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Alternative Energy Futures for North America

Christopher Sands

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Hudson Institute
1015 15th Street, NW
6th Floor
Washington, DC 20005
www.hudson.org

Project in Brief

Hudson has embarked on a study of scenarios for probable futures to 2035 that illustrate the trade-offs among energy supplies, demand, economic growth, policies to address climate change, and investments in energy and transportation infrastructure. Leading experts from around the continent and the world have been consulted, along with a range of studies and estimates, to better understand the range of potential outcomes for key variables. Together, the scenarios provide policymakers a working model of the interplay among the options they now confront, and the implications of decisions that each must take in the years to come.

Hudson's scenarios are intended to provoke discussion with state and provincial governments, as well as between these subnational leaders and federal governments. Perhaps most important, these scenarios will pull together the best thinking on difficult subjects, and permit all governments with responsibilities that bear on the future of energy and the environment to engage one another in a strategic conversation that could lead to cooperation and coordination among them.

This study of *Alternative Energy Futures for North America* has been prepared for the Government of Alberta, Canada, with the intention of engaging leaders and citizens across Canada and the United States in a strategic conversation about the contribution that Alberta's energy resources could make to the future of the continental economy. Hudson is particularly grateful to Alberta for initiating this conversation and for contributing intellectually to the development of this study in a series of discussions in Edmonton, Calgary and Washington, DC.

This paper begins with three sections that provide a propaedeutic treatment of important independent variables that will shape all scenarios: the dynamics of energy supply, demand, and climate policy. The study will then present a discussion of the *surprise-free scenario* for the near-term future of North American energy markets, and a consideration of surprises (shocks) that may alter the trajectory of the surprise-free scenario based on the key dynamic relationships affecting the energy sector.

Section 1: Methodology

Hudson Institute founder Herman Kahn was a pioneer in the student of the future and the development of modern techniques for strategic planning by governments and private organizations. Working with Hudson scholars, Kahn developed a method for thinking rigorously about the future that was based on an understanding of intrinsic system dynamics and the independent variables that drove change. For decision makers as well citizens and stakeholders most affected by their decisions, Kahn's method led to the identification of leading indicators of prospective changes, so that it was possible to see when one expected future became possible or probable, while another might be foreclosed.

Borrowing from the language of the theater, Kahn illustrated possible futures in *scenarios*—brief sketches that highlighted distinctions and differences, along with their particular consequences. In constructing scenarios, Hudson scholars would summarize detailed studies and illustrate relationships and dynamics and provide an accessible understanding of a decision's context. The result could be surprising or reassuring, but was intended to be an educational and practical tool that would help individuals make *better* decisions, not simply recommend a particular decision or strategy.

The Hudson approach is designed to consult a wide range of experts in order to develop a comprehensive view of the decision paradigm, and to formulate realistic alternative scenarios of the near-term future (10 to 15 years ahead) that can serve as an introduction and illustration of the possible options and consequences associated with pressing choices. The approach is normative, in that it seeks to identify the most desirable future and the means to obtain it, but it is not utopian. It is an exercise in knowledge aggregation: it is a team effort drawing on the expertise of many scholars. It results in modularity, producing an appreciation of not one but several axiomatic conditions or elements. The process is therefore collaborative and educational for all involved. It will not result in a single action plan, but a more thorough understanding of the dynamics of the policy problem, illustrated through realistic though prospective scenarios of the near-term future that are heuristic in purpose. As Hudson has shown with its studies over the years, such work can be invaluable in shaping the policy debate for the better.

1.1 Premises for the Study

- There is no such thing as a closed system in policymaking
- The shape of the future 10 to 20 years from now is being determined by decisions taken today
- Therefore, it is possible to envision alternative futures by considering the implications of choices now confronting decision makers

1.2 Implementing the Model: Seven Steps

The development of this study followed seven steps, which are generally sequential but may overlap; it is necessary to continuously revisit and question preliminary conclusions reached early in the study to ensure that they still hold. The seven steps are: (1) Problem Identification; (2) Identification of Themes; (3) Inventory of Relevant/Related Work; (4) Development of a Typology of Variables; (5) Unpack Drivers and Estimate their Potential Trajectory; (6) Build and Challenge Scenarios; and, (7) Identify Scenario-Specific "Leading Indicators" for Early Warning.

At present, the study has progressed through the first four steps on an initial basis. Research, interviews with public and private sector experts, and discussion have generated preliminary results that are briefly described below.

Step 1. Problem Identification

According to the Alberta government's Provincial Energy Strategy (*Launching Alberta's Energy Future*, December 11, 2008) the Province of Alberta intends to:

- remain a global energy leader
- be recognized as a responsible world-class energy supplier
- be an energy technology champion
- develop as a sophisticated energy consumer
- earn a reputation for solid global environmental citizenship

To do so, Alberta is committed to:

- continue to encourage responsible clean production of fossil fuels
- promote development of complementary alternative and renewable energy
- foster the wise use and conservation of energy

Based on these objectives and aims, this study will consider how such outcomes can be achieved through policy and what challenges the provincial government will face in reaching its goals.

Step 2: Identification of Themes

Themes are like plotlines for characters in a play (or a scenario). They provide a clustering of data points around an area of interest that will span multiple scenarios and shape the prospective futures under consideration. For the purposes of this study, the main themes are the sectoral economies of various modes of energy production.

Theme 1: The Fuels Market

- The Natural Gas Economy (domestic/continental/international, conventional, unconventional)
- The Petroleum Economy (domestic/continental/international, oil sands/conventional, refining and processing)
- The Coal Economy (domestic/continental, mitigation, facility conversion)

Theme 2: The Power Market

- The Electricity Economy (domestic/continental, conventional and unconventional generation, transmission, storage)
- The Nuclear Economy (domestic/continental/international, generation, new capacity, waste management)

One related theme was determined to merit attention, based on its relevance to government decision-making:

Theme 3: The Climate Debate

- International debate and action
- Continental debate and action (North America)
- National debate and action (Canada, United States)
- Regional debate and action (state-provincial consortia)
- Local debate and action

Step 3: Inventory of Relevant/Related Work

The Hudson study has gathered material on future plans and proposals by governments, NGOs, firms, and private planners and consultants. This inventory is referenced and where relevant summarized in this paper, with a reference list included for cited materials.

Step 4: Typology of Variables

The development of a typology of variables is a key element in the Hudson approach. The first task is to identify the variable factors that may influence the future as expansively and inclusively as possible. Next, these variables must be ranked in terms of importance to the themes and to the problem identified at the outset, and by the degree of predictability of each. By combining the rankings of importance and predictability, the contextualized list is created, and this becomes a reference tool for the development of the scenarios.

At an early stage, the following variables were identified:

- Voter support for climate policy action (in Alberta, outside Alberta)
- Supply elasticity (by mode and fungibility between modes)
- Demand elasticity (by mode and fungibility between modes)
- U.S. reaction to Alberta (governmental – federal and state, market, public/citizen)
- Low Carbon Fuel Standards (LCFS) and Renewable Portfolio Standards (RPS) set by energy importing jurisdictions (domestic, California, continental, international)
- Carbon pricing systems (influence on investment, approach to leakage)
- International governmental action (UN process, international coalitions)
- Carbon impact of current and future economic activity
- Economic growth (domestic, continental, international)

- Private investment in energy supply (resource development, generation capacity)
- Private investment in energy infrastructure (pipelines, power lines, refineries, smart grid)
- Private investment in energy efficiency (home, commercial, heavy industry, energy production)
- Price volatility (by mode)

The next stage in the development of the typology of variables was to rank these variable factors by their relevance to the goals and objectives of the province, and to consider the degree of predictability of each.

Step 5: Unpack Drivers and Explore Dynamics

Using the ranked variables list, the next step was to classify the variables (as dependent or independent of policy actions that may be considered by the Alberta government) and to identify (unpack) the factors that drive them. Hudson then noted the independent variables that have the largest effect on the most significant dependent variables, and considered the factors that best explain the movement of these independent variables. This led to the identification of three powerful dynamics that synthesized what was known about the behavior of the various variables into clusters. The key dynamics driving energy futures in North America are: the Dynamics of Energy Supply, the Dynamics of Energy Demand, and the Dynamics of Climate Policy. These dynamics allow the mapping of the possible future trajectories of each of these variable factors, with particular emphasis on the realistic assessment of their high, low- and mid-range potential paths over the near term (10 to 20 years ahead). The skeletal lines of these prospective trajectories will give shape to the *surprise-free scenario*, which is the expected course of events based on the expected values of the independent variables and the projected consequences for dependent variables.

Step 6: Build Scenarios

The surprise-free scenario was developed using data and forecasts of the U.S. Energy Information Administration. The EIA's *Annual Energy Outlook* reference case is based on their National Energy Modeling System, which uses data reported to government and publicly available information about investments, production, supplies, and demand—and estimates the impact of new regulations and legislation where possible. Because the EIA does not factor in proposed projects, technologies still in development, or external shocks that cannot be predicted, its annual *Outlook* provides an excellent baseline for the consideration of how key dynamics affect future scenarios.

Step 7: Identify Scenario-Specific "Leading Indicators" for Early Warning

Most decision makers rely on rules of thumb based on past experiences or assumptions in order to assess and choose among a range of policy options. The final step in the Hudson project identified indicators that suggest the inflection points and crossroads ahead at which certain future scenarios become possible, and others become obsolete. These leading indicators should replace the old rules of thumb (or reinforce the best old rules of thumb) and give decision makers a more reliable basis for future decisions.

Section 2: Critical Dynamics

A. Dynamics of Energy Supply

A.1 Modes and Distinctions

Energy supplies are traded in a variety of forms, and this analysis is limited to those forms that are principally traded commercially: ***fuels***, including fossil and non-fossil based fuels which are used by machines to generate energy; and ***power***, normally as electricity, which is a form of energy itself.

Fossil fuels include petroleum (and related products such as crude as well as gasoline, diesel fuels, here generally referred to as oil), natural gas, and coal. These fuels are supplied in conventional forms as well as unconventional forms: oil from shale or oil sands, natural gas from shale recovered through hydrofracturing ("fracking") and other means, and processed or clean coal.[1] In addition, these fossil fuels are often supplied in an adulterated form; for example, with the addition of some measure of biofuel such as ethanol manufactured from corn or sugar as additives. These fuels are burned to generate heat and (in some cases) light, which machines of various types distribute or convert into motive force.

