# Background Papers on Panel Topics

# prepared for

# *The Search for Wise Energy Policy*

# Conference

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**School of Public and Environmental Affairs**

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# Preface

This series of background papers was prepared by a team of graduate students in the School of Public and Environmental Affairs (SPEA) at Indiana University in support of the conference "*the Search for Wise Energy Policy.*" This conference was organized by SPEA and is scheduled for June 11, 2009 in the Mayflower Hotel in Washington, D.C.

The primary purpose of these papers is to provide background information related to most of the primary topics of the conference. The students were asked to review the appropriate literature and web sites in each of seven areas of energy policy and to prepare fairly concise review articles for use of the panelists. These papers have not yet been subjected to expert peer review. The opinions expressed are those of the individual authors, not the School of Public and Environmental Affairs or Indiana University.

This team of students was supervised by Professors Evan Ringquist and J.C. Randolph. Any omissions or errors are the responsibility of this team.

# Panel 2:  Changing Patterns in Energy Supply

## B. Fossil Fuels – *Brian Wright*

### 1.0 The Context for Fossil Fuels

Fossil fuels[1] supply over 85% of the energy consumed in the United States each year (US EIA, 2009a). While increasing world demand has created concern over supplies of fossil fuels, they still remain a relatively abundant and affordable source of energy for electricity and transportation. Fossil fuels are also used by a wide variety of industries as a chemical feedstock. While state and federal government policies such as renewable energy standards will diversify our energy supply, fossil fuels will continue to be the major source of energy for the US. Due to the large volume of material on fossil fuels, this report will focus only on emerging technologies and practices that are likely to affect supply and price of fossil fuels over the next few years.

#### 1.1 Changing Patterns

1.1.1 Projected Energy Demand

US fossil fuel consumption in 2006 was 84.85 quadrillion BTU (US EIA, 2009a). By 2030, this number is projected to be 89.77 quadrillion BTU (US EIA, 2009a). While the rate of annual growth in consumption of fossil fuels is expected to be much less than that of  biomass and renewable fuels, fossil fuel usage will continue to exceed that of other energy sources (US EIA, 2009a).

**Table 1: Comparison of 2006 US energy consumption with projected 2030 energy consumption (EIA, 2009a)**

| **Source** | **2006 Consumption (quad BTUs)** | **2006 Consumption (% of total)** | **2030 Consumption (quad BTUs)** | **2030 Consumption (% of total)** |
|---|---|---|---|---|
| Petroleum and Liquid Fuels[2] | 40.13 | 40.05 | 38.17 | 33.61 |
| Natural Gas | 22.26 | 22.25 | 25.04 | 22.05 |
| Coal | 22.46 | 22.45 | 26.56 | 23.39 |
| Total Fossil Fuels | 84.85 | 84.83 | 89.77 | 79.05 |
| Total | 100.02 | | 113.56 | |

[1] For the purpose of this paper, fossil fuels include coal, natural gas, and petroleum.
[2] This includes liquid fuels derived from coal and natural gas

### 1.1.2 Common Challenges

The different types of fossil fuel pose their own unique challenges and issues, but there are some common themes that impact the use and cost of coal, natural gas, and petroleum.

Carbon Emissions

The combustion of fossil fuels is the top source of $CO_2$ emissions in the country, accounting for 5,735.8 million metric tons (mmt) out of total of 6103.4 mmt emitted in the US in 2007 (US EPA, 2009a). The use and price of all three types of fossil fuels will be affected by carbon emission standards in whatever form they take. Technology and policy will both contribute to determine the final cost of carbon emissions. Policy will likely take the form of either a carbon tax or a cap and trade system. Feasible carbon capture and sequestration (CCS) must be developed if the US is to meet carbon emission reduction goals. In addition to current emissions from fossil fuel use, production of alternative sources of oil such as oil shale and coal liquefaction produce larger amounts of $CO_2$ per barrel of oil produced than traditional oil refining. Natural gas is being looked at as an alternative to coal and petroleum use due to lower carbon emissions. However, this use will likely increase the cost of using natural gas for space heating. Since carbon policy is the topic of the background paper on Panel 4, this paper will focus on the impact of technology, alternative fuels, and fuel shifting on carbon emissions within the US.

Water Usage and Discharge

Freshwater withdrawal and consumption is an important factor in continued fossil fuel use that should be taken into account. The growing US population is increasingly putting strains on freshwater supplies. In many areas of the country, water demand exceeds precipitation (US DOE, 2006). Thermal generation of electricity, which includes fossil and nuclear fuels, accounts for 39% of freshwater withdrawals in the US (DOE, 2008). Only a small portion of the water is consumed, and most of it is discharged back into the supplying water body. However, this high rate of withdrawal could create difficulties in times of water shortage or in areas with limited resources. Fossil fuel extraction and processing consume 1 to 2.66 billion gallons of water per day (DOE, 2008).

