet its demand for energy.

- Although future demand for energy will depend on economic growth, total demand for energy will continue to increase into the future. Population growth is expected to increase the demand for energy across all sectors of use, despite expected gains in energy efficiency.

- The balance of sources of energy supply and the division of energy consumption across sectors is not expected to dramatically change in the future. The United States is projected to still be dependent on hydrocarbons in 20 years.

- Energy is a fundamental input to all economic activity. The prosperity of the U.S. economy is dependent on the adequacy, affordability, and reliability of its energy supply.

- Hydrocarbons are finite resources that will eventually be depleted if used continuously. There are significant concerns over the adequacy and reliability of future supplies of hydrocarbons. The prices of all hydrocarbon energy sources are expected to increase in the long-term future.

- Dependence on hydrocarbons is sustained by costly imports of petroleum and natural gas. This produces a trade imbalance, in which energy imports exceed energy exports, that drains the US economy.

- Continued dependence on hydrocarbons threatens to compromise the strength of the U.S. military and presents the United States with several geo-strategic risks.

Enemies of the United States could exploit the fact that fossil fuels act as the enablers of U.S. military power and economic strength.

- Reliance on hydrocarbons strengthens authoritarian governments in exporting countries and will require the United States to compromise foreign policy objectives far into the future.

- The threats of resource depletion and climate change associated with the use of hydrocarbons presents further security risks for the United States.

- Global anthropogenic (human-caused) greenhouse gas emissions have grown 70 percent between 1970 and 2004, and are likely to continue to grow by 25 to 90 percent thru 2030 if hydrocarbons maintain their dominant position in the global energy mix.

- If atmospheric concentrations of greenhouse gases continue to increase, climate models predict the average temperature at the Earth's surface could increase from 3.2 to 7.2 °F above 1990 levels by the end of the century. These temperature increases will have a devastating impact on the natural and biological systems necessary to sustain life.

- According to the EPA's recently released findings, increasing drought, heavy downpours and flooding, more frequent and intense heat waves and wildfires, greater sea level rise, intense storms and harm to resources, agriculture, wildlife and ecosystems are all likely repercussions of climate change.

- Natural gas emits the least amount of carbon dioxide of all hydrocarbons and has fewer environmental hazards associated with it than petroleum and coal.

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Chapter 3. Alternative Energy Sources

Alternative energy technologies have become an important part of our national energy economy and their supply and role should continue to grow as the reduction of hydrocarbon emissions becomes increasingly urgent. Here, we evaluate 16 alternative energy sources with respect to three major policy areas: national security, the economy, and the environment. Included are the extent to which the technology reduces U.S. dependence on foreign resources and increases domestic energy supply, implementation costs and potential to stimulate economic growth, environmental impacts, and the current stage of technological development including barriers and externalities related to implementation. Of the 16 technologies, the first eight are ordered according to their current installed capacity in the United States. The final eight technologies are not yet sufficiently developed for use and are therefore organized according to their future potential to meet U.S. energy needs.

Wind

Humans have used wind energy to propel sailing vessels and power windmills for centuries. Today, wind energy can be used to spin the blades on a wind turbine and generate electricity (Figure 3.1). Individual wind turbines are commonly grouped together into onshore and offshore wind farms, which have great potential for electricity generation.

Figure 3.1
Wind Turbine Farm

Source: Texas Interactive Power Simulator (TIPS). Online. Available: http://tips.engr.utexas.edu.

Assuming no viable energy storage options, estimates suggest wind power could supply up to 20 percent of U.S. energy requirements.[1] With viable storage, wind power could meet all U.S. energy needs. Today, worldwide wind generation capacity is 94 gigawatts (GW).[2] The United States produces 17 of the 94 GW, with the largest concentration of wind turbines located in Texas.[3] Recent developments in wind turbine technology have led to larger single turbines, capable of providing much more energy per turbine than previous models.

Energy Independence and Security

The primary incentive for developing wind energy is that it is a domestic energy source that is not depleted over time or with use. It has the potential to be the sole energy source for U.S. energy requirements if energy storage can be developed successfully.[4] Using wind to offset energy imports (primarily oil) would, however, require the conversion of our automobile fleet to primarily electric vehicles. Small wind turbines can be used in large sections of the United States, aiding in efforts to decentralize electricity generation.

Economic Impact and Feasibility

Wind power is cheaper, on both capacity and production cost bases, than most other electricity generation technologies. Currently, wind turbines cost $1750 per kilowatt (kW) of installed capacity.[5] Electricity generated with wind turbines is also competitive at a cost of $10 per megawatt hour (MWh) generated.[6] However, significant costs arise with the extensive transmission infrastructure investment required to allow for the integration of wind power into the transmission grid given the remote locations where wind farms will be sited.

Environmental Impact

Wind power is attractive because of its minimal environmental impact. Wind turbines do not produce air emissions, particulate matter, or toxic waste streams and they do not use significant amounts of water. The land footprint of wind power is large, however, requiring 25 acres of land for every megawatt of capacity installed.[7] The operation of wind turbines can also lead to bird and bat deaths. Out of all bird fatalities by unnatural causes, less than 1 in 10,000 deaths are currently caused by a wind turbine. With increasing wind turbine installations, however, industry must be conscious of proper placement to ensure a minimal impact on animal populations.

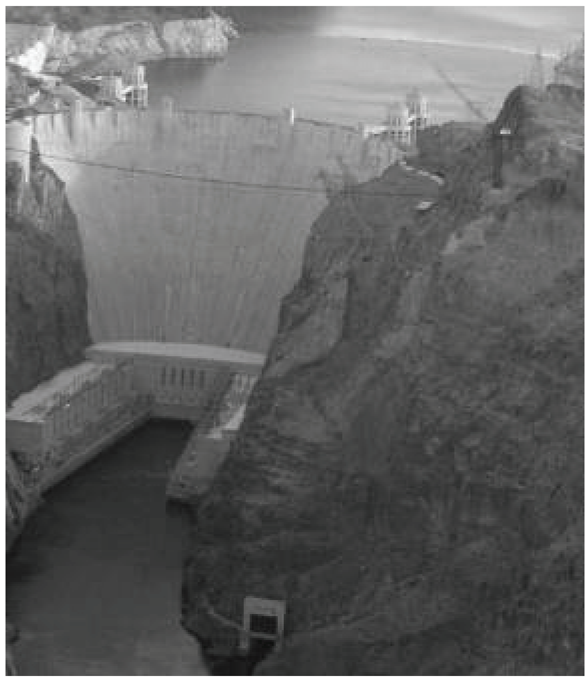
Potential Role and Implications

Wind power could potentially generate a large portion of U.S. energy requirements, primarily in electricity generation. Supplementing current methods of generating electricity with wind power could significantly reduce our dependence on coal power, eliminating many greenhouse gas emissions concerns. Extensive investment in the U.S. transmission infrastructure must occur in order to successfully implement large-scale wind generation. The extensive land use required for this level of implementation also presents an obstacle to the further development of wind power. Without the development of large-scale energy storage, wind intermittency could threaten grid reliability.

Hydroelectric

Hydroelectricity, produced when flowing water powers a turbine to generate electricity, is the most common form of renewable energy (Figure 3.2). It accounts for 6 percent of all U.S. electricity and approximately 71 percent of the electricity generated from renewable sources in 2007.[8]

Figure 3.2
Hoover Dam, a U.S. Hydroelectric Power Generation Facility



Source: Every Stock Photo, Hoover Dam. Online. Available: http://www.everystockphoto.com/photo.php?imageId=763524. Accessed March 27, 2009.

There are three types of hydroelectric plants: storage, run-of-river, and pumped storage facilities. Storage and run-of-river facilities are regarded as conventional hydroelectric technologies, which generate power using one-way water flow. Pumped storage plants, on the other hand, pump water from a low point to a higher reservoir for use during periods of peak demand.

According to the Department of Energy, U.S. hydroelectric capacity, including pumped storage facilities, is about 95,000 megawatts (MW)[9] and three states (Washington, California, and Oregon) account for more than 50 percent of that capacity.[10] Internationally, only China, Canada, and Brazil rival U.S. hydroelectric-generation capacity.[11] Currently, the DOE focuses on improving the efficiency of hydroelectric technology and reducing its environmental impact. As part of this effort, researchers are developing marine and hydrokinetic devices to capture energy from waves, tides, ocean currents, and the natural flow of water without building new dams or diversions.

Energy Independence and Security

Hydropower is an asset to energy independence since the plants create electricity using water, an abundant national resource. In addition, hydroelectric capacity can be ramped up quickly as demand rises, decreasing the likelihood of power outages. Development of small-scale (less than 10 MW) hydroelectric plants could also reduce the nation's reliance on centralized power plants and transmission systems. This electricity could also help lessen U.S. dependence on foreign oil once electrification of the transportation sector proceeds.

Economic Impact and Feasibility

Hydroelectric generating plants are limited to areas with adequate water supply. The average cost of constructing a plant is $1,551 kilowatt hour (kWh) (2006 value),[12] with average operations and maintenance cost of $13.59 kWh (2006). Existing regulations are a significant economic obstacle to developing a hydroelectric power plant as licensing typically costs between $150,000 and $1 million (EIA) per plant and takes 8 to 10 years.[13]

Due to these factors, energy analysts expect there will be no increase in hydroelectric capacity over the next 10 years.[14] Consequently, few jobs will be generated in this area. Emerging hydroelectric technologies, such as *hydrokinetic and wave energy conversion devices*, offer potential ways to produce electricity with the help of running water but without building large dams.

Environmental Impact

Though hydropower does not directly produce greenhouse gases, it does negatively impact the environment. Power plants affect migratory patterns of fish and other aquatic life. Without aids such as fish ladders, fish cannot move past dams and other barriers. Hydropower plants also deoxygenate the water, potentially harming aquatic and riverbank wildlife. Ultimately, the environmental impact has to be determined case by case by examining the location of the plant, the type and size of the project, as well as the existing ecological habitats and climatic conditions.[15] While major accidents involving hydroelectric plants are rare, their impact can be devastating and cause thousands of deaths.[16]

Potential Role and Implications

Hydroelectricity is a mature technology compared to other renewable energy technologies and hydroelectric plants are the most efficient of all major types of power plants, converting as much as 90 percent of the available energy into electricity.[17] Due to cost and environmental concerns, however, large-scale hydroelectricity is less likely to play a role in the U.S. energy technology transition. On the other hand, small hydro projects, with capacities ranging from 1 MW to 30 MW, have potential for growth. In 2006 the DOE identified 5,677 potential sites for hydropower projects across the country with an undeveloped capacity of 30,000 MW.[18] Making existing power plants more efficient could further increase the total capacity of hydroelectric energy nationally. An improvement of only 1 percent would supply electricity to an additional 300,000 households.[19]

Biomass

For centuries, humans have used biomass (bioenergy), the energy from plants and plant-derived materials, for food preparation and warmth.[20] Wood continues to be the most utilized bioenergy resource, but food crops, grassy and woody plants, residues from agriculture or forestry, and the organic components of municipal and industrial wastes (MSW) can also supply energy.[21] Biopower, biomass-generated electricity, uses a number of technologies: direct-firing, co-firing, gasification, pyrolysis, and anaerobic digestion.[22]

The majority of biopower plants use direct-fired systems. This system produces steam by burning raw materials; the steam drives a turbine that converts the energy into electricity. Some biomass producers use the leftover steam for manufacturing or space heating, increasing energy efficiency.[23]

Co-firing technology combines biomass materials with fossil fuels in conventional power plants. Coal-fired power plants that use co-firing systems reduce sulfur dioxide emissions.[24] In fact, biomass feed stocks replace up to 20 percent of the coal used in boilers. These systems not only reduce harmful emissions but also result in lower operating costs. In 2000, the Chariton Valley Biomass Project, involving Alliant Energy, the DOE, and local biomass groups, began co-firing tests using switch grass and coal at Alliant's Ottumwa Generating Station in Iowa. Due to the project's success, in 2005, Alliant obtained permission to build a permanent biomass processing facility at the plant.[25]

Gasification systems use an oxygen-limited environment with high temperatures to turn biomass into synthetic gas. The result, "syngas," can be chemically converted into other products, burned in conventional boilers, or used instead of natural gas to power a turbine.[26]

Using a process similar to gasification, the pyrolyzation of biomass involves the total exclusion of oxygen to convert feed stocks into liquids as opposed to gases. Pyrolysis oil can be burned to generate electricity, or used in chemical processes for making bioproducts.[27]

Anaerobic digestion uses naturally occurring bacteria to decompose organic material in closed reactors devoid of oxygen. The result is waste material that can be converted to compost and gases fit for use in power production.[28]

Energy Independence and Security

Biomass is a renewable resource that can be used for both electricity generation and fuel. Because it is produced domestically, U.S. demand for imported oil is reduced, as is the country's exposure to supply disruptions.[29] Gasification, anaerobic digestion, and other biomass power technologies can be used in small, modular systems. These could prove useful in moving towards decentralized energy generation, providing electrical power to areas not connected to the electrical grid.[30]

Economic Impact and Feasibility

Due to the wide variety of feed stocks and conversion processes, determining a cost for biomass energy is difficult. It is most economical to use biomass locally, as it avoids expensive and energy-intensive transportation. Generally, biomass plants have higher capital and operation/maintenance costs than fossil fuel plants. Additionally, their power output efficiencies are lower, resulting in higher fuel costs. More efficient gasifier technologies are expected to boost output efficiencies.

Conventional biomass combustion costs can range from $0.06 to $0.12 per kWh. Co-firing biomass with coal is much cheaper, however, because the power plant is already built and costs are primarily related to the biomass fuel and its preparation. Co-firing system costs can be between zero and $0.04 per kWh where biomass is 10 to 15 percent of the total fuel input of the power plant. The cost of landfill gas electricity generation can range from $0.035 to $0.079 per kWh.[31] The International Energy Agency (IEA) estimates the capital cost of co-firing systems to be $1,100 to $1,300 per kW. The capital cost of gasification systems that include combined heat and power, however, is estimated at $3,000 to $4,000 per kW.[32]

Farmers and rural areas will reap the benefits of increased demand for and use of biomass resources. Currently, biomass supports 66,000 jobs in the United States. The DOE predicts that advanced technologies under development will help the biomass power industry install over 13,000 MW of power by 2010, creating an additional 100,000 jobs.[33]

Environmental Impact

Although burning biomass materials releases carbon dioxide equivalent to that from hydrocarbons, emissions released from fossil fuels are considered "new" greenhouse gases because they were created and stored millions of years ago. The carbon dioxide release associated with biomass, on the other hand, is considered neutral because the emissions released are relatively equal to the carbon dioxide absorbed during the plant's growth. This balance depends, however, on the amount of energy that was used to grow, harvest and process the material.[34]

Pollutants like sulfur dioxide and nitrogen oxides are significantly reduced by burning biomass instead of hydrocarbons. Water pollution is reduced when using "energy crops" because fewer fertilizers and pesticides are required. Energy crops like trees and grasses can be grown in very large quantities and are typically native to the region. Soil quality is actually improved if energy crops are used instead of high-yield food crops that leach soil nutrients. Biomass crops are also considered better wildlife habitat than food crops, and the wider time window for harvesting allows nesting or breeding seasons to be undisturbed.[35] The reduced use of landfills and the enhanced use and treatment of human and animal wastes are additional advantages of biomass energy production.

The benefits of biomass crops are largely in comparison to the use of food crops like wheat, corn, and soybeans. When comparing land use dedicated to biomass with undisturbed natural habitat, biomass is less appealing. While it is much closer to "nature" than current industrial agriculture, the environmental benefits of biomass depend largely on whether energy crops are managed sustainably.[36]

Potential Role and Implications

For the United States, biomass is the fourth largest energy resource after coal, oil, and natural gas, and the second largest renewable electricity source (14.6 percent) after hydropower.[37] Researchers estimate that approximately 278 quadrillion Btu of installed biomass capacity exists worldwide.[38] According to the EIA, the United States consumed more than 3.4 quadrillion Btu of biomass energy in 2006 compared with other renewable energies like geothermal (0.34 quadrillion Btu), hydroelectric (2.87quadrillion Btu), solar (0.07 quadrillion Btu), and wind (0.26 quadrillion Btu).[39] The United States is the largest biopower producer with more than half of the world's installed capacity. There are approximately 7,800 MW of biomass power capacity installed at more than 350 locations.[40]

Biomass has the potential to be deployed in small-scale, decentralized applications as well as functioning as an integral component in large-scale co-fired coal plants. It is not limited geographically, only by the cost of transporting and storing the materials. Estimates of the ultimate potential for biomass energy vary, however. The DOE estimates that energy crops and crop residues alone could supply as much as 14 percent of U.S. power needs.[41] Global electricity production from biomass is expected to increase from its current share of 1.3 percent to between 3 to 5 percent by 2050. According to the IEA, co-firing is expected to remain the most efficient use of biomass for power generation.[42]

Geothermal Energy

Geothermal energy is heat generated from the earth; this energy can be harnessed by geothermal energy plants (Figure 3.3).[43] In the United States, geothermal technologies generate electricity and supply heating and cooling. Geothermal applications rely on three important conditions: heat, fluid supply, and ground permeability. "Ideal conditions" include: high-level heat flow in close surface proximity, permeable and porous rock, ground composition with optimal fluid saturation and recharge rates, and the absence of volcanic activity.[44] Due to the scarcity of wells possessing all four criteria, geothermal industries typically use the following three hydrothermal power applications to produce electricity, either singly or in combination:

- Dry steam – A direct, open system application in which hydrothermal fluid is transported directly to a rotating turbine.
- Flash steam – A closed-system application in which high temperature, high pressure hydrothermal fluids are sprayed into a low-pressurized tank, causing the fluid to vaporize instantaneously and drive the electrical generator.
- Binary cycle power – This application harnesses energy from moderate temperature wells (194°F to 347°F) by combining hydrothermal fluid and a secondary fluid with a lower boiling point than water into a heat exchanger. The secondary fluid vaporizes rapidly and drives the turbine.

Figure 3.3
Geothermal Plant in Iceland

Source: Every Stock Photo, Nesjavellir Geothermal Plant. Online. Available: http://www.everystockphoto.com/photo.php?imageId=516530. Accessed March 27, 2009.

Heating/cooling technology can be implemented in two ways. Direct-use applications tap low and moderate temperature wells that deliver geothermal fluid to a target site; after delivery, the cooled fluid is reinjected into the ground. Ground source heat pumps are closed, subterranean systems in which heat is either absorbed or transferred into the ground through a series of mechanisms, providing space heating and cooling, and water heating to residential and commercial locations.

Energy Independence and Security

Geothermal energy is a renewable, domestic resource that relies upon underground heat, a replenishing base load energy source. Hydrothermal plants and heating/cooling systems are constructed in close proximity to geothermal wells. Consequently, increasing geothermal energy capacity would strengthen U.S. energy security because it generates heat and electricity locally, reducing dependence on centralized power plants and transmission systems.

Economic Impact and Feasibility

According to the 2005 Geothermal Industry Employment Survey, achieving 5,600 MW of production would provide 9,580 full time jobs and 36,064 full time manufacturing and construction jobs.[45] Geothermal energy, however, is site-specific and disproportionately concentrated in the western half of the United States, including Alaska and Hawaii. According to the DOE, the costs associated with the construction of a geothermal plant are slanted toward the initial investment rather than operational expenses.[46] The initial cost of installation and deployment is approximately $2,500 per installed kW.

Geothermal energy generates power at a cost between $0.05 and $0.10 per kWh.[47] Furthermore, the construction of geothermal reservoirs does not guarantee economic viability. Fluid exiting a wellbore must have a temperature and flow rate either equal to or superseding a designated threshold. Consequently, a reservoir constructed under less than optimal conditions can either cease to generate sufficient heat or require the drilling of multiple reservoirs.

Environmental Impact

Geothermal resources require minimal land use, emit virtually no pollutants, and release fewer quantities of greenhouse gases into the atmosphere than coal or natural gas. According to the 2009 Geothermal Technologies Program (GTP) Report, geothermal power plants emit 35 times less carbon dioxide than the average coal power plant per kilowatt hour of electricity produced.[48] In 2008, the EIA reported that dry steam plants such as the Geysers in California, emitted approximately 90 pounds of carbon dioxide per MWh while flash plants emitted about 60 pounds of carbon dioxide per MWh.[49] Emissions, however, can be eliminated through the installation of a closed loop binary system or by reinjecting cooled hydrothermal fluid into underground reservoirs in accordance with EPA standards. Geothermal plants often generate toxic sludge rich in zinc, sulfur and silica that requires proper disposal in approved sites, and research and development is required to maximize the effectiveness of existing waste management techniques.

Potential Role and Implications

According to the Geothermal Energy Association (GEA) in 2008, the United States remains the world leader in geothermal online capacity, totaling 2957.94 MW or 30 percent of total world capacity.[50] Seven states currently operate hydrothermal power plants: Alaska, California, Hawaii, Idaho, Nevada, New Mexico, and Utah. A 2005 U.S. Geological Survey (USGS) assessment of moderate and high temperature geothermal sources showed the United States has a combined installed and utilized power capacity of 2,500 MW and approximately 15,000 GW of generated power, totaling 25 percent of domestic, non-hydroelectric renewable energy.[51] The mean estimated power production for undiscovered resources is 30,033 MW and approximately 517,800 MW in areas identified as high temperature, low permeability sites.[52]

Solar

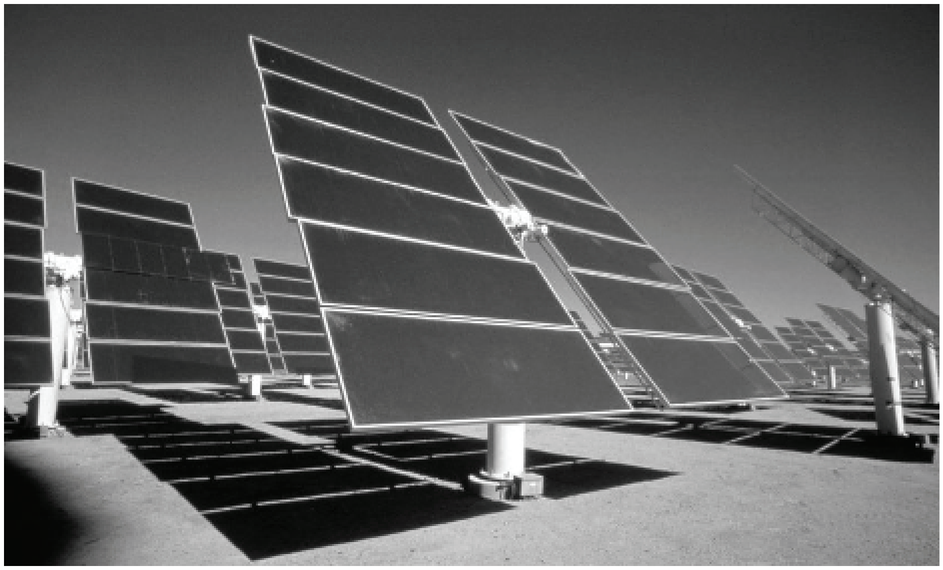
Solar energy technologies convert the sun's energy into electricity (Figure 3.4). There are currently two different technologies used to convert energy from the sun into electricity:

- Photovoltaic cells (PV) – PV technology uses solar cells made of silicon or other materials, packaged in photovoltaic modules. When the sun's photons strike a PV cell, the impact breaks off electrons in the silicon, which move to the top of the PV cell's silicon layer and along metal conductors to wires that feed the electrical current to a converter box.

- Concentrating solar power (CSP) – CSP technology uses mirrors to concentrate solar heat into a PV module or some form of conducting material (e.g., oil, molten salt) that can be piped through a water source to turn a steam-powered turbine. There are three types of CSP systems: parabolic troughs, power towers, and dish sterling. CSP systems are often used for large-scale power generation and are currently more cost-efficient and have higher maximum electrical conversion efficiencies than PV methods.[53]

In the United States, PV capacity has grown slowly since the technology's introduction in the 1970s. Recent federal PV installation incentives, however, have helped to make solar PV the fastest-growing renewable energy source in the United States.[54] Grid-tied PV capacity has more than doubled in the past two years in the United States, from roughly 60 MW at 6,231 installations in 2005 to 150 MW at 12,714 installations in 2007.[55] Domestic CSP development is beginning to accelerate after a 15-year lull in new capacity. Two large solar plants were opened in 2007: ACCIONA's 65 MW Nevada Solar 1 parabolic trough plant and the DOE's 14 MW PV plant at Nellis Air Force Base, Nevada; additionally, 4,000 MW in new CSP projects were planned in 2007.[56]

Figure 3.4
Photovoltaic Solar Cells



Source: NewsGroper. Online. Available: http://www.newsgroper.com/files/post_images/solarpower.jpg.. Accessed March 27, 2009.

Energy Independence and Security

Solar energy is an abundant resource in the United States, especially in western states with large tracts of public land. Because solar electricity would likely replace coal and natural gas, two abundant domestic natural resources, it does not directly decrease U.S. dependence on foreign natural resources in the short term. Once the large scale electrification of the transportation sector proceeds, solar energy will help decrease the demand for foreign energy. Until then, solar electricity is more likely to reshape the domestic energy economy by replacing and/or expanding upon traditional hydrocarbon methods of electrical generation. It faces particular challenges as an intermittent energy resource, however, as energy storage techniques are not yet sufficiently advanced to guarantee base-load power periods of limited sunlight and high electricity demand. Solar photovoltaic technology already strengthens U.S. energy security as it generates electricity locally, reducing reliance on centralized power plants and transmission systems. As PV installations become more commonplace throughout the country, this effect will only increase.

Economic Impact and Feasibility

Cost is a barrier to implementation for solar electric technologies. Excluding government incentives or subsidies, rooftop solar PV generating costs ranged from \$0.20 to \$0.40 per kWh in low-latitude, sunny areas (2,500 kWh/m^2/year) to \$0.50 to \$0.80 per kWh in higher-latitude, cloudier areas (1,000 kWh/m^2/year).[57] Solar CSP generating costs without incentives average $0.18 per kWh.[58] Thus, the most cost-effective solar PV generating is $0.10 to $0.20 more per kWh than average residential, commercial and industrial retail prices for electricity of $0.1147/kWh, $0.1013/kWh, and $0.706/kWh respectively.[59] The price of solar CSP generating without incentives, in contrast, is $0.08 to $0.10 above retail costs.

Experts believe that CSP generation will achieve commercial viability at $0.10 per kWh. Cost reductions in both PV and CSP solar electricity will require the emergence of domestic plant and installation parts manufacturers, economies-of-scale benefits at larger plants, and efficiency improvements through continued research and development. With long-term incentive guarantees from the government, solar manufacturing and distribution could contribute 62,000 new jobs by 2015 as well as stimulate commerce in trade industries (e.g. electricians, plumbers, roofers, designers, engineers).[60]

Environmental Impact

Solar on- and off-grid PV systems are attractive because of their minimal environmental impact. They are zero-carbon emissions systems requiring very little physical space with limited impact on their surroundings. The significant land area needed to develop large-scale CSP systems has been the top environmental concern among conservationists. The Federal Bureau of Land Management has received 80 proposals to build solar plants in California alone, requests that would involve 700,000 acres of desert land.[61] Opponents say that PV capacity is the preferred expansion method because it can be introduced in urban areas, thereby conserving federal desert wilderness.[62]

Potential Role and Implications

A 2002 National Renewable Energy Laboratory (NREL) study suggested that the expansion of 130 square miles of parabolic trough capacity in the western United States could provide enough electricity to replace all other fuels and technologies, including coal, oil and gas, nuclear, and hydropower in 15 U.S. states.[63] Today's PV installations are practical for large, small, on-grid, or off-grid applications, increasing their attractiveness to those residing in places with restricted land area (e.g., cities) or limited sunlight (e.g., eastern and southern United States). Substantial start-up costs of new CSP plants and small residential or commercial PV systems and their energy storage units pose the largest implementation challenge. Lowering operating costs, increasing operating efficiency of PV cells and solar thermal generating technologies, and finding cost-effective energy storage solutions are the industry's primary goals today. Although cost-effective energy storage is the greatest challenge to CSP deployment, this obstacle will likely be overcome and enable the industry to build intermediate-load capacity in less than 5 years, and base-load capacity in 5 to 15 years with proper deployment support.[64] Future prospects for development should increase due to the 8-year extension of the investment tax credit for solar installations for consumers and businesses (including public utilities) provided through the Energy Improvement and Extension Act of 2008.

Nuclear Fission

Fission is the process of splitting a heavy atom into two lighter atoms. Nuclear reactors initiate fission when a neutron collides with the nucleus of a heavy element, usually uranium. The uranium atom captures the neutron and becomes an unstable isotope, splitting into two lighter elements and emitting radiation. Energy is released, proportional to the difference in mass between the reactants and the products. This relationship between mass and energy is reflected in Einstein's famous equation $E=mc^2$, where "E" is energy, "m" is mass, and "c" is the speed of light. The energy radiated from the fissile material is used to generate steam to power turbines that produce electricity.

Currently, about 20 percent of U.S. electricity generation comes from the 104 active nuclear power plants (Figure 3.5).[65] While there have been no new plants in 30 years[66] and more than 100 proposed facilities have been canceled, companies have announced plans to construct an additional 24 reactors.[67] There are no regional or geological requirements for a nuclear power plant other than access to transmission lines and public willingness to allow nuclear power in the area.

While nuclear power is a mature and commercially viable technology, there are many areas of continued development. Breeder reactors, a special kind of reactor that produces more usable fuel than it originally consumed, have been in service since 1951.[68] They have not, however, been scaled up to meet energy demands due to "technical, economic, and regulatory problems," including President Carter's ban on reprocessing due to fear of nuclear weapon proliferation.[69] Carter's ban expired in 1995 and the DOE has since sought "proliferation-resistant" processes.[70] Thorium fueled reactors, which produce less radioactive waste than uranium, are in development in Canada and India.[71] Finally, the United States has yet to solve the problem of nuclear waste storage. The United States is proceeding with development of the Yucca Mountain waste storage site, but it remains controversial and still requires enormous investments to complete site preparations.[72]

Dr. Steven Biegalski, the director of the Nuclear Engineering Laboratory and professor in the Radiation Engineering Program at The University of Texas at Austin stated:

> "The U.S. has the resources and the technology for nuclear power. We are not reliant on other nations for this source of electricity. From a national security perspective, it is a double-edged sword. On one hand, nuclear power could reduce our dependence on oil in a cost effective and safe manner. On the other hand, nuclear technology could be used by rogue individuals, groups and countries for non-peaceful purposes."[73]

Figure 3.5
Nuclear Fission Power Plant

Source: Every Stock Photo, *Nuclear Power Plant in Ohio.* Online. Available: http://www.everystockphoto.com/photo.php?imageId=714554. Accessed March 27, 2009.

Energy Independence and Security

Nuclear energy could advance U.S. energy independence if coupled with energy storage systems to fuel transportation needs, such as charging batteries or producing hydrogen. Uranium is the required fuel for nuclear power plants, however, and, although deposits exist in the United States and other friendly nations, the largest uranium mines are located in Canada.[74] Opponents of nuclear energy also cite increased risks of nuclear weapon proliferation as the United States pursues the waste-reducing and more efficient technique of fuel reprocessing.[75] Lastly, nuclear power plants would tend to centralize domestic energy production, creating high profile terrorist targets and limiting U.S. progress towards a more secure decentralized energy system. Extensive security protections put in place to prevent radiation leaks or reactor meltdowns do help mitigate those risks.

Economic Impact and Feasibility

The primary economic barrier to nuclear energy is the initial building cost, which ranges between $3 and $14 billion, depending on the size and design of the reactor.[76] Considering the full lifecycle, nuclear energy costs about $5,000 per kW.[77] Once a plant is built, however, it has extremely low operation and maintenance costs. The Energy Policy Act of 2005 (EPAct 2005) also provides a Nuclear Production Tax Credit of $0.018 per kWh for up to 6,000 MW of new nuclear capacity for the first eight years of operation, up to $125 million annually per 1,000 MW.[78] There is also Regulatory Risk

Insurance to help cover costs due to delays in construction or permitting and loan guarantees that can cover up to 80 percent of plant construction costs.[79]

According to the EIA's *Assumptions to the Annual Energy Outlook 2006*, a nuclear power plant's capital costs equal $1,913 per kW, the fixed operations and management costs are $61.82/kW per year, and the variable operations and management costs are $0.045 per kWh.[80] The Congressional Research Service (CRS) estimates the break-even point for nuclear power capital costs versus coal-fired facilities initiated in 2015 at about $1,370 per kW of capacity. Under base case conditions, it seems unlikely that a new nuclear power plant would be constructed in the United States, barring a sustained, long-term increase in natural gas prices and the creation of a substantial, mandatory greenhouse gas reduction program that would increase coal-fired and natural gas-fired generating costs.[81]

On average, a nuclear power plant costs $0.017 per kWh to operate, as of 2005.[82] A nuclear reactor can constantly run at full capacity without costing much more in fuel compared to natural gas or coal plants.

Environmental Impact

Public perception of nuclear reactors is often driven by fear of accidents like those that occurred at Chernobyl and Three Mile Island. While the meltdown at Chernobyl was a catastrophe, the plant did not employ the safety features currently found on all U.S. reactors. The Three Mile Island incident was contained and resulted in no casualties. In fact, there have been no deaths associated with commercial nuclear power plants in the United States.[83]

Nuclear energy leaves a relatively small physical footprint compared to other alternative energy technologies, and produces no carbon emissions other than in the mining of the fuel and construction of the facilities.[84] This has lead Patrick Moore, co-founder of Greenpeace, to become a vocal proponent of nuclear energy over other technologies.[85] Nuclear power is, however, more water intensive than hydrocarbon-based plants.[86] If public perception changes and political opposition is reduced, then nuclear energy can replace carbon intensive generation sources like coal and natural gas.

The primary environmental concern is the mining of uranium and the disposal of radioactive waste. To address these concerns, countries such as France reprocess their spent uranium fuel, which reduces both the amount of nuclear waste and the demand for more mined uranium.

Potential Role and Implications

Patrick Moore stated, "It is not possible to reduce fossil fuel consumption by relying on renewables alone. It can only be done by including nuclear energy in the mix and by increasing its share of total energy production."[87]

Fission has the potential to meet a large percentage of U.S. electricity demand. Although nuclear energy is a valid choice for supplying the base load power for an electric grid, it is important to maintain consistent levels of production during high and low usage periods. Proponents also have to deal with negative public perceptions, high building costs, and the potential build up of radioactive waste. Recent announcements describing planned construction of 24 new plants indicate the incentives are in place for an expansion of nuclear energy in the United States. As of November 2008, U.S. capacity was 100.266 million kW and net generation was 732,692 million kWh, accounting for 19.4 percent of electricity generated.[88]

Biofuels

Biofuels refer to fuels derived from recently deceased biological material.[89] Biofuels developed from biomass can be formed into a gas, liquid, or solid and used as an electricity source or transportation fuel. Liquid biofuels are considered most useful as they may substitute for, or supplement, gasoline as a fuel in the transportation sector (Figure 3.6), thereby reducing U.S. dependence on foreign energy resources.

