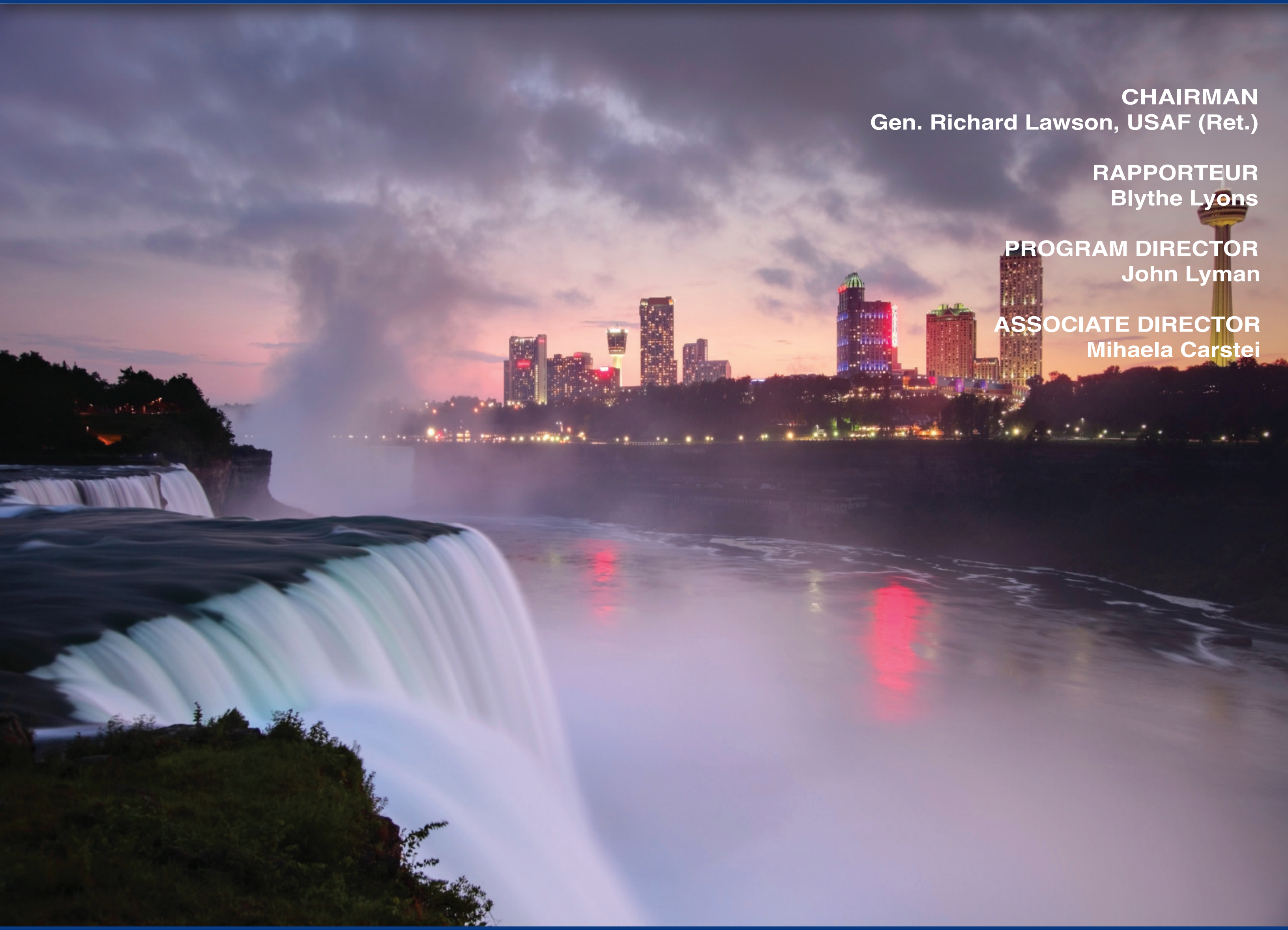
Atlantic Council

# Fueling America and the Energy Water Nexus

## How and Why it Impacts the Nexus and What Next




**CHAIRMAN**
Gen. Richard Lawson, USAF (Ret.)

**RAPPORTEUR**
Blythe Lyons

**PROGRAM DIRECTOR**
John Lyman

**ASSOCIATE DIRECTOR**
Mihaela Carstei


**A Report from the Atlantic Council's Energy Water Nexus Initiative**

The Atlantic Council promotes constructive US leadership and engagement in international affairs based on the central role of the Atlantic community in meeting the international challenges of the 21st century. The Council embodies a non-partisan network of leaders who aim to bring ideas to power and to give power to ideas by stimulating dialogue and discussion about critical international issues with a view to enriching public debate and promoting consensus on appropriate responses in the Administration, the Congress, the corporate and nonprofit sectors, and the media in the United States and among leaders in Europe, Asia, and the Americas. The Council is also among the few forums conducting educational and exchange programs for successor generations of US leaders so that they will come to value US international engagement and have the knowledge and understanding necessary to develop effective policies.

Through its diverse networks, the Council builds broad constituencies to support constructive US leadership and policies. Its program offices publish informational analyses, convene conferences among current and/or future leaders, and contribute to the public debate in order to integrate the views of knowledgeable individuals from a wide variety of backgrounds, interests and experiences.

The Energy and Environment Program at the Atlantic Council explores the economic and political aspects of energy security and supply, as well as international environmental issues. Major shifts in policies, behavior, and expectations are increasingly required throughout the world to meet the challenges of maintaining secure and sustainable energy supplies and protecting the environment while maintaining economic competitiveness. The Energy and Environment Program facilitates international cooperation on developing strategies, policies, and regulations to address the energy security, environmental and economic challenges posed by increasing energy demands and climate change.

# Fueling America and the Energy Water Nexus: How and Why it Impacts the Nexus and What Next


Chairman
Gen. Richard L. Lawson, USAF (Ret.)

Rapporteur
Blythe J. Lyons

Program Director
John R. Lyman

Associate Director
Mihaela Carstei



Atlantic Council

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Atlantic Council
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Washington, DC 20005

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# Foreword

Many factors are driving increasing public and government leaders' interest in energy and water issues throughout the world. The global population continues to grow, and with it demand for freshwater supplies for agriculture, industry, energy and recreation. Into the future, the majority of this growth will be in emerging and developing countries that are already experiencing water and energy security challenges today. Insecure energy supplies are bumping up against reductions in water supplies that are also becoming more costly. Heightened awareness of changes in climate patterns further drives the current debate.

The United States faces energy and water challenges as well. The energy sector is the fastest growing water consumer, and the growth is mainly in areas of the country that are facing stressed water supplies and intense competition for these limited freshwater supplies. As US demand for energy increases alongside a growing population, two major realities need to be examined and addressed. First, water is needed in every aspect of energy production. Water is used for the extraction, production, refining, processing, transportation and storage of primary energy fuels for transportation and electricity production. Water is necessary for every form of electricity generation, except for wind. Second, increasing amounts of energy are needed to pump water from increasingly deeper groundwater sources, to clean water from a wide variety of sources, to transport it, and to recycle it.

This double challenge—water for energy and energy for water is "the energy water nexus" that the Atlantic Council's Energy and Environment Program will focus on over the course of the next several years.

The Energy and Environment Program convened the second of three workshops on the US energy water nexus, focusing on the nexus as it relates to primary energy fuels for energy generation and transportation. Next, the nexus will be explored with regard to efficient use of water and energy in municipal, commercial and industrial water treatment and delivery systems. This work will form the backdrop for efforts in China, India, and other emerging economies over the next several years.

This report highlights the information and recommendations actions necessary to address the unintended consequences of water usage in the production of primary and transportation fuels that came to light in the second workshop. This was made possible thanks to presentations, for which the Council is most grateful, by experts from Capitol Hill, several US government agencies and laboratories, as well as industry and academic representatives, and leaders from the non-governmental organization community. We give thanks also to those who attended the workshop as participants.

Frederick Kempe

President and CEO
Atlantic Council

# Contributors

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Additionally, this report was greatly enhanced by the input and expertise of those who attended the “Energy Water Nexus: Primary Fuels for Power and Transportation in the US” workshop:

**Bill Bellamy**
CH2M HILL

**Steven Bohlen**
Lawrence Livemore National Laboratory

**C. Richard Bozek**
Edison Electric Institute

**Camille Calimlim**
US House Committee on Natural Resources’ Water and Power Subcommittee

**Peter Carlson**
Will and Carlson

**Mihaela Carstei**
Atlantic Council

**Neelam Chawla**
Canadian Embassy

**Matt Chiller**
CH2M HILL

**Ian Duncan**
University of Texas at Austin

**Ben Engleman**
Fuel Cell and Hydrogen Energy Association

**Paul Faeth**
CNA Corporation

**Jerald Fletcher**
West Virginia University

**David Garman**
Decker, Garman, Sullivan and Associates, Inc.

**Peter Gleick**
Pacific Institute

**David Hager**
David Energy Corporation

**Richard Hammack**
National Energy Technology Laboratory

**John Holmes**
National Research Council

**Robert Horner**
Argonne National Laboratory

**Charles Iceland**
World Resources Institute

**John Ingram**
National Weather Service’s Office of Hydrologic Development

**Jordan Kislear**
US Department of Energy

**General Richard Lawson**
Atlantic Council

**Ann Lowery**
Department of Environmental Protection, State of Massachusetts

**John Lyman**
Atlantic Council

**Blythe Lyons**
Atlantic Council

**Jordan Macknick**
National Renewable Energy Laboratory

**Mari-Angeles Major-Sosias**
Areva Inc.

**Jeremy Martin**
Union of Concerned Scientists

**Howard G. McClintic**
CTC Foundation

**Karen Metichs**
US Environmental Protection Agency

**Richard Middleton**
Los Alamos National Laboratory

**Daniel Morris**
Resources for the Future

**Robert Mosbacher**
Devon Energy Corporation

**Stephanie Kuzio**
Sandia National Laboratories

**Marina Moses**
National Academy of Sciences

**Howard D. Passell**
Sandia National Laboratories

**Ron Pate**
Sandia National Laboratories
**Henrik Rasmussen**
Rasmussen Public Affairs

**Michael Ratner**
Congressional Research Service

**Robert Reynolds**
Atlantic Council

**Tim Richards**
GE Energy

**John Riggs**
Aspen Institute

**Tara Rothschild**
US House Committee on Science, Space and Technology Subcommittee on Energy and Environment

**Stephen Schoenholtz**
Virginia Tech

**Erik Shuster**
Arizona State University

**James Slutz**
Global Energy Strategies, LLC

**Jeri Sullivan**
Los Alamos National Laboratory

**Vincent Tidwell**
Sandia National Laboratories

**Tanya Trujillo**
US Department of the Interior

**Jennifer Turner**
Woodrow Wilson Center

**Joyce Wang**
Woodrow Wilson Center

**Dave Wegner**
US House Committee on Transportation and Infrastructure's Water Resources and Environment Subcommittee

**Emily Williams**
American Wind Energy Association

**Alexander Winn**
The George Washington University

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# 1. Executive Summary

A substantive dialogue has emerged in the United States under the rubric of "the energy and water nexus," representing the deepening understanding of the circular relationship between water and energy. Both are essential building blocks of US economic and physical security, and interface with efforts to improve health and prosperity. On a national level, the criticality of this relationship to economic and public prosperity is often ignored, as energy and water impacts are largely specific to a watershed or a local surface water source. Simply put, energy security and the availability of water are both critical elements of US national security. Furthermore, ensuring adequate water supplies underpins the production of energy resources, which remains a major driver of the US economy.

The confluence of political, economic, technical, and energy resource constraints in the United States has reached an inflection point. The nexus has become a national issue because finite water resources are stressed by a range of policies and events. To address these growing national concerns, the Atlantic Council initiated a series of workshops to examine the various facets of the energy and water nexus and what solutions are at hand. In May 2011, the Council's initial workshop focused on the nexus from the perspective of thermoelectric power production. A second workshop was convened in November 2011 to examine the nexus from the vantage point of the extraction and processing of primary energy and transportation fuels.

This report builds on the Council's analysis in "Energy for Water and Water for Energy"[1] which examines the power production connection to the nexus and looks at the nexus from the fuels perspective. It examines the drivers behind the looming crisis, namely, the US energy portfolio, the water needs of these energy sources, and water scarcity realities. For each of the primary and transportation fuels-conventional oil and gas, unconventional oil and gas, biofuels, hydro fuels, geothermal fluids, coal and uranium-the report examines their role, how water is used in extraction and processing and what impacts these operations have on water quantity and quality.

The Council identifies eight major challenges regarding primary and transportation fuels impacts on the energy and water nexus:

- Congressional action is needed more than ever, but is unlikely given fractured committee jurisdictions and the current political climate;
- Federal bureaucracy hinders progress;
- Conflicts in federal and state roles undermine development of water management policies and smart regulations; Comprehensive, up-to-date energy and water nexus data is lacking;
- Biofuel policies reduce fossil fuel usage but incur a significant water cost;
- Coal mining requires continued efforts to protect local water quality amid concerns whether regulations are effective, consistent and working;
- Shale oil and gas revolution raises water quantity and quality issues that industry is working to address; and
- Shifting regulatory and political agendas are leading to an uncertain regulatory outlook for unconventional oil and natural gas at both the state and federal levels.

The November 2011 workshop's discussions and findings provided a basis for the Council's recommendations as to how to best address the water issues related to energy fuels. The recommendations are:

- Publish the "Energy-Water Science and Technology Research Roadmap" prepared by Sandia National Laboratories at the direction of Congress in 2005 and update and expand the roadmap as necessary;
- Create a presidentially appointed task force to address and reduce the federal, state, and local jurisdictional overlaps in regulating energy development, taking into account the role of agencies regulating water supply;
- Improve coordination between the myriad of federal agencies that deal with energy and water issues and streamline the fractured Congressional oversight of these agencies' policies and budgets;
- Develop a new paradigm of cooperation between the federal government's regulatory agencies and businesses on the forefront of US energy production;
- Decentralize water management to the watershed level with a goal of adopting aquifer compacts and increasing stakeholder participation in a collaborative decision making process;
- Improve, modernize and update the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) while recognizing that these laws have been successful in providing environmental protection and have provided models for other countries as well;
- Congress should direct and provide full funding for the United States Geologic Service (USGS) to collect and publish energy and water nexus data, including an understanding of how much water is available, ownership of water rights, the cost of purchasing water rights (where applicable), the stability of groundwater tables, and the feasibility of using substitute waters for fresh water supplies;
- Apply appropriate pricing and rate design principles so that water is appropriately valued, moving away from the public's longstanding assumption that water should be, if not free, then cheap;
- Integrate climate change impacts into water resource planning especially in western and southwestern sectors of the United States;
- Similar to efforts to eke as much energy savings as possible with energy efficiency programs, focus as many resources as possible on water demand reductions; a corollary recommendation is to pursue research and development of techniques that can reduce both the water and green house gas emissions footprint of the current energy production infrastructure;
- Improve energy and water conservation opportunities through improvements to the water delivery infrastructure and co-location of energy and water facilities;
- Re-think water supply through an array of initiatives that can stretch and supplement US fresh water supplies including:
  - harvesting rainwater,
  - increasing water storage using existing aquifers when water supplies are abundant, if it can be done efficiently from an energy point of view and without contamination problems,
  - artificially recharge aquifers, and
  - expand the use of impaired waters such as produced waters from oil and gas extraction and discharges from wastewater treatment plants to use in enhanced oil recovery (EOR) operations;
- Maximize and improve existing hydro resources and provide access to excess federal water supplies to the energy industry;
- Create a national/public dialogue using an innovative communications strategy to raise public awareness of the importance of the energy and water nexus and why better coordination between government, the private sector and stakeholders is necessary;
- Incentivize technology development to bring about:
  - development of new sources of water,
  - transformational changes in the way water is treated so that it can be recycled,
  - and improved agricultural practices to reduce the stress that agriculture (not just energy and fuels)

place on limited water supplies;
- Recognize and advertize the technology developments that can fundamentally change the energy industry's water challenges;
- Drive forward improved water and energy technologies and practices in the Department of Defense (DOD) and Department of Interior (DOI);
- Advance efforts by the Department of Energy (DOE) to develop energy efficiency and water efficiency standards;
- Encourage stakeholders to pressure Congress and the Administration to move forward with policy development and other needed changes;
- Adopt policies at the corporate board level to reduce companies' water footprint and to use water as sustainably as possible; and
- Find examples of good and bad practices and policies, study the approaches other countries have followed in dealing with droughts (Australia), creating a centralized water policy and new institutional strategies (European Union).

Together, government institutions, companies and stakeholders involved in the extraction and process of primary and transportation fuels must take additional steps to deal with the energy and water nexus. The Council also makes recommendations for better policies and standards across all of the fuel sectors.

For the renewable fuels sector:
- Reevaluate ethanol mandates in the renewable fuel standard;
- Develop biofuels policies that transition to production of cellulosic biofuels that rely on less water intensive crops and incentivize the building of a commercial-scale production facility; and
- Coordinate with agriculture policies that support farmers' use of water-wise crops.

For the coal and uranium mining sectors:
- Improve mining regulations by establishing better benchmarks that take into account the wide variability of streams' water quality throughout the United States;
- Mining industry to continue to develop best practices and improved material handling methods.

For oil and gas production sectors:
- Designate a lead federal agency to take the responsibility on promulgating tough but fair fracking regulations;
- Whatever agency is chosen, it must improve its interface with and develop partnerships with the companies involved in fracking;
- More research, transparency and science-based development of fracking regulations that will lead to understand and pinpoint the practices that may lead to contamination, and to distinguish actual fracking impacts from naturally occurring contaminants and chemicals;
- Further study of the methane migration issue, full disclosure of fracking fluids, and banning the use of diesel fuel in fracking fluids, leading to greater public trust in unconventional oil and gas operations;
- Oil and gas industry to address the public's perception about the risks involved in unconventional drilling techniques and make it a priority to gain public trust in its operations; and
- Unconventional oil and gas operators must drive the push for integrating innovative technologies into operations; industry needs to improve well integrity, use alternative well simulation techniques that do not use water, utilize mobile filtration units to clean produced waters and fracking fluids that return to the surface, replace on site diesel engines with natural gas engines to reduce the lifecycle water profile, and use satellite systems to move trucks around intelligently and to reduce water needs to clean trucks and transportation routes.