Land Use/Extraction

A large portion, 68 per cent, of the remaining oil and natural gas resources in the US is located on public lands (NETL, 2009). For oil shale, this number is as high as 80% (Bartis et al., 2005). A balance must be reached between meeting the nation’s energy demands, and the duty of the federal government to act as a good steward of our nation’s public land.

For coal, controversial extraction practices such as mountaintop removal mining and long wall mining should be examined by the Obama Administration. These practices are cost effective methods of extracting large volumes of coal, but can cause significant damage to environmental resources and private property (EPA, 2005; Stout, 2004).

# 2.0 Coal

Coal generates 52% of the nation's electricity (EIA, 2009a), and is an abundant and relatively cheap source of energy. However, use of coal comes with a high environmental price. The focus is on greenhouse gas emissions from the burning coal, but there is growing public awareness on the environmental impacts of mining and coal combustion wastes (CCW).

## 2.1 Projected Supply and Demand

### 2.1.1 US Coal Reserves

The US currently has total coal reserves equal to about 250 years of use at current levels. However, only a portion of these reserves are recoverable due to economic and technological limitations. At best estimate, around a 100 year supply is actually recoverable with existing mining practices and technology. Commercial scale production of liquid fuels through coal liquefaction could reduce this number by up to 50 years (NRC, 2007).

Quality as well as quantity must also be taken into account when evaluating usable coal reserves. The higher quality coals, in terms of high BTU value and lower amounts impurities such as sulfur and heavy metals, are mined first. The remaining poorer quality coals will require that larger tonnages be burned to create the equivalent amount of electricity. Due to higher amounts of impurities in these coals, increased amounts of air and solid waste pollution will also be a concern (NRC, 2007).

### 2.1.2 Domestic Production

In 2007, 23.70 quadrillion BTU of coal were produced. By 2030, this number is expected to rise to 26.93 quadrillion BTU. Total coal generating capacity within the US is 336,040 Megawatts (MW) (US EIA, 2009a).

### 2.1.2 Projected Consumption

US coal consumption in 2006 was 22.46 quadrillion BTU. By 2030, this number is estimated to rise to 26.56 quadrillion BTU (US EIA, 2009a). Coal has the highest projected annual rate of increase in usage of any fossil fuel. Several factors could affect this projected rate of increase:

- Commercial scale production of liquid fuels from coal could lead to significant increases in coal usage.
- Carbon standards could lead to increased use of other sources of electricity, due either to increased costs of coal electricity generation, or to the need to diversify the electricity supply in order to meet carbon caps.
- Increased costs of coal generation due to pollution regulations on mercury and coal combustion waste (CCW).

## 2.2 Emerging Technologies and Practices

### 2.2.1 Carbon Capture Technology for Pulverized Coal Plants

US $CO_2$ emissions from coal were 2086.5 mmt in 2007 (US EPA, 2009a). Reducing $CO_2$ emissions from coal plants is difficult due to the sheer volume of flue gas produced, as well as impurities within the gas.

Traditional pulverized coal plants create flue gas that is about 10-15% $CO_2$ by concentration. In order to make CCS technologically and economically feasible for pulverized coal plants, researchers are focusing on ways to create a pure $CO_2$ flue gas stream that could be collected and sequestered (DOE, 2007). Demonstration projects in the US are experimenting with two processes for accomplishing these goals: oxygen combustion and the chilled ammonia process.

The oxygen combustion process burns the coal in an environment of almost pure oxygen. This process creates a flue gas that is almost pure $CO_2$ and water vapor. The $CO_2$ can then be condensed and transported for sequestration. The major barrier to the oxygen combustion process is finding a low-cost supply of pure oxygen at the volumes needed. Several demonstration projects are testing technology that greatly reduces the costs of oxygen combustion[1] (NETL, 2009).

The chilled ammonia process cools the flue gas to around 35ºF. An ammonia based solvent absorbs the $CO_2$, and the resulting compound is sent to a regenerator where the $CO_2$ is filtered out. The demonstration project has achieved $CO_2$ removal levels of 90%. As a co-benefit, particulates are also removed from the flue gas by the process (AEP, 2008). The cost for the process is estimated at $17/ton of $CO_2$ removed (EPRI, 2006).

### 2.2.2 Coal Gasification

Coal gasification, also referred to as Integrated Gasification Combined Cycle (IGCC), is being proposed as a “clean coal” alternative to traditional pulverized coal plants. Rather than burning the coal, the gasification process heats the coal under high pressure until a gas is produced. The gas is burned to produce electricity. Fourteen IGCC plants are being proposed in the US (Vallentin, 2008).