When speaking of fossil fuels, two figures are often used: production and reserves. Production is the volume of fossil fuel that is extracted from the ground; production capacity may be greater than the actual production rate when demand or prices are low, or the capacity to transport the product or refine it into a usable format is limited (more about these difficulties is discussed in the next section on *Supply Processes*). Reserves are the estimated volume of fossil fuel available for extraction; the reserves figure is a way to measure the capacity of a particular fossil fuel in the future.

In the case of oil, reserves are often qualified by time, specifically the assertion of a peak in annual production that must inevitably be followed by depletion and gradually lower production. The first peak estimates were made in the United States in the 1870s by geologists, and Texas oil producer M. King Hubbert gained notoriety following the First World War by estimating that U.S. oil production would reach its peak in the 1970s. However, estimates of peak production are made solely on the basis of reserve estimates and the rate of current production; where new reserves are discovered, or when technology allows access to additional reserves, the estimate of the peak also shifts. For this reason, peak estimates are interesting but have rarely been reliable guides for consumers, producers, or policy.

Power is a form of energy that is typically generated by another form of energy; that is, it can be a secondary mode produced from fossil and non-fossil fuels, or by nuclear, hydropower, photovoltaic (solar) cells, wind turbines, geothermal, and even tidal generators. These sources generate power in the form of heat or mechanical energy, and this is often transmitted in the form of electricity. Conversion to electricity is desirable

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[1] It should be noted that research is underway on the use of fracking to extract petroleum, or additional petroleum, from certain geological formations.

and practical because electricity can be used by many types of machines and does not generate a waste product when consumed.

The disadvantage of electricity is that it is difficult to store, and decays when placed in most storage media—such as household batteries, which use conductive metal to store electrical current for a limited time. Automotive batteries store a charge using metal and acid, and this charge is renewed by the motion of the vehicle, sometimes captured via regenerative braking. Fuel cells, most reliant on hydrogen, are storage media for electricity with potential, though limited application in 2012.

Electrical power, whatever its source, is measured in two ways: production (also called generation) and capacity. Production is the amount of electricity generated, typically expressed in watts and hours; this reflects the fact that electricity is a current, so it must be measured in both watts (a measure of power) and hours (a measure of time). Consumers see electricity billed in kilowatt hours (kWh) and producers report electricity production in terms of megawatt hours (MWh), gigawatt hours (GWh), terawatt hours (TWh) and so forth. Capacity is expressed using these same measurements, and indicates the maximum power that can be generated or transmitted by means of current equipment.

The time dimension of electricity is significant, because demand fluctuates during a 24-hour period. Most households demand electricity in the morning, evening, and to a lesser extent overnight. Office buildings demand more electricity during working hours, and some manufacturing facilities have high levels of demand based on their shift schedules. By contrast, fossil fuels are easier to store and so available when needed; with the exception of discussions of peak production, the time dimension of fossil fuels is not significant.

Charts in Appendix I of this working paper contain data on the current production and reserves/capacity of energy supply.

A.2 Supply Processes

For any mode of energy production there is a supply process that must precede the availability of energy for consumers. This is significant because of the time that it takes, following a decision to develop additional energy supplies, to bring that energy to the market. The following discussion begins with fuels and then addresses power separately.

Fuels

Exploration is the first stage of the supply process for fossil fuels. There is no time limit on exploration, although often access to areas for exploration is a prerequisite that requires purchase of rights from a private landowner or permission from a government. The rights to explore and develop energy on public lands (and some private lands) frequently come with required lease payments to the landowners payable whether exploration successfully uncovers an energy resource or not, and payable even if no exploration occurs. This means that permissions, such as U.S. federal government permission to explore for oil in the Arctic National Wildlife Reserve, only initiate the uncertain exploration phase that may or may not result in the discovery of a viable (accessible or recoverable, and of a size that would make development profitable) deposit of fossil fuel. Nonetheless, permission typically attaches a cost to the prospective producer that will eventually be reflected in the price of energy produced.

Table 1: Stages of Fossil Fuel Production

Oil, conventional	**Oil, unconventional**	**Gas, conventional**
Exploration	Exploration	Exploration
Extraction	Extraction	Extraction
Transportation	Upgrading	Processing
Refining	Transportation	Transportation
Distribution	Refining	Distribution
Use	Distribution	Use
Byproduct/Waste	Use	Byproduct/Waste
	Byproduct/Waste	

Gas, unconventional	**Coal, conventional**	**Coal, unconventional**
Exploration	Exploration	Exploration
Extraction	Extraction	Extraction
Processing	Transportation	Processing
Transportation	Use	Transportation
Distribution	Byproduct/Waste	Use
Use		Byproduct/Waste
Byproduct/Waste		

After permitting (a process that can vary in duration by jurisdiction, but typically involves a prior environmental impact assessment as well as other approvals) the siting of production facilities for fossil fuels can take an additional one to five years depending on the mode.

Extraction, Upgrading, Processing. Once fossil fuel sources have been developed they must be recovered, and the two basic methods of recovery are through mining and drilling. Mining is appropriate when the resource is relatively underground but close to the surface (less than 250 feet below ground), and the two principal mining methods are pit mining and shaft mining; in pit mining, an area is excavated and fossil fuel is extracted from the excavated ground whereas in shaft mining a tunnel is bored or dug to reach subsurface seams or pockets of fossil resources which are then removed to the surface. Drilling is similar to shaft mining except that a smaller tunnel or bore is used to recover resources in a liquid or gaseous form, and is used to reach far deeper depths. The recent development of directional drilling techniques has enabled access to additional resources and expanded estimates of recoverable reserves of fossil fuels.

Technological advances have also enabled the extraction of fossil fuels from unusual sources, and the fuels produced in these ways are labeled "unconventional." Oil sands deposits, where bitumen is found mixed with sand and other impurities, are a growing source of unconventional petroleum. Oil sands can be mined or recovered *in situ* through drilling combined with either steam-assisted gravity drainage (SAGD) or cyclic steam stimulation (CSS), both of which utilize steam under pressure to press bitumen out of sandy formations underground. The bitumen is extracted and then ***upgraded*** using water in the form of steam to remove impurities and convert the bitumen to heavy oil ready for refining. Hydrofracturing (known as "fracking") techniques have been used in shale formations to open pockets of oil and gas in nonporous rock and extract these resources for use.

Natural gas requires ***processing*** before consumer use. This is because while end-use gas is primarily methane, gas when extracted commonly exists in mixtures with other hydrocarbons—principally ethane, propane, butane, and pentanes. In addition, raw natural gas often contains water vapor, hydrogen sulfide, carbon dioxide, helium, nitrogen, and other compounds. In this form, it is known as "wet gas." These elements are removed by one of four common, but complex processes,[2] typically performed at or near the wellhead, the end-use methane is known as "dry gas" and is ready for pipeline transportation.

Coal is mined using two methods: open pit or strip mining, which involves the removal of soil above a coal seam, and shaft mining by which a shaft or tunnel is dug to reach a coal seam and recover the resource. Pit mining is less expensive but more disruptive and less attractive. Shaft mining poses greater risks to miners and is more expensive, but less disruptive to the surface ecosystem.

The four main types of coal mined in North America are anthracite, bituminous, subbituminous, and lignite and are distinguished by their relative carbon content, a function of the age of the coal, which like oil has its origins in organic matter. Anthracite has the highest carbon content and is the oldest coal type, and lignite the lowest and the youngest. The higher the carbon content the hotter the coal will burn, and the more energy it can produce. Anthracite is found primarily in Pennsylvania, bituminous coal predominates in the Eastern and Mid-continent coal fields, while subbituminous coal is generally found in the Western states and provinces. Lignite is mined primarily in Texas but large deposits exist in Montana, North Dakota, and some Gulf Coast states. Bituminous coal is the most common form mined in North America, used mainly to generate electricity and by industry, and subbituminous coal is the second most common form in the region.

Prior to transportation, coal may be processed to remove some or all of its sulfur content prior to combustion in order to prevent the sulfur from entering the air. The resulting

[2]The four most common processes for refining raw natural gas to remove impurities are Oil and Condensate Removal, Water Removal, Separation of Natural Gas Liquids and Sulfur and Carbon Dioxide Removal. For detail see, http://www.naturalgas.org/naturalgas/processing_ng.asp

"clean coal" is sold at a premium price. Coal may also be processed into a liquid form (a process known as liquefaction) for use as a transportation fuel. Coal-to-liquid processing is more common as a substitute for oil imports in regions with little or no petroleum, according to the World Coal Association.[3] Another unconventional coal product is underground coal gasification or UGS, which involves drilling two wells into a coal seam and then injecting water and oxidants into one well and extracting a syngas product from the other. This method is being experimented with in the United States.[4]

Transportation is the next stage in the production process for fuels, from the extraction or recovery point to a refinery or a distribution point. While natural gas is processed at the point of extraction so that dry gas can be transported by pipeline, petroleum is typically refined closer to the market in which it will be distributed and consumed. This is because oil refining requires large, expensive facilities and oil products are processed to meet specific market needs and regulatory requirements. These can vary by jurisdiction.

Pipelines are used to transport natural gas and petroleum products under pressure over long distances. In certain cases, oil may be transported by rail or even by truck (in smaller quantities), although these transportation methods are more commonly used for the distribution of consumer-ready product.

Typically pipelines are buried underground, with periodic segments of the line rising above ground near pumping stations (to maintain pressure), inspection points, and for maintenance access. In the case of pipelines in arctic regions, the risk to the structural integrity of the pipeline when ground shifts due to permafrost requires that pipelines be built above ground; this is the case with the Trans-Alaska Pipeline, for example. Underground lines are less disruptive to communities transected by pipelines, allowing roads and wildlife migration to pass over them. However unseen buried oil pipelines have some risk of leakage (particularly with older pipeline systems) that could affect soil and groundwater, or rivers and lakes nearby. Natural gas leaks are less common underground. Regulation and public permitting processes are established to examine pipeline designs and routes prior to construction and firms are required to inspect and maintain pipelines to meet government standards.

The solid form of coal is bulk cargo, transported primarily by rail and ship or barge.

Refining. Oil must be refined for consumer use, and regulations require precise chemical characteristics for gasoline, diesel, jet fuel, propane, biofuels, heating oil and other products. Crude oil is classified using the American Petroleum Institute's classification system based on two characteristics: gravity (weight) and viscosity (resistance to flow). Lighter and more viscous crude oils are easiest (and least expensive) to refine, and so are priced more highly. Significant sulfur content makes oil "sour" and less sulfur content

[3]World Coal Association, "Coal to Liquids" available at: www.worldcoal.org/coal/uses-of-coal/coal-to-liquids/
[4]World Coal Association, "Underground Coal Gasification" available at: www.worldcoal.org/coal/uses-of-coal/underground-coal-gasification/

renders the oil “sweet.” Sulfur is removable during refining, but the more sulfur content in the crude oil, the more effort and expense is required to refine it.

