Policy Research Project Report

Building the Bridge to an Energy Secure Future

Energy Policies for the 21st Century

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin

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Building the Bridge to an Energy Secure Future: Energy Policies for the 21st Century

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List of Acronyms

AEC	Atomic Energy Commission
BCF	Billion Cubic Feet
BLM	Bureau of Land Management
BPD	Barrels per Day
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Sequestration
CERN	Organisation Européenne pour la Recherche Nucléaire
CNG	Compressed Natural Gas
DOE	Department of Energy
DOI	Department of the Interior
EIA	Energy Information Administration
EGS	Enhanced Geothermal Systems
EMEC	European Marine Energy Center
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
FORCE	Fundy Ocean Research Centre
FERC	Federal Energy Regulatory Commission
GHGs	Greenhouse Gases
GS	Geological Storage
GW	Gigawatts
H_2S	Hydrogen Sulfide
HDR	Hot Dry Rock
IAEA	International Atomic Energy Agency

IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
INGAA	Interstate Natural Gas Association of America
IPCC	United Nations Intergovernmental Panel on Climate Change
ITER	International Thermonuclear Experimental Reactor
JIP	Joint Industry Project
LENR	Low Energy Nuclear Reaction
LNG	Liquefied Natural Gas
LWR	Light Water Reactor
MCF	Thousand Cubic Feet
MENA	Middle East and North Africa Region
MH	Methane Hydrate
Mi	Miles
MM/BTU	Million British Thermal Units
MMS	U.S. Minerals Management Service
MW	Megawatt
MWh	Megawatt Hour
NETL	National Energy Technology Laboratory
NIMBY	Not In My Backyard
NRAP	National Risk Assessment Partnership
NRC	National Research Council
NRC	Nuclear Regulatory Commission
OPEC	Organization of the Petroleum Exporting Countries
OrpC	Ocean Renewable Power Company
PTC	Production Tax Credit

R&D	Research and Development
RPS	Renewable Portfolio Standards
SSTAR	Small Sealed Transportable Autonomous Reactor
TCF	Trillion Cubic Feet
TEDEC	Tidal Energy Device Evaluation Center
UIC	Safe Drinking Water Act’s Underground Injection Control Program
USGS	United States Geological Survey

Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major part of this program is the nine-month policy research project, in the course of which one or more faculty members direct the research of 10 to 20 graduate students of diverse backgrounds on a policy issue of concern to a government or nonprofit agency. This "client orientation" brings the students face to face with administrators, legislators, and other officials active in the policy process and demonstrates that research in a policy environment demands special talents. It also illuminates the occasional difficulties of relating research findings to the world of political realities.

"Building the Bridge to an Energy Secure Future: Energy Policies for the 21st Century" is a Policy Research Project of The University of Texas at Austin Lyndon B. Johnson School of Public Affairs that seeks to identify and recommend policies that encourage emerging and established energy technologies that will shift the United States towards long-term energy security. The findings are current as of May 2011.

The curriculum of the LBJ School is intended not only to develop effective public servants, but also to produce research that will enlighten and inform those already engaged in the policy process. The project that resulted in this report has helped to accomplish the first task; it is our hope that the report itself will contribute to the second.

Finally, it should be noted that neither the LBJ School nor The University of Texas at Austin necessarily endorses the views or findings of this report.

Robert L Hutchings

Robert Hutchings
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Acknowledgments and Disclaimer

This report was drafted as a group effort by students in a Policy Research Project (PRP) on Building the Bridge to an Energy Secure Future: Integrating Energy Options and Policies for the 21st Century. Participants included Elizabeth Coburn, Julian Dahmen, Zachary Dyer, Tim Eubank, Eric Eyges, Farrah Farley, Sam Marie Hermitte, Simon Kim, Reed Malin, Maureen Metteauer, Patricio Prieto, Audra Teinert, Yasmin Diallo Turk and Miha Vindis. Co-instructors Charles Groat and Thomas Grimshaw provided guidance and supervision to the class. Tom Gerrow, a professional writer, edited the final report.

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Rick Smead, Navigant
Unconventional Gas

Scott Anderson, Environmental Defense Fund
Natural Gas Environmental Issues

Dale Klein, Energy Institute, The University of Texas at Austin
Nuclear Technology, Reliability, Safety, and Security

Eric Schneider, CIEEP, The University of Texas at Austin
Nuclear Fuel Cycle and Waste Issues

Ian Duncan, Bureau of Economic Geology, The University of Texas at Austin
Carbon Capture and Sequestration

Ben Yamagata, Coal Utilization Research Council
Competition for Coal

Alan Kuperman, LBJ School of Public Affairs, The University of Texas at Austin
Nuclear Proliferation

Gary Hamilton, Hamilton & Terrile
1. *Nuclear Risk Assessment and Liability*
2. *Intellectual Property Concerns for New Energy Technologies*

Ed Storms, KivaLabs, and Dennis Letts, Private Researcher
Cold Fusion Science, Policy, and Politics

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None of the sponsoring units, including the Lyndon B. Johnson School of Public Affairs, the Jackson School of Geosciences, 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

In the past several decades, U.S. demand for energy has increased dramatically. Energy production to meet this demand has spotlighted the issues of finite resources, fragile sources of energy supply, and increasing environmental impact. In particular, coal-fueled electrical power generation and petroleum-based transportation, with their attendant greenhouse gas emissions, have raised concern about a potential unstoppable march toward global warming. At the same time, political unrest among some major U.S. energy trading partners has threatened to destabilize the U.S. domestic energy market.

Despite these challenges, policymakers have yet to implement a comprehensive and effective national energy policy that would ensure the future stability of the U.S. energy market. This failure appears to be the result of policymakers' inability to articulate a long-term goal around which to frame such a policy. Energy security appears to be the best candidate for this long-term goal.

Five criteria may be used to evaluate established and emerging energy technologies within a framework of energy security—technological feasibility, economic viability, regulatory framework, environmental impact, and political implications. Three existing resources—nuclear, conventional natural gas, and geothermal—and four emerging or potential resources and technologies—methane hydrate, tidal energy, carbon capture and sequestration (CCS) and low energy nuclear reaction (LENR)—were evaluated to inform energy policymaking in an energy security framework.

Findings

A number of common themes were identified that likely will dominate U.S. energy policy in the next several decades. Several lessons learned were identified in the regulatory and policy approaches used in established resources and technologies. It will be essential to incorporate these common themes and lessons learned in future energy policymaking to ensure U.S. energy security in the future.

- The driving force of U.S. energy remains economics, and not energy security.
- Despite the strong desire to migrate from a carbon-based energy system, the majority of U.S. energy supplies will be derived from fossil fuels for the next quarter century.
- The discovery of large unconventional natural gas reserves is changing the economics of U.S. energy markets.
- Energy policy in the United States is fragmented and short-sighted because political support for various industries continues to exacerbate inequalities and inefficiencies in the nation's energy portfolio.
- In the energy area, the main task of the government should be to focus on basic scientific research.

- Strict environmental regulations and negative public perception of energy relative to the environment are the major hurdles to energy development in the United States.
- Existing energy sources—natural gas and nuclear power—provide key lessons that can inform elected officials and industry leaders as the nation seeks a bridge to renewable energy: (1) price regulation and rules affecting consumption set up problems that led to price shocks for natural gas and incentivized the use of coal for electricity production; (2) choosing "winners and losers" as energy sources can have serious unintended consequences; (3) the energy industry must have consistent and effective regulation to remain innovative; (4) effective regulation and predictable government support can help new technologies find their way to market more efficiently; (5) for emerging technologies, scientists and developers must be able to provide a framework in which to explain their innovations; and (6) public education is crucial to the development and implementation of new energy technologies.

With respect to the specific established and emerging technologies and resources, several additional observations were made.

- Natural gas is moderately environmentally sound and economically viable, while having the potential for large scale production.
- Nuclear energy's minimal carbon footprint is offset by its prohibitive costs and lack of political workability, especially in the wake of the incident in Fukushima, Japan, where severely damaged nuclear reactors released significant radiation in March 2011.
- Geothermal energy, although more politically palatable than nuclear, is not developed to the extent that it can produce at a large scale.
- Tidal energy production suffers from the same set of difficult circumstances as geothermal energy, combined with other geographic limitations.
- CCS offers moderate environmental and economic gains, but enjoys strong political support.
- Neither methane hydrate nor low energy nuclear reaction technologies are sufficiently developed. Low energy nuclear reactions could have extremely positive environmental attributes, but methane hydrates have more public support.

To further evaluate the seven existing and emerging resources and technologies, each one was qualitatively evaluated according to the five criteria listed above for energy security (energy abundance was found to be more significant and was used in place of regulatory framework). The resulting matrix indicates that conventional natural gas and CCS rated highest among the resources and technologies evaluated.

Recommendations

The findings and lessons learned lead to recommendations that focus on improving the viability of emerging, non-fossil fuel energies without significant and immediate cut-backs in traditional energy sources. Many of the recommendations are not specific at the federal level, but are set up to be tailored to the specific conditions in each state or region.

- The energy sector should invest in a public education and awareness campaign for their respective technologies.
- A national renewable portfolio standard (RPS) should be implemented requiring all states to produce a minimum percentage of electricity from renewable or low-carbon alternative energy sources by a specified date, without explicitly favoring any one technology.
- Existing and future federal funds from the Department of Energy should be reallocated to focus primarily on basic research.
- The federal subsidy structure should be changed to favor “bridge-to” technologies, while slowly decreasing subsidies to established and "bridging" technologies: (1) for nuclear and natural gas, the current subsidies should stay in place in the short-term, but they should be gradually decreased as emerging technologies meet technological and scalability challenges; (2) the current political environment is unlikely to produce support for a carbon tax, so the CCS industry (or CCS customer industries) should receive subsidies to speed up implementation; (3) geothermal, methane hydrate, and tidal energy should be considered for subsidy programs—if these “bridge-to” technologies contribute to energy security within acceptable parameters, these subsidies should be slowly increased at the expense of oil industry tax breaks; and (4) research in the LENR field is making very slow progress due to limited funding and fundamental questions about its scientific merits. LENR is in need of further funding for basic research and is not ready for structural subsidies such as tax breaks. Should the theory and application make significant breakthroughs and prove scalable, however, a wide range of subsidies should be considered, given the game-changing potential of this technology.

Chapter 1. Introduction

Purpose

In January 2011, a popular uprising in Tunisia toppled longtime President Zine El Abidine Ben Ali and started a wave of civil unrest in the Middle East and North Africa (MENA) region that crested with Egypt's peaceful revolution and crashed with a de facto civil war in Libya. These demands for democratic reform in the MENA region are inspiring but vividly illustrate the magnitude of the United States' lopsided dependence on politically unstable (and at times unfriendly) regimes for its energy needs. These events are extraordinary, but they are also the most recent of a long line of crises emphasizing the need for a comprehensive energy security policy.

With President Obama's 2008 electoral victory and Democratic control of both chambers of Congress, a comprehensive energy security policy appeared to be on the horizon. Campaign promises involving sweeping environmental legislation that would assign a price to carbon dioxide emissions seemed on the brink of ushering in a new era where costs would finally reflect the externalities of fossil fuel use. But as the American Clean Energy and Security Act of 2009 faltered in the U.S. Senate, it became clear that the carbon pricing so many anticipated would be put off yet again. Immediate legislation regarding U.S. energy policy looks unlikely, but at the time of this writing the Environmental Protection Agency (EPA) is still moving forward with its regulation of carbon dioxide and other greenhouse gases.

While the Obama administration has taken some steps to support "green" jobs, the U.S. alternative energy industry, and EPA regulation of carbon dioxide, these acts do not constitute a long-term energy security policy. Recent events in the MENA region coupled with the March 11, 2011, accident at the Fukushima Daiichi nuclear power plant in Japan have made this report's focus on energy security timelier than its authors originally intended. At this pivotal time in history, the United States has the opportunity to seize the moment and invest in emerging and established energy technologies that will increase the nation's long-term energy security.

The consistent lack of a comprehensive energy security policy and a nascent carbon dioxide control regimen set the stage for this report. "Building the Bridge to an Energy Secure Future: Energy Policies for the 21st Century" is a Policy Research Project of The University of Texas at Austin Lyndon B. Johnson School of Public Affairs that seeks to identify and recommend policies that encourage a shift to emerging and established energy technologies that will move the United States towards long-term energy security.

Goals

To achieve this end, a team of 14 researchers aided by two project directors was assembled. The team researched this report over eight months from August 2010 to

March 2011. Several essential questions guided the research and influenced the methodology behind the report:

- What lessons can be applied from the nuclear and natural gas industries to emerging technologies?
- What lessons can be drawn from low energy nuclear reactions or cold fusion?
- How can these emerging technologies support a shift towards long-term energy security for the United States?

Methodology

Selection of Theme

Due to the broad nature of the energy problems being explored in this research project, the research team conducted an initial discussion to select a focus. The major themes that emerged were: environmental impacts, public health concerns, and energy security. A vote was held and energy security was selected as the primary theme of the policy research project.

Selection of Technologies

To guide the research, a set of core technologies was chosen by the professors at the beginning of the project. These included: nuclear, natural gas, low energy nuclear reaction (LENR), and geothermal. These established and emerging technologies formed the basis for initial investigation into market structure and energy policies. Guest lecturers and class activities focused on understanding and explaining these technologies and their role in the energy market.

After these initial lectures, a group meeting was held to select additional technologies for inclusion. Methane hydrate, tidal, and carbon capture and sequestration (CCS) were selected by consensus. These technologies were selected because they span the range from extremely new and experimental to well-established but lacking wide-ranging implementation. As this project seeks not only to evaluate policy options, but also emerging technologies, it was essential to explore these additional technologies.

Guest Lecturers

Researchers attended lectures from academics, policymakers, industry representatives, and project directors on regulatory, legal, technological, and environmental issues regarding the current energy economy and emerging low carbon emitting energy technologies. Taking place early in the research phase of the report, these lectures established a shared foundation of knowledge that was used to create a research design.

Literature Review

The team divided into two-person groups that specialized in specific technologies. Each group conducted a detailed literature review on their individual technology with specific focuses on technological feasibility, economics, regulation, environmental impacts, and political implications. This secondary research also served as background research for the team's survey of experts.

Original Survey of Experts

Coupled with the literature review, researchers conducted interviews with experts. The individuals surveyed included academics, industry representatives, policymakers, and think tank members. Fifty-two experts were interviewed by telephone, in person, and by e-mail.

Questions used to guide interviews included:

1. What is the main driver for energy?
2. Is the technology practical and feasible? What are the major political/regulatory hurdles?
3. Do the economics of this technology make it feasible?
4. How does the public perceive the emerging technology?
5. What environmental factors affect this technology?
6. How developed is the technology? Is it ready for wide implementation?
7. What lessons from existing technologies (nuclear, natural gas) can be applied to emerging technologies?

These questions guided the expert interviews and secondary source research to produce detailed summaries of existing and emerging technologies.

Findings and Recommendations

Two groups considered the project's findings and recommendations separately. The first synthesized the findings in the technology summaries and expert interviews and developed a metric to compare the various technologies on a qualitative scale. The second group reviewed the former's findings and conducted additional general interviews to develop policy-oriented recommendations for emerging technologies.

PRP Document

Details of the findings from the guest lectures, literature review, case studies, and expert interviews are provided in subsequent sections. These findings outline a plan to implement an energy technology transition to realize long-term energy security for the United States. Specifically, the report adheres to the following progression:

1. The case for the energy security transition

2. The evolution of U.S. energy policy

3. Established low-carbon energy technologies (nuclear, natural gas) and lessons learned

4. Emerging, low carbon emitting technologies

5. Final findings and analysis

6. Recommendations for a comprehensive energy security plan

Chapter 2. Energy Security

The events in the MENA region are especially relevant to U.S. energy security because their timing coincides with the recovery from the most recent global economic recession. From December 6, 2010, to February 28, 2011, two weeks after the fall of former Egyptian President Mubarak, oil prices increased at a steady rate. The price peaked at $112.03 a barrel on March 7, 2011.[1] As of the publication of this report, interruption in oil production caused by Libya's civil war continues to contribute to increased oil prices due to its role as a significant supplier in the world market.[2] Furthermore, rising oil prices have been shown to anticipate recessions.[3] High energy prices and continued political instability may jeopardize the U.S. economic recovery.

Defining Energy Security

The current level of U.S. fossil fuel consumption makes an immediate shift away from fossil fuels unrealistic and perhaps even dangerous. This report used five criteria to assess established and alternative energy technologies within the frame of energy security: technological feasibility, economics, regulation, environmental factors and politics.

Technological Feasibility

Technological feasibility was at the center of this report's recommendations for shifting the United States towards long-term energy security. This criterion asked whether the technology was in use or still in development, and determined its reliability, any geographic limitations to its implementation, and its potential for wide scale deployment. Understanding the technological feasibility of these technologies is essential to assess how realistic these options are for U.S. energy policy.

The transition of emerging technologies from the drawing board to commercial deployment is rife with problems. Pilot projects offer some guidance in understanding how these new technologies will integrate into the existing energy infrastructure. These projects, however, often do not address the problems of scalability and affordability required to significantly contribute to U.S. energy security. Once implemented, these emerging technologies may help reduce U.S. dependency on oil but suffer from inconsistent supply, geographic limitations, and face other hurdles examined in this report. Consequently, there is a strong incentive to address technological feasibility to reach the optimal balance between dependable energy resources and long-term security.

The transition from theoretical models to new innovative technology options will help the U.S. energy sector evolve toward a more secure, long-term model. With the support of Congress, the energy production sector, and the public, the cost of renewable energy technology can be affordable and have benefits that outweigh the initial costs, including public health and environmental impacts.

Economic Viability

The economics behind the establishment of greater energy security in the United States is a complex, pivotal issue. The matter has been widely debated since the oil crisis of the 1970s, and the resulting economic recession. The energy security outlook of today is comparable to the situation 30 years ago, and several key issues have yet to be resolved.

The rate of oil consumption in the United States is the most important issue. The United States consumes more oil than any other nation in the world, including China, Russia, and India. Further, the United States purchases 22 percent of all the oil generated in OPEC countries.[4] This massive outflow of capital from the United States to foreign nations is an important consideration when analyzing the costs and benefits of funding and ultimately establishing a domestic renewable energy portfolio.

As the United States improves its energy security position, it will necessarily reduce its dependence on foreign oil, which is a situation that may have negative consequences. If a new technology allows the United States to reduce foreign oil imports, the economies of some oil-producing nations will be dramatically affected. The price of oil would likely decrease in order to make the resource more attractive to other buyers, such as China. It is also posited that conflicts between nations would increase due to the friction created during the establishment of a new oil consumption status quo.[5] Therefore, the impacts, economic and otherwise, of increased U.S. energy independence will have long-lasting, worldwide effects.

Another consideration is how increased competition for oil will affect the U.S. economy. China and India, along with other developing countries, are causing the overall demand for oil to increase substantially. Oil production across the globe is expected to increase to 121 million barrels per day (BPD) in 2025, up from 77 million BPD in 2001.[6] Without the development and wide-scale implementation of a new technology, the United States is expected to import 20.7 million BPD in 2025, a dramatic increase from 11.5 million BPD in 2002.[7] If the price of a barrel of oil were $80, then the outflow of U.S. dollars to foreign nations in 2025 would be $1.656 trillion.[8] Such figures should be kept in mind when making policy decisions regarding how much capital to invest in new energy technologies.

Another economic justification for policies that increase U.S. energy security is, some experts argue, that sharp increases in the price of oil lead to recessions. If true, the continued lack of energy security in America could result in a greater trade deficit, which has been linked to decreased government spending. This decrease in spending could in turn negatively affect the U.S. economy over the long-term.

As made clear in a speech by President Obama, drilling in Alaska and elsewhere in the United States will not provide the amount of oil this nation requires over the long run.[9] Consequently, investment in alternative energy technologies is an absolute necessity. Further, establishing a leadership role in clean energy technologies will allow the United States to assume a stronger role in the global economy.[10]

Current Regulatory Framework

Regulation is an essential element in the creation and implementation of a more sustainable energy security policy for the United States. After feasibility is established for an energy technology, regulation serves as the government's primary tool to motivate changes in the marketplace to support technologies that contribute to greater energy security for the United States, while also policing their health impacts and environmental safety. Regulation at its best balances the goals and interests of government, consumers, and industry in an impartial, transparent, and accountable manner.[11]

After reviewing several emerging technologies, it is clear that regulating carbon dioxide emissions will be necessary for the United States to develop the diverse basket of energy technologies needed to achieve the goal of long-term energy security. The failure of the U.S. Senate to vote on the American Clean Energy and Security Act of 2009 ended the most recent opportunity for Congress to issue comprehensive guidance on regulating carbon dioxide through taxes or a cap-and-trade scheme. Regardless of the bill's failure in Congress, the Environmental Protection Agency announced that it intends to go forward with its own regulation of greenhouse gases, including carbon dioxide. Starting January 2, 2011, greenhouse gas emissions from the largest stationary sources (electrical generation, cement, refineries, etc.) will be covered under the EPA's Prevention of Significant Deterioration and title V Operating Permit Programs. This action will cover approximately 70 percent of greenhouse gas pollution from stationary sources in the United States.[12] Regulation like this has the potential to level the playing field between more costly alternative technologies and fossil fuel based energy.

Regulation plays an important role in ensuring the health and environmental safety of energy resources, established or emerging. From a public policy perspective, regulation must balance concern for the public welfare with avoiding regulations so draconian that energy producers cannot effectively compete. Environmental, health and safety regulation impacts established technologies—especially nuclear and unconventional natural gas—as well as emerging ones.

Regulating emerging technologies is challenging since some involve infrastructure that does not yet exist or pose challenges that previous lessons learned poorly address. Ill-defined or incomplete regulation also serves as a hurdle for implementing alternative energy technologies. This report considered each technology's current regulatory framework as well as expert opinion on how to improve it when assessing their potential for U.S. energy security.

Environmental Impacts

A recent report from the Center for a New American Security highlighted the importance of moving beyond the price of oil as the motivation for a comprehensive energy security policy.[13] In line with this call for a wider approach to energy security, this report considered a technology's environmental impacts. This included environmental impacts to the surrounding ecosystems including anthropogenic effects to air, land, and water quality. While climate change may seem irreversible at times, the United States—the second largest emitter of carbon dioxide—has the opportunity to mitigate its potentially devastating impact on the environment through its energy policy.[14]

The 2008 National Intelligence Assessment on Global Warming identified that global climate change will have wide-ranging implications for U.S. national security interests over the next 20 years.[15] Climate change has the potential to affect lives through food and water shortages, increased health problems, and increased potential for conflict.[16] Climate change threatens property through ground subsidence, flooding, coastal erosion, and extreme weather events.[17] America depends on a smooth-functioning international system ensuring the flow of trade and market access to critical raw materials such as oil and gas, and security for its allies and partners.[18] Climate change policies could affect domestic stability in a number of key nations, the opening of new sea lanes, access to raw materials, and the global economy more broadly.[19] Even if these events do not affect the United States directly, their impact on other parts of the world could create massive migrations as people flee deteriorating conditions elsewhere.[20]

The report judges that the most significant impact for the United States will be indirect. Climate change impacts will worsen existing problems regarding poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions.[21] Furthermore, climate change could even threaten domestic stability in some states by contributing to intrastate or interstate conflict over access to increasingly scarce water resources, for example.

The calamitous effects of anthropogenic climate change are no longer the purview of science fiction. It is up to the United States and other developed nations to lead the campaigns for awareness, acceptance of inconvenient lifestyle changes, and finding funding to make needed changes.

Political Issues

The energy security of the United States is one of the most important political issues in the nation today. Politicians debate the security of America's energy resource base, how to increase overall energy security, and how such efforts should be funded.

Some have argued that the outflow of U.S. capital to foreign oil-producing nations results in decreased political stability across the globe, as well as strained relations between the United States and other nations. For example, a correlation has been drawn between income from oil sales and increased activity on the part of terrorist groups.[22] Iran used favorable oil prices of the past decade to ramp up development of nuclear devices, while Venezuela embarked upon greater efforts to incite radical change in Latin America.[23] These events and many others highlight the magnitude of political issues surrounding the issue of the United States' continued dependence on foreign oil.

Clean coal is another item at the center of the energy security discussion. While the United States has enormous domestic coal resources, this energy source also produces significant emissions that contaminate air, water, and soil, in addition to having human and animal health impacts. Hand in hand with increased consumption of coal is the related issue of greenhouse gas emissions and global climate change. Climate change has the potential to cause significant effects in the United States and around the world, and is an important political issue as well. To the extent that the United States can develop clean coal and renewable energy technologies that decrease greenhouse gas emissions, the political consequences of climate change can be reduced or avoided.

One way to decrease reliance on foreign oil and to increase U.S. energy security is through policy measures aimed at creating disincentives for such consumption. A carbon tax on oil consumption or a permitting system that limits overall carbon emissions while utilizing a free-market trading system could transform the way energy is consumed.[24] Such regulations could also encourage increased efficiency and conservation.

Another option is to increase public funding for domestic research, development, and demonstration of renewable and clean energy technologies. However, each sector of the energy economy and each constituency are lobbying for public policies that most benefit those sectors, and developing a cohesive, mutually beneficial set of regulations is difficult.

History of Energy Security

In addition to analyzing several key considerations such as economics, technical feasibility, and regulatory environment, the history of energy security in the United States has also been closely examined. A discussion of the inception and development of energy security is helpful because it provides an understanding of why U.S. energy security policy has evolved in the way it has over the past 40 years.

Energy security is an unparalleled strategic challenge for the United States, which requires the integration of economic, environmental, and national security policy considerations. Accordingly, the history of energy security in the United States is inexorably tied to the geopolitical, environmental, and economic factors surrounding the energy sector and the stakeholders affected by energy policy both foreign and domestic.

Energy security in the United States is tied immutably to the nation's dependence on fossil fuels such as coal, natural gas, and oil. Currently, fossil fuels account for approximately 83 percent of the U.S. energy supply. They are projected to provide 78 percent of our energy by 2035 if current energy policies remain unchanged.[25]

Energy is a vital input for all economic activity. As such, maintaining a reliable, affordable, and adequate energy supply is of utmost importance to the economic security of the United States. While the United States has vast coal deposits and natural gas, dependence on oil as our primary transportation fuel has been a major concern for policy makers since the 1970s.

History of Energy Security and Oil

Oil is the lifeblood of the U.S. economy. It currently accounts for more than 40 percent of the energy consumed in the United States each year and supplies 99 percent of the fuel used in cars, trucks, trains, and airplanes.[26] In 2009, the United States imported 51 percent of its oil supply.[27] Much of U.S. energy policy reflects the role that oil plays in the nation's economy. Thus, political events surrounding the global oil market greatly affect economic, environmental, and foreign policy.

Until the middle of the 20th century, the United States was the world leader in exploration, production, and refining of petroleum products. Major finds in Pennsylvania, and then later Texas, sparked an oil boom in the early 1900s that facilitated the U.S. industrial revolution. Ironically, the first series of energy security concerns and policies in the United States were designed to prevent oversupply and cutthroat competition. So grave were the concerns about collapse of the oil industry that in 1931 the governor of Texas called in the state militia to impose quotas on production and transportation of oil.[28]

By 1946, the United States began consuming more oil than it produced domestically for the first time.[29] Post-war era policymakers recognized that the United States would become dependent on foreign oil supplies, which would require a foreign policy that maintained our access to this vital resource. Furthermore, the energy security challenges of dependence on foreign oil were exacerbated by the fact that approximately one third of the world's oil supply is located in the Middle East, which has formidable economic and political implications.

The Arab oil embargo of 1973 demonstrated the security risks posed by reliance on foreign oil.[30] It caused a 70 percent increase in the price of a barrel of oil and quadrupled the cost of a gallon of gasoline.[31] Consequently, President Richard Nixon appointed an "energy czar" to coordinate the nation's energy policy, while Congress passed laws to raise standards for vehicle fuel economy and lower the speed limit to 55 to promote oil conservation.[32]

Only a few years later, President Jimmy Carter declared that the U.S. energy crisis was "the moral equivalent of war," and outlined a plan to reduce U.S. dependence on foreign oil. The plan emphasized conservation and development of alternative sources of energy.[33] Just two years later, a second, major oil crisis precipitated by the fall of the Iranian Shah prompted Carter to establish a major tenet of U.S. foreign policy: the United States would use military force to defend its interests in the Persian Gulf region. The "Carter Doctrine" became a cornerstone of U.S. foreign policy.[34]

By the 1980s, President Ronald Reagan reversed Carter's domestic energy policies and deregulated oil production and distribution. The shift aimed to allow market forces to increase U.S. access to oil, encourage conservation, and develop alternative fuel supplies. As deregulation took effect, and the United States and other countries diversified their oil supplies, OPEC lowered prices as its market share diminished.[35]

Over the last two decades, geopolitical events in the Middle East and elsewhere have continued to dictate oil prices. In 1990, Iraq invaded its oil-rich neighbor, Kuwait, creating an international crisis that led to the 1991 Gulf War where President H. W. Bush led a coalition force to end Iraq's occupation of Kuwait. Still, the 1990s saw healthy economic growth as oil prices declined throughout the decade.

In September 2008, however, oil prices spiked to nearly $140/barrel, a level not seen since the oil shocks of the 1970s.[36] This volatility, which coincided with the onset of a global economic recession, again has pressured governments to create solutions. Yet policymakers, industry groups, and other experts disagree about the causes of this volatility, and about possible solutions to reduce U.S. oil imports.

Major Legislation and Policies

Policymakers in Washington continue to struggle with this delicate balance of foreign policy, economic reality, and intense political pressure. Energy security or energy independence continues to be a major campaign issue in national politics. Despite the political focus on energy, the reality of U.S. energy policy is best described as lacking cohesion and has remained intensively reactive. Most major policies have focused on insulating the economy from the inevitable fluctuations in the oil and gas markets and achieving incremental improvements in energy efficiency. While these measures have been effective in mitigating short-term impacts, these policies are widely criticized for lacking a coherent outlook for long-term security.[37]

The first significant legislation focused specifically on energy security is the Energy Policy and Conservation Act of 1975. Signed into law by President Gerald Ford, this act created the National Strategic Petroleum Reserve, with the express goal of establishing the capacity for the federal government to stockpile oil for release onto the domestic market in times of rapidly increasing prices.[38] This is still essentially the only major domestic policy tool available to the federal government to quickly respond to rapid fluctuations in oil prices.