IGCC plants offer greater potential for CCS than pulverized coal plants because the process can emit $CO_2$ as a concentrated gas stream, which eases capture of the carbon emissions. Nitrogen oxide, sulfur dioxide, and mercury emissions may also be reduced by 90% or more in IGCC plants, compared to traditional pulverized coal plants. The plants still produce large volumes of solid wastes, and disposal may be a concern for IGCC plants. However, capital costs for an IGCC plant may be 20-47% higher than those of a pulverized coal plant (Migden-Ostrander, 2008). These higher costs have led to opposition to proposed IGCC plants from consumer protection groups, due to the impact to ratepayers.

Co-production of Syngas and Liquid Fuels (Fisher-Tropsch process)

The IGCC process allows for co-production of several different products. Synthetic natural gas (also referred to as syngas) can be produced from carbon monoxide (CO) and hydrogen gas

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[3] A list of NETL funded oxygen combustion demonstration projects can be found at http://www.netl.doe.gov/technologies/coalpower/ewr/co2/OxyCombustion.html

streams generated by the gasification process. Combustion of the syngas produces $CO_2$ levels comparable with natural gas, but lifetime syngas $CO_2$ emissions, which includes $CO_2$ produced during the extraction, production, and refining, are higher than that of natural gas - 3550 lb $CO_2$ equiv/MWh and 1250 lb$CO_2$ equiv/MWh, respectively (Jaramillo et al., 2007). CCS controls at the IGCC plant would bring these lifetime emissions levels down to a comparable level with natural gas (Jaramillo et al., 2007).

The syngas produced at IGCC plants can be further processed to produce liquid fuels through the Fisher-Tropsch process, a process that can create a high quality diesel fuel which produces significantly lower $CO_2$ (-4%), NOx (-13%), and particulates (-52%) (Vallentin, 2008). However, lifetime emissions of $CO_2$ for coal-to-liquid (CtL) diesel will be twice as high (~1.2 tons of $CO_2$/BBL vs. ~.6 $CO_2$/BBL) as that of conventional diesel (Vallentin, 2008). As with syngas, CCS would bring these lifetime emissions down to comparable levels with conventional fuels.

## 2.3 Environmental Concerns

### 2.3.1 Water Usage by Coal Power Plants

By 2030, daily withdrawal of freshwater from coal-fired plants may rise from 2.4 billion gallons per day (BGD) to 3.3 BGD (US DOE, 2008). In addition to water supply concerns, withdrawals pose serious threats to populations of fish and other aquatic animals when they are pulled into the cooling water intake or trapped against filter screens. Hundreds of millions of fish die each year, resulting in significant economic loss to recreational fishing (US EPA, 2002a).

About 52% of coal electricity generators rely on once-through cooling systems, those in which the water passes through the plant once and is then discharged. Re-circulating (closed-cycle) systems reuse cooling water multiple times before discharge. These systems reduce water withdrawals by 90%, but actual water consumption is 60-80% higher than once-through cooling systems (CATF, 2004). Dry cooling, which uses air instead of water for cooling, is another alternative to once-through cooling systems, but cost for these systems is higher (NETL, 2003). A combination dry cooling and water cooling system is also an alternative.

In 2001 the US EPA required new power plants to meet best available control technology (BACT) standards for cooling water intake structures, in order to reduce adverse environmental impacts. However, older plants are exempt from the requirement. EPA believes this requirement will result in at least 90% of new plants installing re-circulating systems (US EPA, 2001).

### 2.3.2 Mountaintop Removal Mining

Mountaintop removal mining provides a cost-effective method for extracting valuable low sulfur coal deposits. However, this mining process is coming under increasing public scrutiny due to the serious impact it has on the environment. Recently, the US EPA called for a review of stream fills, the process of filling in stream valleys with mine overburden (US EPA, 2009b). Over 1200 stream segments have been filled in West Virginia. These valley fills can damage stream ecosystems by eliminating important headwater habitats, and will increase the risk of flooding by reducing carrying capacity during large storm events (US EPA, 2005).

Prior to 2002, in order to be permitted under Section 404 of the Clean Water Act, any fill operation being conducted in US waters was required to demonstrate that the fill would have some beneficial end use, such as creating a site for construction,. In 2002, the EPA revised the regulations on fill operations to allow any fill that would replace any portion of water with dry land, or raise the bottom elevation of any water of the US (US EPA, 2002b). The rule also allowed fill for the sole purpose of waste disposal. The rule prevents “garbage and trash” being used for this purpose, but provides no definition for “garbage and trash” (US EPA, 2002b).