Some jurisdictions have established regulatory mandates specifying a particular chemical content for fuel sold there, the most common form of mandate being a low carbon fuel standard (LCFS) such as California’s. To produce gasoline or other products to meet such mandated specifications, refineries must adjust their processing of crude products precisely. This has two significant effects: it renders the resulting fuel more expensive for consumers (raising the price) and also reduces the scale economy for the refinery, since the end-product is crafted for one geographic market. A secondary effect is that for very rigid mandates, supplies of fossil fuels cannot be easily expanded to meet demand since a limited refinery capacity is dedicated to the mandated specifications, and nonconforming fuels from other jurisdictions cannot be brought in to supplement supply and meet a rise in demand. This will be addressed at greater length in Section 3 of this report.

Refineries are critical energy infrastructure. They take up a large amount of land, cost several billion dollars to build, and operate continuously with a large, skilled workforce. They can also be difficult to build due to government permit requirements and regulation. The majority of North American petroleum is refined in the United States, including oil from Canada, Mexico, and other countries. Refineries are optimally located close to consumers, and are found in many regions of the United States.

Distribution. Transporting petroleum, gas and coal products from where they have been processed or refined to consumers is the final step in the supply process for fuels. In North America, pipelines, rail, and truck are the predominant oil and gas modes, all three of which require fixed infrastructure. For heating and industrial fuels, pipelines or barges bring the fuel product from a refinery to a storage terminal and trucks are used to convey the fuel to retailers and intermediate distributors.

It should be noted than one additional fuel, nuclear fuel, is significant in North America. Like coal, the supply process for nuclear fuels begins with exploration, then proceeds to extraction, then to refining (to remove any impurities) and processing (to a specific grade), followed by transportation/distribution. The most common nuclear fuels are uranium and plutonium isotopes; the latter is a byproduct of certain nuclear reactions and not mined but manufactured from material such as uranium or processed nuclear materials.

Byproducts and Waste Disposal are a final step in the fuels supply chain, although they may be generated as part of previous stages and their management may occur alongside each step. For example, carbon capture and storage technologies are being developed to reduce the carbon released into the atmosphere during fuel extraction, processing, or refining. Spent nuclear fuel is especially hazardous and must be disposed of in special facilities. Scrubbers and other filtering technologies installed at refineries and fuel-combustion power plants are another option. Such measures are distinct from those undertaken by responsible end-users such as industrial facilities and car drivers, since for these the cost of disposal of waste is the responsibility of the user. For participants in fuel supply chains, the safe handling and responsible disposal of waste and byproducts is typically a legal requirement and attendant costs are passed on to consumers through price.

Power

Generation. Power is a form of energy, unlike fuels that must be combusted to release energy. There are many ways to generate power, which is then transformed into electricity for transmission, storage, or use. Most methods involve the use of turbines, in which a liquid or gas under pressure turns a mechanism that releases kinetic energy. Hydropower (dams on rivers or tidal basins), geothermal power, wind power, and solar power all harness natural forces to generate electrical power; steam is used in power plants fueled by coal, gas, and nuclear materials.

Table 2: Stages of Power Production

Electrical Power
Generation
Transmission
Distribution
Byproducts/Waste

Transmission of electrical power is by means of above-ground or underwater lines which when linked to one another form a transmission grid. Electricity is transmitted at high voltages (110kV and higher) to reduce the loss of electricity during transmission, and although most electricity transmission uses three-phase alternating current, high-voltage direct current transmission is also used for longer distances. Electrical power is difficult to store, and cannot be stored in large volumes, so the transmission grid must have spare, unused carrying capacity in case of surges or drops in demand and supply.

Distribution of electricity is the final stage in the power supply process. Typically, the network would include medium-voltage (less than 50 kV) power lines, substations and pole-mounted transformers, and low-voltage (less than 1 kV) distribution wiring. Meters record the electricity at the location (building) associated with a particular customer.

Byproducts and Waste may occur during power generation and generators have legal liability for safe handling and disposal.

A.3 Structures of Supply

All of the various stages in the energy supply process may be managed by a single, vertically integrated producer (which may be a public or private entity, or a publicly regulated monopoly), but it is more common in North America that different stages in the supply process are performed by separate entities.

In the case of fuels, exploration is often done by the same firm that handles extraction; transportation is managed by a different company; refining or processing is performed by a third company either tied to the retailer or contracting with independent retailers. Such a set of relationships is known as a fuel supply chain and many firms specialize in a particular part of the supply process, performing that work in North America and elsewhere.

The fuel supply chain has important implications when considering the role played by state-owned enterprises in the oil sector, from Mexico's Pemex to the Chinese National Overseas Oil Corporation (CNOOC). In North America, these firms typically participate like privately owned firms in North America—at only a few points in the supply chain, most often in ownership of reserves and extraction. These state-owned firms frequently rely on the expertise of world-class fuel transportation, refining/processing, and distribution (for local sales) companies. This has been a challenge for Mexico, which has a constitutional prohibition on foreign participation in the oil sector that has hindered access for Pemex to innovative technologies and expertise from firms in the North American fuel supply chain.

In 1997, the U.S. Federal Energy Regulatory Commission (FERC) embarked on an attempt to deregulate the electricity sector and promote competition.[5] A major component of this effort was a rule that firms, particularly public monopoly electrical utilities, could participate in just two of three sectors of the supply chain for power: generation, transmission and distribution. The incentive for utilities was FERC permission for cross-jurisdictional electricity sales, which could be delivered across transmission or distribution lines owned by another entity for a carry charge. FERC envisioned a more resilient national power grid in the United States in which seasonal and short-term shortages in one part of the country could be overcome with electricity from another jurisdiction by guaranteeing open access to the power grid. FERC hoped that this would enable entrepreneurial generators of wind power, solar power, and other alternatives to access the existing transmission grid and incentivize power supply diversity.

The FERC deregulation also permitted contiguous jurisdictions in Canada and Mexico that adopted the open access provisions of the FERC rules in the United States to participate in wholesale power trade with the United States and sell power across the U.S. grid for a carrying charge. Quebec was the first Canadian province to adapt its regulations to meet FERC requirements.

Under the 1997 FERC rules, many U.S. utilities responded by retaining generation (where they had sunk costs in existing generation facilities) and distribution (which is typically state regulated, and where a state-chartered utility has important extant relationships and obligations). The result is that an already inadequate transmission sector has remained weak; firms hoping to build transmission capacity face challenges acquiring right-of-way and securing necessary permits for cross-jurisdictional lines from multiple governments.

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[5] For a detailed discussion of the FERC deregulation effort and its impact, see: Thomas M. Lenard, "FERC's New Regulatory Agenda," *Regulation*, Fall 2002: 36-41

A.4 Elasticity of Energy Supply

Elasticity refers to the capacity of supplies of particular modes of energy to increase or decrease in response to market conditions. Greater elasticity allows supplies to ramp up quickly in response to changes in demand, or to recover from supply shocks that might be caused by weather, war, or other disruptions. When energy supplies are more elastic, the price of energy is more stable. Less elasticity can be the result of bottlenecks in transportation or infrastructure, or limited energy resources. When supply shocks occur for relatively inelastic energy modes, the result is price volatility and even shortages.

Since the oil price shocks of the 1970s, elasticity of energy supplies (also known as energy security of supply) has been a concern for markets and consumers worldwide. Although lower oil prices made possible by the availability of additional supplies of oil diminished the political salience of this concern, energy security of supply returned as a priority in the United States and other developed countries in 2008 when oil prices reached US $147 per barrel.

A related issue is the question whether global oil supply has peaked. If global oil production has peaked, elasticity of supply will steadily and irreversibly diminish. American geological engineer M. King Hubbert advanced the theory that since oil is a finite resource, its production would reach a peak after which it would decline, gradually or rapidly, until the resource was fully depleted. Hubbert predicted a U.S. peak of production would occur in the 1970s. However, the peak oil theory holds only when oil (or other fossil fuel) reserves are precisely known and where extractive technology remains constant; technology, the development of unconventional oil resources such as Alberta's oil sands, and biofuels all complicate peak production estimates and forecasts.[6]

Still, the fuels sector has a natural source of inelasticity in its capacity to extract fuels from proven reserves at a given rate. This is a critical point considering an increase in Alberta's oil sands production capacity from 2.5 million barrels per day (bpd) to as much as 5 million bpd to meet an increase in U.S. demand, or to displace imports from other sources that may be disrupted.

Within the United States, some state governments have mandated specific local fuel compositions, including additives for environmental or public health reasons. This is important to supply dynamics because it differentiates an otherwise fungible product at the market level. A car that takes on gasoline at filling stations in multiple jurisdictions will continue to run even though the fuel mixes vary, but oil refined into gasoline to meet one jurisdiction's requirements may not be sold by retailers in another jurisdiction with different requirements. As a result, gasoline prices can vary widely by jurisdiction, and supply shortages can occur locally when refineries cannot produce enough fuel to meet specific requirements under conditions of rising demand. This is an example of a policy-created inelasticity of supply.

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6 Herman Kahn and Julian Simon observed the fragility of peak oil forecasts in their 1984 book, *The Resourceful Earth* (Basil Blackwell), page 361.

Another example affecting the gasoline fuel segment has been ethanol blend mandates, accompanied by U.S. ethanol production subsidies. Unlike state government blend mandates, federal blend mandates cover all jurisdictions. However, unanticipated shortfalls or price fluctuations in supplies of ethanol introduce another element of inelasticity to fuel supplies.

The natural gas supply in North America has been growing rapidly due to new technologies that have enabled access to pockets of gas trapped in shale and other formations. The principal extractive technology is hydrofracturing. Governments, and the U.S. Environmental Protection Agency, have explored regulation or even prohibition of fracking, and some U.S. states have withheld permission to develop gas deposits using this technique until it can be fully assessed and found safe. Despite these moves, states, such as Ohio and North Dakota, and provinces, such as Alberta and Saskatchewan, have experienced gas production booms under a permissive regulatory approach with the result that natural gas supplies have grown and market prices have fallen. The potential for additional gas supply has made gas among the most elastic components of the North American fuel supply.