Subsequent legislation enacted under President Jimmy Carter—the National Energy Act of 1978 and the Energy Security Act of 1980—focused on creating incentives to reduce consumption of gasoline and imported fuels. This included the iconic "gas guzzler" tax which imposed a tiered tax on manufacturers of low-fuel efficiency cars. The Energy Security Act also represented the first major government sponsored push of renewable energy technologies, with a major emphasis placed on synthetic fuel research. This expanded support for alternative energies had a major effect on several of the technologies discussed in this report, including geothermal.[39]

The next major piece of legislation was the Energy Policy Act of 1992. This law continued efforts to reduce dependence on imported energy sources by providing strong incentives for use of domestically produced natural gas.[40] Additionally, the bill included provisions to promote deregulation of electricity markets by lifting some of the restrictions on participating in the wholesale electricity market.[41] This act also established the Production Tax Credit (PTC) for sources of renewable electricity generation, a provision that has been renewed multiple times and continues to be a major driver for renewable energy developers.[42] The renewal and impact of this subsidy on alternative forms of energy is discussed at length in this report.

In keeping with the trend of a major update occurring once every decade, the 109th Congress passed the Energy Policy Act of 2005. The act continued support for renewable energies, but was strongly focused on provisions for increasing domestic production of oil and gas. This included a controversial provision requiring the inclusion of a set quota of ethanol from domestic sources in all gasoline sold in the United States.[43] The 2005 act also included provisions for ocean energies such as tidal and wave, and renewed the Methane Hydrate Research and Development Act of 2005.

Conclusion

Moving the United States toward long-term energy security is a complicated but important goal. While the recent events mentioned here reinforce the issue's urgency, they are not unique since the first energy crisis occurred in the 1970s. Using the criteria described here, this report aims to recommend policies that leverage existing energy technologies while supporting emerging zero-emission solutions to U.S. energy dependence.

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Chapter 3. Existing Technologies

Since the industrial revolution the world has relied on exhaustible energy resources, primarily coal, to drive economic growth. In the 20th century a number of innovative energy sources were added, including oil for transportation, and natural gas and nuclear power for electricity generation. While natural gas and nuclear power are playing an ever increasing role in the U.S. energy mix, they are still dwarfed by coal. None of these three technologies is sustainable, however, and alone do not contribute sufficiently to U.S. energy security.

The following chapters will provide an overview of nuclear power, natural gas, and geothermal as energy sources. The individual chapters will frame each of these in terms of energy security. While coal is an existing, critical component of the United States'—and the world's—energy mix, for the purposes of this report it will be considered in the next chapter as part of carbon capture and sequestration (CCS), a significant bridging technology.

Note: This report acknowledges that transportation fuel is an important economic driver, but it is not the primary focus on this report. Consideration is given to this issue in the Recommendations chapter.

Natural Gas

Introduction

Formed millions of years ago, natural gas is a traditional fossil fuel comprised of various hydrocarbon gases and is typically found in underground reservoirs. Compared to other hydrocarbon fuels (coal and petroleum), however, natural gas generally emits less carbon dioxide and nitrogen oxides, both of which are major "greenhouse gases."[1] Discovered more than three centuries ago in the United States, commercial and residential use of natural gas began nearly 200 years ago, when it was produced from coal and used primarily for illumination. It was not until Robert Bunsen popularized its use with the invention of the Bunsen burner in 1855 that it became a major consumer energy source.[2]

Today, natural gas is used in a variety of ways. It fuels electricity generation, provides residential and commercial heat, powers industrial sectors, and fuels large-scale transportation (trains) and fleet vehicles (buses and trucks). It is also used in the manufacturing of glass, steel, and other products, and is a raw material in chemicals, plastics, paints, and fertilizers. Natural gas is categorized into two major types: conventional and unconventional.

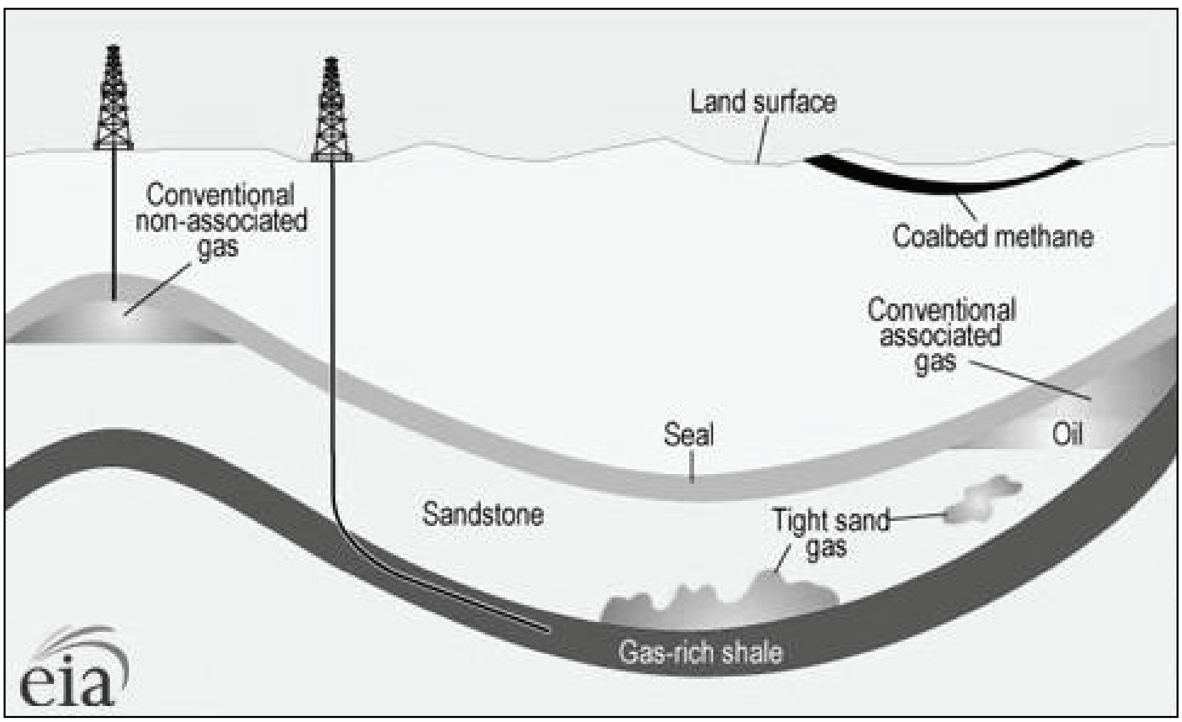
Conventional Gas

Historically, conventional gas refers to natural gas accumulations located in structural and stratigraphic traps and produced by traditional drilling techniques and processes. It is chiefly comprised of methane, with various amounts of other gases, including butane, ethane, and propane. Natural gas comes in two main forms: "dry" gas is usually pure methane, and "wet" gas contains liquids. Gas can also be converted into Liquefied Natural Gas (LNG) by cooling it to -260°F degrees for easier transport and storage or for use as a direct energy source.

Unconventional Gas

Unconventional gas refers to natural gas located in relatively impermeable rock formations, such as shale, or non-traditional reservoirs, such as coal seams. Thanks to revolutionary new technologies and production methods, namely the emergence of hydraulic fracturing, natural gas can now be extracted from these sources. Consequently, the United States has seen a dramatic rise in proven gas reserves. Figure 3.1, produced by the Energy Information Administration (EIA), depicts natural gas sources. Methane hydrate, another form of unconventional natural gas, is addressed in Chapter 4.

Figure 3.1 Geology of Natural Gas



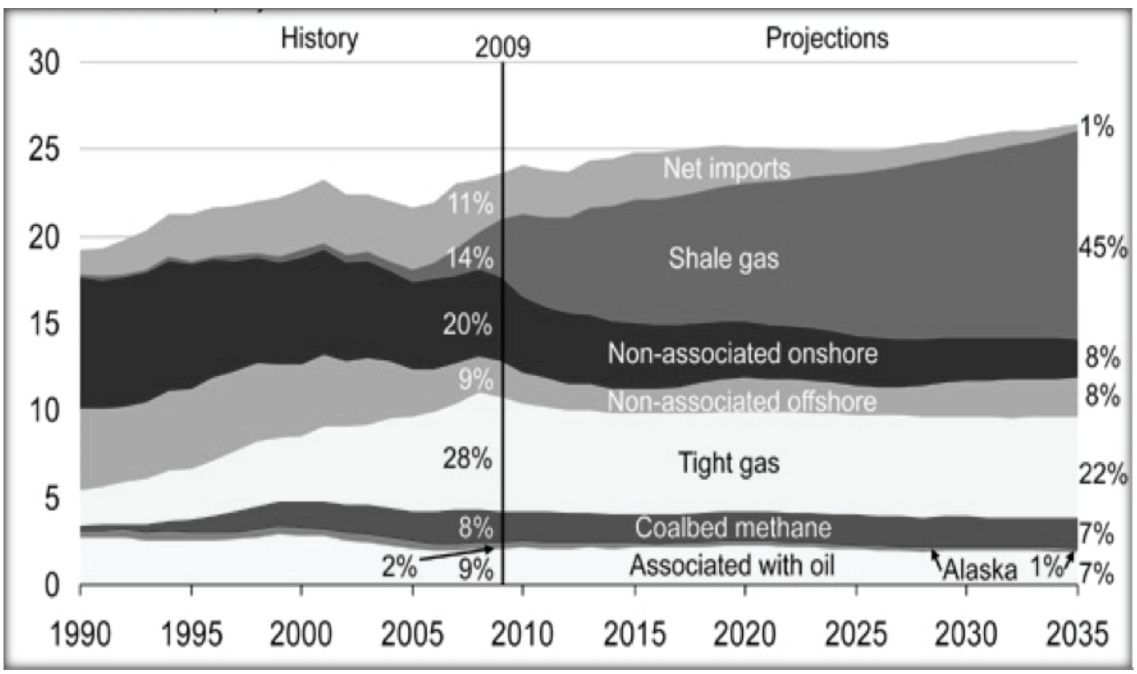
Source: Energy Information Administration, "The geology of natural gas resources," Today In Energy, February 14, 2011; Accessed Feb 22, 2011. (*http://www.eia.doe.gov/todayinenergy/detail.cfm?id=110#*)

Natural Gas Source and Supply

Americans consume about 23 trillion cubic feet (TCF) of gas annually. Roughly 20 TCF is produced domestically and about 3-4 TCF is imported in the form of dry gas or LNG from Canada and other nations.

The Energy Information Agency's Annual Energy Outlook 2011, shown in Figure 3.2, pegs proven natural gas reserves at 2,552 TCF, which constitutes a 25 percent increase thanks chiefly to shale gas production. Based on 2009 consumption rates, that figure would provide the nation with at least 100 years of gas. EIA has also doubled its projection for unproven gas reserves from 327 TCF to 827 TCF since 2009. Consequently, shale gas has driven proven gas reserves to their highest level in nearly four decades.[3] Production of shale gas is expected to increase to 45 percent of the total U.S. natural gas supply by 2035.[4] Production of other forms of gas, such as coalbed methane, tight gas, or oilbed gas, is on the decline, largely due to the rise in shale gas production, according to EIA.

Figure 3.2 U.S. Dry Gas (in trillion cubic feet per year)



Source: Energy Information Agency, Natural Gas, U.S. Dry Gas Reserves, Annual Energy Outlook 2011

For much of the last decade, the United States has imported LNG to fill the gap between the gas consumed and produced domestically. It serves as a flexible fuels source for a variety of industries. Most commonly, electricity generators rely on LNG to meet peak demand. In 2001, the United States imported 238.1 billion cubic feet (BCF) and it exported 66.1 BCF.[5] With major increases in shale gas reserves, the United States might soon become an exporter of LNG.

Technological Feasibility

Natural gas could play a much larger role in the U.S. energy mix, potentially evolving into the majority energy source for the next 100 years or more. One reason for this dramatic shift is the vast improvement over the last decade in exploration and drilling technologies used to extract shale gas.

This innovation is the result of decades of research and experimentation by various oil and gas companies, namely in directional drilling and hydraulic fracturing.[6] In the 1990s, Houston energy mogul George P. Mitchell and his company (Mitchell Energy & Development Corp.) successfully drilled the Barnett shale in Texas. This development helped trigger a wave of similar efforts by other companies to extract gas in other shale plays across the country.

In addition to the production technologies, the infrastructure for increased gas distribution is largely in place, thus making it highly feasible to rely on gas as a fuel source for a variety of energy needs. The United States has more than 210 natural gas pipeline systems, 305,000 miles of interstate and intrastate transmission pipelines, 1,400 compressor stations, more than 11,000 delivery points, 5,000 receipt points, 1,400 interconnection points, and 49 locations for import and export.[7]

Natural gas storage also is a major infrastructure component. Currently, there are more than 400 storage units across the nation, in underground structures such as salt mines or aquifers.[8] Gas also can be stored above ground, though mostly in the form of LNG. The primary purpose for gas storage is to provide stability in the gas supply and meet peak demand. Since gas is a predominant heating source in homes and in industrial and commercial buildings, the consumer infrastructure for gas distribution also could be adapted to include home fueling systems for compressed natural gas vehicles.

There are, however, areas of the pipeline system that must be expanded and upgraded to accommodate steep growth in gas demand, which would require a huge financial investment. The Interstate Natural Gas Association of America (INGAA) estimated in a 2009 report that the nation must invest anywhere from $130 billion to $210 billion in the current pipelines to accommodate bullish forecasts for natural gas consumption.[9] Similar investments also would be needed in storage, although the shale gas revolution has begun creating a push for better gas storage to take advantage of the fuel's abundance.

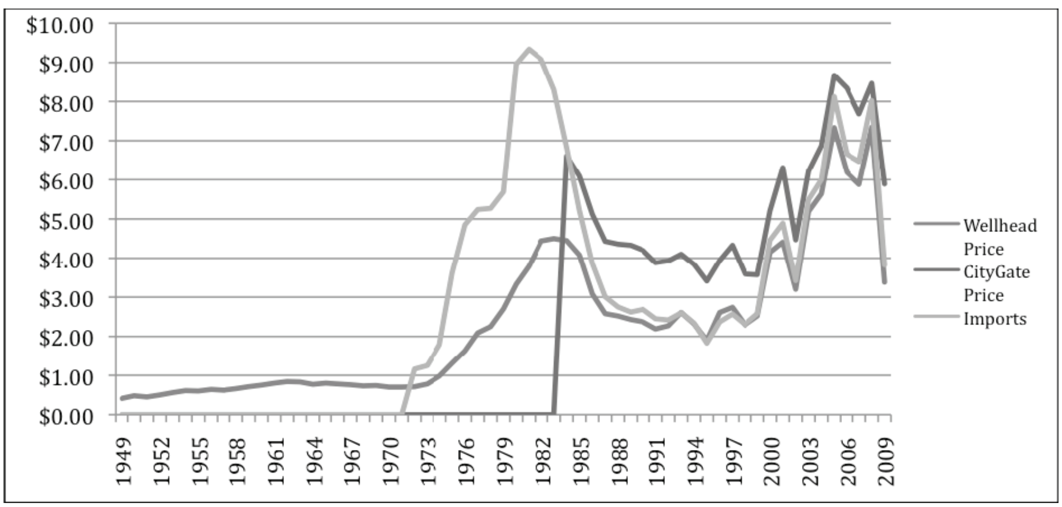
Hurdles to Natural Gas

Despite the robust natural gas technology and infrastructure, price fluctuation historically has impeded large-scale growth. Natural gas prices are affected by changes in the supply and demand over short periods of time. Supply is affected by shifts in production, net imports, and storage levels. Producers can decrease production of natural gas, and weather-related natural disasters such as hurricanes can disrupt major producing areas (the Gulf Coast, Texas, and Louisiana). At the same time, the supply of imports from Canadian and some Mexican pipelines, and the levels of LNG imports, can all affect the cost to consumers.

Demand, on the other hand, can be driven by economic growth, weather cycles, and oil prices. If the economy grows and the industrial level demands more natural gas, then prices will rise. Similarly, if there is a cold winter or a hot summer consumers will demand more electricity and prices will increase. Lastly, industrial consumers of natural gas have the ability to switch between gas and oil and will therefore choose a product according to price. When oil prices are lower, industry might choose oil over natural gas and vice versa.[10]

The utility industry has generally relied on coal for power generation because it is plentiful, cheaper, and more predictable in price than natural gas. Gas has suffered from price volatility over the last few decades. In 2008, the wellhead price of gas peaked at \$10 per thousand cubic feet.[11] Figure 3.3 shows the historic price changes for natural gas annually since 1949.[12]

Figure 3.3 Average Annual Natural Gas Prices 1949-2009



Dollars per Thousand Cubic Feet. Source: Data based on *Natural Gas Wellhead, City Gate, and Imports Prices, 1949-2009* in EIA Annual Energy

Concern over high prices typically have swayed, and could sway in the future, some potential gas consumers away from the fuel and towards something more predictable. Indeed, the rising likelihood that some U.S. producers will seek to export gas—in the form of LNG—may also lead to a price spike. Already some industrial customers fear increased domestic energy costs resulting from policy changes that may grant gas producers long-term export licenses.

Despite wariness of price jumps, several industry experts argue that the availability of shale gas will create longevity and therefore price consistency.[13] Research firm Cambridge Energy Research Associates, for example, stated in a 2010 report that the abundance of shale gas will ultimately lead to price stability over the next several decades.[14] The study suggested that increased "shock absorbers" in the market—largely due to the increase in gas supply—would cushion the dramatic cycles that plagued natural gas for the last two decades.

Another hurdle faced by the natural gas industry is the ability to penetrate the transportation sector. The cost of infrastructure to support gas exports and natural gas vehicles is a major challenge. Fueling stations for gas vehicles are sparse. EIA reports that there are less than 1,000 natural gas stations nationwide.[15] Moreover, the market for consumers to obtain compressed natural gas (CNG) vehicles is limited. Currently, only Honda produces a passenger vehicle (Honda Civic CX) that can run on natural gas, and it typically costs roughly 60 percent more than its gasoline counterpart and requires a home fueling system.[16] There are numerous models that can be retrofitted, but the average cost is about $10,000.[17] There is limited success in large fleet vehicles (trucking and busses), as government-owned fleets and private sector shipping organizations have transitioned to natural gas vehicles. Widespread penetration of this market has not occurred and faces similar challenges to the domestic passenger vehicle market.

Economic Viability

Natural gas currently supplies about 23 percent of U.S. energy consumption. Much of that demand is in the electrical, industrial, and residential sectors. Despite feasibility concerns, the economics of natural gas—which include its abundance and reliability—are highly attractive to a variety of industrial sectors, and thus make it a viable option to serve the United States as a large-scale, reliable energy source for decades.

Price is a major factor in attracting new demand for the fuel. Over the course of the last century, gas prices have fluctuated dramatically for a myriad of reasons. Yale Professor Paul MacAvoy attributes much of this price volatility to the decades-long regulation of gas prices, and later their deregulation.[18]

Today, however, natural gas is at its lowest price in decades.[19] Growth in the shale gas industry accounts for the dramatic supply increase and subsequent assumption by market sources that the fuel will be plentiful for years to come. "It's a game changer," said Skip Horvath, president of the Natural Gas Supply Association in Washington, D.C.

The EIA has revised earlier forecasts and now suggests that new shale "plays" are forming quickly, thus increasing potential gas reserves. For example, in the Marcellus shale, only small portions of production have been tested.

For natural gas to continue to be plentiful, producers must continue to invest in the recovery of shale gas. The EIA estimates that exploration of shale gas is economical at $7 per mm/BTU. Other industry analysts say it is closer to $5 to $6 per mm/BTU.[20] The current gas price hovers around $4 per mm/BTU on average.[21]

This situation, of course, would portend a decline in the exploration of shale gas were it not for a few major trends that will likely make gas more economical in years to come. These trends largely are related to an expected increase in demand for gas thanks to desire for cleaner fuel and the low cost of natural gas. That increase in demand will likely come from electricity generation, vehicle use, and exports.

Power Generation

Natural gas could gain a much larger share of the electricity generation market, displacing competitors such as coal and nuclear, for several reasons, including its low cost, flexibility as a fuel source, forthcoming environmental regulations, and capital costs for construction of power plants.

The price of gas has reached such low levels that it is quickly becoming as inexpensive as coal. EIA reported that coal is $2.29 per mm/BTU for the third quarter of 2010, while natural gas averaged about $3.65 per mm/BTU for that same period. [22] Although they are not on equal footing, the price comparison is much closer than even a few years ago. What's more, coal exports are on the rise. Rising demand from countries like China and India is making U.S. coal an attractive export. EIA reported recently that coal exports were up 39 percent in the third quarter of 2010 over the same quarter in 2009.[23] Although these exports are small, it does indicate growing demand for the resource. With low natural gas prices for the foreseeable future and rising coal prices, economics may ease the transition to natural gas fired electricity plants.

Moreover, environmental rules are potential drivers for natural gas consumption as federal regulations that seek to curb greenhouse gases render competitors, such as coal, increasingly expensive. While natural gas emits various gases, it typically burns cleaner than coal or petroleum. According to the EPA, compared to coal electricity generation plants, natural gas plants produce half as much carbon dioxide, less than one third the nitrogen oxide, and less than one percent of sulfur oxides. Broken down per megawatt hour (MWh), a natural gas plant produces: 1,135 lbs of CO_2 per MWh, 0.1 lbs of sulfur dioxide per MWh, and 1.7 lbs of nitrogen oxides per MWh.[24]

The federal and state rules seeking to limit greenhouse gas emissions are causing utility companies to rethink their use of coal plants. Federal "cap and trade" legislation passed the U.S. House of Representatives in 2009, but stalled soon after. Thanks to a 2010 ruling by the U.S. Supreme Court, however, the EPA can now regulate carbon emissions as part of the Clean Air Act. The agency has declared carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons, per-fluorocarbons, and sulfur hexafluoride as pollutants, and it is implementing rules to restrict their emissions.[25]

States also are reviewing options for mitigating the impact of carbon dioxide.[26] California passed Assembly Bill 32, or the Global Warming Solutions Act, to reduce greenhouse gas emissions by 2020. New York, New Jersey, Delaware, Maryland, and New England are participating in a Regional Greenhouse Gas Initiative which targets electric utility companies.[27]

Numerous utilities say they are looking to use natural gas turbines or natural gas combined cycle to generate electricity in response to the limits on carbon and other byproducts of coal-fire electricity plants. "It's pretty clear that, whether it's caused by future carbon legislation or action by the EPA, the migration away from coal has begun," Constellation Energy Group Chief Executive Mayo Shattuck, told the *Wall Street Journal*.[28]

John W. Rowe, CEO and Chairman of Exelon Corporation, told the Pew Center on Global Climate Change that environmental regulations, which will come into effect by 2020, are driving decisions surrounding power generation today. Rowe referred to the so-called "train wreck" chart, which demonstrates that when EPA regulations take effect utility companies will have to retire 12 to 19 percent of coal plants, potentially raising electricity prices 20 percent to consumers.[29]

Figure 3.4 highlights the growth in natural gas powered electricity over the next few decades. Natural gas will gain a share of power generation from coal. Yet other factors, in addition to the environmental regulations, are persuading electricity generation firms to choose natural gas.

"[Shale Gas] is having big impact. A lot of the utility planners, who plan three to ten years out for capital investments…are looking at investing in gas powered turbines or natural gas combined cycle" for electricity generation, said Revis James, director of Technology Assessment for the Electric Power Research Institute, adding that, "[One] reason for that is the shale gas has driven the gas price so low."[30]

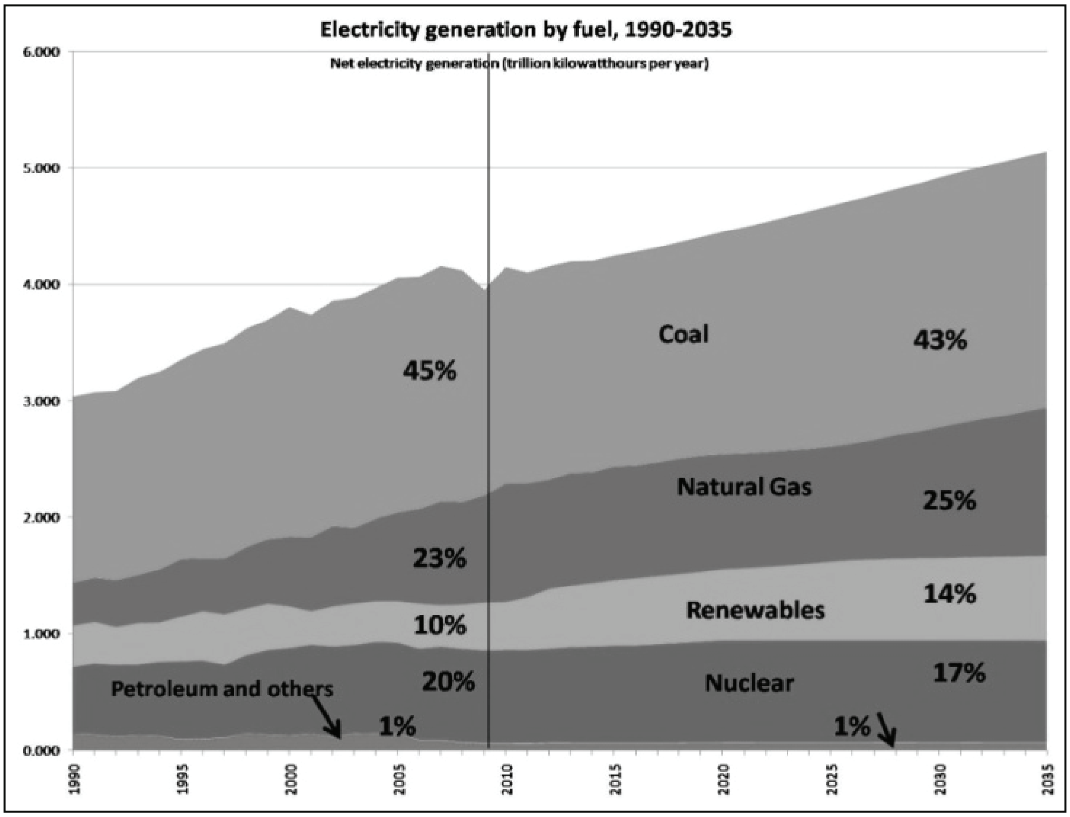
Even if gas prices rise significantly, Revis contends, the electricity industry is still moving towards gas-powered generation due in part to the costs of plant construction and financing. Capital financing for gas powered plants is more attractive than financing traditional coal plants and much more economical than new nuclear plants in terms of base load electricity generation.[31]

Finally, natural gas will likely play a bigger role in electricity generation as a "supplemental" energy source. As more renewable energies occupy a larger share of electricity output, they will require additional power generation that can be ramped up or down, depending upon peak demand. Natural gas can plug the gap when renewable fuel generation sources are too inconsistent to support base load electrical demand.

Transportation

The expanding application of natural gas as a transportation fuel affords another opportunity to reduce emissions generated by petroleum and potentially to limit the impact of supply disruptions and oil price volatility. Consequently, there is growing interest in CNG vehicles, which burn cleaner and emit about a third less greenhouse gases than traditional gasoline. To date, less than 1 percent of U.S. natural gas consumption is dedicated for vehicular use.[32]

Figure 3.4 Electricity Generation by Fuel (1990-2035)



Sources: Annual Energy Outlook 2011; EIA, Annual Energy Review 2009. Projections: National Energy Modeling System, run REF2011.D120810C.

Nonetheless, the rising cost of oil and the relative cheap cost of natural are spurring larger fleets of trucks and light duty vehicles operators to seek the CNG alternative. The gas industry is also working to promote this effort. Chesapeake Energy, the nation's largest independent natural gas producer, recently announced construction of six CNG fueling stations around its home state of Oklahoma.[33]

Many observers argue that the drop in natural gas prices, coupled with higher petroleum costs, create an appealing incentive to switch to CNG as a transportation fuel. In October 2010, the Department of Energy's Alternative Fuel Price Report revealed that CNG is the lowest priced alternative fuel, when comparing gasoline gallon equivalents.[34] Yet, as previously discussed, there are significant cost and infrastructure barriers to widespread implementation of natural gas vehicles.

Exports

With the increase in gas reserves, many suppliers are now contemplating increased exports of U.S. gas products, either through international pipelines or through conversion of gas to LNG.[35] To achieve this change, the private sector would have to invest in the infrastructure to deliver and liquefy gas so that it can be exported. Today, there is only one 30-year-old terminal in Alaska prepared to liquefy and transport natural gas. However, more private investment is fueling a growth in LNG terminals. Cheniere Energy, for example, is investing $3 billion in docks, storage tanks, and two-to-four refrigeration units to export LNG. The company predicts that once the project is finished they will be able to export 2 BCF of LNG a day, or 3 percent of domestic gas production. The only challenges that remain are regulations and funding for the project.[36]

Current Regulatory Framework

The natural gas industry is largely made up of private companies and municipal organizations in several categories: suppliers, processors, pipeline operators, storage operators, and end-use distributors. Gas suppliers often undertake exploration and drilling for natural gas. Processors refine the gas, typically at or near the well, and pipeline transporters move gas to end destinations. Distributors or regional sellers purchase gas and then utilize their own networks to transport it to consumers. Industrial firms may purchase directly from suppliers. U.S. natural gas companies operate in multiple categories and some have monopolies in some regions for distribution.

Major Legislation

The federal government and state governments share oversight for natural gas exploration, transmission, and delivery, thanks to several major laws passed over the last 80 years. Regulation of natural gas began in the 1930s out of monopoly concerns. The first major law, the Natural Gas Act of 1938, sought to regulate prices for transmission of gas via interstate pipelines. It also created the Federal Power Commission, now the Federal Energy Regulatory Commission (FERC) to oversee pricing. Thanks to a 1954 U.S. Supreme Court ruling in *Phillips Petroleum v. Wisconsin,* FERC also began setting wellhead prices for natural gas.[37] The results of that decision precipitated increased consumption of gas, and aided in the gas shortages of the 1970s, which in turn spurred a second major natural gas law—The Natural Gas Policy Act of 1978. That measure authorized FERC to oversee both interstate and intrastate drilling and gas transmission. Ultimately the rules were rescinded under The Natural Gas Wellhead Decontrol Act of 1989, which removed the price ceilings for gas wellhead production and sought to bring prices for the commodity to the true market value.[38]

At the same time, Congress sought to incentivize alternative sources of energy and began offering tax credits for the recovery of unconventional gas. The Tax Credits for Unconventional Gas Recovery Act of 1980 provided an initial credit of around $3 for each 5.8 mm/BTU of energy produced. Meanwhile, the Power Plant and Industrial Fuel Use Act of 1978—legislation that sought to diminish the use of natural gas for electricity generation—had succeeded in driving down gas consumption. Thus, the combination of tax incentives to find additional gas supply, while overall consumption of gas declined, created a 25 percent increase in unconventional gas production.[39]

Gas Exploration and Production

Today, federal and state agencies regulate exploration, drilling, and distribution of natural gas. Much of the regulation of exploration and extraction of natural gas is managed at the state level by various agencies. In Texas, for example, the state's Railroad Commission regulates gas drilling. In other states, public utility commissions may undertake the responsibility, which often includes permitting, well-head construction, safety, and environmental risks and impacts. Each state deals with industry regulation and oversight differently, and much of it is related to how long they have dealt with the natural gas industry. In states where natural gas deposits were recently discovered, such as Pennsylvania, state leaders debate whether to increase regulation and oversight of drilling and production.