### 2.3.3 Coal Combustion Wastes

Each year, the burning of coal within the United States produces over 130 million tons of coal combustion wastes (CCW). The wastes are primarily disposed of in landfills, surface impoundments, or surface coal mines. Regulations on these facilities vary from state to state, and many of the facilities lack environmental safeguards such as liners or ground water monitoring. For example, 3 out of 4 CCW surface impoundments are unlined (US EPA, 2000). A portion of the wastes are also reused for a variety of purposes, including in the production of concrete or asphalt, and as fill material. To date, 67 cases of ground and surface water contamination from CCW have been identified by EPA. Scientific studies have documented ecological damage from CCW contamination, including reproductive problems, deformities, and death in fish and wildlife populations (US EPA, 2007).

These wastes were exempted from federal regulation under the 1980 Bevill Amendment to the Resources Conservation and Recovery Act (RCRA). The Amendment required EPA to conduct an analysis to determine if federal regulations were warranted. In 2000, EPA concluded that a federal rulemaking on CCW was warranted due to the evidence of contamination from CCW and deficiencies in state regulations. Federal regulations on disposal of CCW that would require safeguards such as liners and ground water monitoring would cost the coal industry around $1 billion per year in 2000 dollars (US EPA, 2000). There are currently two separate rulemakings on CCW being conducted: an EPA rulemaking on CCW landfills and surface impoundments, and an Office of Surface Mining (OSM) rulemaking on mine placement of CCW. These efforts should be coordinated because EPA has waste management expertise that OSM is lacking. In 2006, the National Research Council released a report[2] giving recommendations on management of CCW in mines, which should help establish the minimum of what should be required for mine placement of CCW.

# 3.0 Natural Gas

Natural gas is a versatile source of energy, and is used for space heating, electricity generation, and as a chemical feedstock. Natural gas is seen by many as a cleaner alternative to coal and petroleum, but supplies of natural gas are limited.

## 3.1 Projected Supply and Demand[3]

### 3.1.1 US Natural Gas Reserves

[2] Management of Coal Combustion Residues in Mines, http://www.nap.edu/catalog.php?record_id=11592
[3] See Appendix 2.1 and 2.2 for US annual natural gas production and consumption over the last few decades. Up to date information on natural gas supply and demand within the US can be found at the Energy Information Administration website, http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html . The data are updated on a monthly basis.

The US has proven natural gas reserves that have been demonstrated as recoverable under current economic and technological conditions of 237.726 trillion cubic feet (Tcf). Coal bed methane, an alternative source of natural gas, has proven reserves of 21.875 Tcf (EIA, 2000). The Energy Information Administration estimates the total recoverable natural gas supplies in the US may be as high as 1190 Tcf. This figure includes resources that are undiscovered, unproven, or that come from alternative resources (EIA, 2000).

**Table 2: Projected Domestic Supply and Demand of Natural Gas**

| | **2007** | **2030** |
|---|---|---|
| Domestic Supply (dry gas production) | 19.84 quadrillion BTU (19.089 Tcf) | 24.26 quadrillion BTU |
| Domestic Demand | 23.70 quadrillion BTU (23.047 Tcf) | 25.04 quadrillion BTU |
| Unmet Demand | 3.86 quadrillion BTU | 0.78 quadrillion BTU |
| Imports | 4.72 quadrillion BTU | 2.58 quadrillion BTU |
| Exports | 0.83 quadrillion BTU | 1.87 quadrillion BTU |

(EIA, 2009a; EIA 2009b)

### 3.1.2 Domestic Production

Natural gas production within the US has been increasing over the last few years, and this trend is expected to continue through 2030. This estimate is based on assumptions that higher natural gas prices will drive further development in untapped reserves, as well as improvements in drilling technology (EIA, 2009a). Despite this trend, imports will continue to be needed to meet total demand.

**Table 3: Natural Gas Consumption by Sector (2007)**
**(Units in quadrillion BTUs unless otherwise noted)**

| **Sector** | **2007 Consumption** | **Predominant Uses** |
|---|---|---|
| Residential | 4.86 | Space heating (3.21); water heating (1.35) |
| Commercial | 3.10 | Space heating (1.45); combined heat and power, emergency generators, and manufacturing (1.00) |
| Industrial | 6.82 | Combined heat and power (6.27); chemical feedstock (0.55) |
| Transportation | 0.03[4] | |
| Electric Power | 7.06 | |

(EIA, 2009a)

[4] Measured in trillion cubic feet

## 3.2 Energy Security

The bulk of US natural gas needs are met by domestic production, but the US is still reliant on imports to meet total demand, with imports accounting for 16.4% of US consumption in 2007 (EIA, 2009b). Canada is the largest exporter of natural gas to the US, with 3.78 Tcf shipped to the US in 2007 via gas pipeline (EIA, 2009b). Liquefied natural gas imports, which come primarily from Trinidad and Egypt, are steadily growing, make up most of the remaining imports, with .77 TCF shipped to the US in 2007.