U.S. gas suppliers have recently begun to consider liquefaction and seaborne export of natural gas (as liquefied natural gas or LNG) to markets in Europe and Asia. Access to these additional markets would spur production growth, but could also create competition for domestic demand, with the result that North American prices may increase. This will increase the elasticity of supply further, since it will provide an additional incentive for investment in exploration and extraction of gas deposits.

The elastic gas supply and low prices have the potential to lower carbon emissions from power generation where coal-fueled generators invest in conversion to natural gas. This would have the additional salutary benefit of helping power distributors cover demand when variable sources of alternative power (e.g. wind power on windless days, solar power on cloudy days or at night) are unavailable. The elasticity of gas fuel supplies thereby contributes to the elasticity of power supplies as well.

As noted above, fuels extraction and power generation rely on transportation to reach the next stage in their respective supply chains. The capacity of pipelines and powerlines to carry fuels and power is a hard constraint, and the development of additional oil and gas pipeline capacity and new electrical transmission lines has lagged behind the expansion of supply—and proceeded unevenly across the continent—creating bottlenecks within the energy supply system that represent a major source of inelasticity.[7]

Fuel extraction is tied to the location of resources, and often occurs far from large population concentrations such as major cities. Power generation, particularly in areas of growing capacity, such as hydropower, wind power, geothermal and solar power, is similarly occurring at some distance from consumers and requires a connection to the transmission grid.

[7] A discussion of the lead-time required for several types of infrastructure of energy supply, from power plants to pipelines, is included in Appendix 2 of this report.

Natural gas processing is typically co-located with extraction, to upgrade the gas for pipeline transport as methane. For petroleum fuels, a refinery is required, most often located close to consumer markets due to regulation and the particular profile of local demand. A refinery can require as much as a square mile of land and cost more than $1 billion to construct. The nature of a heavy chemical processing facility, such as a refinery, leads to extensive review and permitting processes at the local level that add to the time and difficulty required to expand refining capacity. The result is that existing refineries are expanding capacity and suppliers in North America are competing for current capacity with non-North American oil suppliers. Refinery capacity is an additional source of inelasticity in the petroleum fuel supply chain.

A.5 The Effect of Price

Market prices for fuels reflect costs from every step in the supply chain, plus taxes and other government surcharges. Market prices for power and some fuels are typically negotiated with government regulators. The market price available for a unit of fuel or power sends an important signal to firms in the energy supply chain: it indicates the potential return on an investment in supply capacity. Naturally, high prices will prompt more investment in capacity, and low prices will lead to reduced production.

What is often overlooked is the effect of price volatility, whether created by supply shocks or regulatory action. The lead time required to add extraction, transportation, and refining capacity increases the risk to investors (public and/or private) associated with expanding fuel supply capacity. Rights to proven reserves are an asset. If prices are low, owners may prefer to hold the rights rather than bring to market. In the case of power generation, the inability to store power effectively makes suppliers vulnerable to price fluctuations, which is one reason for public price setting (to create a predictable price environment that will attract capital for the expansion of generating capacity).

Sudden increases in fuel prices due to demand fluctuation or government action can lead to an increase in profits for suppliers with the capacity (supply elasticity) to increase production. This typically results in populist political claims that fuel supplies are enjoying “excess profits” and acting unfairly. Yet, the cost of developing fuel supply capacity is the same whether prices are high or low and investors accept the risk that low prices may lower the rate of return on this investment to the point that some supply volume will be curtailed. Once again, the long lead-times mean that short-term price fluctuations do not result in new investment in supply but provide opportunities and risks only for those already in the fuel supply chain.

While market prices are subject to some local variation, the supply costs for firms in the fuel supply chain vary due to conditions, such as location (how far the resource extraction point is from consumers affects transportation costs; remote production can raise labor costs; weather in locations like the arctic can add to extraction costs) and processing (upgrading oil sands to remove particulate matter adds to costs, for example). The result is that an increase in the market price for a fuel can render extraction of some supplies economical, and a decrease in the market price for a fuel can stall or shut down production for others. These adjustments within the supply chain foster relative price stability where sufficient elasticity of supply is present: high prices attract additional supply, which will depress market prices; low prices lead suppliers to reduce production and the resulting contraction of supplies pushes prices back up. Yet the key to this dynamic is the elasticity of supply, which can be altered by policy.

A.6 The Effect of Policy

Policy decisions have a major effect on supply dynamics at every stage, whether for fuels or power, and also shape the effective elasticity of supply. The major government actions affecting energy supplies include the following:

- Exploration permission: Before a resource has been located, government permits access to exploration on public land, offshore, and using certain methods.
- Extraction regulation: Whether, and under what conditions, a fuel resource may be developed commercially is subject to government approvals at the local, state/provincial, and sometimes federal level in North America. Methods of extraction are subject to regulation for environmental impact, worker safety, and public safety among other reasons; in addition, once extraction has commenced, facilities are subject to regulation of their operation, future expansion, and eventual closure.
- Generation regulation: The construction of new power generating facilities is subject to government approvals at the local, state/provincial, and sometimes federal level in North America. Governments may subsidize certain types of generation (such as environmentally beneficial alternatives) and prohibit others (such as nuclear), and can offer incentives such as rate (price) concessions, mandated purchase quotas imposed on distributors, or publicly-built access to the transmission grid for some generators. Methods of power generation are subject to regulation for environmental impact, worker safety, and public safety among other reasons; in addition, once generation has commenced, facilities are subject to regulation of their operation, future expansion, and eventual closure.
- Processing and Refining: The siting of processing and refining facilities is regulated for environmental impact and public safety. The processing and refining methods used are also subject to governmental approvals and permits. Likewise, operation of refineries and processing facilities is subject to regulation.
- Transportation. Siting and construction, and subsequent operation of pipelines and powerlines and related facilities are subject to regulation for environmental impact, worker safety, public safety, and other concerns. Such regulation is complicated for transportation infrastructure that crosses jurisdictional boundaries and requires unsynchronized approvals and reporting by/to multiple authorities. The construction and maintenance of roads, inland waterways, port facilities (including LNG terminals), and right-of-way for pipelines and powerlines are all public responsibilities.
- Distribution. Fuel distribution is regulated, from storage tanks to truck safety and road usage. Retailers of heating fuels and transportation fuels are regulated for product and consumer safety, as well as facility licensure and equipment inspection. Natural gas distribution is regulated for consumer safety. Electricity

distribution is regulated to ensure citizen access in poor or rural areas, to set prices/rates, and to ensure infrastructure safety, maintenance, and service restoration in the event of disruptions (caused by weather, etc.)

- Market access. For power production, governments typically determine access to the transmission grid and the power distribution system for generators, and often establish a publicly regulated monopoly that generates and purchases power and ensures access to customers in rural areas. Through renewable portfolio standards and regulatory approval of power purchase agreements set for the utility, governments can also provide access for favored types of power generation, such as wind power, industrial cogenerators selling surplus power back to the grid, generators located in particular politically important regions, or firms owned by women or minorities. Fuels supply chains have a more diverse makeup of firms of different sizes, but governments can affect market access across their borders (including international borders) and may introduce renewable fuel standards that mandate refineries to purchase biofuels and other additives for incorporation into retail gasoline.
- Byproducts/Waste Regulation. For environmental reasons, particularly for fuels, the regulation of byproducts and waste such as carbon may be part of an international, national, regional or local regime. Cap-and-trade systems designed to promote reductions in carbon emissions fall into this category.
- Taxation. Taxes are levied on firms in the fuels and power supply chains as well as on the fuels and electricity that they produce, and altered to provide incentives and disincentives to investors, firms, and consumers. This can include carbon taxes and consumption taxes and public rate regulation.
- Labor Market. Energy supply requires skilled labor. Governments are involved in recruiting and training workers; in Canada, federal and provincial governments have worked to recruit foreign skilled labor for work in the oil sands regions. Governments sometimes certify workers as having requisite skills, particularly in the areas of workplace safety, hazardous materials handling, transportation, and emergency preparedness and response. Also, governments establish rules for collective bargaining by energy sector workers.
- Critical Infrastructure Protection. Leaks, spills, weather-related damage (from ice-storms to hurricanes), and acts of sabotage or terrorism are an ongoing risk to the fuels and power supply chains, and the public sector has a role in assessing and sharing information on risks with companies, as well as planning for emergency response. Cyber security is a growing area of concern for the energy sector. Governments play a role in setting standards and imposing requirements on firms in this sector.
- Research and Development. Much of the basic research that contributes to innovation in the energy sector is financed by governments, from the U.S. and Canadian national laboratories to public research universities, including work conducted on behalf of the military and civilian agencies. The Obama administration launched two parallel “Clean Energy Dialogues” in 2009 to link researchers and their findings in the United States with counterparts in Canada and Mexico.

- Government procurement. Governments make direct purchases of energy, including fuels for military vehicles and energy for government installations and facilities. The U.S. Strategic Petroleum Reserve may be refilled with new purchases, or sold to alleviate the effect of price shocks (or in response to political considerations). In addition, governments can influence purchases of fleet vehicles by government agencies and utilities to promote sales of electric and alternative fuel vehicles.

As noted above, this is an incomplete list intended to illustrate the complexity of public policy as an independent variable in the energy supply equation. The Government of Alberta should set its own policies and priorities, while engaging policymakers in other jurisdictions to address disagreements and the unintended (or intentional) consequences of their policy choices for Alberta's energy sector.

The nature of many of the dynamics of energy supply in North America is such that it is difficult to alter their trajectories in the near term: exploration for new resources, new capacity for extraction, refining and processing, transportation and distribution, and new technology for managing byproducts and waste responsibly all take years to emerge under the most encouraging conditions. Sources of instability causing price fluctuations are often exogenous: conflict or unrest in the Middle East, or weather conditions. This highlights policy actions as among the variables most amenable to action in the near term.

Section 2: Critical Dynamics

B. Dynamics of Energy Demand

B.1 Modes and Distinctions

The nature of energy demand is conditioned by use, either the requirements of machinery or technology or the needs of a particular facility or location. Consumer choices are based on their ownership of things that require fuel or power, and irrespective of a consumer preference to opt for another fuel or power source, the limiting effect of their possessions is a constraint on the elasticity of their energy demand.

In North America, three segments comprise the majority of the energy demand market: industry, transportation, and commercial/residential facilities.