The federal government regulates transmission and distribution of natural gas. FERC and the U.S. Department of Transportation (DOT) oversee the nation's vast network of gas pipelines. FERC regulates the transmission of natural gas through interstate pipelines, sets prices for transmission, approves sites and changes to interstate pipeline locations, oversees construction, assesses environmental impacts for pipelines, and coordinates these activities with other federal and state agencies. A landmark order from FERC (Order No. 636) altered the treatment of pipelines and unbundled services, thus making the network "open access" and giving a producers' distributors and retailers access to the system. This deregulation has been lauded as a key reason that gas prices decreased in the 1980s.[40]

At the DOT, the Pipeline and Hazardous Materials Safety Administration oversees gas pipeline and storage safety. The agency contracts with its counterparts in the states to carry out pipeline and storage inspections. It also promulgates standards for how pipeline operators ensure integrity in the system and manage incidents where gas leaks are detected.

Environmental Impacts

While the growth of gas consumption may well provide a stable market for natural gas, environmental issues are the biggest impediment to the growth of the fuel source for energy production.

Embolden by large majorities, Democratic lawmakers in Congress sought to pass the nation's first legislation to limit carbon emissions through a system known as "cap and trade," but the Senate failed to pass the measure. Instead, the EPA is now implementing constraints on carbon and other greenhouse gas emissions in an effort to reduce the negative effects of climate change.

Electrical power companies are making decisions with the notion that carbon emissions will be regulated, thus there is the strong move towards natural gas for electricity generation. Natural gas, however, still emits methane and other gases that are also tagged as pollutants by the EPA. Such a shift towards gas may only work in the very short term without a stated reprieve from potential restrictions that could take effect in 2020.

Industry groups are pushing to obtain a waiver to allow for natural gas powered electrical plants by having the fuel source dubbed "clean" under EPA regulations.

Drinking Water Concerns

The same is true when it comes to gas drilling. Potential regulations and oversight could increase gas costs, which could render the shale gas phenomenon less ground-breaking.

The sharp increase in natural gas supply is due largely to the ability to drill and recover shale gas using hydraulic fracturing. The process requires the injection of large amounts of water, along with chemical mixtures, into the rock in order to break it and allow the gas to seep out. Now, governments and environmental organizations increasingly are concerned over the techniques and chemicals used in hydraulic fracturing (or "hydro fracking") and the potential risks to ground water.

The EPA announced in March 2010 that it would conduct a comprehensive analysis of the fracturing process to address potential water quality, environmental, and public health issues. The agency released its draft study plan in February 2011, indicating that it will examine the entire life-cycle of hydraulic fracturing. The potential fallout from the EPA study could lead to regulations that increase production costs for the industry. That in turn raises the price of gas for consumers and businesses, creating less potential for natural gas to meet U.S. energy needs.

In addition to concerns over drinking water, environmental advocates worry about water consumption. Hydraulic fracturing requires substantial water resources to extract gas from rock formations. EIA estimates that a typical shale gas well requires two million to four million gallons of water per well, depending on various factors including the size of the shale basin and the density of the rock formation. The availability of water in the hot climates of gas rich states such as Texas and Oklahoma raises concerns over competition for the resource. In Texas, restrictions on water consumption in the heat of summer are common, particularly when rainfall is sparse. Increased water demand for gas drilling could create headaches for residential, commercial, and agricultural consumers by driving up water prices.[41]

Pipeline Safety

In 2010, a pipeline explosion in San Bruno, California, triggered public concern and debate over the safety of the underground national pipeline system. As a result of the accident, one person died and five were injured. Sen. Dianne Feinstein, D-Calif., and Sen. Barbara Boxer, D-Calif., have sponsored the Strengthening Pipeline Safety and Enforcement Act, which proposes doubling federal pipeline inspectors over four years, and would raise civil penalties up to $2.5 million for severe violations of regulation.[42] Pipeline inspection falls under the jurisdiction of the National Transportation Safety Board, but the California Public Utilities Commission also has oversight and regulatory capabilities. While some infrastructure may need to be updated, the overall national pipeline system is not unsafe.

Public Perception of Gas Drilling

A confluence of environmental concerns seemingly galvanized communities located on or near large shale gas areas in opposition to the exploration and production of shale gas.

One of the most damaging indictments of the practice has come from Hollywood. A documentary, *Gasland*, released in 2010 sought to depict the risks to ground water contamination. *Gasland* detailed several incidents of water contamination in shale-rich states such as Pennsylvania. The film was nominated for the 2011 Academy Award for Best Documentary Feature. It also is helping several Democratic lawmakers rally support for the reintroduction of legislation designed to regulate fracking and other aspects of shale gas drilling.[43]

Industry officials are quick to dispel myths of various accounts of drilling contamination, and extol the improved safety of fracking and other drilling techniques. The early public scares around potential contamination, however, and the ongoing opposition from individuals who do not want gas drilling in their vicinity (the so-called Not in My Backyard, or NIMBY, groups) has created a public relations battle for the technology. Skip Horvath of the Natural Gas Supply Association argues that concern over public health is the number one "barrier" that the industry faces. Groups that oppose any fossil fuel energy and those who are "NIMBYs" organize and protest locally across the country, making it difficult for producers to explore, lease, and produce gas.[44]

Political Implications and Public Perception

While many view gas as the "bridge" energy that will allow the United States to migrate towards cleaner sources of energy, there are many political issues that can affect the future of the industry.[45]

First, carbon pricing and carbon legislation could favor the natural gas industry and speed up the move away from coal-generated electricity. The current Congress, however, will focus on budgetary and fiscal issues, so the chances of seeing a cap-and-trade or carbon pricing system are very small. After the 2008 financial crisis, the public would be skeptical of any system allowing traders to speculate on carbon futures. Similarly, money for new energy technology R&D or new infrastructure development coming directly from the federal government will be met with skepticism.[46]

Second, any new regulations could affect the price of natural gas. The two areas where this could occur are related to hydraulic fracturing and the management of chemicals used during that process. Today, the public fears contamination of water supplies both from natural gas seepage and from chemical waste generated during the fracking process. State and federal regulators may seek to create new regulations to address public concern, but those rules also may increase natural gas exploration costs. Such a move could drive companies toward more lucrative energy supplies such as oil,[47] just as the price controls of the last century drove down exploration and ultimately production of new gas sources.

Although natural gas is considered a fossil fuel, industry groups are pushing to have it defined as an acceptable source of "clean electricity" and to ensure that gas emissions—which are less than traditional fossil sources—are not caught in increased regulation under the Clean Air Act, which might have oversight of carbon dioxide emissions. This effort may succeed in the short-term; there is concern, however, that once natural gas becomes dominant, it too will be the target for environmental regulations to diminish its use. "Natural gas interests are likely to find that in the fullness of time they will become the next target of environmentalist opposition once coal is interred next to nuclear power," said Steven Hayward, a fellow in environmental studies at the American Enterprise Institute, a conservative think tank.[48]

Regulation aside, investment in infrastructure will be required for any large scale switch to gas as a fuel for electricity and/or transportation. If the natural gas industry makes the investment, then they will require a guarantee that prices will stabilize and they will recover this outlay. Moreover, even if the pipelines and other infrastructure necessary to increase electricity power generation and transportation from natural gas are constructed, the timeline could be lengthy. A typical gas pipeline can take up to 18 months to be approved and permitted for construction.[49]

Finally, the growth in gas could be permanently dampened by environmental regulations and the ongoing perception that the drilling processes are dangerous and cause serious environmental problems. Already, municipalities, states, and even the federal government are investigating whether to ban the practice until its complete effects can be vetted. In New York, former Gov. David Paterson released an executive order temporarily banning drilling of gas to allow for further study by the state's environmental agencies. A similar move came from some lawmakers in Pennsylvania. Numerous water contamination case studies have been documented by environmental groups that suggest the cause of the contamination is due in large part to the drilling of gas and the hydraulic fracturing process. Yet, investigations by regulators have found many of those fears overblown. The EPA, for example, conducted a study of coalbed methane in 2004, and found no major risks to drinking water as a result of the fracturing techniques.[50]

Political Party Power Shift

The 2010 election resulted in a major power shift, giving Republicans control of the U.S. House of Representatives. That outcome likely will bode well for the natural gas industry. Already, many Republican lawmakers have been quick to embrace natural gas and are stepping up efforts to increase its deployment through tax incentives and hearings on upcoming EPA regulation of hydraulic fracturing. The shift also breaks apart the uniform control that Democratic lawmakers had over federal policies, which tended to favor renewable industries, such as wind power, and have threatened to increase taxes on traditional fossil fuel providers.[51]

Moreover, recent civil unrest in the Middle East has affected oil production. Hence, the price of gasoline in the United States could reach levels not seen since 2008, which precipitated changes in behavior and in part caused a large decline in gasoline consumption. The political turmoil, coupled with rising oil prices, could create a ground swell of support for more aggressive policy efforts to speed a transition to natural gas-powered vehicles.[52]

The gas industry has seen some successes recently in lobbying for more policies that would accelerate the shift from coal to natural gas for electricity, and for other incentives that would increase demand for the fuel. For example, the extension of tax breaks passed by Congress and approved by the White House in 2010 included continued incentives for deployment of natural gas fueling stations.[53]

Still, with a strong shift towards gas, there exists the risk that the fuel source may become less "clean" over time and soon be under the same regulatory scrutiny as coal, as Steven Hayward argued.[54]

Conclusion

Natural gas will grow into a more critical part of the national energy portfolio, contributing to: electricity generation, residential and commercial heating, transportation, and powering the industrial sector. At record low prices, natural gas is the abundant domestic energy resource which could be used as the "bridge energy" to move the United States away from other carbon-heavy emitting resources, like oil and coal. This will not occur, however, unless regulatory and pricing issues are addressed. If prices continue their volatile fluctuation, the electricity generation industry will not invest in new gas-fired power plants because recovering their investment will be challenging. Similarly, the companies that distribute natural gas will not invest in infrastructure improvements. Yet, evidence suggests that while gas prices will rise in the near term, the dramatic volatility that has plagued the fuel over the last decades will dissipate and stabilize thanks to its abundance, flexibility, and reliability.

On the regulatory side, the EPA's upcoming polices on carbon emissions will affect the future of natural gas. In the short term, it may drive demand, but if long-term regulations seek elimination of all fossil fuels, then the benefits of gas will be stifled. Finally, for natural gas to solidify its position in the national energy portfolio, the natural gas industry must address public concerns regarding the makeup and environmental impacts of fracking fluids and how drilling techniques affect the quality of local water resources.

The growth in natural gas plays a positive role in helping the United States achieve energy security. The abundance of shale gas provides a strong foundation to transition the nation from less stable sources of fuel, namely petroleum. Stable prices and continued investments in infrastructure could increase consumer use of compressed natural gas or LNG for transportation. Moreover, continued increases in global oil prices may accelerate this trend.

Gas will become instrumental in the path to energy security by helping to keep the cost of energy economical. Its vast abundance could keep prices low for the foreseeable future, thus making it easier for the nation to achieve the same energy inputs with fewer carbon emissions. Gas also will help achieve clean, sustainable domestic energy by meeting peak demand for electricity in concert with renewable generation sources such as solar or wind power. It can also serve as a main source of U.S. energy, while the nation develops more cost effective renewable energies. Natural gas will remain a major aspect of U.S. energy policy for years to come and may finally help the nation re-align its energy diet.

Nuclear Energy

Introduction

Developed under the auspices of the weapons program known as the "The Manhattan Project," nuclear energy has not shed the stigma of mass destruction. The atomic bomb, Cold War politics, and accidents at Chernobyl and Three Mile Island shaped public perception of nuclear energy during its commercial infancy, from 1957 when Westinghouse finished work on the first fully commercial reactor into the 1990s.[55] Since that time, politicians and their constituents have been quick to attack efforts by utilities and other investors to develop nuclear projects. President Jimmy Carter went so far as to ban the use of nuclear fuel reprocessing technology, fearing it would lead to nuclear proliferation and believing other nuclear states would follow his lead.[56] Both assumptions turned out to be false.

Now, in an increasingly carbon and resource constrained environment, nuclear energy could be set to make a comeback. High upfront capital costs and the possibility of cost overruns, the main deterrents for investors, are being mitigated by the government's Loan Guarantee Program. The abundance of uranium has made nuclear fuel the cheapest source of electricity on a dollar per kilowatt hour basis. Furthermore, nuclear power aligns perfectly with environmental strategies that seek to limit carbon emissions as it does not emit any greenhouse gases. In sum, nuclear power addresses both environmental and economic concerns and could thus be a critical player in America's long-term energy security strategy.

Technological Feasibility

Technological improvements in nuclear energy production are aimed at reducing waste and costs, while improving safety. Scholars at the Massachusetts Institute of Technology (MIT) suggest that for the next decades, government and industry in the United States and elsewhere should give priority to the deployment of the once-through fuel cycle, rather than the development of more expensive closed fuel cycle technology involving reprocessing and new advanced thermal or fast reactor technologies.[57]

Unlike other clean energy technologies, nuclear power has been around for more than half a century and many of its initial operational and maintenance kinks have been smoothed out. The safest, most efficient, and cost-effective designs have been certified by the U.S. Nuclear Regulatory Commission (NRC). Nuclear power companies can choose from among these pre-screened designs, further mitigating financial and performance risks.

Currently, most nuclear experts favor the standardized once-through cycle reactor designs due to cost and proliferation concerns, but there are several other types of reactors being developed. The high temperature gas cooled reactor is one of the designs receiving considerable attention. This type of reactor has a helium-cooled, graphite moderated core, which allows for greater safety and a reduction in electricity production costs.[58] However, the helium coolant used in the reactor is expensive.

Other reactors in development include the small sealed transportable autonomous reactor (SSTAR) and the International Thermonuclear Experimental Reactor (ITER) fusion project. SSTART is a relatively small, fast breeder reactor used in the conversion of spent fuel to plutonium. It has safeguards in place that prevent the extraction of plutonium as well as a remote deactivation switch. A prototype is expected to be completed by 2015.[59] ITER is an internationally owned and financed research and development project aimed at the creation a commercially viable nuclear fusion reactor.[60]

Currently, the existing technological infrastructure makes nuclear power extremely competitive in a carbon constrained marketplace. Improvements in existing fission reactor technology, such as those cited above, would increase nuclear power's competitiveness even further, while the development of a commercially viable fusion reactor could be game-changer.

Economic Viability

At present, existing nuclear power plants are not economically competitive with their main rivals in the electricity generation market—coal and natural gas. According to an economic model designed by researchers at MIT, based on current economic conditions and behavior by commercial investors, Table 3.1 shows the average price per kilowatt hour of electricity produced at nuclear power plant is 6.7 cents, whereas coal and moderately priced natural gas cost 4.2 and 4.1 cents per kilowatt hour respectively. The price indicated in the model would provide an "acceptable" return to investors, as well as cover all operating expenses and taxes.[61]

The MIT report assumes the coming deregulation of the electricity generation market. Currently, nuclear plants are operated by a vertically integrated monopoly, being the sole supplier of electricity in a given area and thus being able to pass on all costs to consumers. A deregulated market would allow consumers to choose their suppliers and therefore undermine plant owners' monopoly power. Indeed, only with significant reductions in construction costs, construction time, operating and maintenance costs, and up-front capital costs would nuclear power become economically competitive in a free market with coal and natural gas. Of course, the passage of a carbon tax would alter this equation, with nuclear becoming more cost effective the higher the cost of carbon dioxide production.

Table 3.1 Comparative Power Costs

Comparative Power Costs

CASE (Year 2002 $)	REAL LEVELIZED COST Cents/kWe-hr
Nuclear (LWR)	6.7
+ Reduce construction cost 25%	5.5
+ Reduce construction time 5 to 4 years	5.3
+ Further reduce O&M to 13 mills/kWe-hr	5.1
+ Reduce cost of capital to gas/coal	4.2
Pulverized Coal	4.2
CCGT[a] (low gas prices, $3.77/MCF)	3.8
CCGT (moderate gas prices, $4.42/MCF)	4.1
CCGT (high gas prices, $6.72/MCF)	5.6

a. Gas costs reflect real, levelized acquisition cost per thousand cubic feet (MCF) over the economic life of the project.

Courtesy of "The Future of Nuclear Power Report" at http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf.

Loan Guarantee Program

The Loan Guarantee Program originated in Section 1703 of the Energy Policy Act of 2005.[62] The program's administrators were charged with using congressionally appropriated funds to guarantee private investments in clean energy projects that would otherwise have difficulty obtaining financing due to high perceived risk.

Since their inception, nuclear projects have been one of the primary recipients of loan guarantees. Automotive and transportation technology companies have received the most loan guarantees, mostly in the tens to hundreds of millions of dollars, but those issued for the construction of nuclear power plants have been the largest, usually in the billions. In February 2010, conditional commitments for loan guarantees were issued to Georgia Power Company, Oglethorpe Power Corporation, and the Municipal Electric Authority of Georgia.[63] Furthermore, the Obama administration's proposed budget for 2011 asks Congress for an additional $36 billion in loan guarantees specifically for nuclear projects.[64]

Current Regulatory Framework

The NRC provides the sole regulatory framework for domestic nuclear energy. The NRC was created in 1974 to oversee the use of radioactive materials in generating electricity, while safeguarding the public and the environment. The NRC's stated mission is "to regulate the nation's civilian use of byproduct, source, and special nuclear materials to ensure adequate protection of public health and safety, to promote the common defense and security, and to protect the environment."[65]

The NRC regulates three major areas of energy production: reactors, materials, and wastes.[66] NRC staff inspects commercial reactors and conducts research to improve safety. They also regulate the use of radioactive materials in the medical, industrial, and academic sectors as well as oversee the transportation, storage, and disposal of nuclear materials and waste.

There are five NRC commissioners who are appointed by the president and confirmed by the Senate. NRC commissioners are in charge of policymaking activities that govern and regulate commercial nuclear activities. Regulatory policies of the NRC are closely related to specific laws, including the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, the Nuclear Waste Policy Act of 1982, and the Nuclear Non-Proliferation Act of 1978.[67] The NRC also controls the permitting process for nuclear power plants.

The Atomic Energy Act of 1954

The Atomic Energy Act is the fundamental law governing both civilian and military uses of nuclear materials. It states that "the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise."[68] The act mandates that all nuclear facilities and materials be licensed. It also gives the NRC the authority to regulate other areas of the nuclear power sector.

The Energy Reorganization Act of 1974

The Energy Reorganization Act established the Nuclear Regulatory Commission.[69] Before the act, the Atomic Energy Commission (AEC) was responsible for the production of nuclear weapons and the safety regulations of commercial nuclear power. This act split AEC into two agencies, delegating the oversight of military nuclear production to the Department of Energy (DOE) and civilian nuclear production to the NRC.

The Nuclear Waste Policy Act of 1982

The Nuclear Waste Policy Act requires that the federal government provide for the disposal of nuclear waste. According to the act, nuclear operators are required to contribute to a fund, which the government uses to construct and maintain a geological repository for nuclear storage.[70] In 1987, Congress chose Yucca Mountain as the nation's primary, long-term site for nuclear waste storage and planned to have the site up and running by 1998.[71] A series of delays and political maneuvering have, however, set the inaugural date back several decades. While former President George W. Bush showed an increased interest in the development of Yucca Mountain, this has been countermanded by the Obama administration's effective abandonment of the project.

The Nuclear Non-Proliferation Act 1978

The Nuclear Non-Proliferation Act seeks to limit the spread of nuclear weapons and provides for the strengthening of the international safeguards system for nuclear materials.[72] The act essentially laid the groundwork for the implementation of security measures during all phases of the nuclear energy production process, from the mining and transport phases to the disposal of nuclear waste. The primary aim was to keep nuclear materials that could be used to construct a nuclear weapon out the hands of hostile state and non-state actors.

The Permitting Process

The NRC must approve site and plant designs before ground can be broken on any nuclear plant project. Although some argue that the NRC's regulations are cumbersome and contribute to the high costs associated with plant construction, the commission's practices have actually served to streamline the plant construction process in recent years. Specifically, the introduction of standardized plant designs, which have been pre-certified by the NRC, allows companies to simply select a pre-approved design rather than submit an original design, which may or may not be approved.

Environmental Impacts

Unlike coal and natural gas, the environmentally damaging effects of nuclear power do not come from electricity production, but from uranium mining, spent fuel storage, potentially catastrophic accidents, and nuclear proliferation. The overall impact of nuclear energy use on the environment can be assessed by examining prevailing industry mining practices and safety standards at nuclear power plants, as well as current efforts at waste management.

Uranium Mining

The potentially harmful effects of nuclear power generation begin with the uranium ore mining process. Uranium is extracted by conventional underground and surface mining techniques and by in situ processes where wells are used to produce uranium from the in-place ore body. Figure 3.5 shows the location of major U.S. uranium reserves. The environmental effects of uranium mining are similar to those of other mining activities in that they involve the release of radioactive and non-radioactive materials extracted from the earth into the surface environment, and they subject miners to a variety of health hazards.[73]

Surprisingly, the uranium itself has a very low level of radioactivity—on par with granite.[74] The most recently active uranium mines in the United States use water-based fluids to extract uranium from other elements underground and then isolate the contaminated water in man-made ponds situated in controlled areas. Miners continuously measure levels of radioactivity at the site and in the surrounding environment.

Figure 3.5 Location of Major U.S. Uranium Reserves

Source: U.S. Energy Information Administration. "U.S. Uranium Reserves Estimates". April 26, 2011. http://www.eia.doe.gov/cneaf/nuclear/page/reserves/ures.html

Deadly experiences, like those of early Navajo uranium miners who worked the mines on their reservations in the 1950s and later developed small cell carcinoma, have led to companies taking effective precautionary measures to protect workers and stop the spread of toxic residues to residential land and water supplies.[75] These precautionary measures include: dust control, limiting the area of tailings production, forced mining ventilation systems, and the imposition of strict hygiene standards on workers.[76] In sum, uranium mining practices, and their accompanying safeguards, have been standardized to the point that uranium mining presents only minimal environmental challenges, provided that the mining site is carefully monitored.

Spent Fuel Storage

How to manage spent nuclear fuel is currently one of the most hotly debated topics among nuclear experts. Low, medium, and high-level nuclear waste present dangerous environmental hazards and must be deposited in such a way as to protect nearby ecological systems. Each of the three fuel cycle technologies now in use—once-through, closed, and balanced—produces a different magnitude of waste.

Once-through technology involves passing the nuclear fuel used to produce energy through the nuclear reactor only once. Its products are not reprocessed and passed through the reactor a second time. In terms of environmental impact, this fuel cycle is potentially the most harmful as it produces the largest amounts of high and medium level radioactive waste. The closed-fuel and balanced-fuel cycles, on the other hand, allow for the reprocessing of spent fuel. More importantly for environmentalists, these two cycles also allow for the possible use of breeder plants, which transmute the most radioactive isotopes in the spent fuel into less harmful elements.

At present, all spent fuel in the United States is stored at sites of nuclear energy production as the reprocessing of fuel is currently prohibited by executive order and no site for long-term geological storage has been agreed upon by government officials.[77] The spent fuel is sealed in dry cask containers, made of steel and concrete, to absorb radiation from the waste.

Other options for waste storage exist aside from dry cask storage, including spent fuel pools and centralized interim storage. These options, however, along with dry cask storage, represent temporary solutions. Nuclear waste disposal will ultimately require storage in proper geological sites. The danger under this scenario comes from the spread of radioactive materials to the surrounding environment, as well as during its transportation from the production plant to the storage site.

Nuclear Meltdowns

Of the 2,679 reactors built in the United States since the debut of commercial nuclear power in 1957, there has been only one incidence of nuclear meltdown, the Three Mile Island incident in 1979.[78] Furthermore, probabilistic models developed by MIT researchers put the likelihood of reactor core damage at roughly 1 in 10,000. Meanwhile, new light water reactor designs purport to have reached an even smaller likelihood of core reactor damage, putting the figure closer to 1 in 100,000 reactor years.[79]

Improvements in the safety of the nuclear power generation process should come from both improved reactor designs and a more effectively trained nuclear industry workforce. The MIT report promotes the use of high temperature gas-cooled reactors as they have a very high heat capacity, which would act as a meltdown deterrent in the case of coolant loss. Of special importance is the availability of a trained workforce to construct, operate, and manage the plant.[80]

In sum, both public and private sector actors in the nuclear power industry have worked according to their respective incentive structures to mitigate the environmentally harmful effects of nuclear power generation at each stage of the energy production process. Notorious incidents, such as those at Three Mile Island and Chernobyl, have prompted stricter oversight and enforcement of safety standards by government agencies, particularly the NRC. Meanwhile, utility companies have been equally motivated to promote a culture of safety among plant operators to avoid the enormous financial costs associated with an accident.

On the whole, the environmentally damaging effects of nuclear power are minimal. Nuclear power does not produce greenhouse gases and could therefore be a vital component of America’s long-term energy mix.

Political Implications and Public Perception

A public perceptions survey published in a report by MIT shows that the majority of Americans and Europeans are against building new nuclear power plants to meet future energy demand. After surveying 1,350 adults in the United States about their perceptions of nuclear power and energy in general, they reached several conclusions.[81] They found that public perceptions were informed by ideas about nuclear technology irrespective of socio-demographic characteristics. Nuclear waste, safety, and costs were the critical factors affecting judgment about the future of nuclear energy, and the report concluded that lowering costs, improving safety, and solving waste disposal problems would increase public support dramatically. Perhaps most important, the report's authors found that the American public does not relate a reduction in greenhouse gases with an increased reliance on nuclear power.[82]

Environmental concerns are paramount among the public, and the feeling that nuclear power is at least moderately harmful to the environment pervades.[83] Safety and waste disposal, along with economic costs, came in second and third respectively in the public's nuclear power calculus. Clearly, the Three Mile Island accident and the Chernobyl disaster permanently changed the nuclear industry as well as public perception of the safety of nuclear energy. The MIT report states that while the majority of Americans approve the use of nuclear energy, many of them also oppose the idea of constructing new nuclear plants.[84]

Proliferation

Proliferation is a major concern when expanding the nuclear power sector. Closed fuel cycles, which involve reprocessing and the production of highly enriched plutonium, are associated with a higher risk of proliferation as highly enriched plutonium can easily be converted for use in a nuclear weapon. More generally, spent fuel and other radioactive wastes can be used by sub-national groups to create a "dirty bomb," where a conventional weapon is used to spread radioactive material.

In the United States, safety and regulatory standards are such that proliferation and the spread of nuclear material are greatly impeded. Abroad, however, the regulatory and safety standards are much less restrictive and the International Atomic Energy Agency's (IAEA) power to enforce standards is limited due to lack of funding and enforcement capacity.[85]

Thus, the main obstacles to the implementation of a comprehensive strategy for nuclear sector growth are political, and this circumstance is largely due to a lack of understanding on the part of the general public and a lack of political will among elected officials. Elected officials are hesitant to vouch for nuclear power because they fear political repercussions, and the voting public will not push their representatives to act until they understand the significant benefits that a growing nuclear power industry could bring to the United States.

Conclusion

The greatest obstacles stymieing the development of the nuclear power sector are political in nature and stem from both a lack of public understanding and a lack of political will among elected officials. In reality, given the abundance of uranium ore, a steady growth of the nuclear power sector could certainly help the United States meet its energy security goals. Although upfront capital costs are high, nuclear energy easily outperforms its rivals on a dollar cost per kilowatt hour basis. The financial strengthening of the Loan Guarantee Program will add to the cost competitiveness of nuclear power, and the appropriation of stimulus funds to the program will allow its administrators to provide insurance for investors in large nuclear projects.

Geothermal Energy

Introduction

Geothermal energy is energy from heat present in the earth's crust. This heat, created by radioactive decay of minerals generated during the planet's formation billions of years ago, originates in the earth's core and moves outward into the surrounding mantle and crust via convection and conduction. Humans have used this heat for thousands of years, but only in the last 50 years has it been used extensively to produce power. Geothermal power plants produce electricity by heating water with this natural terrestrial heat. The United States leads the world in installed geothermal capacity and has a long history of geothermal power utilization.

Technological Feasibility

Geothermal energy technologies can be broken into two general categories: direct use and electricity generation. Direct use of geothermal energy for bathing, cooking, and heating is perhaps the oldest form used by humans. At present, geothermal direct use is, generally speaking, a boutique industry that includes spas, exotic fish farming, tourism, and industrial heating and drying. As a proportion of energy consumption, direct uses far exceed electrical generation. These direct uses are difficult to quantify, however, and consumption and usage are often estimated. As such, electricity production provides a more relevant metric for evaluating geothermal as a source of primary energy.

All geothermal electrical energy generation uses the heat, steam, or hot water from geothermal reservoirs or Enhanced Geothermal Systems (EGS) production wells to create the force needed to turn turbine generators and create electricity. The three basic types of geothermal power plants are dry steam, flash, and binary.

In dry steam power plants, steam that is emitted from the geothermal reservoir is piped directly into the power plant and used to turn the turbine generators. In flash power plants, hot water (typically ranging from 300 - 700 F) trapped in the geothermal reservoir or injected into a well is pumped to the surface. Once released from the subsurface pressure of the reservoir or fracture, some of the water converts to steam which powers the turbine generators.

Binary power plants are used in situations where the water trapped in the geothermal reservoir or created using the injection well is not hot enough to convert to an adequate amount of steam for power generation upon reaching the surface. In these situations, the hot water (typically ranging from 250 - 360 F) is pumped to the surface and passed through a heat exchanger. There the heat is transferred to a binary liquid with a boiling point lower than that of water. As this liquid is heated, it flashes to vapor, expands, and is used to power turbines.[86]

In the United States, approximately 2,200 MW of electricity are generated annually by geothermal energy, roughly the equivalent production of four large nuclear power plants.[87] This production, as shown in Figure 3.6, comes primarily from western states—with approximately 1,800 MW in California alone—where geological conditions are suitable. Electricity-grade geothermal resources in the United States are generally confined to the western states, including Hawaii, where geological conditions are most suitable.