Biofuels first moved into the energy spotlight in 1973 during the OPEC oil embargo.[90] They were believed to be a useful fuel source that could guarantee U.S. energy security and independence. When the oil embargo ended, however, attention faded. Not until the late 1990s did biofuels regain financial and political attention as a renewable energy source.[91] The Energy Independence and Security Act of 2007 (EISA 2007) stipulates that of all liquid transportation fuels used in the United States in 2022, 36 billion gallons must be biofuels and up to 15 billion gallons of this amount can be corn-based ethanol.[92]

The two most common forms of liquid biofuels are biodiesel and ethanol. Biodiesel is manufactured for use in petroleum-based diesel engines while ethanol is used in gasoline engines.[93] The E10 blend (10 percent ethanol, 90 percent gasoline) is the most common though other blends exist, including E85 (85 percent ethanol, 15 percent gasoline) and E100 (100 percent ethanol). While B20 (20 percent biodiesel, 80 percent mineral diesel) is the most common blend of biodiesel, pure biodiesel (B100) is becoming more readily available.[94]

Both biodiesel and ethanol are produced from carbon-based feed stocks. Biodiesel is made from oilseeds, animal fats, and vegetable products. Ethanol, the most widely used biofuel worldwide, is an alcohol primarily produced from biomass high in sugar and starch content, such as corn and sugarcane.[95] Methods to develop ethanol from other feedstocks such as algae or cellulosic materials are undergoing research.[96] The European Union dominates the production and use of biodiesel while the United States and Brazil produce the highest amounts of ethanol.[97]

Figure 3.6
Biofuel-Powered Bus

Source: Every Stock Photo. *BioBus*. Online. Available:
http://www.everystockphoto.com/photo.php?imageId=2377348. Accessed March 27, 2009.

Energy Independence and Security

Biofuels may reduce U.S. dependence on foreign oil. The United States can produce biofuels domestically as well as import feed stocks and fuels from "friendly" countries. Biofuels, however, are unable to satisfy current and mid-term U.S. transportation energy needs. Though the Renewable Fuel Standards Act establishes a target of 36 billion gallons of ethanol by 2022, this represents less than 20 percent of current U.S. transportation energy use.[98] Only by increasing the amount of land dedicated to growing feedstock for biofuels or improving biofuel technology (realizing other feedstock sources) can the United States become independent of foreign oil.

Economic Impact and Feasibility

The cost of biofuels largely depends upon the type of feedstock. In 2002, corn feedstock comprised 57 percent of the total production cost of corn-based ethanol, while soybean oil made up 70 to 78 percent of the total production cost of soybean oil-based biofuels.[99] When crop prices are stable and the blenders' tax credits are factored in to the cost equation ($0.51 per gallon of ethanol and $1.00 per gallon of biodiesel), biofuels are economically competitive with petroleum based on volume.[100] A higher volume of biofuels, however, is necessary to achieve the same capacity of energy; E85's energy content is only 74 percent of that found in petroleum.[101]

Though biofuels are financially competitive with petroleum, the United States cannot produce the equivalent amount. Studies indicate that up to 16 billion gallons of ethanol can be produced from corn in 2015 without affecting its price or upsetting export markets.[102] Yet in 2005, the United States consumed 3.904 billion gallons of ethanol, the equivalent of only 2.85 percent of all transportation fuels.[103] Even assuming no increase in energy demand, 16 billion gallons of E85 would provide merely 7 percent of U.S. transportation energy needs.[104]

The EIA estimates that the cost of providing infrastructure to established gasoline stations for distribution of E85 (85 percent ethanol) and B100 (100 percent biodiesel) ranges from $22,000 to $80,000 per retrofitted filling station.[105] The infrastructure cost for a new station is no more than that of a new petroleum-only station.[106]

One organization in the biotechnology industry reported that up to 800,000 new biotechnology jobs could be created by 2022 in the area of advanced biofuels.[107] Another organization suggested that up to 1.18 million new jobs in all sectors could be created by 2022 as a result of expanding the ethanol industry.[108]

Environmental Impact

The full lifecycles of biofuels must be assessed in order to determine their environmental impacts, including the types of feedstock used, the processes used to develop the land, the biodiversity lost, and operational emissions of the end-vehicles.[109] The current policies driving both the European Union and United States to increase the percentage of biodiesel and ethanol are contributing to deforestation by slash and burn methods in other countries. The European Union imports palm oil intended for biodiesel production primarily from Malaysia and Indonesia.[110] In 2002, 48 percent of new palm oil plantations in these two countries involved forest destruction resulting in loss of biodiversity, nitrous oxide emissions, and water pollution.[111] Similarly, much of Brazil's 14 million acres of sugarcane was planted on land that was once forest, contributing to biodiversity loss and increased carbon dioxide emissions.[112]

The United States increased corn acreage from 79 million acres in 2006 to 90 million acres in 2007, displacing soybean fields and other crops.[113] Of this land, approximately 20 percent is dedicated to ethanol production. This increase has contributed to the disappearance of wetlands, the decline of conservation land in Nebraska, and an increase in local water consumption.[114] Approximately 3-4 gallons of water is required to produce one gallon of ethanol.[115] One acre of corn yields 370 gallons of corn-based ethanol.[116]

Current lifecycle assessments estimate that corn-based ethanol creates 19 percent fewer greenhouse gas emissions than the gasoline standard.[117] Biofuels made from liquid manure and biodiesel made from waste cooking oil emit 50 percent less when compared to gasoline.[118] Because the largest percentage of greenhouse gas emissions results from agricultural cultivation, biofuels made from waste materials provide the greatest environmental benefits.[119]

Potential Role and Implications

Biofuels will play an important role in the future of transportation in the United States. Investments in biofuels represent a move away from dependency on oil and a decrease in greenhouse gas emissions. The strength of biofuels in the future largely depends upon new advances in next generation feedstocks. One option is ethanol produced from cellulosic feedstocks, which not only produce lower greenhouse gas emissions, but also have a higher net energy value than corn-based ethanol. Table 3.1 compares these advanced feedstocks. Cellulosic ethanol also allows for diverse crop systems supporting relative biodiversity.[120] However, it is not yet commercially viable. More research, development and investment must be completed before biofuels can displace a significant percentage of foreign oil.

Table 3.1
Advanced Biofuel Feedstocks

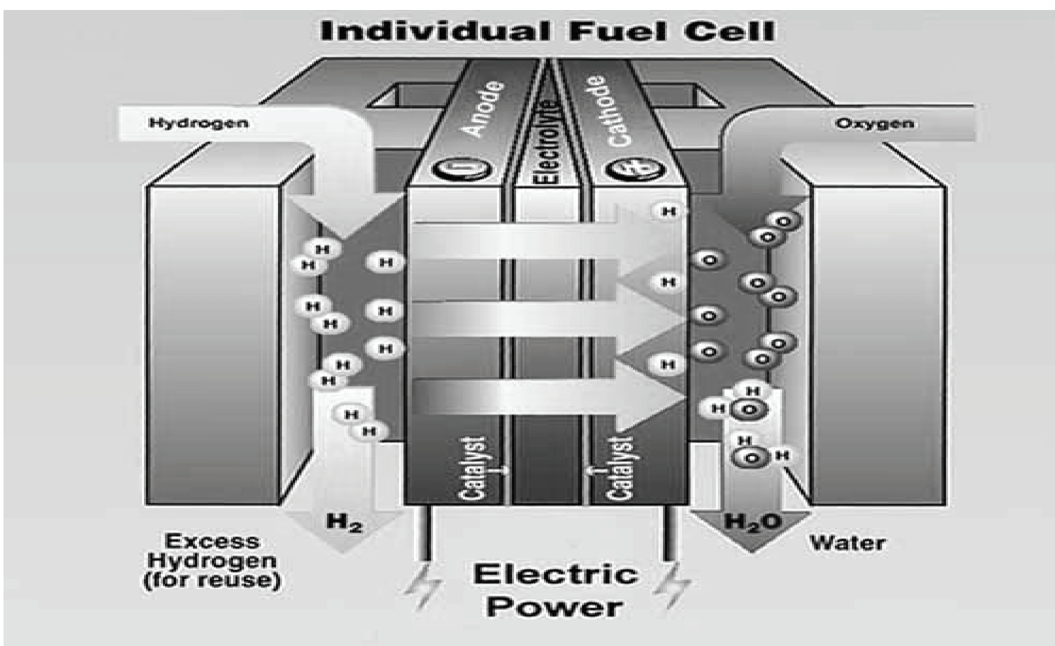
Feedstock	Pros	Cons	Viability
Mixed Prairie Grasses	• Offers biodiversity benefits • Higher biomass yields • Yields more energy than monoculture systems • Users water and nutrients more efficiently than first generation fuels • Reduces greenhouse gases	-	• It is uncertain when mixed prairie grasses will be economically viable
Jatropha	• Can survive extreme drought and poor growing conditions • Requires little maintenance • Easily modified into biodiesel	• Requires significant amounts of water • May replace native vegetation and decrease biodiversity	• Investments are increasing in Africa, India, Indonesia, and China • Projects are being funded by the energy industry
Sweet Sorghum	• Does not require conversion from starch into sugar • Can be used as both food and fuel without competition	• Cannot be stored as long as other feedstocks, so must be converted into ethanol quickly	• It is not yet economically viable • Developments are under way to produce a hybrid crop, thereby increasing viability
Algae	• Leaves a small environmental footprint • Yields a high quantity of biomass per acre • Can utilize CO_2 emissions from coal-fired power plants	• Requires high amounts of nitrogen and phosphorous to survive • Requires intensive management to maintain growth	• It is not yet economically viable • It is uncertain whether algae will be appropriate for large-scale productions

Hydrogen

Hydrogen is the most abundant element, constituting approximately 75 percent of the universe's elemental mass. Not a source but a carrier of energy, hydrogen exists as a gas at normal temperatures and pressures. In this form, hydrogen has the highest energy content by weight of any fuel and the lowest energy content by volume. Fuel cells can convert this energy into electricity (Figure 3.7). DOE materials[121] describe the process, which creates water as a byproduct, as follows:

> "Hydrogen fuel is channeled through field flow plates to the anode on one side of the fuel cell, while oxidant (oxygen or air) is channeled to the cathode on the other side. At the anode a platinum catalyst causes the hydrogen to split into positive hydrogen ions (protons) and negatively charged electrons. The polymer electrolyte membrane (PEM) allows only the positively charged ions to pass through to the cathode. The negatively charged electrons travel along an external circuit to the cathode, creating an electrical current. At the cathode the electrons and the positively charged hydrogen ions combine with oxygen to form water, which flows out of the cell."

Figure 3.7
Hydrogen Fuel Cell



Source: Iowa Department of Natural Resource, *Hydrogen*. Online. Available: http://aq48.dnraq.state.ia.us/prairie/Hydrogen_En.htm. Accessed March 27, 2009.

The power produced by a hydrogen fuel cell depends on a variety of factors including its type, size, the pressure at which gases are supplied, and the temperature at which it operates. A single cell produces approximately 1 Volt – barely enough electricity for even the smallest applications. To increase the amount of electricity generated, individual fuel cells are combined to form a stack. This scalability ensures that fuel cells can be used for a variety of applications, from laptops (50 to 100 Watts) to vehicles (50 to 125kW) to central power generation (1 to 200MW) and others.[122]

Energy Independence and Security

By implementing hydrogen technology on a large scale, the United States could take a considerable step towards energy independence in the long term. After all, fuel cell technology has the potential to replace gasoline combustion engines as the motor of all light duty transportation. As hydrogen is an abundant resource and can be produced using a variety of domestic technologies, the United States would no longer have to import oil to meet transportation energy needs.

In addition, hydrogen fuel cells can generate electricity locally and allow companies that rely on high quality electricity to become independent of the grid. Two current examples of private sector enterprises taking advantage of the technology are the First National Bank of Omaha, whose 200,000-square-foot Technology Center has a power plant of 400-kW (.00004 MW) fuel cells, and the Sierra Nevada Brewery in Chico, California, with four 250-kW hydrogen (.000025 MW) fuel cells that generate enough electricity to power their entire production.[123]

Economic Impact and Feasibility

Great costs are the biggest hurdle to the implementation of a "hydrogen economy." While prices for hydrogen fuel cells have dropped by 65 percent since 2002, today's fuel cell still costs around $107 per kW.[124] As a result, even the newest hydrogen cars total many hundreds of thousands of dollars in production cost.[125] The National Academy of Sciences estimates that $55 billion of government investment is necessary to reach a goal of two million hydrogen cars on the road by 2023, assuming that the cost of fuel cells drop to $30 by 2015.[126]

Storing and distributing hydrogen is also costly and thus problematic. At room temperature and pressure, hydrogen contains less than one three-hundredths the energy in an equivalent volume of gasoline. To fit into a reasonably sized storage tank, the gas has to be liquefied or compressed. Since trucking hydrogen is inefficient—a 44-ton-vehicle that can carry enough gasoline to refuel 800 cars could only carry enough hydrogen to fuel 80 vehicles[127]—the gas needs to be distributed via pipeline. Yet constructing hydrogen pipelines costs approximately $1 million per mile[128] and only 700 miles exist today, compared with more than 300,000 miles of pipeline for natural gas.[129]

If these economic barriers could be overcome, however, a transition to a hydrogen economy throughout the coming 25 years could create as many as 675,000 new jobs, according to a July 2008 DOE report.[130]

Environmental Impact

Although hydrogen fuel cells do not emit any greenhouse gases, hydrogen cannot be considered a clean fuel. After all, ninety-five percent of the 9 million tons of hydrogen produced in the United States annually comes from natural gas, a polluting hydrocarbon. The majority of the remaining 5 percent is created in a process called electrolysis, which uses electricity to split water into its constituent parts, hydrogen and oxygen. Hydrocarbons, however, generate nearly 70 percent of the nation's electrical power.[131] Thus an increase in the production of hydrogen, a fuel produced with the help of electricity, would increase greenhouse gas emissions.

Potential Role and Implications

Fuel cells could potentially replace combustion engines as the motor of all light-duty transportation. Already, hydrogen buses and cars are used in public transportation and government fleets around the world, and all major automobile manufacturers are developing hydrogen cars. Yet automakers and energy companies currently have little incentive to push for the advancement of hydrogen technology. They ask themselves: "Why build hydrogen cars, if there is nowhere to fill them up? And why build hydrogen filling stations, if there are no cars to use them?" Instead, automakers are investing in hybrid and electric car technologies, which are more mature and have been proven commercially successful. Local power generation, therefore, will likely remain the most common application for fuel cells in the short and mid-term.

Nuclear Fusion

Nuclear fusion is the process by which the sun and stars release energy. Man-made nuclear fusion reactions on earth replicate this stellar process, fusing two hydrogen nuclei to form a helium nucleus. The resulting mass of the helium nucleus is less than the combined mass of the two hydrogen nuclei. In accordance with Einstein's equation, $E=mc^2$, this change in mass releases energy. In the most developed process of nuclear fusion, the nuclei of two heavy isotopes of hydrogen (deuterium and tritium) are fused together in a containment device.[132] The reaction creates helium, a neutron, and excess energy in the amount of 17.6MeV ($7.833\ e^{-19}$ kWh).[133] Energy can be harnessed once the fusion process becomes self-sustaining, releasing more energy than is necessary to maintain fusion power.[134]

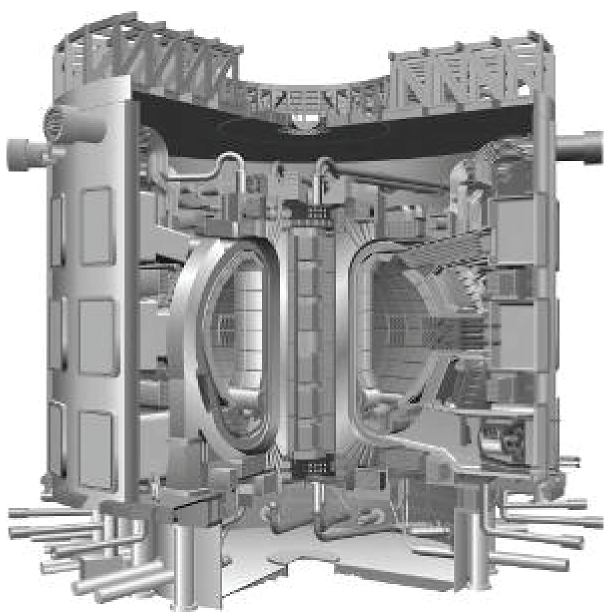
Nuclear fusion is still undergoing research and development, primarily funded by governments. The largest and most recent containment device is the Joint European Torus (JET), a tokamak (Figure 3.8), or magnetic containment device, built by the European Fusion Development Agreement.[135] The next experiment, ITER, is a joint initiative between Europe, the United States, South Korea, India, China, Russia, and

Japan.[136] Once built, ITER is expected to be the first device to become self-sustaining by producing 500 MW of fusion power for 400 seconds.[137]

Energy Independence and Security

Once nuclear fusion overcomes technological barriers, power plants could be built in the U.S. to provide electricity via the energy grid much like nuclear fission power plants, thereby advancing U.S. energy independence.

Figure 3.8
Tokamak Fusion Containment Device



Source: Every Stock Photo, *Tokamak Fusion Containment Device*, http://www.everystockphoto.com/photo.php?imageId=1767455. Accessed March 27, 2009.

Economic Impact and Feasibility

Current projections related to economic feasibility are strictly estimates. Experts project an additional €60 billion to 80 billion ($79 billion to $105 billion) of research and development funding is needed before the first fusion power plant is built. Once built, a single power station could provide electricity to 2 million households.[138] Capital investments represent the largest cost associated with the development of nuclear fusion. Building one power station is projected to cost $0.035 per kWh. Once established, fusion power should cost approximately $0.03 per kWh.[139]

Environmental Impact

Nuclear fusion would have a negligible impact on the environment. A 1 million MW power plant would require 250 kg of fusion fuel.[140] Helium is the immediate byproduct of fusion power; plants release 4 pounds of helium per 1,000 MWe plant.[141] Fusion power would not contribute to global warming because power plants would emit no greenhouse gases.[142] In contrast to fission, fusion is not a chain reaction so power plant accidents are less likely.[143] Since only the metal components located inside the containment device's reactor become radioactive, radioactive leakage would be minimal.[144] Tritium has a short half-life and its radioactivity lasts only decades, making it possible to reuse spent materials after 100 years.[145]

Potential Role and Implications

Resources needed for fusion are readily available. Deuterium and lithium (used to breed tritium) are nonrenewable, but naturally plentiful.[146] Lithium reserves could supply the United States for close to 1,000 years; deuterium resources are expected to last billions of years.[147] Once technological barriers are overcome, nuclear fusion could potentially satisfy the world's energy needs for an extended period of time. Unfortunately, fusion power will not be viable for at least another 30 years.

Cold Fusion

Cold fusion differs from nuclear fusion in that it occurs at room temperature and involves placing a palladium-coated electrode into heavy water and injecting an electrical current.[148] Scientists have long held the belief that such a reaction could only occur at extremely high temperatures, such as those found in the sun's core. Chemists Dr. Stanley Pons and Dr. Martin Fleischmann, however, announced they observed excess heat during experiments they performed during the late 1980s, which they believed to be the result of a nuclear fusion reaction. If nuclear fusion could be achieved using such a process, it would provide a cheap, abundant, and clean energy source that could be used in large-scale centralized facilities or in small-scale, portable applications for individual vehicles or appliances.[149] In the years following the Pons-Fleischmann announcement, there has been an array of experiments preformed using different metals and various concentrations of deuterium that have yielded different results, including transmutation of materials, excess heat, or no reaction at all. While largely discredited by the physics community, there are still scientists conducting independent research into cold fusion.

Energy Independence and Security

Proponents of cold fusion argue that, if successful, it could provide complete energy independence for the United States. Additionally, the metals and heavy (sea) water needed to complete the reaction are domestically available. Cold fusion is not burdened by any of the weapons applications that are associated with nuclear fission or hot fusion.

Economic Impact and Feasibility

Cold fusion could potentially provide an inexpensive source of unlimited energy. Current experiments in cold fusion use small capsules that are no bigger than a drinking glass. These capsules could be used for personal applications or potentially scaled-up for a centralized energy grid. Cold fusion could also solve transportation issues for the nation, by replacing the combustion engine. Cold fusion's ability to become a significant energy source, however, remains unproven as scientists continue to debate the technology's viability. Therefore, it is impossible to accurately estimate lifecycle costs. Ed Storms estimated that an investment of $200 million annually for five years is necessary to establish the science of cold fusion and to make it commercially viable.[150]

Environmental Impact

Cold fusion does not produce any carbon emissions and results in minimal radioactive waste. Because there are multiple prototypes in operation and an assortment of metals in use, quantifying cold fusion's environmental impact at this early stage of development is difficult. It does, however, have potential to provide an environmentally clean source of energy for the United States.

Potential Role and Implications

If cold fusion could be effectively harnessed to produce excess heat on a consistent basis, then small capsules could be sold as a power source for houses, buildings, cars, or machinery. It could potentially fulfill all U.S. energy needs. At this time, there are no tested commercial applications of cold fusion and it is impossible to provide reliable estimates for the costs and potential impact of cold fusion as an energy source.

Geopressured and Co-Produced Fluids

Geopressured and co-produced fluids include two different types of energy sources: geopressured reservoirs and co-produced geothermal fluids. Geopressured reservoirs consist of gas-saturated brines, which contain three forms of energy: natural gas dissolved in water, heat from hot water, and hydraulic pressure exerted by water flow. To generate electricity, wells are drilled into a geopressured reservoir to bring gas-saturated brines to the surface, where the natural gas is burned as a fuel and the heat energy is converted into electricity, typically at a binary cycle geothermal power plant.

Experts are still studying the best way to develop geopressured reservoirs. For example, in a pilot project in the northern Gulf of Mexico's sedimentary basin, researchers operated a 1 MW power plant in Pleasant Bayou, Texas, on a combination of heat and natural gas. Ultimately, this attempt was technically successful though not economically viable. More projects are likely to follow, however, since the United States could have access to 59,000 trillion cubic feet (tcf)[151] of dissolved natural gas in brines compared to just 211 tcf of proven natural gas reserves.

Co-produced geothermal fluids, on the other hand, are hot, aqueous fluids produced during oil and gas operations in states including Alabama, Arkansas, California, Florida, Louisiana, Mississippi, Oklahoma, and Texas. Once these hot liquids reach the surface, their heat energy is converted into electricity in geothermal power plants (usually binary cycle plants). Estimates indicate that power generation from co-produced hot water associated with existing hydrocarbon production could reach 5,000 to 10,000 MW by 2015[152] and 50,000 to 60,000 MW by 2025.[153]

Energy Independence and Security

Geopressured and co-produced fluids are a reliable, continuously available, domestic base load energy source. NREL experts estimate that the total energy could be 450 million barrels of oil equivalent, which could be added to domestic hydrocarbon reserves. However, geothermal energy production from oil and gas fields, and the recovery and production of geopressured gas resources, is insufficient to encourage private investment in long term projects. Further research and development is required if geopressured/co-produced fluids are to become a viable alternative energy option. The EISA 2007 provides $10 million a year for research and development, but this amount may not be sufficient to deliver a major technological breakthrough in this area.

Economic Impact and Feasibility

A new technology, the binary Organic Rankine Cycle (ORC), could generate electricity locally in small (typically 250 KW) power plants. Recently, binary cycle ORC power plants have been installed at Chena, Alaska, as well as Las Animas, New Mexico, and Casper, Wyoming. The latter project is unique in its production of on-site renewable power and has the potential to increase the productivity and longevity of existing U.S. oil fields. Harnessing hot water produced during oil production to power the oil field could lead to more economical access to reserves, especially in older, depleted fields.[154] The electricity this technology creates would cost roughly $1350/kW at installed capacity. Operating costs are projected at less than $0.05/kWh. Finally, experts estimate that 1.7 permanent jobs could be created per megawatt of capacity installed.[155]

Environmental Impact

Despite environmental concerns such as brine disposal, reservoir compaction, surface subsidence, and fault activation, including geopressured/co-produced fluids as part of a national energy mix is largely advantageous. Geopressured/co-produced fluids do not require as much land as other fossil fuel or alternative energy sources and, since the resources are tapped directly at the source, no transportation or additional infrastructure is necessary to harness this energy. Over 30 years, a geothermal facility uses only 404 m^2 of land per GWh, while a coal facility uses 3632 m^2 per GWh.[156] In addition, no additional greenhouse gases are emitted.

Potential Role and Implications

Co-produced fluid resources are available for development in existing oil fields today. Distributed generation facilities such as those found at the Chena Hot Springs in Alaska, the Burgett greenhouse in Las Animas, New Mexico, and the Rocky Mountain Oil Test Center in Wyoming are examples of small-scale electricity production, which satisfy the electricity needs at each facility. Excess electricity is sold back to the grid providing additional revenue for these projects. Finally, this source of energy can help fulfill Renewable Portfolio Standards (RPS) that attempt to diversify domestic energy supply, because it is clean and emits far less greenhouse gases than equivalent fossil-fuel electricity generation.

Wave Energy

As wind energy passes over water, an energy transfer occurs that creates waves. Wave energy is determined by the square of the amplitude and the period of the motion.[157] Waves with a long period (7 to 10 seconds) and large amplitude (~2 meters) can store about 40 to 50 kW per meter of energy. Large waves are located at the 30° to 60° latitude.[158] In the United States, states such as California, Hawaii, Virginia, Rhode Island, and Oregon have been conducting wave energy research and development activities.[159] Other regions which have advanced technologies are the European Union, China, India and Japan. Wave energy extraction devices are designed based on location and are categorized as onshore, offshore, and far offshore. The United States primarily focuses on offshore and far offshore wave technologies. Wave energy devices use a variety of methods, such as using water flow to force air through a turbine, the oscillating movement of an electric coil around a magnetic shaft, or the flexing of floating devices to power hydraulic pumps that produce electricity. [160]

Energy Independence and Security

Wave energy reserves show potential to diversify the U.S. energy mix. If current extraction technology matures, projections estimate that the United States could economically exploit 140 billion to 750 billion kWh per year of wave energy with the potential to reach as high as 2,100 billion kWh per year.[161] Though wave energy technology will not contribute to decentralization, it may help secure U.S. energy independence by increasing domestic energy supplies.

Economic Impact and Feasibility

Although research into wave technology began in the 1970s, most device designs are still in prototype and demonstration stages, with very few operating commercially. Due to this uncertainty, capital cost investments are high at $4,000 to $15,000 per kW.[162] Continued research and development will be required to decrease these initial costs. Early projects intended to prove the validity and feasibility of wave energy technology are suggested to cost between $0.15 and $0.20 per kWh.[163] The California Department of Energy predicts electricity harnessed from wave energy technology along the West

Coast will eventually cost approximately $0.10 to $0.11 per kWh after tax incentives.[164] While the economic impact of increased wave technology implementation is unknown, concerns exist that wave energy devices may disrupt commercial fisheries, shipping patterns, military exercises, and scientific research.[165]

Environmental Impact

Compared to traditional fossil fuels, wave energy technology has a relatively small carbon footprint, emitting no greenhouse gases or other atmospheric pollutants during operation. According to estimates, wave energy devices release 11g of CO_2 per kWh throughout their full lifecycle.[166] There is evidence that wave energy may have a significant impact on the environment, but minimal hard data is available. The devices used in wave energy extraction restrict sunlight, which in turn reduces food production, thereby affecting marine life. Devices that pump in ocean water may trap invertebrates and other small organisms, while those using magnetic and electrical fields may interfere with migration patterns.[167] Wave height, seafloor surfaces, and water and air quality in the immediate area may be adversely affected by the energy devices' construction and maintenance. For example, toxins used to maintain the extraction devices and biocides used to maintain platform surfaces may leach into the water,[168] harming marine animals and small organisms.[169] Furthermore, accidental collisions during construction or operation may release oil, diesel, or other contaminants into the water.[170]

Potential Role and Implications

The DOE estimates that North America has 240 million kW of wave energy resources, thus covering approximately 75 percent of U.S. electricity demand.[171] Specifically, the Pacific Northwest region has a capacity at 40 to 70 kW per meter of coastline.[172] Considering obstacles related to technology, economics, government, and the environment, marketable wave power may be much smaller. For consideration as a viable component to the future U.S. energy mix, wave energy technology will depend on significant collaboration between the government and private sector.

Tidal Energy

Tidal energy conversion generates electricity by converting the hydro-kinetic energy of the tides into mechanical energy through a turbine. As tidal currents ebb and flow through channels, force is created by the velocity of this moving water. The energy of this moving water can be converted to electricity in a manner similar to conventional hydroelectric dams, by either barraging the tidal channel like a river dam and capturing the tide for release through turbines or installing underwater turbine units that convert the energy of the tidal in-stream current without barraging the channel.

Since tidal barrages have significant environmental consequences, only in-stream current systems are being pursued in the United States. The cost of electricity generated by tidal energy conversion depends on the location and technology used. Current in-stream turbine technology can generate 1 to 2 MW per unit.[173] This technology is still in the development stages and requires further testing and improved efficiency before it is commercially viable. Even then, the potential for development is limited by the number of sites available for installation. Primary interest in tidal energy conversion is found in countries with large tidal ranges such Canada, the United Kingdom, and Ireland. The one commercial tidal energy operation in existence is off the coast of Northern Ireland, but several other projects are being planned around the United Kingdom and in Canada. All U.S. projects are still in the research and development phase.

Energy Independence and Security

Full development of domestic tidal energy resources will contribute minimally to the domestic energy supply and thus have little impact on national security interests. If U.S. tidal energy and river in-stream resources were developed to full capacity, they would generate only 140 terawatt-hours (TWh) per year (approximately 3.5 percent of total U.S. electricity demand).[174] Full development of national tidal energy resources would therefore not significantly reduce U.S. dependence on foreign sources of energy.

Economic Impact and Feasibility

Economic viability of tidal energy conversion systems depends on the environmental factors that determine the power density of the water, and also the performance of the technology used. The technology has low operating but substantial construction costs and requires great capital investment. Due to the variety of technologies used, the costs for construction and operation vary widely. Current estimates for the cost of producing in-stream tidal electricity range from $0.04 to $0.12 per kWh.[175] Capital costs range from $1.70 to $4 per watt produced, and operations and maintenance costs range from hundreds of thousands to several million dollars annually, depending on the technology used and size of the operation.[176]

Despite the high fixed costs, the technology does have the potential to generate economic profits in large-scale operations over the long-term. High power density and a large number of turbines can have a significant effect on reducing the cost of energy.[177] There is, however, little economic incentive to invest in this technology for commercial development until it can generate higher amounts of energy at lower cost. Jobs would be created by investing in the tidal energy industry, but this would divert investment resources from more productive forms of energy conversion.

Environmental Impact

The primary environmental incentive for developing tidal energy conversion is that no carbon emissions are produced during electricity generation. The uncertainty about the environmental consequences of submarine electricity generation, however, creates barriers to its future development and requires small pilot projects for further study.[178] The installation of underwater tidal energy conversion technology will require anchoring to the seafloor, which could disturb the marine habitat and adversely affect marine life. Also, experts have limited the performance of turbines to 15 percent, presuming that a conversion system that extracted more tidal energy would significantly disrupt the marine environment.[179] This limited extractability rate presents another barrier to future commercial development of the technology.

Potential Role and Implications

Due to its limited site potential, economic costs, and environmental impact, tidal energy conversion plays a small and limited role in the future U.S. energy economy. The technology has the potential to provide energy to areas of the world with high tidal velocities but is not feasible across the United States. Tidal energy conversion might play a role in a broad ocean renewable energy plan, but will not solve the energy crisis by itself.

Ocean Current

Ocean current energy can be harnessed to turn underwater turbine blades, producing electricity with the help of a generator. It is estimated that taking 1/1000th of the available energy from the Gulf Stream could supply Florida with 35 percent of its electricity needs.[180] While five ocean currents pass near the United States, only two, the Gulf Stream and the Florida Straits Current, flow with enough power to generate significant energy. Also, this technology is still in the early stages of development. To date, no turbine has been deployed in the Gulf Stream for more than a few hours, and no commercially operating turbines are connected to an electric-power transmission or distribution grid.[181] The majority of the projects in development will operate off the Florida coast due to its proximity to both the Gulf Stream and Florida Straits Current. Engineers working on ocean current technologies are developing new turbines as well as adapting turbines similar to those used in tidal currents. Internationally, countries such as Bermuda, Taiwan, Japan, and Australia are conducting research in this area.

Energy Independence and Security

Florida imports the vast majority of its energy.[182] The opportunity for such an energy-dependent state to increase domestic energy production deserves attention. Ocean current energy technology, however, will not significantly decrease the demand for foreign energy sources until an efficient transmission system is developed and the electrification of the transportation sector increases. In the near future, ocean current energy has little application because of its high cost and early stage of development.

Economic Impact and Feasibility

The estimated cost per kWh for ocean current energy varies across projects and technologies. Camille Coley, Program Manager at Florida Atlantic University's Center for Ocean Energy Technology, estimates a cost of between $0.05 and $0.14 per kWh.[183] Christopher Sauer, President and CEO of the Ocean Renewable Power Company (ORPC), gave preliminary projections of $0.08 per kWh for a 20 MW project involving the OCGen device.[184] The developers of VIVACE (a non-turbine technology) estimate their energy could cost as little as $0.055 per kWh.[185] According to both Sauer and Coley, between $25 million and $50 million would be required to achieve commercial viability for OCGen (ORPC) and Florida Atlantic University's technology, respectively.

A new "green" industry that includes ocean current energy could create as many as 26,000 new jobs in Florida.[186] The presence of underwater turbine arrays could, however, conflict with shipping routes and fisheries, thereby causing increased shipping and fishing pressures in other areas.[187] Interference with recreational water use and fishing is also possible.[188]

Environmental Impact

Energy harnessed from ocean currents is renewable and largely clean, with carbon emissions limited to the construction and maintenance of facilities. Potential environmental impacts include damage to the ocean floor during construction and harm to marine life from two sources: construction noise and the impact of turbine blades. The southern Atlantic is home to numerous endangered or depleted marine mammal species whose highly developed sensory systems are known to be vulnerable to powerful man-made ocean noise.[189] Although the turbine blades move relatively slowly, larger fish and marine mammals could be harmed if struck by a moving blade. Protective fences around the structures or sonar-activated detection systems could help prevent injury to marine life.[190]

Potential Role and Implications

The total power in ocean currents, worldwide, is estimated to be 5,000 GW, with a density of power around 15 kW/m^2.[191] Eight projects off the Florida coast intend to generate 168 to 336 GWh annually.[192] Sauer estimates that less than 5 years will be required to develop OCGen technology to commercial viability,[193] while Ms. Coley stated 5 to 15 years will likely be necessary for commercial viability.[194] Since there are currently no commercially operating turbines providing power through a transmission grid, it is difficult to ascertain the future competitiveness of this technology. Until the United States develops a nationwide distribution grid, ocean current energy will only be useful to the handful of states, such as Virginia and South Carolina, which are adjacent to America's most powerful currents, the Gulf Stream and Florida Straits Current.