The United States is at a crossroad. Can the favorable trends toward increasing domestic production of energy and transportation fuels be accomplished while still maintaining sustainable water supplies? The United States today needs new policies and significant infrastructure investment in order to meet the increasing demand for water and energy, while dealing with the constraints of growing water scarcity and potential threats to water quality.

# 2. The Energy and Water Nexus Has Become a Crucial National Issue

A substantive dialogue has emerged in the United States under the rubric of "the energy and water nexus," representing the deepening understanding of the circular relationship between water and energy. Both are essential building blocks of US economic and physical security, and interface with efforts to improve health and prosperity. On a national level, the criticality of this relationship to economic and public prosperity is often ignored, as energy and water impacts are largely specific to a watershed or a local surface water source. **Simply put, energy security and the availability of water are both critical elements of US national security. Ensuring adequate water supplies is essential to assure production of energy resources.**

The confluence of political, economic, technical, and energy resource constraints in the United States has reached an inflection point. The nexus has become a national issue because finite water resources are stressed by a range of policies and events, including:

- Biofuel gasoline mandates;
- Bioenergy yields being reduced by low precipitation, droughts, heat waves, and floods;
- Emergence of wide-scale hydraulic fracking for unconventional oil and gas;
- Severe droughts in fossil fuel-rich areas;
- Continuing push for renewable energy production, some of which is water-intensive;
- Efforts to scale back primary fuels extraction, such as coal and uranium mining, to avoid water quality impairments exacerbated by low water conditions;
- Increasing number of water bodies in the East that are experiencing diminished stream flows;
- In three of the fastest growing regions in the country, the Southeast, Southwest, and Northwest, new power plants have been opposed because of potential negative impacts on water supplies; and
- Surface water supplies have not increased in 20 years, while groundwater tables and supplies are simultaneously decreasing.

The environmental impacts and availability of water impacts associated with the extraction of energy and transportation fuels are becoming increasingly important issues. **The competition for water between traditional users and the energy industry has intensified.** In just one scenario, likely to be replayed in many other regions of the country, the severe drought in Texas is exacerbating tensions as oil and gas drilling companies are outbidding farmers in the ongoing rush to purchase water rights. Texas rice farmers may decrease production for lack of irrigation water at a cost they can afford. In select areas, oil- and gas-drilling water needs are concentrated and have a magnified local impact on already-stressed water supplies. Hurting for jobs, communities may trade off the loss of river and aquifer water supplies for the employment and income gains to be had in drilling for unconventional oil and gas. This could potentially lead to a negative impact on the US food supply if cattle farmers decide that the returns on selling water for oil and gas production far outstrip the profits to be earned from raising cattle.

**Layered on top of these realities is the growing chorus of public concern about water quality issues in energy production.** Even in areas of the country not suffering from drought conditions, some stakeholders argue that the economic and energy security benefits of increasing primary energy fuels or growing non-greenhouse-gas-producing biofuels are not worth the perceived environmental costs. In short, different stakeholders' philosophies are at odds, and US prosperity could suffer if the competing interests are not balanced.

To address these growing national concerns, the Atlantic Council initiated a series of workshops to examine the various facets of the energy and water nexus and what solutions are at hand. In May 2011, the Council's workshop focused on the nexus from the perspective of thermoelectric power production. A second workshop was convened in November 2011 to examine the nexus from the vantage point of the extraction and processing of primary energy and transportation fuels. Plans are underway to hold a third workshop that will focus on how water and energy are consumed and can be conserved in municipal, commercial and industrial water treatment and delivery systems.

# 3. Energy and Water Nexus Drivers

## 3.1 Modest Economic Growth with Continued Increases in Energy Supply and Demand

Over the next two decades, the U.S. Energy Information Agency (EIA) predicts that the United States will see modest economic growth, increased energy efficiency[2], growing domestic energy production (of oil and gas primarily), and continued adoption of non-petroleum liquids (for transportation purposes). Due to slower growth than usual after a recession, gross domestic product (GDP) average growth is forecast to be 2.6 percent between 2010 and 2035. Transportation related energy demand and electricity demand are forecast to grow 0.2 percent and 0.8 percent, respectively, during that time period.

Even with a modest GDP growth forecast through 2035, primary energy consumption is forecast to increase. According to the most recent EIA annual energy outlook, total primary energy consumption was 101.4 quadrillion British Thermal Units (Btu) in 2007 and will grow by 10 percent from 98.2 quadrillion Btu in 2010 to 108.0 quadrillion Btu in 2035 (which is 6 quadrillion Btu less than the EIA's 2011 projection for 2035.)[3]

The United States is expected to add a net 223 gigawatts (GW) of new power capacity from 2009 to 2035 in order to meet increasing demand.[4] The primary driver behind this expansion is an expected population increase of 70 million people from the early 2000s to 2030.[5] EIA predicts that in the period 2010 to 2035, the share of electricity generation by fuel type will change as follows:

- Natural gas increases from 24 to 27 percent;
- Renewables increase from 10 to 16 percent;
- Coal declines from 45 to 39 percent;
- Nuclear shows modest declines from 20 to 18 percent; and
- Oil remains at 1 percent.

**The vast majority of the new installed electric power capacity will come from natural gas, wind, and other renewables. The reality is, however, that under current US policies, even with the rapid growth in renewable power production, fossil fuels will still provide 78 percent of total US energy use.** In 2035, EIA estimates that total US energy use will be provided 10 percent by (non-liquid biofuel) renewables, 21 percent by coal, 24 percent by natural gas, 3 percent by liquid biofuels, 33 percent by oil and other liquid fuels, and 8 percent by nuclear power.[6]

## 3.2 Energy Related Water Requirements are Growing

**The energy sector is the fastest growing US water consumer.[7] This growth is driven by overall rising energy demand, increased domestic mining and processing of primary fuels, and shifts to the use of more water intensive energy sources (such as biofuels.)** Under EIA's forecast that assumes current policies remain in place, the growth in electricity-generation capacity correlates to a 36 percent increase in water consumption by 2035.[8] In addition, water for transportation fuels may triple over the next 15 years due to more miles being driven by an increasing population and the increasing water intensity of transportation fuels as just mentioned. Without further major changes in existing policies and practices, these increases are unlikely to be fully offset by improved car and truck fuel efficiency gains.[9]

Questions remain as to how changes in the electricity generation portfolio, as well as changing transportation fuel use patterns, might influence and potentially alter future water demand. Demand changes cannot be precisely determined at this time because of the high number of variables. For example, if production of natural gas increases significantly as expected, the key factor will be the percentage of the supply coming from shale fracking. Fracking is forecast to grow from contributing 23 percent of domestic gas production in 2010 to 49 percent by 2035. Shale gas production in some shale plays, as discussed below in section 4.3, will consume large quantities of water. Some renewable transportation fuels also require significant amounts of water as discussed in section 4.0. Global market forces, not just domestic resource availability, will play a large role in determining the future role these energy resources play-and the demands on our water resources. It is too soon to tell what will happen to the water footprint of US fuels.

### 3.2.1 Water Consumption

It is often noted that energy-related water consumption is relatively small on a national level. The Council's report, "Energy for Water and Water for Energy,"[10] showed that of the 100 billion gallons of water the US population consumes per day, only a small fraction—less than 5 percent—is consumed in the production of electricity and primary fuels. In the overall water picture, over 80 percent of the water consumed is for irrigation purposes; 4 percent is consumed for thermoelectric power production; and only 1 percent is used for fuel production/mining.

**Relatively speaking, this low level of water consumption seems minor at first glance. However, it is a significant issue, even though largely unnoticed by the population at large, because both water resources and demands are not evenly distributed, and demand and availability are not well correlated.** The energy sector is growing in areas facing strained water supplies; take for example the drought has led to decreasing water tables in Texas just when oil and gas production is significantly increasing. In areas where water is abundant, it is still expensive to transport to other areas where it is needed, and it is problematic to store due to evaporation and environmental issues at dams. Added to this fundamental mismatch is the concern that even in areas where scarcity is not the overriding issue, there may still be negative impacts on the water quality. Locally, fuel extraction and processing can have a significant impact on water resources.

A report by the Congressional Research Service (CRS), "Energy's Water Demand: Trends, Vulnerabilities and Management," forecasts large water demand growth from 2005 to 2030 with significant increases in two of the three components, bioenergy and power plant cooling.[11]

Table 1 shows that energy related water consumption in 2005 approximated 12 billion gallons per day (BGD) and is slated to grow to 18 BGD by 2030. Water consumed for mining, production and processing of fossil fuels reached over 38 percent of the 12 BGD energy consumption but drops to 27 percent by 2030. By 2030, water for bioenergy crop irrigation and processing will exceed that consumed by fossil fuels and will grow by quite a large amount from 1.5 BGD in 2005 to 5.3 BDG by 2030. The CRS report forecasts that the 4.6 BGD for mining, production and processing of fossil fuels in 2005 will stretch only slightly to 4.9 BGD by 2030.[12] Variables that could change this outlook include the potential increase in unconventional gas and oil production that would result in increased water consumption. Also, changes in biofuel feedstocks, irrigation methods, local climate conditions, biofuel mandates and potential advancement in cellulosic biofuel production could all lead to a decrease in the amount of water used for biofuel production over time.

## Table 1: Comparison of Energy-Related Water Consumption; 2005 to 2030 in Billion Gallons per Day (BGD)[13]

| Source | 2005 | 2030 |
|---|---|---|
| Fossil Fuels Mining, Production, and Processing | 4.6 | 4.9 |
| Bioenergy Crop Irrigation and Processing | 1.5 | 5.3 |
| Thermoelectric Plant Cooling | 6.1 | 8.2 |
| Total | 12 | 18 |

### 3.2.2 Water Withdrawals

To put the discussion of water for mining and producing fuels into perspective, the water withdrawn for thermoelectric power production is first reviewed. The Council's report, "Energy for Water and Water for Energy," showed that 41 percent of water withdrawal for thermoelectric power production, topping all other withdrawal categories. It can lead to competition for water availability, as well as have an impact on water quality, mainly due to water temperatures changes.

For further perspective, total US water withdrawals per day are examined. About 410,000 million gallons per day (Mgal/d) of water was withdrawn for use in the United States during 2005. About 80 percent of the total withdrawal (328,000 Mgal/d) was from surface water, and about 82 percent of the surface water withdrawn was fresh water. The remaining 20 percent (82,600 Mgal/d) was withdrawn from groundwater, of which about 96 percent was fresh water. If withdrawals for thermoelectric power in 2005 are excluded, withdrawals were 210,000 Mgal/d, of which 129,000 Mgal/d (62 percent) was supplied by surface water, and 80,700 Mgal/d (38 percent) was supplied by groundwater.[14]

Out of the US daily water withdrawal total of 410,000 Mgal/d, water withdrawals for mining were estimated to be 4,020 Mgal/d, or about 1 percent of total US withdrawals. Groundwater sup¬plied 63 percent of water withdrawn for mining purposes, and about 58 percent of mining withdrawals were fresh water.[15] **Mining related water withdrawals are very small as a percentage and relative to total water usage, but in the current era of water competition and heightened water quality consciousness, water usage is an issue**.

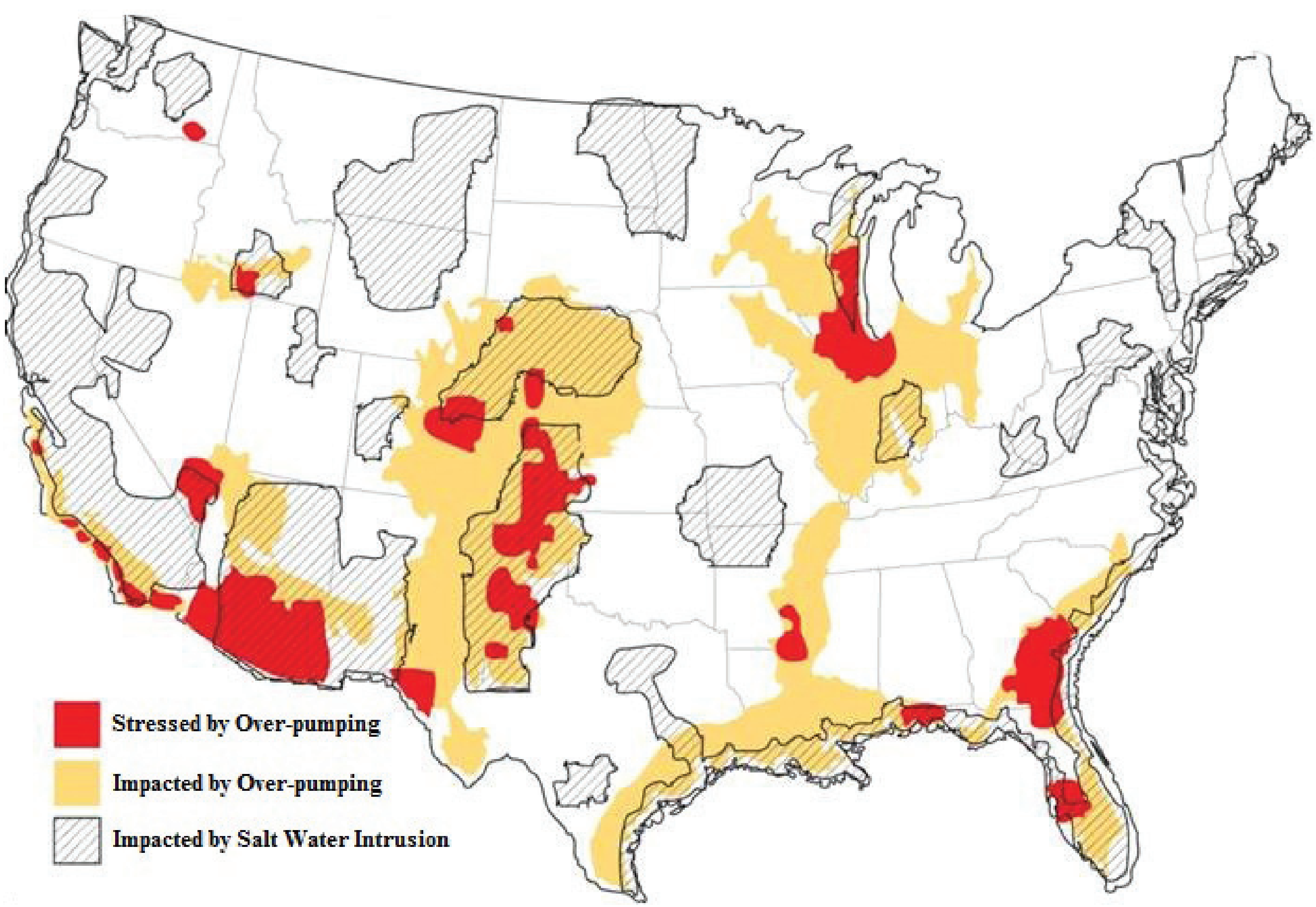
### 3.2.3 US Water Scarcity Realities

These are the realities and some of the causes of water scarcity in the United States today:

- Few new reservoirs built since 1980;
- Surface waters have not increased in the past 20 years;
- Localities increasingly depending on groundwater sources while groundwater tables are declining;
- Drought conditions may exacerbate depleted aquifers in the Southwest, Florida, California and in the High Plains;
- Increased aquifer pumping runs up energy demand;
- Aquifer pumping has lead to ground subsidence in some areas;
- Population continues to grow in water constrained areas;
- Climate change may hasten surface and groundwater loss trends in energy producing areas; and
- Transportation and electricity policies may add to energy's water demands.

Map 1 indicates potential water-crisis areas and stressed aquifers in the United States. **While water stressed areas are due mainly to population increases and severe drought, not mining or electricity production, energy related water needs can exacerbate local water scarcity.** Areas that are experiencing exploding irrigated biofuels growth and potential oil- and gas-producing activities are clearly found in water-stressed environments. The map shows that the stressed aquifers are located near the major corn-based ethanol-producing states of Nebraska, Minnesota, Iowa, and Illinois. Some of the major North American shale plays that might be developed—such as Eagle Ford, Fayetteville, Haynesville, and Barnett—are also located in water-stressed areas.

Map 1 Stressed US Aquifers[16]



# 4.0 Facts and Issues for Water and Primary and Transportation Fuels

## 4.1 Overview of Primary and Transportation Fuels' Water Requirements

Figure 1 provides a comparative picture of the water consumption of primary and transportation fuels, excluding unconventional gas. This comparison, based on gallons per million British Thermal Units (MMBTU), shows that for the transportation fuels:

- Water for soy and corn irrigation and ethanol processing is far greater than for all other fuels;
- Water consumption to turn coals into transportation fuels is comparable to that for oil from tar sands;
- Water for petroleum extraction is fairly low but quite high for refining;
- EOR requires wide ranges and potentially very large quantities of water;
- And while water for in situ oil production is only slightly higher than that for coal mining, water for oil shale retort is much higher-and comparable to water needs for tar sand production.
- Comparisons of the primary fuels shows:
- Water for coal washing and mining is on a comparable level as water for uranium mining and processing-both are fairly low;
- Coal gasification has relatively high water needs, but less than EOR production;
- Neither conventional natural gas pipeline operations, nor extraction and processing procedures, require much water;
- And conventional gas requires the least amount of water of all the primary fuels.

**Looking at just transportation fuels, from the water consumption perspective, natural gas would be the most efficient fuel source.** Unconventional gas would require almost seven times more water than conventional but would be on par with conventionally produced oil. Electricity as a transportation fuels is not evaluated in these comparisons; its water footprint is dependent on the source of electricity. A comparison of the water consumption footprint to produce one MMBTU of energy shows:[18]

- Conventional natural gas requires 2.5 gallons;
- Unconventional gas requires 16.5 gallons;
- Conventional oil requires 15.5 gallons;
- Irrigated corn based biofuel requires 17,808 gallons; and
- Irrigated soy based biofuels requires 50,295.5 gallons.