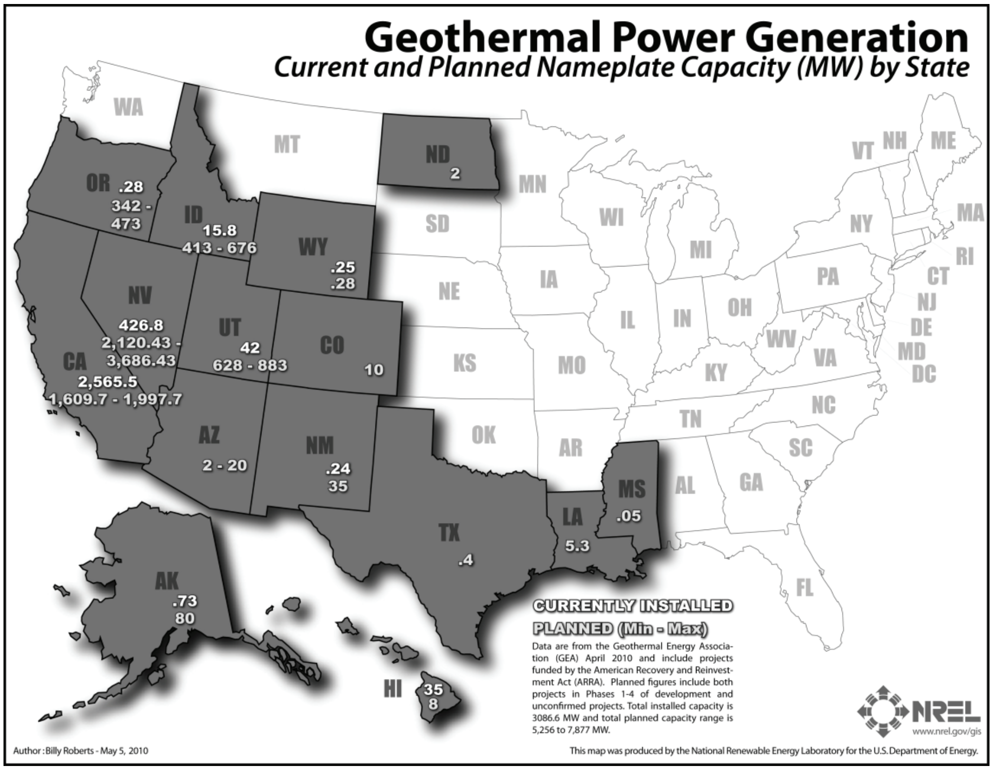
Within geothermal electricity generation there are two general categories: conventional resources and EGS. Conventional systems represent virtually all of the currently installed generating capacity and are an established, stable technology. EGS is the emerging frontier in geothermal energy, which encompasses a range of technologies that focus on creating or enhancing fractures in hot, impermeable rocks.

Conventional Systems

Conventional geothermal systems or hydrothermal systems form in proximity to volcanic activity caused by tectonic plate subduction. These conventional systems—which are known for their prominent surface features such as geysers and hot-springs—are formed in very high temperature and permeable, young volcanic rocks. They are often associated with large volcanic calderas, such as Yellowstone National Park in Wyoming or the Geysers Geothermal Field in Northern California. These waters interact with magmatic heat sources, becoming superheated, chemically altered, and saturated with minerals.

Starting in 1904 in the Ladarello field in Italy, people began to exploit these hydrothermal systems for electric power. In geothermal fields where dry steam is available, the steam is simply piped directly into a generator's turbine. In the more common fluid dominated reservoirs, geothermal brine is extracted then flashed to steam to drive a generator. This same type of system is still in use today, enhanced by more sophisticated methods such as specialized working fluids to conduct heat and binary systems that use proprietary technology to extract additional energy from a secondary cycle. Geothermal electricity generation is a mature technology, with gradual improvements being made in efficiency and steam field management, but the same basic designs have been in use for more than 50 years. The largest cluster of geothermal electricity generation projects is currently the Geysers, located just north of San Francisco, with more than 1,500 MWe of capacity installed.

Figure 3.6 Distribution of Current and Planned Geothermal Power Generation in the United States

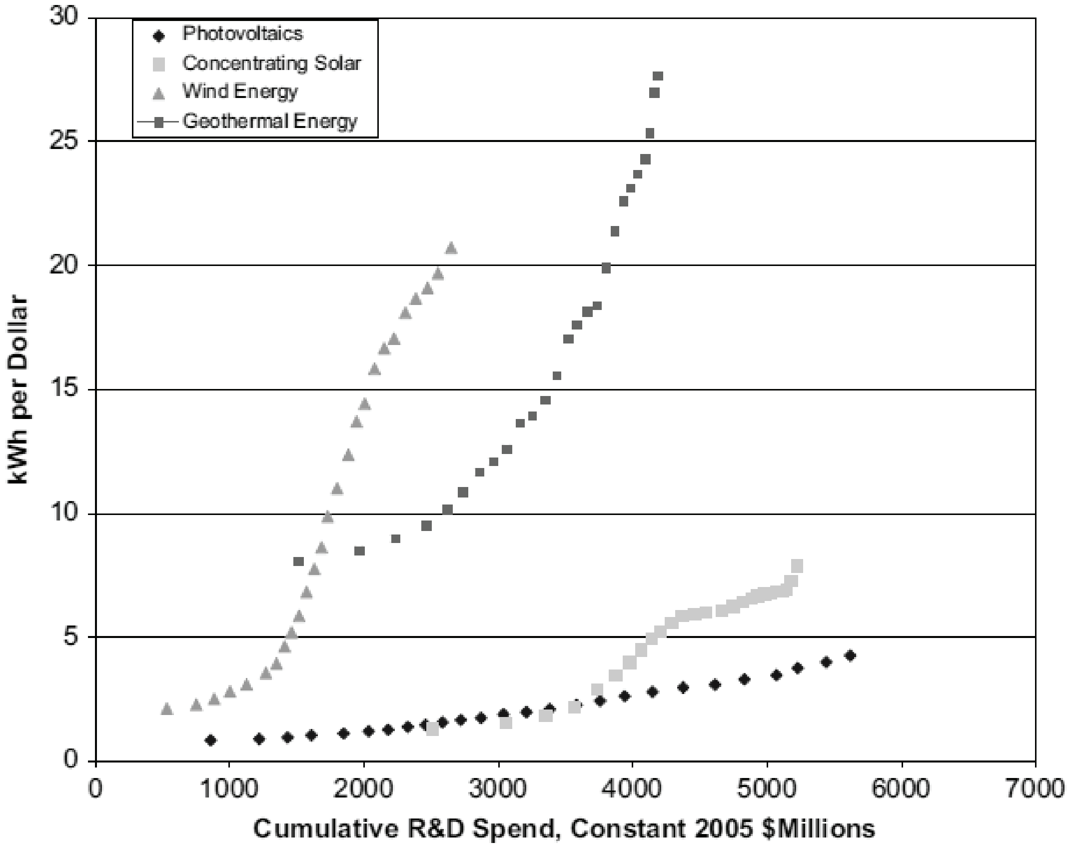


Source: United States National Renewable Energy Laboratory. “Geothermal Maps” *NREL Website*. Accessed March 21, 2011. http://www.nrel.gov/gis/geothermal.html

The major technical problem that conventional systems face is the unpredictability and fluid nature of geothermal systems. Because reservoirs are dynamic systems, predicting the size and amount of extractable energy present in a reservoir is extremely difficult. In addition, exploitation of geothermal systems causes the pressure of the reservoir to gradually decline over time. While this can be managed with careful reinjection programs, heavy extraction of steam will, over the course of decades, decrease the amount of energy available from a system.

Starting in the early 1980s, following the first major oil shocks, the U.S. government began to increase investment in geothermal technologies. This investment focused on a range of technologies and created rapid improvements in generation efficiency and the cost effectiveness of geothermal. These allocations included funding for reservoir modeling and power generation efficiency improvements, both of which greatly contributed to improved efficiency and increased installed capacity. As demonstrated in Figure 3.7, geothermal has produced the greatest return on cumulative R&D investment among competing renewable technologies.[88]

Figure 3.7 Technology S-curves in Renewable Energy Alternatives



Source: Schilling, M.A., Esmundo, M. (2009, "Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government." Energy Policy, Vol 37, no 5 (2009): 1767-1781.

EGS Technologies

The latest push in the development of geothermal technologies, both in the United States and internationally, has been so-called "Enhanced Geothermal Systems." This term usually refers to a specific technology used to create fractures in hot, but dry, bodies of granite, and then circulating water through these artificial reservoirs in the same way as conventional systems. These EGS reservoirs rely on the same basic principles to produce electricity but lack the natural permeability and abundance of fluids that makes conventional geothermal so convenient.

In contrast to the highly permeable, fluid rich, dynamic geological systems that characterize conventional geothermal systems, the targets for EGS are geologically stable, relatively unfractured, and impermeable. The entire premise of EGS is based on the idea that the manufactured reservoir must be well studied and geologically defined and therefore must be created in a relatively homogenous, predictable zone of basement rock.[89]

Because of the substantial cost of drilling, EGS research and development has focused on geological areas where temperatures are anomalous and reach 400 F or greater within the first 2 to 3 miles of crust. Fortunately, there are many places worldwide where these geological conditions prevail, which is what has made EGS an extremely attractive option. Based on the authoritative DOE-sponsored MIT report, if this heat could be effectively mined, geothermal energy could provide "about 2,000 times the annual consumption of primary energy in the United States in 2005."[90]

However, EGS in its current iteration has not been proven technologically feasible on a commercial scale. Since the initial test program by the Los Alamos National Laboratory in the 1980s at Fenton Hill, New Mexico, EGS technologies have greatly improved and proven successful on a research scale in Germany and France. These projects, however, were heavily subsidized, required heavy pumping, and could not generate electricity on commercial scales.[91]

Conversely, not all EGS technologies are explicitly tied to stimulated or HDR (Hot Dry Rock) reservoirs. EGS has expanded to include a variety of geological environments such as sedimentary basins, which are reliable sources of lower-temperature geothermal waters. The true emerging trend within EGS is this new focus on diverse forms of geothermal systems that can be "enhanced" through improved heat recovery techniques and low-temperature generation units.[92]

While conventional, hydrothermal geothermal is a proven and mature power generation technology, EGS is an emerging and, on some levels, experimental technology. Though major advances have been made in the generation technologies required to produce electricity from these lower temperature resources, the geoscientific barriers to reservoir creation and management have hindered commercial adoption.

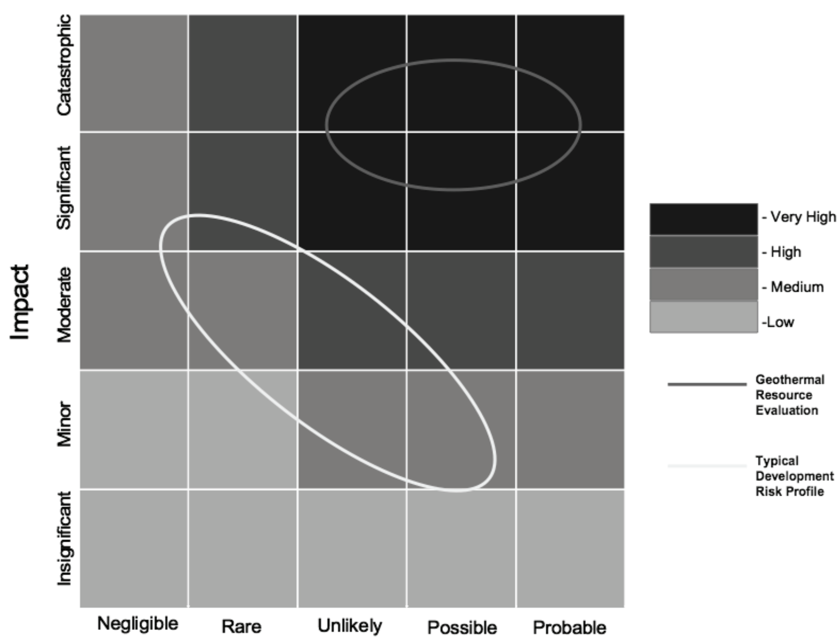
In conclusion, policy makers must understand that geothermal power generation technologies should not explicitly be defined as "emerging," but instead as a semi-mature technology. Unlike fossil fuel and hydro power plants, which have essentially been perfected, geothermal power plants still have room for efficiency and field management improvements. Geothermal is, however, a commercially proven and reliable form of renewable energy. The primary remaining technical hurdles for geothermal energy to overcome are its geographical and geological limitations. In this respect, emerging EGS technologies represent the best chance for geothermal to increase its installed capacity and expand its role in the U.S. electricity supply.

Economic Viability

The key reasons why geothermal energy has not been exploited more widely are the technological challenges associated with drilling and reservoir development. Virtually all geothermal drilling technology comes from the oil and gas industries. Unlike the oil and gas industries, however, returns on investment are much lower in geothermal power production. The chronic financial issues for geothermal power projects are the high upfront costs and the long return-on-investment timeframe. These factors have continued to discourage private investors and created the need for geothermal developers to increasingly self-finance the early stages of projects.

The early project development stage of a geothermal power producing facility is extremely capital intensive. Unlike solar and wind, finding appropriate locations for geothermal requires extensive geological exploration, and many geothermal systems are completely invisible from the surface of the earth. To accurately quantify the amount of energy that can be extracted, developers must invest heavily in exploration technologies. Furthermore, investment in exploration does not guarantee success, so many investors are leery of inputting any capital until a resource is well defined and a return may be guaranteed. Figure 3.8, taken from a government commissioned evaluation of investment risk in geothermal, illustrates the typical risk profile of a geothermal electricity generation project.

Figure 3.8 Geothermal Risk Mitigation Strategies



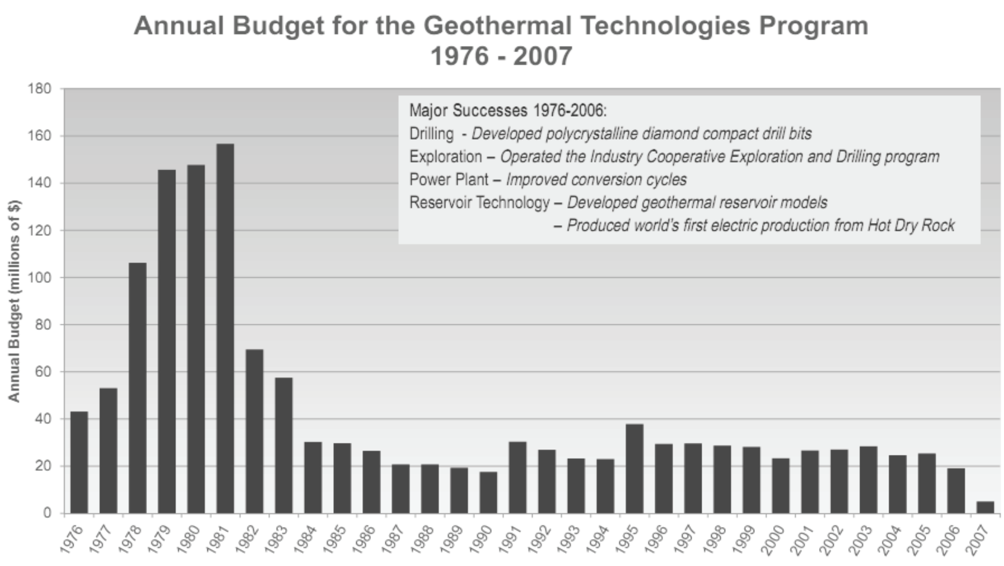
Source: Deloitte. "Geothermal Risk Mitigation Strategies Report: Department of Energy – Office of Energy Efficiency and Renewable Energy Geothermal Program" February 15 2008, 31.

As a result of the private sector's aversion to the upfront risk of geothermal, government investment has been pivotal in motivating development. The major driver of geothermal investment and technology research has historically been the DOE's Geothermal Technologies Program. The government's support for the development of geothermal energy has fluctuated significantly during the life of this program. In the 1980s, federal grants were used to develop geothermal technology, and during this decade virtually all district heating systems in the United States were implemented. During this time frame, funding for geothermal was around $80 million annually. This funding, however, later dropped to $25 million annually and was then targeted for elimination altogether as geothermal was designated a "proven technology." Funding dipped as low as $2 million annually in 2007, but is now closer to $40 million on yearly average.[93]

With the renewed political focus on energy security in the federal government and the contributions of the American Recovery and Reinvestment Act, there has been a major spike in federal funding for loan guarantees, drilling insurance, and investment in R&D in the geothermal sector. As Figures 3.9 and 3.10 illustrate, drilling activities in California—which is a strong proxy for activity nationally—have a strong correlation to spikes in government investment in the geothermal sector.

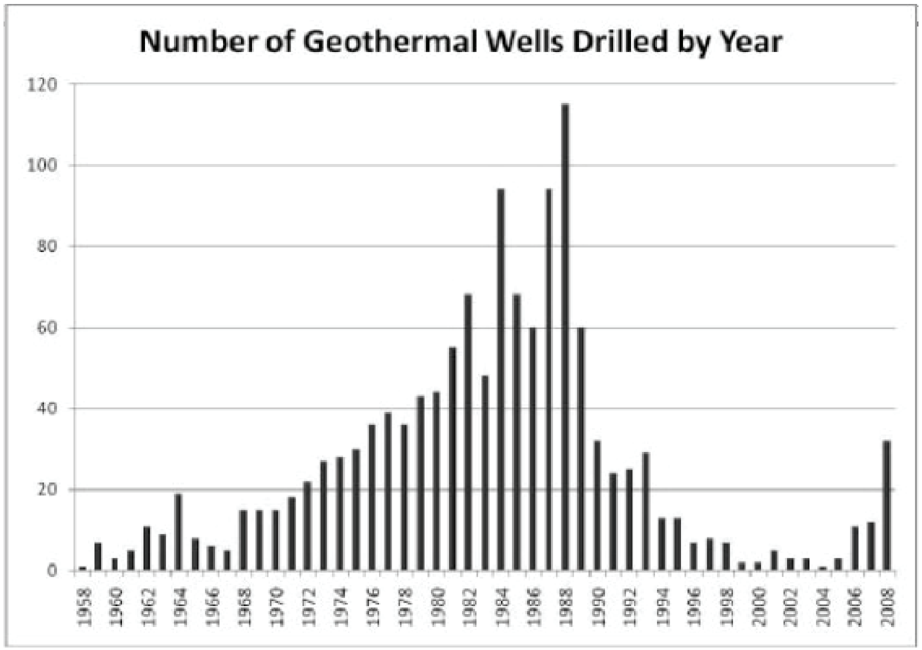
The key financial concern facing geothermal energy development is the current 2013 expiration of the federal Production Tax Credit. Because geothermal projects typically have a development cycle of six to ten years, maintaining momentum for projects with return on investment beginning beyond this horizon has been difficult. Attaining this level of financial longevity will be a critical next step for both conventional and EGS geothermal programs. Because geothermal is already approaching cost competitiveness, due to its baseload nature, financial incentives are critically important for getting projects through the risky initial phases.

Figure 3.9 Annual Budget for the Geothermal Technologies Program 1976-2007



Source: DOE Geothermal Technologies Program. "Fiscal Year 2012 Budget Request Briefing" Presentation February 17 2011. Slide 6. Available http://www.geo-energy.org/pdf/GTP_FY12_Overview_forGEA2-22-11Final2.pdf

Figure 3.10 Number of Geothermal Wells Drilled by Year - California



Source: State of California Department of Conservation, "2008 Annual Report" (Annual Agency Report, Sacramento, 2009), 251. ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2008/PR06_Annual_2008.pdf

While there are many specific financial policies—such as drilling insurance, carbon credits, etc.—that could boost geothermal development, the largest issue is still one of risk mitigation. The DOE has taken the approach of investing heavily in applied scientific R&D through the Geothermal Technologies Program with the strategic goal of improving scientific understanding of geothermal resources. By doing this, it is hoped that techniques for exploration and exploitation will improve and gradually begin to reduce the risk curve for investors.

Current Regulatory Framework

For thousands of years geothermal resources have been employed for various direct use purposes, such as the use of geothermal waters for cooking and medicinal purposes by Native Americans, in what is now the United States. The federal government, however, did not begin to directly regulate geothermal until the early 1970s, first with the implementation of the Geothermal Steam Act in 1970 and later with the enactment of the Geothermal Energy Research, Development and Demonstration (RD&D) Act in 1974. This second act instituted the Geothermal Loan Guaranty program, which provides investment security to both private and public sector groups engaged in the development of geothermal resources,[94] and it provided a framework for the coordination and management of geothermal programs and research.[95] The act continues to function as one of the two most important laws governing and directing the DOE's geothermal research programs.[96]

Including the RD&D Act of 1974, the DOE's Geothermal Technologies Program acknowledges nine laws as currently sanctioning and guiding the research and development of geothermal energy technologies in the United States. The eight additional recognized pieces of legislation are:

- Department of Energy Organization Act (1977)
- Energy Tax Act of 1978
- Energy Security Act (1980)
- Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989
- Solar, Wind, Waste, and Geothermal Power Production Incentives Act of 1990
- Energy Policy Act of 1992
- Energy Policy Act of 2005
- Energy Independence and Security Act of 2007

Of these, the Energy Independence and Security Act of 2007 is considered one of the more influential pieces of legislation that governs geothermal research activities.[97] Subchapter V, Subtitle B of the act required the Secretary of Energy to support geothermal research and development and set the protocol and parameters for that support.[98] The act also mandated the creation of a center for geothermal technology transfer, authorized appropriations for the implementation of the act through fiscal year 2012, and set reporting requirements. This act, the RD&D Act, and the additional pieces of legislation listed above provide the basic framework for U.S. geothermal energy policy at the federal level.

There are also federal, state, and local regulations that affect the geothermal energy drilling and development processes. At the federal level, the Bureau of Land Management (BLM) regulates the leasing of public lands for geothermal energy production. In May 2007, the Department of the Interior (DOI) updated geothermal energy production regulations on federal land by requiring the Bureau's leasing process to be more competitive. The DOI also stipulated that $4 million in royalties must be shared annually with the counties where geothermal energy is produced and that the process of calculating royalties must be simplified. As of July 2010, 247 million acres of public lands were available for leasing in 11 western states and Alaska, including 104 million acres of National Forest managed by the U.S. Forest Service.[99]

At the state and local levels, regulations vary significantly. Not all counties require that a permitting process be undertaken, though some do. The cost and requirements of these permits, such as public notice, also differ from place to place within a given state and require that the company contact county offices to determine specific requirements. At the state level, multiple types of permits must often be obtained before production or drilling can begin, such as permits for drilling, sewage discharge, housing facilities, facility construction, building construction, hazardous materials, drinking water supplies, geothermal water appropriation, geothermal water production injection, and geothermal surface disposal.[100] The requirements of all state and local permits must be satisfied in addition to the BLM's federal drilling requirements before geothermal production activities can begin. Additionally, as EGS technology is further refined and subsequently implemented on a larger scale, regulatory areas that deal specifically with this technology may need enhancement.

Thus, the regulatory framework surrounding geothermal energy production is extensive, though it is comparable to the scenario faced by some fossil fuel sources. The clearest example of this is natural gas. As both of these energy sources involve drilling coupled with fluid injection and subsequent extraction, there are many similarities in the drilling permitting process. Geothermal energy is not transported long distances, however, so the scope of the overall regulatory process is more limited than that of natural gas.

Nonetheless, the expansion of geothermal energy production has been constrained by the complexity of existing state and federal regulations, particularly those surrounding the leasing of areas controlled by the BLM. Because geothermal projects generally operate on a delayed rate of return on investment, any additional delays due to permitting processes can further endanger the success of these projects.[101] Currently, there is no unified federal policy regarding geothermal development, and the issues faced by project developers vary on a state-by-state basis. For example, development in states such as Texas has been slowed due to operator concerns over lawsuits and land stake disputes.[102] Until geothermal is deployed more widely, it is unlikely that many of these small political issues will be resolved.

Environmental Impacts

While there are a number of potential negative side effects associated with geothermal projects, most have proven minor both in scale and impact. The most significant impacts include gaseous emissions, water use issues, land use issues, microseismic activity, and land subsidence. As conventional geothermal power plants have been in operation for decades, their environmental impacts are well known and documented. Those impacts are widely understood to be minimal, particularly in comparison with other forms of electrical power generation.

The potential consequences of EGS technology, on the other hand, are not well documented since it is still under development. Experts anticipate, however, that the lessons learned from conventional geothermal development can be applied to EGS. With the exception of microseismicity, these systems are anticipated to have similar or reduced environmental impacts in comparison with those associated with conventional geothermal.[103]

Gaseous Emissions

Geothermal power plants create minimal gaseous emissions, particularly when compared to the emissions generated by fossil fuel-based plants. Binary geothermal plants, which operate on a closed-cycle, produce effectively no emissions. Flash and steam plants produce very low amounts of noncondensable gases, the two most common of these being carbon dioxide (CO_2) and hydrogen sulfide (H_2S). However, 99 percent of H_2S emissions are removed from hydrothermal steam using scrubbers, and the level of CO_2 emissions is approximately 4 percent of the quantity released by fossil fuel plants.[104] Overall, emissions of noncondensable gases from geothermal power plants are extremely low.

Water Use

Geothermal projects require the use of water to facilitate multiple phases of the power generation process, and this water consumption can be of concern to communities. Water is required to drill, to stimulate the reservoir, and to maintain circulation once it is operational. It may also be needed for the condensation of fluids required for the plant's operation.[105] The amount of water required to facilitate these processes, however, is generally small. Air-cooled binary plants use no fresh water, while other geothermal plants use five gallons of fresh water per megawatt hour on average. Natural gas plants, by comparison, use 361 gallons per megawatt hour.[106] Nonetheless, geothermal heat sources within the United States are most commonly located in the western portion of the country where water is often a scarce resource. In these cases in particular, sound water conservation practices and management of water resources in conjunction with the local community are essential.

Water produced during geothermal operations contains higher concentrations of dissolved minerals than water from cold subsurface reservoirs, and some of these minerals have the potential to contaminate ground or surface waters and to damage vegetation if released.[107] Release of geothermal fluids into adjacent water supplies is rare, however, as geothermal well casings are typically several layers thick and cemented into the ground. Multiple barriers exist between the inside of the well and surrounding geologic structures. Additionally, geothermal streams stored above ground are kept in impermeable, lined catch basins that prevent the mixing of geothermal waters with the surrounding environment. These streams are eventually re-injected deep underground.[108]

Land Use

The footprints of geothermal power plants vary by site, but they are generally much smaller than those of other types of power plants. Over a period of 30 years, the time frame typically used to measure the life cycle of various types of power plants, the total land per gigawatt (GW) hour used by a geothermal plant is 4,350 square feet compared to 39,000 square meters per GW hour for a coal-fired plant.[109] Additionally, though the total area for well fields can be significant, from 3-6 square miles on average, the proportion of land actually covered by well pads is only approximately 2 percent of this area.[110] Given this ratio, geothermal fields can be used for multiple purposes simultaneously, including agriculture and hunting, and revegetation can minimize visual disturbances.

Also, geothermal wells can potentially be developed using the same drill pads that have been used in natural gas or petroleum production. In these cases, there is no real geothermal footprint as the land has already been disturbed and is simply being reused for the further extraction of additional resources used for power generation.[111]

Seismic Activity

Induced seismic activity has generally not been a problem in conventional geothermal settings as these areas are naturally seismically active. The processes involved in EGS, however, are in some ways different from conventional geothermal techniques and may pose some risk of seismic activity. Opening fractures and injecting fluids at high pressure to access and stimulate geothermal reservoirs have the potential to induce seismic activity, but the magnitude of such activity is generally low.[112] Seismic events generated through geothermal processes are known as "microearthquakes" as they measure below 2 or 3 on the Richter scale and are typically not perceived by humans.[113] Additionally, induced seismic activity is a concern in all types of energy technology that involve extensive drilling and fracturing, including natural gas, enhanced oil exploration, and carbon capture geologic sequestration. Thus, this concern is not unique to geothermal.[114]

In most cases, geothermal companies voluntarily measure seismic activity as it is a cause for public concern. The DOE has also developed a protocol that can be used for such purposes.[115] In both cases, baseline data are taken at potential geothermal sites to aid in determining if future seismic disturbances are naturally occurring or generated by geothermal processes, and this information can be helpful in informing the public. The likelihood of future events can also be calculated, and possible effects of any disturbances on local infrastructure and communities taken into consideration.[116]

Land Subsidence

If more geothermal liquids are extracted from the subsurface environment than are recharged, the land may begin to compress and eventually sink or subside, ultimately causing a decline in surface elevation. This phenomenon was observed early in conventional geothermal development in New Zealand in the Wairakei field where subsidence rates in one area of the field reached as high as 1.5 feet per year.[117] Since that time, geothermal operators have managed geothermal reservoirs more closely, and this combination of improved management in conjunction with modern injection techniques has effectively mitigated this potential impact.

In sum, the negative environmental impacts of geothermal power production are minimal, particularly in comparison to the impacts of fossil fuel-based energy sources. Like nonrenewable energy sources such as coal and natural gas, geothermal provides base load power generation, yet its footprint and gaseous emissions are of much lower magnitude.

Thus, use of geothermal resources reduces gaseous emissions, land use required for generation of electricity, and dependence on non-renewable sources of energy.

Political Implications and Public Perception

In the United States, geothermal energy has a relatively small political profile. Because of its concentration in Western states with lower populations, geothermal energy occupies a political niche and does not play a significant role in national politics. Sen. Harry Reid, D-Nev. and Senate Majority Leader, is a major backer of geothermal development in the Western states, particularly Nevada. Nevada is currently the greatest focus of geothermal development in the United States, with approximately 14 geothermal power projects in advanced stages of development.[118]

California, which if taken individually, has the largest amount of geothermal capacity in the world, continues to be a major player in development of geothermal. Due to its high energy demand and renewable portfolio standards, California is a leading political and economic force for geothermal development in the Western states, with municipalities and cities looking to purchase geothermal energy from as far away as Utah.[119]

With regards to the public, geothermal is generally perceived very positively when it is specifically asked about. Outside of the Western states, however, knowledge of geothermal remains very low. Solar and wind have much higher political and public profiles than geothermal, with one major poll indicating that 70 percent of Americans seeking a job in renewable energy would opt for solar or wind, with only 9 percent identifying geothermal.[120] Surprisingly, geothermal industry advocates do not take this apparent marginalization negatively. In fact, the geothermal lobby relies on the collective bargaining power of the renewable energy industry to obtain subsidies and incentives that would be difficult to attain specifically for geothermal.[121]

The major exceptions to this positive perception are the issues regarding induced seismicity associated with new EGS technologies. In 2009, a DOE funded project in northern California received major attention from the national and international press due to the potential for induced seismic events.[122] The public outcry over these potential environmental impacts led the DOE to reevaluate the project and ultimately relocate it to a different site in Oregon. These events, however, have pushed the geothermal industry and regulators to devise clear best practices and a formal induced seismicity protocol, which have been effected for all future EGS projects.[123]

Aside from this concentration of development in the western United States, geothermal power is essentially a political non-issue. As with other forms of renewable energy, tax incentives and renewable portfolio standards are the lifeblood of geothermal development, and industry lobbying is crucial in maintaining these subsidies. The geothermal industry's largest political issue is not justifying the technologies, but rather explaining the highly technical geoscientific and engineering issues that distinguish geothermal from more conceptually simple power sources such as wind and solar.