> ***Industry*** includes a variety of activities from manufacturing to oil refineries, chemical plants and natural gas processors; it includes the energy consumption associated with the energy supply chain and agricultural energy use.
>
> ***Transportation*** includes energy consumption by motor vehicles, aircraft, rail and maritime shipping.
>
> ***Commercial and Residential*** buildings consumption of energy for heating, cooling and equipment is the third segment of the energy market. This includes

offices and homes, shopping malls, university classrooms, and government buildings.

The EIA estimates that industry accounts for 50 percent of U.S. demand, transportation for 30 percent, and commercial/residential use for 20 percent. This breakdown is roughly consistent with demand patterns in Canada.

Fuels are used by all three segments but are the primary requirement for transportation. Power is demanded by all three segments but is the primary requirement for commercial and residential uses. Transportation can move to distribution locations, such as gas stations, but industry and commercial/residential segments require that power and fuels be delivered to them directly, making infrastructure connections essential.

Most consumers participate in two or more of the energy demand market segments simultaneously: households own cars, industry relies on transportation to bring inputs to and from factories; and, transportation may be owned and operated by industry or commercial property owners. Yet because the type of energy demanded and the volume required is linked to the nature of the intended use and not the characteristics of the consumer paying for the power or fuel, these three segments establish valuable distinctions for the analysis of demand patterns.

B.2 The Structure of Energy Demand

A number of factors drive shifts in energy demand, and the following list is a non-exhaustive selection of some of the most salient.

Geography and Location influence demand patterns. Geography is an indicator of climate and weather conditions that affect energy consumption for purposes such as heat and air conditioning. Geography also pertains to spatial distribution and the need for transportation fuel for regular activities such as commuting and shopping, which are higher in suburbs and rural areas than in cities. Densely populated areas tend to be better served by infrastructure and, therefore, offer more consumer choice and competition; remote areas, in contrast, have fewer choices.

Population and Wealth also influence energy demand: while large populations use more energy, relatively wealthy populations on a per capita basis have more things that require fuel and power. This dynamic has two important implications: First, cities and wealthy suburbs are areas of high energy consumption (including for significant infrastructure needs) and can drive energy demand. And second, populations with rising per capita incomes will demand more power and fuel, thereby explaining demand growth in developing countries and regions benefiting from a surge in economic activity.

Season and Time influence demand patterns throughout the year and during each 24-hour period. Seasonal factors like outside temperatures affect demand for heating and cooling, as well as industrial cycles, such as agricultural harvest and production of holiday items. Transportation fuels are in greater demand on major holiday weekends and popular vacation times. Demand for power can vary during the day, with demand higher in commercial areas during the workday and higher in residential areas in the evening. Some industrial users operate constantly with stable demands for power and fuels, while others operate only one or two shifts.

Table 3: Drivers of Energy Demand

Factors Affecting Energy Demand
Geography, Location
Population, Wealth
Season, Time
Infrastructure
Economy
Preferences

Infrastructure is an important factor in demand patterns, since it can determine the availability of supplies to particular locations. Some residential and commercial users have installed electric heat and cooking equipment because natural gas lines are not available to power alternatives. Areas with abundant electrical power often develop industries reliant on that form of power and have concentrated demand. For owners of electric vehicles, the availability of charging stations can influence power consumption and the decision to take a long trip away from home.

Reliability is a consideration when it comes to infrastructure that can influence investments in equipment. When local infrastructure is being used to its full capacity, this can affect the quality of service and generate localized price shocks. Areas prone to brownouts, or loss of electricity due to weather or weak infrastructure, can see rising fuel consumption as industrial, commercial and residential users acquire generators. Heating oil shortages can lead homeowners to switch to natural gas heat where gas connections are available.

The health of the ***economy*** drives demand up in periods of strong growth and down during recessions, broadly speaking, but also locally with a plant closure diminishing demand in a community and a plant opening having the opposite effect. Similarly, if the economy of a foreign trading partner is in recession, as the U.S. economy recently experienced, this influences the energy demand in Canada by serving as a drag on Canadian exports.

In addition, certain ***preferences*** can influence demand if consumers have the ability to make choices among energy suppliers or modes. Some consumers would elect to purchase low-carbon fuels if given that option, and may seek out alternative power generation that is perceived to have a less harmful impact on the environment. In other cases, consumers might opt for fuels produced in their home country or by a friendly foreign country. This kind of conscientious consumption is common in the U.S. and Canadian economies but is not a major factor in the market for fuels and power. This is because suppliers have not marketed supplies based on such characteristics, and distributers value the flexibility to switch among sources of supply in response to price and other considerations. Fueling stations offer octane choice, diesel, and biofuel blends mandated by regulators but nothing equivalent to "fair trade coffee" – an ecofuel, or patriot gas option, for example. Smart grid technologies in use in some parts of North America have empowered distributors with information about consumption, but technology to empower consumer choice has not yet become common. Thus, power distributors respond to signals from regulators for purchases of power from wind farms or hydroelectric dams, rather than signals from consumers who elect to pay premium prices for power generated by renewable means.

B.3 Elasticity of Energy Demand

Elasticity refers to the capacity of consumers of particular modes of energy to increase or decrease consumption in response to market conditions. Greater elasticity allows end users to use more power or fuel in response to changes in supplies, or to recover from supply shocks that might be caused by weather, war or other disruptions. When energy demand is more elastic, the price of energy is more stable. When demand shocks occur for relatively inelastic consumers, they may sustain consumption of fuels and power but reduce consumption of other items.

In the short-term, much energy demand is relatively inelastic and nondiscretionary: inelastic because it is related to a sunk cost in equipment (e.g. a car, truck, machine tool or home HVAC system) and nondiscretionary because usage is tied to essential activity, such as running a business, home heating, refrigerated storage of perishable food and medicine, and commuting. When prices rise, consumers can try to conserve energy to reduce outlays for fuels and power, but with only marginal effects without the replacement of equipment or such things as windows and insulation. Instead, most consumers will continue to demand energy volumes at new higher prices and curtail expenditures in other areas – postponing a vacation or planned capital investment.

With time, demand can become more elastic as consumers adjust to energy price shocks or energy gluts and shortages by purchasing new equipment, taking steps to lower their consumption (such as insulating a home, replacing windows, buying a smaller vehicle, investing in more efficient equipment), or increasing it (purchasing a light truck, setting the thermostat at a higher temperature in winter).

The key to adjustment of energy demand is capital, since demand is conditioned by equipment and property, and change requires new expenditure – a greater outlay in the short term to shift costs in the longer term. Demand elasticity over the near term (as defined for this study, 10 to 15 years ahead) is greatest for segments of the energy market where capital is concentrated and available; demand elasticity is lower for segments of the energy market where capital is less readily available. In a weak economy, adjustment is slower; in a booming economy it is more rapid. But this also applies to households.

Since power and fuel consumes a larger portion of the income of poorer households and businesses than wealthier ones, in inelastic demand markets like energy price increases are highly regressive. All consumers suffer from inelasticity, but poorer consumers have less ability to invest in equipment to reduce consumption and must sacrifice expenditures from a smaller budget for discretionary expenses. Over the near term, poorer consumers will struggle to accumulate or borrow the capital to upgrade equipment (such as home HVAC, or kitchen appliances), or, in the case of renters, pay the higher rents for properties whose owners have made these investments.

Industrial energy consumers and commercial transportation plan for capital equipment replenishment on a routine basis as their use of equipment generates revenue that can be reinvested in new equipment and is more intensive generally than for households. Depreciation of the value of the equipment as a taxable asset in some jurisdictions is a further reminder of the replenishment cycle. Since newer equipment tends to use energy more efficiently than older equipment, businesses will experience a greater elasticity of demand as they update their machinery on a schedule measured in years rather than months or weeks.

For transportation, adjustment to new energy market conditions is different for commercial and other vehicles. There are roughly 280 million motor vehicles in the United States and Canada, and annual vehicle sales of 10 to 17 million vehicles sold. Fleet replacement takes 15 to 25 years at this pace, with at least 10 years before a new technology can become prevalent in the driven vehicle fleet (based on the prevalence of seat belts, air bags, and central brake lights after each was mandated by regulators). Commercial vehicles are replaced at a faster rate given more intense utilization, particularly commercial trucks, but aircraft and ships tend to remain in service for decades with occasional upgrades (engine replacements, for example) possible.

B.4 The Effect of Price

Prices for power and fuels send an important signal to consumers, and the relative inelasticity of energy demand in the short term ensures that the signal does not go unnoticed. A spike in gasoline prices, or in heating bills, becomes a topic for conversation at the office, the grocery, and the dinner table.

The effect of price volatility is even more important, since in determining whether or not to make adjustments, energy consumers must weigh the costs of investing in altering their demand by purchasing new equipment, or riding out a short-run fluctuation in price and conserving capital. The uncertainty associated with price volatility will tend to confuse adjustments and prolong negative impacts of disequilibrium between supply and demand.

For most consumers, even relatively inelastic demand is not perfectly inelastic – some reduction in consumption is possible in the event of high prices. If price volatility is judged to be temporary, efficiencies can be gained from planning and caution regarding energy consumption.

Substitution is a second strategy, and one that can have a mitigating effect for more durable price fluctuations. Using public transportation instead of a personal vehicle, or carpooling to lower fuel costs associated with commuting are two examples. Using videoconferencing to avoid business travel for certain meetings is another.

Changes in price also have an effect on public opinion regarding environmental policy. Higher relative energy prices can reduce demand for environmental policy measures that can increase the cost of fuels and power and come to be seen as luxuries in weak economies.[8] This topic will be revisited in the section of this study on the Dynamics of Climate Policy.