Ocean Thermal

Ocean thermal energy conversion (OTEC) uses the ocean's thermal gradients (temperature differentials) to create energy. When ocean waters of varying temperatures come into contact, energy is produced and electricity can be generated.[195] Surface temperature varies in different parts of the world but a minimum temperature difference of approximately 20° C or 36° F between shallow water and deep water is required for OTEC to function. Temperate zones, areas located in warmer climates, specifically the region between the Tropics, have the highest potential for OTEC, because temperature gradients are largest in these zones.[196]

There are three types of ocean thermal energy conversion systems: open, closed and hybrid systems. In an open system, water is boiled in a low pressure container to produce water vapor. The water vapor expands, driving a low pressure turbine that powers an electric generator. The water vapor, now devoid of salt, is condensed back into a liquid using cold ocean water. A closed system uses a liquid with a low boiling temperature, such as ammonia, to turn an electricity-generating turbine. Cold water cools the vaporized ammonia, condensing the vapor and converting it back to a liquid. The liquid ammonia is pumped back into the system and the process repeats itself.[197] A hybrid system combines both an open and a closed system to drive a low pressure turbine.[198]

The Natural Energy Laboratory of Hawaii Authority (NELHA) is considered the world's leading research facility on ocean thermal technology. Though the facility is not currently producing electricity, it uses cold water to power air-conditioning systems in its administration buildings. The cold water off-sets nearly 200 kW of energy at peak demand and approximately $4,000 a month is saved in electricity costs.[199] The Taiwan Industrial Technology Research Institute and Lockheed Martin have announced plans to build a 10 MW OTEC plant as a joint venture.[200]

Energy Independence and Security

OTEC can produce energy continuously because water temperature does not fluctuate significantly, differentiating it from wind and solar power, which are subject to weather conditions.[201] Consequently, OTEC could contribute to an increased domestic energy supply, and reduce demand for foreign energy sources.[202]

OTEC plants can be established not just in deep water far off-shore but both on land and on floating facilities near shore. Near shore and on land facilities can transmit not only electricity, but desalinated water, and nutrient-rich cold water for use in mariculture.[203] The ability to have OTEC plants in deep off-shore water, near shore or on land could aid in developing a decentralized system of electricity while producing other beneficial byproducts.[204]

Economic Impact and Feasibility

There are two significant barriers to OTEC development and implementation. First, building an OTEC plant requires substantial investment, and most of the capital required is dedicated to piping and heat exchangers. Since cold water from lower depths is required, pipes may need to go as deep as 3,000 feet. A 100 MW plant would require 3,400,000 gallon per minute to operate and would also require pipes with diameters as large as 10 meters.[205] Capital costs can range from $7,000 to $15,000 per kWh, over ten times the cost of conventional electricity generation systems.[206]

Second, OTEC has not demonstrated an energy efficiency rate suitable for large-scale use. The slight difference in temperature gives OTEC a thermal-to-electricity ratio of around 3 percent. In contrast, coal- or oil-powered plants have temperature differences of as much as 500 degrees and have ratios around 30 to 35 percent. For an OTEC plant to produce useful electricity, pumping large quantities of water is required.

OTEC could benefit many different industries. Deep ocean water is rich in nutrients and the OTEC process transfers phytoplankton, a food source for many marine species, from deeper, colder water to shallow, warmer water, benefiting the mariculture industry. Cold water produced from ocean thermal energy conversion can also be used to cool soil and promote the growth of fruits and vegetables grown in regions outside of sub-tropic environments. OTEC technology also produces desalinated water; a plant with a 2 MW net electricity capacity could produce 4,300 m^3 (14,118.3 ft^3) of desalinated water daily.[207]

Environmental Impact

OTEC has little adverse effect on the environment in comparison to other major energy sources like oil, natural gas, coal, and nuclear power. OTEC processes do not produce exothermic energy on the scale of hydrocarbon-based fuels. OTEC does not create pollution; therefore it does not have a significant impact on global warming.[208]

Though there are some concerns about the effects of OTEC on marine life, test facilities operated by the Department of Energy concluded that OTEC had no significant impact on the local marine environment.[209]

Potential Role and Implications

OTEC could have commercial viability in the next five years.[210] The cost of producing aluminum pipes and heat exchangers is declining and, coupled with increasing costs and environmental concerns associated with the use of hydrocarbon-based fuels, OTEC is becoming an attractive source of energy.[211] While initial capital costs are high, these can be offset by the lack of fuel costs over the plant's life cycle. Large-scale government funding may be needed for further research and development but corporate investment will be required to fully develop the potential for ocean thermal energy.[212] In the United States, OTEC is geographically restricted to temperate zones and could only be viable in coastal states located at lower latitudes like California, Hawaii, and Florida.[213] Increased development in electricity transmission could take OTEC's potential beyond low-latitude states. The ocean is a vast resource and if OTEC can be developed on a commercial scale, it could prove a valuable alternative energy source.

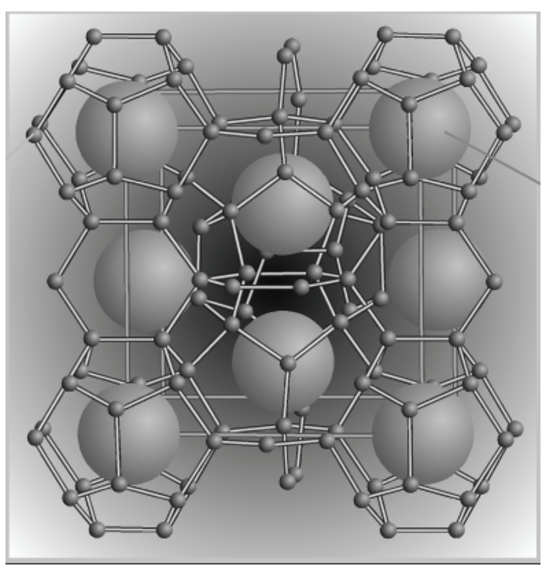
Methane Hydrates

Methane hydrates are an untapped natural resource that could supply the United States and the world with energy for the next century. Methane hydrates are formed when underground methane gas is trapped in an ice-like structure due to high pressures and low temperatures (Figure 3.9). They are found in great abundance around continental margins and in the arctic permafrost. Methane hydrates can be harnessed for energy production much like natural gas. Once released from hydrate form, methane could power electricity-generating turbines. Currently, the technology to harvest methane hydrates in an environmentally safe and economically viable fashion is undeveloped. Japan, however, will likely be the first to attempt commercial extraction within the next few years.

Energy Independence and Security

Domestically, the United States has 1,400 trillion cubic feet (Tcf) of natural gas while the USGS estimates a domestic supply of 200,000 tcf of methane hydrates.[214] By capturing just 1 percent of this resource, the United States could double its supply of a natural gas alternative. Current projections estimate that the Blake Ridge, off the coast of South Carolina, contains 1,300 Tcf of methane hydrates, potentially supplying the United States with an abundant natural resource.[215] There is twice as much energy potential in methane hydrate form than is found in all hydrocarbon-based fuels (oil, coal, natural gas) combined.[216] This indicates that methane hydrates could power the world for another 1,000 years at current energy consumption rates. By harvesting its supply of methane hydrates, the United States could be energy independent and benefit from a fully domestic energy source for decades.

Figure 3.9
Methane Hydrates



Source: University of Bergen, Norway

Economic Impact and Feasibility

The technology to safely and economically harvest methane hydrates on a commercial scale is still undeveloped. Because methane hydrates are buried deep below the earth's surface in solid form, they are not transportable through a drill stem. As a result, one of two methods must be used to extract the resource – depressurization or thermal injection. Neither method is currently economically viable so cost estimates are not available. Costs associated with extracting energy from methane hydrates, however, will likely include building drill systems and platforms in remote areas around the nation, including the outer continental shelf off the east and west coasts and the Gulf of Mexico.

Environmental Impact

While methane hydrates burn carbon dioxide more efficiently than any other hydrocarbon, 1 cubic foot of methane hydrates can release up to 180 cubic feet of methane (CH_4), a greenhouse gas ten to 20 times more powerful than carbon dioxide.[217] Accelerated climate change could result if large quantities of methane escape into the atmosphere during extraction. The Permian Extinction and the Late Paleocene Thermal Maximum are attributed to large releases of methane into the atmosphere. Drilling could also disrupt fragile and unique marine ecosystems like the newly discovered methane ice worms found on the sea floor in the Gulf of Mexico.

Potential Role and Implications

World supply of methane hydrates is estimated by the USGS to be 300 million Tcf. Not only could methane hydrate energy generate the bulk of U.S. electricity, it could decrease the country's dependence on foreign energy sources. The technology to viably harness and efficiently transport this natural resource, however, is still under development. Additionally, there are severe environmental consequences if extreme caution is not used during extraction.

Summary

Summaries of the energy technologies described in this chapter—and their associated costs and environmental impacts—are provided in Tables 3.2, 3.3, and 3.4, respectively.

- All mentioned technologies can generate energy domestically and therefore improve energy independence and national security.
- Most alternative technologies have drawbacks regarding environmental impacts, such as the large land footprint required for wind farms, but most emit less greenhouse gases than fossil fuels.
- Most of these technologies are location specific (for example, solar requires a region with steady and direct sunlight) except for nuclear fission, nuclear fusion, cold fusion, hydrogen, and biomass.
- All these alternative technologies currently rely on government support in various forms, including capital investment and tax credits.

- Except for hydroelectricity and nuclear fission power, the price of energy generated from oil and coal is cheaper than the price of energy generated from clean alternative technologies without government intervention.

- The time required for government approval, licensing, and construction range from immediate (solar) to many years (nuclear fission).

- Technologies that are mature: solar, wind, geothermal, geo-pressured and co-produced fluids, biomass, and nuclear fission.

- Technology that needs more research and development: ocean current, ocean thermal, wave, tidal, nuclear fusion, cold fusion, methane hydrates, hydrogen, and bio-fuels.

- Technology that is already at capacity: hydroelectric.

Table 3.2
Summary of Energy Technologies

Energy Name	Fuel/Source	Technologies	Current Production	Available Energy/Quantity of Resource (U.S.)	Region
Solar	Sun	Photovoltaic (PV); Concentrating Solar Power (CSP)	PV – 150 MW	Potential to replace current sources of electricity in regions with high amounts of sun	Areas with high amounts of sunlight
Wind	Blowing wind	Wind turbine (onshore & offshore)	17 GW	Potentially unlimited (with advances in energy storage); 20% of energy demands without energy storage advances	Areas with large wind power
Hydroelectric	Moving water	Storage; run-of-river; pumped storage facilities		95,000 MW	Areas with adequate water supply
Wave	Ocean's wave movement	Onshore Device; Offshore Device; Far Offshore Device	0; Projects are moving forward on the West Coast	2,100 TWh/year	Coasts
Ocean Thermal	Ocean's temperature differences	Open System; Closed System; Hybrid System	0; Commercial viability is possible in 5 years		Regions between the Tropics / Coasts
Nuclear Fission	Uranium	Nuclear Reactor	100,266 million kW	Potentially unlimited	No regional limitations
Nuclear Fusion	Heavy water (Deuterium); Lithium	Magnetic Confinement Device; Inertial Confinement Device	0; Estimated R&D is $79 – 105 billion before commercial viability is possible (>30 years)	Potentially unlimited	No regional limitations
Cold Fusion	Heavy water		0; No R&D funding	Potentially unlimited	No regional limitations
Geothermal	Earth's heat	Dry Steam; Flash Steam; Binary Cycle	2957.94 MW	517,800 MW	
Geopressured & Co-Produced Fluids		Organic Rankine Cycle		59,000 Tcf	
Ocean Current	Moving water	Underwater turbine; VIVACE (non-turbine)	0; Eight projects off the coast of Florida intend to generate 168-336 GWh/year	5,000 GW worldwide	States with access to the Gulf Stream and Florida Straits Current
Tidal	Tides	In-stream current systems	0; U.S. projects are in the R&D phase	140 TWh/year	Coasts
Methane	Trapped methane	Depressurization; Thermal	0; Japan is likely to be the	2,000 Tcf	Coasts

Hydrates	gas – organic carbon	Injection	first country to extract methane hydrates		
Biomass	Plant-derived materials	Direct-firing systems; Co-firing systems; Gasification; Pyrolyzation; Anaerobic Digestion	7,800 MW	Expected U.S. installation of 13,000 MW by 2010; 278 quadrillion Btu of installed capacity worldwide	No regional limitations
Hydrogen	Gas	Fuel Cell	First National Bank of Omaha – 400 kW; Sierra Nevada Brewery – 350 kW	-	No regional limitations
Biofuels (Corn-based ethanol)	Corn	-	3.904 billion gallons produced in 2005 (2.85% of transportation energy)	Estimated 16 billion gallons by 2015 without upsetting the economy	Production – Corn belt; Consumption – no regional limitations

Table 3.3
Summary of Costs, TBU

Energy Name	Capital Cost	Operation Cost	Job Potential
Solar	-	$0.20 - 0.40 / kWh (PV in low latitudes); $0.50 - 0.80/kWh (PV in higher latitudes); CSP - $0.18/kWh	An estimated 62,000 new jobs could be created by 2015 due to solar technology
Wind	$1,750/kW to build wind turbines; transmission lines increase cost	$0.01/kWh	-
Hydroelectric	$1,700 - 2,300/kW	$0.004/kWh	-
Wave	$4,000 - 15,000 kW (Projection)	$0.15 - 0.20/kWh; $0.10 - 0.11/kWh after tax incentives	-
Ocean Thermal	$7,000 - 15,000 kW (Projection	Unknown	-
Nuclear Fission	$1,913/kW	$0.018/kWh	-
Nuclear Fusion	$0.035/kWh (Projection)	$0.003/kWh (Projection)	-
Cold Fusion	Unknown	Unknown	Unknown
Geothermal	$2,500/kW	$0.05 - 0.10/kWh	An estimated 9,580 new full time positions could be created with an increase to 5,600 MW of installed geothermal technology
Geopressured & Co-Produced Fluids	$1,350/kW	$0.05/kWh	An estimated 1.7 new permanent jobs per MW of energy
Ocean Current	Unknown	$0.05-0.14/kWh (Projection)	An estimated 26,000 new jobs could be created in Florida with the advancement of ocean current technology
Tidal	$1,700 - 4,000/kW	$0.04 - 0.12/kWh	-
Methane Hydrates	Unknown	Unknown	Unknown
Hydrogen	Fuel cell – $107/kW; Constructing hydrogen pipeline - $1 million/mile	-	An estimated 675,000 new jobs could be created in the next 25 years
Biomass	Co-firing - $1,100 – 1,300/kW; Gasification (Combined heat & power) - $3,000 – 4,000/kW	Conventional – $0.06-0.12/kWh; Co-firing - $0.00-0.04/kWh; Landfill gas electricity generation – $0.035-0.079/kWh	Currently supports 66,000; DOE estimates an additional 100,000 jobs by 2010
Biofuels (Corn-based ethanol)	Retrofit Petroleum Filling Stations – $22,000 – 80,000	Volumetrically competitive with petroleum	An estimated 800,000 new jobs in the biotechnology industry for advanced biofuels; Estimated 1.18 million in all sectors by 2022 if ethanol expands.

Table 3.4
Summary of Environmental Impact

Energy Name	Operations Emissions	Water Requirements/Affects	Land Use	Other Environmental Concerns
Solar	Zero greenhouse gas emissions	-	PV - increased capacity possible in urban areas (minimal land requirements); CSP - Requires heavy land resources	-
Wind	Zero greenhouse gas emissions	Minimal water requirements	25 acres per MW of installed capacity	Less than 1 in 10,000 unnatural bat & bird deaths due to wind turbines
Hydrogen	Zero greenhouse gas emissions from hydrogen, but 95% of hydrogen sources are from natural gas, a polluting a hydrocarbon	5% of hydrogen is from electrolysis, (splitting water)	-	Requires pipeline development to transport the hydrogen gas
Hydropower	Zero greenhouse gas emissions	Requires regions with adequate water supply; Deoxygenates the water supply	-	Affects migratory patterns of fish & aquatic life and riverbank populations
Nuclear Fission	Zero greenhouse gas emissions	Water intensive compared to hydrocarbon based plants	-	Problems related to uranium mining and lack of permanent storage facility for the radioactive waste
Nuclear Fusion	Zero greenhouse gas emissions	Water required for fuel	-	Small concern of nuclear proliferation; Minimal radioactive waste
Cold Fusion	Zero greenhouse gas emissions	-	-	Minimal radioactive waste
Ocean Current	Zero greenhouse gas emissions	Ocean Technology	-	May damage the ocean floor and injure threatened or endangered marine life due to construction and operation of the turbines; Noise pollution may disrupt animal communication
Ocean Thermal	Zero greenhouse gas emissions	Ocean Technology	-	May adversely affect marine life
Wave	Zero greenhouse gas emissions	Ocean Technology	-	May adversely affect marine life; Device may trap small organisms, noise pollution may disrupt animal communication; Toxins used on device may leach into ocean water
Tidal	Zero greenhouse gas emissions	Ocean Technology	-	Device may damage the seafloor and disturb the marine habitat

Geothermal	Dry steam plants emit 90 lbs of CO2 per MWh; Flash plants emit 60 lbs of CO2 per MWh; Possible to reduce these emissions in a closed loop binary system	-	Minimal land use	Requires proper disposal of toxic sludge rich in zinc, sufer, and silica
Geopressured & Co-Produced Fluids	No additional greenhouse gas emissions	-	Minimal land use; 404 m2 of land per GWh	Requires brine disposal; Concerns of reservoir compaction, fault activation, & surface subsidence
Methane Hydrates	1 ft3 of methane hydrates releases up to 180 ft3 of methane - a greenhouse gas 10-20 times more powerful than CO2	-	-	May accelerate climate change if methane is released; drilling may disrupt fragile marine ecosystems
Biofuels (Corn-based ethanol)	Corn-based ethanol produces 19% fewer greenhouse emissions than gasoline; biofuels from waste products produce up to 50% fewer greenhouse gas emissions	3-4 gallons of water required per 1 gallon of ethanol produced	1 acre of corn required to produce 370 gallons of corn-based ethanol; Land degradation and large-scale deforestation are results of production	Decline of land dedicated to conservation; Loss of wildlife habitat; Increased greenhouse gas emissions due to slash & burn
Biomass	"Balanced" carbon dioxide emissions similar to amounts released by burning hydrocarbons; Emits less amounts of other greenhouse gases including sulfur dioxide and nitrogen oxides	Due to decreased use of pesticides, water pollutionis reduced when using energy crops in replace of high-yield food crops	Soil quality improves if energy crops are planted in replace of high-yield food crops	Better habitat option for wildlife when compared to food crops; Finds use of animal and human waste reducing landfill use

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Chapter 4. Technologies to Optimize Energy Use

A successful transition to a new, cleaner energy economy requires that the United States not only rethink energy sources but also implement new ways of delivering, managing and using energy. Concurrent with a significantly increased use of alternative energies from the previous chapter must be a heightened effort to reduce energy consumption and the potentially disastrous effects of carbon dioxide emissions. This chapter discusses the role of technological innovation in improving energy distribution and use by focusing on five distinct areas: efficiency and conservation, infrastructure (smart grid and distributed generation), transportation, renewable heating and cooling, and energy storage.

Energy Conservation and Efficiency

"Conservation" and "efficiency" are terms easily confused but refer to different methods of reducing energy consumption. Energy conservation involves an actual change in behavior (i.e. doing less) to use less energy, while energy efficiency applies technology and best practices to reduce wasted energy, allowing one to do the same or more with less.[1] Conservation and efficiency describe equally valid methods to decrease the amount of energy used and the amount of emissions released into the environment.

Energy conservation elicits greater skepticism from those concerned with economics, as the thought of doing less implies slowing economic growth. Perry Been of the Texas State Energy Conservation Office (SECO) elaborates, "energy conservation carries the connotation of sacrifice and doing without. This leads to production losses, economic instability, and short-term concessions."[2] There are numerous instances, however, where energy conservation practices such as carpooling, taking public transportation, and increasing vigilance regarding electricity usage should be an integral part of future policies.

Demand Side Management (DSM) is the implementation of policies and measures which strive to control and reduce electricity demand and consumption while preserving the same level of service and comfort. DSM is an established method used by some utilities and electricity providers to take advantage of both energy conservation and efficiency measures to control the demand for electricity at peak times. High efficiency equipment and the efficient use of electricity are both hallmarks of DSM. Interruptible load, another tool used by DSM programs, involves interrupted service during peak times of day to participating customers. Because DSM reduces peak electricity demand, and thus the need to build more power plants, all experts surveyed agreed that utilities should be encouraged to adopt DSM programs as part of any effort to reduce greenhouse gas emissions.[3]

Energy efficiency, on the other hand, is widely viewed as a mandatory part of all future energy policies. Former Secretary of Energy Samuel Bodman summarized the role of energy conservation:

> "As most of you know, the largest source of immediately available 'new' energy is the energy we waste every day. Indeed it is the cheapest, most abundant, cleanest, most readily available source of energy Americans can access…"

The United States uses nearly $1 million worth of energy every minute and, though less than 5 percent of the world's population, consumes close to 25 percent of the world's energy resources. Further, the average American consumes six times more energy than the world average.[4] The United States must confront its excessive energy use and make the changes necessary to decrease energy consumption, thereby providing a model for other developed and developing nations in how best to foster a growing economy and a healthy environment.

Energy Consumption

The DOE categorizes national energy use into four sectors: residential, transportation, commercial, and industrial. The residential, transportation, and commercial sectors account for almost 66 percent of total U.S. energy consumption.[5] Space heating and cooling account for more than half of energy use within the residential sector, followed by lighting/appliances and water heating. As wealth gradually increased in the United States, so too did the demand for appliances, which resulted in an ever increasing need for energy. Thanks to federal programs like *Energy Star* and *Zero Energy Homes,* the promotion of more efficient appliances and building guidelines has resulted in falling energy use over time, both per capita and per household.[6] Electricity use for lighting is also expected to decline due to increased sales of highly efficient compact fluorescent light bulbs and requirements that inefficient incandescent light bulbs use less wattage.

While water heating typically accounts for around 14 percent of a utility bill, using less water, adjusting temperature requirements, and insulating the water heater and pipes can help reduce costs.[7]

The transportation sector includes all vehicles for personal and freight transportation. Fuel economy targets for passenger vehicles (cars and light trucks) were initially set in 1975 in reaction to the 1973 Arab Oil Embargo. Although the average fuel economy of cars almost doubled following the establishment of these targets, fuel economy standards have not significantly changed in the last 20 years.[8] Cars and light trucks, under the Corporate Average Fuel Economy (CAFE) standards, are considered separately and are held to different standards. Additionally, CAFE standards do not apply to vehicles with gross vehicle weight ratings over 8,500 pounds. Manufacturers can also choose not to comply with CAFE standards and instead pay penalties (in the 2006 model year this included BMW, DaimlerChrysler, Volkswagen, Ferrari, Porsche, and Maserati).[9] Overall, due to new fuel economy standards, slower economic growth, and higher recent fuel prices, the rate of growth in energy consumption is expected to decrease for cars and light trucks. The same cannot be said for heavy trucks and aircraft. Heavy vehicles accounted for 18 percent of the sector's energy use in 2006, while aircraft accounted for 9 percent. Strong growth in infrastructure and air travel is expected, which will only increase their energy consumption.[10]

The commercial sector includes retail stores, offices, restaurants, and schools. Similar to the residential sector, space heating and cooling uses the most energy while energy dedicated to lighting is a close second. The EIA's *Annual Energy Outlook for 2008* projects commercial energy consumption per capita to increase by 12 percent from 2006 to 2030, due to U.S. movement towards a service economy. With increased use of improved heat exchangers for space heating and cooling equipment, solid-state lighting, more efficient compressors for commercial refrigeration, and building energy codes, energy consumed by the commercial sector could decrease.[11]

The industrial sector includes manufacturing, construction, farming, mining, water management and the production/processing of goods. Due to heightened concerns over global economic competition and reducing costs, the industrial sector has made substantial efficiency improvements over the last 30 years. Subsectors that reduced their consumption by at least 25 percent include those that manufactured steel and paper products, petroleum and aluminum refineries, and cement producers. A great deal of the reduction in consumption has been due to the recycling of waste material and the use of cogeneration equipment (using excess heat from production to produce electricity and heat for the facility). The future rate of energy consumption for each specific industry subsector depends on growth, or lack thereof, in the economy. Energy consumption is expected to fall for industries such as bulk chemicals, cement, iron, steel, and aluminum, while the highest consumption rates are expected to come from computer and glass industries as well as refineries that will be required to use more energy for the production of other liquids like biofuels, coal, and heavier crude oil.[12]

Leaders in Energy Efficiency

The most energy efficient countries are linked by several common characteristics: wealth, limited access to abundant energy sources, and a concerted effort to achieve energy independence following the 1973 Arab Oil Embargo. Japan, Denmark, and Switzerland are the top three countries in energy efficiency. Austria, Germany, the United Kingdom, Israel, Ireland, and Italy are among the 15 most energy efficient countries.[13]

Japan uses 4,500 Btu per U.S. dollar of GDP, a measure known as "energy intensity" (an instrument frequently used to gauge the quantity of energy used). The ten most efficient countries use 7,500 Btu or less. The United States, on the other hand, uses more than 9,000 Btu per dollar of GDP. China and the nations comprising the former Soviet Union are among the least efficient countries, using 35,000 Btu and 138,000 Btu respectively.[14]

The most energy efficient countries use a number of techniques to obtain substantial energy efficiencies. Japan harnesses waste heat and gases from cement factories and steel mills to provide electricity, mandates steep taxes on petroleum, sustains government investment in energy research, and maintains a national consensus on the need to reduce energy consumption.[15] Denmark recycles waste heat from coal-fired power plants and waste incinerators (as there are no landfills) and uses it for home heating and hot water. Additionally, Denmark emphasizes modes of transportation other than cars, levies self-imposed gasoline and carbon dioxide taxes, and employs vigorous building-and-appliance efficiency standards.[16]

Germany is not only aiming to improve its energy efficiency by 3 percent a year to meet the EU target of reducing carbon dioxide emissions to 20 percent below 1990 levels by 2020, but they are also proposing a plan to cut emissions by 40 percent in 13 years and to become the most energy-efficient country in the world. Their action plan involves citizens using 11 percent less electricity by 2020, thereby eliminating 40 million tons of carbon dioxide emissions. Subsidizing Germany's extensive railway system to promote use of rail over air travel as well as doubling the number of combined heat and power plants (which collect and reuse heat generated in power production instead of releasing it) is also part of their proposed plan. Lastly, the German government has agreed to generate more than 25 percent of its power from environmentally friendly sources, such as wind, solar, and biofuels, by 2020.[17]

Previous U.S. Energy Efficiency and Conservation Measures

The Energy Policy and Conservation Act of 1975 was signed into law by President Ford. It contained the earliest energy efficiency measures with the CAFE fuel economy standards, but at its core, it was meant to address the nation's energy demands through an extension of oil price controls as well as the creation of strategic petroleum reserves.[18]

The National Energy Act of 1978, signed by President Carter, contained the Conservation Policy Act (NECPA) that addressed the use of fewer nonrenewable natural resources and the increased use of energy efficiencies. The act included the development and implementation of residential and commercial conservation plans that increased the eligibility for weatherization grants, authorized grants for energy audits, required more disclosure of vehicle fuel efficiency, and established energy efficiency standards for certain household appliances. Additionally, the NECPA expanded the industrial energy reporting system to include major energy-consuming industries (those using at least one trillion Btu of energy per year). Finally, the Secretary of Energy was charged with establishing a program to demonstrate solar heating and cooling technology in federal buildings and to promote the use of energy conservation, solar heating/cooling, and other renewable energy sources in federal buildings.[19]

In 1988, the Federal Energy Management Improvement Act dictated 10 percent improvements in the energy efficiency of new federal buildings and established a task force charged with promoting energy efficiency in federal operations.[20]

The first Energy Policy Act, signed into law in 1992, directed the Secretary of Energy to establish new energy efficiency standards for buildings. Provisions to label commercial and industrial equipment with energy efficiency information were included along with grant programs for industrial energy efficiency plans.[21]

The next Energy Policy Act, which became law in 2005, attempted to tackle competing interests like energy security, economic growth, and environmental quality. The EPAct 2005 contained $14.5 billion in tax reductions with $1.3 billion for energy efficiency and conservation measures enacted through new statutory standards, federal action requirements, and incentives for voluntary improvements. While efforts to increase fuel economy standards were defeated, daylight-saving time was extended by almost a month to decrease the amount of energy used for night-time lighting. In an effort to lead by example, congressional facilities were required to expand their energy efficiency capabilities through enhanced measurement and accountability as well as attain a new energy reduction goal of 20 percent by 2015. Continued efforts to increase efficiency of appliances and commercial equipment were included in the bill, along with tax breaks for homeowners making energy conservation improvements. Skeptics of the EPAct 2005 point to $7.5 billion worth of incentives and exemptions for oil and gas producers, as well as an increased focus on coal, as evidence that the legislation was little more than a broad collection of subsidies for already dominant U.S. oil and coal companies.[22]

The EISA 2007 was signed into law in December of that year. The bill originally sought to cut subsidies to the petroleum industry to promote alternative energies, but those measures were removed because of Senate opposition. The final product emphasized an increase in automobile fuel economy and energy efficiency in lighting and public buildings. To address energy security, the CAFE standards were increased, requiring automakers to boost fleet-wide gas mileage (including light trucks) to 35 mpg by 2020. Energy savings measures revised standards for appliances and lighting, including a 25 percent greater efficiency for light bulbs phased in from 2012 through 2014. The EISA 2007 had new initiatives promoting conservation in buildings and industry, including the use of Energy Star products to provide lighting in federal buildings, and new standards and grants for furthering efficiency in government, public institutions, and small business energy programs. The EISA 2007 also incorporated policies relating to pressing topics like a training program for "green job" workers; new initiatives for highway, sea and railroad infrastructure; and modernization of the electricity grid to improve efficiency.[23]

While previous laws attempted to save money and lower energy consumption, limited attention has been applied to robust energy conservation and efficiency measures. Whether through general recommendations, concrete incentives, consumer education, or municipally-owned utilities embracing energy conservation, such efforts have recently increased.

Recent Trends in Energy Conservation and Efficiency

Ideas and recommendations for improving energy conservation and efficiency are increasingly available through groups including: the Alliance to Save Energy, Edison Electric Institute, Energy Future Coalition, and the Natural Resources Defense Council.

They suggest low-income home weatherization; energy efficiency retrofits for homes, as well as commercial and government buildings; strengthened national building codes; enhanced product efficiency standards; and energy efficiency investment by utilities. They also advocate creating state regulations that allow utilities to earn a rate of return on new efficiency investments, since the current system encourages utilities to make more money by selling more energy, as opposed to saving it.[24]

Austin Energy, a municipally owned utility in Austin, Texas, has achieved great success with its pioneering Energy Efficiency, GreenChoice, and Solar Initiative Programs. Their creative use of rebates and loans for home energy efficiency improvements, free energy audits, and free weatherization resulted in sizeable reductions in energy used, costs and emissions. In 2007, Austin Energy achieved a reduction of 65.4 peak MW, saving 119 million kWh of energy and $11.3 million. They also reduced emissions of carbon dioxide by 70,000 tons, mono-nitrogen oxides by 48 tons, and sulfur dioxide by 44 tons.[25]

By combining innovation, education, and leadership, the United States will increasingly employ serious efficiency and conservation-minded policies. The Obama administration's American Recovery and Reinvestment Act may signal a new era that meets immense challenges with bold and thoughtful actions to ensure the prosperity of future generations.

Infrastructure Technologies

Smart Grid

Electricity, not oil, is the backbone of the U.S. energy economy. It has emerged as the only form of energy that can power today's and tomorrow's information technologies and ensure the wealth of our post-industrial world. Already, more than 60 percent of GDP comes from industries that run on electricity,[26] and electricity constitutes roughly 50 percent of total energy consumed in the United States.[27] As these numbers continue to grow, the role of the national electricity grid in the nation's future can hardly be underestimated and neither can the risks due to reliance on a largely antiquated electricity infrastructure.

Power outages and quality issues already cost domestic businesses upwards of $100 billion per year.[28] These problems are the direct result of the fragmented structure of the grid as well as the outdated technologies it uses. And the problems are growing. According to the DOE, the average power outage affected 15 percent more consumers from 1995 to 2000 than from 1991 to 1995. Also, of the five massive blackouts in the past 40 years, three have occurred in the past 10 years.[29]

Despite the central importance of the grid to U.S. society and the rate of technological advances in all other sectors of the economy, research and development investment in the area of electricity transmission has been amongst the lowest in all industries. More than 70 percent of all transmission lines are 25 years or older, as are more than 70 percent of all transformers. Also, upwards of 60 percent of all circuit breakers are more than 30 years old.[30] While hundreds of thousands of high-voltage transmission lines cross the country, only 668 additional miles of interstate transmission have been built since 2000.[31]

The single mission of the contemporary grid seems to be keeping the lights on. Today's transmission system is not capable of addressing important modern concerns such as energy efficiency, environmental impacts, and customer choice. In a way, running today's digital society through yesterday's grid is like running the Internet through an old telephone switchboard. Drastic improvements are necessary.

"Smart Grid" Description and State of Development

The future electricity infrastructure is commonly referred to as the "smart grid." The term represents a vision for a digital upgrade of distribution and long distance transmission to optimize current operations and open up new markets for alternative energy production. While specific and proven smart grid technologies are in use today, "smart grid" is an aggregate term for a set of related technologies rather than a name for a specific technology.

The smart grid technology most commonly referenced is the smart meter. While a conventional electricity meter only collects data on the total amount of energy households and businesses consume, this device maps energy consumption in real-time throughout the day and communicates this information back to the utility.

A nationwide smart grid would transform the way Americans live and work. Constructing such an intricate system has been compared in significance to building the Interstate Highway System and the development of the Internet. Modern smart grid technology will revolutionize electricity infrastructure by incorporating the following seven functions, which the DOE describes in its "Modern Grid Initiative" report:[32]

- Accommodate generation options: Smart grids seamlessly interconnect with fuel cells, renewables like wind and solar, microturbines, and other distributed generation technologies at local and regional levels.

- Allow consumer participation: A smart grid incorporates consumer equipment and behavior in grid design, operation, and communication. Consumers will be able to tell "smart appliances" and "smart equipment" when and at what price they should operate, and interconnect energy management systems in "smart buildings," thus managing energy use effectively and reducing energy costs. At the same time, the grid will be able to tell devices when to reduce performance or power off temporarily during peak demand. Furthermore, homes or small businesses that use small generation technology locally will be able to sell power to their neighbors or back to the grid. Larger commercial businesses that have renewable or back-up power systems will be able to do the same. This participation by smaller entities is often referred to as the "democratization of energy."

- Enable an open electricity market: Improvement in transmission capacity and management will help create an open marketplace where energy producers of all sizes using different types of generation technology can sell electricity to geographically distant locations.

- Heal itself: Embedded sensors and automated controls will anticipate, detect, and respond to system problems in real time, thus avoiding or mitigating power outages, power quality problems, and service disruptions.

- Resist attack: Real-time information enables grid operators to isolate areas affected by natural or man-made disruptions to redirect power flows around damaged facilities.

- Provide high quality power: Outages and power quality issues cost U.S. business billions of dollars each year. Cleaner, more stable power with less downtime will prevent such high losses.

- Optimize assets: The main goal of the modern grid will be the delivery of desired functionality at a minimum price. It will help utilities reduce their maintenance and operations costs, reduce waste, and maximize the flow of lowest-cost generation resources on local, regional, and national levels.

Enactment of EISA 2007 made implementing smart grid technology U.S. policy. The law allocates $100 million in funding per fiscal year from 2008 to 2012. In addition, it establishes a matching funds program for states, utilities, and consumers to build smart grid capabilities, and creates a Grid Modernization Commission.[33] Recently, the American Recovery and Reinvestment Act contained $4.5 billion in smart grid investments.[34]

Austin, Texas, has been developing a smart grid since 2003. Its municipally owned utility, Austin Energy, first replaced one third of its manual meters with smart meters that communicate via a wireless mesh network. It currently manages 200,000 devices in real time, including smart meters, smart thermostats, and sensors across its service area. By the end of 2009, the utility expects to support as many as 500,000 devices. Boulder, Colorado, completed the first phase of its smart grid project in August 2008. U.S. utilities that are currently developing smart grids include Pacific Gas & Electric, Florida Power & Light, Oklahoma Gas & Electric, and American Electric Power.[35]

Incentives for Developing a Smart Grid

Developing a smart grid would have a profound impact on the U.S. economy. It would limit financial losses due to power outages, reduce electricity prices and the need for expensive fuels, and encourage job creation through private investment in the energy sector. Finally, financial savings would only increase as environmental costs are factored into economic equations.