Conclusion

Geothermal energy is a semi-mature emerging technology that has enormous potential to improve U.S. energy security by increasing the nation's supply of reliable, clean domestic energy. Geothermal provides baseload, emission-free power generation and has the potential to be deployed nearly anywhere in the United States. Geothermal energy must, however, overcome large—but not insurmountable—technological hurdles before it can form a major part of the domestic energy comparison.

Conclusion: Existing Technologies

It is evident from this review that established energy sources will continue to play a critical role in U.S. energy supplies. But the range of issues surrounding these technologies, particularly exhaustibility, environmental concerns, and cost, will require a new approach to attaining energy security in the United States. The PRP team believes that while reliance on these sources of energy will be crucial—if not inevitable—in the medium term, the United States should take concrete steps to move away from these as primary energy sources.   The Findings and Recommendations chapters will further outline this approach.

Notes

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[12] U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook 2009, August 19, 2010, pg. 198. Natural gas pricing follows various price points. Wellhead prices refer to the raw cost of the resource; Citygate prices reflect the costs of refining and treatment.

[13] Rowdy Lemoine, Vice President of Production, Plains Exploration, Interview with Maureen Metteauer, March 2, 2011.

[15]U.S. Department of Energy. Alternative Fuels and Advanced Vehicles Data Center, "Alternative Fueling Station Total Counts by State and Fuel Type," under Alternative Fuels, (Washington, D.C., February 28, 2011). This data combines the February 2011 count of compressed natural gas and liquefied natural gas. http://www.afdc.energy.gov/afdc/fuels/stations_counts.html

[16] Price comparison between the 2011 Honda Civic Coupe ($15605) and the Honda Civic CX NGV ($25490) according to Honda.com. http://automobiles.honda.com/civic/#Disclaimers (Accessed March 2, 2011).

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[19] U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook 2009, August 19, 2010, pg. 198.

[20] Rowdy Lemoine, Vice President of Production, Plains Exploration, Interview with Maureen Metteauer, March 2, 2011; and Skip Horvath, President, Natural Gas Supply Association, Interview with Maureen Metteauer, February 3, 2011.

[21] At this writing, the natural gas price is based on the average reported by the Energy Information Administration's monthly analysis and forecasts for natural gas futures. Energy Information Administration

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[26] Environmental Protection Agency, "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act," Final rule**,** *Federal Register* / Vol. 74, No. 239 /

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Chapter 4. Emerging Technologies

Because U.S. reliance on fossil fuels, natural gas, and nuclear power will not wane significantly in the immediate future, four emerging energy technologies were selected that show promise to eventually replace existing energy sources. Domestic production and minimal negative environmental impact were emphasized in selecting the technologies. This chapter outlines these emerging technologies and addresses some of the challenges each technology faces before mass implementation could be possible.

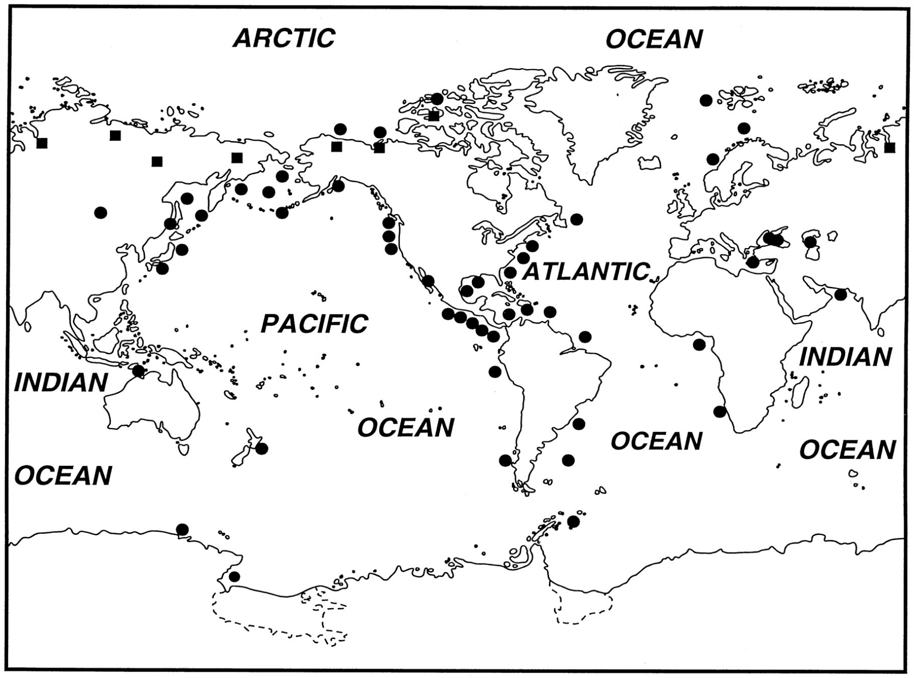
Methane Hydrate

As noted in Chapter 3, natural gas is a vital energy source accounting for nearly a quarter of the U.S. energy supply and will likely play an increasingly important role in the nation's energy portfolio. It is used widely in domestic, commercial, and residential markets, and will continue to grow as a key energy source for the nation. The EIA projects that the United States will need to increase its production of natural gas by 10 percent annually to meet projected demand over the next 25 years.[1] Since natural gas is an affordable, relatively clean burning base-load energy source, it is considered an integral bridge fuel as the nation shifts to incorporate less carbon-intensive energy sources. Therefore, as environmental and national energy security issues become increasingly exigent in combination with growth in energy demand, domestic natural gas will be an important energy source to develop.

One such potential domestic energy source is unconventional natural gas in the form of methane hydrate. Methane hydrate is methane gas, the primary component of natural gas, trapped within a cage-like lattice of ice crystals. It forms where natural gas and water interact in the proper geological conditions of high pressure and low temperature. Found in both terrestrial and marine environments (Figure 4.1), methane hydrates are abundant within permafrost in polar regions, and along the continental shelves below 500 meters of depth. To recover natural gas from methane hydrate requires that the hydrate be either warmed by thermal injection or depressurized; both processes result in methane gas and water. Moreover, methane hydrate is an energy dense resource: one cubic meter of methane hydrate yields 164 cubic meters of natural gas once disassociated. The energy density of methane hydrate is one reason there is considerable interest in developing commercial production.[2]

The Potential Gas Committee estimated that the current U.S. natural gas endowment is approximately 2,074 trillion cubic feet (TCF), which includes conventional and unconventional deposits.[3] While estimates of methane hydrate vary widely, a 2008 study by the U.S. Minerals Management Service (MMS) reported that the methane hydrate resource in the Gulf of Mexico is between 11,000 and 34,000 TCF. If one-third of the natural gas in the Gulf of Mexico were technically and economically recoverable, according to the MMS assessment, the United States could potentially double its domestic natural gas resource.[4] Furthermore, this figure only represents natural gas

Figure 4.1 Location of Gas Hydrate Occurrences



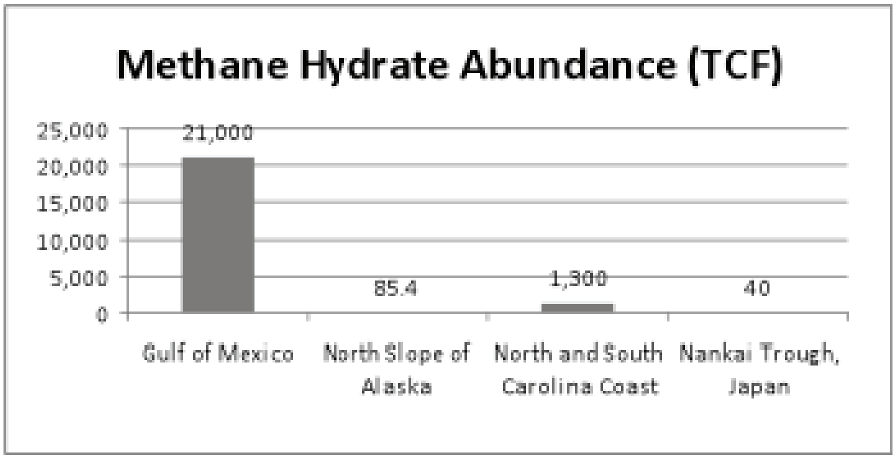
Source: Keith Kvenvolden. "Potential effects of gas hydrate on human welfare". 1999. http://www.pnas.org/content/96/7/3420/F3.large.jpg

resource potential from methane hydrate in the Gulf of Mexico. Figure 4.2 shows estimates of potential natural gas resource to be found under the permafrost on the North Slope of Alaska and eastern continental shelf, as well as the Gulf of Mexico.

Although estimates of the domestic methane hydrate resource are robust, the majority is not economically viable to develop. According to Ray Boswell and Tim Collett, of the National Energy Technology Laboratory (NETL) and the USGS, respectively, the methane hydrate deposits that have the best potential for economic development occur where highly concentrated hydrate is found in arctic sandstone or deepwater sandstone deposits.[5]

The DOE has been developing a foundation of knowledge to enable the commercial production of natural gas from methane hydrate since 1982. While funding for methane hydrate research was discontinued in 1992, Congress reauthorized methane hydrate research through the Methane Hydrate Research and Development Act of 2000, and the Energy Policy Act of 2005.[6] The DOE Methane Hydrate Research and Development Program aims to generate the scientific and technical expertise for "efficient and environmentally sound development" of methane hydrate.[7] The program was established to report on the impact of methane hydrate formation and degassing on global climate change, while researching the basic knowledge necessary for commercial development of the methane hydrate resource. Conducted through partnerships with private industry, research universities, and the DOE's National Laboratories, the program funded

Figure 4.2 Methane Hydrate Abundance



[1]Mean MMS estimate of methane hydrate in the Gulf of Mexico

[2]Mean USGS estimate of technically recoverable methane hydrate on the North Slope of Alaska

[3]USGS estimate

Source: Committee on Assessment of the Department of Energy's Methane Hydrate Research and Development Program: Evaluating Methane Hydrate as a Future Energy Resource. *Realizing the Energy Potential of Methane Hydrate for the United States*. Edited by Charles Paull. Washington, D.C.: The National Academies Press, 2010. p. 160. Print.

approximately 40 new and on-going methane hydrate projects from fiscal years 2006 through 2009.[8]

Technological Feasibility

While the timeline remains unclear, experts at the National Research Council (NRC) believe commercial production of methane gas from methane hydrate will be technically feasible with appropriate industry and governmental commitment. The NRC stated that research on methane hydrates "has not revealed technical challenges that are insurmountable in the goal to achieve commercial production of methane from methane hydrate in an economically and environmentally feasible manner."[9] According to the chair of the NRC committee, Charles Paull, "DOE's program and programs in the national and international research community provide increasing confidence from a technical standpoint that some commercial production of methane from methane hydrate could be achieved in the United States before 2025."[10]

The DOE's methane hydrate program sponsored the Joint Industry Project (JIP) that has developed hydrate sand deposits in the Gulf of Mexico. JIP has demonstrated the feasibility of finding concentrated hydrates in reservoir sands that have the best possibility for commercially and environmentally viable development. Also in 2008, Japan and Canada demonstrated in an independent, joint venture that the depressurization method, which reduces pressure in the hydrate deposit by withdrawing fluids through the well bore, can produce industrial quantities by extracting methane for 6 days.[11] The long-term effect of gas-extraction upon hydrate reservoirs, however, requires longer-term production tests that have yet to materialize.[12] Yet, the Japanese government, after their prior success, has announced plans to commercially develop methane hydrate by 2018, which may prove that commercially viable extraction is possible with the proper commitment.[13]

Economic Viability

The economic and environmentally sustainable commercial production of methane hydrate has yet to be achieved. The methods of extraction, depressurization, and thermal injection, are not currently economically viable. According to the 2010 NRC study, in order to realize economically and environmentally viable commercial production of methane hydrate as an energy source, researchers will have to address "complex scientific challenges, which may require the development of new technologies."[14] Due to this fact, energy production from methane hydrates remains unclear. Furthermore, uncertain market conditions further inhibit and obscure the possible development of methane hydrate as a potential energy source in the near term.

Nonetheless, the DOE has been partnering with industry leaders to develop the technological and scientific expertise necessary to create a commercially sustainable methane hydrate industry. On the Alaska North Slope, for example, the DOE has partnered with British Petroleum to develop a demonstration site. Also, the DOE has partnered with Chevron in the Gulf of Mexico to "address critical questions in the marine methane hydrate exploration and geohazard assessment."[15]

As of 2008, the DOE had contributed $24.6 million to the work conducted in the Gulf of Mexico and $10 million on the Alaska North Slope project.[16] Furthermore, the DOE brought together the National Renewable Energy Laboratory, other governmental agencies, and foreign governments including, but not limited to, Canada, India, and Japan, to conduct high caliber research in the field of methane hydrate.

Successful commercial development of methane from methane hydrate is, however, largely contingent upon "favorable regulatory conditions and market economics" that remain uncertain in the near-term for policy makers seeking to develop commercial methane hydrate production.[17]

Furthermore, exploitation of unconventional gas sources throughout the continental United States continues to depress gas prices which makes the commercial production of methane hydrate less desirable for industry.

Since the United States has a large endowment of methane hydrate deposits along the continental shelves in the Gulf of Mexico, the Pacific and Eastern seaboards, as well as in the permafrost on the Alaska North Slope, commercial production of these deposits could enhance U.S. energy independence and security by allowing the United States to scale back energy imports from politically unstable regions. With lower carbon dioxide emissions compared to other hydrocarbons, methane hydrate is environmentally more appealing, particularly since the energy source is so dense. Commercial production of natural gas from methane hydrates is a highly preferable policy outcome that could become economically viable with stakeholder and government commitments.

Current Regulatory Framework

Methane hydrate research and development in the United States is funded primarily through the Methane Hydrate Research and Development Act of 2000 and the Energy Policy Act of 2005. The Methane Hydrate Research and Development Act of 2000 was established "to promote the research, identification, assessment, exploration, and development of methane hydrate resources, and for other purposes," and has provided increasing funding for methane hydrate research. The Energy Policy Act of 2005 extended funding of methane hydrate research and development.

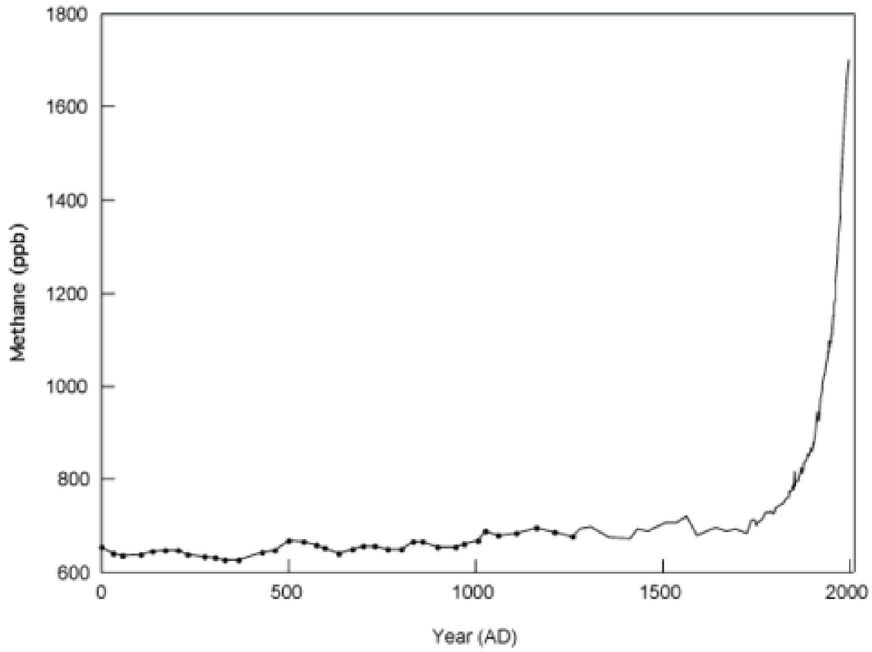
The distribution and vast quantity of methane hydrate deposits could provide for a shift in U.S. energy independence as well as alter the control of the international energy supply. MH production is pre-commercial and economically unproven; therefore, a federal-industry-academic collaboration is working to better understand the potential production, environmental impact, and viability of methane hydrate as a domestic energy source.

The Gulf of Mexico Gas Hydrates Joint Industry Program, working with NETL/DOE, is such a collaboration researching naturally occurring gas hydrates in the Gulf of Mexico. This 11-year project will conclude in 2012, costing the DOE more than $40 million, with $15 million in performer contributions. The JIP's objective is to lead technological advances through collaborative research to achieve a better understanding of the safety hazards involved in drilling and producing oil and gas through hydrate containing sediments in deepwater.

Environmental Impacts

The key environmental concern with the commercial development of methane hydrate is methane's potential effect on the future climate and its possible detrimental effects on public health. To date, the role of methane hydrate deposits in the global carbon cycle is poorly understood and this remains an obstacle to environmentally sustainable commercial production of methane from methane hydrate. Methane creates less carbon dioxide when combusted than other hydrocarbons currently in use as energy sources; as a free-gas, however, methane is 10 to 20 times more potent than carbon dioxide as a greenhouse gas, making possible escaped gas from extraction sites a public health concern. In addition, polar ice core data indicates that current atmospheric concentrations are greater now than at any time over the past 400,000 years.[18] Figure 4.3 shows the ice-core data with current atmospheric methane concentrations, which have stabilized at approximately 1,751 parts per billion.[19] Furthermore, methane remains in the atmosphere for about a decade before chemically decomposing into carbon dioxide, the most prevalent greenhouse gas.[20]

Figure 4.3 Current Atmospheric Methane Concentrations



Source: Archer, D. "Methane hydrate stability and anthropogenic climate change." Biogeosciences Discuss 4 (2007): 993-1057.

Among the other environmental concerns associated with methane hydrate are the effects of methane seepage, both natural and human-caused, on local environments and populations, which requires further research to assess properly.

Also, extraction of methane hydrates on the continental shelves could disrupt fragile marine ecosystems and cause landslides that destroy equipment and endanger human lives. Yet, the majority of these concerns are associated with the long-term warming of sediments that contain methane hydrate, which is not a technologically insurmountable problem.[21]

The NRC report emphasizes that the DOE program's projects "have substantially addressed the potentially enhanced impacts expected from the commercial exploitation of methane hydrate."[22] Thus, the possible environmental effects of the commercial production of methane from methane hydrate remain unclear, while the technical aspects of commercial production are entering their final research and development stages. Interagency coordination and environmental research is becoming increasingly important.

Political Implications and Public Perception

Methane hydrate is highly appealing to political leaders because of its potential as a major, domestically produced energy source, which would create jobs and reduce U.S. dependence on imported energy. Yet the recent explosion of the British Petroleum rig in the Gulf of Mexico has raised public ire over off-shore development, which prompted the Obama administration to ban new deepwater projects for the near-term. It should be noted, however, that one of the advantages of hydrate reservoirs is their location in relatively shallow regions. Similarly, if carbon dioxide emissions are severely restricted by a "cap and trade" law, then commercial development of methane hydrate would be even more viable. As is the case with natural gas, methane hydrate emits less carbon than coal or petroleum. Such regulation could touch off a vast switch in the U.S. energy portfolio and may incentivize industry to produce hydrate more quickly.

Though extensive research and development has taken place, the public remains largely unaware of the methane hydrate resource. While many environmentalists are wary of the possibility of escaped gas and continental shelf destabilization, the scientific community has yet to reach conclusions as to methane hydrate's interaction with oceanic environments or the global climate. Due to this uncertainty, the public is also wary of commercial development of methane hydrate, as evidenced by Japan's recent announcement of commercial hydrate projects and the concern voiced by environmentalists. Thus, the DOE's current effort to advance the scientific understanding of methane hydrate will become increasingly important in the near-term.

Conclusion

Pipeline infrastructure and depressed gas prices are the primary barriers to bringing methane hydrate into commercial production. The domestic abundance of methane hydrate and the low carbon intensity of methane make it a preferable resource for maximizing U.S. energy security. While methane hydrate represents a potentially vast source of energy, the near-term economic climate prohibits the commercial production of methane from methane hydrates as a viable policy option. Though no significant technical issues inhibit the commercial development of methane hydrate, the geological role of methane hydrate and its potentially negative environmental impacts presents a formidable barrier to commercial development.

Tidal Energy

Introduction

In the 1930s, President Franklin D. Roosevelt unveiled a federal project to harness tidal power using dams as part of the National Industrial Recovery Act. This project fell through, but it may provide the current administration with a framework for further incorporating tidal energy into the U.S. energy mix. Though the bulk of U.S. tidal energy capacity is concentrated in Alaska, tidal could generate as much as 13 GW nationwide.[23] Tidal energy at scale has the potential to augment or replace nonrenewable energy sources in coastal areas, where more than half of America's electricity is consumed.

Tidal energy, also known as marine and hydrokinetic energy, is a form of hydropower that converts the energy of ocean tides into electricity or other forms of usable energy.

Tidal magnitude is determined by a combination of several factors such as the sun's and moon's gravitational pull on ocean water, sea floor and coastline topography, and Earth's rotation. The amount of energy that tides produce and the ability to generate electricity from that energy is determined by tidal magnitude, variation, and speed. Some areas of the world (such as Bay of Fundy and the Bristol Channel) are, geographically speaking, well positioned to produce energy-intensive tides.

Technological Feasibility

The energy from these tides may be captured by a variety of tidal power technologies that can be divided into two main groups: tidal barrage methods and tidal current methods. Both face economic, environmental, and geographic challenges which will be discussed in later sections of this chapter.

Tidal barrages harness energy generated by daily sea level changes. The most suitable sites for tidal barrages are enclosed bodies of water with significant tidal variation, such as bays and lagoons, where sea levels fluctuate by as much as 33 meters per day. It is also possible to site tidal barrages at man-made lagoons. Tidal barrage plants are located worldwide. A prime example is France's La Rance Barrage, which has operated since 1966 at a 240 MW capacity; it draws power from a 23-foot sea level variation. Other sizable barrages include Nova Scotia's Annapolis Royal barrage and China's Jangxia Creek barrage, which operate at capacities of 18MW and 500KW, respectively. Reliability is a technical challenge when operating tidal technology in a bay, as operation environments can be harsh and long-term system maintenance can be costly.

Tidal current technology, the other principle category of tidal energy production, relies upon strategically placed waterway turbines to capture energy from local tidal currents. When water flows through the turbines, they turn an electric generator that produces electricity. This technology is comparable to wind turbine technology and is operational worldwide. Tidal turbines are arrayed underwater in rows and function best where coastal currents run between 3.6 and 4.9 knots (4 and 5.5 mph).[24] In currents of that speed, a 49.2-foot diameter tidal turbine generates as much energy as a 197-foot diameter wind turbine.[25] Turbine farms are best sited close to shore in waters 65.5–98.5 feet deep,[26] and can also be situated along tidal fences that reach across channels between small islands or across straits between the mainland and an island.[27] Turbines could potentially hurt fish and other sea life, which could become problematic for those ecosystems and for human food supplies.

Examples of tidal current facilities in operation include Northern Ireland's Strangford Lough generator, Vancouver's Race Rock facility, and South Korea's Jindo Uldomok plant. These facilities operate at 1.2 MW, 65 kW, and 1 MW capacity, respectively, and all are designed to function with minimal environmental impacts to waterways.

Development of tidal energy infrastructure is in its infancy. Globally, it is estimated that more than 300 hydrokinetic endeavors are planned or underway.[28] Although the vast majority of these projects are nowhere near reaching commercialization, energy-generation potential is vast. Within the next four years, power from hydrokinetic sources could reach as much as 3.8 GW.[29] If the present day projects produce viable mechanisms for converting tidal energy into electricity, such power could reach 200 GW by the year 2025.[30]

Many at-sea technology device concepts and laboratory tests are in the development stage but there is very limited at-sea testing. Currently, only two at-sea test centers for tidal hydrokinetics exist, one at the European Marine Energy Center (EMEC), located on the Orkney Islands in Scotland, and another at the Fundy Ocean Research Centre (FORCE), at Minas Passage, Canada.

Though there is a limited amount of federal funding for tidal energy technology, Figure 4.4 shows that the United States also has several ongoing projects.[31] The U.S. Navy is working on Puget Sound Demonstration Projects, Verdant Power (Roosevelt Island), Clean Current (Race Rocks, Canada), Open Hydro (Fundy Open Research Center), and Marine Current Turbines (as used in Scotland). The Maine Maritime Academy is partnered with the Tidal Administration and Evaluation Center. There are also private partnerships with Open Hydro.

Tidal energy is both predictable and reliable, and the available technology used in ongoing U.S. projects is effective in producing energy for local communities. Ocean currents carry more energy than air currents (wind) because seawater has a much higher density than air.[32] Thus, tidal is capable of producing energy more efficiently than wind-generated energy. Analysis of current technology available globally indicates that tidal has proven to be highly effective in terms of energy supply and cost efficiency in Canada, Scotland, and Ireland.

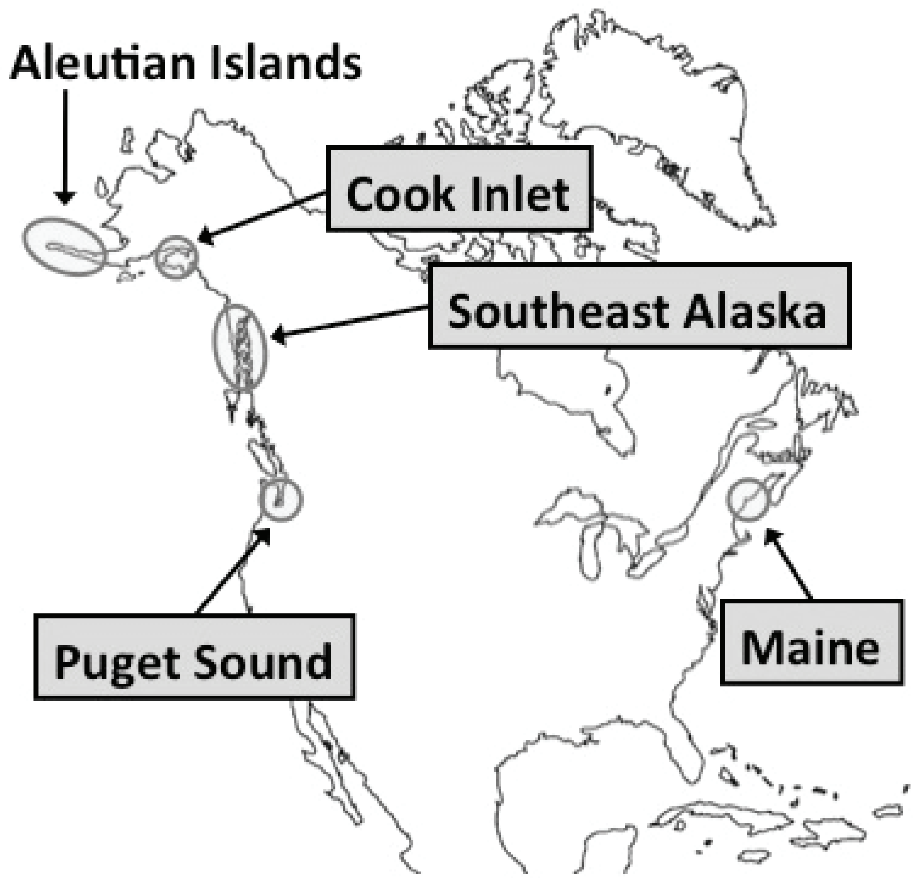
The tides along the Pacific Northwest coast fluctuate dramatically, as much as 12 feet per day, and thus are ideal for implementing tidal current technology such as newly-developed undersea turbines. Oregon State University, the University of Washington, and the Northwest National Marine Renewable Energy Center are working on projects in Pacific Northwest waters. Also, the coasts of Alaska, British Columbia, and Washington have exceptional energy available. In Maine, the Ocean Renewable Power Company (OrpC) launched the first U.S. tidal grid-compatible power system in August for $2.5 million.

Economic Feasibility

The economic feasibility of tidal energy is a complicated matter and depends in large part on the consideration of variables heretofore not included in most cost analyses.

First, it must be noted that development of the tidal energy-generating infrastructure is in its infancy. Around the globe, it is estimated that over 300 hydrokinetic endeavors are in the making.[33] Although the vast majority of these projects are not anywhere near reaching commercialization, the potential that exists is vast. Within the next four years, power from hydrokinetic sources could reach as much as 3.8 GW, which could result in a considerable offset in greenhouse gas emissions.[34] Further, if the present day projects in

Figure 4.4 Ongoing Tidal Projects in North America



Source: Polagye, Brian. "Tidal Energy: Status and Trends." NW National Marine Renewable Energy. Northwest Fisheries Science Center (*PowerPoint*, slide 5) December 8, 2009.

process produce viable mechanisms for converting tidal energy into electricity, such power could reach 200 GW in the year 2025.[35]

One concern is that if the 300 or so projects currently underway do not produce sufficiently efficient machinery to compete with conventional sources of electric generation, then the potential offsets mentioned above will never come to fruition.[36] The essential component is the development of commercial-scale endeavors that will attract investors and provide suitable motivation for business ventures. Ultimately, it is creating a suitable profit motive that will ensure that this technology is utilized to its fullest potential, with the concomitant reduction in greenhouse gas emissions.

Several studies have been conducted to determine the actual cost of generating electricity through tidal energy conversion. The results are mixed, but most point to the same conclusion—at this point in its development, generating electricity from tidal generation is not competitive with conventional power generation. Such a conclusion is to be expected, however, given that tidal energy is in many ways still in its infancy, despite having been utilized in select locations for longer periods of time.

As shown in Table 4.1, the cost from low to high, in dollar per Megawatt-hour for electric generation is as follows: tidal from \$194 to \$453, solar from \$226 to \$424, thermal solar from \$238 to \$313, offshore wind from \$143 to \$260, biomass from \$86 to \$189, onshore wind from \$62 to \$119, coal fired from \$56 to \$63, and geothermal from \$52 to \$112.[37] Tidal, sitting at the high end of these costs, cannot be expected to be competitive with a cheaper fuel, like coal.

Table 4.1 Electricity Generation Cost Range

Electricity Generation Cost Range (US Dollars per megawatt-hour)		
Energy	**Low**	**High**
Solar (c-Si PV)	\$226	\$424
Tidal	\$194	\$453
Solar (Thermal)	\$238	\$313
Wind (Offshore)	\$143	\$260
Biomass	\$86	\$189
Wind (Onshore)	\$62	\$119
Coal-fired	\$56	\$63
Geothermal	\$52	\$112

Source: "The Economics of Alternative Energy," *Bloomberg Businessweek* 4199 (2010): 58.

One caveat that must be noted is that the above figures do not include the cost of carbon or other greenhouse gas emissions, which if quantified, could be substantial. While installation of tidal energy-producing equipment involves greenhouse gas emissions, the day-to-day energy-producing operations of the facility do not.