## 4.2 Overview of Impacts on Water Quality

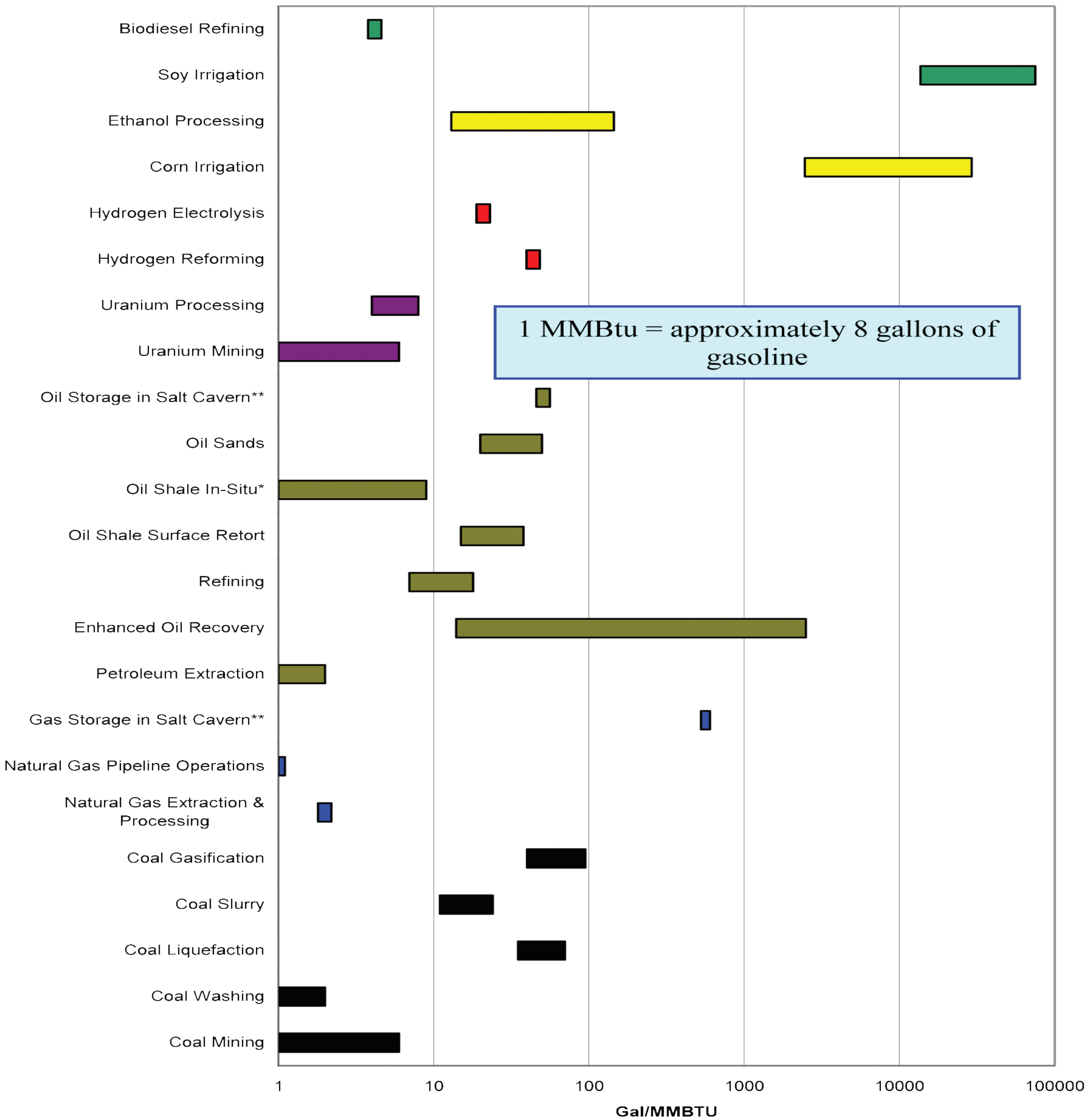
Table 2 summarizes the water needs and impacts of all of the fuels. Each of these is discussed in greater detail in the following sections.

## 4.3 US Oil and Gas Production

### 4.3.1 Background on the Revival of Domestic Oil and Gas Production

Domestic crude oil production started to decline in 1986 but changed course over the past few years. Domestic production in 2007 was 5.1 million barrels per day. Production in 2010 rose to 5.5 million barrels per day and is slated to rise to 6.7 million barrels per day by 2020. Production is forecast to remain above the 6 million mark

## Figure 1 Water Consumption Comparison of Primary and Transportation Fuels[17]



through 2035. The increases are driven by development of tight oil resources and increases in offshore oil in the Gulf of Mexico.

Natural gas production is forecast to grow from 21.7 trillion cubic feet in 2010 to 27.9 trillion cubic feet by 2035. This growth is expected to lead to an excess in production over domestic consumption such that the United States may become a net exporter of liquefied natural gas in 2016. The role of unconventional gas production (which is discussed in section 4.4) will undergo major changes. Starting in 2005, unconventional shale gas began to provide significant domestic supplies. By 2010, it provided 23 percent of domestic production. By 2035, unconventional shale is forecast to provide 49 percent. Conventional gas is forecast to come 21 percent from tight gas, 7 percent from non-associated offshore sources, 7 percent coal bed methane, 7 percent from oil drilling operations and 9 percent from non-associated offshore operations.[19]

### 4.3.2 Water is Utilized in all Facets of Oil and Gas Exploration, Production and Processing

Water is used for a variety of functions in conventional oil and gas production:

In EOR wells, water is used to displace and move oil and gas from aging wells to new wells. The water is pumped into an oil well in liquid or steam form to release additional production. This process can be very water-intensive, but high-quality surface waters are rarely used. Increasingly, $CO_2$ is being utilized for tertiary production and is becoming important in complementing $CO_2$ capture and storage;

- Some water is used in refinery processes and most of this water is lost to evaporation;
- Water is also used to carve out storage space in geologic formations for excess oil and gas;
- Water slurries create the salt caverns in which the United States stores the oil for the Strategic Petroleum Reserve; and
- Water is used in crude oil refining operations for steam, as part of the refining process itself, and as wash water and for cooling purposes.

Up-to-date US data, shown in Table 3, was presented at the November 2011 workshop for freshwater consumption for oil and gas recovery; oil and gas exploration, production, and transportation; and oil refining and gas processing. The new data takes into account the crucial regional differences in water intensities. Over the past sixty years, there have been dramatic reductions in water withdrawals, consumption, and discharges at oil refineries due to more-effective recycling, dry-cooling, and desalination of the wastewater. For North America, the trend is expected to continue, with the refinery water intensity in 2010 of 1.0 cubic meters ($m3$) per tonne, dropping to 0.2 $m3$/tonne by 2035.

### 4.3.3 Oil and Gas Production and Processing Impacts on Water Quantity and Quality

This section addresses impacts for three oil and gas related water uses: for exploration, processing operations; and produced waters.

Water for oil and gas exploration may impact shallow groundwater quality. Without correct handling of the refining and processing operations, by-product and wastewater streams can cause water contamination. Fuel additives such as methyl tertiary-butyl ether, used to reduce air emissions, have led to groundwater contamination. While natural gas requires little processing, in oil processing refineries, process water may come in contact with the petroleum product and can then contain residual product, water treatment chemicals, and/or dissolved solids.

Water trapped in underground formations being tapped for oil and gas is brought to the surface, and it is referred to as produced water. These waters may be significant in quantity and must be properly treated to minimize its impact on surface and ground waters.[21] In new wells, such water makes up a small fraction of liquid produced. However, in crude oil wells reaching the end of productive life, water can comprise as much as 98 percent of the liquid produced.[22] Natural gas wells produce much lower volumes of water compared to oil wells. Water also comprises 98 percent of the total volume of exploration and production waste generated by the oil and gas industry.[23]

Statistics from the American Petroleum Institute show that in 1996, 18 billion barrels of produced water were generated in the United States. Three percent of the produced water, mostly low in salinity from coal bed methane production,

## Table 2 Water Needs and Impacts of Selected Primary and Transportation Fuels

| Fuel Type | Process | Water Needs | Water Impacts |
|---|---|---|---|
| Uranium | Open Pit Mining | • Suppress airborne dust | • Tailings and drainage may impact surface and ground water |
| | Underground Mining | • Similar to underground coal mining | • Water must be treated to remove trace metals before disposal<br>• Concern surface water could run through waste piles to contaminate groundwater |
| | In Situ Mining | • Make up water for leaching fluids | •Aquifer waters could contaminate if not purified |
| | Milling | • Process water used | • Waste liquors are held in retention ponds so as not to contaminate local water supplies |
| Conventional Oil and Gas | Exploration | • Relatively minor for drilling operations | |
| | Extraction and Production | • Minor needs for extraction and some needed for refining process<br>• Significant quantities of produced waters can be used for multiple purposes | • Potential to contaminate surface water and shallow groundwater with toxic and chemical contaminants<br>• Hydrocarbon spills can contaminate surface/ground waters<br>• Produced brackish water could contaminate local waters if not contained properly<br>• Depends on quality, but some supplies can be recycled for ERO uses<br>• Can impact surface and ground water supplies |
| | Onshore EOR | • Water/steam injected into mine and can be recycled for EOR operations | • Can add to local water supplies<br>• Reduces fresh water needs for EOR operations |
| | Processing | • Process water required; little water required for natural gas processing | • Most water lost to evaporation<br>• By-products and wastewater streams could cause local water contamination<br>• Fuel additives (MTBE) can contaminate groundwater<br>• Pipeline accident could contaminate surface/ground waters |
| | Pipeline Transportation | • Water for hydrostatic testing | |
| | Oil Cavern Storage | • Slurry mining of caverns requires large amounts of water<br>• Seawater, if nearby, can be used and returned to its source<br>• One gallon of storage capacity requires seven gallons water | • 30-40 percent water discharged may be contaminated by residual product, water treatment chemicals and increased dissolved solids<br>• Slurry disposal impacts surface water quality and ecology |
| | Gas Cavern Storage | • Same as above | • Saline discharge water must be disposed of |

| Fuel Type | Process | Water Needs | Water Impacts |
|---|---|---|---|
| Unconventional Oil Shale and Tar Sands | Above Ground Retorting | • Water main component of fracking fluid at this time and it can be recycled for additional fracking needs | • Most water lost to evaporation<br>• By-products and wastewater streams could cause local water contamination<br>• Fuel additives (MTBE) can contaminate groundwater<br>• Pipeline accident could contaminate surface/ground waters |
| | Below Ground Retorting | • Water associated with the electricity production<br>• Water for processing and mine decommissioning | • Much of water used can be recycled |
| Coal to Luquids | Fuel Refining | | |
| | Upgrading to Fuel | | |
| | Gasification | | |
| Corn Ethanol | Irrigation and Processing | • Crop irrigation-varies by state and climate conditions<br>• Milling process water-amount depends on mill type<br>• Refining process water-similar to oil refining water needs | • Can deplete aquifer water supply<br>• Fertilizer runoff can pollute local surface waters<br>• Nitrogen and phosphorus runoff impacts on Mississippi River and Gulf of Mexico |
| Soy Based Biodiesel | Irrigation and Processing | • Crop irrigation<br>• Some consumption for conversion process | • Wastewater treatment required<br>• Fertilizer pollution |
| Coal | Surface Mining | • Reclamation of mine<br>• Dust suppression<br>• Revegetation of mine | • Coal sludge spills can contaminate local groundwaters<br>• Mine operations can generate large amounts of water |
| | Underground Mining | • Coal cutting<br>• Dewater coal seam<br>• Pump out mine<br>• Dust suppression | • Excess water and discharged processing water are contaminated and need to be treated<br>• Runoff from mine operations and tailings piles can reduce pH levels and increase heavy metals concentrations in drainage waters |
| | Coal Washing | • Water for washing | • Contaminated water must be treated |
| | Barge Transport | • 10% coal delivered to utilities on rivers | • Spills and accidents |
| | Slurry Pipeline | • Underground aquifers tapped for water | • Contaminants could contaminate freshwater supplies |

### Table 3 Freshwater Consumption for Primary Energy and Transportation Fuel Extraction[20]

| Extraction Process | Freshwater Consumption (Cubic Meters per TJ) |
|---|---|
| Water Flooding for Secondary and Tertiary Oil Recovery | 43 |
| Oil Exploration, Production, and Transportation | |
| • Drilling Mud | 0.9 to 1.3 |
| • Hydrostatic Pipeline Testing | Less than 0.001 |
| • Other Plant Operations | 0 |
| Conventional Natural Gas Exploration, Production, and Transportation | |
| • Drilling Mud | 0.9 to 1.3 |
| • Hydrostatic Pipeline Testing | Less than 0.001 |
| • Gas Processing | 0.05 |
| • Other Plant Operations | 0 |

was discharged to surface waters; 3 percent was disposed in percolation pits and in treatment plants or evaporated on site; 2 percent went to beneficial uses; 75 percent-the vast majority, was used for EOR; the remaining 18 percent was injected into Class II wells for disposal.[24]

Without further processing, the salts and organic and inorganic compounds in produced waters can impair soils, vegetation and water resources.[25] Some of these compounds include hydrocarbon residues, heavy metals, hydrogen sulfide, boron and heavy concentrations of salts. Because the specific amounts of constituents are so highly dependent upon the geographic location of the well, the geologic formation with which the produced water has been in contact over the centuries and they type of fuel being produced, this report does not discuss specific types of potential contamination. It was concluded in a study by the Argonne National Laboratory that, “The[se] chemicals, either individually or collectively, when present in high concentrations, can present a threat to aquatic life when they are discharged or to crops when the water is used for irrigation.”[26] Regulatory agencies prohibit discharges to most onshore or near-shore locations.

## 4.4 Unconventional Gas

### 4.4.1 Background on the Unconventional Gas Revolution

The US natural gas resource base has risen 55 percent since 2008 because drilling techniques are now able to unleash vast quantities of unconventional gas supplies.[27] At this resource level, the United States may have over a hundred years of natural gas supply at current consumption levels. The Potential Gas Committee announced in April 2011 that the United States possesses a “technically recoverable” total resource base of 1,898 trillion cubic feet (tcf) as of the end of 2010.[28]

There are six main categories of unconventional natural gas. These are: deep gas, tight gas, gas-containing shales, coal bed methane, geopressurized zones, and Arctic and sub-sea hydrates. This section focuses on shale gas.

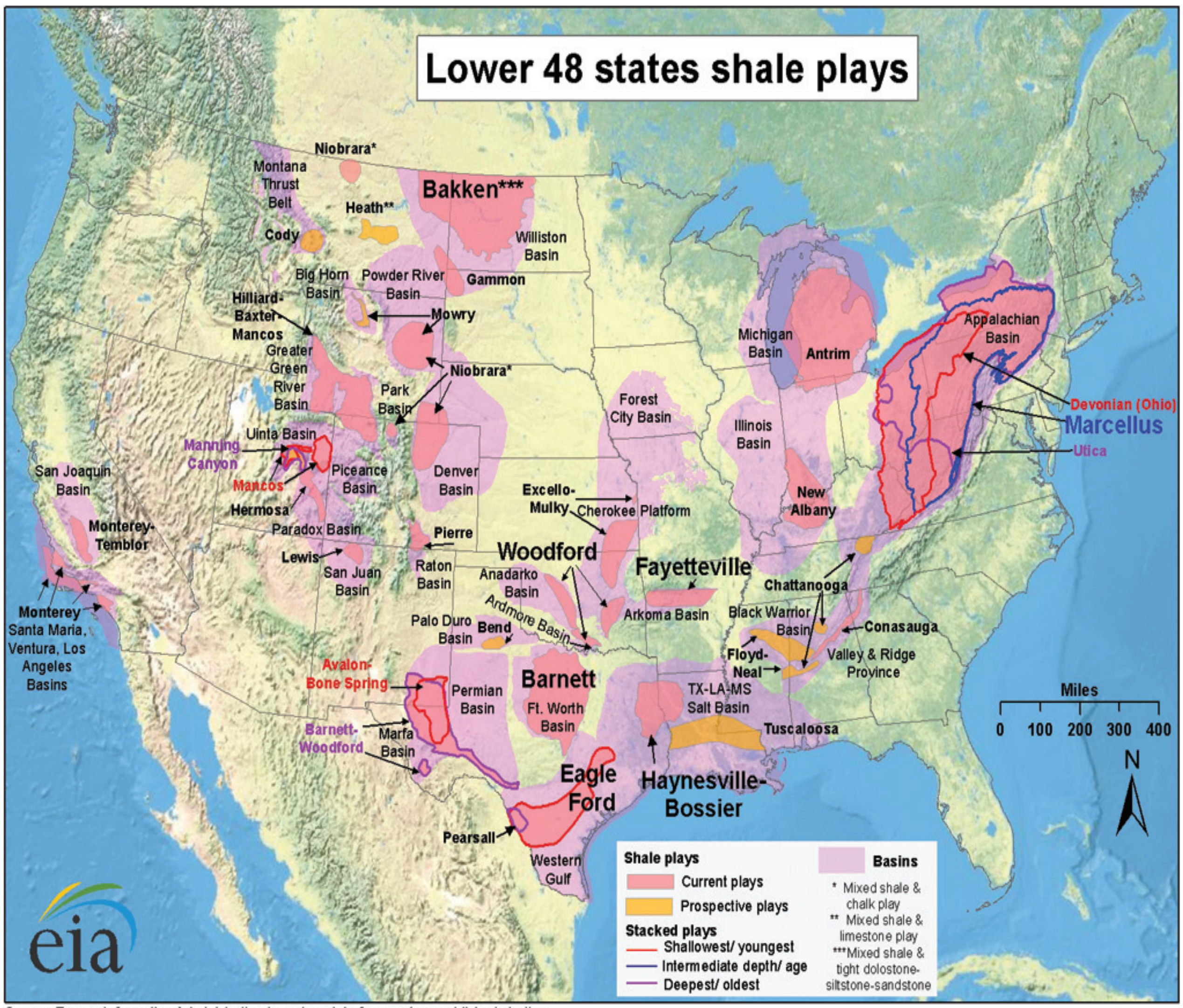
In the EIA’s most recent (reference case) Annual Energy Outlook, the estimated unproved technically recoverable resource of shale gas for the United States is 482 trillion cubic feet, substantially below the estimate of 827 trillion cubic feet reported in 2011 Annual Energy Outlook. The decline largely reflects a decrease in the estimate for the Marcellus shale, from 410 trillion cubic feet to 141 trillion cubic feet. New data collection, based on actual drilling results, has lowered previous estimates. In any case, it can be expected that the resource base numbers will fluctuate over the coming years. The amount of gas that can be competitively recovered will depend largely on gas prices and decline rates at existing fields—two very big unknowns.[29]

Annual shale gas production in the United States increased almost fivefold, from 1.0 to 4.8 trillion cubic feet between 2006 and 2010. The percentage of contribution to the total natural gas supply grew to 23 percent in 2010; it is expected to increase to 46 percent by 2035.[30] Shale gas production increases from almost 5.0 trillion cubic feet in 2010 (23 percent of total U.S. dry gas production) to 13.6 trillion cubic feet in 2035 (49 percent of total U.S. dry gas production).[31]

Map 2 shows the location of known shale gas deposits, often referred to as shale plays. The location and percentage of US resources are:[32]

- Northeast: primarily the Marcellus (63 percent);
- Gulf Coast: Haynesville, Eagle Ford (13 percent);
- Southwest: Barnett and Barnett-Woodford (10 percent);
- Mid-Continent: Fayetteville, Woodford (8 percent); and
- Rocky Mountain: primarily Mancos and Lewis (6 percent).