Investment in a smart grid would produce quick returns by making national electricity infrastructure more reliable and reducing the number of blackouts. One such event in Silicon Valley totaled $75 million in losses, and the Northeast blackout of 2003 resulted in a stunning $6 billion economic loss to the region.[36]

Furthermore, developing a nationwide smart grid will lower the price of electricity by allowing the market to function more efficiently. Utilities would be able to trade nationwide and put their plants' idle capacity to productive use. For example, the capital-related cost of electricity would decrease by 20 percent if plants connected to a smart grid were fully used up to 15 hours a day, instead of 12.[37] Nationwide trading of electricity would also allow utilities to rely less on expensive natural gas, which currently powers the majority of plants that come online as demand peaks. When and where a grid pools demand enough to let cheaper fuels displace more expensive ones, the cost of electricity can be cut by as much as 40 percent.[38]

A smart grid will further reduce the cost of electricity by allowing investors to "site new plants where they are welcome, where land is cheap, where environmental objectives can be attained at the lowest cost, and where renewable energies are readily available."[39] In fact, a smart grid is necessary to maximize the full potential of renewable sources of energy. Without modern transmission technology, wind or solar energy harvested offshore or in the heartland will never reach the population centers of the East or West Coasts. Similarly, the market for hybrid and electric cars will grow more slowly if the infrastructure that delivers fuel for these vehicles is not strengthened considerably.

The development of a smart grid is thus a major factor in keeping American companies competitive in the global market place. According to a report published by the GridWise Alliance in January 2009, a federal investment of $16 billion over the course of four years would spur $64 billion in private investments in the smart grid sector and create as many as 280,000 new jobs.

Energy Independence and National Security

The development of a smart grid will drastically improve U.S. national security. Right now, the contemporary grid's centralized structure leaves the country "open to attack," according to the DOE:[40] "The interdependencies of various grid components can bring about a domino effect – a cascading series of failures that could bring our nation's banking, communications, traffic, and security system … to a complete standstill."

The smart grid will also reduce the country's dependence on foreign oil by enabling the expansion of the plug-in hybrid and electric car market. With the advent of these vehicles, electricity will begin to squeeze oil out of the transportation sector, allowing the United States to focus on abundant energy, which it can readily produce at home.

Environmental Impact

By relying on a smart grid, the United States will significantly reduce its emissions of GHG as well as toxic pollutants such as nitrogen oxide, sulfur oxide, and particulates. The electricity sector alone emits 40 percent of all the carbon dioxide produced, twice as much as the transportation sector. If the grid were only 5 percent more efficient, the energy savings would be equivalent to permanently eliminating the fuel and greenhouse gas emissions from 53 million cars.[41]

Barriers

While cost and technological barriers stand in the way of swift smart grid deployment, the main obstacles are a confusing patchwork of regulations and powerful existing business interests.

First and foremost, the advancement of large grid projects across regions and states is a regulatory challenge. Federal, regional, state, and municipal agencies must all have their say and, depending on the nature and location of the project, some may opt to delay its progress. This is not only a bureaucratic problem but an economic one, because it deters private investors.

At the same time, investor-owned utilities serve roughly 74 percent of domestic consumers.[42] These entities often have no incentive to improve their transmission efficiency. Current ratemaking structures reward them for producing more energy. Producing and transmitting less energy, on the other hand, will cause their sales to drop without any offsetting benefit to the utility and its shareholders. Thus they continue to rely on old technologies, which in many cases were developed long before microprocessors were invented, reaping profits from sunk investments.

In addition, the advent of the smart grid, while beneficial to the economy and society as a whole, threatens the status of existing privately owned utilities as the industry moves from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive. These issues make the development of a nationwide smart grid, which some sources say might cost $1.5 trillion[43] over the next 20 years, a huge economic and political challenge.

Potential Role and Implications

A smarter grid is the essential building block of a future energy economy. It will allow the United States to fully realize its renewable energy potential by enabling the seamless integration of distributed generation technologies and making long-distance transmission of electricity practical. At the same time, it will dramatically increase the efficiency of our antiquated electricity infrastructure and stimulate growth in all sectors of the economy that depend on electricity.

Distributed Generation

Distributed Energy Resource (DER) or Distributed Generation (DG) systems are small-scale power generation systems, usually in the range of 3 kW to 20 MW, that produce electricity near a center of demand. They enhance—and in some places provide a local alternative to—large centralized generation facilities such as coal, nuclear or hydropower. DER systems may include the following technologies:

- Combined Heat and Power (CHP): These systems recover heat normally wasted in the process of generating electricity and use it to produce one or more of the following: steam, hot water, heating, desiccant dehumidification or cooling. Because they recycle waste heat, CHP systems achieve efficiencies of up to 90 percent.[44] Conventional fossil-fuel power plants, on the other hand, only reach average efficiency levels of 33 percent.[45]

- Micro Combined Heat and Power (MicroCHP): While industrial CHP systems generate heat as a useful by-product of electricity, the opposite is true for MicroCHP systems, which operate (typically at 5 kW or less) in homes or small commercial buildings. The excess electricity these systems generate, which is not immediately used on site, is then sold to the local electric utility.

- Microturbines: These systems resemble small combustion turbines, approximately the size of a refrigerator. Microturbines, which usually generate 25 to 500 kW, offer a number of potential advantages over other technologies for small-scale power generation, including lower emissions, lower electricity costs, and—thanks to the ability to use waste fuels—efficiencies of more than 80 percent.[46]

- Reciprocating Engines: Also called internal combustion engines, reciprocating engines for power generation range from 0.5 kW to 6.5 kW and require fuel (gasoline, natural gas, or diesel), air, compression, and a combustion source to function. When properly treated, these systems can run on fuel generated by waste treatment (methane) and other biofuels. They also make up a large portion of the cooling, heating and power (or cogeneration) market.

- Fuel Cells: These systems convert chemical energy in different energy carriers into electricity. A detailed description of hydrogen fuel cells can be found on page 46 of this report.

- Photovoltaic Systems: Solar cells convert light into electricity. For a detailed description of this technology see page 36 of this report.

- Small Wind Power Systems: Turbines convert wind power into electricity. A detailed description of this technology starts on page 27 of this report.

The key drivers for distributed generation include the systems' relatively low pollution contribution, high efficiency, and reliable supply of high quality power at a competitive price.

Advantages of Distributed Generation

Although the field of distributed generation covers a broad range of technologies, a number of key advantages are common to all. First and foremost, on-site production of energy minimizes both transmission and distribution losses and costs, and helps to bypass congestion in existing transmission grids. This reduces the likelihood of regional brown- or blackouts, a growing problem in the United States that costs the national economy upwards of $100 billion per year.[47] In fact, a number of companies whose business success depends on reliable, high-quality power have chosen to become independent of the grid by installing DG systems on their premises.

Distributed generation also provides advantages to businesses or organizations that require substantial heat, and it offers opportunities to those that have access to low cost fuels including landfill gas and biofuels or renewable energies such as wind and solar. Aside from meeting their energy needs and protecting themselves from volatile electricity prices, these companies can sell their excess electricity to utilities. Further, from an investment point of view, it is generally easier to locate sites for DG technologies than for large-scale power plants.

Grid system operators benefit from increased distributed generation, because they are able to defer upgrades of transmission and distribution systems, reduce losses from their distribution systems, and oftentimes provide network support and other services. Emissions of greenhouse gases, as well as sulfur and nitrogen oxides, are also greatly reduced due to higher efficiencies for carbon-fuel based generators and the increased use of renewable energy sources. Similarly, these increased efficiencies and additional renewable energy resources decrease U.S. dependence on energy imports.

Finally, all technologies offer new market opportunities and create greater industrial competitiveness in the United States. The implementation of new energy management models will also provide businesses with expertise and knowledge of immense export potential.

Disincentives and Barriers to the Expansion of Distributed Generation

DG technologies running on carbon-based fuels perpetuate U.S. dependence on foreign energy resources and release dangerous emissions. Yet their superior efficiencies compared to common centralized power plants make them an important source of power in tomorrow's energy economy. Ultimately, they face barriers similar to those of "green" distributed energy resources, which prevent them from increasing their market share despite a lengthy list of environmental and economic benefits. Such barriers include technological obstacles and economic disincentives in connecting to existing electric utility grids, as well as regulatory problems. This is especially true for CHP technologies.

The installation of CHP equipment and systems is usually subject to regulatory and policy issues at the federal, state, and local levels. The systems must meet varying interconnection standards, local utility terms and conditions, air quality standards, as well as site and permitting regulations. This can hinder or lengthen the installation process, making it difficult, expensive, or cumbersome to install and operate new units. Similarly, the lack of consistent, uniform interconnection standards creates a labyrinth of rules, standards, and fees. The result is that manufacturers, engineering and installation companies, and energy service companies can hardly discern what the requirements and subsequent costs of CHP systems will be.

Since the beginning of the 21st century, state governments as well as Congress have begun to dismantle some of the barriers faced by distributed energy resources. EPAct 2005 required states to adopt interconnection and net metering policies to support the development of small-scale distributed generation projects.[48]

Transportation

Energy use in the transportation sector presents unique challenges to policy-makers. Not only are habits hard to break, but new technology and production from profit-driven industries are also required to shape an energy transition.

According to the EIA, about two-thirds of U.S. petroleum usage is dedicated to transportation. While airplanes, trains, and ships use significant amounts of energy, personal automobiles account for the majority of energy consumed in the transportation sector.[49] Although petroleum is required for more than 95 percent of all transportation energy use, it accounts for less than 20 percent of the energy consumed for other, stationary uses.[50]

The challenge is magnified by the fact that automobile manufacturing is an important source of jobs for the U.S. economy. President Obama and much of Congress have clearly stated the importance of U.S. automakers to the nation's economy and job market. In fact, the government has already directed part of the original 2008 stimulus funds to these ailing companies.

The motor vehicle and parts manufacturing industries employed 703,900 people at the end of November 2008, according to the Bureau of Labor Statistics. The sector has shed 116,500 jobs since November 2007, a 14 percent decline, according to the agency. Auto dealers account for about 1.1 million jobs. The Big Three automakers employ about 201,000 workers, according to the Center for Automotive Research, compared with about 113,000 working in the United States for foreign automakers such as Toyota Motor Corporation, Nissan Motor Company, and Honda Motor Company. The industry as a whole, the research group estimates, indirectly employs between 2.5 to 3 million workers, most of whom are employed by suppliers or in services such as warehousing and parts. As a whole, the industry accounts for 13 percent of U.S. manufacturing jobs.[51]

Future policies must address the transportation sector if U.S. goals are to decrease dependence on foreign oil, reduce climate change and carbon dioxide emissions, and protect consumers from volatile energy prices. Several strategies could help reduce U.S. dependence on hydrocarbons.

- Modify community transportation systems and citizens' travel habits. Some metropolitan areas already rely heavily on public transportation, so further increasing the use of subways, light rail, and buses could reduce individual reliance on personal automobiles, thus decreasing gasoline usage. Alternative strategies, however, would be required in the South, Southwest, and Midwest regions of the United States, where dispersed populations make implementing public transportation a challenge.

- Modify individual travel habits. Increased carpooling and use of bicycles, as well as driving at lower speeds, moving closer to work, or working from home are examples of methods that could decrease individual energy use. However, the effectiveness of policy in successfully encouraging these broad scale behavioral changes has yet to be proven.

- Encourage the auto industry to increase average fuel economy standards. Not only are conventional vehicles capable of significantly better fuel economy than current levels suggest, but enormous strides in fuel efficiency are possible by pairing combustion engines with rechargeable battery-powered electric motors in hybrid vehicles. Although many automobile manufacturers currently offer some kind of hybrid vehicle, some show only modest fuel efficiency improvements. Creating incentives to encourage increased hybrid vehicle use offers several advantages: Congress could implement increased fuel economy standards and provide subsidies for advanced technology research and development with relative ease, and such vehicles would not require any change in infrastructure or current travel habits.

- Encourage use of alternative fuels and technologies. At the present time, vehicles powered by biofuels, hydrogen fuel cells, and electricity are on the road. While biofuels are the most developed alternative, both domestically and globally, controversy surrounds biofuels due to the environmental degradation and food price problems that surround it. Research and development continues for less environmentally damaging biofuels made from switchgrass or algae. For a more detailed description of biofuels, see page 42 of this report.

Hydrogen fuel cells have been used in vehicles like the BMW Hydrogen 7 and city school buses. The use of hydrogen fuel cells has not become widespread, however, due to the need for an infrastructure to distribute hydrogen for refueling. While the only emission from a hydrogen fuel cell car is water vapor, producing the hydrogen itself is an energy intensive process requiring the burning of natural gas. These two significant disadvantages explain its limited development for transportation applications. For a more detailed description of hydrogen as a fuel source, see page 46 of this report.

Several major automakers are developing plug-in hybrid electric vehicles that recharge using a standard electrical outlet. Additional battery capacity reduces their reliance on the gasoline engine to an even greater extent than previous hybrid vehicles. Chevy is planning to introduce the Volt before 2010, and each brand under the Chrysler umbrella (Jeep, Dodge, and Chrysler) has plans to introduce a plug-in hybrid electric vehicle in the 2010 model year.

Pure electric vehicles, by relying solely on electricity for propulsion, are likely to significantly reduce U.S. consumption of hydrocarbons as increasing amounts of electricity are produced using clean, renewable energies. There are several companies producing pure electric vehicles: Tesla Motors, ZAP, and Mini.

Better Place, an innovative company striving to encourage the transportation sector's transition to pure electric vehicles, starting with personal automobiles, has teamed up with Denmark, Israel, and Hawaii. Using electricity derived solely from clean energy sources, they are developing a new electric vehicle infrastructure. Readily available plug-in locations, as well as battery swap stations, are the company's short-term goals. Not only will electric vehicles provide an emission-free form of transportation, once the smart grid and smart meters are widespread, electric car batteries will provide a form of energy storage. Vehicle-to-grid, or V2G, technology enables car owners to charge their vehicles overnight (a time of low demand) and draw power back from their vehicle to their home or to the grid during peak usage hours. (See Energy Storage on page 103 for more information.)

Achieving widespread use of electric vehicles does pose a considerable challenge. New infrastructure is required, along with improved battery performance and longevity. To facilitate demand, consumer outreach and education must be improved and the price must become more competitive with gasoline-powered vehicles.

Renewable Energy Heating and Cooling Systems

The IEA describes renewable energy heating and cooling (REHC) as the "sleeping giant" of renewable energy. Using mature REHC technologies is a cost-effective way to decrease carbon emissions and fossil fuel dependency; the quest for renewable electricity generation, however, has often limited REHC technology investment and development.[52]

Globally, heating and cooling for the residential, commercial, and industrial sectors make up 40 to 50 percent of total energy demand.[53] In the United States, heating and cooling is responsible for about one fifth of the total energy consumed every year, according to the DOE's Energy Efficiency and Renewable Energy department, and accounts for more than half of energy use in the average U.S. home.[54] Water heating takes up a significant portion, frequently consuming an additional 14 to 25 percent of total household energy use.[55] Several REHC technologies exist that can not only provide electricity with low to no emissions but also produce space heating and cooling, and water heating. While ocean thermal energy conversion supplies only air conditioning, biomass, solar, and geothermal technologies can provide space heating and cooling, and water heating.

Ocean Thermal Cooling

Ocean thermal energy conversion (OTEC) uses temperature gradients naturally occurring in different ocean depths and requires a difference of at least 20°C (36°F) to operate. Typically this technology is available only to regions found in the tropics and temperate zones. Although its use in providing electricity is still being researched, OTEC currently provides air conditioning to administration and laboratory buildings at the National Energy Laboratory of Hawaii Authority (NELHA). At this facility, the seawater provides around 50 tons of air conditioning, offsetting the equivalent of 200 kW of peak electrical demand. Using the seawater cooling system saves NELHA almost $4,000/month in electricity cost, and the system requires far less maintenance than traditional systems.[56] For more information on ocean thermal technology see page 57 of this report.

Biomass Heating & Cooling

Biomass materials that provide space heating and cooling include wood and crop residues, organic wastes, crops grown specifically for energy production, animal wastes, black liquor (from pulp and paper production), and municipal solid waste (MSW).[57] Heat producing biomass combustion, which includes wood burning stoves, MSW incineration, pellet boilers, and anaerobic digestion, is a mature technology that is largely cost competitive with fossil fuels. While biomass is not necessarily freely available and does require collection, it is easily stored with existing technology for long periods of time (unlike other renewable technologies).

Further, agricultural residues, animal wastes, and MSW can have low to negative costs where disposal or treatment costs can be avoided. Biomass transport costs, however, can be high due to low energy density when compared to fossil fuels. The overall cost for delivered energy, therefore, can vary greatly depending on the biomass type, transport distance, and storage costs.[58] Land use for biomass production is limited due to biodiversity concerns and the need for resources like food, animal feed, material, and fiber.

Traditional biomass is used for heat by billions of people in the developing world; however, the outdated stoves used to burn it produce carbon emissions that could be avoided with the use of well-designed and enclosed stoves. For example, commercial bioenergy heat production plants produce around 5 to 15 grams per gigajoule (g/GJ) of particulate matter while older domestic wood stoves can emit up to 150 g/GJ.[59]

Harvesting plants and trees (benevolent consumers of harmful carbon emissions) for energy does contribute to the current climate deterioration. Therefore, for biomass-driven heating and cooling to be considered carbon neutral, replacement crops and forests must be continuously planted.[60] For more information on Biomass, see page 31 of this report.

Solar Heating & Cooling

Solar thermal energy can be used to provide space heating and cooling as well as water heating. Passive solar heating and cooling methods that require no equipment are gaining popularity as architects and consumers learn of the simple techniques that harness the sun's energy to naturally regulate indoor temperatures. Active solar heating systems are either liquid-based or air-based. Liquid-based systems heat water or an antifreeze solution in a hydronic collector, while air-based systems heat air in an air collector. In both systems solar radiation is collected, absorbed, and transferred directly into the interior space or into a storage area that further distributes the heat and is capable of providing hot water. The use of solar heating systems vastly reduces greenhouse gas emissions from heating processes that traditionally involve fossil fuels.[61] Deployment of solar technology for REHC is limited, however, by constraints on roof installations, high up-front costs, and a lack of skilled technicians.[62]

The price of installing an active solar heating system varies with the size of the collector area. Most readily available systems can cost from $30 to $80 per square foot of collector area, and the larger systems typically result in lower costs per unit. Most systems come with warranties of ten years or more, although the equipment should last decades longer. The system's potential is maximized when it also provides water heating, because it stays active instead of becoming idle during warm summer months.[63]

Solar heating systems are best used in conjunction with a supplemental heat system. It is most economical to have a solar system that provides 40 to 80 percent of a home's heating needs, particularly if used in conjunction with passive solar heating methods such as large insulated windows on south-facing walls, concrete slab floors, or heat-absorbing walls. Relying on an active solar heating system to supply 100 percent of the necessary heat is not cost effective, and many building codes and mortgage lenders require a back-up heating system such as a wood stove or a conventional central heating system.[64]

Solar-assisted cooling, while still a thermally driven process, is more complicated than solar-assisted heating and needs considerably more research and development before its cost and performance will compete with conventional cooling technologies. Since peak demand for cooling typically occurs at times of peak solar radiation, there is great potential for solar cooling technology to be useful and effective. One alternative is using solar-generated electricity to power conventional cooling or refrigeration devices, though this technique continues to be quite costly.[65] Passive solar cooling techniques such as window overhangs and reflective coatings for windows, walls, and roofs can further reduce household energy demands. For more information on solar energy see page 36 of this report.

Geothermal Heating & Cooling

Geothermal heating and cooling, also known as GeoExchange, earth-coupled, ground-source, or water-source heat pumps, uses the constant temperature of the earth as the heating or cooling medium (as opposed to outside air temperature). Although air temperature can vary tremendously across the country, a relatively constant temperature is maintained a few feet underground. Depending on the location, ground temperature can range from 45°F (7°C) to 75°F (21°C). A geothermal heat pump (GHP) exchanges heat with the earth through a ground heat exchanger which maintains a comfortable indoor temperature whether it is cold outside (and warmer underground) or warm outside (and cooler underground). Both geothermal heat pumps and water-source heat pumps can supply hot water to a home in addition to warm and cool air.[66] Deep geothermal systems transfer heat from depths of 500 to 5000 meters underground and are ideally used in district heating, agricultural, or industrial contexts. Shallow geothermal systems, on the other hand, use heat from depths of less than 300 meters and are best suited for domestic, commercial, and neighborhood settings.[67]

Installing a GHP unit can be expensive, several times that of a traditional air-source system with the same heating/cooling capacity. The energy savings received over 5 to 10 years, however, often make up for the high up-front expense, and domestic-scale systems can be installed almost anywhere. Geothermal heat pump systems are highly efficient at 300 to 600 percent, compared to air-source heat pump's 175 and 250 percent efficiency. Once installed, a GHP makes no noise and takes up relatively little space. Indoor components are estimated to last 25 years while the underground loop is expected to last for more than 50 years. Approximately 50,000 geothermal heat pumps are installed in the United States every year.[68] For more information on geothermal energy, see page 33 of this report.

REHC Conclusions

REHC technologies that have already achieved mass-market (mature) status include passive solar heating and cooling, solar water heaters, biomass combustion, and deep geothermal power generation. Though mature, these technologies are not necessarily pervasive due to varying levels of both natural resources and supportive policies. The technologies not yet mature enough to compete in the mass market without some continued support are: solar active heating, biogas digestion, pellet combustion, and shallow geothermal heat pumps. In many countries, solar thermal systems are widely used without government incentives; adoption in the remaining countries is uncertain. Solar cooling is still under development and will require considerable research and development investment to continue.[69] Interestingly, it appears that the key to the future success of not only REHC but renewable energy in general is the ability to store the energy (heat in this case) that is produced. Until storage technology is fully operational, the potential of renewable energy will be limited.[70]

While REHC systems for space heating and cooling, and water heating, are available to consumers, there are geographic and cost limitations at present that prevent their wide use. Policies will undoubtedly vary by region depending on availability of natural resources. In areas where plentiful natural solar, biomass and geothermal resources exist, less government investment will be needed to bring REHC technology to maturity. Where these resources are scarce, however, more strict and costly policies may be required.[71]

In regions where REHC technologies are not yet at mass-market stage, policies should aim to increase their availability, thereby resulting in cost reductions. It is undoubtedly most beneficial to the environment and consumers to increase the prevalence of REHC while keeping the overall cost low. A comprehensive package that includes financial incentives, certification, labeling, minimum performance standards, public education, and training of trade workers will help REHC technologies claim a greater share of the market going forward.[72]

Policymakers face several challenges when attempting to develop sweeping measures to increase the use of REHC. Due to regional differences in renewable heating and cooling resources, small-scale policies aimed at the state or local level will be required. The volatility of oil and gas prices will make ensuring the affordability of REHC difficult. Imposing a gas tax or providing hefty incentives and rebates, along with increasing cap-and-trade policies, have the potential to ensure that REHC will be cost-competitive. A rigorous consumer-education campaign should also be a part of future policies to inform the public of their options when choosing between conventional and more efficient and carbon neutral heating and cooling technology.

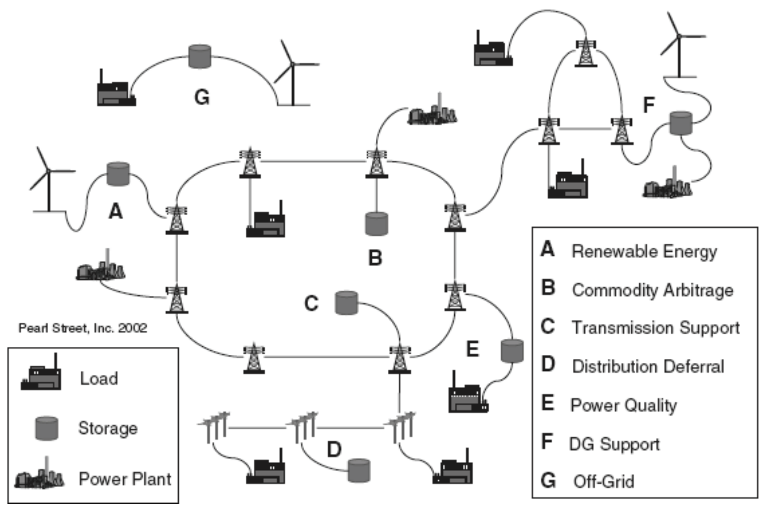
Energy Storage

Energy storage encompasses a wide array of technologies that conserve and divert power generating capacity from one application to another. The importance of energy storage in an energy technology transition varies depending on the energy stakeholder group considered. Renewable energy industry advocates cite the lack of cost-effective energy storage as one of top the barriers to implementing more renewable power capacity in the United States.[73] Similarly, finding new, affordable battery technologies and hydrogen fuel cells suitable for alterative vehicles is a challenge for automakers striving to meet the demand for cleaner-operating vehicles. Those working to improve energy efficiency feel energy storage can be better employed to achieve higher conversion efficiencies of traditional single and combined cycle power plants. Experts surveyed for this report represented many different energy disciplines and political positions; however, most agreed that energy storage was one of the best ways to address national energy concerns.[74]

Grid Storage

Energy storage provides greater efficiency and reliability in electrical power systems. An illustration of the many points of entry for energy storage in the power grid is shown in Figure 4.1.

Figure 4.1
Applications of energy storage in the electrical grid



Source: Septimus van der Linden, "Bulk energy storage potential in the USA, current developments and future prospects," *Energy* 31 (2006): 3446-3457.

This section will describe a number of energy storage technologies that, when implemented into the current electrical power infrastructure, can serve bulk storage, distributed generation, power quality, and off-grid/renewable support applications.

Bulk Storage

Bulk energy storage technologies enable power utilities to better accommodate daily fluctuations in energy demand by either deferring power generation or increasing base load power for peak demand use. They also provide the highest discharge power ranges (from 10-1,000 MW) over the longest periods of time (1-10 hours) at substantial capacity of 10-8,000 MWh of power.[75] It is estimated that plants with proper bulk energy storage systems could operate with 40 percent less generating capacity than would otherwise be required; and this could offer existing power utilities substantial cost and emissions level reductions.[76] Examples of bulk energy storage techniques include:

- Pumped hydroelectric storage: During off-peak energy periods, pumped hydroelectric storage systems pump water in lower reservoirs back to the upper reservoir for later, peak-demand application.[77]

- Compressed air energy storage (CAES): These systems store energy in natural gas power plants by using off-peak, low-cost energy to compress air into underground geologic formations (such as an aquifer or salt cavern) or surface vessels.[78] During peak-demand, the compressed air is discharged and combined with a small amount of natural gas to power the natural gas turbine. CAES is a mature technology demonstrated in two plants worldwide: a 290 MW plant opened in Germany in 1978 and a 110 MW plant opened in 1991 in Alabama.

- Na/S, Zn/Br, Ni/Cd battery systems: Battery packs use electro-chemical reactions for bulk energy storage.[79]

Storage for Distributed Generation

Storage systems with smaller power discharges, lower storage capacity, and shorter discharge power durations (100-2,000 kW discharge of 50kWh to 8mWh of power over 0.5 to 4 hours) are used for distributed generation.[80] Distributed generation uses stored energy for power generation during periods of peak demand to avoid peak energy purchase prices, a process called "peak shaving." Distributed generation might also involve deferring transmission to off-peak periods. Battery storage is the most prominent distributed generation application; however, several alternatives have emerged, including surface CAES (see description above), flywheels, thermal energy storage, flow batteries, and hydrogen fuel cell storage:

- Battery systems: Na/S, Zn/Br, Ni/Cd, Lithium-ion, and V-redox batteries are used for distributed generation applications.

- Flywheels: Flywheel systems store energy mechanically by applying excess generating capacity to turn a rotor or disk in one direction on its axis. This stored mechanical energy is later released by slowing the disk's rotation. According to the Federal Energy Management Program, flywheel systems are becoming a more attractive alternative to battery storage in uninterruptible power supply systems.[81] Although a greater capital investment, flywheels offer distinct advantages to batteries in that they can survive frequent and deep discharges and higher operating temperatures; they also last longer, are easier to maintain, and have a smaller footprint.[82] Flywheels are either high speed or low speed, and their application affects their engineering. For example, high-speed flywheels are more energy dense and are designed to withstand higher rotating speeds during discharge.

- Thermal energy storage: Thermal energy storage applies specific heat materials (e.g. water, cement), thermo-chemical reactions, or phase change materials to store energy created during heat-intensive generating processes. For example, excess heat or electricity can be used heat or chill water, a sensible heat material, which is stored in large water tanks during off-peak hours for later use as hot water or air heating and cooling during peak energy periods. Thermal energy storage that involves thermo-chemical reactions captures energy in chemical bonds formed by applying heat to a material. Phase change materials such as paraffin and hydrated salts capture thermal energy in the form of a phase change as that material heats. As it cools, stored energy is released to power steam turbines.[83]

- Hydrogen fuel cell storage: A hydrogen storage system applies hydrogen fuel cell technology, described in the hydrogen section of this report on page 46, for electrical storage by bundling fuel cells together for central power storage (e.g. on the MW scale). Fuel cells can capture and store electricity when the utility applies excess electricity to the process of ionizing hydrogen in the fuel cell. When ready for use, oxygen is combined with the ionized hydrogen to recreate electricity and the byproduct water.

Storage for Power Quality

Power generation companies also ensure power quality by using energy storage techniques that provide short bursts of energy (from 100kW to 2MW discharged in less than 30 seconds) to the grid when needed through the use of high-speed flywheels (see description above), Superconducting Magnetic Energy Storage, super-capacitors, and batteries.[84]

- Superconducting Magnetic Energy Storage (SMES): These systems "store energy in a magnetic field created by the flow of DC current in a coil of cryogenically cooled, superconducting material."[85] An estimated 100MW in global SMES capacity exists in the United States, Japan, Europe, and South Africa.[86]

- Super-capacitors: Modifications of the traditional capacitor, these power quality systems store energy as an electric charge between two plates that are either metal or another conductive material.[87] Super-capacitors have achieved advances over ordinary capacitors in plate surface area that enable higher energy density and quick recharge.[88]

- Batteries: Lead acid and lithium-ion battery technologies are also used to guarantee power quality in electrical systems.

Storage for Solar and Wind Applications

The introduction of intermittent energy resources into the electrical power system has elevated the importance of energy storage systems that allow wind and solar plants to better redistribute energy supply to periods of limited wind force or sunlight. Research and development efforts in energy storage for solar and wind applications seek to improve the reliability of renewable power systems over longer periods of time. Phase change and sensible heat materials have entered the demonstration phase as an energy storage application for large-scale CSP.[89] In large-scale wind generation, a number of energy storage techniques have been applied including pumped hydroelectric and compressed air systems. Researchers also are experimenting with flywheel systems for wind power applications.[90] For small residential and commercial solar and wind energy storage, deep cycle lead acid batteries are commonly used.

Storage for Transportation

Dr. Peter Hall, Professor of Chemical and Process Engineering at the University of Strathclyde in Glasgow, Scotland, calls the modern transportation sector a "battle-ground for competing technologies, [including] conventional liquid fossil fuels with improved efficiency through hybridization, fuel cells and hydrogen, electrochemical (battery and superconductor), and bio-derived liquid fuels."[91] Because no clear victor has emerged from the available technologies, new energy storage solutions have been developed simultaneously for vehicles powered by non-liquid stored fuels: the electric and hydrogen-powered vehicles.

Electric Vehicles – Implementing Battery and Ultracapacitor Innovation

Hybrid vehicles are the first stage in the transition to pure plug-in electric vehicles. Hybrids combine conventional vehicle technologies with new battery technology to achieve better fuel efficiency and lower emissions. The conventional element powering hybrid vehicles is the traditional lead-acid battery. The lead acid batteries included in all conventional vehicles are used to achieve ignition and power electrical appliances. Hybrid vehicles employ two additional technologies: the propulsion battery and the ultracapacitor. Propulsion batteries made of nickel-metal-hydride battery packs allow regenerative charging in hybrid vehicles.[92] In regenerative charging, the electric motor uses energy captured during braking to recharge the nickel-metal-hydride battery, which then supplements power from the automobile's internal combustion engine.

Ultracapacitors are energy storage units used to improve power and acceleration performance, supplementing the lead acid and propulsion batteries. Ultracapacitors, like capacitors and supercapacitors, store energy through electrostatic (rather than chemical) means. They can provide quick bursts of stored power, reducing the energy requirements of a vehicle's other batteries, extending battery life, and improving vehicle fuel efficiency in city stop-and-go driving.[93]

Improving battery technology for ultimate use in pure electric and plug-in vehicles is the main objective of the NREL Energy Storage Research and Development program. The primary technological barrier to the full commercial implementation of electric vehicles is reducing the cost and weight of the batteries. Another chief concern of DOE scientists in the Battery Technology Development program is proper thermal control of electric vehicle batteries, which they see as "critical to achiev[ing] life, performance, cost, and safety goals of the energy storage system for vehicle applications under the FreedomCar and Vehicle Technologies program."[94] NREL Energy Storage Research and

Development is also investigating methods of reversing the electrical exchange to provide "vehicle-to-grid" capabilities, allowing vehicle users "to meet peak demand, provide grid support services or respond to power outages."[95]

Hydrogen-Powered Vehicles – The Hydrogen Fuel Cell

Hydrogen vehicles apply fuel cell storage as the primary on-board fuel resource. For more about hydrogen fuel cell technology, see page 46 of this report. To date, hydrogen vehicles have been the technology of choice for traditional transportation fuel industry interests, primarily because it is the most inclusive technology, "capable of being made from virtually any energy feedstock, including coal, nuclear, natural gas, biomass, wind, and solar."[96] Also, the DOE's Freedom Car and Fuel Partnership (a cooperative research endeavor between the public and private sector) has made transition to a hydrogen economy a technical goal. To this end, it hopes to "support technologies to enable high volume production of affordable and reliable hydrogen fuel cell vehicles and a hydrogen infrastructure.[97] Currently, hydrogen fuel cell storage is being demonstrated in public bus fleets and cars globally on a small scale. Experts believe, however, that "without leadership from automakers, the transition will be slow, building on small entrepreneurial investments in niche opportunities, such as fuel cells in off-road industrial equipment, hydrogen blends in natural gas buses, innovative low-cost delivery of hydrogen to small users, and small energy stations simultaneously powering remote buildings and vehicle fleets."[98]

Summary

- Implementing smart grid technology and using more Distributed Generation would allow the United States to use existing resources in a more efficient manner.

- Regulations, such as utility and state public service commission policies, are a significant barrier to implementing both smart grid technology and Distributed Generation.

- Energy storage is one of the most effective methods to address the nation's energy concerns because it would improve efficiency and reliability in the nation's electrical grid system, increase renewable energy capacity, aid in the development of a grid system for electric or hybrid vehicles, and assist advanced hydrogen fuel cell technology.

- Transportation sector policies, such as fuel economy standards, the development of electric and hybrid vehicles, and conservation methods such as carpooling and public transportation, will make the nation more energy independent, mitigate environmental concerns, and protect consumers from volatile hydrocarbon pricing.

- There are several renewable heating and cooling technologies that, if subsidized and implemented where geographically appropriate, would decrease carbon emissions and decentralize energy production, thus shifting the nation away from a dependence on foreign sources of hydrocarbons and vulnerable transmission infrastructure.

- Energy efficiency will be more easily implemented, but energy conservation also plays a vital role in reducing the consumption of energy, and curbing carbon emissions. Strong leadership and a concerted effort will be required to expand these energy saving methods.

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Chapter 5. The Continuing Role of Hydrocarbons

The development of alternative energy technologies and reductions in energy demand will only partially reduce dependence on hydrocarbons. Transforming the energy economy will take time, and demand for energy will continue to increase, ensuring a continuing role for hydrocarbons in the future. To make this practical, however, it will be necessary to develop unconventional hydrocarbon technology and lower the costs of hydrocarbon use. As conventional hydrocarbons are depleted or become more difficult to extract, unconventional hydrocarbons will contribute more to the nation's future energy portfolio. Carbon capture and sequestration technology must also be developed to mitigate the emissions associated with hydrocarbon use. If these technologies are adequately developed, many of these problems will be ameliorated, enabling continued hydrocarbon use for a much longer period of time.