One of the greatest benefits of tidal power, especially in economic terms, is its predictability. Therefore, the rate of return on a project, once tested and in operation, will be reliable and will eliminate the added uncertainty, or risk, costs that another type of energy project would incur. The tide comes in and goes out in a predictable fashion each day, allowing for tidal power to be neatly incorporated into a municipality's power portfolio.[38]

On the other hand, the rising and falling of the tides do not necessarily coincide with peak demand, which makes tidal power a little less convenient than a fuel source such as natural gas, which can be switched online to meet unexpected need. Another cost associated with incorporating tidal power is that when tidal power displaces coal power, complications from such cycling arise. An example of this is that when coal-fired electric generating units are turned on and off, the coal-fired equipment undergoes a significant amount of wear and tear. This in turn increases maintenance costs and the time associated with repairs of those facilities.[39] When such operating and maintenance costs applicable to coal-fired plants are added to the estimates for generating electricity from tidal energy, the resulting price is much higher than other energy sources. It has been postulated that the overall costs of tidal generation would outweigh any societal benefits, from the reduction of greenhouse gas emissions, such electric production generates.[40]

In another study conducted in Canada, the price of electricity generated from tidal power was found to be far more competitive over a 20-year time horizon. This study focused on the Quatsino site near Vancouver, in British Columbia, Canada. That study found the average cost of tidal electricity to be about 8 cents per Kilowatt-hour, which at the time was only slightly greater than the price of conventional electricity.[41] These figures reflect the site-specific nature of price forecasting-proposed tidal energy projects.

On the whole, tidal energy could one day provide around 4 percent of the nation's energy needs.[42] Put in perspective, this represents a relatively substantial portion of the energy generation sector, about one-fifth of the amount of energy currently generated from nuclear power.[43] Additionally, with the improvements in design taking place in laboratories and at test sites across the nation, within the next five to seven years tidal energy production could become competitive with other forms of electricity.[44]

Moreover, tidal energy should be considered in light of what it can provide that conventional energy production cannot. Many towns in coastal areas and small island communities generate power from diesel generators, which creates a significant amount of air pollution. Conventional energy generators have determined that the costs of connecting such dispersed towns into the main energy grid are prohibitive. In such a situation, tidal energy could play a pivotal role in providing affordable energy, without the negative environmental costs that come with diesel power.[45]

An additional consideration, and one often overlooked, is the economic benefit that tidal energy production can bring to a community. Small towns dependent on fishing have seen tough financial times over the years, and this decline has had a significant impact on the ability to retain a labor force. This decline can be offset by an energy industry that stimulates the economy with new jobs and related profits from the enterprise.[46]

Current Regulatory Framework

The Federal Energy Regulatory Commission (FERC) has primary federal jurisdiction over the licensure of tidal energy projects. According to FERC, hydrokinetic projects are "Projects that generate electricity from waves or directly from the flow of water in ocean currents, tides, or inland waterways."[47] Therefore, the various groups conducting cutting-edge research in tidal energy conversion must work with FERC when transitioning from concept to implementation.

The entire licensing process is rather straightforward and has been streamlined to accommodate the participants in this budding field of energy. Initially, one must apply to FERC for a preliminary permit which grants up to three years of authorization to conduct formal studies at a specific site. This permit requires regular updates to the commission detailing recent actions and the overall status of the project.[48]

Three different permitting mechanisms are available to participants who are ready to proceed to the construction phase. These mechanisms are integrated, traditional, and alternative. The integrated licensing process focuses on gathering information and conducting studies on the front end of the process. The traditional licensing process follows a more conventional three-stage authorization procedure. The alternative licensing process involves tailoring the procedure on a case-by-case basis.[49] These permits grant the operator from 30-50 years to generate electricity from tidal power.[50]

Further, FERC has put alternative mechanisms in place that allow some flexibility in the licensing process. One example is the authorization for small or low impact power plants. This program facilitates the authorization of projects that would not substantially impact the environment.[51] Another example is the pilot project licensing procedure that FERC has instituted to encourage development of tidal technologies. These authorizations facilitate on-site testing of experimental technology while ensuring that negative environmental impacts are avoided.[52]

One drawback associated with licensing tidal energy technologies is that other federal agencies besides FERC weigh in on the decision of whether to grant authorization. Many attempts to obtain a license to generate tidal power have been stymied because of concern over fisheries brought forward by the federal government.[53] Therefore, despite support and flexibility on the part of FERC, other federal regulatory agencies have yet to embrace this nascent technology. For instance, the Army Corps of Engineers or the National Marine Fisheries Service may not have specific jurisdiction over the issuance of licenses to generate power, as FERC does, but these agencies do weigh in on the possible impact of such operations on the ecosystem.[54]

An example of the difficulties involved in getting a tidal energy project licensed can be found in Ocean Renewable Power Company's TidGen project, proposed for Eastport, Maine. This project was begun six years ago, and is still laboring through the process of federal authorization. The hope for this industry is that this initial licensing attempt will be the beginning of a learning curve for federal agencies having jurisdiction over, or an interest in, the placement of tidal power systems in rivers, bays, or the ocean. If every tidal energy power project took in excess of six years to permit, then this energy source would not be an economically viable alternative to conventional sources of energy, such as coal or natural gas.[55] States also have permitting procedures for tidal energy projects that vary by jurisdiction.

Environmental Impacts

Since no GHGs are emitted from tidal energy, there are fewer environmental impacts compared to other traditional energy resources. Although environmental impacts from tidal energy devices and systems are nascent, the available 2009 DOE research indicates that tidal energy produces minimal environmental and human health impacts.[56] Tidal power technology builds on lessons learned from hydropower, wind, and offshore oil industries. This section explores the potential negative consequences and compares them with the few available observations of the effects on marine habitats. The observations to date have not demonstrated impacts to the extent that DOE research hypothesized. Instead, observation and research continues to encourage the tidal power industry to move forward with investing in the development of this renewable energy resource. To anticipate and understand the full extent of this technology, all research hypotheses must be considered and discussed in detail.

Impacts on Marine Life

Only a limited number of devices have been tested at sea. Consequently, the tidal power industry does not have a standard preferred technology.[57] Specifically, research on offshore wind environmental impacts, ecological effects assessment, and monitoring literature is useful for future research and analysis of tidal power.[58] Environmental effects of components in the marine environment are similar but not completely analogous to effects associated with offshore wind installation.

Tidal energy turbines spin relatively slowly, unlike wind turbines. Research studies support the claim that tidal energy does not disrupt normal habitats, and that ecosystems are not negatively affected or disturbed by tidal energy.[59]

In contrast, other research claims that tidal power plants which dam estuaries have the potential to disturb sea life migration, and that resulting silt build-ups behind facilities could affect local ecosystems.[60] Today, tidal turbines appear as the least environmentally damaging of the tidal power technologies because they do not block migratory paths. However, a DOE 2009 analysis claims that migrating animals such as anadromous fish, Dungeness crab, sea turtles, marine mammals, and birds could be impacted negatively if the installation is placed in a migration path. Therefore, while there is research that supports the claim that ecosystems are not disturbed by tidal power technology, the DOE contradicts such claims and warns that tidal technology installations have the potential to affect migration paths negatively in the short term. Since there is not yet sufficient long-term research available, it is too soon to understand fully the extent of the impact on the marine environment. Further observation of tidal technology and its impacts is needed to gain a thorough understanding.

Tidal Energy Device Evaluation Center (TEDEC) Executive Director, Rick Armstrong, admits that agencies' initial reactions to tidal turbines are that they are a "sushi maker."[61] He clarifies that turbines are aeronautical, however, with blunt front-ends where pressure builds up while lacking a component to suck in and tangle fish.[62] Ongoing concern with marine mammals remains since TEDEC does not have any data yet on nearby schools of dolphins, though TEDEC has helped develop conservation areas for scallops off the coast of Maine.[63]

There are, however, numerous potential adverse environmental impacts from tidal energy development.[64] This includes alterations of currents, waves, substrates, sediment transport and deposition, and habitats for benthic organisms. Additionally, potential generation of electromagnetic fields, interference with animal movements and migrations, and strike by rotor blades or other moving parts exists.[65] Depending on the tidal energy technology, several types of hazardous materials could be present, such as hydraulic fluids for hydraulic power trains, dielectric fluids, anti-biofouling paints and coatings, and lubricants.[66] Chronic release of these chemicals could result in toxicity and bioaccumulation of toxins including heavy metals.[67]

Increased activity at sites of device platforms, anchors, and cables could potentially lead to habitat disturbance and destruction. Impacts include direct and localized habitat destruction and alteration if suspended sediments smother neighboring habitats.[68] Device presence can displace benthic plants and animals or change their habitats by altering flow, wave structure, water quality, or substrate composition.[69] This substrate change could attract a rocky reef community of fish and invertebrates not previously present at the site, which could either increase biodiversity or enable the introduction of invasive species.[70] To reduce these impacts, minimal device assembly could be required using a barge or special-purpose vessel, though specific installation components depend on the particular technology. All devices require anchoring methods at the site and some means to transmit the power to shore.[71] Currently, devices are assembled on land as much as possible to minimize operations at sea, thus minimizing noise disturbance in marine habitats.[72]

Sediment Transport, Erosion, and Deposition

Slower currents, due to the tidal power facilities, will increase sediment deposition but decrease sediment transport.[73] These changes may alter bottom substrates in locations downstream, which could cause localized changes to plant and animal communities.[74]

According to Armstrong, "During operation, the formation of eddies in the wake of tidal devices may promote the deposition of sediment, while accelerating velocity around the structures may promote sediment scour, resulting in significant changes in sediment that may disrupt the benthic community."[75] Increased sedimentation has the potential to increase the accumulation of sediment toxins and may negatively affect sea grass beds in shallow water near the tidal installation by smothering or decreasing growth rates.[76]

On the other hand, the presence of tidal generating devices on the seabed may provide benefits to some marine species and habitats, most immediately by limiting access and fishing at the site.[77] The 2009 DOE example indicates that device structures in the pelagic environment may act as fish aggregation/attraction devices, which may in turn increase predation on aggregated species.[78] Placement of new tidal energy generation structures at the scale required for commercial operations would likely interfere with animal movements and migrations.[79]

Water Quality

Potential spills from increased boat traffic during installation could increase local water turbidity from suspended sediments and mobilization of contaminants associated with those sediments.[80] Many tidal energy sites, however, have coarse sediments, including cobble or rock, so that sediment re-suspension will not occur.[81] In semi-enclosed bays or estuaries, there is a risk of reduced water circulation that could create or exacerbate existing water quality concerns, including accumulation of effluent, eutrophication, and hypoxia.[82] Tidal energy projects could affect sea surface temperature and seasonally influenced biological processes such as phytoplankton growth.

Installation of tidal turbines in coastal waters could affect tidal heights. Even small changes could have a profound effect on near shore habitats.[83] Changes in the tidal height of only a few millimeters to a centimeter could change the strength and timing of the estuarine plume from rivers and streams, further altering near shore habitats.[84]

Environmental Impact Summary

Overall, there is a general consensus that the environmental impact of tidal technology is minimal. While some industry experts claim that there are no negative impacts on marine life, some research studies indicated that there remains a potential negative impact on migratory paths during the installation process. Air emissions are also associated with the construction of an underwater tidal power facility.

Damming a bay or estuary could result in negative impacts on aquatic and shoreline ecosystems, as well as navigation and recreation, by changing tidal flows.[85] The few studies that have been undertaken have determined that each site has unique environmental impacts, depending on local geography.[86] For example, the La Rance barrage has changed the tides slightly, with a negligible environmental impact, while it is estimated that in the Bay of Fundy, tidal power plants could decrease local tides by 15 centimeters.[87]

While tidal power causes some negative impacts to the marine environment, this energy source does provide some offsetting benefits, including no GHG emissions. There is not yet enough research and analysis, however, to thoroughly show the long-term impact on the marine environment.

Political Implications and Public Perception

Tidal energy is popular for three principal reasons: (1) it is renewable, (2) it does not involve GHG emissions during routine operation of the plant, and (3) the resource is domestic and does not rely on foreign cooperation. For these reasons, the federal government has been quite supportive of tidal energy in recent years.

In 2010, the DOE granted $37 million to marine and hydrokinetic projects, much of which was applied directly to tidal energy research and implementation. The Ocean Renewable Power Company based in Portland, Maine received $10 million to continue development of a tidal plant connected to the energy grid. Public Utility District No. 1 in Snohomish, Washington, received $10 million to install a system that will generate 1 MW of peak energy.[88] Taken together, these awards and others reflect the overall support of clean energy projects by both elected officials and the public at large.

The public initially had grave concerns over the impact of tidal energy projects in their backyard. When plans were announced to begin testing new technologies in the rivers of the Northeast, local citizens protested such research because of fears of environmental degradation and negative impacts on wildlife and fishing operations. However, the tidal power industry made clear that the kinds of technologies to be used would not have a destructive influence on the ecosystem. By increasing communication between researchers and the community, experts in tidal energy technologies were able to allay fears and generate support for these efforts.[89]

Concerns over the economic wellbeing of coastal communities also fueled initial public skepticism about the impact of tidal energy. For instance, in Eastport, Maine, local fishermen derive much of their livelihood from harvesting scallops in the local bay. These fishermen were initially concerned about preserving the habitat for their cash crop. Over fishing had, however, resulted in a decrease in the local scallop population in recent years. One benefit of placing a network of tidal energy turbines in the bay would be to provide a refuge for the scallops, thus preventing localized decimation of the species.[90] This example may be site-specific, but it represents the varied nature of tidal energy projects and the unique circumstances that may apply in a given situation.

Conclusion

Tidal technology is one of the cleanest renewable resources in terms of non GHG-emitting energy alternatives. The technology, once in place, is available at a competitive cost and the North American coast possesses many geographic advantages for harnessing tidal power. While the environmental impacts appear minimal, both additional research and continued monitoring of marine habitats are required. Tidal technology enjoys both general public acceptance and industry support as a reliable, renewable energy resource for the 21st century.

Low Energy Nuclear Reactions

Introduction

In the simplest terms, cold fusion refers to a process in which nuclear fusion takes place within electrolysis cells at room temperature, giving off excess heat. Today, the process of cold fusion is often referred to as low energy nuclear reactions (LENR) since it takes place at room temperature—a low energy state—whereas hot fusion occurs at very high temperatures.

The term “cold fusion” appeared as early as 1956 in a *New York Times* article discussing Luis Alvarez’s work on muon-catalyzed fusion.[91] Even before the concept appeared in print, however, scientists Friedrich Paneth and Kurt Peters were studying cold fusion as early as the late 1920s. They reported the transformation of helium into hydrogen by means of a nuclear fusion reaction, but they later retracted this report, indicating that the helium was actually from the background air.[92] In 1927, another scientist working in the field, J. Tandberg, reported that he had fused hydrogen into helium and applied for a Swedish patent for "a method to produce helium and useful reaction energy."[93] The recent retraction by Paneth and Peters fueled a denial of this patent and it can be argued that these events cast early doubts and skepticism on cold fusion research.

In 1989, Martin Fleischmann of the University of Southampton in England, and Stanley Pons of the University of Utah, published an article entitled "Electrochemically induced nuclear fusion of deuterium" in the *Journal of Electroanalytical Chemistry* on March 11, 1989.[94] Soon after, the team held a press conference. Fleischmann and Pons reported that they measured excess heat production in the form of fusion reactions. Yet, after their announcement many laboratories and scientists within the United States and around the world were not able to consistently reproduce Fleischmann's and Pons' results. The two scientists even conceded in their 1989 article that "the results reported here raise more questions than they provide answers, and that much further work is required on this topic."[95]

After suffering bad press in the months and years following the 1989 announcement, and being relegated to a "pseudo-science" status in many researchers' opinions, the LENR moniker may help current and future researchers associate less negativity to this ongoing field of research.

Technological Feasibility

In its current state of development, LENR is not technologically feasible because experimental results are not replicable or consistent. Despite numerous attempts around the world, most LENR experiments have failed. Dr. Douglas Morrison of CERN (Organisation Européenne pour la Recherche Nucléaire) commented that "... essentially all West European attempts to duplicate the Pons-Fleischmann experiments had failed."[96]

Not only is the science of LENR not sufficiently developed, but neither are the complementary technologies. Both material sciences and laser technology may be insufficient to pursue large-scale LENR related research. Also, the current scientific theories behind LENR do not sufficiently explain the excess heat production. A scientific explanation of LENR accounting for such excess heat production would require rethinking many accepted theories in nuclear and particle physics, if not the development of new theories all together. For example, gamma radiation, which should be released in the common LENR reaction, has never been detected in experiments.[97]

Economic Viability

Since LENR technology is not yet easily replicable and is not widely accepted, the economic viability of mass implementation is entirely speculative. Although the infrastructure is in place to deliver the necessary water, the cost of building new, or converting existing, power plants to use the technology is unknown. Given the high costs of nuclear plant construction undertaken in the 20th century, however, one hopes that should the price be high, it would not be the sole deterrent for development of the technology.

If LENR technology attains mass implementation, there would likely be notable economic disruptions in the short term as markets adjust to the incorporation of this new technology. Economic stability in the Middle East is likely the most vulnerable since oil is a primary commodity, and the main driver of economic growth within the region. Beyond the known economic disruptions that would occur within the fossil fuel industry, it is difficult to predict how significant or long-lasting the total economic impacts associated with implementation of the technology would be. Much of the scope of the impacts will depend on how the technology is developed, implemented, and distributed.

At present, the economics of LENR relate essentially to funding and how research money is distributed. These topics are discussed in more detail below.

Current Regulatory Framework

Currently there is no regulatory framework for existing LENR technology, as it has yet to achieve public and scientific acceptance. Much as with the economic implications, it is difficult to specify what framework would be required should LENR reach mass implementation. Since it produces no toxic waste, it cannot be compared to the highly regulated nuclear industry. Since it would not require excavation, processing, or a new method of distribution to households, it cannot be compared to the coal or natural gas industries' regulatory frameworks.

Unlike current electricity generation technologies, LENR generators could be installed in individual homes and businesses. In a theoretical distribution system, LENR technology could be implemented in households through the existing power infrastructure.

Ultimately, a new system of regulations would have to be developed since the dangers associated with LENR lie in the hypothetical amount of power it can produce. Ensuring against proliferation of the technology for destructive purposes would likely be the main focus of LENR regulations.

Environmental Impacts

Were LENR to achieve mass implementation as an energy source within the United States and worldwide, the environmental impacts would be significantly positive. There are no carbon emissions or toxic byproducts resulting from LENR. Compared to the current primary energy sources of coal, natural gas, and nuclear, LENR has virtually no carbon footprint. This is possible not only because there are no carbon emissions, but also because the primary resource needed to activate LENR is water. Therefore, no new infrastructure would be required for households to implement the new technology; existing water supply lines suffice. Based on very approximate figures, the American household that uses 50 kW of electricity per day would only need between 12 and 24 gallons of water per day, depending on the number of hours spent at base and peak load.[98]

Political Implications and Public Perception

LENR has suffered several political setbacks in the past few decades from which the field has never fully recovered. Most pundits have changed the name of the field itself from "cold fusion" to "low energy nuclear reaction" in an attempt to distance it from the 1989 Fleischmann and Pons incident. These attempts have not—as far as mainstream science is concerned—been persuasive. One respected physicist elaborated: "technology is practical art based on demonstrated fundamental science...and there is no such basis for 'cold fusion.'" He contends that the only development in the field is that "the small circle of zealots who keep pushing on this have changed the name from 'cold fusion' to the less incendiary one of 'low energy nuclear reactions' or LENR."[99]

The view that LENR is "pseudo-science" was furthered by 1989 and 2004 DOE reports and the department's consequent handling of funding requests. The 2004 report summarized the panel's findings by stating that the experiments conducted to date "do not present convincing evidence that useful sources of energy will result from the phenomena attributed to cold fusion."[100] The report recognized the promise in some of the experiments carried out to that time, but most of the panelists noted the need for a more rigorous scientific approach. But when modest funding requests were made to pursue further research in areas that the 2004 report highlighted, they were summarily refused.[101]

Thus, despite some progress in the field, there has been little recognition and virtually no funding from government sources. This is likely because of competition from a different, yet related, field of research: hot fusion. Unlike LENR, where reactions can occur at room temperature, hot fusion reactions require very high temperatures and generally use plasma. There are a number of hot fusion reactors, such as tokamaks, around the world that have successfully demonstrated hot fusion and replicated the results. The largest of these is currently under construction in France and is called the International Thermonuclear Experimental Reactor (ITER). This international project is funded by the United States, European Union, China, Japan, Korea, Russia, and India. The total price tag will be around $21.5 billion.[102]

With such a large investment in a competing field—coupled with a number of public relations disasters—it is unlikely that science policy makers will reverse their position on LENR funding. In an interview with an independent LENR researcher, he suggested that if LENR researchers could receive just a small amount of federal funding their collaborative progress could be significant. A few hundred thousand dollars dedicated to LENR research would be considered a substantial amount by this small group of researchers.[103]

In addition to a lack of funding, he also believes that "there is a huge PR crisis" facing LENR research. When pressed on what could reverse this trend and return some prestige to LENR, he says that a working, applicable, and marketable device would be needed. He elaborates that "nothing else will save our field."[104] Given the current lack of funding and buy-in, however, if a working prototype is not built, progress is anticipated to be very slow.

The recent announcement by Andrea Rossi of the University of Bologna must also be considered. At the time of publication, Rossi has plans to unveil a 1 mW device at the end of October, based on his nickel-hydrogen catalyzer.[105] The four LENR experts interviewed for this chapter were all in agreement that if Rossi's device is successful the timeline for implementation will be fast-tracked. Consequently, the whole playing field for energy technologies will be transformed.

Conclusion

If Rossi's device is not successfully delivered within the next year, combined with the lack of funding, overwhelming skepticism in the scientific community, and lack of peer reviewed articles, it is unlikely that this technology will see much development over the next few decades. This leads us to conclude that LENR, if technically viable, could only be a part of the U.S. energy mix in the 22nd century, or beyond. Additionally, if LENR is able to reach mass implementation, it is difficult to say whether it would be a "secure" source, based on our definition of "energy security." Although LENR could be produced domestically and would greatly reduce the detrimental environmental impact of the current energy mix on the planet, the uncertainty regarding LENR's economic viability and the future regulatory framework do not support the case for the technology's "security."

If, however, Rossi can deliver his device in a timely manner the questions revolving around economic and technical viability will be answered much sooner. Moreover, a clean energy source will have been identified and an energy revolution will begin.

Carbon Capture and Sequestration

Introduction

In his 2011 State of the Union address President Obama identified "clean coal" as part of his list of clean energy sources.[106] Carbon capture and sequestration (CCS) technology offers the ability to balance the security advantages of a plentiful conventional energy resource with the growing concern over carbon dioxide emissions. Besides providing nearly 70 percent of U.S. electricity, coal is also an important mainstay of many state economies. Furthermore, CCS has the potential to increase U.S. domestic supplies of oil through Enhanced Oil Recovery. This chapter will explore the technical, regulatory, environmental, political, and economic facets of CCS and geological storage (GS) and their implications for energy security.

Technological Feasibility

Carbon capture and sequestration has the potential to significantly reduce the amount of carbon dioxide released into the atmosphere from coal-fired power plants by preventing the carbon dioxide from ever getting into the air. The carbon dioxide produced by burning coal is captured and then transported by pipeline or truck to a sequestration well where it is injected and permanently stored in geologically stable formations deep underground. These formations include saline aquifers and unmineable coal seams.

There are three principal capture systems for CCS: pre-combustion, post-combustion, and oxy-fuel combustion. Pre-combustion systems convert the fuel into gaseous components by applying heat and steam under pressure. This allows the capture of carbon dioxide while it is still highly concentrated before the fuel mixes with air and burns. Post-combustion systems burn coal in the presence of air and capture carbon dioxide after the coal burns. Post-combustion is the least effective way to capture carbon dioxide. Oxy-fuel combustion burns coal in an oxygen enriched environment rather than air. The result is carbon dioxide and water vapor. The water can easily be separated, leaving a stream of carbon dioxide ready for capture.[107] While some older coal-fired power plants can be retrofitted to utilize these CCS systems, Integrated Gasification Combined Cycle (IGCC) coal-fired plants offer the most cost effective turbine technology for CCS.[108]

Captured carbon dioxide can be injected into depleted oil and gas reserves to improve extraction efficiency through a process called Enhanced Oil Recovery (EOR).[109] In the EOR process, carbon dioxide is injected into older oil reservoirs that have already produced most of the oil possible through conventional extraction. By pumping carbon dioxide into an injection well, EOR can recover as much as 30-60 percent of a reservoir's oil compared to conventional extraction methods which recover only about 20-40 percent of a reservoir's total oil.[110]

The EOR process works in the following manner: carbon dioxide is pumped down injection wells in a liquid form. The carbon dioxide combines with the oil and reduces its viscosity and "stickiness." The result is that the previously "trapped" oil separates from rock to flow into the production well more easily. The carbon dioxide may then be recaptured and used to repeat the EOR process, until it is eventually stored indefinitely in the exhausted reservoir.

EOR using carbon dioxide is used in many places in the United States including the West Texas Permian Basin where it originated in the early 1970s. Naturally occurring carbon dioxide reservoirs are usually harnessed for injection, but pilot projects in Texas and other parts of the country are capturing carbon dioxide from gas plants, as well as other industrial plants, for use in EOR processes. The DOE estimates that EOR could be used to recover 43 billion barrels of what they term "stranded" oil in mature U.S. oil reservoirs. In Texas alone, there are more than 800 identified EOR candidate reservoirs.[111] EOR applications are geographically limited, though, so large-scale CO_2 mitigation efforts will require economical commercial development of CCS to capture CO_2 from power plant operations.

CCS also occurs outside of the United States. The Weyburn/Midale project in Southern Canada (Saskatchewan) began in 2000 and is the largest CCS project in the world. A 200-mile pipeline pumps carbon dioxide from a gasification plant in North Dakota to an oil reservoir in Canada. It is expected to add about 25 years of production life to the Saskatchewan oil fields. Another accomplishment of this project is that it has proven the safety of underground carbon dioxide storage on a small scale for more than a decade, with about 18 million tons of carbon dioxide pumped underground and stored.[112]

Based on a 2010 DOE/NETL report, advanced technologies will not be ready for full-scale demonstration until 2020, with commercial deployment estimated at 2030.[113] Besides cost, geological CCS still faces the uncertain factor of time. While the Weyburn/Midale facility has safely sequestered CO_2 below ground for more than a decade, the time frame for geologic storage is indefinite. More research and development, as well as commercial support, is needed for CCS technology to move beyond concept testing and into commercial use.

Economic Viability

Currently, the only economically viable way to implement CCS is in conjunction with enhanced oil recovery, as the sales from the additional produced oil offset the costs associated with CO_2 capture and/or transport. The potential secondary revenue stream from CCS as a CO_2 provider for EOR stands out compared to other green technologies. Today, however, CCS technology's cost is prohibitive for commercial deployment. Currently, the DOE supports research and development to make CCS more cost effective. The DOE is funding multiple demonstration projects, including one at The University of Texas at Austin, with more than $4 billion in hopes of reducing CCS implementation costs through refining technology. Private investment in current demonstration projects totals about $7 billion.[114] The main CCS expense categories are capture, transport, and storage costs.

Capture

The most expensive part of CCS is the capture process, which currently makes up about 75 percent of the cost.[115] Capture costs are about $25-$65 per ton of CO_2, depending on the type and age of the plant as well as the type of capture technology implemented.[116] Further, a typical power plant is at least 20 percent less efficient with the addition of the current CCS capture technologies.[117] Improvements in capture technology could, however, reduce this number to as little as 6 percent.[118] Currently, CCS capture adds between 2 and 12 cents per kilowatt-hour, depending on the type and age of the plant.[119]

The higher electricity costs resulting from CCS will be paid by electricity consumers, state or federal governments through subsidies, utilities companies, or some combination of all three. The high costs associated with retrofitting older coal plants could render this option uneconomical absent carbon pricing mechanisms.[120]

Transportation/Storage

The IEA estimates that between 200,000 and 360,000 kilometers of new pipelines will be necessary to implement CCS technology on a commercial scale worldwide between now and 2050. Building this new infrastructure to pipe carbon dioxide to storage sites will cost between $0.5 trillion and $1 trillion over the next four decades.[121]

Depending on the distance transported, the volume of CO_2 flowing through a given pipeline, and the choice of storage site (saline aquifers, offshore brine, depleted oil and gas reservoirs, etc), transport costs plus storage costs equal between $5 and $15 per ton of CO_2.[122] [123] The CO_2 value for tertiary oil recovery can offset CCS costs significantly (and even zero out costs completely), depending on the type of capture and pressurization techniques used and the volume of CO_2 transported. Capture methods for a gasification plant are far more efficient and thus cheaper than for a conventional pulverized coal plant because gasification plants yield a pure CO_2 stream. Further, depleted oil and gas fields present the most economical storage sites because the infrastructure for injection is already in place and the geology is well-known.[124]

Additional Costs

Another potentially significant source of CCS costs comes from possible subsidization of developing countries' participation in CCS projects. If the United States values greenhouse gas reduction as a component of energy security, it must consider exporting CCS technology at a low cost to developing countries and paying them to implement CCS. Otherwise, those countries may have little immediate incentive to do so. Developing countries' economic growth and rising standards of living generally depend on access to cheap, readily available energy sources such as coal. The infrastructure expenses of CCS implementation, as well as the recurring cost of reduced plant efficiency, make it unlikely that developing countries will voluntarily adopt CCS technology without monetary incentives that make up economic growth losses. Given that 40 percent of all electricity generated globally is produced by coal-fired power plants,[125] this level of cost prohibition will remain a concern.

China and India represent two developing countries whose energy activities account for a rapidly growing percentage of global greenhouse gas emissions. Though China is investing in "greener" energy, such as wind, its coal consumption is expected to double over the next two decades. China derives 80 percent of its electricity from coal and is adding an average of one new coal-fired power plant per week to its fleet. Its current coal-fired plants emit twice the amount of carbon dioxide as U.S. coal plants,[126] though it is currently developing a number of CCS pilot plants, including GreenGen, which aims to increase efficiency of Chinese coal-fired plants. China is driven to develop these higher efficiency plants due to concerns about the amount of freshwater that is being diverted to coal plants in the country. Experts contend that coal's influence on climate change in the country has already diminished the amount of China's freshwater reserves. It is important, however, to consider whether China actually has near-term incentives to deploy CCS technology on a commercial scale. At least one reason that China is developing CCS technology is for energy security purposes; if greenhouse gas emissions become internationally restricted in the future, China could continue to utilize their coal reserves via CCS and also export the technology abroad.[127]

Current Regulatory Framework

Effective regulation of CCS is essential to energy security to promote the technology's development and safe commercial application. Regulation of CCS and GS of carbon dioxide is split between the federal government and the states. While there has been recent EPA movement to clarify certain regulatory issues that have impaired the commercial application of CCS, there is still a need for clarification in other areas.