B.5 The Effect of Policy

Policy decisions have a major effect on demand dynamics in each segment, whether for fuels or power, and also influence (and can mitigate) the inelasticity of demand. The major government actions affecting energy demand include the following:

- Industry. Industrial users can be encouraged or regulated to make changes in machinery and equipment to reduce demand, or to undertake cogeneration to mitigate the effects of industrial demand on the available supply (in effect, expanding supply but also reducing net industrial demand on extant supplies of fuels or power.)
- Transportation. Governments have set miles per gallon (kilometers per liter) performance standards for the regulatory approval for sale of new vehicles, and encourage fleets of commercial vehicles to convert to alternative fuels.
- Commercial/residential. Building codes and standards for new construction, as well as financial assistance to property owners for investments in efficient appliances and systems to upgrade existing buildings, can be provided by governments to facilitate demand adjustments.
- Price Regulation. Power sold over a publicly owned grid or distributed by a public monopoly often faces rate regulation by a government commission or agency. Such an entity can prevent power suppliers from passing cost increases to consumers in the form of higher prices. For short-term fluctuations, this can smooth out the price volatility to the benefit of consumers. For more durable price changes, the rate setting power by governments can only forestall an eventual adjustment – supplies will adjust in the short run by trimming maintenance and repair budgets, delaying planned reinvestment in their capital equipment, and other measures. Over the near term, however, if rates are not allowed to adjust to changes in the cost of providing power, the amount of power available will fall. Generators will sell in other markets, or because capital investments were not made, generating capacity will not increase to meet rising demand for low-cost (relative to other jurisdictions) power.
- Subsidies and taxation. Subsidies may be directed to energy consumers to facilitate adjustment by capital expenditure and capital equipment replenishment, particularly under weak economic conditions. Tax policy provides a number of options for mitigating the effects of price volatility and improving elasticity of energy demand: tax credits or write-offs for capital equipment replenishment or certain home improvements are effective subsidies for households paying taxes. Taxes may also be imposed to penalize failure to adjust or high energy use

[8] See Kahn and Kotchen (2010) for further discussion.

(temporarily worsening the demand elasticity for those individuals so that the pressure to adjust becomes acute).

- Mandates. Governments can mandate energy efficiency standards as a precondition for approval for new construction and renovations, or for new motor vehicles. Government may also ban inefficient products, such as incandescent light bulbs, to improve demand elasticity by leaving consumers no option but to replace current bulbs with more environmentally friendly ones.
- Public information. While the energy supply sector shows a relatively higher degree of concentration and coordination, demand is diffuse and consumers may operate with imperfect information about supply trends, price expectations, and the technology available to facilitate demand adjustments. Governments can foster greater awareness of the opportunity costs associated with adjustment and non-adjustment of demand to switch among fuels and power modes.
- Transportation Infrastructure. Public transportation systems can allow some consumers to substitute personal transportation for collective transportation. Better roads and more road capacity can reduce excess fuel consumption due to traffic congestion and road resistance.
- Supply Intervention. To mitigate the effects of a supply shock on relatively inelastic demand, government can sell fuels from stockpiles (if feasible), ease regulatory obstacles to supply expansion (such as limits on hours of operation, or environmental mandates affecting generation or transmission). More aggressively, governments can seek to shut down some supplies; the Obama administration has threatened to bankrupt coal-fired power plants with litigation unless they close or switch to less carbon-intensive fuels.[9]
- Demand Intervention. During the energy crises of the 1970s, governments resorted to rationing, prohibitions on certain types of energy consumption (often at peak demand times, or for purposes such as lawn mowing). These measures are difficult to sustain politically for long but can have an ameliorative effect on energy demand for a time.

As noted above, this is an incomplete list intended to illustrate the complexity of public policy as an independent variable in the energy demand equation. The Government of Alberta should set its own policies and priorities, while engaging officials in other jurisdictions to address disagreements and the unintended (or intentional) consequences of their policy choices for Alberta's energy sector.

As is the case with supply, the dynamics of energy demand in North America is such that it is difficult to alter their trajectories in the near term: investment in new equipment to reduce demand, or to switch from the use of a particular energy mode to another, all take years to attain prevalence even under the most encouraging conditions. Sources of instability arising from price fluctuations can hinder adjustments and poor economic conditions can limit capital available for equipment replacement and replenishment to

[9] Institute for Energy Research (2012)

shift demand to new modes or lower levels. This highlights policy actions as among the variables most amenable to action in the near term.

Section 2: Critical Dynamics

C. Dynamics of Climate Policy

C.1 Modes and Distinctions

It is important to note at the outset that the brief discussion of climate policy included in this paper is not a judgment on the merits of actions (or inaction) to address climate concerns. It is instead an acknowledgement of climate policy as a dynamic that could alter the dynamics of energy supply and demand in North America, and which must be accounted for in scenarios for the near-term energy future.

The emission of carbon and some other particulates during the combustion of fuels is a primary concern for its impact on air pollution but also the climate. Carbon-intensive fuels, such as coal, petroleum, and natural gas, may contribute to carbon release into the atmosphere to varying degrees and depending upon the method of combustion and the presence of remediating countermeasures, such as filters, scrubbers and carbon capture equipment. Biofuel combustion also produces carbon emissions, but these are considered preferable to fossil fuels because they are produced from plant matter and therefore renewable; the land use necessary for the biofuel feedstock crops is a concern for some environmentalists, underscoring the dilemma facing climate policy: there are tradeoffs in the production and use of fuels, and none without an impact on the environment of some sort.

Power production raises climate concerns, in part because of the use of certain high-carbon fuels in power production such as coal. Yet as with fuels, some of the non-carbon fuel options such as nuclear power generation raise environmental concerns only indirectly tied to the climate, and confront policymakers with the challenge of navigating tradeoffs that divide citizens and the environmental community.

The relative inelasticity of demand has contributed to the modest success of policy measures aimed at shifting energy demand to lower carbon emissions. Supply side efforts have been more successful due to the already-regulated supply chain for fuels and power, and the concentrated nature of the energy supply market which is comprised of a relatively few producers in comparison to the diffuse array of consumers. But both supply and demand have been affected by climate policy dynamics.

Each stage in the fuels supply chain has been targeted by policymakers in the effort to address climate concerns. Exploration for carbon-intensive fossil fuels has been banned from public lands and offshore or discouraged in particular locations. Extraction has been constrained through the use of regulation, permitting, exhaustive review processes and delayed approvals that tie up capital for prolonged periods and raise the cost of market entry for potential suppliers. Resource rents and taxation have been adjusted by governments to alter the economics of extraction projects, and mandates placed on extractors for environmental cleanup, and site remediation. Upgrading and processing face similar challenges from policymakers seeking to ensure a minimal environmental impact from new and existing operations.

Fuels transportation has become contentious, particularly the construction of new pipeline infrastructure; some climate policy activists have claimed that insofar as transportation of fossil fuels makes them available, they feed an "addiction" to fossil fuels. Thus, blocking new pipeline construction is advocated as a means to reduce fossil fuel access, increase overall prices due to the resulting artificial supply constraint, and discourage demand (and encourage demand adjustment and overcome the inelasticity of demand in the short term). These are arguments that have been made regarding the Keystone XL pipeline extension through the U.S. Plains.

Refineries and processing facilities have come under new scrutiny and permitting standards have been increased so that it is more costly and difficult to site new facilities or to expand existing ones. Refineries have been mandated to remove more sulfur and other chemicals from fuels, and to blend in biofuels and additives that reduce the climate impact of combustion by consumers, but add to the cost of production for refiners.

Distribution of fuels is also affected by climate policy, with local governments raising the requirements for the siting and construction of gasoline stations and limiting their locations, as well as those of central distribution facilities and fuel storage tanks. Renewable fuel standards imposed to limit the carbon emissions from fuel combustion by transportation and industrial users have also added to supply costs and constraints. Byproduct and waste management standards have steadily increased for fossil fuels in particular, and government have encouraged the adoption of carbon capture and storage technologies.

Power production has also been affected by climate concerns at each stage in the power supply chain. The differential carbon emissions associated with different modes of power generation has led governments to adapt policy to favor power generation by certain modes, such as solar, wind, and hydropower, and to provide subsidies for the installation of new capacity of favored modes. Transmission grids have been opened up to access by smaller generators, and transmission lines extended to provide such producers access to the grid. Distributors and publicly regulated utilities have been subject to government mandates to purchase power from non-fossil fuel generators, and those generators utilizing fossil fuels have been challenged by policymakers – and, in some cases, fossil fuel generating capacity has been shut down entirely at the behest of governments.[10]

Nuclear fuels and nuclear power production offer low-carbon alternative generation, but governments have not encouraged new nuclear generating capacity and have imposed tough regulations on the transport of nuclear fuels and nuclear waste byproducts. A mode that might have been expected to benefit from climate policy concerns has been also been hampered by low natural gas prices, which discourage the construction of costly nuclear generation capacity.

[10] This has been the case for coal fired plants in the United States. See Institute for Energy Research (2012)

C.2 The Structure of Climate Policy Actions

The foregoing description of the climate policy effects on the dynamics of energy supply referred only to governments in the generic sense. The dynamics of climate policy are shaped by the nested relationships of differing levels of governments and of potential policy action.

Chart 1: Climate Policymaking Relationships

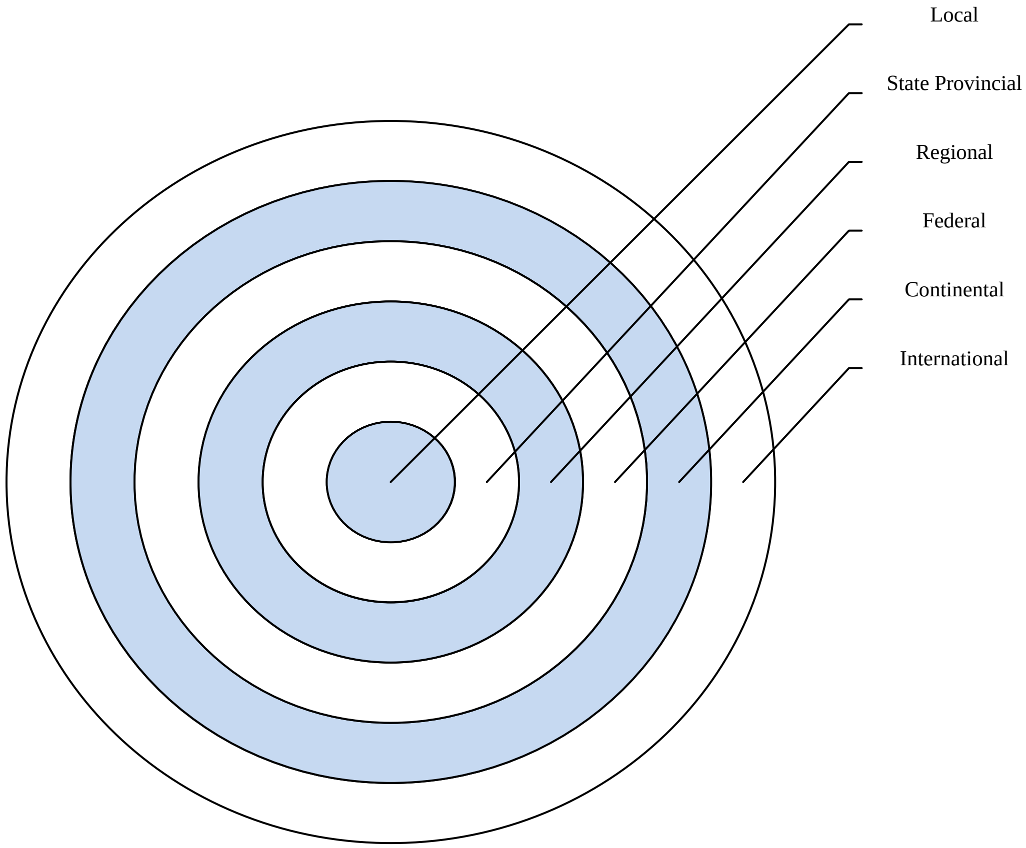

Chart 1 illustrates the levels of climate policy activity as a set of concentric circles. In the center is local government, which can affect the siting of new infrastructure, subsidize or otherwise encourage capital equipment replenishment and property improvements to benefit climate. Local governments can offer public transportation, tax incentives, and mandate energy conservation by local government entities, such as schools and public buildings. Local governments may also be involved in local power purchases, and the siting and taxation of fuel distribution infrastructure. Local efforts can contribute to climate policy goals through such actions but only very modestly.