Hydrocarbon Dependent Industries

As the production of both renewable and alternative energy technologies expands, some industries will not be able to easily transition from hydrocarbons to more environmentally friendly sources. This includes airlines, shipping companies, and any industry dependent on heavy trucks and diesel powered vehicles, as well as industries with products that use petroleum as an input, such as plastics. Currently, the industrial sector accounts for nearly one-third of total U.S. energy demand. Furthermore, industrial demand for hydrocarbons constitutes a large portion of the estimated growth in oil and natural gas use, both globally and in the United States. By 2030, global industrial demand for natural gas is predicted to increase by 50 percent. Demand for oil from the industrial sector is expected to grow by 5 million barrels per day.[1] Until alternative solutions for these industries are developed, a transition away from hydrocarbons in the industrial sector will not occur.

Coal will continue to feature prominently because it is the nation's primary source of base load electricity generation. The United States possesses 255 billion tons of coal and generates more than 50 percent of its electricity through coal power plants, which account for 36 percent of the country's annual carbon dioxide emissions.[2] Furthermore, coal can produce energy at costs ranging from $1 and $2 per million Btu (MBtu) compared to $6 to $12 per MBtu for oil and natural gas.[3] Given the abundance of coal deposits and low economic costs associated with coal production, incentives exist to continue to use coal. Without adequate substitutes for base load electricity generation, coal will be required to power the nation's electric grid.

Unconventional Hydrocarbons

It is necessary to develop unconventional hydrocarbon technology and lower the costs of hydrocarbon use. As conventional hydrocarbons are depleted or become more difficult to extract, unconventional hydrocarbons will contribute to the nation's energy portfolio. Meeting future world-wide energy demand will also require exploration, extraction, and production of these unconventional fuel sources. Unconventional hydrocarbons include deposits found in oil shale and tar sands. Unconventional fuel sources, however, are carbon intensive and require large quantities of water to produce crude oil.[4] Without carbon sequestration and other carbon mitigating technologies, production of unconventional fuel sources is environmentally harmful.

Carbon Capture and Sequestration

Although plants, soil, and the ocean naturally store carbon dioxide, the term carbon capture and sequestration most commonly refers to the process of injecting carbon dioxide captured from coal power plants underground for storage. Such injections are technically possible at locations that meet specific geological characteristics, including depleted oil and gas reservoirs, unmineable coal seams, deep saline formations, shale, and basalt formations. In fact, energy companies have been employing this process for decades to extract more oil and gas from their reservoirs.

Theoretically, carbon sequestration would allow the United States to maximize the potential of its abundant coal resources while minimizing the harmful carbon dioxide emissions of coal power plants. The costs of carbon sequestration include capture, transport, and sequestration underground, as well as monitoring and maintaining the system. The process of sequestration would require involvement from federal and state agencies such as the EPA, insurance companies, carbon dioxide producers, sequestration site operators, and landowners. In addition, construction costs need to be considered.

The potential positive environmental impact of effective carbon sequestration is enormous though the technology has yet to be proven. According to NETL, "post-combustion, pre-combustion, and oxy-combustion capture systems being developed are expected to be capable of capturing more than 90 percent of flue gas CO_2."[5] However, many unanswered questions exist. With geologic sequestration, fears exist that carbon dioxide will leak into the water table. Also, earthquakes could release large amounts of carbon dioxide into the immediate surroundings of a storage site and into the atmosphere. Storing carbon in the ocean by pumping it deep underwater could prove disastrous if it disrupts fragile marine ecosystems.

Carbon sequestration is still undergoing extensive research. In Germany, however, a clean coal plant using geologic carbon sequestration recently went online. According to a Massachusetts Institute of Technology (MIT) study, the largest current carbon sequestration project is attempting to inject 1 million tons of carbon dioxide from the Sleipner gas field into a saline aquifer under the North Sea.[6] The DOE, EPA, and a handful of energy companies are still trying to implement carbon sequestration policies and technologies. FutureGen, a project between the FutureGen Industrial Alliance and the DOE, sought to design, build, and operate a clean coal power plant in Eastern Illinois. The goal of the project was to capture and store 1 million metric tons of carbon for 4 years, effectively proving the feasibility of carbon sequestration. When the project costs ballooned to $1.8 billion, the DOE pulled out and the project ended. President Obama, however, has earmarked $1 billion in his stimulus package for “fossil energy research and development,” which could mean the FutureGen project, so the project could still be viable.[7]

With effective carbon sequestration, the United States could rely on its abundant coal supplies for decades to come. If safe carbon sequestration can be realized, the NETL says that the Regional Carbon Sequestration Partnerships (RCSP) have identified “more than 88 billion metric tons of geologic storage potential in 9,667 oil and gas reservoirs distributed over 27 states and three provinces.” In addition, RCSP estimates that more than 180 billion metric tons of carbon dioxide sequestration potential exists in unmineable coal seams in 24 states and three provinces.[8]

Growing concern over the environmental effects of petroleum products is likely to result in an expansion of policies designed to curb carbon emissions. Coupled with uncertainty over supply, the increasing costs associated with producing coal, oil, and natural gas will render them less economically viable. Without advances in carbon sequestration techniques and other carbon mitigating technologies, continued production of both conventional and unconventional fuel sources will be environmentally and economically unsustainable.[9]

Summary

- Hydrocarbons will continue to play a role in the world’s energy portfolio.
- Due to growing concern over environmental effects related to the use of hydrocarbons, an expansion of policies to curb carbon emissions is likely to occur.
- Without advances in carbon capture and sequestration and other carbon mitigating technologies, continued production of both conventional and unconventional fuel sources will be environmentally unsustainable.
- Some industries, such as mining, steel, shipping, airlines, and those using petroleum as an input, will not be able to easily transition from a reliance on hydrocarbons to other environmentally friendly sources.
- Currently, coal is an important part of the nation’s energy economy because it is the main source of electric power generation.
- There are many environmental concerns associated with the use of coal; specifically carbon dioxide emissions.
- Meeting future U.S. energy demand may require the extraction and production of large deposits of unconventional resources, such as oil sands and oil shale.

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Chapter 6. The Evolution of U.S. Energy Policy

Policymaking is a dynamic field in which political actors are often placed in a unique position to either hinder or facilitate the development of an energy technology. Consequently, a bill's passage ignites potential conflicts that arise from differing priorities regarding economic growth, national security, environmental impact, and political gain.

As the 1973 oil embargo and the 2008 spike in oil prices have shown, the United States typically responds to energy crises with legislation aimed at conserving, securing, and increasing hydrocarbon based energy production. Energy independence and greenhouse gas reduction are, however, increasingly important priorities in energy policy. Three major energy bills have recently been enacted in response to changing priorities in energy policy. The Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and the Energy Improvement and Extension Act of 2008 all reveal some general patterns to the development of energy policy. Specifically, these legislative initiatives display the incrementalism, fragmentation, and polarization of U.S. energy policy. To successfully address current problems in energy policy, legislation must enact a National Energy Plan that is comprehensive, coordinated, and crafted to appease as many interests as possible.

Energy Policy Act of 2005

The Energy Policy Act of 2005 (EPAct 2005) was the first omnibus energy legislation in a decade, winning the approval the 109th Congress and President Bush four years after first being introduced[1] The bill was designed to address public concern over economic growth, the environment, and energy security. The legislation affected nearly all energy industries by providing $14.5 billion in tax incentives for domestic energy production in the traditional areas of oil, natural gas, and coal ($5.6 billion) as well as a range of renewable energy and electricity technologies ($7.5 billion) spanning solar, wind, geothermal, closed-loop biomass, ethanol, hydroelectric, hydrogen fuel cell, ocean wave and tidal, carbon sequestration and clean coal, nuclear, energy storage, hybrid and flex-fuel vehicles, and methane hydrate applications. The law also provided business and individual tax incentives for energy conservation and efficiency improvements ($130 million). The Congressional Research Service summarized several significant policy acts in the EPAct 2005:

- A Renewable Fuels Standard (RFS) requiring the use of a baseline 4.0 billion gallons of renewable fuels such as biofuels for transportation in 2006, with a growth in that requirement to 7.5 billion gallons by 2012.

- Greater authority for the Federal Electrical Regulatory Commission (FERC) to enforce reliability in the national power grid system and to cite new transmission capacity in the national interest.

- Amends PURPA 1978 mandate to require public utilities to provide interconnection services to enable net metering and smart metering arrangements with energy consumers.

- Increased access to federal lands for domestic energy production.

Leadership

EPAct 2005 was introduced in the House as H.R. 6 by Rep. Joe Barton, R-Tex., Chairman of the House Committee on Energy and Commerce. It was introduced in the Senate by a bipartisan team of Sen. Pete Domenici, R-N.Mex., Chairman of the Senate Committee on Energy & Natural Resources and Sen. Jeff Bingaman, D-N.Mex., Ranking Member of the Senate Committee on Energy & Natural Resources.

Legislative Story

Rising energy prices and growing support for energy independence and security combined with mounting public interest to pass energy legislation in the 109th Congress provided the context for the passage of EPAct 2005. President Bush had asked Congress throughout his first term and into the first year of his second term for a comprehensive energy bill that would develop domestic energy resources, including more renewable resources. At the same time, members of the 109th Congress had come under increased pressure to pass energy legislation from both constituents seeking relief from volatile energy costs; oil and gas interests, who contributed more than ever before to 2004 Congressional campaigns, $16.7 million in total; and growing renewable industry advocacy groups.[2]

The House version of the bill was generally viewed as more friendly to the traditional energy industry.[3] The bill offered tax breaks to industry that totaled $8 billion as well as liability protection for manufacturers of the gasoline additive methyl tertiary-butyl ether (MTBE) which had begun contaminating local drinking water supplies. The inclusion of an MBTE provision in the House version was particularly controversial, because the Senate had blocked legislation including the same provision in 2003 after the two chambers failed to compromise on the issue.

The Senate version of the bill differed markedly on several provisions. First, it benefited from bipartisan support in its Senate passage. After settling several differences, Domenici joined bill sponsor Bingaman to craft the legislation; a move which differed from previous years where Democrats were left out of negotiations on the large energy bills.[4]

Second, the Senate bill included a number of policies to enhance the development of renewable energies and energy efficiency that the House bill did not. The Senate narrowly passed a 10 percent national renewable portfolio standard goal for the year 2020 although it rejected a resolution to reduce U.S. use of foreign oil by 40 percent in 20 years.[5] Tax incentives were also substantially larger overall, and specifically for renewable industries, in the Senate bill, at $18 billion over 10 years compared to the House's $8 billion over 10 years. Finally, the Senate bill included additional incentives for energy efficient commercial buildings, homes, and appliances.[6] The Senate version did not include a policy to open the Arctic National Wildlife Refuge (ANWR) in Alaska to oil drilling as the House version did. Both chambers did, however, approve budget resolutions for opening ANWR that had not reached a final vote at the time of the EPAct 2005 debate.[7]

Finally, the Senate seemed more concerned with acknowledging the findings of emerging environmental studies; Senate bill sponsor Bingaman proposed a plan to "cut emissions of greenhouse gases by 2.4 percent per unit of economic growth beginning in 2010," a policy expressly opposed by members of the House and the Bush Administration for its potential detriment to industry. Environmental groups and others criticized both energy bills for not going far enough to reduce emissions or dependence on foreign oil in the transportation sector. Both the House and the Senate versions mandated the implementation of biofuels for transportation by 2012. Environmental groups, however, believed that increasing mileage standards for vehicles would be a more effective policy to reduce emissions and U.S. demand for vehicle fuel.[8]

Factors Assisting Bill Passage

On July 28, 2005, differences between the House and Senate versions of the bills were resolved in conference. At this stage, several policy provisions were dropped: [9]

- The 10 percent national renewable portfolio standard (Senate) – The RPS provision was most likely abandoned to appease President Bush, who had stated his opposition of this provision in a June 14 statement to Domenici.[10]

- Liability protection for manufacturers of MTBE provided in the House bill – House Republicans, led by House bill sponsor Barton, "jettisoned" this provision at the strong urging of Senate sponsors Bingaman and Domenici, who felt it might kill the bill.[11] House Republicans were, however, able to keep a provision that allowed either party of a future MTBE lawsuit to bring the case to federal court, which was seen as a small "win" for companies that used the gas additive.

- Opening of ANWR for oil and gas exploration provided in the House bill.

President Bush signed EPAct 2005 into law on August 8, 2005, praising the legislation for "promot[ing] dependable, affordable, and environmentally sound production and distribution of energy for America's future."[12]

Legacy

EPAct 2005 is generally regarded as an incremental, but note-worthy, step toward energy security, economic transformation and environmental improvement in the United States. The bill was opposed by many Democrats who believed it contained far too many financial incentives for traditional energy producers and too few for clean, renewable energy. It was criticized by some Republicans for not going far enough to release federal lands for domestic energy production and for interfering with market processes in energy production by subsidizing industries unequally. Although many supporters of the bill admitted that EPAct 2005 was "not perfect," Congress has continued to sustain and expand some its provisions:[13]

- Production tax credits for traditional and renewable energy producers
- Renewable energy tax credits for residential energy investments
- Manufacturing incentives and consumer tax credits for hybrids and fuel efficient vehicles
- Renewable fuels standards

EPAct 2005 also reinvigorated debate over a number of policies that failed to make the final version of the bill. These policies emerged as key issues in subsequent debate of the Energy Independence and Security Act of 2007, the Emergency Economic Stabilization Act of 2008, and during the 2008 Presidential Election: ANWR exploration, renewable portfolio standards, federal emissions standards, net metering and smart metering arrangements, and CAFE standards. Ultimately, Congress' 4-year effort to pass comprehensive energy legislation revealed that building consensus in U.S. energy policy is difficult, especially in the presence of many competing interests. In this light, perhaps the greatest accomplishment of the 109th Congress was overcoming long-standing barriers to energy legislation: partisanship, regionalism, and inertia.

Impact on Industry and the Economy

As the first omnibus energy legislation passed in nearly a decade, EPAct 2005 played a significant role in encouraging new ventures in renewable energy, primarily through its provision of production tax incentives for near-market technologies and research and development funding for other energy technologies. Tax incentives for domestic energy production were especially successful in expanding renewable wind and solar electricity generating capacity. Renewable fuel standards have increased since EPAct 2005, expanding the role of first- and second-generation biofuels in the transportation sector. Furthermore, EPAct 2005 investments and incentives helped usher mass-produced models of hybrid and flex-fuel vehicles to market. The U.S. automotive industry plans mass sale of the first plug-in hybrid vehicles as early as 2010.

Energy Independence and Security Act of 2007

The Clean Energy Act of 2007, the original name of the Energy Independence and Security Act of 2007 (EISA 2007), had a variety of important goals: increased energy independence and security, production of clean renewable fuels, and consumer protection. Making products, buildings, and vehicles more energy efficient, and promoting research and deployment of greenhouse gas capture and storage options, were also significant features of the legislation.

Leadership

The House sponsor of the Clean Energy Act was Rep. Nick Rahall, D-W.Va. There were 198 additional representatives who cosponsored the bill.

Legislative Story

The Clean Energy Act's mandate was to reduce foreign oil dependence by generating revenue for alternative energy and cutting subsidies to the oil industry. The original bill passed in the House by a vote of 264 to 163 without amendment in January 2007, due to a majority of support from Democrats. Speaker Nancy Pelosi, D-Calif., described the vote as "the first step toward a future of energy independence."[14]

The bill was introduced in the Senate in June 2007. In contrast to the House version, the Senate bill focused more on energy efficiency and renewable energy. To reconcile the two versions, Speaker Pelosi planned to use informal bipartisan negotiations.[15] The key matters under negotiation were CAFE standards, the RFS, a 15 percent RPS provision in the House bill, a proposed repeal of certain oil and natural gas subsidies to offset costs for new energy efficiency, and renewable energy tax incentives.

In December, the House amended a new version of the bill and renamed it the Energy Independence and Security Act of 2007. The addition of new CAFE and RPS standards along with significant trimming and modifying of the original House bill resulted in the new EISA 2007 bill.[16] Even though the legislation would increase taxes on the oil industry and raise automobile fuel-efficiency standards, which the Republicans and White House were against, the bill passed the House on December 6, 2007, by a vote of 235 to 181.[17]

The House version of the bill included $13 billion raised from the oil industry, a mandate that utilities rely on renewable energy for at least 15 percent of their power generation, and a $21.8 billion 10-year tax package. The oil and automobile industries, and the U.S. Chamber of Commerce, strongly opposed the measures; the House version failed to pass by a one-vote margin.

Due to a Republican filibuster and the threat of a presidential veto, Democratic leaders were forced to exclude the bill's tax package, which resulted in its passage with overwhelming bipartisan support on December 13, 2007. When the final version returned to the House, it was approved by a 314-100 vote on December 18. President Bush signed it into law the following day.

Factors Assisting Bill Passage

Important factors in the final bill's passage in Congress were record high oil prices and concerns regarding global warming. A *Washington Post* reporter wrote, "The inexorable rise in oil and gasoline prices has concentrated the public mind on the cost of foreign oil and the price of the gas-guzzling American car fleet."[18] The public had also come to recognize and accept global warming as a serious threat, nearly 30 years after scientists first raised the alarm. Consequently, expectations grew for the House to pass an energy package that included measures to slow and reverse the nation's production of greenhouse gases.[19]

In January 2007, energy legislation became a top priority for Congress after Democrats assumed control of the House and the Senate, as well as for private industry leaders. Automakers became increasingly supportive of fuel efficiency standards, which they had opposed for 32 years. Also, a strong coalition of renewable industry advocates began to lobby Congress.

"What has happened in the last couple of years is that you have had a number of additional and very potent voices join the discussion. The upheaval in the Middle East has crystallized recognition that these issues are much bigger than just how many jobs in the upper Midwest are affected. Other industry leaders, outside of the auto industry, are starting to express concern that the volatility of oil and gasoline prices are exposing a fundamental weakness in our economic competitiveness," said Jason Grumet, executive director of the bipartisan National Commission on Energy Policy.[20]

President Bush also changed his approach to the challenges of energy security and climate change. Although President Bush threatened to veto the original bill containing the tax package, he still "endorsed stringent new mileage rules, a sharp increase in production of renewable fuels and concerted international action on climate change."[21] Without the president's approval, the final bill would have likely failed.

Legacy

Although EISA 2007 contained neither the proposed RPS and nor many of the tax provisions, it did include measures designed to increase energy efficiency and the availability of renewable energy.[22]

Key provisions of EISA 2007 as described by the Congressional Research Service are:

- The corporate average fuel economy (CAFE) standard
- The renewable fuels standard (RFS)

- The energy efficiency equipment standards
- The repeal of oil and gas tax incentives

Additionally, the legislation authorized the DOE to establish an incentive program consisting of both grants and direct loans to support the development of advanced technology vehicles and associated components in the United States.

Impacts on Industry and the Economy

EISA 2007 was the first enacted bill to "increase vehicle fuel efficiency significantly since 1975 and the first economy wide bill to address global warming since scientists raised the alarm in the late 1980s."[23]

The bill had a measurable impact on the farming and automobile industries, wind and solar energy developers, and environmental groups. Some considered EISA 2007 a major setback for the automobile industry because it mandated new fuel efficiency standards.[24] High oil prices and concerns about U.S. dependence on imported petroleum, however, overcame business concerns over the new fuel efficiency standards, and created widespread support in Congress. Further, the mandated renewable fuel standards would benefit farm states because of the provision calling for of the use of 36 billion gallons a year of corn-based ethanol and other biofuels by 2022.

Wind, solar, and environmental groups protested the removal of the original bill's tax package and renewable portfolio standard, and requested tax credit and incentive extensions to help them complete major planned projects. Daniel J. Weiss, senior fellow and director of climate strategy at the Center for American Progress, expressed a common sentiment among renewable energy representatives, saying the Senate had given the green light to more-efficient cars and renewable fuels but gave a red light for renewable electricity from wind, solar, and other clean sources.[25]

Energy Improvement & Extension Act of 2008

President Bush signed H.R. 1424, the Emergency Economic Stabilization Act of 2008, on October 3, 2008, in an attempt to stabilize the struggling U.S. economy.[26] This included a notable piece of energy legislation, the Energy Improvement and Extension Act of 2008 (EIEA2008), targeted at stimulating the energy technologies sector with particular focus on renewable energy technologies. Key provisions were incorporated to continue and expand incentives for energy production and conservation efforts, as well as to provide tax relief for those investing in certain energy technologies that aid in U.S. efforts toward a more sustainable energy economy.

EIEA2008 specifically targeted the Internal Revenue Code of 1986 that created tax incentives for investment in and power generation from renewable energy sources. The act extended key tax credits and incentives for those who invest in certain energy technologies.[27] While this could arguably serve to stimulate the green jobs market, it is clear that this section of the Emergency Economic Stabilization Act of 2008 was a bargaining chip used to gain important votes for passage of the overall legislation.

Legislation also included the renewal, extension, and creation of taxes, tax incentives, and tax credits aimed at all energy sectors. Of particular emphasis were the residential and commercial electricity sectors as well as transportation fuels, including large sections on biofuels development and use. Renewable energy incentives included the extension of the renewable electricity production tax credit (PTC) for wind and refined coal facilities through 2009. The PTC was also extended through 2010 for biomass, solar, landfill gas, small irrigation power, trash and biomass, and hydropower facilities. EIEA2008 further extended the authority to issue clean renewable energy bonds through 2009.[28]

Finally, EIEA2008 included several provisions for the transportation sector. Specifically, tax credits for biodiesel and renewable diesel used as a fuel, alternative fuels, and fuel mixtures were extended through 2009. Significantly, it established a new tax credit for qualified plug-in electric drive motor vehicles.[29] This tax credit is set to expire in 2014.[30]

Leadership

On May 14, 2008, Rep. Charles Rangel, D-N.Y., proposed the Energy Improvement and Extension Act of 2008 (H.R. 6049) along with seventeen co-authors in the House, all members of the Democratic Party. The main sponsor of the Emergency Economic Stabilization Act of 2008, and in turn the Energy Improvement and Extension Act of 2008, was Rep. Patrick Kennedy, D-R.I. The bill was co-sponsored by more than 270 other representatives.[31]

Legislative Story

The act moved quickly through the House of Representatives, passing on a vote of 263-160 on May 21, 2008, only one week after its introduction. It then went to the Senate for approval. After failing two motions to invoke cloture on June 10 and June 27, 2008, the bill stalled. On July 29, 2008, a motion to reconsider the invocation of cloture on the motion to proceed to consider H.R. 6049 failed. It was subsequently amended three times and finally passed on September 23, 2008.[32] Differences between the House and Senate versions, however, were never resolved and so it never reached President Bush for his signature. With Congress in turmoil as a result of the crashing U.S. economy, H.R. 6049 died as stand-alone act.

H.R. 6049 was subsequently included in the Emergency Economic Stabilization Act of 2008 (H.R. 1424).[33] Originally introduced on March 9, 2007, by Rep. Patrick Kennedy, the Emergency Economic Stabilization Act of 2008 took nearly a year to come up for a vote in the House. It passed the House on March 5, 2008, by a vote of 268-148 and moved on to the Senate. After several amendments and additions, the Senate passed an amended version of H.R. 1424 by a vote of 74-25. Under extreme pressure from a country now in economic turmoil, it took just 4 hours for the Senate's amended version of H.R. 1424 to pass the House by a vote of 263-171. It was signed into law by President Bush on October 3, 2008, and became public law number 110-343.[34]

Factors Assisting Bill Passage

The Energy Improvement and Extension Act was eventually passed as a part of a much larger bill targeted at tackling the most pressing issue for U.S. citizens at the time - the crumbling economy. H.R. 6049 was a popular bill in its original form and was actually used to draw more support for H.R. 1424 at a time when Congress was under tremendous pressure to act quickly to address the declining stock market and failing financial system. Notably, it did not incorporate extensive new tax credits and incentives, but mainly extended existing credits beyond their previously set expiration dates and clarified some controversial definitions of what did and did not qualify for these credits.

Features of Upcoming Energy Proposals from the President and Congress

In his Inaugural Address on January 20, 2009, President Obama professed his commitment to tackling the current energy crisis stating, "To finally spark the creation of a clean energy economy, we will double the production of alternative energy in the next three years."[35] To attain this goal, he has proposed a New Energy for America plan that will include initiatives to help create five million jobs by strategically investing $150 billion over the next 10 years and ensure that 10 percent of U.S. electricity comes from renewable sources by 2012, and 25 percent by 2050.[36]

President Obama's first legislative priority was the passage of the American Recovery and Reinvestment Bill of 2009, aimed at providing long-term economic growth through job creation, tax cuts, and strategic investments. The package included the Clean, Efficient, American Energy initiative that provides $32 billion to transform the nation's energy transmission grid and invest in renewable energy, $16 billion to repair public housing and make key energy efficiency retrofits, and $6 billion to weatherize modest-income homes. [37]

Congressional committees are currently developing energy policy and global warming legislation. Newly appointed Energy and Commerce Chairman Henry Waxman, D-Calif., set a Memorial Day, 2009, deadline for presenting a comprehensive package of proposals to Congress. Rep. Ed Markey, D-Mass., the new Chairman to the Subcommittee on Energy and the Environment, will push a cap-and-trade proposal co-authored in 2008 by Rep. John Dingell, D-Mich., and Rep. Rick Boucher, D-Va. The proposal places limits on greenhouse gas emissions and allocates emissions credits for trade, sale or investment.[38]

Most recently, top officials in the Obama administration declared that the EPA will be expected to regulate greenhouse gas emissions contributing to global warming.[39] The decision would have an impact on the transportation sector, as well as utility costs and power generation. The EPA is currently under Supreme Court order to determine whether carbon dioxide is a pollutant according to Clean Air Act standards. These recent actions show gathering momentum towards a more comprehensive treatment of policy through the use of government agencies.

Summary

- The United States needs a comprehensive National Energy Plan that effectively addresses three principal goals: economic growth, environmental protection and national security.

- The definition of renewable energy has been expanded over time to include an assortment of renewable technologies. Concern regarding environmental issues has also increased.

- Negotiation was a crucial component of the legislative process; compromise was needed among the various interest groups and political parties to ensure each bill's passage.

- Policies adopted in these bills include tax incentives for energy conservation and efficiency improvements, production tax credits for traditional and renewable energy producers, renewable energy tax credits for residential energy investments, manufacturing incentives and consumer tax credits for hybrid and fuel efficient vehicles, plus other financial incentives (grants and loans) for renewable energy technologies, renewable fuel standards, CAFE standards, energy efficiency equipment standards, smart grid, and research and development funding.

- Although EIEA 2008 offered no tax credits for renewable technologies not previously included, the act illustrates a trend toward extending or creating tax incentives and tax credits in all energy sectors.

- Policy options available for new legislation include national renewable portfolio standards, certain oil and natural gas subsidies to offset costs for new energy efficiency and renewable energy tax incentives, continued and expanded incentives for energy production and conservation efforts, cap-and-trade programs, and research and development funding.

- President Obama will support congressional passage of a clean energy economy bill to double the production of renewable energy.

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http://money.cnn.com/2008/10/03/news/economy/house_friday_bailout/index.htm?postversion=2008100309. Accessed: October 7, 2008.

[27] CroweHorwath. Tax Effects of the Financial Rescue Package. Online Avaiable:http://www.crowehorwath.com/crowe/Publications/detail.cfm?id=1777. Accessed: February 1, 2009.

[28] Govtrack. H.R. 6049: Energy Improvement and Extension Act of 2008. Online. Avaiable:http://www.govtrack.us/congress/bill.xpd?bill=h110-6049. Accessed: January 22, 2009.

[29] HybridMile. Wall Street Bailout Includes Energy Improvement and Extension Act of 2008. online, Available: http://www.hybridmile.com/alternative-fuel/street-bailout-includes/. Accessed: January 24, 2009.

[30] Govtrack. H.R. 6049: Energy Improvement and Extension Act of 2008. Online. Avaiable:http://www.govtrack.us/congress/bill.xpd?bill=h110-6049. Accessed: January 22, 2009

[31] Govtrack. H.R. 1424: Emergency Economic Stabilization Act of 2008. http://www.govtrack.us/congress/bill.xpd?bill=h110-1424. Accessed: January 20, 2009.

[32] Govtrack. H.R. 1424: Emergency Economic Stabilization Act of 2008. http://www.govtrack.us/congress/bill.xpd?bill=h110-1424. Accessed: January 20, 2009.

[33] Govtrack. H.R. 1424: Emergency Economic Stabilization Act of 2008. Online. Available: http://www.govtrack.us/congress/bill.xpd?bill=h110-1424. Accessed: Retrieved January 20, 2009

[34] Govtrack. H.R. 1424: Emergency Economic Stabilization Act of 2008 – Roll Call Votes. Online. Available: http://www.govtrack.us/congress/bill.xpd?bill=h110-1424. Accessed: January 20, 2009.

[35] Whitehouse Agenda. *Remarks of the President-Elect Barak Obama As Prepared for Delivery: American Recovery and Reinvestment*. Online. Avaiable: http://whitehouse.gov/agenda/economy/. Accessed: January 24, 2009.

[36] Ibid.

[37] Committee on Appropriations. *Executive Summary American Recovery and Reinvestment*. http://appropriations.house.gov/pdf/RecoveryBill01-15-09.pdf. Assessed: January 26, 2009.

[38] Geof Koss. “World Intersects at House Energy Panel.” Roll Call. Online. Available: http:www.rollcall.com/issues/54_81/news/31892-1.html. Accessed: February 1, 2009.

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Chapter 7. Case Studies and Lessons Learned: Cold Fusion and Biofuels

Analysis of major energy legislation since 2005 demonstrates that political decisions often produce unintended consequences. The following case studies represent two extremes along the policy spectrum and provide a framework for understanding the political, economic, and environmental ramifications associated with the development and implementation of energy policy.

Cold Fusion

Cold fusion is an example of a prospective energy technology that perhaps should have been supported by the federal government, given its enormous promise for resolving domestic energy supply issues. Instead, cold fusion was ostracized by mainstream academia, government officials, and politicians.

On March 23, 1989, two chemists, Dr. Stanley Pons of the University of Utah and Dr. Martin Fleischman retired from the University of South Hampton, made an unexpected announcement during a press conference organized by the University of Utah. The chemists claimed success at creating a cold fusion reaction.[1] Cold fusion, a term coined by E. Paul Palmer of Brigham Young University in 1986, is the anomalous production of excess heat caused by a nuclear fusion reaction at room temperature. While cold fusion would be revolutionary for the worldwide supply of energy, the findings of Drs. Pons and Fleischmann were dismissed because the announcement was premature and deviated from academic standards.

In 1988, Drs. Pons and Fleishman sought DOE funding for a set of experiments focused on the production and replication of cold fusion reactions. Dr. Steven E. Jones of Brigham Young University acted as a peer reviewer during the evaluation process. Jones, a colleague of the chemists, had previously worked on muon-catalyzed reactions and published an article in *Scientific American* in July 1987 entitled *Cold Nuclear Fusion.* The three chemists agreed to publish their cold fusion results simultaneously in *Nature* magazine. In a surprising turn, however, Pons and Fleishman submitted their paper to *The Journal of Electroanalytical Chemistry* and announced their findings at the now infamous press conference.[2] The involvement of the press, which circumvented normal scientific protocol, in addition to discrepancies in their findings marked the beginning of cold fusion's descent into obscurity. The scientific community was unable to consistently replicate Pons' and Fleischman's results, and their claims that nuclear byproducts were produced during the reaction could not be confirmed. The DOE conducted subsequent studies in 1989 and 2004 that resulted in the theory's dismissal and a denial of government funding.

In the years following Pons and Fleischman's announcement, a wide array of experimental designs have been tested using various metals and deuterium concentrations. The results have yielded inconsistent outcomes, sometimes producing transmutations, excess heat, or no reaction at all. While largely discredited by the physics community, a small group of scientists in the United States continues to conduct independent research under the title of low energy nuclear reactions. Recently, the U.S. Navy announced "significant" results in the production of cold-fusion like reactions.[3]

An adhoc press conference and the absence of peer reviewed research with clear methodology and replicable procedures, coupled with mass skepticism by the scientific community, all contributed to cold fusion's demise. By heeding the lessons learned from cold fusion, perhaps future scientific breakthroughs can be addressed more cautiously and in collaboration with the academic community and the government. It is important to consider that significant breakthroughs and future alternative energy sources may come from the most surprising of places.

Biofuels

Corn ethanol is a story of U.S. policy attempting to prematurely select an energy technology as a preferred option. Due to unintended consequences associated with life cycle costs and food supplies, the government should not have supported corn ethanol. This case illustrates the uncertainty surrounding energy policy decisions and the need for policymakers to use caution when making such decisions.

In the United States, fluctuations in oil prices have spurred demand for alternative energy sources capable of offsetting foreign oil while also reducing greenhouse gas emissions and increasing domestic economic activity. In the 1990s, a renewed interest in corn-ethanol catapulted the industry into the spotlight. Consequently, policies aimed at bolstering corn production generated a new set of unintended consequences. By diverting corn reserves from feed stocks and underestimating life cycle costs associated with production, corn ethanol's feasibility has come under close scrutiny by environmental organizations and the American public.

For the past 6 years, the U.S. Congress has provided farmers and refiners with lucrative incentives aimed at increasing ethanol production.[4] EPAct 2005 included a subsidy of 51 cents per gallon of ethanol blended with gasoline and a mandate requiring the annual production of 7.5 billion gallons of renewable fuels by 2012. Most recently, the Food, Conservation, and Energy Act of 2008, an omnibus bill passed in May, allocates $300 million for the Bioenergy Program for Advanced Fuels over the next 5 years and also establishes the Biomass Crop Assistance Program for agricultural and forest landowners.[5] The recipients of such subsidies, grants, and other financial assistance packages are heavily concentrated in the Midwest, a key region that has gained importance during presidential primaries and national elections. During the 2008 presidential campaign, Sen. Barack Obama, D-Ill., the second largest corn producing state in the nation, publicly announced his support for the continued funding of corn ethanol.

Passage of EPAct 2005 resulted in an initial increase in corn ethanol production. Current projections indicate that production will exceed 12 billion gallons in the following years, surpassing the 7.5 billion gallon mandate established for 2012.[6] However, 12 billion gallons of corn ethanol produced annually would only substitute for 7.5 percent of domestic oil consumption and would require 31 percent of total corn produced.[7] Projections also suggest that devoting the entire corn supply to ethanol production would offset only 12 percent of U.S. oil consumption.[8] These findings suggest that corn ethanol could not effectively replace oil without an assortment of energy alternatives to offset such consumption. It is also apparent that EPAct 2005 contained measures that inadequately addressed life cycles costs and risks associated with weather conditions and carryover stocks.

Price volatility associated with adverse weather conditions and overall decreases in carryover stocks could compromise other industries, specifically soybean, wheat, and poultry. Continuously growing corn on lands that usually undergo two-year crop rotation cycles requires increased quantities of fertilizers and pesticides. Consequently, annual corn yields would eventually decrease and annual wheat and soybean supplies would be limited, thereby inducing volatile price fluctuations in the farming and livestock sectors. Studies analyzing life cycle costs and energy net yield associated with corn ethanol production have indicated both negative and positive yields. It is evident, however, that ethanol production would require significant quantities of water, fertilizer, pesticides, land usage, electricity, and gasoline to power tractors and fuel transportation.

In conclusion, corn ethanol provides a salient example of the importance of analyzing the full consequences of new alternative energy resources. The findings ultimately call into question ethanol's ability to offset greenhouse gas emissions while ensuring an abundant, domestic energy source that would further enhance the nation's energy independence and security.

Summary

- Premature reporting and the inadequate development of the theoretical basis of cold fusion contributed to its dismissal.

- A lack of consensus among the scientific community compromised cold fusion's potential as a legitimate alternative energy source.

- It is vital for the scientific community to adhere to protocol when researching and developing new technologies.

- Inadequate research and development by the federal government can compromise potentially viable energy technologies.