## Map 2: U.S. Shale Gas Plays[33]




Source: Energy Information Administration based on data from various published studies.

### Table 4 Average Shale Well Fracking Volumes[35]

| Unconventional Development | Average Fresh Water Volume for Drilling | Average Fresh Water Volume for Fracturing | Average Salt Water Volume for Fracturing |
|---|---|---|---|
| Barnett | 25,000 | 4,600,000 | 0 |
| Eagle Ford | 125,000 | 5,000,000 | 0 |
| Haynesville | 600,000 | 5,000,000 | 0 |
| Marcellus | 85,000 | 5,600,000 | 0 |
| Niobrara | 300,000 | 3,000,000 | 0 |
| Horn River (Apache) | 250,000 | negligible | 8 to 12,000,000 |

### 4.4.2 Water Use Front and Center in Unconventional Gas Operations

As opposed to conventional natural gas—for which relatively little water is used for production (mainly for drilling fluid)—**water issues are center stage in the production of unconventional gas.**

Water is used in hydraulic fracking operations for drilling mud, fracturing the shale with proppants, pipeline testing, and gas processing. There are significant variations in the amount of water used for both drilling and hydraulic fracking, depending on the location of the shale play. In Barnett Shale wells, the average freshwater volume for drilling and for fracturing is 250,000 and 4,600,000 gallons per well, respectively. In Marcellus Shale plays, the average freshwater volume for drilling and fracturing are 85,000 and 5,600,000 gallons per well, respectively.[34] In general, however, the consumption of water is relatively low.

Table 4 compares fresh water for drilling and fracking well in each of the major shale plays in the United States. It shows that the water needed for well drilling varies widely between shale plays with the Marcellus play requiring the least amount of drilling water. Fracking water requirements also are location specific with a low of 3 million gallons needed at the Niobrara sites and as much as 5.6 million gallons at Marcellus sites.

**Depending on the location of the shale play, water availability to initiate and keep fracking operations going may or may not be a significant issue. It primarily depends on the availability of the local water resource.** The impact may also depend on the number of wells in a particular area. In the four major US shale gas plays—Barnett, Fayetteville, Haynesville, and Marcellus—shale gas represents 0.40 percent, 0.10 percent, 0.80 percent, and 0.06 percent of each region's total water use.[36] Industry has taken steps to reduce its consumption through recycling, reuse, and other methods. As the fracking processes mature, total water usage can be expected to decrease. Forecasts of water usage in Texas shale plays indicate that it will peak in 2020 and rapidly decline thereafter.[37] Rapid development of fracking technology and using microseismic measurements at the well sites have led to significant decreases in the amount of water used per well.[38] The following graph, Figure 3, demonstrates that industry efforts have led to a 52 percent reduction in average water usage per well in the United States in a period of less than two years.

### 4.4.3 Fracking Impacts on Water Quantity and Quality

What will the impact be on the availability and quality of local water supplies as the United States takes advantage of this exploding domestic energy supply?

As described in section 3.2, some of the major shale plays are located in areas with stressed ground and surface waters. **While compared to farm demand for water, shale operations represent a minor consumer of water. However, concentrated drilling in stressed areas can negatively reduce aquifer supplies, if not controlled.**

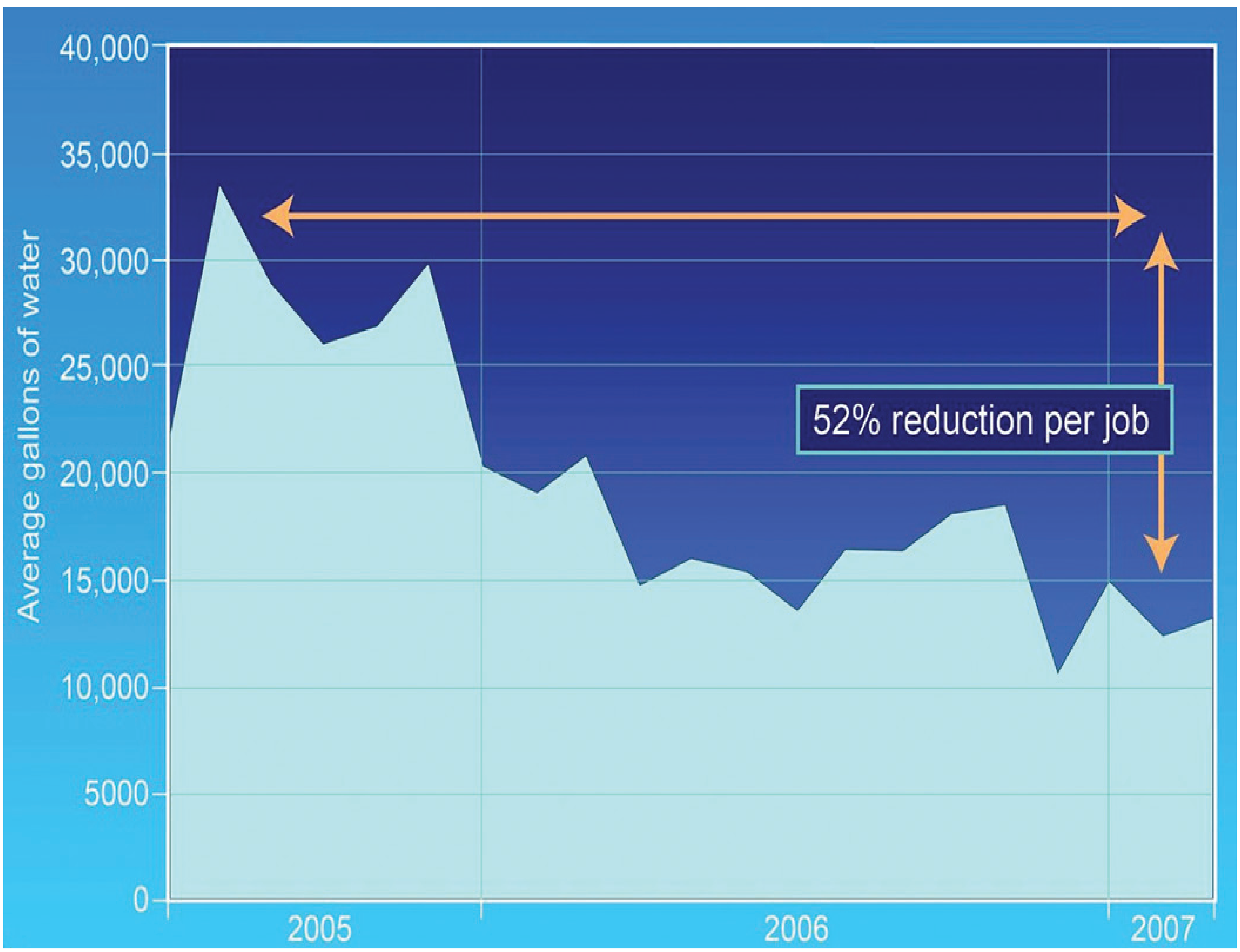
There are environmental impacts on ground and surface waters from fracking operations, as well as impacts on local communities, land use, wildlife and the ecology. Specifically with regard to water, the impact concerns include:

- Whether chemicals in the fracking fluid have potential for drinking water contamination;
- Fracking fluid seepage causing contamination of aquifer water;
- Well water contamination; and
- What happens to flow back and produced waters.

While the fluid that is injected into the hydraulically fractured well is mostly composed of water,[40] chemical additives in the fracking fluids have given rise to public concerns over **drinking water contamination**. The Natural Gas Subcommittee of the Secretary of Energy Advisory Board chaired by John Deutch (formerly Deputy Secretary of Defense and Director of Central Intelligence) issued its final report in 2011, referred to as the "Deutch Report," which concluded, "The Subcommittee shares the prevailing view that **the risk of fracturing fluid leakage into drinking water sources through fractures made in deep shale reservoirs is remote.**"[41]

Regardless of whether fracking fluids are getting into drinking wells, outstanding questions remain regarding chemicals used and their safety.[42] Many of the fracking chemicals are permitted to be used in industrial and home products. **The public is concerned, however, that they do not know all of the components in the fracking fluids. Fraking fluid disclosure rules vary from state to state**. Texas state law requires public disclosure. Colorado, in December 2011, legislated a requirement that companies disclose the chemicals they add to their fracking fluids during the oil and gas extraction process. Energy companies are allowed to withhold the names of substances that are considered trade secrets The Marcellus

Figure 2 Water Use Per Fracking Job 2005 to Mid 2007[89]



Shale Coalition Board of Directors has passed a resolution requiring all of its members to disclose and register fracking fluid composition its web site, "Frac Focus." While critics criticize the effort because it is voluntary and potentially not adhered to by all industry participants, industry has taken steps to publicize the chemicals currently in use. **However, further investigation into the risk to humans based on amounts released into the local environment, the depth of release and potential for water contamination is necessary to assure the public about the drinking water risks.**

Increasingly there are anecdotal reports of **aquifer water contamination** by fracking fluids.[43] There are documented well blowout accidents in which drilling fluids have spilled out onto local fields and streams. A recent study by the Energy Institute at the University of Texas at Austin studied the claims, investigations and the research on the issue and found:

> However, there is at present little or no evidence of groundwater contamination from hydraulic fracturing of shales at normal depths. Although claims have been made that "out-of-zone" fracture propagation or intersection with natural fractures, could occur, this study found no instances where either of these has actually taken place. In the long term after fracturing is completed, the fluid flow is toward (not away from) the well as gas enters the well bore during production. Some allegations indicate a relatively small risk to water supplies from individual well fracturing operations, but that a large number of wells (in the Marcellus shale) has a higher likelihood of negative impacts. However, the evidence for this risk is not clearly defined. No evidence of chemicals from hydraulic fracturing fluid has been found in aquifers as a result of fracturing operations. ...[I]t appears that the risk of such chemical additives is greater from surface spills of undiluted chemicals than from actual fracturing activities.[44]

**To date, evidence does not point to groundwater contamination by fracking fluids from drilled wells, which are almost uniformly located far below the groundwater aquifers.** Contamination of groundwater due to surface operation accidents are a separate issue and are discussed below.

**Well water contamination** is the public's largest issue. Their concerns are that methane may migrate into the well water, chemicals such as iron and manganese may seep into the well water, and the well water's color, odor and turbidity may change. These properties and chemicals may be present in the well water before fracking operations commence. **If there has been no systematic well testing prior to fracking operations, the exact impacts of fracking operations are difficult to establish.**

A study by the Center on Global Change at Duke University[45] documented evidence for methane contamination of drinking water associated with fracking operations in the Marcellus and Utica Shale plays in northeastern Pennsylvania and New York.[46] Their conclusion was that "methane migration is less likely as a mechanism for methane contamination than leaky well casings" but that a lack of baseline data collection makes it impossible to determine the source of the problem and the needed remediation efforts.

The Duke study calls for **more research on mechanisms for methane contamination, its potential health consequences and establishment of baseline data.** Given the public concerns and the lack of baseline studies, the Deutch Committee report echoes the Duke study findings and also recommends "Additional field studies on possible methane leakage from shale gas wells to water reservoirs...[and] [r]equirements for background water quality measurements (e.g., existing methane levels in nearby water wells prior to drilling for gas) and report in advance of shale gas production activity."[47]

The disposition of the **flow back and produced waters** is another environmental concern in fracking operations. The flow back of the water injected into the well varies in a wide range of 20 to 70 percent[48] and possibly as high as 80 percent.[49] The rate of produced water also depends on the shale play, with the highest rate found in the Barnett shale play and the lowest rate in the Haynesville shale play.[50] The higher the amount of produced and flow back water, the lower water requirement for the fracking operation.

The recovered water quality varies according to the shale play area. These waters contain sand, clay and silt particles, grease and oil, organic compounds and total dissolved solids (TDS). The wide variation in water quality can be seen with TDS of 13,000 ppm for the Fayetteville, 80,000 ppm for the Barnett, and 120,000 ppm for the Marcellus.[51] The Energy Institute study finds these and other water quality issues:

> The potential risk of naturally-occurring contaminants like arsenic in flow back and produced water is also a major concern. Similar concern about risk may be associated with organic chemicals in flow back and produced water that may be present in injected hydraulic fracturing fluids or in the formation water of the shale.

The water that flows back from the fracking operations is not permitted to be disposed of in surface waters without significant treatment. In the Barnett and Haynesville shale play areas, these waters have typically been disposed of by permit into injection wells in underground saline aquifers, or in Class II underground injection control wells (governed under provision of the SDWA). For shale plays in areas like the Pennsylvania Marcellus Shale area, where there are relatively few Class II wells that can accept discharged waters, the public has expressed concern over the treatment of waters that have been transported to industrial or municipal sewage treatment facilities. A report by the Ohio Department of Natural Resources has found that fracking fluids from the Northstar 1 disposal well intersected with an unmapped fault line and induced a series of earthquakes near Youngstown, Ohio. **More rigorous review of geological data prior to well drilling can address the issue.**

## 4.5 Unconventional Oil

### 4.5.1 Unconventional Oil Background

New geopolitical realities concerning the increasing potential for domestic oil supply, increased crude prices, and new technologies are bringing unconventional oil exploration and production options into play in both the United States and Canada. Some of the world's largest oil shale deposits are located in the Green River Formation underlying Colorado, Utah and Wyoming.  The Obama administration is looking at reducing the area where companies can conduct oil shale research in Colorado, Utah and Wyoming.[53] The Bush administration in 2007 opened up 1.9 million acres to oil shale research, but the Interior Department is considering shrinking that space to about 32,640 acres.

Texas and Alaska are the number one and two, respectively, oil producing states. North Dakota recently surpassed California as the third-largest US oil-producing state. In January, oil output was 546,050 barrels per day, a 59.2 percent increase from production rates a year earlier. California's average 2011 crude oil output clocked in at 537,500 barrels per day. The rise in North Dakota's oil production was due to output from its Bakken Shale play.[54]

### 4.5.2 Unconventional Oil Water Use Depends on the Production Process

There are two primary processes of producing oil from shale; mining and retort or in situ production. In the former process, the shale is mined, crushed, and then heated so that the kerogen it contains can be liquefied and then processed into oil. In the latter process, the rock may either be heated for several years to liquefy the kerogen or the kerogen can be separated from the host shale by chemical extraction. Potentially large quantities of water may be necessary for the production of the energy needed in the mining and processing procedures. Water is also needed for the post mining processing operations.

### 4.5.3 Unconventional Oil Impacts on Water Quantity and Quality are Under Study

The production of oil from mining or in situ recovery of shale oil remains under study. Without question, the tension between agricultural interests, cities, and the oil and natural gas industry over aquifers and access to surface waters will only continue to grow in the years to come.

The Bureau of Land Management (BLM) has studied the impacts on water quality. It finds that in hard rock mining operations, the shale waste rock piles would be exposed to air and water and could leach hydrocarbons, salts, trace metals and other minerals such as nitrates, arsenic, boron, barium, iron, lead, selenium, and strontium. Water extracted in processing operations may degrade local supplies if contaminated. The BLM has expressed further concerns that if the produced waters were contaminated, it could leak into surface or ground waters from retention ponds or from the wells into which it was re-injected.

**Water quality issues have been documented for oil shale production.** The Colorado River Basin reportedly has costly salinity related damage. This problem is due to the high salt content of the post-processed shale residue that can migrate to surface waters.[55] In areas of Texas, increased oil production from hydraulic fracturing of shale wells is stressing already-drought-stricken aquifers. Many more water wells are expected to be drilled to support unconventional shale oil, and the amount of water per oil well is climbing as well. A number of companies are continually improving processes to recycle and treat flow-back water. Other companies are following the American Petroleum Institute's best practices advice to use nonpotable water for fracking wells to the greatest extent possible.

## 4.6 Geothermal Resources

### 4.6.1 Geothermal Background[56]

There are 3,102 MW of geothermal power in production in nine states: Alaska, California, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah and Wyoming. Developers have 756-772 MW of new capacity in the drilling/construction phases which should be completed in the next few years. The new projects are under development in 15 states: Nevada, California, Utah, Idaho, Oregon, Alaska, Louisiana, Hawaii, New Mexico, Arizona, Colorado, Mississippi, Texas, Washington, and Wyoming. There are (confirmed and announced) projects of approximately 5102 – 5745 MW of additional geothermal resources being developed as of mid 2011. Policies at the federal and state level, and particularly stimulus funding, which support geothermal development. The federal tax credit continues through January 1, 2014, and state climate and renewable energy laws also promote the purchase of geothermal power.

### 4.6.2 Intrinsic Water Use for Geothermal Fluid Utilization

For geothermal electricity production, geothermal fluids are the primary fuel. For all types of production (dry steam, hydrothermal flash, hydrothermal binary, and enhanced geothermal systems), water is used in well-drilling operations to obtain geothermal resources. **Water usage depends on the quality of the geothermal resource, which is categorized by its temperature, depth, and how many wells are needed. Usage is location-specific.** For enhanced geothermal systems, water is used for "well stimulation" and in drilling, and as shown in figure 4, usage depends primarily on the depth of the drilled well. In these wells, water use per well can be greater than in unconventional gas well fracking.