The next level of the chart shows state and provincial governments, which play a larger role in setting fuel mandates for retail sale and commercial use and in regulating power generation, transmission and distribution, as well as rates in many cases within their jurisdictions. State and provincial governments can also use fiscal spending on subsidies and incentives, research and development at local universities and firms, transportation infrastructure (including public transportation), and tax abatements and incentives to encourage or discourage energy supply and demand to favor climate policy goals.

Some states and provinces have acted boldly within their spheres of authority to advance climate policy objectives. The California Air Resources Board has been able to set vehicle emissions targets and foster alternative energy generation capacity; the province of Ontario has sought to attract manufacturing of alternative energy generation equipment (and so called “green jobs” for Ontarians) by offering fixed-rate contracts to prospective power generators prior to the installation of capacity. These efforts at industrial policy at the subfederal level have caused friction with other jurisdictions.

The Province of Alberta has invested $2 billion toward research and development of carbon capture and storage (CCS) technologies and public transportation. It has also set up the only functional carbon emissions offset market with a price on carbon in North America.

Yet there are limits to what can be accomplished within the jurisdictional boundaries and limits of a state or province, and this has led state and provincial governments to cooperate in the establishment of regional climate policy initiatives. Most notably in North America were the establishment of the Western Climate Initiative (WCI) and the Regional Greenhouse Gas Initiative (RGGI) which set caps and targets for carbon emission reductions and allowed emissions trading among firms in participating states and provinces. The WCI even attracted some Mexican states to pursue observer status.

Such efforts were ameliorative, but federal governments have greater powers in Canada and the United States to regulate economic activity. To date, however, the United States has been unable to pass comprehensive climate legislation or to ratify international commitments to the Kyoto Protocols or subsequent United Nations-sponsored climate policy initiatives. The Government of Canada under Prime Minister Stephen Harper has argued against Canadian action unless and until the United States acts, to avoid placing additional costs on Canadian firms that could benefit their U.S. competitors in the Canadian domestic market and hurt trade. The Government of Mexico under former President Felipe Calderon has sought financial assistance from countries like the United States and Canada to help finance new energy infrastructure and capital equipment upgrades to reduce Mexico’s carbon emissions. Without such firm commitments to date, Mexico has acted within its limited capacity to improve the carbon emissions profile of its energy supply and demand mix.

This record of modest action by the three North American federal governments (outside their domestic regulatory competence, fiscal and tax policy measures) underscores the challenge for each of the three countries acting independently. The United States has initiated Clean Energy Dialogues to share research and information on energy innovations and climate policy options bilaterally with both Canada and Mexico. But a continental carbon policy has not emerged from the three countries.

One reason for this is that the broader context for climate policy action is international. As the challenges of climate changes are not confined within national borders, many advocates of action by governments believe strongly that a global response is required. This has been the motivation of a series of United Nations sponsored negotiations and summits in pursuit of a global climate treaty.

These concentric circles of climate policy activity challenge the dynamics of supply and demand with problems of assessing risk, setting expectations, and making adjustments and investments. How durable is the climate policy intervention of a lower order of government? How likely is a global consensus? Do the policy signals that emerge from climate policy warrant hedging or significant changes in direction by consumers and suppliers?

The global economic downturn that began with the 2008 financial crisis and continues to hamper economic growth and recovery in employment in all three North American countries and elsewhere in the world has also affected climate policy action. As Kahn and Kotchen (2012) note, public support for environmental policy actions perceived to be costly falls during recessionary economic periods.

This is not to say that the dynamics of climate policy are not affecting the dynamics of supply and demand; rather, that the difficulty in creating a stable and comprehensive climate policy regime that can provide suppliers and consumers with clear signals to guide behavior has led to the mixed and sometimes confused reaction of energy markets to climate policy initiatives enacted at various levels. Citizens frustrated with the lack of climate policy progress have sought to force governments to take action, sometimes just to have some action taken. For example, while some critics of the Keystone XL Pipeline extension were concerned to ensure that wildlife and sensitive ecosystems were protected, others ought to block the pipeline to strike a blow against the fossil fuel economy – even though Canadian oil would eventually reach world markets by another means, making a victory against this particular pipeline a pyrrhic victory at best for environmentalists.

Such is the state of the climate policy dynamic: the nested levels of government policy action compete and conflict, and the most important levels for action are also those at which consensus has proven the most difficult. Frustration prevails among citizens and environmental groups, suppliers and consumers, and governments as well.

Section 3: Scenarios

A.1 The Surprise-Free Scenario

The "surprise-free" scenario is the baseline for the study of alternative futures and establishes the trajectory of key variables. It is surprise-free in the sense that nothing happens in it that is not reasonably expected: the supplies of fuels and power are those currently available and what will become available based on capacity changes already underway (not proposed plants and hoped-for developments); demand is steady and linked to population and economic growth. Technology is a constant: no innovations or breakthroughs occur in the surprise-free scenario. Instead, energy market indicators follow logical trajectories.

The Hudson approach works well in the energy sector because of the lead times required to see significant changes in supply and demand. Supply changes require planning, permitting and construction lead times, and inelastic energy demand results from the need for large numbers of consumers to make changes to equipment and machinery that take time to become prevalent enough to reshape demand dynamics.

The U.S. Energy Information Administration constructs a bi-annual "International Energy Outlook" that employs a methodology sufficiently similar in its assumptions about the near-term future to the requirements of Herman Kahn's original method to function as a surprise-free scenario for the purposes of this study. Using the reference case from EIA's *International Energy Outlook 2011*, this section will outline the key features of the surprise-free near-term future before proceeding to a discussion of the main features of selected alternative scenarios and the potential impact of exogenous shocks on energy markets.

A.2 Surprise-Free Expectations of Population and Growth

Modest population growth is anticipated in all three North American countries through 2035. The U.S. population should rise from 305 million to 390 million by 2035 based on a 0.9 average annual percentage change. Mexican population growth in this period is expected to occur at a slower pace, with an average annual percentage change of 0.6, resulting in an increase from 125 million to 149 million by 2035. Canada will experience the greatest population growth during this period, with an anticipated full percentage point of average annual population growth driving the Canadian population from 33 million to 43 million people by 2035. These population growth estimates suggest a total population of 582 million for the NAFTA countries by 2035.

Economic growth should outpace population growth in all three markets. The EIA forecasts U.S. GDP growth to average 2.5 percent per year, while Canadian GDP rises by 2.1 percent per year on average and Mexico attains a 3.7 percent average GDP growth rate per year through 2035. Fluctuations will occur during this period, but the near term outlook to 2035 anticipates that the NAFTA countries will have a combined GDP (calculated on a purchasing power parity basis in 2005 dollars) of more than US$32 trillion.

The combination of rising population and economic growth is a clear indication that in the broadest sense energy demand will increase and that energy supply will need to expand to meet future need in the surprise-free scenario.

A.3 Surprise-Free Expectations of Fuels and Power Capacity

The EIA uses a category of "liquid fuels" in its estimates, defined as: "petroleum and other liquid fuels including petroleum-derived fuels and non-petroleum derived liquid fuels, such as ethanol and biodiesel, coal-to-liquids, and gas-to-liquids. Petroleum coke, which is a solid, is included. Also included are natural gas liquids, crude oil consumed as a fuel, and liquid hydrogen" (EIA 2011: 25). This definition combines several categories of oil (conventional and unconventional), gas (conventional and unconventional) and also some coal as previously discussed in reviewing the dynamics of energy supply.

The EIA estimates the liquids production will increase in the NAFTA countries by an overall average annual percentage growth rate of 1.3 percent to 2035, faster than the rate of population growth but more slowly than the expected rate of GDP growth. This suggests that energy efficiency gains (to slow the rate of growth of energy demand), power and fuels not included in this category will be necessary to support economic activity in the near term.

The United States and Canada are each expected to expand liquids production in the years through 2035: the United States by an average annual percentage growth rate of 1.5 and Canada at 2.6. Mexico, in contrast, is forecast to shrink is average annual production of liquid fuels by 2.4 percent per year to 2035. Proposals that would see the Mexican constitution amended to allow foreign participation in the Mexican oil sector are not included in this surprise-free scenario.

Of this change in liquids production, the EIA estimates that the majority of the U.S. liquids production growth will be of conventional liquids, while the decline in Mexican liquids production will come mostly in the form of reduced conventional liquids production. However, Canada's conventional liquids production is estimated by the EIA to remain stable to 2035, with its growth in liquids production coming entirely from an increase in unconventional liquids, which would include oil sands products: oil sands bitumen production in Canada is forecast to grow by an annual average rate of 4.4 percent between 2008 and 2035.

Natural gas fuel (excluding LNG) production is anticipated by the EIA to grow through 2035, mainly through the expansion of tight gas – unconventional natural gas extraction from shale and coal-bed methane and other deposits through the use of fracking and other methods. U.S. total natural gas production by 2035 is forecast to reach 26.4 trillion cubic feet (tcf) by 2035, of which 19.8 tcf will be unconventional. Canada, too, will see an increase in total gas production to 9.0 tcf by 2035, of which slightly more than half, 4.6 tcf, will come be unconventional. Mexico is forecast to reach 2.1 tcf in total natural gas production by 2035, but just 0.4 tcf of this total will be unconventional.