- Collaboration between the scientific community and the federal government is critical to the development of energy-based technologies and their applications.

- It is important to consider the economic, political, and social implications associated with the development of energy technologies.

- The EPAct 2005 prematurely subsidized corn ethanol and mandated increased production of renewable fuels without considering the impact on corn supplies and other agricultural industries.

- Continued investment in region-specific alternative energy resources may be politically motivated and often does not achieve a healthy balance between economic, environmental, and geopolitical priorities for the nation as a whole.

- Alternative energies may incur life cycle costs that compromise priorities related to the environment; therefore, a proper assessment of a technology's environmental impact should be made prior to implementation.

- In order to offset the consumption of hydrocarbons, the U.S. economy should not be completely vested in one energy technology but rather an assortment of potential alternative sources.

Notes

[1] Malcolm W. Brown. "Fusion in a Jar: Announcement by 2 Chemists Ignites Uproar." New York Times. March 28, 1989. Pp1.

[2] Stanely Pons and Martin Fleishman. "*Electrochemically induced nuclear fusion of deuterium",* Journal of Electroanalytical Chemistry *261 (2A): 301–308.*

[3] Erik Berger. "Navy Scientist announces possible cold fusion reaction." *Houston Chronicle*. Online. Available: http://www.chron.com/disp/story.mpl/headline/nation/6333164.html. Accessed on March 27, 2009.

[4] Erika Wage. "U.S. Energy Policy Response to International Food Prices: The Costs and Effects of Corn Ethanol Production." *Politics and Policy (36:05).* p792.

[5] 2008 Farm Bill Side-by-Side. USDA Economic Research Service. Online. Available: http://www.ers.usda.gov/FarmBill/2008/Titles/TitleIXEnergy.htm#bioenergy. Accessed on March 25, 2009.

[6] Paul C. Wescott. "USDA Agricultural Projections to 2005." *USDA Economic Research Service Staff Report No. WAOB-97-1.* (April 23).

[7] Wage, *U.S. Energy Policy Response,* p. 794.

[8] Ibid.

Chapter 8. Viewpoints of Energy Experts

Experts in the energy technology and policy field were surveyed after baseline research of energy economics, technologies, and policies was completed. The survey of experts was performed in order to ensure up-to-date information and to secure viewpoints of experts for development of energy policy recommendations. Experts were chosen based on their practical knowledge of the topic as demonstrated by their academic and professional pursuits. The selected experts work in the energy industry, academia, or within state or federal government. Survey forms were developed and distributed, and the interviews were conducted in person, by phone, and by e-mail. Four specific areas of interest were covered -- the continuing role of hydrocarbons, energy technologies, energy conservation and efficiency, and energy policy. The questionnaires were designed to obtain technical and political information, garner expert opinions and experiences, and define the top U.S. concerns related to an energy technology transition. The survey itemization can be found in Table 8.1.

The research team contacted 156 energy experts and received a total of 27 responses for a response rate of 17 percent. Each expert was asked five general questions found in Table 8.1 as well as additional questions based on their specialty. The responses were then tabulated for each question. Specific themes emerged from responses across the different questions, thus the reported findings are not categorized by question and are instead derived from responses to many questions. In general, the findings are presented at an aggregate level as many interviewees wished to remain anonymous.

Table 8.1 displays all questions for each energy area, the expertise of respondents, and the number of experts that answered each question. Please note each area was not equally represented in survey responses. Specifically, the technology interviews do not cover all energy technologies discussed in this report. Samples of each survey can be found in Appendix 1. The general findings and the findings for each of the four areas of interest are summarized below.

General Findings

Energy policy is *just as important* as any other policy area. Of the 27 interviewees, 26 agreed that energy policy is just as important as or more important than any other policy area. Of these, nine added that energy affects all other policy areas due to its integration into other policy issues.[1] Perry Been, a specialist in energy conservation, explained that "energy plays a vital role in just about every other policy issue… whether [it's] healthcare costs, [the] global economy, [or] climate change. Energy is no longer just a 'cost of doing business,' but is rather a 'manageable cost' affecting every segment of business, industry, and government."[2] Three others asserted that because of the consequences of inaction, energy policy is at least as important as all other policy issues.[3]

Table 8.1
Survey Itemization

Area & Interviewee Breakdown		Question & Number of Responses for Each Question	
A. General	*Experts in:* • Hydrocarbons • Alternative Technologies • Conservation & Efficiency • Policy	What are the most important reasons the United States should transition away from hydrocarbon-based energies?	26
		Briefly describe what you think the consequences would be for the U.S. and the world to continue our current dependence on hydrocarbons?	20
		What should be the goal in terms of percentage of renewable energy incorporation in the United States' energy plan in 2012, 2025, 2050, and beyond 2050?	24
		Which of the following best describes the future role of energy policy in the U.S. in the next 10 years?	27
		What energy technologies, once implemented, will allow the U.S. to best advance policy objectives in the areas of energy independence, environmental protection, and economic progress?	27
B. Role of Hydrocarbons	*Experts in:* • History • Industry	What are the key issues to note about the energy history of the U.S. in respect to oil, natural gas, and petroleum?	2
		In your opinion, what parallels do you see between the period of the 1970s and the oil crisis, and where we are today? What are some of the differences?	2
		In your opinion, is the geo-political landscape of today, in respect to the need for the petroleum based commodities, different from the period of the 1970s oil crisis? How and why?	2
		Historically, has the U.S. had any leverage over OPEC countries in the past? In what ways? Were there consequences to U.S. energy supply as a result?	2
		How would you articulate the lessons that can be learned from looking at the ways in which the U.S. has dealt with oil and petroleum based products?	2
		What do you believe the role of hydrocarbons will be in the future as we move towards an energy technology transition?	1
		Do you believe that sustaining the current U.S. energy supply mix will have negative consequences? Why or why not?	1

C. Energy Technologies	*Experts in:* • Solar CSP • Hydrogen • Nuclear Fission • Nuclear Fusion • Cold Fusion • Methane Hydrates • Ocean Current • Ocean Thermal • Wave • Distributed Generation • Smart Grid	In a best-case scenario, how long will it take to develop your energy to be commercially viable?	15
		In order for your energy to become commercially viable, what top 3 steps need to be taken?	15
		What would be an estimate of the financial investment necessary for your energy to achieve commercial viability?	16
		In a best-case scenario, what percentage of the U.S.'s electricity demand could be covered by your energy in the years 2012, 2025, 2050, and beyond 2050?	11
		What is the largest technological barrier to the development of your energy?	16
		What past policies have successfully promoted the advancement of your energy in the U.S. or internationally?	16
		What past policies have hindered the advancement of your energy in the U.S. or internationally?	15
		Which alternative energy technologies do you believe SHOULD NOT be a part of the United States' energy technology transition and energy future?	16
		Which alternative energy technologies do you believe SHOULD be a part of the United States' energy technology transition and future?	14
		Which alternative energy technologies are useful ONLY in a transitional role?	14
		How do you anticipate a cap & trade policy would affect the development of your technology?	12
		Please briefly explain how your technology addresses the following national policy areas: • U.S. national security & energy independence • Pollution & the environment • U.S. economy	14

D. Energy Conservation & Efficiency	*Experts in*: • State • Federal • Private	Assuming equally ambitious policies are instated in each sector, please rank the following sectors in order of their potential to decrease energy consumption in the United States: residential, commercial, transportation, and industrial	4
		Which method of reducing energy consumption will be *most* useful for the U.S. in terms of energy saved and ease of implementation: energy conservation or energy efficiency?	4
		What role should demand-side management practices have in future energy conservation and/or efficiency policies?	4
		Please identify the past energy conservation and/or efficiency policies which had the greatest impact by decreasing energy consumption the most.	4
		Which past policies had the least impact by decreasing energy consumption the most?	4
		What energy conservation and efficiency measures, if utilized, would decrease the United States' reliance on fossil fuels the most?	4
E. Energy Policy	*Experts in*: • Congress • Academia • Advocacy	What are three important policies or political forces hindering the transition to more renewable energy resources in the U.S.?	7
		In your opinion, what factors (economic, political, cultural, etc.) are necessary for the United States to achieve President-elect Obama's stated goal of 10 percent renewable electricity by 2012?	7
		In the transition to more renewable energy resources, what specific roles should the government and private sector play?	7
		Based on your experience with any of the following pieces of legislation, can you describe the most important factors contributing to its passage/failure/modification in the House/Senate? Were there any features of the legislation that were more controversial than others? If so, what were they? What other challenges did you encounter in the process as a professional? • Energy Policy Act of 2005 • Energy Independence and Security Act of 2007 • Emergency Economic Stabilization Act of 2008 Division B: Energy Improvement and Extension Act	5
		In the new administration, which new and existing policies will be most effective in developing and distributing renewable energy supply / demand in U.S. markets?	4

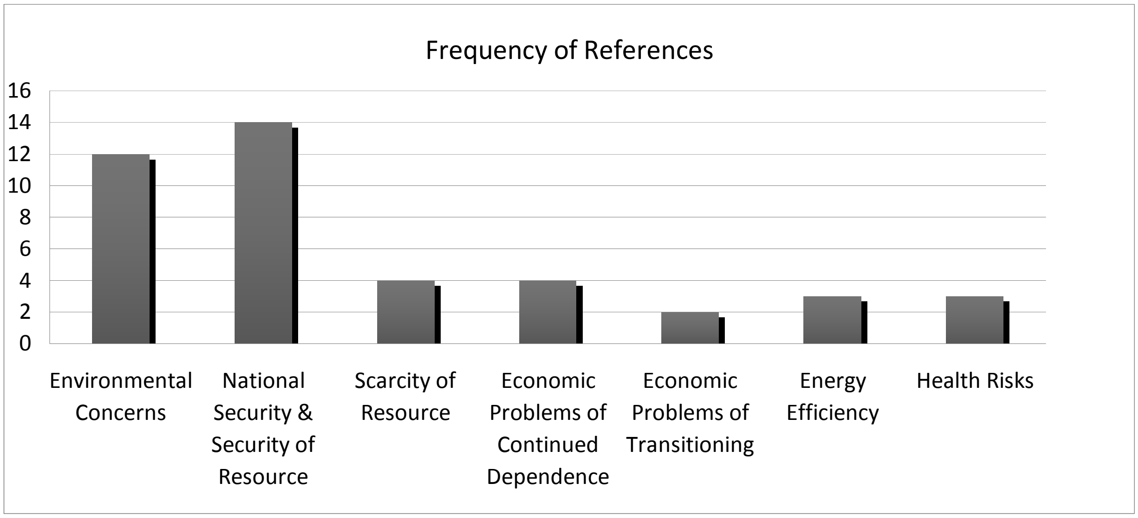
The United States should transition away from hydrocarbon-based energy sources. As an aggregate, the responses asserted that the top three reasons to engage in an energy transition were *national security*, *economic issues*, and *global climate change*. Of the experts that added to their answer, Steven W. Pullins of NETL stated that the United States should not necessarily move away from hydrocarbon-based energies, but instead move "toward energy technology that can create a new U.S. industrial base…If we transition away from such solutions [solely] because [they are] hydrocarbon-based, we create an ever increasing waste and biomass issue in the world."[4] A fusion scientist at the DOE added that the United States needs to transition away from hydrocarbon-based energies in order to "conserve oil for other uses."[5] Only one interviewee stated that there was no reason to transition away from hydrocarbon-based energy sources.[6]

Continued dependence on hydrocarbons may threaten national security. Of the 20 responses that described the consequences of continued U.S. dependence on hydrocarbons, 14 indicated that the top concern related to U.S. national security and security of the energy resource. Figure 8.1 displays the frequency of reference for each concern. Camille Coley from the Center for Ocean Energy Technology stated that "U.S. dependence on hydrocarbons is damaging to U.S. foreign policy and U.S. national security. Countries like Russia, Iran, and Venezuela have been increasingly able to use their energy resources to pursue their strategic and political objectives while the United States and other energy dependent countries are finding that their growing dependence on imported energy increases their strategic vulnerability to the countries [that] are hydrocarbon rich."[7] David Spence at The University of Texas at Austin added, "There will be negative consequences for sustaining the current U.S. energy supply mix because of dependence on unstable or hostile regimes for imports."[8] Another expert shared, "oil contributes to a transfer of wealth to unstable and potentially aggressive governments."[9]

Continued dependence on hydrocarbons may negatively impact the environment. Twelve of the 20 interviewees specified that a continuing dependence on hydrocarbon-based energy sources may lead to negative environmental consequences. As a whole, experts indicated that there could be problems associated with carbon emissions, air quality issues, continued degradation of the environment, and global climactic instability.[10] Patrick Moore at Greenspirit Strategies Ltd. added that "if there are alternative technologies that can do the same job, especially if they [reduce] impact on the environment and health, and are cost-competitive, we should switch off fossil fuels."[11]

An energy transition may create economic problems or economic opportunities for the United States. Responses mentioned economic problems as a consequence of both continued dependence on hydrocarbons as well as a quick transition. Steven Biegalski at The University of Texas at Austin said "we should not push ourselves away from hydrocarbons if it is not economically justifiable."[12] With similar sentiment, Robert Erlich of Petrolifera Petroleum Limited added, "Alternative sources of energy cannot be made competitive with fossil fuels at present without major government subsidies or even huge taxes on fossil fuels, either of which could cripple the economy."[13]

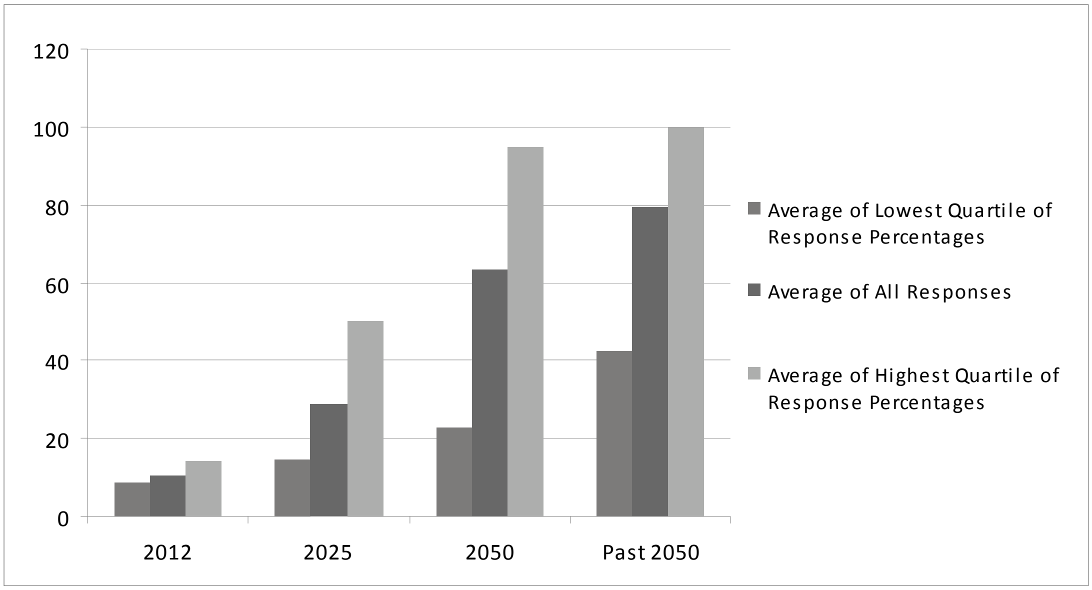
Figure 8.1
Frequency of References in Response to the Consequences of Continued Dependence



On the other hand, Chris Sauer of Ocean Renewable Power Corporation stated there may be concerns due to continued dependence on hydrocarbons such as price volatility and limited economic recovery and growth.[14] Perry Been added that if the United States maintains its current energy mix, a power shift may take place where those with the remaining resource supplies will hold economic power.[15] Finally, Tommi Makila, an expert in energy conservation, pointed to the economic benefits of an energy transition: "If we don't act now, the United States would be missing out on a great economic opportunity. As the world will undoubtedly be moving toward non-carbon energy sources, those leading the way and developing the technologies will reap the great economic benefits."[16]

The United States should incorporate increasing amounts of renewable energy technology into its energy portfolio. Twenty experts offered estimates of the percentage of renewable energy technology that could be incorporated into the U.S. energy plan by 2012, 2025, 2050, and beyond 2050. These estimates are found in Figure 8.2. Each year shows the average of the lowest quartile of response percentages, the average of the highest quartile of response percentages, and the average of the total responses.

Figure 8.2
Percentage Estimates of Renewable Energy Technologies in the U.S. Energy Portfolio



Common themes from additional comments include:

- The United States should incorporate as much renewable energy as possible, as quickly as possible.[17]
- The United States should continue to use the main sources of base-load power (coal and nuclear) because they are cost-effective, domestic resources.[18]
- The United States should first focus on reducing energy consumption and increasing energy efficiency.[19]

Role of Hydrocarbons

Hydrocarbon-based resources need to be managed on the demand side as well as the supply side. Two experts questioned agreed that focus should be placed on demand side resource management. David Painter, a professor at Georgetown University, stated, "Higher costs are increasing the visibility of oil-related issues, but the potential to solve problems of security and cost of supply by focusing on supply-side solutions has diminished considerably."[20] Robert Erlich of Petrolifera Petroleum Limited added that currently there are multiple countries "in direct competition for the same resource supply shared by only two main consumers 30 years ago." Yet, even now most people never think about turning off lights or appliances in unoccupied rooms.[21]

Hydrocarbon-based resources will continue to play a role in the world's energy mix. The experts expressed the belief that not only will hydrocarbons maintain their significant role in the world, but further added that their role will increase in developing nations. David Painter suggested that developed nations need "to use less oil and natural gas so that developing nations are able to improve their economies by using more."[22] He added that this would keep total world demand relatively stable.[23] Robert Erlich agreed, stating, "The developed world may adopt the restrictive policies necessary to achieve a substantive level of renewable energy contributions, but it will not drag the underdeveloped world along with it."[24] Painter also asserted, "Hydrocarbons, especially oil and natural gas, will continue to play an important role, but we should try to be much more careful in the use of them."[25]

Energy Technologies

The top technologies to advance the policy objectives of energy independence, economic growth, and environmental progress are solar, grid technology, energy storage, wind, and nuclear fission. All experts ranked the following technologies from most helpful to least helpful according to their ability to advance the above stated policy objectives. The five top ranking energy technologies of each response were tallied and totaled.[26] The results are displayed in Table 8.2.

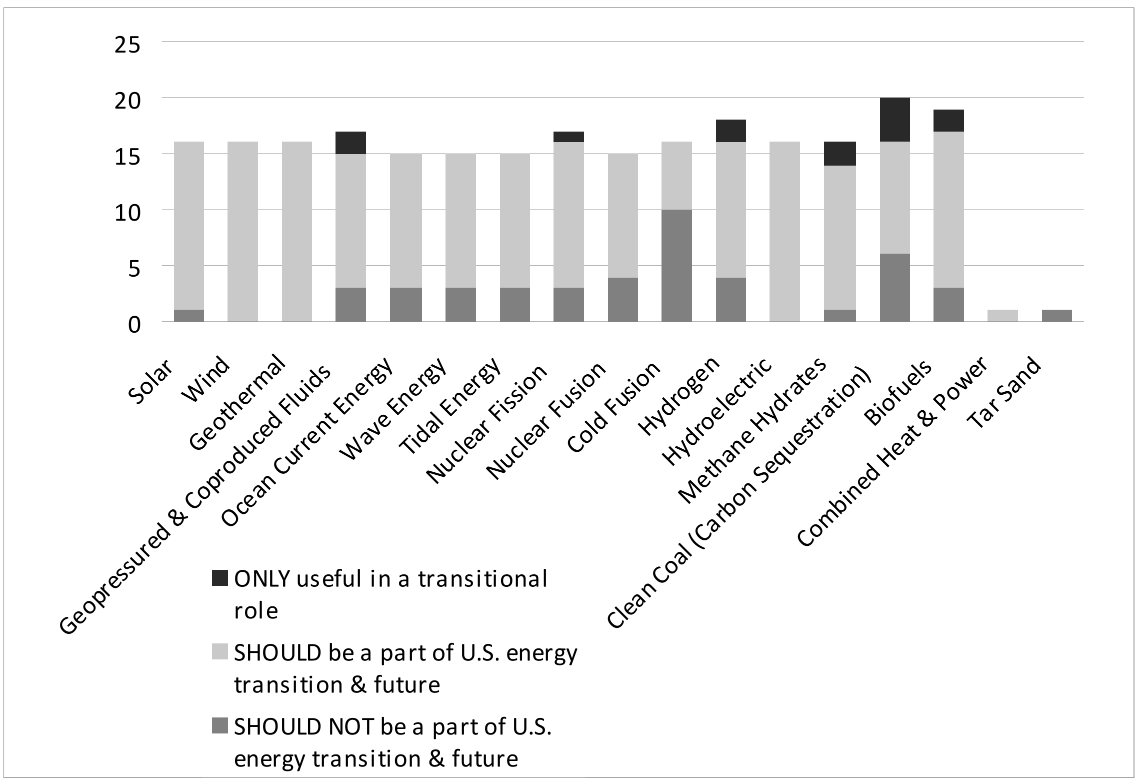
Table 8.2
Top Renewable Technologies to Advance Policy Goals

Top 5	Middle 7	Bottom 5	Additions
Solar	Clean Coal/Carbon Sequestration	Cold Fusion	Biomass
Grid	Geothermal	Methane Hydrates	Energy Efficiency
Energy Storage	Biofuels	Geo-pressured & Co-produced Fluids	Combined Heat & Power
Wind	Nuclear Fusion	Hydrogen	Plug-in Hybrids
Nuclear Fission	Hydroelectric	Ocean Current	
	Tidal		
	Wave		

Several interviewees added energy sources, technologies, and strategies to their top selections. Biomass, energy efficiency, combined heat and power, and plug-in hybrids were added to the list. Ross Baldick at The University of Texas at Austin further defined his preference for biofuels, noting that "only nonfood-based biofuels should be utilized."[27] One interviewee qualified his top technologies adding, "There has to be an integrated, broad, and balanced attack on the issue as there is not one simple solution to the problem."[28]

Experts disagree about the appropriate roles and uses of many energy technologies. Sixteen respondents selected technologies that should not be a part of the U.S. energy future, technologies that should be a part of the U.S. energy future, and technologies that should only be used for the transition. The results of those responses are found in Figure 8.3

Figure 8.3
Role of Technologies in an Energy Transition



Several interviewees further explained their choice of energy sources or technologies. Ross Baldick asserted that certain resources and technologies, such as nuclear fusion, could not play a role in the energy technology transition as they are not yet developed.[29]

Many sources and technologies will play a role in the future of U.S. energy. Five responses indicated that in the future the United States will need a diverse energy portfolio. Therefore all sources of energy may play a role.[30] Steven W. Pullins at NETL elaborated further, "The truth is that the U.S. needs a portfolio approach to energy production/conversion/generation using all sources that make sense in the portfolio."[31]

U.S. policies leading to successful development or implementation of alternative energy technologies are both political and financial in nature. Ten of the interviewees suggested that policies offering political support by streamlining regulations and processes, enacting renewable portfolio standards and environmental protection standards, and contributing to research and development most successfully promoted the advancement of alternative technologies.[32] Of the four responses that suggested international collaboration and international competition promoted technological development, all stated that the policies resulted in increased research and development funds.[33] Figure 8.4 displays the percentage of policy mentions per type of energy source. Please note that responses did not represent all technologies.

- Viable renewable energy sources: solar, wind, hydroelectric, geothermal, & biomass

- Renewable energy sources that are still in research stages: wave, ocean current, ocean thermal, tidal, hydrogen, and geo-pressured and co-produced fluids

- Viable alternative energy sources: nuclear fission

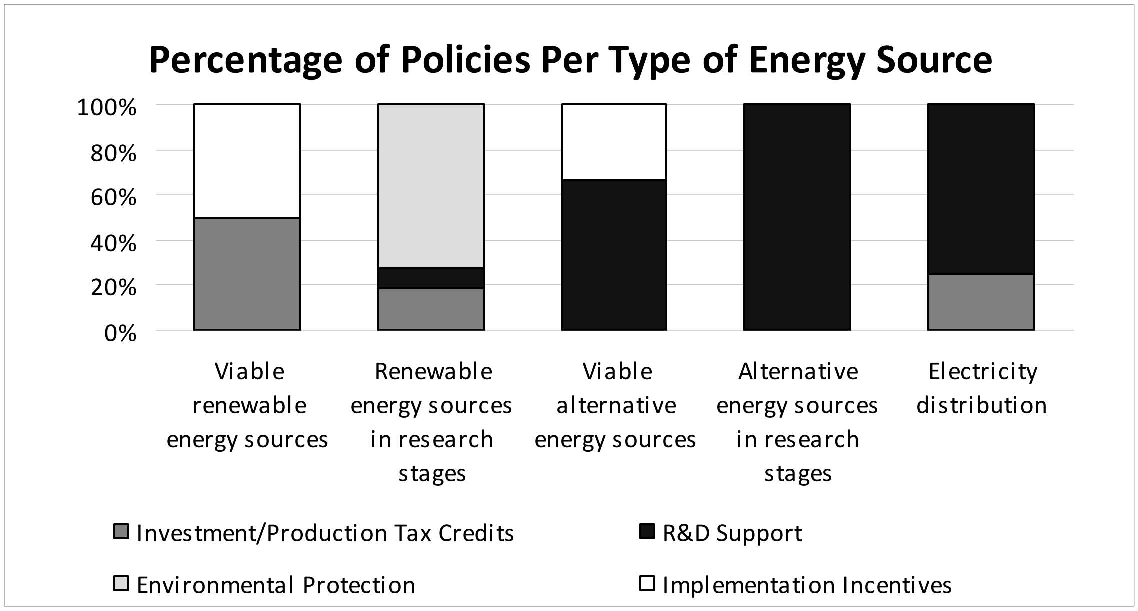
- Alternative energy sources still in research stages: Nuclear fusion, methane hydrates, and cold fusion

- Electricity distribution: smart grid and distributed generation

Some experts also mentioned international policies that have successfully promoted the advancement of energy technologies. Mark Mehos of NREL added, "Spain's feed-in tariffs have helped bring in a large number of new [Concentrated Solar Plants]." One interviewee explained that deregulation and competition have led to infrastructure improvements in the United Kingdom, Australia, and the Scandinavian countries.[34]

U.S. policies hindering the advancement of energy technologies in the United States and internationally are due to political opposition and lack of funding. Responses from experts in six energy technologies suggested that political opposition or indifference hindered the development and implementation of energy technologies. One interviewee asserted that the primary policy hindrance to the development of nuclear fusion is the lack of commitment from Congress and the Administration.[35] Steven Biegalski added that both President Carter's decision to create a policy against nuclear fuel reprocessing and the Nuclear Nonproliferation Treaty have stalled implementation of new nuclear energy plants.[36] Experts in CSP, nuclear fission, and nuclear fusion indicated that the

Figure 8.4
Percentage Policy Mentions Per Type of Energy Source



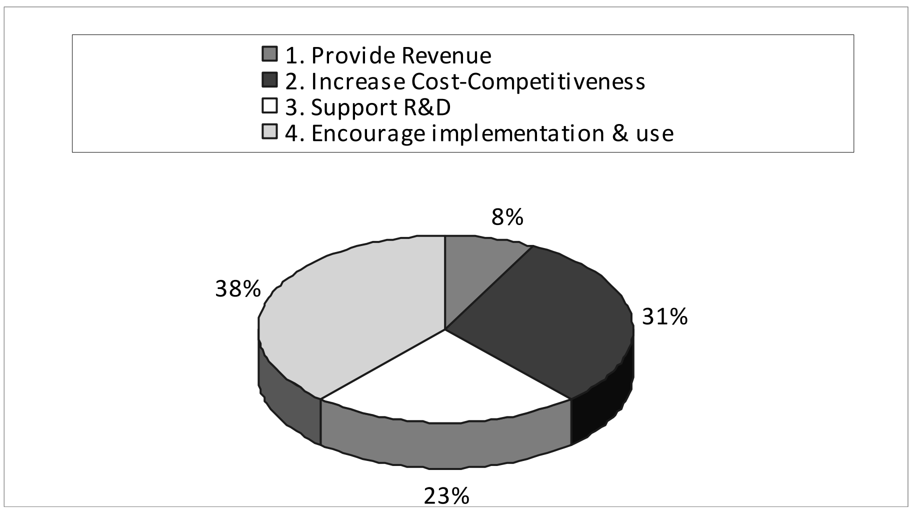
lack of funding coupled with high research and implementation costs have delayed technological advancements.[37]

Other responses faulted low environmental protection standards and the lack of coherent energy policies. Chris Sauer asserted that the development of ocean current technology has suffered from "subsidies of fossil fuels through preferential tax treatment [and the] relaxation of clean air standards."[38] Camille Coley stated that "non-acknowledgement of climate change as an issue" has prevented further advancements of renewable technologies.[39] Brynne Ward added that hydrogen has suffered from the "nonexistence of a set of uniform codes and standards."[40]

Instituting a carbon cap-and-trade system would promote research, development and deployment of alternative energy technologies. All responses indicated that a well-implemented cap-and-trade system would promote the advancement and use of alternative technologies. The top noted effects of a cap-and-trade system were that it would provide revenue, support research and development, increase the cost-competitiveness of alternative technologies, and encourage implementation and use of alternatives. The breakdown by number of mentions is displayed in Figure 8.5 on the following page.

Additional comments from technology experts were that cap-and-trade systems could level the playing field by reflecting the true cost of energy, and that it would ultimately promote any low carbon emitting technology.[41] Some responses also showed hesitancy toward a cap-and-trade policy. Mark Mehos added that the policy might benefit CSP if it was strict and assigned a high cost to pollution, but preferred a renewable portfolio standard to a cap-and-trade policy.[42] Bud Deflaviis, a specialist in hydrogen fuel cells, explained that the system would not impact short-term development of hydrogen fuel cells.[43] In comparison to a cap-and-trade policy, Ross Baldick suggested that a "carbon tax would work even better."[44]

Figure 8.5
Effects of Cap-and-Trade System



Energy Conservation and Efficiency

Reducing energy consumption will be most easily implemented through energy efficiency methods. All interviewees stated that energy efficiency methods of reducing energy demand are more easily implemented than energy conservation practices. Experts agreed that conservation connotes "sacrifice" and doing without.[45] Conservation is therefore not a politically preferred practice. Efficiency "leads us to do the same or more with less."[46] Additionally, though energy conservation may save more energy than energy efficiency, efficiency measures are easier to implement.[47]

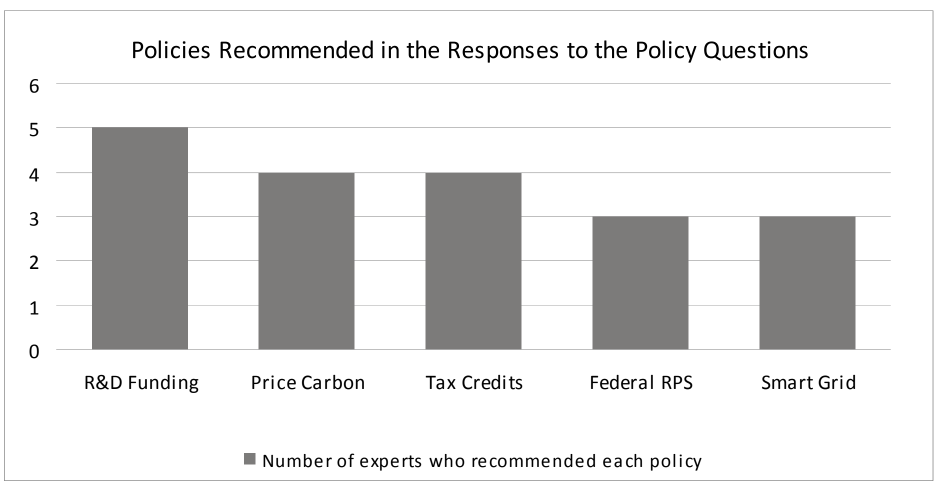
Process innovation and sustainable building design would decrease U.S. reliance on fossil fuels. Each expert discussed measures to help decrease U.S. reliance on fossil fuels in four sectors. For both residential and commercial sectors, suggestions were to increase appliance, building, and equipment standards.[48] These should include weatherization, insulation, and lighting standards. Development of next generation biofuels, vehicle efficiency standards, and electrification were suggested measures to decrease consumption of fossil fuels in the transportation sector.[49] Measures to reduce consumption in the industrial sector were process innovation, improvement, and electrification.[50]

Perry Been further recommended offering education in each of the four sectors as a way to decrease U.S. reliance on fossil fuels.[51] Tommi Makila suggested that implementing a carbon tax in the transportation and industrial sectors would decrease reliance on fossil fuels.[52]

Energy Policy

Any energy transition must be motivated by proper market incentives. All of the experts agreed that increasing the cost of carbon-based fuels and reducing the costs of renewable energy technologies would be required for a transition to occur.[53] This conclusion is also illustrated in Figure 8.6, which shows the frequency of responses of the top five policy recommendations. Most experts recommended a combination of increased research and development funding and various forms of tax credits for renewable energy technologies, along with an additional pricing scheme for carbon-based sources of energy. One of the respondents, David Spence, an expert on solar energy, also emphasized the importance of the support technologies, energy storage and smart meters, for renewable energy technologies to become competitive in the market.[54]

Figure 8.6
Policies Recommended in the Responses to the Policy Questions



Note that "Price Carbon" refers to the government setting a price on carbon emissions. Experts did not indicate a preference for a cap-and-trade system versus a carbon tax within these policy responses.

The United States should strengthen the federal government's role in determining energy policy and ensure that economic incentives for renewable technologies are reliable and long-lasting. Of the responses, five experts specifically mentioned the need for federal funding, in the form of tax credits or grants for renewable technologies, to be reliable and long-lasting.[55] The interviewees indicated that such incentives were necessary to make renewable technologies price competitive with fossil fuels. Companies need to be able to rely on the incentives year after year in order to make the required investments. Robert Erlich, an expert in exploratory geology and new energy technologies, also pointed out the importance of streamlining government regulation to facilitate the distribution of renewable energy.[56] Three of the experts specifically cited the need for a smart grid, which would require the federal government to expand its authority over the states to build transmission cables across various jurisdictions.[57] Three respondents also stated that there should be a federally determined Renewable Portfolio Standard.[58] Each of these policies requires a stronger role for the federal government. According to the experts, they would need to explicitly extend longer than the normal two-year political cycle of the House of Representatives to be successful.

Government regulations can be an effective tool to increase energy efficiency and the implementation of renewable energy. Four of the experts surveyed recommended regulations they believed were necessary to induce an energy transition. Specifically, they recommended increasing CAFE standards, enacting building codes with minimum energy and water efficiency standards, and streamlining regulations for renewable technologies and the laying of transmission lines.[59]

Expansion of renewable energy technologies has been hindered by inefficient policy-making from a national perspective. The experts provided many reasons why Congress has made irrational decisions in developing energy policy for the nation. First, Michael Webber, a professor of energy and environmental policy, said there is a "lack of objective technical expertise in the policy-making process."[60] Tom Weimer, staff director for the House Committee on Energy Independence and Climate Change, echoed this problem by explaining that Congress picked corn-based ethanol as a "winning" technology without realizing the unintended consequences it had on food prices.[61] This led Weimer to conclude that the government should fund everything until the market decides it is not viable. Second, Weimer and Erlich stated that congressmen defend the economic interests of their own state, thus states rich in coal and oil resources are going to be reluctant to price carbon emissions or appropriate money to make renewable energy technologies more cost competitive, even if it benefits the rest of the nation.[62] Third, while congressmen derive political power from their home state, additional pressure can also be applied by special interest groups.[63]

Renewable energy technologies have been hindered by budgetary constraints and the relative importance given to other programs. Four of the experts agreed that any new spending on tax credits or grants must be balanced against existing programs and the growing debt.[64] Robert Erlich expressed that the costs of the Iraq war consumed too much of the government's funds, making it more difficult to pay for an energy transition.[65] Another expert on solar energy stated that the credit crisis is currently the primary obstacle to expanding renewable energy, because companies cannot get the capital required to construct new power plants.[66]

In order to reach the Obama administration's goal of 10 percent renewable electricity by 2012, there must be a cultural shift in how Americans view and consume electricity. Four of the experts argued that any energy transition must be consumer driven and requires a cultural shift in the way Americans use and view energy.[67] A solar energy expert stated that the shift in consciousness has started, but consumers need more tools, like smart meters, to measure their consumption and the impact of behavioral changes.[68]

The themes that emerged from the survey indicate the necessity of transitioning to a diverse energy portfolio that balances the goals of producing clean energy, encouraging long-term economic growth, and promoting U.S. national security. The federal government should enact a National Energy Plan that reflects these goals to ensure an effective and efficient energy transition. The experts suggested that the United States must recognize that energy policy is just as important as every other policy and accordingly develop a comprehensive and cohesive plan.