Figure 3 Hydraulic-Stimulation Water Use in Enhanced Geothermal Wells[57]

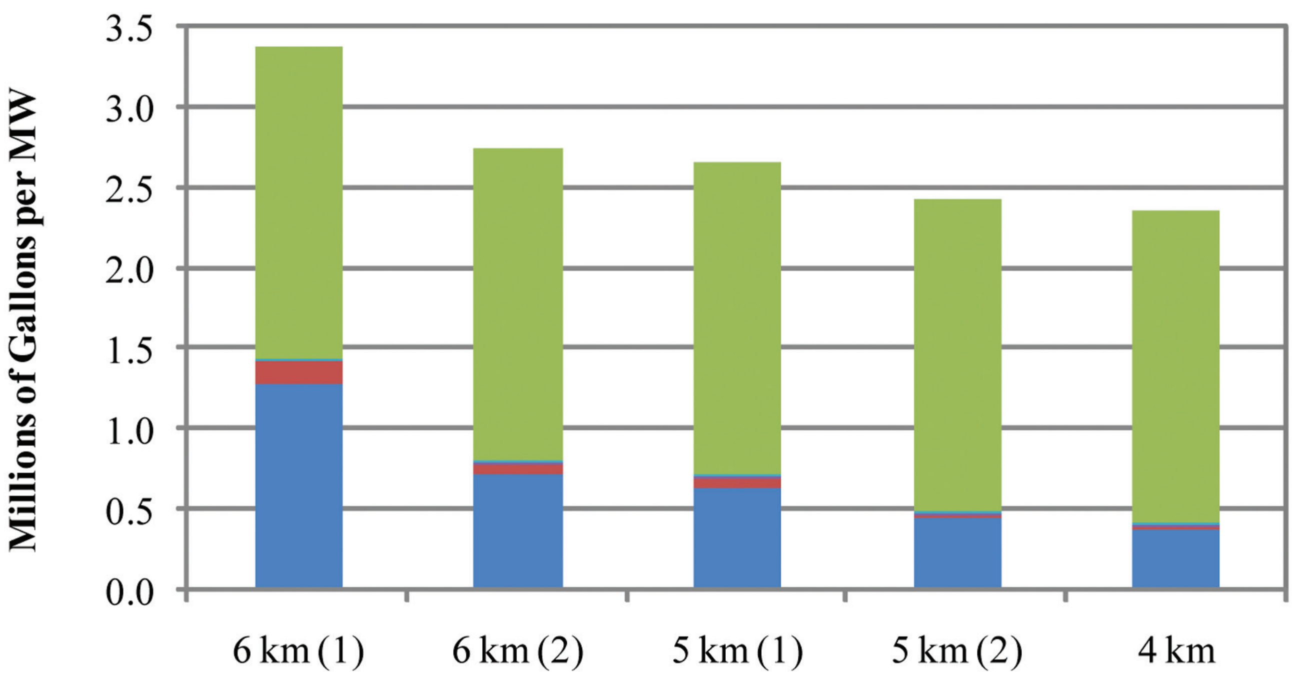
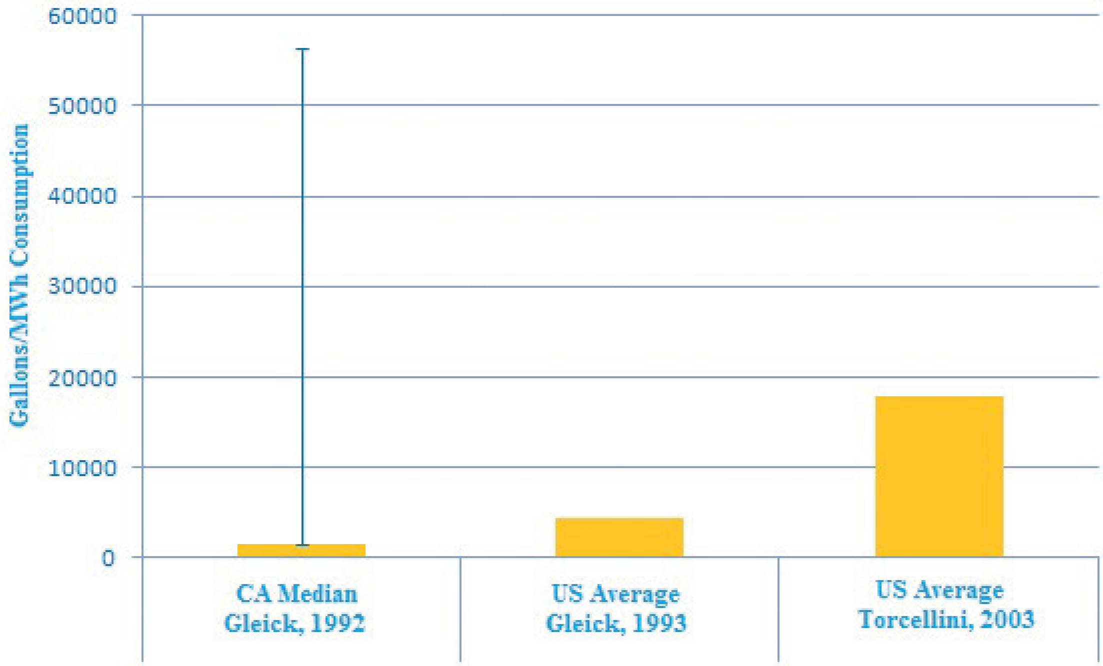


Figure 4 Hydropower Reservoir Evaporation Rates[61]




### 4.6.3 Impact of Geothermal Operations on Water Quantity and Quality

**As with all fossil fuel extraction, the quality of local water supplies may be impacted due to geothermal well-drilling and well-stimulation accidents.** As the temperature of the geothermal fluids rises, the presence of TDS and toxic materials increases. These risks can be mitigated or avoided altogether by proper well drilling and blowout prevention practices. However, contaminants and other solids may pose issues for local water resources. According to a study by Argonne National Laboratory:

> The comparison with the drinking water standards clearly shows that there is a risk from the release of geofluids into drinking water, especially in terms of toxics such as antimony, arsenic, lead, and mercury. Although not universal, in general higher concentrations of contaminants were observed in the high-temperature than the moderate-temperature geofluids. It is important to note that this analysis is focused on geothermal sources likely to be used for utility scale geothermal power production and is not necessarily applicable to shallow, low temperature wells typically used for ground source heat pumps.[58]

## 4.7 Hydro Resources

### 4.7.1 Hydro Resources Background and Water Use

For both reservoir-based and run-of-the-river hydropower facilities, water is the primary fuel, and is "consumed" through evaporation. As shown in figure 5, hydropower reservoir evaporation rates are highly variable and site-specific, depending on reservoir depth, temperature, shape, surface area, size of the river, and local climate conditions. In the hot and dry Southwest region, evaporative losses can be up to two meters per year.[59] Since reservoirs are used for public water supply, flood control and recreation, it is hard to pinpoint energy related water consumption. The CRS report finds that accurate data regarding both current and future water consumption for hydroelectric power facilities does not exist and needs to be collected.[60] This consumption may exceed 50,000 gallons per megawatt hour (MWh).

### 4.7.2 Impact on Water Quantity and Quality

**Overall, the temperature and sediment levels, along with the aquatic habitat of local water resources, can be impacted as the water travels to or is stored for the hydropower facility.** Some reservoirs are fed by completely dewatering long stretches of rivers which can have an ecological impact. The temperature of water flowing downstream of reservoirs can be altered. Water seeping into ground water can leach contaminated materials into the ground water supply. Local animal habitats can be affected by changes to stream flows and when local rivers are inundated by reservoir water.[62] Like other fuel extraction and processing endeavors, concerns over environmental impacts for hydro resources have led to utilities having to reduced withdrawal and consumption rates. For example, the Bonneville Power Administration has reduced water supplies to its hydropower facilities resulting in a 1000 megawatt reduction in output due to efforts to repair salmon and steelhead habitats.[63]

## 4.8 Biofuels

### 4.8.1 Background on Rising Biofuel Production

The United States currently produces 14 billion gallons of corn based ethanol and has the infrastructure to produce 2.7 billion gallons of biomass based diesel fuel.[64] Currently, there are no commercial refineries to produce cellulosic feedstocks into biofuels.[65]

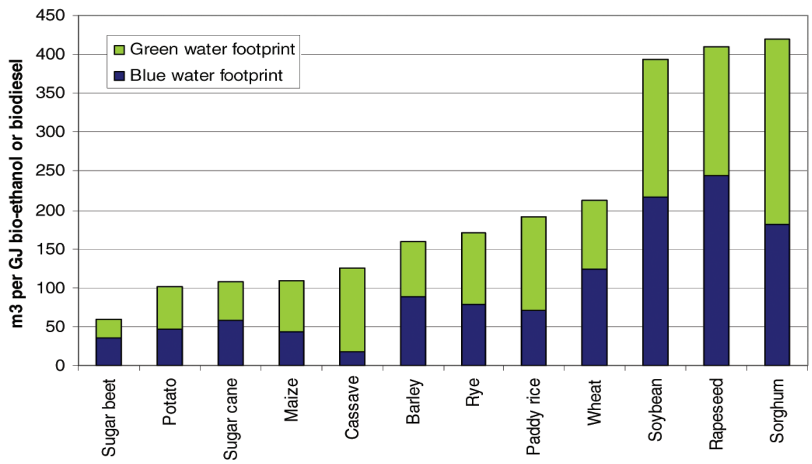
The US Congress enacted the Energy Independence and Security Act (EISA) in 2007 (110. P.L.140). The 2007 law requires US fuel suppliers to produce 36 billion gallons of renewable transportation fuels by 2022 and 16 billion gallons of the renewable fuels to come from cellulosic biofuels. In October 2011, the National Academy of Sciences found that the target for this category of biofuels would not be met "unless innovative technologies are developed that unexpectedly improve the cellulosic biofuels production process."[66] **The outlook for emerging cellulosic conversion technologies and other advanced algae biofuels is uncertain**, and depends on many variables, such as production location, whether the bioenergy feedstock is irrigated, and where—and whether—biochemical or thermochemical conversion is used to produce the biofuel. There are other efforts besides biofuels substitution to wean the United States from its current heavy reliance on petroleum based transportation fuels, such as the electrification of the transportation sector and the raising of fuel efficiency standards. These efforts are expected to make a substantial difference over time, but they are not expected to eliminate completely the need for petroleum and/or natural gas based fuels. For example, most heavy-duty vehicles are still expected to require diesel fuel; it is unclear that the commercial aviation sector will change over to advanced biofuels, and the auto sector's transition to electricity may be hampered by the rate at which vehicle battery storage is becoming more cost effective.

### 4.8.2 Water Use Key for Biofuels

For biofuels,[67] water is consumed through evapotranspiration during crop production and in the production of the biogas itself. Actual water usage for biofuel crop production is highly variable, and is based on the crop chosen, agricultural practices employed, and the local climate conditions. For example, among biofuel crops, sugar beets require 50 cubic meters of water per gigajoule (GJ) of electricity produced, whereas common rapeseed and jatropha biocrops require almost 400 cubic meters of water. Bioethanol is less water intensive than biodiesel, however, the water intensity of both fuels is significantly greater than for other petroleum based transportation fuels.

Figure 6 compares the water intensity for a wide variety of bio crops based on a weighted global average for both its green and blue water foot print (WF). The former refers to rainwater that evaporated during production, mainly during crop growth, and the latter refers to surface and groundwater for irrigation evaporated during crop growth. Currently, sugar beet is the most favorable crop and sorghum the most disadvantageous, with a difference of a factor of 7 in terms of the size of the WF. **In the United States, corn is more attractive than sugar cane (78 against 104 m3/GJ ethanol) from a water consumption perspective.** This figure also shows the distinction between green and blue water. On a global basis, the blue WF of cassava is smallest. Other efficient crops are sugar beet, potato, maize, and sugar cane. In terms of blue water, sorghum is unfavorable. On average, to produce 1 liter (L) of ethanol from sugar beet takes 1,400 L of water, production from potato takes 2,400 L, production from sugar cane takes 2,500 L, and production from corn takes 2,600 L. Sorghum is the most inefficient crop, needing 9,800 L of water for 1 L of ethanol. The WF of biodiesel derived from soybean, rapeseed, and jatropha shows considerable differences among the main producing countries. **Hence,**

## Figure 5 Weighted Global Average Water Foot Print for Biofuel and Biodiesel Crops[68]




**it is difficult to make a blanket statement about which crop is best suited for biodiesel production.** On average, it takes 14,000 L of water for soybean or rapeseed, and 20,000 L for jatropha.

**Biofuels' water penalty is significant.[69] When comparing biofuels to petroleum based fuels, the former requires in the range of 62 to 2,400 gallons of water per gallon of gasoline equivalent, and the latter requires only 1.4 to 2.9 gallons of water per gallon of gasoline equivalent.[70]**

The Argonne National Laboratory (ANL) 2009 study on the production-through-lifecycle water needs of transportation fuels confirms that corn based fuels requires comparatively huge quantities of water compared to petroleum based fuels. Moving toward cellulosic fuels, as envisioned in the 2007 EISA, would bring water consumption levels closer to that for petroleum based fuels. The ANL study found:[71]

- Saudi light crude oil required 2.8 to 5.8 gallons of fresh water for one gallon of gasoline;
- A composite of US crudes requires between 3.4 to 6.6 gallons of fresh water to produce one gallon of gasoline;
- Canadian oil sands requires between 2.6 to 6.2 gallons of fresh water for one gallon of gasoline;
- Switchgrass based cellulosic ethanol production requires between 1 and 10 gallons of freshwater per gallon of ethanol;
- And production of one gallon of corn based ethanol requires between 10 and 324 gallons of freshwater.

### 4.8.3 Biofuels' Impacts on Water Quantity and Quality

**The major biofuels water quality impact is caused by agricultural runoff from corn for ethanol production, which accounts for 90 percent of US biofuel production.[72]** 52 percent of the nitrogen pollution and 25 percent of the phosphorous pollution entering the Gulf of Mexico comes from the fertilization of corn and soybean crops in the Upper Mississippi River Basin.[73] Corn and soy are grouped together, because they are grown on the same fields in rotation, but corn receives 97 percent of the nitrogen fertilizer and 80 percent of the phosphorus. While not all of the nitrogen pollution can be attributed to biofuel production, this pollution does adversely affect the drinking water in rural communities. More than 50 percent of the groundwater in agricultural areas has elevated nitrate concentrations, and more than 20 percent has so much nitrate that it is unsafe to drink, and must be treated.[74]

The runoff from the Upper Mississippi River Basin also contributes to the creation of a dead zone in the Gulf. High levels of sediment, nitrogen and fertilizer combine with summer weather to causes algae blooms, which in turn reduce the oxygen content to below what is required for fish to survive resulting in large fish kills. This "dead zone" peaks in size every summer, and over the last five years has averaged more than 6,000 square miles—larger than the state of Connecticut.

**It is possible that genetically modified crops may reduce water and fertilizer needs, but it is unclear as to whether the US public will accept such crops. There is also an unresolved issue as to whether climate-change temperature increases will decrease productivity. In any case, production of corn ethanol does pose a threat to US freshwater supplies.**

There will be many challenges to sustainably scale up biofuels production and reduce its water footprint. Efforts to move to advanced biofuels are behind schedule.

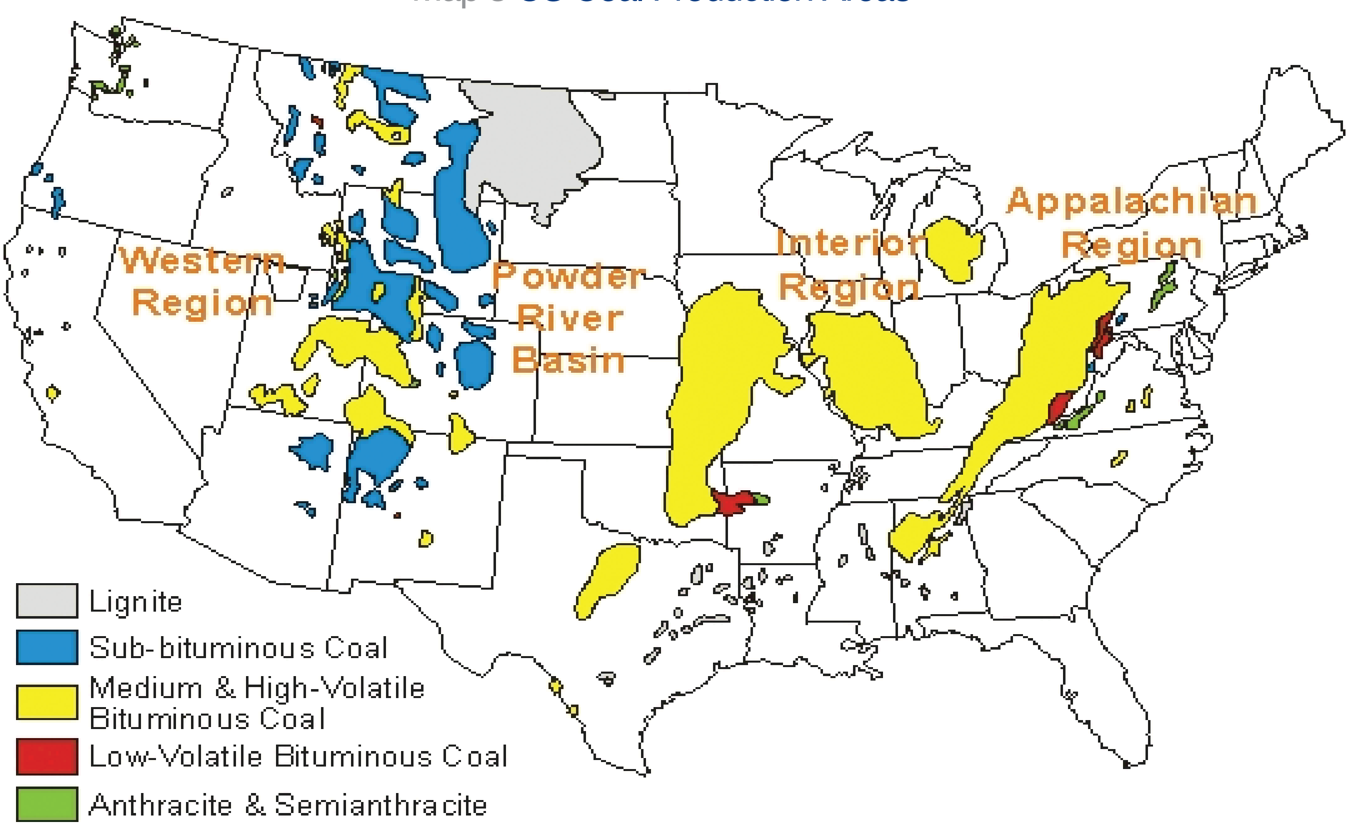
## 4.9 Coal

### 4.9.1 Background on Coal's Changing Outlook

There are four major coal production areas in the United States. The western and Powder River Basin regions produce lignite, sub-bituminous and medium and high variable bituminous coal. The interior and Appalachian regions produce almost exclusively medium and high-volatile bituminous coals. Coal for power generation comes mainly from the Appalachian and Powder River Basin areas. A comparison of this map to Map 3 of US fresh water aquifers, shows that the key coal producing regions are also in stressed aquifer areas.