## 3.3 Emerging Technologies and Practices

### 3.3.1 Liquefied Natural Gas (LNG)

LNG is natural gas that has been condensed down to 1/600$^{th}$ of its original volume for ease of transport (FERC, 2009). LNG is primarily shipped to the US via ship, and special terminal facilities are required to decompress the gas for shipment in US natural gas pipelines. Eight (7 import and 1 export) LNG terminals currently operate within the US. 40 more terminals have been proposed to the Federal Energy Regulatory Commission (FERC), but market analysts suspect that only 12 will be constructed, due to costs and market demand (FERC, 2009). Some concern exists over compatibility of LNG with US appliances because of a higher BTU value than pipeline natural gas, and some impurities that form during decompression (FERC, 2009). The natural gas industry and FERC are working together to develop voluntary standards for the decompressed LNG that they believe will address these issues. Because of the long distances LNG is transported and the energy used to compress and decompress the gas, LNG has lifetime $CO_2$ emissions that are higher than pipeline natural gas; 1600 lbCO2 equiv/MWh and 1250 lb CO2 equiv/MWh respectively (Jaramillo et al., 2007).

<u>Terminal Facilities</u>

Local opposition has developed to some proposed LNG facilities due to concerns of over-development in sensitive coastal areas. Concerns have also been raised over issues of increased ship traffic and security issues.

### 3.3.2 Coal bed Methane

Coal deposits are a potential source for large volumes of methane-rich gas, known as coal bed methane (CBM), which provides a good substitute for natural gas. In order to collect the gas, groundwater in the coal seams must be drained in order to lower pressure in the coal seam and allow for escape of the gas. The coal deposits must also be fractured, typically through injection of chemicals into the seam, to allow the gas to be released. The composition of these chemicals is unknown, and concerns have been raised about possible ground water contamination (US House, 2007). Economically recoverable methane in CBM deposits may equal 100 Tcf (USGS, 2000).

<u>Environmental Concerns</u>

CBM production does create challenges. A large volume of water is produced, and while some of the water can be used for drinking and agriculture, it can exceed EPA standards for total dissolved solids, and in some cases contain trace levels of heavy metals (USGS, 2000). Methane can also escape during extraction into the atmosphere, where it is a potent greenhouse gas, or into surrounding groundwater. A Colorado study has found elevated levels of methane in residential water wells as a result of nearby CBM extraction (Thyne, 2008). In some cases, ranchers and farmers have complained about the discharge water flooding their property and causing damage to crops or grazing land.

The Energy Policy Act of 2005 exempted natural gas development from meeting the stormwater runoff requirements of the Clean Water Act. The Act also exempted the practice of hydraulic fracturing from regulation under the Safe Drinking Water Act. A study by the National Academy of Sciences on the surface and ground water impacts from CBM development was required by the Act, and is currently underway (US House of Representatives, 2007).

### 3.4 Natural Gas as a Low Carbon Fossil Fuel

Carbon emission standards could create increased demand for natural gas as an energy source, because it has lower greenhouse gas emissions compared to coal and petroleum (EPA, 2009a),. However, barriers exist to increased use. Natural gas supplies may not be sufficient to meet a large increase in demand. A large shift to natural gas for electricity generation would consume all of the expected increase in supply of imported LNG (NETL, 2008). Due to cost, natural gas generation is typically limited to peak demand times. Increased use of natural gas could increase electricity prices by as much as 31% (NETL, 2008). Increased use of natural gas for generating electricity would also likely increase the cost of gas for space heating.

Use of natural gas as transportation fuel is limited by infrastructure. Very few natural gas fueling stations exist within the US[5]. Most of these sites are private facilities owned by businesses or government entities, and are not open to the general public.

## 4.0 Petroleum

Petroleum is our most heavily used fossil fuel, but two-thirds of our supply of crude oil supply comes from imports. Oil shale deposits could significantly boost domestic supplies of petroleum, but development of this resource faces technological and environmental barriers.

### 4.1 Projected Supply and Demand[6]

#### 4.1.1 US Petroleum Reserves

As of 2007, the US has proven oil reserves of 21.317 billion barrels (EIA, 2009c). Mean estimated total onshore reserves are 48 billion barrels, and 78 billion barrels are estimated to exist on the outer continental shelf (USGS, 2008). Retrievable oil shale resources are estimated at between 500 billion and 1.1 trillion barrels of oil. The exact number will be dependent on the extraction method used and the price of oil (Bartis et al., 2005).