Notes

[1] Telephone interview by Rachel Veron with Anonymous, Solar Energy Industries Association, January 22, 2009.; Written interview by Emily Owens with Chris Sauer, President/CEO, Ocean Renewable Power Co., Portland, ME, February 3, 2009.;Written interview by Axel Gerdau with Brynne Ward, Communications Coordinator, US Fuel Cell Council, Washington, D.C., February 4, 2009. ; Written interview by Jonathan Wang with Andrew N. Shepard, NOAA Undersea Research Center at UNCW, Wilmington, NC, January 6, 2009.; Written interview by Jonathan Wang with Ed Storms, Austin, Texas, January 19, 2009.; Written interview by Axel Gerdau with Steven W. Pullins, President, Horizon Energy Group; National Energy Technology Laboratory Modern Grid Strategy, February 5, 2009.; Written interview by Emily Owens with Perry Been, Texas State Energy Conservation Office Austin, TX, January 9, 2009.; Written interview by Emily Owens with George Edgar, Wisconsin Energy Conservation Corporation, February 10, 2009.;Written interview by James Ovelman with Steven Biegalski, Nuclear Engineering Teaching Laboratory Associate Professor, Mechanical Engineering Department, The University of Texas at Austin, Austin, Texas, February 7, 2009.

[2] Written interview by Emily Owens with Perry Been, Texas State Energy Conservation Office Austin, TX, January 9, 2009.

[3] Written interview by Emily Owens with Tommi Makila, Texas Energy Conservation Office, Des Moines, IA, January 12, 2009.; Written interview by Axel Gerdau with Ross Baldick, Electrical and Computer Engineering, The University of Texas at Austin, Austin, Texas, January 29, 2009.; Written interview by Kymberlie Koch with Gene Nardella, Office of Fusion Energy Sciences. U.S. Department of Energy, January 20, 2009.

[4] Written interview by Axel Gerdau with Steven W. Pullins, President, Horizon Energy Group; National Energy Technology Laboratory Modern Grid Strategy, February 5, 2009.

[5] Written interview by Kymberlie Koch with Anonymous, Office of Fusion Energy Sciences, U.S. Department of Energy, February 3, 2009.

[6] Written interview with Steven W. Pullins.

[7] Written interview by Emily Owens with Camille Coley, Center for Ocean Energy Technology, January 15, 2009.

[8] Written interview by Lei Wu with David Spence, McCombs School of Business, The University of Texas at Austin, Austin, Texas, January 29, 2009.

[9] Written interview with Anonymous at Office of Fusion Science

[10] Written interview by Melissa Lott with Ray Kopp, Resources for the Future, February 2, 2009.; Written interview with Perry Been; Written interview with Christopher Sauer.; Written interview with Anonymous at Office of Fusion Science.

[11] Written interview by James Ovelman with Patrick Moore, Greenspirit Strategies Ltd., Mexico, January 7, 2009.

[12] Written interview with Steven Biegalski.

[13] Written interview by Jose Chavez with Robert Erlich, Vice President, Petrolifera Petroleum Limited, Houston, TX, January 15, 2009.

[14] Written interview with Christopher Sauer.

[15] Written interview with Perry Been.

[16] Written interview with Tommi Makila.

[17] Written interview with Brynne Ward.

[18] Written interview with Steven Biegalski.

[19] Written interview with Steven W. Pullins.; Email interview by Axel Gerdau with Barry Sanders, American Distributed Generation, Waltham, MA, February 3, 2009.

[20] Written interview by Martin Kareithi with David Painter, Georgetown University, Washington D.C., January 23, 2009.

[21] Written interview with Robert Erlich.

[22] Written interview with David Painter.

[23] Ibid.

[24] Written interview with Robert Erlich.

[25] Written interview with David Painter.

[26] The technology, ocean thermal, was not a multiple choice option on the survey.

[27] Written interview by Axel Gerdau with Ross Baldick, Electrical and Computer Engineering, The University of Texas at Austin, Austin, Texas, January 29, 2009.

[28] Written interview with Anonymous at Office of Fusion Science.

[29] Written interview with Ross Baldick.

[30] Written interview with Steven W. Pullins.; Written interview with Brynne Ward.; Written interview with Gene Nardella.; Written interview with Steven Biegalski.; Written interview with Andrew N. Shepard.

[31] Written interview with Steven W. Pullins.

[32] Telephone interview with Mark Mehos.; Written interview with Steven W. Pullins. Written interview with Christopher Sauer.; Written interview with Camille Coley.; Written interview with Brynne Ward.; Written interview with Steven Biegalski.; Written interview with Andrew N. Shepard.; Written interview with Anonymous at Office of Fusion Science.; Written interview by Kymberlie Koch with Joe O'Hagan, California Energy Commission, California, February 2, 2009.

[33] Written interview with Gene Nardella.; Written interview with Anonymous at Office of Fusion Science.; Written interview with Steven Biegalski.; Written interview by Axel Gerdau with Anonymous, Austin, Texas.

[34] Written interview with Anonymous in Austin, Texas.

[35] Written interview with Gene Nardella.

[36] Written interview with Steven Biegalski.

[37] Written interview with Anonymous at Office of Fusion Science.; Telephone interview with Mark Mehos.; Written interview with Steven Biegalski.

[38] Written interview with Christopher Sauer.

[39] Written interview with Camille Coley.

[40] Written interview with Brynne Ward.

[41] Written interview with Christopher Sauer.; Written interview with Ross Baldick.; Written interview by Jonathan Wang with Ed Storms, Austin, Texas, January 19, 2009.

[42] Telephone interview with Mark Mehos.

[43] Written interview with Brynne Ward.

[44] Written interview with Ross Baldick.

[45] Written interview with Perry Been.

[46] Written interview with Perry Been.

[47] Written Interview by Emily Owens with Anonymous, Lawrence Berkeley Laboratory, Berkeley, California, February3, 2009.

[48] Written interview with Perry Been.; Written interview with Anonymous atLawrence Berkeley Laboratory.; Written interview with George Edgar.; Written interview with Tommi Makila.

[49] Written interview with Perry Been.; Written interview with Anonymous at Lawrence Berkeley Laboratory.; Written interview with George Edgar.; Written interview with Tommi Makila.

[50] Written interview with Perry Been.; Written interview with Anonymous at Lawrence Berkeley Laboratory.; Written interview with George Edgar.; Written interview with Tommi Makila.

[51] Written interview with Perry Been.

[52] Written interview with Tommi Makila.

[53] Telephone interview with Anonymous, Solar Energy Industries Association.; Telephone interview by Rachel Veron with Tom Weimer, Minority Staff Director, House Select Committee on Energy Independence and Global Warming, January 29, 2009.; Written interview by Melissa Lott with Michael Webber, Ph.D., Associate Director for the Center for International Energy & Environmental Policy, The University of Texas at Austin, Austin, TX, February 1, 2009.; Written interview by Melissa Lott with Ray Kopp, Resources for the Future, February 2, 2009.; Written interview with David Spence.; Written interview with David Painter.

[54] Written interview with David Spence.

[55] Telephone interview with Anonymous, Solar Energy Industries Association.; Written interview with David Spence.; Telephone interview with Tom Weimer.; Written interview with Ray Kopp.; Written interview with Michael Webber.; Written interview with Robert Erlich.

[56] Written interview with Robert Erlich

[57] Telephone interview with Anonymous, Solar Energy Industries Association.; Telephone interview with Tom Weimer.; Written interview with David Spence.

[58] Telephone interview with Anonymous, Solar Energy Industries Association.; Written interview with David Spence.; Written interview with Michael Webber.

[59] Telephone interview with Anonymous, Solar Energy Industries Association.; Written interview with David Spence.; Written interview with Robert Erlich.; Written interview with Michael Webber.

[60] Written interview with Michael Webber.

[61] Telephone interview with Tom Weimer.

[62] Telephone interview with Tom Weimer.; Written interview with Robert Erlich.

[63] Written interview with Michael Webber.; Written interview with David Painter.; Written interview with Robert Erlich.

[64] Written interview with Tom Weimer.; Written interview with David Spence.; Written interview with David Painter.; Written interview with Robert Erlich.

[65] Written interview with Robert Erlich.

[66] Telephone interview with Anonymous, Solar Energy Industries Association

[67] Telephone interview with Anonymous, Solar Energy Industries Association.; Written interview with David Spence.; Telephone interview with Tom Weimer.; Written interview with David Painter.

[68] Telephone interview with Anonymous, Solar Energy Industries Association.

Chapter 9. Analysis of Findings

The following findings are based on an analysis of the information compiled in the previous chapters of this report. During this analysis, several salient findings emerged regarding continued reliance on fossil fuels, alternative sources of energy, abatement technologies, and current policies. These findings form the basis for the recommendations in the next chapter.

Finding 1: The "business as usual" model of depending on greenhouse gas emitting fuels has negative effects on the environment, the economy, and national security.

- Continued reliance on fossil fuels such as coal will further degrade air quality and contribute to global warming. (Ch 2, 5, 8)

- Continued reliance on hydrocarbons impedes economic growth. The U.S. economy will be susceptible to price volatility in fossil fuel markets and will continue to transfer wealth to resource-rich nations. Failure to develop alternative energy resources misses an opportunity to revitalize a deteriorating energy infrastructure and energy economy. (Ch 2, 8)

- Continued reliance on imported oil and gas, on which the United States is heavily dependent, weakens national security. Relying on foreign hydrocarbon resources also enriches foreign regimes (Venezuela, Iran, Russia) that are not friendly to the United States. Additionally, fossil fuels will eventually run out, potentially resulting in future conflicts over resources. (Ch 2, 8)

- SOLUTION: Create a comprehensive National Energy Plan that decreases the nation's reliance on traditional hydrocarbons and facilitates a transition to cleaner fuels and technologies using benchmarks to ensure a gradual and successful transition.

Finding 2: Hydrocarbons will play an important role in energy policy.

- Due to technological limitations associated with implementing alternative energy resources, hydrocarbons will play an important role in any national energy policy. (Ch 2, 5, 8)

- The United States will continue to use hydrocarbons in the immediate future due to many factors, including its lower cost and the significant time required to build and implement alternative clean energy technologies. (Ch 3, 4, 5, 8)

- The transportation sector's infrastructure and technology is designed to consume oil. Industries such as trucking, airlines, and shipping lack the technology to replace hydrocarbons as the chief fuel. Other strategies will be required for the transportation sector, such as using bio-fuels and raising efficiency standards. (Ch 3, 4, 5, 8)

- SOLUTION: The National Energy Plan needs to recognize that there is no immediate replacement for hydrocarbons in transportation and other energy sectors. Therefore, the resources that are currently available should be conserved for those sectors' usage.

Findings 3: Implementation of clean energy sources and abatement technologies can decrease greenhouse gas emissions, encourage economic growth, and improve national security.

- Clean energy emits little or no greenhouse gases, could stimulate and expand a new national industry, and would improve national security by providing a domestic energy source. (Ch 3, 4, 8)

- Energy efficiency, storage, and conservation methods could optimize and reduce hydrocarbon demand. Smart grid, weatherization, and industry efficiency standards are some examples of tools that could increase energy efficiency. (Ch 4, 8)

- Carbon capture and sequestration may prove effective in limiting greenhouse gas emissions. (Ch 5, 8)

- SOLUTION: The National Energy Plan should create disincentives for the use of greenhouse gas emitting technologies while simultaneously providing incentives for the development and use of renewable energy sources and abatement technologies. The United States can implement a successful transition by taxing carbon emissions; providing loans and grants for research, development, and deployment of alternative technologies; and encouraging a shift in energy consumption patterns.

Finding 4: Not all clean energy technologies are sufficiently mature for implementation during an energy transition.

- Viable alternative technologies include solar, wind, geothermal, co-produced fluids, biomass, and nuclear fission. (Ch 3, 8)

- Nuclear fission, in particular, has many advantages. It is mature, reliably provides a base load of power for the nation, is price competitive, and relatively non-location specific. However, the spent nuclear fuel issue must be addressed. (Ch 3, 8)

- All technologies need to be evaluated based on their life cycle costs, greenhouse gas emissions, land footprint, water consumption, and other environmental factors. (Ch 3, 4, 7, 8)

- SOLUTION: Reliable, market-ready clean energy technologies should be implemented first in an energy transition. Those that require more research and development should not be prematurely forced into the transition.

Finding 5: The United States needs a coherent National Energy Plan.

- Energy policy is as important to the nation as other issues, yet there is no clear national energy strategy. (Ch 8)

- With no clear energy strategy, market forces and government policies have created an energy system that emits millions of tons of greenhouse gases, changing the world's climate and jeopardizing the nation's economy, security, and environment. (Ch 2, 8)

- Previous clean energy bills lacked long-term commitments, which led to investor timidity. Tax credits are only guaranteed for short periods of time, making it hard for companies to plan ahead. (Ch 7, 8)

- Additionally, states and regions play an important role in determining national policy. States rich in hydrocarbons will be reluctant to take any measures that decrease the demand for their resource. (Ch 6)

- SOLUTION: If the United States is serious about meeting its current and future energy needs while curbing global warming, a clearly stated comprehensive National Energy Plan must be created that empowers each state to maximize its energy resources. (Ch 2, 6, 8)

Finding 6: The government has proven ineffective in choosing winners and losers, and should pursue a diverse energy portfolio.

- The nation will be better equipped to meet its energy needs with a diverse portfolio of energy options. (Ch 2, 3, 4, 8)

- Research and development funding should not be withheld from any potential clean energy technology in hopes that those technologies might be market ready in the future. (Ch 3, 4, 6, 7, 8)

- SOLUTION: Governments should fund the research and development of all potential clean energy technologies, but allow the market to establish the final energy portfolio.

Finding 7: All clean energy technologies rely on government support and will continue to do so until the true price of hydrocarbons is reflected in its market price.

- Clean energy technology relies on government subsidies, tax incentives, capital investments, and research and development funding because of market skepticism. (Ch 3, 4, 6, 8)

- Without government incentives, the market will not invest in alternative technologies. (Ch 3, 4, 6, 8)

- The market price of hydrocarbons does not include social and environmental costs associated with greenhouse gas emissions. (Ch. 2, 8)

- Government intervention in the form of a cap-and-trade system or carbon tax could be implemented to reflect the true social and environmental costs of hydrocarbons. (Ch 8)

- SOLUTION: The government should require carbon emitting energy industries and consumers to pay the true life cycle cost of energy, while also increasing the funding for research and development of promising clean energy alternatives, ensuring their cost competitiveness.

Finding 8: Traditionally, consumers have been largely unaware of the detrimental effects associated with their excessive energy use.

- A fundamental behavioral change in the way Americans view and consume energy is required for the United States to reduce greenhouse gas emissions, encourage economic growth, and assure national security.

- While aggressive research into energy conserving methods must be encouraged, technologies exist today that could facilitate decreased energy usage with less sacrifice to facilitate the transition.

- SOLUTION: A National Energy Plan should incorporate educational tools to help facilitate a cultural shift from using greenhouse gas emitting fuels to clean sources of energy. (Ch 8)

Chapter 10. Policy Recommendations

The previous analysis clearly indicates a need for Congress to create a comprehensive National Energy Plan that carefully balances the priorities of clean energy, economic growth, and national security. This plan should directly address the issues raised in the research findings. Recommended policies are grouped into seven areas:

- National Energy Policy 2010-2050
- Hydrocarbon Transition Policies
- Transportation Innovation Policies
- Energy Efficiency and Conservation Policies
- Renewable Electricity Development Policies
- Nuclear Energy Development Policies
- Policies to Promote Public Awareness of the Energy Technology Transition

National Energy Policy 2010-2050

Energy policy in the United States has become an agglomeration of uncoordinated efforts: efficiency standards, research and development programs, information and awareness programs, public-private partnerships, and innovative funding mechanisms. These policies were designed by Congress to solve specific aspects of the nation's energy problem, but have failed to set a clear direction for a national energy future. A national energy policy must be created to guide the United States in a transition from depletable and polluting hydrocarbon sources of energy to a future energy economy that relies on nuclear, renewable, and clean hydrocarbon sources of energy.

Any successful National Energy Plan must address three important areas: energy independence and security, economic impact and feasibility, and environmental impact. To ensure national security, policy should reduce dependence on foreign fuel resources, promote decentralized power generation, and improve the safety of energy production. To promote economic growth and feasibility, policy should both mitigate the harmful economic effects of an energy transition on consumers and businesses and optimize the economic potential of new energy industries. To address environmental concerns, it must promote the commercialization of more clean energy technologies and reduce the adverse environmental effects of the nation's consumption of GHG-emitting energy resources.

The strategy to achieve these three objectives is two pronged and will require a long-term focus. First, federal policy should help bring to market those technologies that improve the way Americans consume current resources and introduce new solutions for electrical, transportation, heating/cooling, and other energy applications. Second, federal policy should help reduce the demand for and harmful effects of hydrocarbon resources throughout the transition period.

With this long-term strategy in mind, Congress should pursue both new and existing policies that will succeed in balancing the objectives of improving energy independence and security, sustaining economic growth, and reducing environmental impact. Policies presented in the following six sections are designed to do just this.

Hydrocarbon Transition Policies

As part of the National Energy Plan, hydrocarbon transition policies are designed to reduce carbon dioxide emissions associated with U.S. energy use. Experts have cited the importance of demand side management in reducing carbon emissions, especially in light of the continuing important role hydrocarbon-based resources are likely to play throughout the energy technology transition both domestically and abroad. Selected interviewees also commented that coal, natural gas, and nuclear energy should have a continuing role in base-load power generation, as they are both cost-effective and domestic. In this context, the National Energy Plan should encourage the responsible and efficient use of hydrocarbon resources to mitigate the consequences of their use during the energy technology transition. First, the United States should establish a national carbon reduction goal and a transparent carbon tax. To increase the use of less carbon-intensive hydrocarbons, continued investment should be made in research to develop cleaner methods of hydrocarbon energy generation. The continued use of hydrocarbons will also require innovative strategies to reduce carbon dioxide emissions through natural processes or carbon capture and sequestration.

1. Establish a national carbon emissions reduction goal of 80 percent by 2050.

Acknowledgement of climate change as a policy issue in the United States is a relatively recent phenomenon. The United Nations, however, has determined that it is “very likely” that global warming is due to increased concentrations of anthropogenic greenhouse gases in the atmosphere. Carbon dioxide is considered the most important GHG because it represents the largest share of GHGs emitted and its current atmospheric concentration greatly exceeds its natural range over the last 650,000 years.[1]

To set the course for a sustainable energy future, Congress should adopt the goal of an 80 percent reduction in carbon dioxide emissions from 1990 levels by 2050. An 80 percent reduction from 1990 emission levels (5,021 million metric tons) would decrease annual carbon dioxide emissions to 1,004 million metric tons by 2050. The Obama administration has stated it plans to work toward this recommended goal, and Congress should join by expressing a similar carbon reduction goal.[2] Although it is an ambitious target, it is reasonable and achievable. A national carbon reduction goal also provides the direct motivation for establishing a tax on carbon dioxide emissions and the criteria for evaluating its success.[3]

2. Establish a national carbon tax of $35 per ton emitted after 2014.

A national carbon tax on energy producers, refiners, and industrial emitters would significantly change energy economics in the United States by pricing the external costs of carbon emissions. This tax will encourage a gradual shift to a low or non-hydrocarbon based energy economy by reducing the demand for the sources of emissions and raising revenue to develop alternative energy resources. Increasing the cost of carbon-emitting sources of energy will reduce demand, according to its elasticity with respect to price. Since energy consumption is sensitive to price, the higher costs for energy from hydrocarbons would first reduce consumption and then encourage the development of cleaner energy alternatives.[4] Estimates suggest that a carbon tax of just $15 per ton would decrease total GHG emissions by 14 percent and carbon emissions specifically by 8.4 percent in the near term, with further substantial decreases to carbon emissions in the future.[5]

Mark Mehos, a solar energy expert at NREL, suggests that a carbon tax must be set at a rate sufficient to curb emitting behavior, adding that $30 per metric ton of carbon dioxide emitted may be effective.[6] A tax rate of $35 per metric ton, based on 2007 carbon dioxide emissions levels of 6,022 million metric tons, would generate approximately $210.76 billion in revenue.[7] Recognizing the potential short-term economic strain of a carbon tax, it should be delayed until after 2014, allowing time for the economy to recover from the downturn; political circumstances may also be more favorable.

Many public officials, including President Obama, support implementing a cap-and-trade system over a carbon tax. In a cap-and-trade system, the federal government would sell at auction a set number of carbon emission permits to companies each year. These permits could then be traded, creating a securitized market for pollution rights. While both approaches can be calibrated to have the same results on both the price and amount of carbon emitted, there are substantive differences. Under a cap-and-trade system, the government sets the amount of total carbon emissions allowed and the market sets the price per ton; a carbon tax prices emissions at a predetermined rate per ton, then allows the market to set the level of emissions.

A carbon tax is preferable to a cap-and-trade system because it is simpler, more transparent, and less susceptible to loopholes. Cap-and-trade systems require an exchange market to form for the permits to be traded, the carbon tax does not. Cap-and-trade is, according to Tom Weimer, Staff Director for House Committee on Energy Independence and Climate Change, a hidden or covert tax on carbon emissions.[8] This makes it more politically palatable, but not as transparent to American citizens. Finally, cap-and-trade pricing schemes are flexible, which allows policymakers to provide loopholes for special interest groups or render the system ineffective at reducing emissions. For example, cap-and-trade polices often include a safety valve provision, a predetermined price ceiling for the market price of the carbon permits that, if reached, allows the government to issue more permits to reduce the trading price.[9] It is also common to "grandfather" in some industries, providing free permits to these select companies and then auctioning the rest. This can lead to windfall profits for politically connected corporations.[10] Although the carbon tax would not be as politically feasible, it is recommended for its transparent pricing of the external costs of carbon emissions in an equitable system that distributes the cost of emitting behaviors among energy producers, energy consumers, and other energy interests in the absence of exemptions.

Interviewees stated that the government must put a price on carbon emissions for a transition to occur; however, they did not indicate a preference for cap-and-trade systems versus a carbon tax pricing scheme.[11] All of the experts surveyed agreed that a properly implemented cap-and-trade system would benefit renewable energy technologies.[12] One expert, Ross Baldick, a professor of electrical and computer engineering, believed a "carbon tax would work even better."[13]

3. Continue DOE Loan Guarantee Program for low-carbon solutions to coal-based power generation.

Congress should continue using federal guaranteed loans and grant programs to promote the commercialization of new low-carbon energy technology. The DOE currently promotes the commercialization of new technology by issuing loan guarantees to commercially viable projects. To qualify, these projects must reduce emissions using new and advanced technology, and the DOE has been given the authority to issue the loan guarantees if there is a reasonable expectation of repayment of the principal and interest by the borrower. The program is currently accepting solicitations for coal-based power generation and industrial gasification facilities that incorporate carbon capture and sequestration.[14] Efforts to find more efficient methods of using existing hydrocarbon resources will be necessary to abate the costs of the carbon tax in the near term, and essential to carbon emissions reduction as the energy infrastructure transitions.

4. Continue Clean Coal Initiative, FutureGen, and other federal initiatives to reduce emissions of existing coal and natural gas power facilities.

The Office of Fossil Energy within the DOE is currently directing research programs to reduce the emissions of coal and natural gas power and is coordinating efforts between the various national laboratories in this area. These research and development programs include the Clean Coal Initiative that funds programs to reduce various air pollutants released by coal power plants, the $1 billion FutureGen projects to build new coal power plants with carbon capture and storage technology; retrofitting existing power plants; developing gasification technologies, fuel cells, and combustion turbines; and pursuing an advanced research program in hydrocarbon energy power systems.[15]

Coal gasification and cleaner natural gas have the potential to provide needed energy in the future with lower carbon emissions. Carbon capture and sequestration also, in concept, promises emissions-free coal power. Twenty experts interviewed for this report believe that carbon capture and sequestration should be part of a U.S. energy transition and future, either in a transitional or permanent role. Because carbon capture and sequestration is still in demonstration, however, it is uncertain whether it will play a substantial role in the energy technology transition, as more mature, cleaner technologies (nuclear, wind, and solar) are already available as alternatives. Because of the promise it holds both for the United States and developing countries, however, Congress should continue to support research efforts.

Impact of Hydrocarbon Transition Policies on National Objectives

Energy Independence and Security

Each hydrocarbon transition policy introduced will reduce the use of hydrocarbon resources, both domestic and foreign, throughout the United States. Reduced reliance on foreign fuels in the transportation sector, largely as a result of price adjustments due to the national carbon tax on retail gas, will reduce the volatility of energy prices in the United States and the susceptibility of the United States to geopolitical conflict.

Economic Impact and Feasibility

A carbon tax would be costly but fair, affecting both the producers and users of carbon dioxide emitting activities. Taxed entities—including electricity generators and EPA-regulated industrial sites—are expected either to shift the entire incidence of the tax on to consumers through higher prices, to reduce operations, and/or to absorb the cost of the tax, whichever is most profitable. The carbon tax will significantly affect the economy by increasing the cost of electricity from coal, natural gas, and oil; therefore, prices of all goods and services will likely increase. This short term increase in cost, however, is necessary for the prosperity of the nation in the long term. The total economic impact of these policy proposals will largely depend on how Congress intends to shape exemptions, rebates to working-class Americans; and how consumers adjust their use of energy in reaction to pricing in a carbon tax regime.

Environmental Impact

By increasing the cost of emitting carbon, the carbon tax will encourage the use of cleaner methods of electricity generation and transportation propulsion. Investments in technology that either reduces emissions from hydrocarbon energy generation or captures and sequesters emissions will reduce the negative impact that energy from hydrocarbons will have on the environment. By reducing their environmental impact, continued use of hydrocarbon resources will be more feasible when conversion to alternative resources is not feasible for U.S. regions.

Transportation Innovation Policies

The goal of the transportation policy presented in this section is to facilitate a two-step transition from the dominant use of traditional, gas-powered vehicles to pure electric or hydrogen powered vehicles by 2050, through the gradual replacement of traditional gasoline-powered vehicles by hybrids, plug-in hybrids, hydrogen-powered vehicles, and next generation biofuels during the interim. Due to technological limitations, there will likely be a continued role for hydrocarbon-based fuels in airplanes, heavy commercial trucking, and shipping. Acknowledging this, the transportation policies presented here encourage not only the commercialization of advanced vehicles, but also sustained and robust research and development support for cleaner-burning solutions for other forms of transportation.

1. Increase research and development grants for battery and hydrogen fuel cell technology.

The federal government should help foster a domestic battery industry for use in hybrid, plug-in hybrid, and electric vehicles by providing more research and development grants for both basic research in electric storage technology and for deploying advanced battery technologies into the market. It should do the same for hydrogen fuel cells. It is likely that the market will eventually pick a winning technology; however, during the interim it is premature to declare which technology should receive funding and which should not.

Battery and hydrogen fuel cell powered vehicles can both dramatically improve fuel efficiency and eventually eliminate the need for gasoline to power cars. Both may also be adapted to provide vehicle-to-grid support, allowing consumers to sell electricity from their vehicle back to the utility grid. The additional government spending will grow these industries in the United States, creating domestic jobs and the ability to export these technologies to the world. Expanding these industries will also ensure that domestic car manufacturers can produce the vehicles that consumers demand as the nation transitions away from hydrocarbon intensive energy sources and the price of gasoline increases.

2. Maintain current fuel efficiency standards and proposed increases.

The federal government should maintain the recently increased CAFE standards, set at 30.2 miles per gallon for cars and 24.1 miles per gallon for light trucks for 2011, along with the target of 35 miles per gallon for cars by 2020.[16] If the carbon tax does not motivate car manufactures to offer more fuel efficient vehicles, then the CAFE regulation will ensure some base level of deployment. If the carbon tax and research and development grants are effective in encouraging rapid deployment of more fuel-efficient models, there will be no need to maintain the CAFE standards after 2020.

The EPA must also decide how it will determine fuel efficiency ratings for plug-in hybrid, electric, and hydrogen fuel cell vehicles for CAFE compliance measurement and vehicle marketing. The marketability of plug-in hybrids, electric, and hydrogen fuel cell vehicles depends heavily on how their estimated miles per gallon is tested and calculated. For plug-in hybrid vehicles, two numbers should be reported – how far it can travel on battery power alone and miles per gallon once all the initial charge is used, if applicable. Pure electric vehicles should be measured by how far they can travel on a single charge. It would also be helpful to show consumers the cost per mile of the electric powered portion, based on regional average utility rates. A general standard must also be developed for hydrogen fuel cells that can be easily compared against electric and conventional gasoline powered vehicles. These standards must be incorporated into CAFE standards to provide additional incentives to auto-manufacturers and aid in compliance.

3. Repeal the current Renewable Fuels Standard, reinstating it when next-generation biofuels become available.

The passage of the RFS was premature. Any RFS should only mandate the use of "next generation" biofuels, those produced from algae or other non-food stock crops. Currently available first-generation biofuels produced to meet RFS are harmful to the environment and increase food prices for consumers both domestically and globally. Only when next generation biofuels become widely available should an RFS be reinstated.

4. Extend tax credits for purchases of hybrids, plug-in hybrids, pure electric, and hydrogen fuel cell vehicles until these vehicles comprise 50 percent of the U.S. auto fleet.

Hybrid, plug-in hybrids, pure electric, and hydrogen fuel cell vehicles are more expensive than conventional vehicles because of the advanced technologies they contain. Until they become cost-competitive with conventional vehicles, their purchase should continue to be subsidized by the federal government. Currently, the federal government provides a $3,400 income tax credit for purchasing a hybrid vehicle and $4,000 for purchasing an electric or hydrogen fuel cell vehicle, with some state and local governments providing additional incentives. The federal tax credit for hybrids is limited to the first 60,000 vehicles sold for each manufacturer.[17] The tax credit should be extended until hybrid, plug-in hybrid, electric and hydrogen fuel cell vehicles make up 50 percent of the total number of consumer vehicles on the road. This policy will increase the demand pull for these vehicles, accelerating their deployment across the nation. It also reduces the economic burden placed on consumers by the carbon tax.

5. Extend consumer tax credits for converting older vehicles to improved efficiency technologies.

The federal government should also make similar tax credits available to consumers who cannot afford or do not wish to purchase a new car, but see value in increasing the fuel efficiency of their vehicles. Local body shops have begun to provide services retrofitting conventional internal-combustion engine vehicles for hybrid, plug-in hybrid, or pure electric use; however, these conversions can be expensive, mostly due to the costs of the batteries required. The $3,400 and $4,000 tax credits should be extended to these conversions as well, depending on the type of conversion, and paid for using carbon tax revenue. Tax credits should also be offered to consumers converting to hydrogen fuel cell powered vehicles. This policy will promote the growth of a new industry in refitting outdated vehicles and protect consumers from increased gasoline costs due to the carbon tax. These tax credits, too, should expire when hybrid, plug-in hybrid, electric, and hydrogen fuel cell vehicles make up 50 percent of the total number of consumer vehicles on the road.

6. Increase research and development to ensure the use of next generation biofuels, electric batteries, and/or hydrogen fuel cells in heavy trucks, ships, and airplanes.

It is clear there will be a continuing role for hydrocarbons in heavy-duty trucks, ships, and airplanes. Efforts should, however, be made to improve the fuel efficiency and performance of existing technologies and to design engines less reliant on hydrocarbon-based fuels. Developing flexible fuel engines that use next-generation biofuels and electric and hydrogen fuel cell engine systems for these applications would help complete the transportation transition away from petroleum.

Impact of Transportation Innovation Policies on National Objectives

Energy Independence and Security

According to the EIA, the United States "imports nearly 60 percent of the petroleum it consumes and dedicates more than 60 percent of its petroleum consumption to transportation." [18] By reducing the petroleum used for transportation and some consumption in other sectors, the United States will no longer rely on foreign nations for petroleum. The United States can also develop its own battery industry, so it will not be reliant on foreign nations, such as Japan, for that component of hybrid and electric vehicles. By reforming the transportation industry, the United States may not become energy independent, but it will reduce its reliance on other nations and provide more flexibility in what new energy sources it chooses.

Economic Impact and Feasibility

By investing in advanced batteries and hydrogen fuel cells, the United States will foster the growth of a new domestic industry and help a struggling U.S. auto industry recover. Tax credits for consumers will increase the demand for new, more fuel-efficient vehicles. Reducing the transportation sector's reliance on petroleum will decrease the need for energy imports, helping to balance U.S. trade deficits. More efficient vehicles will, in the long run, decrease the cost of transporting goods, making most goods cheaper for consumers and encouraging greater consumption. Such improvements in the efficiency of the transportation system should be reflected by increases in GDP. If the market is functioning properly, CAFE standards should not overly burden auto manufacturers, because the market will move the fleet average well above the set standards. Private industry should also see value in constructing corridors of electric battery recharging/swapping stations or hydrogen fuel cell refueling stations, depending on which technology emerges as the dominant choice of the market. As the number of plug-in hybrid and electric vehicles or hydrogen fuel cell vehicles increases, the demand for these new types of stations will increase, while the demand for gas stations will decrease. Relying on hybrids and plug-in hybrids for the interim period will provide the time needed for these corridors to be completed at a measured pace, minimizing economic disruption.

Environmental Impact

It would be technically difficult and very expensive to sequester the carbon emissions produced by the millions of mobile internal combustion engines currently used for transportation in the United States. In the near to mid-term, however, the United States has the capability to replace these engines with ones that are more fuel efficient–alleviating the consumer burden of a carbon tax regime. Plug-in hybrids and electric vehicles will dramatically reduce transportation emissions, especially as battery storage capacities increase to accommodate the daily commutes and commerce of more Americans. Hydrogen fuel cell vehicles can also provide these savings. CAFE standards will ensure a base level of deployment of alternative vehicles from manufacturers, ensuring supply meets ever-increasing consumer demand for more efficient vehicles. Transitioning heavy-duty trucks, ships, and airplanes to next generation biofuels and improving engine efficiency after the 40-year horizon of our recommendations will also reduce emissions.

Energy Conservation and Efficiency Policies

Energy efficiency will play an important role in the national energy strategy as a way to significantly reduce carbon dioxide emissions and minimize the burden of carbon taxation early in the transition. To spur investments in energy efficiency, five policies are recommended—increasing minimum efficiency standards for appliances, providing financial incentives for renewable energy heating and cooling applications, investing in energy storage technology, establishing a smart grid, and enhancing research and development for energy efficient products and services—which are designed to optimize the use of energy in homes and businesses across the United States.