The federal government manages regulation of GS through the EPA. In November 2010, the EPA finalized its rules regarding GS under Class VI of the Safe Drinking Water Act's Underground Injection Control (UIC) program. This included new rules on Drinking Water Protection and Greenhouse Gas Reporting. The Drinking Water Protection provision is designed to ensure that wells used for geologic sequestration of carbon dioxide are appropriately sited, constructed, tested, monitored, and closed. The Greenhouse Gas Reporting provision sets requirements for facilities that conduct GS.[128] The UIC regulates the construction, operation, permitting, and closure of injection wells that place fluids—or in this case, carbon dioxide—underground for storage or disposal.[129]

While the EPA is the enforcement arm of the federal government's involvement in CCS, the DOE also plays an important role in supporting CCS technological advancements through research and development funding. DOE's project with the National Energy Technology Laboratory (NETL) is specifically aimed at reducing the cost of CCS implementation and maintenance across the fossil fuel sector. The DOE's CCS research and development budget received an additional $3 billion from the 2009 American Recovery and Reinvestment Act. The hope is that government investment in CCS-related infrastructure along with private cost-sharing plans will further hasten CCS implementation across the United States. Some of the biggest beneficiaries include:

- $800 million for the Clean Coal Power Initiative which provides government co-financing of more efficient coal technologies

- $1 billion for FutureGen 2.0, a clean coal repowering program and CO_2 storage network

- $1.5 billion for Industrial Carbon Capture and Storage, a competitive solicitation for large-scale CCS projects from industrial sources (cement plants, refineries, etc.) [130]

States have several means to influence CCS implementation through policies regarding permitting, property rights, long-term stewardship (liability and funding for it), and support for studies and incentives. The states have the most comprehensive regulatory framework to date for CCS, and specifically GS, thanks to their control over several activities crucial to geological storage, including mineral and water rights. Washington, Montana, North Dakota, Colorado, Utah, Kansas, Oklahoma, Texas, Louisiana, and West Virginia have the most developed frameworks for regulating CCS and GS to date. Despite the regulatory frameworks established by several states, there are several issues requiring further clarification including property rights, permitting, and long-term stewardship.[131]

Property rights are perhaps the most contentious issue facing CCS state regulation. Property rights include ownership of the CO_2 and of the pore space (the area underground where the CO_2 will be stored), mineral rights, liability during operations, and unitization (the exploration and development of an entire geologic structure or area by a single operator so that drilling and production may proceed in the most efficient and economic manner).[132] Access to the pore space, however, is generally attributed to the surface owner.[133]

No one single framework has emerged across the states for permitting. Permitting duties are dispersed across oil and gas, and environmental agencies, or variations of the two. Permitting can take either the form of a freestanding permit for a CO_2 storage facility or state implementation of the UIC program.

Long-term liability is another key concern for CCS. Kansas, Louisiana, Montana, North Dakota, Texas, and Wyoming all established funds for long-term monitoring with some going as far as to assume long-term ownership and liability for the GS facilities.[134] Most states, however, are not assuming tort or climate liability. Tort liability would involve payment of compensatory damages caused during long-term stewardship. This would include damage done to underground drinking water or mineral resources. Climate liability is even farther reaching, obliging the state to compensate for leakage of CO_2 from GS into the atmosphere.[135]

CCS is a relatively new technology that would not only impact the power industry but also a whole new arena of environmental, health, and safety concerns. Since the implementation of CCS is still largely limited to pilot projects, there is an absence of targeted regulation to clarify liability concerns, address health risks, and create incentives to encourage commercial expansion. Some specific regulatory ambiguities that CCS advocacy groups seek to clarify include:

- Comprehensive regulation of geological sequestration
- Compensation, liability, and long-term stewardship for CCS
- Framework to regulate carbon dioxide pipelines to transport the greenhouse gas to storage wells[136]

CCS advocacy groups feel that the current federal regulation of GS in the form of the UIC program does not sufficiently address the major issues facing storage and long-term liability. The CCS Regulatory Project, a CCS advocacy project based at Carnegie Mellon University, recommends that the federal government issue a statement in favor of GS as a means to "mitigate the detrimental effects of climate change." They also recommend the creation of an independent public entity to approve and accept responsibility for appropriately closed geological storage sites.[137]

Environmental Impacts

CCS has the potential to significantly reduce the greenhouse gas output of fossil fuel intensive industries, but the technology is still unproven in the long term. There have been no major accidents to date, but much of the environmental, health, and safety concerns about CCS are contingent on quality site selection, effective regulations and oversight, safe operation of the facility, and proper monitoring of CO_2 underground.

Burning coal is the greatest contributor to rising global CO_2 levels. Developing nations such as China and India are burning coal at exponentially rising levels due to its low cost and availability. The Western world has reached a plateau in coal-based emissions, but only after burning it since the 19th century. Addressing the long-term climate change risks associated with rising CO_2 levels demands curbing CO_2 emissions. Cost effective CCS could help balance developing countries' needs for energy with limited CO_2 emissions.

CCS, however, has its own environmental risks. For CCS to meet the environmental concerns in the context of energy security, it cannot endanger critical resources like drinking water or risk physical damage to infrastructure in the form of micro-seismicity. This section will address some of the environmental concerns surrounding CCS.

Note: This report only examines the environmental issues surrounding CCS, not those surrounding coal mining. Practices like mountaintop removal that have disproportionate impacts on the environment are not examined here but must be considered eventually.

Air Quality

Leakage of CO_2 to the surface is the most basic risk associated with CCS. Not only could surface exposure to large quantities of CO_2 be dangerous, it would negate any climate change mitigation resulting from sequestration. The threat comes from improperly sealed wells or leakage through a fault or fracture. In either case, the slow release of CO_2 would most likely diffuse to safe levels for humans.[138] Both of these scenarios could be addressed with proper monitoring of CO_2 and appropriate site selection. Proper site selection greatly mitigates the risks associated with CO_2 leakage.

The most dramatic fear associated with CCS GS is an abrupt catastrophic release of carbon dioxide. A famous example of a naturally occurring limnic eruption occurred in 1987 at Lake Nyos, Cameroon, where a sudden eruption of 0.25 million tons of CO_2 from beneath the lake suffocated more than 1,700 people. The Lake Nyos limnic eruption, however, was caused by the sudden release of a large build up of carbon dioxide. It is highly unlikely that such a sudden, massive release of CO_2 would occur due to the nature of the geologic structures used in CCS GS.[139]

Water Contamination

Potable water is a strategic resource for all nations and any risk of contamination from CCS should be carefully considered. There are two ways geologically stored carbon dioxide could contaminate drinking water: a direct CO_2 leak into underground sources of drinking water, and the forced migration of salty brines into potable groundwater sources. Carbon dioxide leakage into a potable water source would most likely take place along a fault/fracture and could alter the taste, color, and odor of the water. Improperly plugged abandoned oil or water wells run a similar risk. At its worst, carbon dioxide could affect the pH balance of the water and reach concentrations that would make it unusable for drinking, agricultural, and industrial use.[140]

The migration of salty brine into a potable aquifer would be a site-specific risk and should be weighed in the site's selection. A report from the Lawrence Berkeley Laboratory said that such displacement was unlikely because of how small pressure increases in the GS formation could mitigate this incursion. While risks exist, there have not been any known cases of CO_2 contamination of groundwater or other potable water sources.[141]

Induced Seismicity

Concerns have been raised that CCS GS could cause earthquakes. High-pressure injection of fluids into the ground can in fact cause small earthquakes, and regulatory agencies today restrict dangerous injection rates. Monitoring early in the project would be necessary to ensure the injection rate is safe and causes no unintended microseismicity.

Environmental Risk

Funding from the American Reinvestment and Recovery Act is being used to support a National Risk Assessment Partnership (NRAP) to ensure safe, long-term storage. NRAP will design a monitoring protocol to track all stages of project development to minimize the uncertainty in the site's predicted behavior. Research is specifically aimed at addressing reservoir performance and wellbore integrity, natural seal integrity, groundwater systems, strategic monitoring for risk assessment, and systems modeling for science-based risk assessment.[142]

Risk monitoring is an essential part of CCS GS if it is to be a successful technique for the mitigation of greenhouse gases. There is also a need for continued research and especially pilot projects to test various scenarios for CCS GS, as the window of storage using this technology is not decades, or even centuries, but millennia. The environmental, health, and safety risks associated with CCS can only be addressed through quality site selection, constant monitoring of CO_2 during and after injection, and appropriate emergency responses in the event of a leak.

While CO_2 accumulation contributes to climate change, it is only immediately dangerous in extremely high concentrations. Proper care and sequestration are important issues, but through all the safety precautions it is easy to forget humans exhale CO_2 with every breath. Large amounts of CO_2 can be safely vented into the air near people without adverse health effects.

It is important to note that while CCS GS has a brief history, underground storage of natural gas has been active in the United States for many years with few incidents. These natural gas stores are much shallower than CCS GS sites and operate with low levels of unintended leakage or microseismicity.[143] Enhanced Oil Recovery (EOR) has also been applied for years in the United States without widespread groundwater contamination or other environmental safety impacts.[144]

Political Implications and Public Perception

In 2010, the Senate failed to pass the much-anticipated climate bill which would have created a cap-and-trade market and carbon pricing mechanisms. The global recession, coupled with pressure by groups that question the validity of anthropogenic climate change, led to the bill's ultimate collapse. Given that carbon dioxide does not have an inherent value, CCS needs strong, credible regulatory action such as that proposed in the aforementioned climate bill to guarantee a market before investors will be willing to take on the high capital costs of its implementation.

To reduce uncertainty about the costs of CCS, CCS in non-EOR applications will require carbon pricing and government creation of a strong demand-pull scheme. These scenarios are unpopular with industry players, however, as they would clearly increase operating costs. Those opposed to a carbon tax scheme charge that it would detrimentally affect the U.S. economy by driving companies to operate in countries with lower energy costs.

Public education about CCS is poor in general, and public perception may work against it due to the implementation costs, technological uncertainty, and property rights issues associated with it. On the technological side, a politically sensitive issue is carbon dioxide storage. The "not in my backyard" attitude towards storage could be a difficult hurdle to overcome as the public is generally risk averse. Constituents may question whether storage sites will be prone to leakage, and taxpayers may be opposed to states assuming liability for such events. Additionally, property rights as discussed early in the chapter could present an obstacle to widespread implementation in terms of CO_2 ownership and long-term storage sites.

Beyond the immediate logistics of CCS, many environmental advocacy organizations are critical of CCS, Integrated Gasification Combined Cycle (the high efficiency turbine used in "clean" coal plants) and any expansion of the coal industry, or America's continued dependence on the fossil fuel. The Sierra Club supports moving away from fossil fuels altogether and advocates shifting toward renewable and more efficient energy sources. While the Sierra Club does not entirely discount CCS and its accompanying technologies, they insist that there is no proven way to continue burning coal today without accelerating global warming and that it will be years until pilot projects like FutureGen 2.0 yield results that could be translated to wider industry.[145]

On the positive side, several states including Texas enjoy legislative support on both sides of the political aisle for CCS (especially in conjunction with EOR). Texas in particular has both a long history of EOR success and plenty of potentially viable storage areas both on and offshore. States involved in CCS may choose to generate revenue by charging to store CO_2 on state lands. Politically speaking, however, it may be easier to gain support for CCS operations if storage sites are located away from communities in offshore geological formations, thereby limiting perceived risks to human health from leakage and avoiding certain property rights issues.

Conclusion

Coal is the greatest contributor to global CO_2 emissions, accounting for more than 40 percent of the total. It is also the world's second most important primary fuel source behind petroleum, and is responsible for 27.4 percent of primary energy production.[146] Considering coal's central role in global and U.S. energy production and the infrastructure that supports it, moving away from coal in the near future seems unlikely if not unreasonable. This is especially true for the United States, where plentiful domestic coal deposits are an important contributor to energy security. CCS walks a tightrope between the old and new energy economy as a bridge technology. But despite the criticism of CCS as an extension of the fossil fuel economy, there is little option but to encourage CCS as part of the basket of low/zero emission technologies if the United States is serious about greenhouse gas reduction. The technology to capture and inject CO_2 is established but expensive. Moving CCS into the commercial sector requires legislative, regulatory, and—perhaps most importantly—economical solutions.

Conclusion: Emerging Technologies

Cleary, a variety of challenges must be overcome before any of these emerging technologies will reach mass implementation. The PRP team believes that a single technology alone cannot solve the energy security problem. The team is, however, optimistic that if the United States continues to research and fund these technologies then all regions of the nation could be served by a secure energy source. The following chapter summarizes the findings in the existing and emerging technology chapters, and also examines what lessons can be learned from existing energy technologies about public perception, market pricing, and research funding.

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Chapter 5. Findings

As stated earlier, several energy resources and technologies were investigated in this Policy Research Project to evaluate their potential to enhance U.S. energy security by playing a larger role in the nation's energy portfolio. The existing and emerging energy technologies analyzed are listed in Table 5.1.

Table 5.1 Existing and Emerging Energy Resources and Technologies

Existing	Emerging
Natural Gas	Carbon Capture and Sequestration (CCS)
Nuclear	Low Energy Nuclear Reaction (LENR)
Geothermal	Methane Hydrate
	Tidal Energy

The results of the analysis are presented in two sections: "Energy Resource and Technology Comparison," and "General Findings and Lessons Learned." In the energy comparison, the project team analyzed and ranked the energy sources to discern which are most likely to be deployed extensively during the next few decades. We categorized several of these as "bridging" and "bridge-to" technologies. We consider "bridging" technologies to be cleaner energy sources that can meet the nation's demands until more environmentally friendly renewable energies can become economical. "Bridge-to" technologies are renewable energy sources that the United States should seek to make dominant in the nation's energy supply chain.

Next, we compiled common themes and principles that we uncovered in the research process for each of the technologies. We also detail some specific lessons garnered from earlier policy approaches to existing energy sources and how those lessons can inform government policies for emerging energies in the coming decades.

Energy Resource and Technology Comparison

The energy sources and technologies were rated according to the energy security criteria set forth in Chapter 2:

1. environmental impact/effects on public health,
2. economic viability at scale,

3. technological feasibility at scale,
4. public and political feasibility, and
5. abundance level as estimated by the Energy Information Administration.

For the purposes of creating a comparison among energy sources, Regulatory Framework and Political Issues were condensed into a single category. Estimates of abundance were added as an additional measure of the long-term viability of the energy source.

The comparison assesses economic viability in terms of total cost of ownership and at a scale to meet current demand levels. “Public and political feasibility” is defined as the political and public support currently displayed for the technology, in addition to the regulatory framework currently in place. Finally, “abundance” of the energy source is defined as the available supply that could be exploited if all necessary technologies are in place.

As these categories suggest, the energies and technologies that receive a “high” rating: (1) have minimal negative effects on the environment and public health, (2) are economical and can scale with demand, (3) are technically feasible, (4) can garner public and political support, and (5) are deemed plentiful by EIA. Thus, the energies that scored well aid in the goal of achieving energy security because they can serve as viable fuel sources that can compete with the importation of oil and other sources of energy from unstable regions of the world, but in a cost effective and environmentally sensitive manner.

The energy sources were assessed relative only to one another and rankings were weighed based on interviews and research data. Table 5.2 reveals the results of this analysis.

As the table shows, natural gas and CCS rated highest among the energy technologies reviewed. They are well-equipped to advance the United States toward a cleaner energy future because they span the divide between traditional fossil fuels and renewable energy sources. Therefore, this report considers them "bridging technologies."

Natural gas ranked highest due to several factors. It is abundant, thanks to drilling technologies that have unlocked trillions of cubic feet of gas from shale rock formations. Gas also can be deployed quickly to meet current demand through its vast pipeline infrastructure. Consequently, experts believe that gas prices will remain stable throughout the next decade, making gas economically viable to serve as a major fuel source for electricity generation and potentially for transportation, which would decrease U.S. dependence on oil. Environmental rankings for gas are neutral mainly due to the fact that gas does emit some greenhouses gases and there are some concerns over the safety of shale gas drilling. Still, government regulators believe hydraulic fracturing is largely safe, and gas is cleaner than current traditional fossil fuels.

Table 5.2 Energy Resource and Technology Comparison

Energy Type	*Environmental Impact/Effects on Public Health*	*Economic Viability at Scale*	*Technological Feasibility at Scale*	*Public and Political Feasibility*[1]	*EIA Source Estimate/ Abundance*
Natural Gas	Medium	Medium[2]	High	Medium[3]	High
Nuclear	High[4]	Low	High	Low	High
Geothermal	High	Low	Medium	Medium	High[6]
Tidal	High	Low	Low	Medium	Medium
CCS	Medium[5]	Medium	Medium	High	High
Methane Hydrate	Medium	Low	Low	Medium	High
LENR	High	Medium	Low	Low	High

Matrix Key	
Low	***Unfavorable conditions***
Medium	***Neutral conditions***
High	***Favorable conditions***

Notes: Rankings reflect 21st century timeframe.

1. Public and political feasibility are defined as the political and public support currently displayed for the technology, in addition to the regulatory framework currently in place.
2. Although natural gas is currently economically viable at scale, the price volatility and lack of carbon taxes make it less competitive than coal.
3. Not rated "high" due to public concern over hydraulic fracturing and other drilling techniques that have attracted the attention of regulators.
4. Given a "high" ranking since the probability of a man-made accident, such as the Chernobyl disaster, is very low.
5. Although CCS as a stand-alone technology would be given a high grade we included the environmental impact of coal mining and the uncertainty of the affects of underground carbon storage, hence a medium ranking was conferred.
6. Although geothermal is low in its conventional use, Enhanced Geothermal Systems would allow for abundant, dense energy.

CCS is also a strong contender to serve in the short-term as major energy technology. CCS provides an option to maintain current coal-fired electricity generation by cleaning its byproducts, namely carbon emissions, and making the production process more environmentally friendly. Coal powers more than 45 percent of the nation's electricity, so improving its performance would create an abundant secure energy solution. CCS scored a neutral ranking in other categories, making it a viable option from an economic, environmental, and technological perspective.

Nuclear power also can be considered a significant "bridging technology" that can aid in achieving energy security. Nuclear power emits no carbon and has a low marginal cost for electricity generation. If financial support can be rallied for construction of new plants, nuclear power could meet base load electricity demand for decades to come. Since the likelihood of a man-made disaster is relatively low, the comparison chart shows nuclear as rated "high" for public perception and the environment. The recent earthquake and tsunami in Japan highlighted the risks nuclear energy faces from natural disasters, but it is unclear just how seriously the failure of Japan's Fukushima Nuclear Plant will affect domestic demand for nuclear-generated electricity.

Although methane hydrates are a vast potential source of energy dense fuel, it is not economical at present. Industry experts believe the fuel is more than a decade away from development. Still, it shows potential to serve as a bridging fuel source, but not for a few decades. Once it is commercially developed, it could help meet U.S. energy demands through the end of the century, or until renewable energies are more competitive.

The energy comparison further highlights how renewable energy technologies, such as enhanced geothermal systems and tidal energy, could become larger sources for electrical power generation. These energy technologies rank as "bridge-to" technologies. Over the long term, geothermal and tidal energy are excellent candidates to play larger roles in the nation's energy portfolio. They are sustainable, energy dense, and could be adapted regionally to accommodate power needs. Tidal and geothermal energy, however, do have some drawbacks. First, both technologies have high up-front production costs. They also lack needed infrastructure and wide-spread popular and political support. But as the economics of energy storage improve, and as the United States seeks more renewable energy sources, their appeal as key fuel sources will increase.

Finally, although LENR scored well in the environmental and abundance columns, it lacks a realistic framework for development. Until academic, industry, and governmental organizations support further research for LENR, it is unlikely to be a significant, long-term energy source.

General Findings and Lessons Learned

In addition to the energy comparison, we highlight some common themes in the energy economy that likely will continue to dominate U.S. energy policy for the next several decades, as well as the key lessons from the regulatory and policy approaches used in the existing fields like natural gas and nuclear power.

1. **The driving force of U.S. energy remains economics, and not energy security**

   For the last several years, many politicians, industry leaders, and other experts have touted the need for energy security. Much of that emphasis is focused on maintaining reliable and affordable energy, preferably obtained from politically stable regions of the world. Yet, experts contend that the major driver for U.S. energy continues to be the availability of cheap energy, regardless of where it is produced or how clean it is. This likely will remain the case in the near term for several reasons.

Experts seem to agree that the U.S. economy cannot grow without a steady supply of inexpensive energy. Energies with low capital costs and existing infrastructure are the strongest contenders to either become or maintain their status as dominant suppliers in the industry. Existing fossil fuels, such as coal and natural gas, are inexpensive, and have robust infrastructure in place. Moreover, private financing is readily available for less capital-intensive power plants, such as natural gas plants. The availability of financing for viable renewable energy projects, like tidal or geothermal energy, is exceedingly difficult to obtain. Similarly, the high cost of constructing nuclear plants has been a major barrier to nuclear expansion. Although the marginal cost of nuclear power is among the lowest in the nation, the up-front capital investments for construction cannot be recouped quickly enough to be profitable.

Consequently, U.S. industries are seeking energy sources that are the most cost effective. This finding could change significantly if government finances more electricity generation or development of other fuel sources, or if more foreign energy organizations decided to increase their investment share of large energy projects, such as a nuclear facility.

Furthermore, political *and* energy industry leaders simply lack the appetite for a large-scale overhaul of the U.S. energy system by switching to sources that would increase a stable energy supply and diminish negative environmental affects. Political parties are divided on the solution to securing the nation's energy system and reducing reliance on energy sources from politically unstable regions, such as Venezuela or the Middle East. Republicans want to support the energy industry, which is largely built upon fossil fuels, and Democrats seem determined to support renewable energy sources, even if they are not reliable and cannot meet energy demand.[1] The current crop of fossil fuels, even with the price shocks that plague oil consumption, is cheaper than embracing emerging energy technologies or renewable energies. Thus, leaders largely let the market continue to decide which energies will dominate in the United States.

The energy industry benefits from this "status quo" approach in a number of ways. As long as fossil fuels continue to dominate energy supply, entrenched industries will maintain their business models and enjoy predictable results. Even fledgling renewable energy companies benefit from the current crop of subsidies that the federal and state governments provide.

Finally, although respondents in this study stated that "energy security" is the critical issue in U.S. energy policy, most of them defined "security" in terms of the price of energy or the availability of "cheap" energy. Charles Ebinger, director of the Energy Security Initiative at the Brookings Institution, underscored this sentiment when he stated: "The key is reliable and affordable." Despite the desire of political and industry leaders to build a more affordable supply of clean energy, the reality of "security" means that cheap energy will continue to dominate until the cost and reliability of alternative sources can compete in the marketplace

2. **Despite the strong desire to migrate from a carbon-based energy system, the majority of U.S. energy supplies will be derived from fossil fuels for the next quarter century**

   If cost is the major driver in selecting energy sources, then the United States will remain a heavy consumer of fossil fuels for at least the next 25 years. The new-found abundance of cleaner natural gas is helping to make the fuel more economical and readily available, and it is likely to be a strong alternative to coal or even petroleum as its cost decreases. Nuclear power, which emits no carbon, is unlikely to be adopted as a larger energy source for the United States chiefly due to the large capital investments required for nuclear plant construction and to ongoing public concern over nuclear waste storage. Furthermore, damage to nuclear facilities in Japan in the wake of a massive earthquake and tsunami has revived public fear of nuclear disaster and radiation leaks. Thus, the public relations fallout from the crippled nuclear reactors likely will have a major chilling effect on nuclear expansion in the United States.

   Renewable sources are growing, but most are still in the development phase and are unlikely to reach commercial scale for another 20 years. Some sources, like tidal and geothermal energy, show great promise in terms of their energy density; these particular energies, however, suffer from significant drawbacks. Tidal energy, for example, is limited to specific geographical locations, usually along coastlines. Furthermore, both tidal and geothermal are still experimental in many respects. Some experts predict that enhanced geothermal systems (EGS) will not be ready for commercial application for at least another 10 to 20 years.

   Moreover, the price point of established fossil fuels diminishes support for development of renewable energy sources—like tidal and geothermal energies—in favor of faster development of methane hydrates or CCS. "It's hard for a lot of these more exotic technologies to take off as long as there are reliable fossil fuels," said Ebinger.

3. **The discovery of large unconventional natural gas reserves is changing the economics of U.S. energy markets**

   The abundance of unconventional natural gas reserves that are predicted to meet demand for the next 100 years has lowered natural gas prices to such an extent that it now operates as a competitive cleaner fuel and a significant alternative to oil and coal. This transformation is evident in the electricity markets, where numerous power companies and utilities are switching their fuel source from coal to gas. Although the construction of natural gas and dual cycle plants is several years away, it signals growing confidence that price volatility and other issues that plagued gas over the last few decades are diminishing.

This phenomenon also provides the basis of a strong argument for needed investments to help natural gas begin to displace oil as a primary transportation fuel, thus providing competition for imported oil and protecting the U.S. economy from oil price shocks. Greater utilization of natural gas, particularly in transportation, likely would facilitate an increase in current gas prices, rendering methane hydrate drilling more viable.

4. **Energy policy in the United States is fragmented and short-sighted because political support for various industries continues to exacerbate inequalities and inefficiencies in the nation's energy portfolio**

Despite promising research and the desire for the United States to produce more sustainable energy, policies that seed new technologies are now considered the lifeblood of renewable energy. Nearly all emerging technologies—tidal, CCS, enhanced geothermal—are not cost effective without government subsidies. Additionally, emerging technologies, like LENR, could yield energy advances, but are starved for any real support from the DOE. Traditional energy sources, like gas and nuclear power, do not benefit from subsidies; rather, they receive favorable tax treatment such as the accelerated depreciation of assets and tax credits for depleted resources. Even those treatments, however, create an unequal playing field for various energy technologies.

Government support encourages investment in some energy sources that are less economical and politically realistic. For example, CCS is subsidized heavily and may lack strong economics but will become necessary should the United States begin taxing tax carbon emissions. The seed money that the DOE and others have invested in CCS will allow it to develop and prepare for deployment if and when carbon emissions are regulated. The use of predictable incentives or a low, transparent corporate tax rate actually may trigger bigger shifts in our current energy portfolio by spurring entrepreneurs and private industry to cultivate alternative energy supplies domestically to reduce the nation's reliance on petroleum or other fuels that can expose the U.S. economy to serious price shocks.[2]

5. **In the energy industry, the main task of the government should be to focus on basic scientific research**

One of the best things that government policy could do over the long term is to step away from applied research where it seeks to commercialize current technologies, and focus its resources towards more basic research to achieve a new energy paradigm. The government is uniquely positioned to sponsor and/or conduct scientific exploration and research that will uncover materials and technologies to meet energy needs in 50-100 years. In some cases, this shift in resources may warrant renewed examination of previously rejected technologies, such as LENR. The problem, though, is disagreement among policymakers over what type of research to fund.[3] Applied research tends to produce more short-term technologies, but does not change the energy paradigm.[4] Foss advocates for research that will uncover "new building blocks" for energy that will provide abundant, dense energy supplies. Moreover, this is research the private sector will not conduct because the short-terms costs may outweigh the benefits. When government conducts applied research, it is investigating specific technologies that are semi-developed. This not only undercuts private sector research efforts, but also continues the cycle of the government picking energy "winners and losers" through resource allocation.

6. **Strict environmental regulations and negative public perception of energy relative to the environment are the major hurdles to energy development in the United States**

Environmental "impact" refers broadly to a variety of potential negative effects. Some technologies have completely unknown effects, while others are well documented. Yet, most energy technologies examined in this report have environmental consequences that must be balanced against their benefits.

Though other factors contribute, experts argue that current environmental regulations, increased advocacy for stricter rules, and negative public perception related to environmental risks are the major hurdles for the expansion of existing and emerging energy sources.

Natural gas emits less carbon than coal or petroleum, but environmental activists have raised major concerns over the environmental impact of its drilling methods. Those concerns, in turn, stoked public fear. Public perception of the dangers of shale gas drilling reached a crescendo with the release of the documentary film *Gasland* that identified specific cases of water contamination, which were purportedly linked to gas drilling.

Similar concerns create hurdles for the development of other energy technologies. Like natural gas, geothermal and CCS, for example, must fight the public perception that the production cycle creates seismic activity. Tidal energy is promising, but must endure a range of regulatory hurdles to ensure that it does not have an overly negative impact on fish and other wildlife.

Moreover, environmental concerns contributed to the growing number of individuals and organizations that may support energy development, but do not want it infringing on their property or in their communities. The "not in my backyard" (NIMBY) constituency continues to constrain energy development, even in sustainable energy sectors. Misperception of environmental effects from emerging energy technologies has played a role in killing potential research, as is the situation with nuclear energy.

7. **As existing energy sources, natural gas and nuclear power provide key lessons that can inform elected officials and industry leaders as the nation seeks a bridge to renewable energy.**

   Past policy approaches to natural gas, nuclear energy, and other existing technologies demonstrate that inconsistent regulation can have negative consequences on energy production and can create new problems.

   i. **Price regulation and rules on consumption set up problems that led to price shocks for natural gas and incentivized the use of coal for electricity production.** Throughout the last quarter century, many industry and policy experts now agree that price regulation helped create the boom/bust cycles of gas and increased price volatility while simultaneously encouraging the deployment of other fossil fuels.

   ii. **Choosing "winners and losers" as energy sources can have serious unintended consequences.** When the federal government banned the use of natural gas for electricity in 1978, the unintended consequence was a major shift to coal as a fuel source to generate electricity. Although coal is economical, it creates major costs for the nation's environment. To avoid similar cycles, market-driven energy pricing through careful deregulation can encourage innovation.

   iii. **The energy industry must have consistent and effective regulation to remain innovative.** The nuclear power industry has suffered in part from continuous changes in regulation and licensing standards by the Nuclear Regulatory Commission. This inconsistent regulation has effectively limited construction of new nuclear plants and paved the way for a *de facto* 30-year moratorium on nuclear power. Only in the last few years has the NRC issued permits for new nuclear plants. And again, the momentum has been halted due to the NRC's review of safety at all U.S. nuclear plants as a result of the Japanese nuclear disaster. This regulatory approach has made nuclear power companies reluctant to invest billions of dollars in new plant construction. Even budding technologies like tidal energy face a slew of regulations and oversight from various government agencies, which are slowing development of potentially effective renewable energy sources.

   iv. **Effective regulation and predictable government support can help new technologies find their way to market more efficiently.** Once policymakers removed price caps from natural gas and the barriers for consumption, private industry found a new incentive to develop technologies that would improve exploration and drilling. Hydraulic fracturing is one such technology that has unlocked trillions of cubic feet of natural gas from shale rock formations. As mentioned earlier, this new paradigm is creating tangible competition in energy markets, and could insulate the nation from oil price shocks as well as serve as a long-term bridging energy. "The most sensible thing is to provide clear, transparent, workable markets with competitive, simple corporate tax regimes and sensible, streamlined, light-handed policy and regulatory oversight," said Michelle Foss, chief economist for the Bureau of Economic Geology at The University of Texas at Austin. She also added that, "The biggest lesson of any of the myriad lessons is that what we have on the books now is no longer favorable and no longer a comparative advantage."

v. **For emerging technologies, scientists and developers must be able to provide a framework in which to explain their innovations.** Although LENR has shown promise as an emerging technology, a majority of policymakers, academics, and industry leaders are quick to dismiss it. Much of the treatment of LENR relates to the lack of a scientific framework for explaining the technology. Although some researchers believe LENR holds serious promise, and several LENR experiments have been replicated successfully, academic and policy leaders are unwilling to allocate funds for further research because the science behind LENR is not well understood. This is an area that might be ripe for "basic" research funding, if government agencies freed up finances by focusing less on applied research.

vi. **Public education is crucial to the development of economical energy.** One of the biggest lessons from the regulation of existing energy sources, and the burgeoning focus on emerging energy technologies, is that public perception and support can be critical to success. Much of the public's perceptions can center on the negative effects of energy, be they traditional fossil fuels or even new energy sources. For example, poor public perception and the lack of a coherent theoretical framework slowed support for development of LENR. Furthermore, public perception was the main factor in halting growth in the nuclear sector.