[5] An interactive map showing natural gas fueling stations can be found at http://www.afdc.energy.gov/afdc/stations/find_station.php

[6] See Appendix 2.3 and 2.4 for US annual petroleum production and consumption over the last few decades. Up to date information on petroleum supply and demand within the US can be found at the Energy Information Administration website, http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html . The data is updated on a monthly basis.

**Table 4: Projected Domestic Supply and Demand of Petroleum**

| | **2007** | **2030** |
|---|---|---|
| Domestic Supply | 10.73 quadrillion BTU (1.848 billion barrels) | 15.96 quadrillion BTU |
| Domestic Demand | 40.13 quadrillion BTU (6.759 billion barrels) | 38.17 quadrillion BTU |
| Unmet Demand | 29.40 quadrillion BTU | 22.21 quadrillion BTU |
| Imports | 29.86 quadrillion BTU | 23.07 quadrillion BTU |
| Exports | 2.84 quadrillion BTU | 3.17 quadrillion BTU |

### 4.1.2 Domestic Production

The projected increase in domestic production is based on assumptions of when drilling in outer-continental shelf deposits will begin, drilling in newly discovered deposits such as the Bakken Shale, and oil shale production (EIA, 2009a; EIA, 2009c).

### 4.1.3 Domestic Consumption

The largest uses of petroleum are gasoline and distillate fuel oil[7]. Beyond uses as a fuel, petroleum is also important as an industrial feedstock and in the production of asphalt and road oil.[8]

## 4.2 Energy Security

In 2007, US petroleum consumption exceeded domestic production by 4.911 billion barrels, and total imports were 4.916 billion barrels (EIA, 2009c). Over the last decade, imports have consistently exceeded domestic supplies by more than a two to one margin. The US relies on crude oil shipments from at least 114 different countries. The five largest importers to the US, in order, are Canada, Saudi Arabia, Mexico[9], Venezuela, and Nigeria (EIA, 2009c).

## 4.3 Emerging Technologies and Practices

### 4.3.1 Oil Shale

Extensive oil shale deposits exist within the Western United States. These deposits could produce as much as 3 million barrels of oil per day, and generate $50 billion per year in revenue (Bartis et al, 2005). However, several barriers exist that could slow or prevent development of this resource:

[7] Consuming 3.389 and 1.531 billion barrels respectively in 2007 (EIA, 2007d)
[8] Consuming .235 and .180 billion barrels respectively in 2007 (EIA, 2007d)
[9] Saudi Arabia and Mexico have rotated between the second and third spot over the last few years

- Current technology is not sufficient for supporting commercial scale production.
- 80% of oil shale deposits are located on public lands. Large scale extraction operations on these lands could generate significant public opposition
- Oil shale production could use between 105 and 310 million gallons of water per day. Population growth in the area to accommodate the production would account for usage of an additional 58 million gallons per day (Bartis et al, 2005).
- Areas adjacent to the oil shale deposits are classified Prevention of Significant Deterioration (PSD) Class I and II in regards to air quality, meaning strict air pollution controls will be needed.

Development of the technology and infrastructure needed for commercial scale extraction is estimated to take 20-30 years (Bartis et al., 2005). Public challenges over extraction on public lands and water rights may delay development beyond this time frame. Oil can be extracted from the shale deposits in one of two ways: mining and surface retorting (extraction of the oil and refining) or in-situ retorting. The method selected will play a key role in how quickly and at what cost oil shale can be brought to commercial scale production.

Mining and Surface Retorting

This method involves extracting the oil shale through surface or underground mining. The shale would then be heated at a surface retorting facility to release the oil from the shale. Oil produced by this method is similar to a light sweet crude. Estimated production costs for this process is between $70 and $95 per barrel (Bartis et al., 2005).

Mining and surface retorting would require large scale, permanent impacts to public lands. Thousands of acres of land would have to be mined to support each production facility. The retorting process will result in emission of criteria air pollutants including SOx, NOx, and particulates, and the process is expected to result in higher greenhouse gas emissions than oil refining (Bartis et al., 2005). For each barrel of oil produced, 1.2 to 1.5 tons of spent shale is created. This would amount to 3.6 to 4.5 million tons of waste created each day. Runoff from these wastes could leach salts, arsenic, and selenium, and pose serious threats to water quality (Bartis et al., 2005).

In-Situ Retorting

The in-situ method developed by Shell involves drilling pipes into the shale to heat it in place. After about a 2 to 3 year period, the shale is heated enough to release the oil from the deposit. A freeze wall[10] is put into place to prevent migration of any released hydrocarbons outside of the extraction area (Brandt, 2008). Energy outputs for the process exceed energy inputs by 1.2 to 1.6 times. Cost of this process is estimated to be in the mid $20s per barrel (Bartis et al., 2005).