The outlook for US coal production is driven by a combination of industry efforts to move operations to more easily accessible areas that are less labor intensive and thus less expensive to mine, as well as regulatory issues and the availability of low-cost domestic supplies of natural gas. While US domestic demand for coal is projected to decrease, rapidly rising global demand is prompting US coal exports to be at their highest levels since 1992, especially US coking and steam coal from the Power River Basin of Wyoming and Montana.[76] Most US coal production today comes from Wyoming, West Virginia and Kentucky; Wyoming produces about 41 percent. In 2010, the western area produced 591.6 million short tons, the interior mines produced 156.7 million short tons and the Appalachian region produced 334.3 million short tons. Production will continue to shift from the Central Appalachian to western

Map 3 US Coal Production Areas[75]



regions.[77] It is forecast that by 2035, production in the Appalachian area would be reduced to a third of its capacity today.[78]

The outlook for US coal production will be impacted by the changing US electricity generation portfolio. The share of electricity generated by coal is expected to decrease (see section 3.1). However, growing demand for electricity is expected to lead to an increase in the actual amount of coal used, in the absence of new policies to limit or reduce emissions of carbon dioxide and other greenhouse gases. Such new policies could significantly change the outlook for coal use.

### 4.9.2 Coal's Water Use

Water is required at all stages of coal production and conversion, from coal mining to power generation and coal-to-liquids production. All technologies that convert coal-to-liquids for transportation fuels require process water, boiler-feed water, and cooling water (which is the largest water consumer). For coal mining, water use varies by region but is mainly used for coal cutting and washing. In the Central Appalachian and eastern coal fields, where coal comes primarily from underground mines, washing is required, and so water use is high. In the Powder River and other western regions, water use is comparatively much lower. In the United States, water usage for slurry pipeline transportation is very limited. Much of the data reported in recent government reports and scientific journals relies on data that dates back to Dr. Peter Gleick's 1994 report, "Water and Energy" in the Annual Review of Energy and Environment.[79] His analysis cites data from the 1970s and 1980s. Therefore, **improved data collection and reporting are long overdue and estimates in current government reports may be outdated.** Another presentation, based on current data developed by researchers at the University of Texas at Austin, showed that freshwater consumption for coal mining activities was 0 to 40 (cubic meters [m3] per terajoule [TJ]) for coal mining, 0 to 32 m3 per TJ for coal washing and 0 for other plant operations.[80]

Other data presented at the November workshop showed that, on average, between 50 to 59 gallons of water are used per ton of coal. Water use can range between a low of 10 to a high of 150 gallons per ton of coal—again, depending on the production region.[81] Assuming the highest average amount of water per ton of coal produced, in 2010 the total amount of water used for mining of 1, 085 million tons of coal would amount to 196,000 acre-feet per year.[82]

### 4.9.3 Coal's Water Quantity and Quality Impacts

**While overall there is relatively little water consumed in coal mining operations, water quality issues can be significant from an environmental point of view.** Coal mining's local water supply impacts depend upon whether the mining is underground or on the surface and the different geologic formations in the eastern and western regions of the United States. All mining operations require removal of materials, topsoil, soil and rocks. Oxidation of trace materials from the material and waste coal piles can lead to leaching of acids and alkyls into surface waters. When mines are depleted, continuing drainage (which varies according to mining method used, geology, climate and rainfall) can lead to ground water contamination.

In some western areas, coal seams serve as local aquifers. While drilling depletes the aquifer and requires it to be recharged, the more important water impact concerns the disposition of the produced waters due to high levels of salts and alkaline materials.[83] When western coal mines are reclaimed, the backfill materials which would have been exposed to oxidation are returned to the mine to bring it back to its original contour as much as possible. Rain water can percolate through these materials and leach pollutants into groundwater supplies. In western mines, operations and reclamation efforts can affect the natural aquifer recharge rate. Efforts to mitigate ground water contamination by compressing backfill materials can lead to reduced water availability due to lowered recharge rates.

**Coal mining impacts on eastern aquifers are generally due to acid formation.** In the Central Appalachian region, the water impacts include: legacy acid mine drainage (AMD), loss of streams and other hydrologic modifications, changes in water temperature, and the presence of TDS and selenium which impact the aquatic biota, and water use.[84] In West Virginia, currently the pressing issue relates to mountain top removal and the ecological and biological-as opposed to chemical-impacts that ensue.[85] Water temperature impacts are an increasing issue. There are environmental groups who are suing a West Virginia coal production company (Alpha Natural Resources Inc.) alleging that underground slurry injection operations are causing well water pollution. The West Virginia Department of Environmental Protection issued a study showing in one of 33 tested wells, the lead drinking water standard was exceeded.

Mountain top mining (MTM) can lead to stream loss and changed stream flows particularly because the use of explosives to access coal seams generates large volumes of rocks and soil that bury adjacent streams and fills valleys. MTM can compromise water quality, often causing permanent damage to ecosystems and rendering streams unfit for drinking, fishing, and swimming.

In the Central Appalachian coalfields, mountaintop mining has resulted in a 4 percent loss of streams.[86] A study by the EPA noted that streams in watersheds below valley fills tend to have greater base flow; streams are sometimes permanently covered up; wetlands are, at times inadvertently and other times intentionally, created. Such wetlands provide some aquatic functions, but are generally not of high quality. Forests may become fragmented (broken into sections); and the re-growth of trees and woody plants on re-graded land may be slowed due to compacted soils. The study concludes that water-quality, hydrological, and physical habitat changes have the potential to negatively affect stream's aquatic life.[87]

AMD can be a challenge at coal mining operations. AMD is metal-rich water formed from the chemical reaction between water and rocks containing sulphur-bearing minerals. The runoff formed is usually acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite, a sulphur-bearing mineral. However, metal-rich drainage can also occur in mineralized areas that have not been mined. AMD is formed when the pyrite reacts with air and water to form sulphuric acid and dissolved iron. This acid run-off dissolves heavy metals such as copper, lead and mercury into ground and surface water.

**There are mine management methods that can minimize the problem of AMD, and effective mine design can keep water away from acid generating materials and help prevent AMD occurring.** AMD can be treated actively or passively:

- Active treatment involves installing a water treatment plant, where the AMD is first dosed with lime to neutralize the acid and then passed through settling tanks to remove the sediment and particulate metals; and
- Passive treatment aims to develop a self-operating system that can treat the effluent without constant human intervention.

Advances in the geochemical characterization of mine sites and improvements in mining technology have substantially reduced the number of recently permitted mine sites with poor post-mining water quality. Most of the AMD comes from abandoned mines that operated prior to adoption of modern mining regulations.[88]

In the Central Appalachian region, elevated **TDS from past and current mining activities affects aquatic life**. The specific effects on biota and the relationship to TDS variability is currently under study. **Because TDS levels are not the only factor affecting the stream biota, there may be better ways for the EPA to establish regulations based on benchmarking.**[89] **Industry will be challenged to meet the current EPA recommended guidance levels and more study is needed to produce appropriate EPA regulations.**

Selenium[90] had a pronounced impact on the aquatic biota and is found in elevated levels in streams below some mining operations in the Central Appalachian mining region. It is found in the reduced sulfur minerals and other geologic materials associated with coal mining. The selenium can bioaccumulate causing birth deformities at higher trophic levels. It is possible to mitigate selenium effects. For example, as strata of rock with a high quotient of selenium appears above the coal seam. Industry has developed methods to isolate this material during the mining process.

## 4.10 Uranium

### 4.10.1 Background: Domestic Production Showing Signs of Change

There are nine uranium production mines operating today in Wyoming, Nebraska, and Texas. In the past, uranium wash also mined in Colorado, New Mexico, Utah, Arizona, Florida, and North Dakota. The outlook for new mines in the future is mixed but will likely include operations in some of the states that have produced in the past, and possibly in Virginia, which is openly debating whether to allow development of a new uranium mine in Pittsylvania County. In January 2012, the Obama Administration announced a ban on issuing leases for hard rock mining on federal lands in the Grand Canyon National Park area. This area would have been a prime site for uranium mining due to the existence of high grade uranium ore deposits. In late February 2012, US District Court Judge William Martinez for the District of Colorado reaffirmed a 2011 court ruling that blocked DOE's program for leasing government tracts on 25,000 acres in southwestern Colorado until further environmental reviews are completed by DOE. While there are no active mines on this tract, companies have leased land for potential development. The leasing program is opposed by environmental groups concerned over mining's impact on natural resources near the Dolores and San Miguel rivers.

Uranium is as abundant in the earth's crust as tin, tungsten, and zinc, for example, and is even found in seawater and the ash produced by coal-fired electric power generating plants. Uranium is readily soluble in its oxidized state and geochemically mobile, and thus, local concentrations can be found in host rock formations

Before a mineral resource can be mined it must first be prepared for mining, that is, the deposit must be developed. Development will consist of either removing overburden so open pit mining can begin, sinking shafts and opening access passageways in the case of underground mining, or drilling well-fields in the case of in-situ leaching (ISL) mining. Uranium deposited in commercially economic concentrations is referred to as ore. In the United States, ISL recovery (ISR) is the dominant methodology because of the need to minimize the cost of mining low grade ores.

The uranium may be recovered by mining the ore and processing the mined ore. Conventional mining consists of either open pit mining or underground mining. Open pit mining is sometimes referred to as surface mining, strip mining, or open cast mining. Open pit mining consists of excavating or stripping off the overburden material to expose and recover the ore deposit. Underground mining simply consists of sinking an access shaft or shafts down to the level of the ore body so that it can be mined and hoisted to the surface for subsequent processing. In some cases underground access may be by means of a declining passageway. The decision to mine an ore-body by either open pit or underground or ISL methods is largely dictated by economics, which will depend strongly on how deeply buried the ore body lies, its configuration and ore grade.

Where conventional mining is too costly, the uranium may in some instances be recovered by ISL, that is, by dissolving the uranium from the surrounding rock by means of a liquid leachant pumped into the ore bed through an array of drilled holes and extracting the dissolved uranium in solution through yet another hole drilled in the middle of the array. Uranium may also be recovered by spraying crushed ore with a leaching solution; this is called solution mining.

The mined ore must be processed to recover the uranium contained in it. The processing steps, called concentrating or milling, generally consist of crushing, grinding, leaching, purifying, filtering, and drying can involve the use of water. The result of the concentrating process is a semi-refined product containing uranium usually but not always, in the form of U3O8, commonly called "yellowcake" because of its bright yellow color. It is sometimes colloquially referred to as uranium oxide. The concentration of U3O8 in the concentrate product will be typically on the order of 70 percent to 80 percent, though higher and lower values may be encountered.

### 4.10.2 Uranium Mining Methods Determine Water Use

**The World Energy Council estimates that mining, milling, conversion and processing of uranium uses less water per energy unit than oil, natural gas or coal.**[91] As seen in Figure 1 from Section 4.1, water use in processing operations ranges from six to nine gallons per MM BTU, and mining consumes one to eight gallons per MM BTU. By comparison, the lowest water consumer is conventional natural gas drilling and processing which uses under five gallons per MM BTU. Uranium mining and milling water consumption is roughly inline with that of coal washing and mining and is less than the majority of mining and extraction water needs for other primary and transportation fuels. A report prepared by an organization evaluating (and opposing) the development of a potential

Pittsylvania County uranium mine, states that over the life of the proposed mine, over five billion gallons of water would be used.[92]

Water is required in varying quantities to support mining and processing, with the amounts depending on the type of mining and processing, as well as local ground water conditions. For example, in open pit mining, water is used to cool equipment and suppress dust levels associated with drilling, blasting, and excavation of rock. In addition, the mining operations generate liquid effluents which typically contain the radioactive elements uranium and radium as well as non-radioactive contaminants such as nickel, arsenic, manganese, molybdenum, selenium, fluorides and sulfates. The amount of water consumed will depend on technology uses and mining ground water conditions.

Heap leach mining operations for either primary uranium recovery or mining clean-up involves the spraying of ore with a water based leachant and the collecting of uranium free effluents. Uranium bearing streams are collected for processing and uranium recovery.

ISL mining involves the extraction of uranium from an ore deposit without the introduction of miners or major equipment into the ore body. It involves two distinct components; ore deposit leaching and uranium content recovery. In general, an alkaline leaching solution or simply carbon dioxide and oxygen are injected into the mineralized zone through a series of drill-holes. Common leaching solutions (lixiviants) are sodium carbonate-bicarbonate in Texas and Wyoming, and sulfuric acid in Kazakhstan and Australia. The first leach solution is an alkaline base leachants and the second is acid. The leaching agent migrates (permeates) through the ore zone taking uranium into solution for recovery through a production well. The uranium-bearing solution thus recovered is processed through resin ion-exchange columns to upgrade uranium such that yellowcake can be produced. The injection and extraction process is performed in a continuous cycle, each taking about half a day. This well field operation cycle is typically repeated 25 to 50 times (or sweeps) before moving several hundred yards to the "next" well field. Wells are drilled to the base of the ore body, and lined with polyvinylchloride or fiberglass casing and cemented to prevent movement or loss of leachant. The solution flow through the aquifer from injection to production (or recovery) well is normally governed by the tightness or permeability of the sandstone formation in which the ore is found. Hydrological factors such as aquifer temperature, distance between wells, pressure drop between wells and well bore radius all contribute to the ultimate flow capacity from the production wells. Leachant recycle minimizes water consumption, but some make-up is routinely required.

### 4.10.3 Changing Outlook for Uranium Production's Impact on Water Quantity and Quality

**Waste rock, uranium mill tailings, mine dewatering effluents and mining explosives are potential sources of water contamination if not designed for at the outset.** Depending on the local condition, water withdrawals and consumption could reduce groundwater levels and compete with other water resource demands.

Water quality in uranium mining may be impacted in the following ways:

- In open pit and underground mines, contaminated water which contains elevated concentrations of radioactive materials could potentially seep through the waste rock into groundwater supplies;
- Discharged process waters from mines which contain radioactive and toxic materials as listed above, must be anticipated in facility design and prevented from contaminating groundwater supplies;
- The unintentional release of contaminated water from mining or milling operations, for example due to natural events such as hurricanes, earthquakes or intense rainfall could contaminate surface and/or ground water must be mitigated against by the use of berms and impervious barriers, supported by monitoring;
- Milling process waste liquors held in retention ponds could be accidentally released in to local streams if safe operating procedure are not prescribed and adhered to;
- In situ mining aquifer waters could contaminate other ground water supplies if not rehabilitated to original purity; and
- Uranium mill tailings ponds should be designed

to prevent leakage of radioactive liquors that could contaminate drinking water supplies or local surface waters inhabited by fish and other species.

Research reports show that in areas previously mined for uranium in the 1950s to 1970s, there are instances of elevated levels of uranium in drinking water; higher than allowed arsenic levels have also been detected.[93] There have been accidents leading to significant local water contamination from mill tailings dam failures in 1977 at a Grant, New Mexico mill and in 1979 at a Church Rock, New Mexico mill. Other legacy mining issues are still being dealt with today on Navajo Nation lands and in Utah, Colorado, New Mexico and Arizona. Congress continues to support programs and funding for the cleanup of hundreds of abandoned mines, primarily a legacy of the U.S. governments cold war programs.

The environmental impact study by the National Academy of Sciences concerning potential impacts from a proposed uranium mine in Virginia concluded that the current **best practices on design, construction and operation of mining, processing and reclamation activities can substantially reduce the environmental impacts that have occurred to date.** The report concluded:

> Over the past few decades, improvements have been made to tailings management systems to isolate tailings from the environment, and below-grade disposal practices have been developed specifically to address concerns regarding tailings dam failures. Modern tailings management sites are designed so that the tailings remain segregated from the water cycle to control mobility of metals and radioactive contaminants for at least 200 years, and possibly up to 1,000 years. However, because monitoring of tailings management sites has only been carried out for a short period, monitoring data are insufficient to assess the long-term effectiveness of tailings management facilities design and constructed according to modern best practices.[94]

**All industry sectors—especially those involved in energy—are evaluating their "water risks," and realize that financial gains are possible by saving both water and energy in their operations.** Companies such as Areva, with significant uranium mining operations, are setting internal policies with specific water-conservation targets, and are incentivizing employees to generate innovative energy- and water-saving concepts.