Energy firms must help educate the public on the value of energy sources: where they come from, how they are used, and how they can benefit the nation. Public perception, through activism and advocacy of increased regulation, can hamper potential long-term energy sources. Any group that seeks to exploit energy sources in a community—whether drilling for shale gas, installing tidal turbines or constructing a geothermal plant—must engage in an education campaign. Such an effort can communicate the benefits of energy production while mitigating hurdles to promising energy sources.

Notes

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Michelle Foss , Chief Economist, Bureau of Economic Geology, University of Texas, e-mail Interview with Patricio Prieto, March 20, 2011.

[3] Steven F. Hayward , F. K. Weyerhaeuser Fellow in Environmental Studies, American Enterprise Institute, Interview with Maureen Metteauer, February 22, 2011. Hayward specifically listed "basic research" as the one task that government is well-positioned to execute as part of sensible energy policy.

[4] Interview with congressional staffer at the House Science Committee who asked to remain anonymous. February 22, 2011.

Chapter 6. Recommendations

Introduction

The 21st century likely will be a "bridging century" for the U.S. energy portfolio. This view is supported by the findings of this study and by recent global developments, including the unrest in the Middle East and serious regional and global environmental concerns. These challenges all stress the importance of a cohesive and stable energy security policy.

Our recommendations, based on the findings and resulting energy comparison, focus on improving the viability of emerging, non-fossil fuel energies without significant and immediate cut-backs in traditional energy sources. We are cautious of making recommendations that are too specific at the federal level, as many of the policy recommendations need to be tailored to local conditions in each region or state. While this approach may seem cautious, it is intended to allow for policies that would have a better chance of acceptance in local legislatures.

Recommendations:

1. **The energy sector should invest in a public education and awareness campaign for their respective technologies.**

   As depicted in the energy comparison, a primary hurdle that several of the emerging technologies face is poor public perception. To overcome this obstacle, the industries should invest in public awareness campaigns to bring their technologies to the forefront of energy discussions. The campaigns should be targeted to specific regions based on feasibility. Specifically, public education and awareness campaigns should be implemented for geothermal, tidal, and methane hydrate technologies.

   As mentioned in the geothermal chapter, because of its concentration in Western states with lower populations, geothermal energy occupies a political niche and is not on the radar of national politics. We argue that neither is it on the public's radar nationally. Although conventional geothermal energy is limited to specific regions, enhanced geothermal systems (EGS) may be employed in a much wider area. Public awareness must be increased for this technology so there are no misconceptions regarding drilling and other technical aspects. Once the public is informed of the benefits—and the potential electricity generation their specific region could gain from conventional and EGS—they will likely take more action to push for the implementation of this green, and secure, technology. Regarding the energy comparison, we believe this would increase the "public and political feasibility" grade from low to medium, if not high. Public support often leads to political support, in turn putting geothermal technology on the national radar. Political support, in turn, increases the chance of federal, or private, funding. If the technical hurdle of identifying productive EGS regions can be overcome, the increase in funding could help the technology reach economic viability at scale.

Tidal faces geographic restrictions, much like geothermal. As mentioned in the tidal chapter, however, more than half of America's electricity is used in coastal states. But public support for tidal technology is lacking. Aside from small regional areas where tidal technology is already in use, the technology lacks clout in the public's view. Much like geothermal, if the public is educated on tidal technology and made aware of the potential electricity generation, it may garner more political support and funding at the federal level.

Methane hydrate technology is certainly the least publicized and most unrecognized by the American public. This is unfortunate as this technology holds great potential and could use the existing natural gas infrastructure. As pointed out in the methane hydrate chapter, if one third of the natural gas in the Gulf of Mexico was technically and economically recoverable, the United States could potentially double its domestic natural gas resource. It is crucial for the methane hydrate industry to educate the public on this valuable resource and technology. Since economical mass implementation is a looming issue for this technology, an educated public will be essential for securing the necessary funding to do so. Once methane hydrate technology garners public and political support, its grade on the energy comparison will improve, as will the grades for economic and technological feasibility.

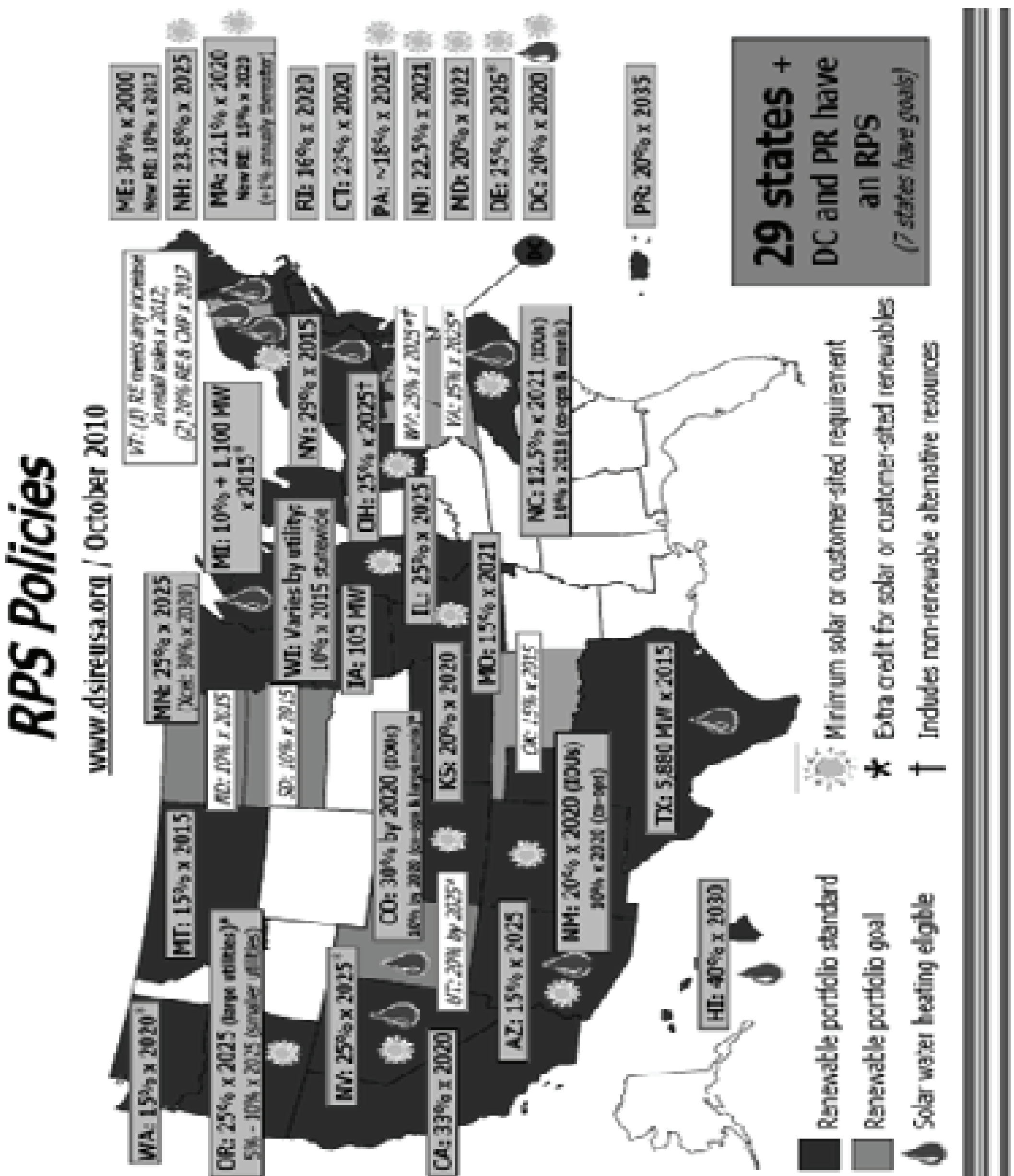
As described above, an educated public can have a domino effect on political and monetary support. Since the public is already exposed to a range of ad campaigns, a logical first step is to educate the public regarding our country's energy supply options. Whether the campaign is initiated by private or public entities is immaterial. The only concern is that action be taken to create more public awareness.

2. **<u>A national renewable portfolio standard (RPS) should be implemented requiring all states to produce a minimum percentage of electricity from renewable or low-carbon alternative energy sources by a specified date, without explicitly favoring any one technology.</u>**

As shown in Figure 6.1, 29 states have renewable portfolio standards that mandate either a set volume or a percentage of total sold energy that must be derived from renewable sources by future target dates. Seven states have voluntary standards programs.[1]

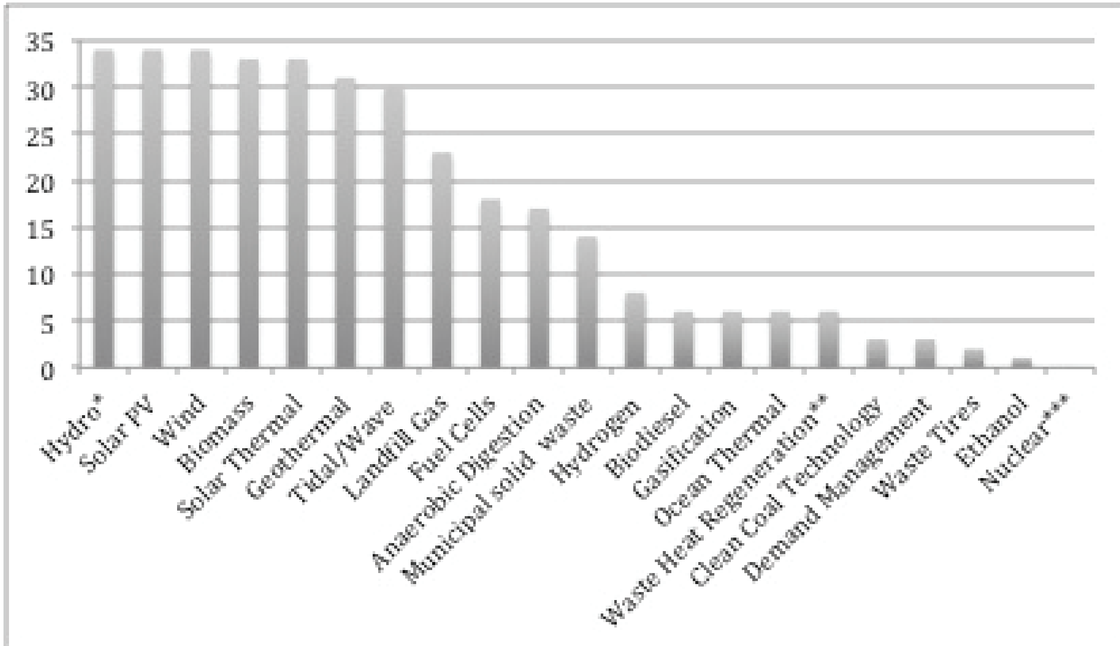
Though most state RPS programs include established renewable sources, such as solar, wind, and hydroelectric power, as eligible technologies, there is a wide discrepancy between states regarding technologies that count towards renewable portfolio goals (see Figure 6.2). For instance, few states allow clean coal technology to count towards RPS, but a majority of states with renewable

Figure 6.1 State Specific RPS Standards



Source: Southern States Energy Board. *Renewable Portfolio Standards in the United States of America.* Available: http://www.sseb.org/wp-content/uploads/2010/05/Matrix-of-State-RPS.pdf. Accessed: March 20, 2011

Figure 6.2 Numbering of States Accepting Various Types of Energy as "Renewable"



*Hydro: Highly limited in most states to exclude new large-scale hydro
**Waste Heat Regeneration: Two states allow Combined Heat and Power systems only
***Nuclear is somewhat addressed in S.3813 where it is eliminated from the denominator in calculating the percentage of renewable energy generated.
Data compiled from various sources on state renewable energy standards

Source: ALT Energy Stocks. *Renewable Energy Standards: Savvy or Silly?* Available: http://www.altenergystocks.com/archives/2011/03/renewable_energy_standards_savvy_or_silly.html. Accessed: March 20, 2011

portfolio standards or goals count geothermal and tidal energy as eligible technologies.[2]

We recommend that the minimum federal standard designate a broad array of technologies as standard-eligible. This includes methane hydrates as it improves in technical feasibility on the energy comparison, and alternative energy sources like clean coal technology (and plants that implement CCS technology). Geothermal and tidal seem to be widely eligible for RPS in states where the technology is applicable, but their blanket inclusion should nonetheless be codified in the national standard. If LENR improves in technological feasibility on the energy comparison in the future and proves scalable, it too should be added to the list of acceptable national RPS technologies.

Further, we recommend that the federal RPS require states to count energy efficiency as an eligible resource, as only a few state RPS programs currently include efficiency gains.[3] For example, efficiency improvements in state utilities' distribution systems should count towards a federal RPS. Additionally, utilities should receive RPS credit for efficiency gains realized by switching energy sources from conventional coal-fired plants to IGCC plants, or to natural gas combined cycle plants. In this example, efficiency gains will naturally be accompanied by lower greenhouse gas emissions, which should also receive credit in federal RPS.

Some states mandate that a portion of energy that qualifies for RPS inclusion must be derived from specific technologies. Maryland requires that at least 2 percent of its 20 percent renewables by 2020 standard be satisfied by solar-electric technology.[4] In states with similar technology minimums, utilities must generate the specified energy, purchase it from a separate entity, or (when permitted by state law) buy energy credits locally or otherwise. We recommend, however, that a national RPS program refrain from explicitly favoring certain technologies in this fashion. Stringent minimum technology requirements create a less efficient market compared to permitting utilities to satisfy an overall renewable/alternative energy percentage by choosing among all eligible technologies. Therefore, we recommend that a national RPS give states the freedom to choose a mix of eligible technologies deemed cost effective by individual state utilities.

3. **Existing and future federal funds from the Department of Energy should be reallocated to focus primarily on basic research.**

Although the United States has yet to answer the question of where it will get its energy supply in the long-term—100 years or more—funding for R&D within the DOE dropped significantly in the last several decades. As illustrated in Table 6.1, total R&D funding in 2007 was only 35 percent of total R&D funding in 1978. Yet, the United States still faces a finite supply of fossil fuels and the surety of the Middle Eastern supply is no more certain today than three decades ago.

We will not address the concerning trend of decreased total R&D funding, as this would require making recommendations regarding sources of new funding, and what level of R&D funding is best—neither of which our project investigated. Yet, we do recommend reallocating existing R&D funds to more heavily favor "bridge-to" technologies. To continue to foster a culture that places significant importance on emerging and nascent technologies, the "bridge to" technologies need more basic research funding. As noted in the methane hydrate chapter, successful commercial development of methane from methane hydrates is largely contingent upon "favorable regulatory conditions and market economics." This technology appears efficient and promising, but without the federal government's support it will not reach critical scale. As shown in Table 6.2, funding for basic R&D performed primarily through the General Science Program decreased since 1999, but applied R&D for coal increased. Some of the applied R&D funding for coal is due to investments in CCS technologies. But a long-term perspective must

Table 6.1 Summary of U.S. R&D Expenditures, 1978-2007 (in millions U.S. dollars, 2007)

Fiscal Year	Renewable Energy	Coal	Other Fossil	Nuclear	End Use	Clean Coal Technology	Total
1978	1,046	1,709	275	2,938	561	0	6,529
1979	1,302	1,685	322	2,614	541	0	6,464
1980	1,367	1,657	203	2,373	413	0	6,011
1981	1,196	1,464	184	2,018	377	0	5,239
1982	588	975	97	1,954	155	0	3,769
1983	454	497	68	1,313	99	0	2,432
1984	346	500	80	1,110	106	0	2,142
1985	328	523	71	702	81	0	1,705
1986	270	504	63	586	61	0	1,484
1987	224	430	55	450	55	0	1,213
1988	253	502	63	422	55	309	1,603
1989	159	383	75	492	64	284	1,457
1990	155	435	78	494	47	796	2,004
1991	223	439	105	463	60	543	1,833
1992	277	513	95	500	54	563	2,002
1993	282	331	122	419	61	0	1,216
1994	355	231	222	441	64	291	1,604
1995	416	224	238	471	61	47	1,456
1996	314	335	208	289	45	185	1,377
1997	289	258	202	980	42	(3)	1,768
1998	300	182	192	1,218	398	(124)	2,166
1999	344	174	218	900	438	(49)	2,024
2000	326	172	244	742	595	(173)	1,905
2001	468	400	150	643	634	120	2,415
2002	317	486	144	570	632	48	2,197
2003	319	482	123	570	603	(52)	2,045
2004	298	535	105	754	498	(106)	2,083
2005	376	511	81	1,124	502	(168)	2,424
2006	356	530	64	1,062	470	(20)	2,462
2007	444	470	0	946	414	0	2,273
Total	13,392	17,537	4,147	29,558	8,186	2,491	75,302

Source: Energy Information Administration. Federal *Financial Intervention and Subsidies in Energy Markets 2007*. Online. Available at http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/chap3.pdf. Accessed: March 14, 2011.

Table 6.2 DOE Research and Development Funding

R&D Program Category	FY 1999 Appropriation	FY 2007 Operating Plan
Basic R&D		
General Science	1,968	1,942
General Energy Science	996	1,292
Environment, Safety, and Health	57	28
Other Allocated	60	250
Fusion Energy Sciences	270	319
Basic R&D Sub Total	3,352	3,831
Applied R&D		
Coal	489	574
Natural Gas and Petroleum Liquids	198	39
Nuclear Power	740	922
Renewable and Other Electric Technologies	587	867
End Use	487	418
Applied R&D Sub Total	2,500	2,819
Total	5,853	6,650

NOTE: Total may not equal sum of components due to independent rounding.

Source: Energy Information Agency. Federal Financial Intervention and Subsidies in Energy Markets 2007. Online. Available: http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/chap3.pdf. Accessed: March 14, 2011

be taken to realize that coal, too, is a finite resource. Funding for renewable technologies that will sustain the country well past the 21st century is vital. Without the proper financial backing, researchers will not be inclined to continue investigating what they consider a promising energy source. This is especially true for LENR research. Each LENR expert interviewed agreed that energy is being produced, but without the funding to investigate the phenomenon thoroughly, a sound scientific explanation is lacking. Should another technology emerge that shows promise but cannot be explained scientifically, then funding should be increased, not decreased, so the scientific community can reach a consensus regarding its potential as an energy source.

As defined by the EIA, it is our hope that the DOE direct more funds towards "research to develop new technologies," with the purpose of "discover[ing] new scientific knowledge for which there is potential for commercial application," yet for which "the probability of success is uncertain."[5] Private funding generally avoids risky investments. It is up to the federal government to take on some risk in the hopes of discovering a breakthrough technology, and to more readily fund those technologies already showing potential.

4. <u>The federal subsidy structure should be changed to favor "bridge-to" technologies, while slowly decreasing subsidies to established and "bridging" technologies.</u>

We recommend that the subsidies to the oil industry be gradually reduced and funneled into "bridging" and "bridge-to" energy technologies as their technical, economic, and social challenges are overcome.

The current federal model of market intervention involves research funding and subsidies. The program of subsidies, including various tax breaks, heavily favors existing technologies. This is especially true of coal, natural gas, and oil. Data from the EIA, which operates under the DOE, and the nonpartisan Environmental Law Institute, both clearly support this conclusion. Figure 6.3 demonstrates how skewed the current subsidy policy is in favor of existing fossil fuel technologies.

We believe that there are justifiable social and economic reasons for these subsidies, primarily to keep energy prices at affordable levels. While the magnitude of the effect is disputed, a 2009 study by Resources for the Future found decreasing these subsidies would have only a "slight effect".[6] The study does concede that a decrease in subsidies—keeping other factors constant—would lead to a small decrease in oil production at home and a larger reliance on imports. This would have a negative effect on energy security, but we believe that our policy recommendations would promote the development of alternatives that could make up this shortfall.

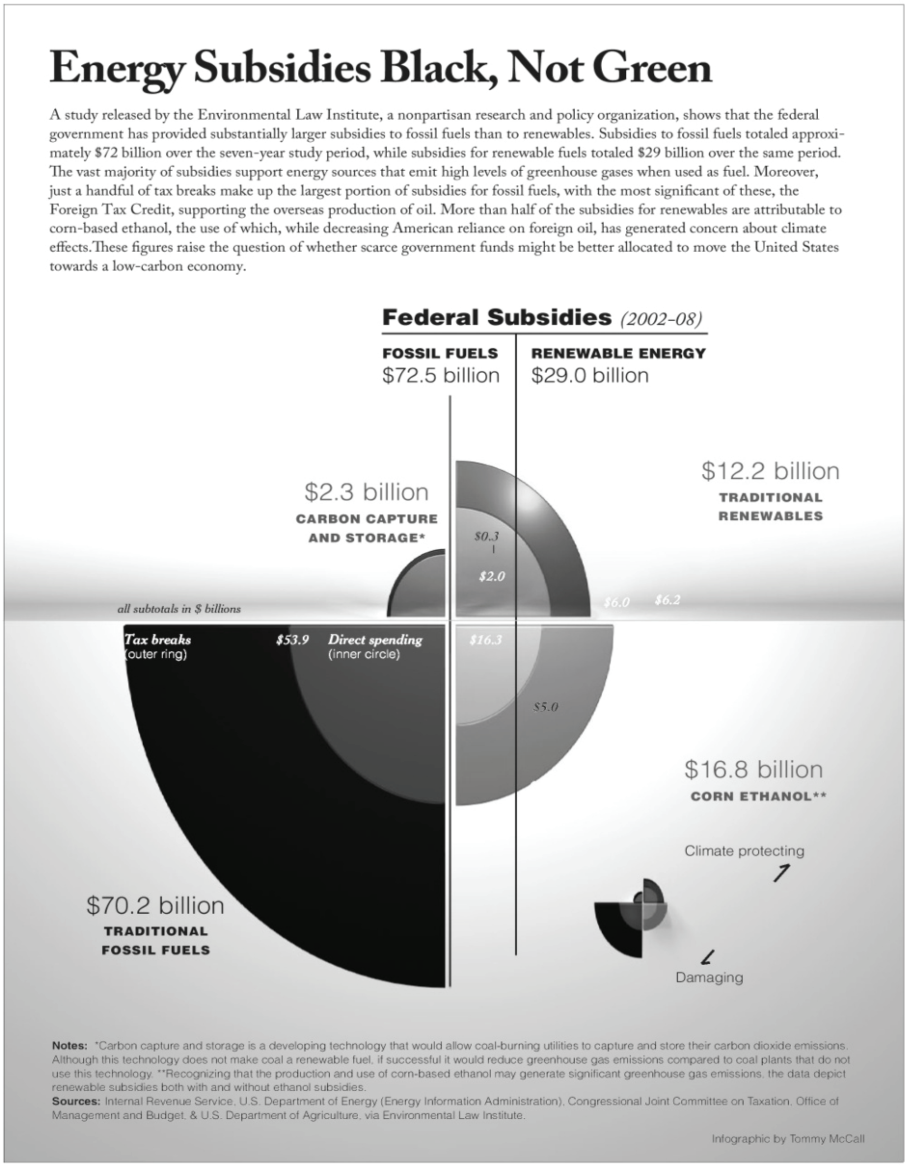
Nuclear and Natural Gas

For nuclear and natural gas, we recommend that the current subsidies stay in place in the short-term, but that they are gradually decreased as emerging technologies meet technological and scalability challenges.

The current incentives for investment in the nuclear and natural gas industries are sufficient to promote development in these technologies. The Loan Guarantee Program is successful at stimulating development in the nuclear industry and a number of new plants have conditional loan guarantees. While nuclear power is relatively more expensive than coal or gas (at current prices), it has a minimal effect on GHGs and depends on a reliable, abundant raw resource.

Natural gas has enjoyed a significant increase in federal funding and the current expansion of conventional and unconventional supply is a good indication that the subsidies are working. Combined with new extraction technology, the price of natural gas is at its "lowest in decades." As an alternative to coal, natural gas is especially attractive due to its limited environmental impact and economical modern gas turbines. Since much of the new supply is domestic and affordable, natural gas is likely to be a key "bridging" technology.

Figure 6.3 Energy Subsidy Breakdown



For press inquiries contact Brett Kitchen at 202-939-3833. Full report text and pdf of this graphic may be found online at: *http://www.eli.org/pressdetail.cfm?ID=205*

Source: Environmental Law Institute. *Energy Subsidies Favor Fossil Fuels Over Renewables.* Online. Available: http://www.eli.org/Program_Areas/innovation_governance_energy.cfm. Accessed:

Carbon Capture and Sequestration

The current political environment is unlikely to produce support for a carbon tax. Therefore, we suggest that the CCS industry (or CCS customer industries) receive subsidies to speed up implementation.

CCS has implications for a number of energy technologies, especially coal. Since coal power plants provide nearly 70 percent of U.S. electricity, it is likely to continue playing a pivotal role in the 21st century. CCS technology is prohibitively expensive, however, and commercial deployment is unlikely unless there are financial incentives for coal (and other fossil-based energy sources). While technological advances are likely to decrease this cost, we believe that federal financial incentives are necessary.

Geothermal, Methane Hydrate, and Tidal

We recommend that geothermal, methane hydrate, and tidal energy be considered for subsidy programs. If these "bridge-to" technologies contribute to energy security within acceptable parameters, we would recommend slowly increasing these subsidies at the expense of oil industry tax breaks.

These three technologies are still undergoing development and further research is necessary, especially in the applied field. While they are promising technologies, all carry high costs. The technology chapters detail individual issues, but all three have high start-up costs and some will likely require costly infrastructure upgrades (i.e. pipelines for gas). It is unlikely that the private sector will be willing to make significant investments without some form of government subsidy or guarantee of revenue stability. This is similar to the case of solar power, which has made great strides due to generous increases in federal funding (see Table 6.3).

Low Energy Nuclear Reaction

Research in the LENR field is making very slow progress due to limited funding and fundamental questions about its scientific merits. LENR is in need of further funding for basic research and is not ready for structural subsidies such as tax breaks. Should the theory and application make significant breakthroughs and prove scalable, however, then a wide range of subsidies should be considered, given the game-changing potential of this technology.

Meeting energy needs in the 21st century will require a blend of established, "bridging," and "bridge-to" technologies. But to strike the right energy balance in the present, and to continue moving away from reliance on finite resources, the United States should take several steps as described in the foregoing paragraphs of this chapter. Through public awareness campaigns for lesser-known technologies, industry developers can position these resources for easier political uptake that will in turn increase the likelihood of additional subsidies and funding. Greater public awareness of available technologies may also lead to strong political support for a national RPS program to standardize

Table 6.3 Energy Subsidies in the U.S. (2007)

Beneficiary	Direct Expenditures	Tax Expenditures	Research & Development	Federal Electricity Support	Total
2007 Subsidies					
Coal	-	290	574	69	932
Refined Coal[1]	-	2,370	-	-	2,370
Natural Gas and Petroleum Liquids	-	2,090	39	20	2,149
Nuclear	-	199	922	146	1,267
Renewables	5	3,970	727	173	4,875
Electricity (Not fuel specific)	-	735	140	360	1,235
End Use	2,290	120	418	-	2,828
Conservation	256	670	-	-	926
Total	2,550	10,444	2,819	767	16,581
1999 Subsidies					
Coal	-	79	489	-	567
Natural Gas and Petroleum Liquids[2]	-	1,878	198	-	2,077
Nuclear	-	-	740	-	740
Renewables	5	1,000	412	-	1,417
Electricity (Not fuel specific)	-	139	175	-	314
End Use	1,545	103	487	-	2,135
Conservation	191	-	-	-	191
Federal Electricity Programs	-	-	-	753	753
Total	1,741	3,199	2,500	753	8,194

Total may not equal sum of components due to independent rounding.

[1]Tax expenditures attributable to the Alternative Fuels Production Tax Credit.

[2] In 1999, the Alternative Fuels Production Credit was realized mostly from the production of coalbed methane; valued at $1.2 billion, that subsidy is reported in Natural Gas and Petroleum Liquids.

Source: Energy Information Agency. Federal Financial Interventions and Subsidies in Energy Markets 2007. Available at: http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/execsum.pdf. Accessed: March 14, 2011

eligible forms of renewable and alternative energy. A federal RPS that follows the recommendations above will boost energy diversity while minimizing market inefficiencies. Finally, through increased understanding of these “bridging” and “bridge-to” technologies, the public and, in turn, the political arena may become more comfortable with relaxing subsidies for established energy sources and reprioritizing funding to focus on basic research for “bridge-to” technologies.

Notes

[1] "Renewable Portfolio Standards in the United States of America." Southern States Energy Board. October 2010. Available at: http://www.sseb.org/wp-content/uploads/2010/05/Matrix-of-State-RPS.pdf

[2] Gold, David. "Renewable Energy Standards: Savvy or Silly?" Alt Energy Stocks. March 17, 2011. Available at: http://www.altenergystocks.com/archives/2011/03/renewable_energy_standards_savvy_or_silly.html

[3] "States with Energy Efficiency Resource Standards." Pew Center on Global Climate Change, Last modified October 2007. Available at: http://www.pewclimate.org/node/2041

[4] "Maryland Incentives/Policies for Renewables & Efficiency." Database of State Incentives for Renewables & Efficiency. Last modified May 21, 2010. Available at: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MD05R&re=1&ee=1

[5] "Federal Financial Interventions and Subsidies in Energy Markets 2007," p 40, Energy Information Administration. Available at: http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/chap3.pdf

[6] Allaire, Maura and Stephen Brown. "Eliminating Subsidies for Fossil Fuel Production: Implications for U.S. Oil and Natural Gas Markets." December 2009. Available at: http://www.rff.org/RFF/Documents/RFF-IB-09-10.pdf