The surface impact of the in-situ process is greatly reduced from that of mining and surface retorting, but a significant amount of infrastructure would still need to be constructed (Bartis et al., 2005). Water consumption is equal to that of the other method. The freeze wall is expected to prevent any ground water contamination, but until this claim can be verified, bonds should be considered in order to cover cleanup costs if contamination does occur. Greenhouse gas emissions from the in-situ retorting are 21 to 47% larger than those from conventionally produced oil (Brandt, 2008).

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[10] A series of pipes are inserted around the extraction area, and coolant is run through the pipe in order to freeze the ground.

# 5.0 Conclusions

Each of the three fossil fuels can be put to a variety of uses including electric generation, space heating, and fuel for transportation. Supplies of all three fuels are finite, and the US must depend on foreign imports to meet domestic demand of petroleum and natural gas. Extraction, processing, and use of fossil fuels come with significant environmental costs. Technology and end use of the fuels will help to determine demand, affordability, and environmental impact of fossil fuels. The federal government should consider the full life-cycle impacts of varying uses for fossil fuels in designing policies that avoid unintended consequences on supply, affordability, and the environment.

## 5.1 Costs and Affordability

Affordability is important both in terms of overall price and of stability of prices. Sudden spikes in energy prices can be hard on the public and the economy, especially for low- income individuals and families. Major factors that will influence affordability of fossil fuels include:

- Supply and demand of fossil fuels, both in the domestic and world markets
- Regulatory standards for fossil fuels
- Development and utilization of alternative sources of fossil fuels and new technologies for use

### 5.1.1 Comparative Costs

**Table 5: Comparison of costs for electric generation by various fossil fuels**

| **Fuel type** | **2007**<br>**Dollars per million BTU** | **2030**<br>**Dollars per million BTU** |
|---|---|---|
| Steam Coal | 1.78 | 2.95 |
| Natural Gas | 7.02 | 12.61 |
| Distillate Fuel Oil | 14.77 | 33.51 |

(EIA, 2009a)

**Table 6: Comparison of costs for various liquid fuels**

| **Fuel type** | **2007**<br>**Dollars per million BTU** | **2030**<br>**Dollars per million BTU** |
|---|---|---|
| Gasoline | 22.98 | 46.54 |
| Diesel | 20.92 | 41.44 |
| Compressed Natural Gas | 15.46 | 23.55 |

(EIA, 2009a)

**Table 7: Comparison of Cost of Alternative Supplies of Petroleum**

| **Source** | **2009**<br>**Cost per barrel** |
|---|---|
| Crude oil | $50-60 |
| Coal liquefaction | $40 |
| Oil shale (mining and surface retorting) | $70-95 |
| Oil shale (in-situ retorting) | $20-30 |

(Bartis et al., 2005; EIA, 2009c)

### 5.2 Carbon Emissions

Carbon emission standards will impact the price of energy use, but may also affect relative use of different fuel types and sources due to differences in carbon emissions per unit of energy produced.

**Table 8: Lifetime Greenhouse Gas Emissions from Electric Generation**

| **Source** | **Greenhouse gas emissions (lb $CO_2$ equivalent/MWH)** |
|---|---|
| Pulverized coal | 2270 |
| Natural gas | 1250 |
| Liquefied natural gas | 1600 |
| Syngas | 3550 |

(Jaramillo et al., 2007)

**Table 9: Greenhouse Gas Emissions from Refining of Alternative Petroleum Sources**

| **Source** | **Greenhouse gas emissions (metric ton $CO_2$ equivalent/barrel)** |
|---|---|
| Crude oil | 0.42 |
| Diesel | 0.6 |
| Coal liquefaction | 1.2 |
| Oil shale[11] | 0.52-0.62 |

(Brandt, 2008; EPA, 2009; Vallentin, 2008)

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[11] Calculated based on estimated greenhouse gas emissions by Brandt (2008)