# 5.0 Eight Major Findings and Challenges

### One: Congressional Action is Needed More than Ever, but is Unlikely with Fractured Committee Jurisdictions and the Current Political Climate

Just when national leadership is most needed, the 112th Congress faces seemingly intractable roadblocks. Even without the political obstacles posed by the upcoming 2012 presidential election, **congressional action is hampered by fractured committee jurisdiction over the myriad federal agencies that both write the rules and control sizable tracts of land that contain fuel production areas.** Committees are scaling back funding in an effort to reduce the federal deficit, even though there is a significant need to fund public water infrastructure improvements and to collect comprehensive data to support a reassessment of policies and regulations. **There is a lack of political will to pass comprehensive energy and water legislation, partly because stakeholder/public interest is not being adequately expressed to representatives and senators, and also because little pressure is being exerted on them to make a change.**

Fortunately, the energy and water nexus issues remain on several committees' agendas as they are holding hearings and writing legislation. Bipartisan bills on hydropower, nuclear energy, and oil and gas reserve inventories have cleared a key Senate committee. **However, no comprehensive energy and water legislation is expected to pass by the end of the 112th Congress.**

### Two: Federal Bureaucracy Hinders Progress

There are over twenty federal government agencies that have jurisdiction over the extraction and production of primary energy and transportation fuels. Although agencies are cognizant of the problem and are making improvements in coordinating programs, **federal government interagency coordination is still inadequate when it comes to actually addressing system complexities.**

While some argue that the federal government has not set a national energy and water policy, it has woven a set of laws and supporting regulations that de facto serve as US national policy. The two major pieces of legislation that underpin US policy are the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). Government agency priorities are not always consistent and complementary, however. As seen in the following case, the federal government's commitment to provide energy to transport water, initially made in the 1960s, is bumping up against greenhouse gas policy priorities of the twenty-first century.

In the 1960s, the US government made commitments to provide power from the Navajo Generating Station in Page, Arizona to transport water supplies from the Colorado River to urban areas such as Phoenix. Population increases now require additional water supplies and more power for their transport. The Colorado River water is oversubscribed, and the problem is exacerbated by the current severe drought in the West. To live up to its commitments, the Department of the Interior (DOI), the majority owner of the Navajo plant, must increase the coal plant's capacity, but the EPA argues that its nitrogen oxide emissions pose a hazard to the local residents. (Operators and the local coal mining industry urged the EPA to accept low-nitrogen oxide burners as a solution to the problem.)  This is a classic energy and water nexus conundrum that is proving difficult to resolve due to multiple agency jurisdictions, priorities, and regulations.

**Efforts to develop a comprehensive federal roadmap on energy and water issues have failed to produce an effective plan. Congress approved the 2005 Energy Security Act that directed the U.S. Department of Energy to develop a National Energy-Water Roadmap.** The draft roadmap was developed through a series of workshops and was designed to evaluate the effectiveness of federal programs in addressing water-energy issues and provide recommendations in defining the direction of research, development, demonstration, and commercialization efforts. It was expected to be finalized in September 2006 and to be available by March 2007. But even after 22 rewrites, the Department of Energy has not released the final report.

### Three: Conflicts in Federal and State Roles Undermine Development of Water Management Policies and Smart Regulations

Industry and state government agencies bear most of the responsibility for managing and meeting the energy sector's water demand. However the federal government's drive to develop energy security policies and responses to potential climate change impacts, may change the role the federal government plays going forward. It may accomplish this through its ownership of lands where primary fuels are located and where solar and hydropower facilities may be sited. In fact, the Bureau of Reclamation manages some of the country's largest energy and water resources (in cooperation with state and local authorities).

State laws and regulations primarily define the rules governing the use of water regarding fuel extraction and processing. Ownership of surface and underground water rights differs from state to state and lack of clarity, especially in states west of the Mississippi River, is making it difficult to sort out competing water demands. For example, Texas is debating whether landowners have a vested interest in the water below their property or whether the public may have overriding interests in the water. Until these rights issues are disposed of, it will be difficult to carry out aquifer management plans.

Environmental regulations on mining and water disposal also differ between states. Most states establish their own regulations and are granted permitting powers under the CWA through the EPA's National Pollutant Discharge Elimination System. The EPA is increasingly exercising oversight rights on the process and permits by sending letters of complaint or objections to state actions.[95] **The state and local rules may be impacted or even superseded by federal regulatory initiatives now underway. Conflicts may also arise because the federal government both owns fuel mining land with watersheds spanning many states and hydroelectric facilities that use water from rivers that provide water for several states downstream.**

The jurisdictional conflicts between state and local communities are evident as well. In Pennsylvania the state government recently passed legislation to establish uniformity in regulations, reducing local communities' abilities to enact stricter laws that adopted at the state government level. In Colorado, the debate is ongoing. Governor John Hickenlooper (D) has announced the formation of a 12 member task force to address the state and local government agencies' roles in regulating energy development. The state already has a Local Government Designee program that allows local regulators to participate in the Colorado Oil and Gas Commission decision regarding energy project development. However, localities are pressing for more oversight roles and authorities. The debate is far from settled in Colorado.

Legislation has been introduced in both the House of Representatives and Senate that would impact water permits issued under CWA permitting programs, and more importantly, fundamentally change the federal and state relationship. The Clean Water Restoration Act was introduced in the House by James Oberstar (D-Michigan) and in the Senate by Russ Feingold (D-Wisconsin). Provisions of the proposed legislation would grant the EPA and the Corps of Engineers jurisdiction over all intrastate waters, including according to some analysts, ground water, ditches, pipes, streets, municipal storm drains, gutters and would grant these agencies power to regulate all activities affecting these waters. Critics of the legislative proposal argue that the powers now exercised by state and local authorities over water rights, permitting, regulation of water quality, mitigation requirements, placement of points of diversion would be usurped by the federal government and break a longstanding balance of powers that had existed under the CWA to this point in time.

**There is an important and legitimate discussion underway regarding the appropriate federal and state institutional roles-as well as the proper relationship between state and local authorities regarding the regulation of energy development activities. In particular, the issue of EPA's regulatory initiatives versus state laws and regulations is reaching a boiling point. A middle ground must be found to reduce overlapping regulatory and compliance monitoring regulations and procedures.**

### Four: Comprehensive, Up-to-Date Energy and Water Nexus Data is Lacking

**Congressional and federal agency policymakers claim they lack the comprehensive nationwide data necessary to make appropriate decisions and plans.**[96] This is especially problematic because of the long lead time required to implement major infrastructure projects.

For over 50 years, the USGS collected and published water use data every five years. However, while the agency continues to assess water withdrawals, it stopped collecting water consumption data after its 1995 survey due to funding constraints and data reliability problems.[97] The General Accounting Office (GAO) submitted a report to Congress recommending that the USGS resume its data collection efforts.[98]

The Subcommittee on Water Availability and Quality (SWAQ) was established in 2003 under the National Science and Technology Council Committee on Environment and Natural Resources and was comprised of 25 federal agencies with responsibility for the science and technology of water availability and quality. It issued a report in 2004, "Science and Technology to Support Fresh Water Availability in the United States."[99] This report purported to be the first step in the development of a coordinated plan to "improve research to understand the processes that control water availability and quality, and to collect and make available the data needed to ensure an adequate water supply for the Nation's future."[100] The report admitted that the last time national water use and availability was assessed was in 1978. The report identified the data deficiencies, knowledge gaps in the relationships between surface water, ground water, the ocean, land surfaces and the atmosphere, and outlined a plan to solve the problem.

Five years after this first national call for data and information, the SECURE Water Act in 2009 required the Bureau of Reclamation (BR) to undertake a systematic groundwater-monitoring program and to form a water-use and -availability assessment program. The BR issued an assessment of the problems faced by the Colorado River Basin. In March 2012, the agency announced it will provide $2.4 million in funding (while also requiring the non-federal partners to pay the remaining costs) for water supply and demand studies in five areas including the Los Angeles Basin in California; the Pecos River Basin in New Mexico; the Republican River Basin in Colorado, Kansas and Nebraska; the Sacramento-San Joaquin River Basins in California and the Upper Washita River Basin in Oklahoma.[101] Neither the BR nor any other agency is currently working on a complete national assessment of the country's water uses, needs, and constraints.

The USGS undertakes a review of water use in the United States on a periodic basis. Unfortunately, the data compilation for the report "Estimated Use of Water in the United States in 2010" is off to a delayed start. Report completion and data availability is not expected until 2014.

There are limited efforts underway to address the data issue. The Western Governors' Association, with funding from the DOE, began an energy and water nexus project in 2010 that will address water availability in the west. It will evaluate projected water demands for large river basins and aquifer systems and is expected to consider drought and potential climate change implications on the availability of river flows and water supply for regional energy development. It is hoped the project will issue recommendations by the end of 2012.[102]

**Unfortunately there is no nationwide data collection by an appropriate government authority.** The data that is collected is fragmented, difficult to compare, and outdated by five decades in some instances. The good news is that there is probably sufficient data available now to make reasonable models for a variety of scenarios to estimate the future water demands for energy extraction. Its collection is key because without sufficient information, Congress may not be in a position to develop appropriate policies and state and local planning authorities will not be able to allocate aquifer resources properly or fairly. **Without comprehensive long term water commitments, energy**

**producers cannot make the investments needed to provide US energy supplies.**

### Five: Biofuel Policies Reduce Fossil Fuel Usage but Incur A Significant Water Cost

**There are water-wise biofuel practices that can reduce but not totally resolve water-consumption issues. No matter how or where it is done, there will be a significant water penalty for biofuels as compared to petroleum-based fuels.** To drive an average car one mile takes about eight ounces of ethanol. But to grow the corn to produce that ethanol, using irrigated corn from Nebraska, uses 31 gallons of water. 31 gallons per mile, not miles per gallon; it is staggering. An ethanol vehicle requires between 130 and 6,200 gallons of water to travel 100 miles; a gas-fired engine can drive those same miles consuming only 7 to 14 gallons of water.[104]

Another comparison of water consumption by biofuels to conventional and unconventional oil and gas for transportation finds that to produce 1 million BTUs, roughly the equivalent of the energy it takes to drive from Washington, DC to New York City, water consumption falls into these ranges:

- 14 gallons for traditional oil;
- 2.5 gallons for conventional natural gas;
- 15 gallons for unconventional natural gas;
- 273 gallons for oil sands;
- 1429 gallons from enhanced oil recovery; and
- 15,759 gallons from irrigated corn based biofuels.[105]

### Six: Coal Mining Requires Continued Efforts to Protect Local Water Quality Amid Concerns Whether Regulations are Effective, Consistent and Working

**In the Central Appalachian mining areas, many of the concerns relate to mountaintop coal removal's impact on headwater streams, loss of streams, stream-direction changes, altered timing, duration and volume of the stream flow, and the negative impacts on the ecological and biological character of local streams.** Treatment of legacy AMD remains a problem, and there are concerns related to selenium and water temperatures as well. While it appears that the regulatory agencies and the industry have made progress in managing issues such as those related to selenium,[106] there are questions as to whether the mine operators in the Central Appalachian region can achieve the allowable TDS levels set forth by the EPA. Industry has identified mining practices that can decrease the TDS with innovative over-burden material mining methods.

At the workshop, concern was voiced over EPA standards. The regulatory agency should not establish one standard for the entire country as local conditions differ greatly. Second, as exemplified by EPA's current TDC guidance of SC=300-500 µS/cm, regulatory policies may be ahead of needs and science. Specific effect levels on biota and its elationship to TDS variability remain under study and it is not certain that industry can handle materials to achieve allowable TDS levels.[107]

Mining activities are subject to a complex permitting process that is often undergoing revision. For example, for surface coal mining activities, CWA Section 404 regulates the placement of mined or backfill materials into waters of the United States. The US Army Corps of Engineers issues permits for surface coal mining under section 404 of the CWA while EPA assesses the environmental and water quality impacts of the proposed permits. These activities may also require a DOI-issued Surface Mining Control and Reclamation Act (SMCRA) permit, a state-issued CWA Section 401 water quality certification, and a state-issued CWA Section 402 permit. Although the Corps has responsibility for issuing CWA Section 404 permits, EPA, in conjunction with the Corps, is responsible for developing and executing guidelines for environmental evaluation of applications. EPA issued in early 2012 final guidance on Appalachian surface mining which updated its interim guidance that was issued on April 1, 2010.[108]

The DOI's Office of Surface Mining is preparing a proposed rule on the placement of mining waste near streams that is expected to affect both surface and underground coal mining operations throughout the United States. EPA has proposed rules to restrict mining companies placement of waste rock and debris materials by requiring buffer zones around the streams while requesting mining enterprises to move in phases so that they can better monitor their environmental footprints.

### Seven: The Shale Oil and Gas Revolution Raises Water Quantity and Quality Issues that Industry is Working to Address

**New unconventional oil and gas supplies will significantly increase the security of the US domestic supply, as well as reduce the carbon footprint of the domestic electricity supply, since natural gas will partially replace the burning of coal for electricity.**[109]

**Water quality protection is a key issue with regard to unconventional gas production. Proper well design and monitoring is critical in protecting groundwater supplies. While the public has been most concerned over the possible migration of methane into local well waters, the real problems are mostly associated with the handling of water and chemicals on the surface.**

While best management practices can lead to relatively small withdrawal rates from local watersheds, disposal of the discharged waters must be safely managed in order to protect the public water supply. **Mitigation efforts must be locally designed and implemented, and on-site treatment and reuse of flow-back and treated water is essential to ensure sound practices, both ecologically and economically.** Drilling companies are considering on-site water treatment options such as advanced oxidation and membrane filtration processes. These treatment plans may bring up to 80 percent of the flow back waters to potable standards. Recycling water practices will benefit from new technology and innovation.[110] Devon Energy Corporation is using distillation units at centralized locations in the Texas Barnett Shale Play to treat produced waters in order to recycle the water into other wells. Drilling companies in Marcellus shale plays are finding that it is cheaper to recycle with reverse osmosis rather than purchasing new fracking water, trucking the water out of state and incurring out-of-state injection fees.[111]

**Changes in the energy industry's water- and energy-related goals are in turn driving service companies and industry equipment suppliers to develop innovative technologies and practices.** General Electric alone is investing $10 billion over the next five years into new technologies that will reduce the impacts of primary energy and transportation fuels extraction and production on water supplies and quality, based on its expectation that US shale gas and oil production has the potential to "change the global order." In fact, the industry is moving swiftly, often faster than regulators, developing technology to improve well integrity; designing mobile filtration units to clean water on-site; developing next-generation gas-fired and electric generators to replace diesel units; and designing tracking and planning systems to move trucks around more intelligently. For example, to improve oil-recovery capabilities, next-generation pumps are being designed that can lift oil from 13,000 or more feet.

National labs are also proposing innovative wastewater treatment options. For example, improvements are coming that will involve advanced membrane technology. In the workshop it was proposed that discharged water from fracking operations could be moved to nearby coal-fired plants for treatment. Coal plant waste heat could be used to treat the brackish water (by powering membrane distillation operations that only need a 20 degree centigrade differential), which could then be recycled as makeup water in fracking wells, further reducing water consumption and withdrawal. **Increasingly, solutions to decreasing the consumption of both water and energy will be found by integrating processes across industries.**

While some stakeholder complaints may be unfounded, scrutiny of industry practices is justifiable. **Industry must seize the moment to demonstrate to the public's satisfaction that, as it claims, hydraulic fracking is safe and time-tested, and that it is working in an environmentally acceptable manner.** A new approach should be considered by industry that explains past accidents and how current practices make such events highly unlikely. Industry should recognize that fracking fluids have spilled, some waste waters have not been handled as best as they could have been, and that there has been documented instances of relatively minor earthquakes caused by water injection wells being drilled in potentially unstable geologic formations.

Industry efforts to develop and disseminate best practices can and should be applauded. For example, ExxonMobil Corporation and GE Energy announced in March 2012 contributions of $1 million each to support shale oil and natural gas research and training initiatives. The grants are aimed at programs in established and emerging shale development zones, with Penn State University, the

Colorado School of Mines and the University of Texas at Austin slated to receive funding.

## Eight: Shifting Regulatory and Political Agendas Lead to an Uncertain Regulatory Outlook for Unconventional Oil and Natural Gas at the State and Federal Levels

There is an evolving and complex web of federal, state, and local laws, regulations, and practices regarding fracking operations. Beyond these rules and regulations, stakeholder groups review industry operations and suggest best practices. The State Review of Oil and Natural Gas Environmental Regulations (STRONGER) is comprised of industry representatives, environmental groups, and federal and state agency representatives. Since 1999, STRONGER has been meeting to study and review states' regulatory practices and provide recommendations.

The November 2011 workshop addressed the evolving federal regulatory approach to the practice of hydraulic fracturing of shale plays. The CWA gives the EPA the authority to establish water-quality standards and criteria, effluent limitation guidelines, and other discharge permits. The SDWA gives the EPA direct authority to establish the rules for underground injection sites for discharges from produced waters/flow-back waters, enhanced oil recovery operations, natural gas storage, hydraulic fracturing using diesel fuels, mine backfill injection wells, and uranium-related injection wells. Often the state and local agencies implement and enforce federal laws as well as their own requirements. In some instances, the EPA is designated as the state implementing authority for SDWA-related regulations, as in the case of Pennsylvania and New York. However, The Energy Policy Act of 2005 exempted fracking fluids from EPA regulations under the SDWA.

In March 2010, the EPA announced its intention to conduct a study at the request of the US Congress of the water-cycle profile of hydraulic fracturing operations on ground water supplies, from the origin of the water to its disposal. A draft findings report is expected in 2012, with a final report to Congress in 2014. In addition, on October 20, 2011, the EPA announced that the agency would propose national standards for discharge wastewater associated with natural gas production from underground coal bed and shale formations prior to its transportation to a treatment facility. Referred to as "effluent guidelines," they are expected to be proposed by 2014.

The BLM is also developing disclosure regulations for fracking fluids and methane leakage from well casings. The disclosure rules would apply to fracking operation only on federal lands, although to date, relatively minor volumes of unconventional oil and gas are being produced on federal lands. At the time of this report, the rules have not been made public. They are expected to require companies to list both the names and concentrations of individual chemicals used in fracking fluids, report the total volume of fracking fluid, and methods that will be used to recover and dispose of the fracking fluids.

The FY 2013 Obama Administration federal budget proposes to fund a multi-agency study of the impacts of fracking on air quality, water quality and ecosystems. The USGS, DOE and EPA are developing a memorandum of understanding to map out the responsibilities of each agency in carrying out this study. It is questionable as to whether the 112th Congress will authorize the expenditure of the $45 million needed for this study and/or whether the Obama Administration could reprogram monies authorized for other energy related programs already funded by Congress.