1. Expand minimum efficiency standards to more electric appliances and commercial equipment.

Interviewed experts believe that a reduction in energy consumption will be most easily implemented through efficiency improvements, which have proven more palatable to consumers than energy conservation initiatives. In this avenue, minimum efficiency standards (MES) have had a significant impact, reducing U.S. electricity use by 2.5 percent and total energy use by 1.3 percent and reducing peak energy use by 21,000 MW in 2000.[19] Consumers saved an estimated $50 billion between 1990 and 2000 simply through the use of MES products.[20]

New legislation should authorize the DOE to establish MES for a greater array of electric appliances and commercial equipment, including “residential torchiere lighting fixtures, building transformers, commercial unit heaters, traffic lights, illuminated exit signs, commercial refrigeration equipment, residential furnace fans, residential ceiling fans, vending machines, and consumer electronic products that ‘leak’ electricity when not in use."[21] According to the American Council for an Energy Efficient Economy, placing minimum efficiency standards on these products could save approximately 73 TWh of electricity by 2010 and 164 TWh by 2020.[22] It would also save consumers and businesses more than $80 billion in discounted net benefits.[23]

2. Expand and continue financial incentives for renewable energy heating and cooling.

Heating and cooling applications represent 40-50 percent of global energy demand each year.[24] Reducing reliance on electricity and natural gas for these applications through the development and deployment of renewable energy heating and cooling systems—solar, geothermal, biomass, and ocean thermal—could significantly reduce carbon emissions. Currently, federal incentives for installing renewable heating and cooling equipment in the United States include investment tax credits. The IEA reports, "Mature REHC [renewable energy heating and cooling] technologies using solar, biomass and geothermal resources are currently available as cost-effective means of reducing both carbon dioxide emissions and fossil fuel dependency under many circumstances."[25] However, these renewable energy heating and cooling methods—although further along in product life cycles than many renewable electrical generating technologies—have suffered from a lack of market up-take due to geographical and cost constraints in some regions. To increase the popularity and deployment of these market-ready systems, Congress should provide more aggressive installation and operating incentives in conjunction with state incentives. Efforts to improve energy storage (see below) will work in conjunction with these policies to improve the technological efficiency and return on investment of REHC installations.

3. Increase investment in energy storage technology.

The lack of mature energy storage technologies for a wide array of applications (e.g., utility-scale power, CSP, wind, vehicles), combined with difficulties in recovering the capital costs associated with those energy storage technologies, make realizing efficiency gains through energy storage extremely difficult in the United States. At the same time, interviewed experts believe that energy storage is one of the top five technologies available that could advance national policy objectives for energy independence, economic growth, and environmental progress.

The U.S. Department of Energy's Electricity Advisory Committee noted that the benefits of energy storage are universal, that energy storage technologies "are not an alternative to any particular resource decision" but "a valuable adjunct to all resources and they will allow increased capacity to be derived from any given quantity of physical resources."[26] To help develop and deploy useful energy storage solutions for a variety of applications, the government should increase investment in research, development, and deployment of energy storage technologies. These include battery storage and hydrogen fuel cell storage for transportation applications as well as the various forms of grid energy storage methods outlined in Chapter 4 that ensure bulk storage, distributed generation, and power quality to the grid, including pumped hydroelectric, CAES, flywheel storage, thermal storage, SMES, ultracapacitors, supercapacitors, and other battery storage. These investments will ensure that a variety of technologies and applications will be ready for implementation by utilities, cogeneration facilities, and industrial plants seeking to reduce carbon tax burdens through more efficient use of existing energy resources.

4. Promote implementation of smart grid technologies.

According to the Galvin Electricity Initiative, smart grid technology can reduce power disturbance losses by $49 billion per year and reduce the need for massive infrastructure investment by between $46 billion and $110 billion over the next 20 years.[27] But the development of smart grid technology—according to experts Steven W. Pullins and Barry Sanders—is deterred primarily by government regulation and lack of consumer participation. Pullins believes that although capital, raw materials, and labor costs for the smart grid would require significant investment, the future benefit to all users should be heavily weighed in its favor.[28]

The passing of the EISA 2007 made smart grid advancement U.S. policy. The law allocates $100 million in funding per fiscal year from 2008 to 2012. In addition, it establishes a matching program to states, utilities, and consumers to build smart grid capabilities and create a Grid Modernization Commission.[29] Congress has provided $3.325 billion as part of the DOE's Smart Grid Investment Program for smart grid demonstration and deployment to promote market learning in the industry, demonstration of utility-scale energy storage, and demonstrate grid-monitoring technologies through the American Recovery and Reinvestment Act of 2009.[30]

Much work remains to be done, however, to modernize the U.S. electrical grid. Do to the presence of burdensome federal and state transmissions development standards, combined with little to no momentum among local public and private utilities to undertake infrastructure development, the case for a federal role in this effort is great. Investment in smart grid infrastructure that improves the efficient distribution of power, accommodates a variety of energy applications, decentralizes supply, and facilitates permanent and considerable reductions in carbon emissions will require a substantial and long-term federal financial and planning commitment to achieve. The efficiency benefits of such an investment, however, will be manifold in the U.S. energy future.

5. Enhance research and development for more energy efficient products and services.

Congress should continuously support research and development to discover new ways to decrease consumer costs, reduce emissions, and conserve resources through more efficiently-designed products and services. Interviewed experts identified that improving energy efficiency spans appliance, building, and equipment design; weatherization, insulation, and lighting standards for buildings; and industrial sector process innovation, improvement, and electrification. Research and development efforts in economic efficiency can also become an economic driver. A study from the American Council for an Energy-Efficient Economy noted that "pursuing energy efficiency policies that stimulate high efficiency products and services would generate over 800,000 jobs by 2010, as well as almost $31 billion in new wages and $14 billion in GDP."[31]

Impact of Energy Conservation and Efficiency Policies on National Objectives

Energy Independence and Security

Energy efficiency investments in energy storage and smart grid technology lower the likelihood of outages caused by grid accidents or terrorist attacks, increasing the reliability of the electrical system through decentralization.

Economic Impact and Feasibility

Investing in energy efficiency implementation today would lower consumer energy bills and encourage new job creation. Minimum energy efficiency standards, renewable energy heating and cooling, energy storage, and smart grid technology will be costly, but could also stimulate economic growth by increasing employment and wages in new construction projects, retrofitting buildings, and maintaining new efficiency systems. While a short-term economic impact might be hard to see, investments in energy efficiency could provide a longer-term technological and research benefit for the alternative energy sector as well.

Environmental Impact

Findings suggest that energy efficiency improvements represent the most easily-accessible and substantial ways to reduce the nation's carbon footprint for all consumers. Samuel Bodman, the Secretary of Energy from 2005-2009, once mentioned that the energy we waste is "the cheapest, most readily available source of energy Americans can access."[32] Harnessing wasted energy for productive use means consumers do more work with fewer emissions, starting with traditional hydrocarbon energy resources.

Renewable Electricity Development Policies

National policy should be used to encourage the development and deployment of renewable generating technologies that optimize regional strengths. Collectively, the five policies discussed here—a national renewable portfolio standard, tax incentives, deployment partnerships, research and development, and education—are designed to provide a "supply push" of feasible alternatives within the current market system to address the "demand pull" for cleaner energies expected in a carbon tax regime. Congress should prioritize renewable electricity policy as an important part of the larger integrated the National Energy Plan that shapes the energy technology transition.

1. Enforce achievement of a national Renewable Portfolio Standard of 15 percent renewable electricity by 2030.

The United States should establish a 15 percent minimum state target for electricity generation and begin enforcing that standard in 2030, with qualified renewable electricity generation from biomass, solar thermal, photovoltaic solar, concentrating solar power, geothermal, wind, fuel cells using renewable fuels, small hydropower, digester gas, landfill gas, ocean wave, ocean thermal, and tidal current.

According to interview findings, perspectives varied widely on whether a national RPS should be pursued, when it should begin and end, and what final mix of renewables might be achievable in the United States. One conclusion that emerged, upon consideration of expert interviews and an extensive literature review, is that a national RPS should be designed to serve two purposes: one as an enforceable "back stop" to more aggressive state RPSs and the other as a minimum renewable achievement standard in a carbon tax regime.

The average state RPS standards are generally more aggressive than the national RPS we recommend, with renewable targets ranging from 10 to 15 percent as soon as 2015, to 15 to 20 percent by 2020, to 15 to 25 percent by 2025.[33] As of March 2009, 28 states had enacted RPS legislation, and five more had set renewable energy goals.[34] A specific objective for a national RPS was selected in the context of a national energy strategy, focused on coordinating the development of a sustainable energy future through diversified renewable state energy assets, rather than dictating any specific mix of technologies for renewable electricity generation. When combined with the carbon tax, the nation-wide RPS would prevent the crowding-out of clean, renewable electricity by more immediately cost-effective large-scale nuclear or clean carbon development and demonstration projects during the transition.

The national RPS target we recommend is structured 20 to 30 years into the energy technology transition to avoid several undesirable consequences of implementing a national RPS too quickly. First, a near-term RPS goal would force states to implement the most "market-ready" solutions, not necessarily the most feasible or optimal renewable technologies. According to a 2007 EIA report, reaching a 25 percent RPS by 2025 would require 70 percent of all new generating capacity to come from renewables, representing a ten fold increase in current levels of non-hydropower renewables generation.[35] Thus, accomplishing aggressive state RPS goals will require considerable investment in renewables, many of which are not yet technologically mature. A 2030 deadline for a national RPS gives states time to assess the strengths and weaknesses of their energy infrastructure and to seek creative renewable solutions through research and development partnerships that conform to these assessments. Second, a longer-term national RPS target reduces overall implementation costs by allowing time for the growth of an adequate domestic manufacturing market for renewables parts.

2. Establish reliable support for production tax credits and investment tax credits for renewables.

Production tax credits and investment tax credits for renewable energy generators should be scheduled reliably over time and political regimes. The production tax credits provide large-scale centralized renewable generators a more profitable return on investment through a subsidy for each kWh of generation they produce for the first 10 years of plant operation. Investment tax credits encourage the installation of renewable electrical systems by offering an income tax reduction for businesses and small residences equal to a designated portion of the system's purchase price.

Interviewed experts cited these two incentives as most important for market-viable renewable energy resources (such as solar, wind, hydroelectric, geothermal, and biomass), renewable energy resources in research stages (wave, ocean current, ocean thermal, tidal hydrogen, and geopressured/co-produced fluids) and electricity distribution technologies such as smart grid and distributed generation investments. Mark Mehos, Concentrating Solar Power Manager at NREL, said, "Investment tax credits are key whether they are federal tax credits or state tax credits… Investment tax credits need to be implemented in the near-term to increase deployment while costs are still high." [36]

Tom Weimer, Minority Staff Director of the House Select Committee on Energy Independence and Global Warming, also noted that industrial growth in renewables has suffered starts and fits because of the lack of sustained federal commitment to production tax credits or investment tax credits over time.[37] For example, production tax credits for renewables were allowed to expire three times between 1999 and 2004, creating a boom and bust cycle of energy development projects that may have otherwise grown more smoothly.[38] Establishing more consistent support of investment and production tax credits over the next 5-15 years will enable a smoother and more predictable energy technology transition by signaling to renewables developers that it is safe to proceed with large capacity projects that may take several years to permit and construct.

In the future, more reliable tax incentives for renewable energy can be used to urge renewable generating companies to achieve market parity. For example, clear per kWh credit reductions or phase-outs in the production tax credit can be used to encourage more cost-effective operations through the short and medium term (over 5-15 years). When combined with the carbon tax, renewables will achieve market parity more rapidly, as higher production costs of coal and natural gas will also raise consumer market prices toward the higher, renewable generating price.

3. Rapidly deploy and extend new DOE loans for renewable electricity.

The 2009 American Recovery and Reinvestment Act amends EPAct 2005 to provide additional government loans to renewables through the Temporary Program for Rapid Deployment of Renewable Energy and Electric Power Transmission Projects (Temporary Program). Secretary of Energy Steven Chu has announced his intent to streamline the loan process and release the first loans under this title as soon as possible in 2009.[39] The renewables portion of this "temporary" program favoring renewable electricity should be rapidly deployed, extended, and expanded over time to emerging technologies to ensure that states have the new renewable capacity necessary to meet national RPS quotas.

First authorized under EPAct 2005, government guaranteed loans for energy investments were limited to projects that "avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases" and that "employ new or significantly improved technologies as compared to technologies in service in the United States at the time the guarantee is issued" where "there is reasonable prospect of repayment of the principal and interest on the obligation by the borrower."[40] In 2008, Congress authorized the first $38.5 billion in loan guarantees, including $20.5 billion for nuclear and advanced nuclear power; $10 billion for renewable systems, energy efficiency and manufacturing and distributed generation transmission and distribution; $6 billion for coal plant retrofits for cleaner burning carbon; and $2 billion for coal gasification. Eligible renewables projects included hydrogen fuel cell, batteries, alternative vehicles, ocean wave/tidal, solar, wind, geothermal, and biomass.[41] The Temporary Program now reserves more government loan guarantees solely for renewable thermal or electric energy systems, electric power transmission systems, and leading-edge biofuel demonstration projects.[42]

Considerable deployment of new renewable generating capacity is impossible without public and private sector interest. Government loans as implementation incentives were cited by interviewed experts in research and industry as most important to implementing viable renewable energy sources (solar, wind, hydroelectric, geothermal, and biomass) and nuclear fission energy resources. The public sector's role, then, should be one of encouraging more rapid deployment of renewable electricity through encouraging private up-take of risk associated with new market technologies. This can be achieved by either reducing that risk (e.g., public-private partnerships) or increasing incentives to assume risk (e.g., production and investment tax credits). A long-term government loan guarantee program for renewables encourages the deployment of renewable alternatives through the former, and the second recommendation addresses the latter.

4. Continue to support basic and applied research in renewable energy technologies.

Research and development fuels technological progress and has been the driving force behind U.S. economic growth for generations. Unfortunately, the U.S. electrical infrastructure is aging, and replacement technologies have not been implemented rapidly enough, leaving the nation with a crumbling electrical infrastructure largely reliant on mature power generation processes that emit billions of tons of greenhouse gases each year. Renewable electric technologies can drive cleaner economic growth in the United States, but for them to have any large impact requires substantial federal research and development support now. This support should help companies improve the efficiency and cost-effectiveness of existing renewable energy systems and fund basic and applied research to discover entirely new renewable energy resources. Without these investments, private industry will be unable to produce a sufficient quantity and diversity of clean renewable electricity to meet the demands of regions and states.

In 2006, the IEA identified the world's most pressing research, development, and deployment priorities for renewable electric technologies.[43] For mature, first-generation renewable technologies introduced at the end of the 19th century such as hydropower, biomass combustion, and geothermal power and heat, these needs are largely met by private industry. Public sector support, then, is most needed for "exploiting the remaining resource potential… and [overcoming] challenges related to environment and social acceptance." For second-generation renewable technologies now entering markets due to investments in the late 1970's and early 1980's prompted by global oil crises, research, development, and deployment involves both the public and private sectors. These technologies—solar heating and cooling, solar PV, wind, and modern bioenergy (e.g., biomass power and heat, co-firing biofuels)—require public sector support to improve cost-effectiveness, promote market learning through larger-scale deployment, and improve engineering and power reliability for applicable technologies (e.g., wind, solar). For third-generation renewable technologies not yet commercially available, research, development, and deployment is highly dependent on public sector investment. The following technologies must overcome technological challenges and improve cost-effectiveness to reach commercial scale: CSP, ocean energy, enhanced geothermal systems (e.g. hot dry rock), and integrated bioenergy systems.

Impact of Renewable Electricity Development Policies on National Objectives

Energy Independence and Security

Renewable electricity policy is less likely to address national security, since the United States derives most of its power supply through domestically-produced coal and natural gas. Operating independently from other countries, the U.S. electrical market in the energy technology transition will simply shift from domestic hydrocarbon-based resources to cleaner, renewable resources. Consumer tax credits for small renewable installations in homes and business, however, do promise added national security in the form of more distributed electrical networks, which offer a buffer against natural disasters, utility disruptions and other grid disturbances.

Economic Impact and Feasibility

Government guaranteed loans, production tax credits, and consumer tax credits will help spur investment in clean renewable electricity, small commercial investments and residential units. These three policies provide a more certain return on investment for all scales of generation, and they are necessary—at least in the short- to mid-term—to make renewable energy generation economically feasible. Once market-parity for each renewable technology is achieved, these policies can either be eliminated or continued in a fashion which directs investment to future emerging renewable technologies.

Environmental Impact

Without a national RPS, production tax credits, and government guaranteed loans, it's unlikely that the market-derived mix of energy would include a significant portion of clean renewables in an aggressive energy technology transition. Even in a carbon tax regime, more mature technologies such as nuclear and cleaner natural gas power plants might be favored. The clean energy policy set forth in our recommendations establishes a clear, national priority for renewable electricity. It also acknowledges specific but separate roles for federal and state governments in energy policy: federal coordination and standard setting with states determining the optimal mix of renewables for each region.

Nuclear Energy Development Policies

As the country's energy needs grow, nuclear power will play an increasingly important role in the energy mix because it is emissions free, efficient, proven, sustainable, and price competitive. The following policy proposals—increased research and development, including efforts focused on central storage, reprocessing, and spent fuel disposal; government guaranteed loans; and the nuclear production tax credit—encourage an innovative long-term solution for nuclear power as a viable and desirable base-load energy alternative.

1. Expand nuclear research, development, and deployment efforts with a focus on central storage, and the reprocessing and disposal of spent fuel.

Nuclear power should be pursued as a base-load power source that is efficient, operationally cost-effective, and clean. Interviewees Tom Makila, David Spence, Joe O' Hagan, Patrick Moore, Tom Weimer, and Ray Kopp expressed strong support for nuclear energy development. Mark Mehos said, "It is not possible to reduce fossil fuel consumption by relying on renewables alone. It can only be done by including nuclear in the mix and by increasing nuclear's share of total energy production."[44]

For this reason, the government should increase allocations for nuclear fission and fusion research and development, specifically in the areas of central storage, and the reprocessing and disposal of spent fuel such as the DOE's Advanced Fuel Cycle Initiative. As noted by Steve Bielgalski, the issue of waste disposal must be addressed.[45] If not, it could become a severe environmental and national security liability.

Central Storage

The 1982 Nuclear Waste Policy Act has failed as a long-term solution for nuclear spent fuel storage and a new policy must be established. The act failed because of political and financial delays in building a central nuclear spent fuel repository at Yucca Mountain in Nevada. The act promised nuclear operators that the U.S. government would collect and store nuclear spent fuel starting in 1998 in exchange for a consumer tax on nuclear power that has accumulated more than $27 billion, of which $8 billion has been spent for central repository research.46 The revised schedule for transportation of spent fuel to Yucca Mountain would now begin in 2020.47 The federal government's failure to provide a central repository has resulted in $11 billion in spent fuel liabilities, and nuclear power plant operators have resorted to storing spent fuel on site in dry casks and storage pools.[48]

The Nuclear Regulatory Commission (NRC) has determined that spent nuclear fuel can be safely stored on site for 30 years after a reactor shuts down and is proposing to extend that period to 60 years.[49] With the 40-year license of a nuclear reactor, on-site nuclear spent fuel can be safely stored for up to 100 years in dry casks.[50] Spent nuclear fuel is radioactive for thousands of years, however, so on-site storage in dry casks and cooling storage pools is merely a temporary and very expensive option for both the government and nuclear plant operators. Already, cooling pool storage space is running out, and space for on-site dry cask storage eventually will, too. The government should fulfill its obligation to nuclear reactor operators and provide a permanent central repository for spent fuel to decrease its liabilities and alleviate on-site spent fuel storage.

An aggressive policy to complete a central, secured repository should be a top priority for Congress. Yucca Mountain could safely store from 70,000 tons to 120,000 tons of spent fuel; however, residents in Nevada strongly oppose the site.[51] Monetary incentives should be considered to resolve the issue. A portion of the $19 billion fund from the 1982 Nuclear Waste Policy Act could be awarded to Nevada for housing the spent fuel.[52] If not Yucca Mountain, then another central storage center should be established. Regarding the safety of transporting spent fuel, the NRC states: "Over the last 30 years, thousands of shipments of commercially generated spent nuclear fuel have been made throughout the United States without causing any radiological releases to the environment or harm to the public."[53] Fears of transporting spent nuclear fuel across the country are unfounded.

Spent Fuel Reprocessing

One method for reducing the buildup of nuclear spent fuel is reprocessing. In the current once-through fuel cycle for commercial reactors, nuclear fuel is used once and then removed for storage. This process creates tons of unusable radioactive spent fuel. So far, the nation has amassed 56,000 tons of spent fuel; at this rate, spent fuel would fill Yucca Mountain by 2010.[54] With more nuclear power plants on the horizon, storage for more spent fuel will be needed.

Advanced fuel cycle technologies like fourth-generation fast breeder reactors (FBRs) should be developed and implemented. FBRs use a "closed" fuel cycle, meaning they can reuse spent fuel. FBRs also create fuel, helping to preserve the United State's limited uranium resources. FBRs can also use thorium, which is more abundant than uranium. FBRs are more costly to build and operate than current light water reactors and reprocessing spent fuel could lead to weapon-grade plutonium. Due to fears of nuclear proliferation, President Carter banned plutonium reprocessing in 1977.[55] New techniques in reprocessing developed since 1977, however, safeguard against plutonium weaponization. Advanced fuel cycle plants, such as FBRs, should be considered once more due to the increasing buildup of spent fuel. Japan, Russia, India, and China have and continue to explore the potential of FBRs and spent fuel reprocessing. The United States should join them in this effort.

Spent Fuel Disposal

Research and development for spent fuel disposal should be a priority considering its extended radioactive life. There is no long-term plan to dispose of spent fuel. A means of disposal, or at least reducing the half-life of spent fuel, should be investigated. At The University of Texas at Austin, physicists have developed a fusion-fission hybrid reactor that could burn nuclear waste, thus reducing the need for geologic storage sites.[56] They are seeking funding to build a prototype. Research funding for such emerging technologies should be made available.

2. Continue government guaranteed loans for new advanced nuclear power plants.

The government should continue guaranteed loans for new advanced nuclear power plants because high capital costs and lengthy licensing and construction periods prohibit the private development of new nuclear power capacity. Capital costs and infrastructure for nuclear fission power plants are currently estimated at $3 billion to $12 billion, depending on type and size. The EIA estimates a 6-10 year lead time for new nuclear reactors (4 years to finish the licensing application, 1-2 years for NRC licensing approval, and 3-4 years to build the power plant).[57] The lengthy application and licensing process increases costs and delays potential power for the nation. Private industry will not pursue projects with such high capital costs without government guaranteed loans, and demand for government guaranteed loans for nuclear expansions is high. There is $18.5 billion in loan guarantees available under the June 30, 2008, Nuclear Power Facilities solicitation,[58] but the nuclear industry has petitioned for $122 billion in guaranteed loans.[59] Since 2007, the NRC has received applications for 17 new nuclear reactor operating licenses covering 28 new reactors and expects to receive a total of 22 applications for 33 new reactors by the end of 2010.[60] With the carbon tax, demand for clean nuclear energy will increase even more rapidly. The federal government should continue guaranteeing up to 80 percent of project costs for new reactors to encourage new nuclear power plant construction and operation. In particular, the United States should encourage government loans for advanced fuel technologies in order to minimize spent fuel and costs.

3. Continue nuclear production tax credits.

Under the EPAct 2005, a qualifying advanced nuclear power plant can claim a credit of $0.018 per kWh for the first 8 years of operation for electricity produced. This credit applies up to 6,000 MW and is comparable to the tax credit granted to the wind and solar energy industry.[61] Tax credits to encourage nuclear use should be continued and expanded to new plants.

Impact of Nuclear Energy Development Policies on National Objectives

Energy Independence and Security

Nuclear energy provides a safe and reliable domestic source of energy. By providing government guaranteed loans and nuclear production credits, the government would help foster the expansion of nuclear power and, if used to charge batteries or produce hydrogen for cars, diminish the nation's dependence on imported petroleum from unfriendly nations.

Economic Impact and Feasibility

By investing in nuclear power, new jobs will be created in advanced research, construction and maintenance of new power plants, and storage and disposal facilities. The United States could once more lead the world in advanced nuclear technology. Additionally, as Greenpeace co-founder Patrick Moore pointed out in a survey response, the United States would reduce its purchase of offshore oil and natural gas, reducing the costs of importing energy.[62]

Environmental Impact

As discussed earlier, nuclear energy leaves a small physical footprint compared to other alternative energy technologies and produces no carbon emissions other than in the mining of the fuel and construction of the facilities.[63] By expanding research and development efforts and continuing government guaranteed loans and nuclear production credits, nuclear power can meet the base-load energy demands for the nation efficiently and with reduced carbon emissions. Further research and development must address issues surrounding spent fuel, including central storage, reprocessing, and disposal, that may lead to environmental degradation and health issues.

Policies to Promote Public Awareness of the Energy Technology Transition

The government should partner with private industries to educate the public about the policies fostering a transition away from hydrocarbon-emitting energy sources to ease misgivings about higher prices for goods, build trust, and enable Americans to make informed energy decisions. A public/private campaign should explain the reasons for a carbon tax and how it affects consumers. The campaign should address the importance of energy efficiency to households and businesses and the potential effects of renewable energy and nuclear power. The government will build trust and confidence through this awareness campaign and mitigate concerns over the carbon tax. The government will then be seen as pursuing the best interests of society and the environment. As noted by an expert at the Solar Energy Industries Association, informing the citizenry will allow individuals to make the best decision themselves.[64]

The campaign should be launched before the carbon tax and other policies take place so the public will be prepared in advance for the changes. Television and internet ads should be used and expenses for ad space should be shared by both the government and private industries because both have a vested interest in making these policies work. While the policies are being implemented, ads should address the successes or failures of the policy to encourage the effort. Ads should also address whether states are meeting their RPS and carbon reduction goals, and whether the carbon tax is working. With an informed citizenry and a transparent government, consumers will be more willing to accept policies for a transition to clean energy.

Impact of Public Awareness Policies on National Objectives

Energy Independence and Security

The awareness campaign will address how these policies make the nation more secure. The United States will no longer depend on foreign nations for expensive sources of fuel, nor will the nation be subject to the price controls of foreign energy cartels like OPEC. The nation will have a domestic and clean supply of energy that is limitless and sustainable. The awareness campaign will highlight these facts and garner more approval for transition policies.

Economic Impact and Feasibility

The awareness campaign will highlight how the carbon tax reflects the true cost of hydrocarbon-emitting energy sources and how it will raise prices on virtually every good in the short term. In the short term, the economy might suffer, but after the initial stages of higher prices, the economy will grow because of new technology and advances in clean energy resulting from the transition policies. A new clean energy sector that offers jobs and promises economic growth will be created and a sound, fundamental industry will rise. The campaign will address all these economic promises which will relieve public fears regarding the economy in the short term.

Environmental Impact

The public/private awareness campaign will bolster the public's acceptance and support for the transition to clean energy. Without the campaign, the public will remain ignorant of the short- and long-term benefits of clean energy, and reject clean energy due to its higher costs. Consumers will embrace the transition if they are given enough time to consider the pros and cons of the policies.

Conclusion

These recommendations are based on extensive literature research, expert presentations, and professional interviews gathered at one of the most important times in our nation's energy history. They are each designed to advance national energy interests in unique, yet coinciding, ways:

- Hydrocarbon transition policies will increase the cost of carbon-emitting activities and raise/redistribute revenue to encourage the development of clean technologies.

- Transportation innovation policies focus on reducing and eventually eliminating U.S. dependence on oil in the transportation sector, relying on the disincentive to use gasoline provided by the carbon tax while using these tax revenues to bring more efficient vehicles to market at lower costs to businesses and consumers.

- Energy efficiency and conservation policies take the "path of least resistance" to a sustainable energy future by encouraging the wide-spread use of those technologies that reduce the nation's energy consumption.

- The renewable electricity development policy and the nuclear development policy both seek to replace hydrocarbon-intensive electricity generation with clean and domestic sources of energy. Their effectiveness depends on the carbon tax, which increases the price of carbon-emitting operations, and research and development investments in advanced renewable power generation, nuclear waste disposal technologies, and low-emitting hydrocarbon-intensive processes; all of which make available new technologies that can replace old pollution-emitting methods of power generation.

- Policies to promote public awareness will inform the public about the energy transition and to help consumers make informed choices about products and energy usage. It will increase the transparency of the carbon tax and help drive demand for the most energy efficient products.

Combined, these policies if incorporated in a National Energy Plan for 2010-2050 will reduce greenhouse gas emissions, create new domestic industries and green jobs, reduce the costs and consequences of continued reliance on hydrocarbon energy resources, create a diverse energy portfolio that is both more robust and resistant to market volatility, and improve informed consumer choice in energy consumption. Each policy depends on the successful execution of the others. Combined, they are the best approach to an energy technology transition that considers the risks and hardships faced by U.S. citizens and businesses in securing a sustainable energy future.

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Appendix 1.
Survey Questions

General Questions

1. What are the most important reasons the United States should transition away from hydrocarbon-based energies? (Please rate all that apply; 1-most important to 7-least important)

-____ Global climate change

-____ Other environmental concerns

-____ National security

-____ Security of resource

-____ Economic issues

-____ Energy independence

-____ We should not transition away from oil-based energies

-____ Other ____

2. Briefly describe: What you think the consequences would be for the U.S. and the world to continue our current dependence on hydrocarbons?

3. What should be the goal in terms of percentage of renewable energy incorporation into the United States' energy plan? (Please provide a % for each date)

________ By 2012

________ By 2025

________ By 2050

________ Past 2050

Other? ______________________________

4. Which of the following best describes the future role of energy policy in the U.S. in the next 10 years? Why?

-More important than the other pressing policy issues (example-health care; education)
-Just as important as the other pressing policy issues
-Not as important as the other pressing policy issues

Other ______________________________

5. In your opinion, what energy technology, once implemented, will allow the U.S. to best advance policy objectives in the areas of energy independence, environmental protection and economic progress? (Rank all that apply *up to 10 please*)

- ____ Grid technology

- ____ Storage

- ____ Clean coal (carbon sequestration)

- ____ Solar

- ____ Wind

- ____ Geothermal

- ____ Geopressured & Co-produced liquids

- ____ Ocean current energy

- ____ Wave energy

- ____ Tidal energy

- ____ Cold fusion

- ____ Hydrogen

- ____ Hydroelectric

- ____ Methane hydrates

- ____ Nuclear fission

- ____ Nuclear fusion

- ____ Biofuels

Energy Conservation & Efficiency Questions

1. Assuming equally ambitious policies are instated in each sector, please rank the sectors below in order of their potential to decrease energy consumption in the United States.

(1-most potential to decrease energy consumption to 4-least potential to decrease)

-_____ Residential

-_____ Commercial

-_____ Transportation

-_____ Industrial

2. Which method of reducing energy consumption will be *most* useful for the U.S. in terms of energy saved and ease of implementation?

a) Energy conservation
b) Energy efficiency

Why?

3. What role should demand-side management practices have in future energy conservation and/or efficiency policies?

a) Extremely important (most utilities should be encouraged to adopt)
b) Moderately important (leave it to the utility's discretion)
c) Not very important (only useful in specific contexts)

4. Please identify the past energy conservation and/or efficiency policies which had the greatest impact (by decreasing energy consumption the most)?

Which past policies had the least impact?

5. What energy conservation and efficiency measures, if utilized, would decrease the United States' reliance on fossil fuels the most? (Please provide one or two measures per sector.)

Residential -
Commercial -
Transportation -
Industrial -

6. Please use the space below to include any additional comments related to energy conservation and efficiency policy or the United States energy situation in general.

Role of Hydrocarbons Questions

1. What are the key issues to note about the energy history of the U.S. in respect to oil, natural gas, and petroleum?

2. In your opinion, what parallels do you see between the period of the 1970s and the oil crisis, and where we are today? What are some of the differences?

3. In your opinion, is the geo-political landscape of today, in respect to the need for the petroleum based commodities, different from the period of the 1970s oil crisis? How and why?

4. Historically, has the U.S. had any leverage over OPEC countries in the past? In what ways? Were there consequences to U.S. energy supply as a result?

5. How would you articulate the lessons that can be learned from looking at the ways in which the U.S. has dealt with oil and petroleum based products?

6. What do you believe the role of hydrocarbons will be in the future as we move towards an energy technology transition?

7. Do you believe that sustaining the current U.S. energy supply mix will have negative consequences? Why or why not?

Technology Questions

1. In a best-case scenario, how long will it take to develop your technology to be commercially viable?

a) It is commercially viable (profitable) now
b) Less than 5 years
c) 5 to 15 years
d) 15 to 30 years
e) More than 30 years

2. In order for your technology to become commercially viable, what top 3 steps need to be taken?

3. What would be an estimate of the financial investment necessary for your technology to achieve commercial viability?

4. What percentage of the U.S.'s electricity energy use could be covered by your technology in the following years?

_____________ By 2012

_____________ By 2025

_____________ By 2050

_____________ Beyond 2050

5. What is the largest technological barrier to the development of your technology?

(Rate all that apply; 1-biggest barrier; 7-minimal barrier) Please give examples where possible.

- _____ Research ___________________________________

- _____ Development _________________________________

- _____ Price parity ___________________________________

- _____ Storage ___________________________________

- _____ Transmission _______________________________

- _____ Production _________________________________

- _____ Other______________________________________

6. What (past) policies have successfully promoted the advancement of your technology in the U.S. or internationally? (Please limit your answer to the top three)

7. What (past) policies have hindered the advancement of your technology in the U.S. or internationally? (Please limit your answer to the top three)

8. Which alternative energies do you believe SHOULD NOT be a part of the United States' energy technology transition and energy future? (please circle those you believe are NOT part of the answer)

-Solar
-Wind
-Geothermal
-Geopressured & Co-produced liquids
-Ocean current energy
-Wave energy
-Tidal energy
-Nuclear fission
-Nuclear fusion
-Cold fusion
-Hydrogen
-Hydroelectric
-Methane hydrates
-Clean coal (carbon sequestration)
-Biofuels
-Other ____________________

9. Which alternative energies do you believe SHOULD be a part of the United States' energy technology transition and energy future? (Please circle all that apply)

-Solar
-Wind
-Geothermal
-Geopressured & Coproduced liquids
-Ocean current energy
-Wave energy
-Tidal energy
-Nuclear fission

-Nuclear fusion
-Cold fusion
-Hydrogen
-Hydroelectric
-Methane hydrates
-Clean coal (carbon sequestration)
-Biofuels
-Other _____________________

10. What technologies, in your opinion, are useful ONLY in a transitionary role? (NOT part of a long-term energy solution)

-Solar
-Wind
-Geothermal
-Geopressured & Co-produced liquids
-Ocean current energy
-Wave energy
-Tidal energy
-Nuclear fission
-Nuclear fusion
-Cold fusion
-Hydrogen
-Hydroelectric
-Methane hydrates
-Clean coal (carbon sequestration)
-Biofuels
-Other _____________________

11. How do you anticipate a cap & trade policy would affect the development of your technology?

12. Please briefly explain how your technology addresses the following national policy areas.

- U.S. national security & energy independence
- Pollution & the environment
- U.S. economy

Energy Policy Questions

1. What are three important policies or political forces hindering the transition to more renewable energy resources in the U.S.?

2. In your opinion, what factors (economic, political, cultural, etc.) are necessary for the U.S. to achieve President-elect Obama's stated goal of 10 percent renewable electricity by 2012?

3. In the transition to more renewable energy resources, what specific roles should the government and private sector play?

4. We understand that the passage of energy legislation requires a significant amount of time, energy and political effort. Based on your experience with any of the following pieces of legislation (see below), can you describe the most important factors contributing to its passage/failure/modification in the House / Senate? Were there any features of the legislation that were more controversial than others? If so, what were they? What other challenges did you encounter in the process as a professional?

Energy Policy Act of 2005

Energy Independence and Security Act of 2007

Emergency Economic Stabilization Act of 2008

(Division B: Energy Improvement and Extension Act)

5. In the new administration, what new and existing policies would be most effective in developing and distributing renewable energy supply / demand in U.S. markets?

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