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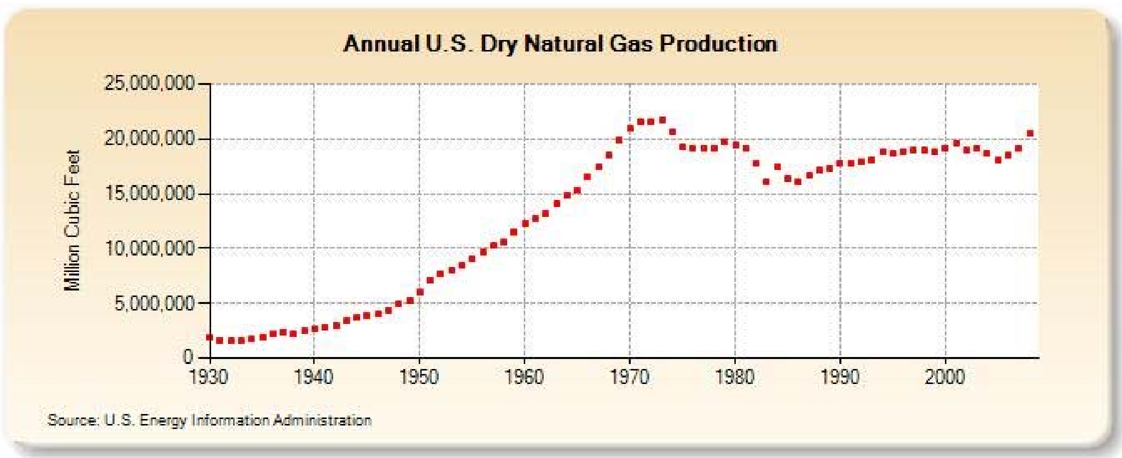
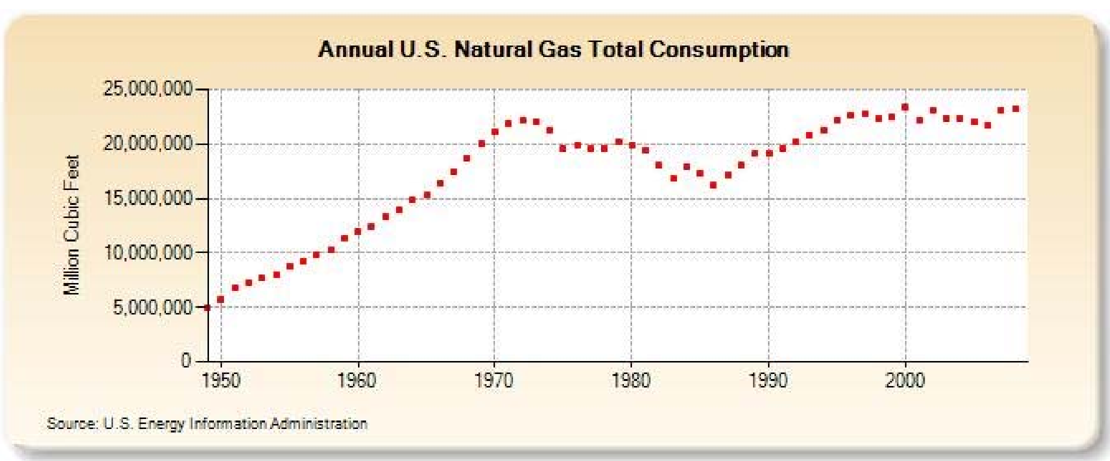
# Appendices

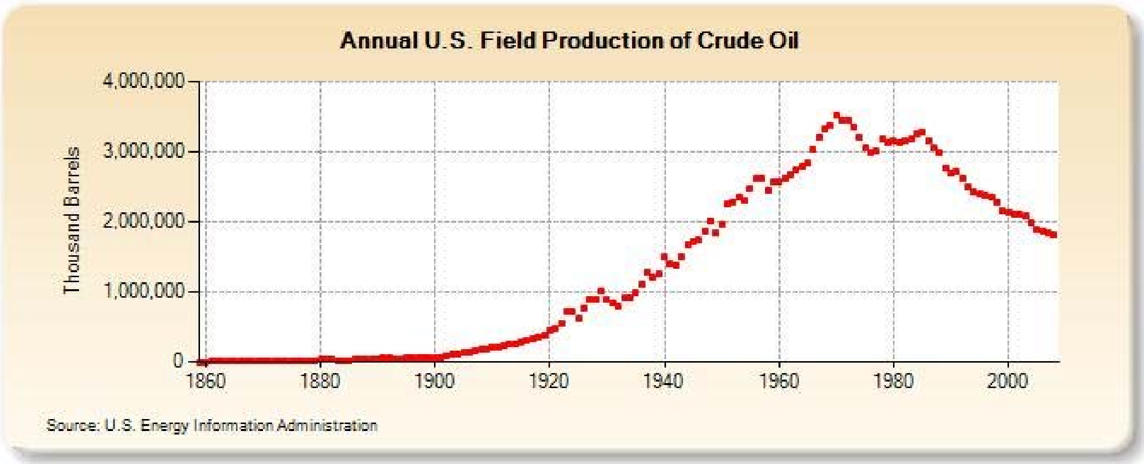
### Appendix 2.1




### Appendix 2.2



**Appendix 2.3**




**Appendix 2.4**