State governments are enacting and updating laws governing fracking operations. In February 2012, the Pennsylvania government passed legislation that would require state regulatory agencies to craft drilling wastewater transportation rules and enforcement measures concerning drilling operator qualifications. The legislation also increases the minimum required distance between drilling sites and public water sources. In August 2011, Governor Chris Christie of New Jersey imposed a one year fracking moratorium in the state. Colorado has enacted fracking chemical disclosure rules. Pennsylvania, Arkansas, Michigan, and Wyoming require companies to post fracking fluid composition on the internet. New York has a temporary fracking ban in place while its state legislators debate an environmental impact statement and related regulations to control fracking within its borders.[113] Meanwhile, several municipalities have enacted drilling bans, and one such area has had its local ban upheld by a New York State Supreme Court.[114]

**Successful regulatory actions regarding unconventional gas fracking will depend on the extent to which the state and federal regulatory agencies are**

**able to balance competing interests.** The American public wants protections to human health using the best available technologies that are economically achievable, while allowing for the continued development of shale gas resources. New regulations can be expected that will reduce the risk of contaminating water resources and capture fugitive emissions on natural gas. However, it is not likely that production will be halted. Rather, **it is expected that the industry will have to implement new procedures and invest in prevention and treatment assets that will raise the cost of production somewhat.**

# 6.0 Recommendations

The Council recommends pursuing an agenda that will build a consensus on how the United States can address the energy and water nexus. Dealing with the nexus should be seen as an opportunity to simultaneously advance the United States' national economic and environmental health. Pursuing these core recommendations will improve US energy and water policies:

- **Publish the Energy-Water Science and Technology Research Roadmap** that was prepared by Sandia National Laboratories at the direction of Congress in 2005 and update and expand the roadmap as necessary;
- **Create a Presidentially appointed task force to address and most importantly, reduce, the federal, state and local jurisdictional overlaps in regulating energy development** taking into account the role of agencies regulating water supply;
- **Improve coordination between the myriad of federal agencies** that deal with energy and water issues and streamline the fractured Congressional oversight of these agencies policies and budgets;
- **Develop a new paradigm of cooperation between the federal government's regulatory agencies and businesses** on the forefront of US energy production;
- **Decentralize water management to the watershed level** with a goal of adopting aquifer compacts and increase stakeholder participation in a collaborative decision making process;
- **Improve, modernize and update the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA)** while recognizing that these laws have been successful in providing environmental protection and have provided models for other countries as well;
- **Congress should direct and provide full funding for the USGS to collect and publish energy and water nexus data**, including an understanding of how much water is available, ownership of water rights, the cost of purchasing water rights (where applicable), the stability of groundwater tables, and the feasibility of using substitute waters for fresh water supplies;
- **Apply appropriate pricing and rate design principles** so that water is appropriately valued, moving away from the public's longstanding assumption that water should be, if not free, then cheap;
- **Integrate climate change impacts into water resource planning** especially in western and southwestern sectors of the United States;
- Similar to efforts to eke as much energy savings as possible with energy efficiency programs, **focus as many resources as possible on water demand reductions.** A corollary recommendation is to pursue research and development of techniques that can reduce both the water and green house gas emissions footprint of the current energy production infrastructure;
- Improve energy and water conservation opportunities through improvements to the water delivery infrastructure and co-location of energy

and water facilities;
- Re-think water supply through an array of **initiatives that can stretch and supplement US fresh water supplies** including including:
  - harvesting rainwater,
  - increasing water storage using existing aquifers when water supplies are abundant , if it can be done efficiently from an energy point of view and without contamination problems, and
  - artificially recharge aquifers and expand the use of impaired waters such as produced waters from oil and gas extraction and discharges from wastewater treatment plants to use in enhanced oil recovery (EOR) operations;
- Maximize and improve existing hydro resources and **provide access to excess federal water supplies to the energy industry**;
- **Create a national/public dialogue using an innovative communications strategy** to raise public awareness of the importance of the energy and water nexus and why better coordination between government, the private sector and stakeholders is necessary;
- **Incentivize technology development** to bring about:
  - development of new sources of water,
  - transformational changes in the way water is treated so that it can be recycled, and
  - improved agricultural practices to reduce the stress that agriculture (not just energy and fuels) place on limited water supplies;
- **Recognize and advertise technology developments** that can fundamentally change the energy industry's water challenges;
- Drive forward **improved water and energy technologies and practices in the DOD and DOI**;
- **Advance efforts by the DOE to develop energy efficiency and water efficiency standards**;
- **Encourage stakeholders to pressure Congress and the Administration to move forward** with policy development and other needed changes;
- Adopt policies at the corporate board level to reduce companies' water footprint and to use water as sustainably as possible; and
- **Find examples of good and bad practices and policies**, study the approaches other countries have followed in dealing with droughts (Australia), creating a centralized water policy and new institutional strategies for many member states (European Union), integrating regional approaches to water management (Russia), and addressing the pressures of moving from a developing to a developed economy (China).

Together, government institutions, companies and stakeholders involved in the extraction and process of primary and transportation fuels must take steps to deal with the water and energy nexus. The Council also makes recommendations for better policies and standards across all of the fuel sectors.

For the renewable fuels sector:
- **Reevaluate ethanol mandates in the renewable fuel standard**; and
- **Develop biofuels policies that transition to production of cellulosic biofuels and other water friendly crops**, incentivize the building of a commercial-scale production facility, and coordinates with agriculture policies which support farmers' use of water-wise crops.

For the coal and uranium mining sectors:
- **Improve mining regulations by establishing better benchmarks** upon which regulations are based and which take into account the wide variability of streams' water quality throughout the United States; and
- Mining industry to continue to **develop best practices and improved material handling methods**.

For oil and gas production sectors:
- **Designate a lead federal agency** to take the responsibility on promulgating tough but fair fracking regulations. Whatever agency is chosen, it must improve its interface with and develop partnerships with the companies involved in fracking;
- **More research, transparency and science-based development of fracking regulations**

is needed. This will lead to a better understand of and pinpointing the practices that may lead to contamination, and distinguishing the actual fracking impacts from contaminants and chemicals naturally occurring in shale areas;

- **Further study of the methane migration issue, full disclosure of fracking fluids**, and banning the use of diesel fuel in fracking fluids will lead to greater public trust in unconventional oil and gas operations;
- **Oil and gas industry to address the public's perception about the risks involved in unconventional drilling techniques and make it a priority to gain public trust in its operation; and**
- Unconventional oil and gas operators must drive the push for and **integrate into operations innovative technologies** to improve well integrity, alternative well simulation techniques that do not use water, mobile filtration units to clean produced waters and fracking fluids that return to the surface, replacing on site diesel engines with gas engines to reduce the lifecycle water profile, use GPS to move trucks around more intelligently and to reduce water needs to clean trucks and transportation routes.

# Concluding Observations

The complex interrelationship between energy and water is leading to a growing dialogue among US government, industry, and nongovernmental organization leaders. However, much greater public and governmental focus on addressing the energy and water nexus is needed if major crises are to be avoided, or at least diminished. **The United States is fortunate in that the potential for crises tend to be regional rather than national. But this is also a curse, as it diminishes the national political will to address topics that can undermine national prosperity.** The challenge is to channel the public's demand for clean, sustainable, and affordable energy and water supplies into appropriate government policy and regulatory action that will drive industry innovation.

National requirements for energy are anticipated to increase even with major improvements in energy efficiencies. Renewable energy usage will grow, but the need for base-load power and fossil transportation fuels will remain for many decades. **Ensuring that a sustainable supply of usable water meets the growing needs for energy and agriculture will become increasingly difficult due to greater water stress and changing environmental regulations.**

US energy security has significantly improved due to dramatic increases in domestic production of oil, gas, wind, and solar. The energy industry has been growing, adding jobs and wealth in the traditional and renewable fuel sectors while also reducing energy imports. Net US crude oil imports reached their peak, at over 60 percent of domestic petroleum consumption in 2005. Today, because of increased domestic production, decreased consumption from stricter fuel economy standards, and substitution with alternative fuels (such as ethanol), oil imports have dropped to less than half of our consumption. At the same time, refinery capacity is expanding for the first time in decades, and the United States is poised to become a net exporter of refined fuels. While the United States is importing a greater percentage of its oil today than in 1973—when the country first began to talk seriously about energy independence—a significant proportion of our imports now come from friendly neighbors, with Canada and Mexico providing approximately 25 percent and 11 percent, respectively.

**The United States is at a crossroad. Can the favorable trends toward increasing domestic production of energy and transportation fuels be accomplished while still maintaining sustainable water supplies?** The United States today needs new policies and significant infrastructure investment in order to meet the increasing demand for water and energy, while dealing with the constraints of growing water scarcity and potential threats to water quality.

Efforts to deal with the energy and water nexus must be ever mindful of the context in which solutions may be found, and the impacts they may have on these other equally important challenges. **There is a danger that in the desire to solve one set of environmental problems, actions may be taken to diminish the country's responsible utilization of its existing substantial resources of conventional fuels that will continue to be required for many decades.**

**Outside the United States, the energy and water nexus is, or will be, exponentially more difficult to deal with**

**for many countries. The United States has the opportunity to provide leadership on solving this issue. US companies can and will, help develop integrated solutions and design new technologies that reduce the consumption of water for energy production and use less energy to provide clean water.**

The Council's continuing dialogues are intended to tackle this complex subject, and to bring forth information and policy recommendations on how the United States can develop solutions to reduce the growing tension between energy and water usage. The Council will subsequently take the insights gained from this discussion of domestic issues to engage in international dialogues with countries facing even more difficult challenges than are arising in the United States.

ATLANTIC COUNCIL

# Energy Water Nexus:
# Primary Fuels for Power and Transportation in the US

November 10, 2011 • Washington, DC
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General Richard L. Lawson, Vice Chairman, Atlantic Council

Congressional Perspectives
House Committee on Science, Space and Technology; Subcommittee on Energy and Environment
Tara Rothschild, Senior Professional Staff Member
House Committee on Natural Resources; Subcommittee on Water and Power
Camille Calimlim, Professional Staff Member

Open Discussion
Moderator: General Richard Lawson, Vice Chairman, Atlantic Council

Current Forecasts
Energy Supply and Demand Forecasts
John J. Conti, Assistant Administrator of Energy Analysis, Director of the Office of Integrated Analysis and Forecasting, United States Energy Information Agency
Water for Primary Fuels Forecasts
Ian Duncan, Program Director, Bureau of Economic Geology, University of Texas at Austin
Water for Electricity Production Forecasts
Vincent Tidwell, Principal Member of the Technical Staff, Sandia National Laboratories

Open Discussion
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Water Intensity in the Extraction and Processing of Primary Fuels for Power and Transportation
Water Demand for Biofuels Production
Ron Pate, Principal Member of the Technical Staff, Sandia National Laboratories
Other Transportation Fuels: Oil, Gas, Coal-to-Liquids, and Hydrogen
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Coal and Uranium Mining
Jerald Fletcher, Natural Resource Analyst Center, West Virginia University

Renewables for Electricity Production: Water, Wind, Solar, Biomass

Jordan Macknick, Energy and Environmental Analyst, National Renewable Energy Laboratory

### Open Discussion

Moderator: Paul Faeth, Senior Fellow, CNA Corporation

### Keynote Speech: CH2M HILL's Perspective on the Energy and Water Nexus

Bill Bellamy, Senior Vice President and Technology Fellow

### Environmental Issues Regarding Primary and Transportation Fuels Extraction and Processing

Biofuels

Jeremy Martin, Senior Scientist, Union of Concerned Scientists

Unconventional Gas Fracking

Ian Duncan, Program Director, Bureau of Economic Geology, University of Texas at Austin

Coal Mining in the Central Appalachian States

Stephen H. Schoenholtz, Director, Virginia Water Resources Research Center, Virginia Tech

### Open Discussion

Moderator: David Garman, Principal, Decker, Garman, Sullivan and Associates Inc.

### Federal and State Laws and Regulations Impacting Water Supplies and Quality

Tanya Trujillo, Office of Water, Department of the Interior

Ann Codrington, Division Director, Drinking Water Protection Division, Office of Groundwater Drinking Water, Environmental Protection Agency

Ann Lowery, Deputy Assistant Commissioner, Office of Energy and Environmental Affairs, State of Massachusetts

### Open Discussion

Moderator: C. Richard Bozek, Edison Electric Institute

### The Outlook for Innovation and Technology Advances

Marie Angeles Major-Sosias, Vice President, International Advocacy Strategy, Areva

Tim Richards, Senior Vice President, GE Energy

Richard Hammack, National Energy Technology Laboratory

### Open Discussion

Moderator: Howard Passell, Senior Member of the Technical Staff, Energy Security Center, Sandia National Laboratories

### Keynote Speech: Peak Water and the Energy Water Nexus

Peter Gleick, Cofounder, Pacific Institute

### Closing Remarks

General Richard Lawson, Vice Chairman, Atlantic Council

## Endnotes


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37. Ibid, slide 22.
38. Ibid, slide 20.

39. There is a growing trend for reduced water usage in fracking operations. In the March 19, 2012, On Point's interview, Charif Souki, Chief Executive Officer of Cheniere Energy Partners confirmed this and stated that "John Berge was talking last week about being able to reduce the amount of water used in the fracking process by 80 percent over the next few years. So, this is going to become a better and better process." See http://www.eenews.net/tv/transcript/1502.
40. Duncan, slide 12.
41. The fracking fluid is composed of 90 percent water, 9.5 percent proppant particles and less than 1 percent chemicals.
42. U. S. Department of Energy, "Shale Gas Subcommittee Second Ninety Day Report," November 18, 2011, page 17, http://www.shalegas.energy.gov/resources/111811_final_report.pdf.
43. Industry has used diesel fluids for some fracking operations but states that this practice has been discontinued. Under the 2005 Energy Policy Act, any company that performs hydraulic fracturing using diesel fuel must receive a permit to be in compliance with the Safe Drinking Water Act. The EPA is in the process of issuing "guidance" for permitting wells using diesel fuels.
44. In December 2011, the EPA issued a controversial report that methane, petroleum based compounds and other chemicals from the Encana Corporation's fracking operations may have contaminated groundwater supplies in Pavillion, Wyoming.
45. Charles G. Groat and Thomas W. Grimshaw, "Fact Based Regulation for Environmental Protection in Shale Gas Development: A Report by the Energy Institute University of Texas at Austin," February 2012, page 17, http://energy.utexas.edu/.
46. Stephen G. Osborn et al, Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing Proceedings of the National Academy of Sciences 2011 May 17; 108(20): 8172–8176 accessible at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3100993/.
47. This same study found no evidence of drinking water contamination from the flow back or fracking fluids.
48. U. S. Department of Energy, "Shale Gas Subcommittee Second Ninety Day Report," November 18, 2011, page 17, http://www.shalegas.energy.gov/resources/111811_final_report.pdf.
49. Passell, May 2011, slide 37.
50. Charles G. Groat and Thomas W. Grimshaw, "Fact Based Regulation for Environmental Protection in Shale Gas Development: A Report by the Energy Institute University of Texas at Austin," February 2012, page 24, http://energy.utexas.edu/.
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55. See http://www.eenews.net/energywire/2012/03/12/.
U.S. Department of Energy, "Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water," December 2006, page 58,
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60. Ibid, page 48.
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62. Intermountain West," Pacific Institute, November 2011, page 22.
63. Nicole T. Carter, Specialist in Natural Resources Policy, "Energy's Water Demand: Trends, Vulnerabilities, and Management," Congressional Research Service, Report 7-5700, January 5, 2011, pages 12-13.
64. Jordan Macknick, National Renewable Energy Laboratory, "Water intensity in the extraction and processing of primary fuels: The case of renewables," presentation delivered at Workshop on Primary Fuels for Power and Transportation in the US, the Atlantic Council, November 10, 2011, slide 8.
65. H. Cooley, J. Fulton, P. Gleick, "Water for Energy: Future Water Needs for Electricity in the
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67. Environment and Energy Daily, "House Panel to probe impacts of regulations on hydropower," May 2, 2011, http://www.eenews.net/EEDaily/print2011/05/02/3.
68. National Academy of Sciences, "Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy," National Academy of Sciences National Academies Press, Washington DC, 2011, http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/Renewable-Fuel-Standard-Final.pdf.
69. DuPont has announced that in mid 2012 it will be breaking ground on a 28 million gallon per year cellulosic ethanol facility that will have an 18 month construction time period, putting it up and running in 2014. It is possible that three or four other companies may make similar announcements in 2012 and 2013.
70. National Academy of Sciences, "Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy," National Academy of Sciences National Academies Press, Washington DC, 2011, http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/Renewable-Fuel-Standard-Final.pdf.

71. This report discusses biofuels as opposed to bioelectricity which uses biomass crops for electricity and/or heat production. It is important to note that the water footprint of bioelectricity is smaller than that of biofuels because it is more efficient to use total biomass than a fraction of the crop (its sugar, starch, or oil content) for biofuel. According to the study, Gerbens-Leenes, W., A.Y. Hoekstra, and T.H. van der Meer, "The water footprint of bioenergy," Proceedings of the National Academy of Sciences, 2009, Volume 106, pp. 10219-10223. "[B]iomass can provide different forms of bioenergy: heat, electricity, and biofuels such as ethanol and biodiesel. First-generation biofuels are presently available biofuels produced using conventional technology, i.e., fermentation of carbohydrates into ethanol, and extracting and processing oil from oil crops into biodiesel. Biomass not only contains starch, sugar, and oil that can be processed into biofuel; it also contains large amounts of cellulosic matter. To date, the cellulosic fraction has been used for energy by burning it to provide heat and produce electricity. It is expected that these cellulosic fractions will form an attractive source for the production of next-generation biofuels. Next generation biofuels are biofuels available in the future, produced using new technology, now under development, that aims to also convert cellulosic fractions from crops into biofuels, e.g., ethanol. In this way, biofuel produced per unit of crop can be increased substantially." http://www.pnas.org/content/early/2009/06/03/0812619106.full.pdf+html.
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78. Martin, slide 29.
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