Coal production will continue to grow in North America to 2035 as forecast by the EIA. Canadian coal production will grow at the greatest average annual rate, 1.1 percent for the period to a total of 2.1 quadrillion Btu by 2035. The EIA combines it forecast of Mexican coal production with its forecast for Chilean coal production, but the combined production of both countries is estimated to be just 0.3 quadrillion Btu by 2035. The United States is anticipated to have only a 0.4 percent annual average growth rate in coal production through 2035, but will remain the largest volume producer in North America extracting 26.5 quadrillion Btu in 2035 according to the EIA forecast.

Power production capacity will rise in all three NAFTA countries under the EIA forecast model, which estimates average annual percentage growth rates for total installed generating capacity for the United States, Canada and Mexico of 0.7, 1.3 and 2.5 respectively.[11] The composition of power production by mode of generation is expected to shift in each nation but accompanied with some consistent trends: average annual decline in liquid-fired generation as a percentage of installed capacity, and growth in hydropower and other alternative power generation capacity for all three.

The trend in U.S. power generation installed capacity will lead to a greater reliance on natural gas and hydropower (and other alternatives) by 2035. Coal- and nuclear-fueled generation is expected to grow but represent a smaller proportion of total capacity by 2035. Table 4 shows the trends and absolute capacity figures (in gigawatts) for 2008 (actual) and 2035 (EIA forecast).

Table 4: U.S. Power Generation Capacity 2008-2035

	Average annual percentage change	**Total 2008 capacity (in gigawatts)**	**Total 2035 capacity (in gigawatts)**	**Percentage of total 2008 generation capacity**	**Percentage of total 2035 generation capacity**
Liquid-fired	-0.9	116	90	11.5	7.4
Natural gas-fired	1.3	338	482	33.5	39.4
Coal-fired	0.2	313	334	31.0	27.3
Nuclear-fueled	0.4	101	111	10.0	9.1
Hydro/ alternatives	1.4	141	205	14.0	16.8

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

[11] In the case of installed power generating capacity, the EIA reports its forecasts for Mexico and Chile and a combined figure, which obscures the Mexican component of the 2.5 annual average growth rate for power production capacity. This is the case for all of the references to power generation by type that follow.

As Table 5 data show, Canada is anticipated to reduce liquid- and coal-fired generation capacity, while increasing capacity in natural gas and nuclear fueled generation by 2035. But, by far, the largest increase in installed power generation capacity for Canada through 2035 will be in hydropower and other alternatives (the majority of which is estimated be from hydropower.

Table 5: Canadian Power Generation Capacity 2008-2035

	Average annual percentage change	**Total 2008 capacity (in gigawatts)**	**Total 2035 capacity (in gigawatts)**	**Percentage of total 2008 generation capacity**	**Percentage of total 2035 generation capacity**
Liquid-fired	-1.0	4	3	3.1	1.7
Natural gas-fired	1.5	16	24	12.5	13.2
Coal-fired	-0.8	16	13	12.5	7.2
Nuclear-fueled	1.8	13	22	10.2	12.2
Hydro/ alternatives	1.6	79	119	61.7	65.7

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Since the EIA combined the power generation capacity figures for Mexico with those for Chile in its reference case, a less definitive picture of the trends in Mexico can be seen in Table 6. Overall, only liquid-fired generation is expected to decline in these countries. Installed capacity growth for natural gas, coal, and hydropower (and alternative) generation will see each assume a greater proportion of the total energy capacity mix in Mexico and Chile, compensating for the decline in liquid-fueled generation. The anticipated 2 percent average annual percentage rate growth of nuclear generating capacity between 2008 and 2035 will leave reliance on nuclear power unchanged at 1.4 percent.

Table 6: Mexican (and Chilean) Power Generation Capacity, 2008-2035

	Average annual percentage change	**Total 2008 capacity (in gigawatts)**	**Total 2035 capacity (in gigawatts)**	**Percentage of total 2008 generation capacity**	**Percentage of total 2035 generation capacity**
Liquid-fired	-0.8	17	14	24	10.1
Natural gas-fired	3.3	29	68	40.7	49.4
Coal-fired	3.3	6	14	8.5	10.1
Nuclear-fueled	2.0	1	2	1.4	1.4
Hydro/ alternatives	3.1	18	40	25.4	29

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011. Note: EIA combines power generation figures for Mexico and Chile.

A.4 Surprise-Free Expectations of Demand Drivers

Among the drivers of energy demand, some remain constant: geography and location of national markets, and seasonal and time variations that are relatively consistent year to year. The EIA forecast treats infrastructure (other than extraction or generation capacity), such as energy transportation infrastructure (e.g. pipelines and powerlines), as a constant and does not estimate the effects of bottlenecks or new routes. Change in population size, GDP and wealth (as a proxy, GDP per capita) were discussed in Section 3.A.1 above, and predict increasing energy demand in all NAFTA countries. And as for preferences, consumers are assumed to follow patterns of prior consumption in future years; this may not be a reliable assumption in the real world, but it does reflect the relatively inelastic demand in energy markets. The EIA forecast also estimates consumption, rather than demand *per se*, which is consistent with the treatment of preferences as constant.

Expected consumption patterns vary by country in the EIA forecast, with some overall trends all three countries should experience: growth in total primary energy consumption and increasing liquids, natural gas, nuclear, hydroelectric and other alternative power consumption. Coal is the fuel where the three countries diverge: the United States is anticipated to see a modest 0.3 percent average annual growth rate in coal consumption; Mexico (and Chile) are expected to have a higher 2.6 percent average annual growth in coal consumption; while Canada should reduce coal consumption by a 0.7 percent average annual decrease.

Table 7: U.S. Energy Consumption Patterns, by fuel 2008-2035

	Average annual percentage change	**Total 2008 consumption**	**Total 2035 consumption**
Liquids (million bpd)	0.4	20.7	21.9
Natural gas (tcf)	0.5	21.7	26.5
Coal (quadrillion Btu)	0.3	22.5	24.3
Nuclear (Billion kWh)	0.3	787	874
Hydro/Alternatives (quadrillion Btu)	1.9	6.4	11.8
Total primary energy, all modes (quadrillion Btu)	0.5	99.8	114.2

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table 7 summarizes the EIA forecasts for consumption patterns by primary source input (fuel type). The rate of total primary energy consumption growth (0.5 percent average annual increase) is lower than the anticipated rate of GDP growth (2.5 percent) but higher than the rate of population expansion (0.9 percent) during the period from 2008 to 2035. This reflects an expectation of increases in the efficiency of energy use despite the overall increase in consumption.

Canadian energy consumption estimates by the EIA anticipate an increase in total primary energy consumption (all fuels combined) of 1.0 percent in average annual growth – a rate double that of the United States for the period from 2008 to 2035, during which the Canadian population is anticipated on average to increase by 1.0 percent per year and average Canadian GDP growth is estimated at 2.1 percent per year.

Table 8: Canadian Energy Consumption Patterns, by fuel 2008-2035

	Average annual percentage change	**Total 2008 consumption**	**Total 2035 consumption**
Liquids (million bpd)	0.2	2.3	2.4
Natural gas (tcf)	1.5	3.3	5.0
Coal (quadrillion Btu)	-0.7	1.4	1.1
Nuclear (Billion kWh)	2.2	93	162
Hydro/Alternatives (quadrillion Btu)	1.5	3.7	6.0
Total primary energy, all modes (quadrillion Btu)	1.0	14.0	18.8

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Regrettably, the EIA forecast of consumption for Mexico is combined with its estimate for Chile, obscuring the estimates of Mexican consumption to 2035. As emerging markets, it is not surprising that total primary energy consumption is expected to increase at a higher average annual percentage rate than for either the United States or Canada. Slowing population growth in Mexico (0.6 percent annually on average) and 3.7 percent average annual GDP growth for the period from 2008 to 2035 suggest that for the Mexican component of the figures in Table 9, the EIA expectations reflect an economy with rising GDP per capita that will consume more energy, and in all modes.

Table 9: Mexican (and Chilean) Energy Consumption Patterns, by fuel 2008-2035

	Average annual percentage change	**Total 2008 consumption**	**Total 2035 consumption**
Liquids (million bpd)	0.7	2.4	2.9
Natural gas (tcf)	3.4	2.5	5.5
Coal (quadrillion Btu)	2.6	0.6	1.1
Nuclear (Billion kWh)	2.4	10	18
Hydro/Alternatives (quadrillion Btu)	4.0	0.6	2.1
Total primary energy, all modes (quadrillion Btu)	2.1	8.5	14.7

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011. Note: EIA combines power generation figures for Mexico and Chile.

A.5 Observations about the Surprise-Free Scenario

The surprise-free scenario provides a baseline for the consideration of the near-term future that includes grounds for optimism about North America's energy markets: an assumption of economic growth, accompanied by increases in energy supply and consumption. Since the EIA estimate of the future considers climate policy only to the extent it has taken effect in energy markets, the frustrating dynamics of climate policy action limit the impact of policy constraints on supply or demand.

Yet significant vulnerabilities are inherent in the surprise-free model, and make it unlikely to be realized precisely as forecast by the EIA. In particular, new infrastructure capacity is crucial to connect new fuel and power supplies to consumers and new refinery and processing capacity will be needed as fuels supplies increase. Capacity constraints at both stages in the fuels supply chain will create artificial scarcity of supply and higher prices where they occur. Consumer preferences are also held constant, and yet may influence policy decisions in each country that would alter future consumption patterns. Prices are not factored into the EIA model, and as discussed previously, governments may intervene in the energy supply and demand markets with taxation, subsidies and other measures intended to alter prices to advance policy objectives. If the surprise-free scenario were to emerge as the EIA forecast, that in itself would be surprising.

Nonetheless, the surprise-free model does enable a discussion of how changes, and, in particular, shocks exogenous to the baseline model of the near-term energy future in North America might react. Following the discussion of shocks, two alternative scenarios will be explored.

Section 3: Scenarios

B.1 Shocks

Shocks are exogenous events that cannot be anticipated by the surprise-free model, but which will have an effect on its assumptions. By reference to the dynamics of energy supply, energy demand and of climate policy conjectures as to the altered trajectories of certain dependent and independent variables can be made and used to prompt further thinking on the alternative futures that may be possible in the near term.

B.2 Considering Effects of a Technology Shock

Technological innovation is actively sought in the energy sector by governments and firms, working together and independently. It cannot be predicted, but a new technology can alter assumptions about the trajectories of supply and demand in the short term.

In recent years, breakthroughs in directional drilling and hydrofracturing have expanded fuel resource reserves of natural gas and petroleum by enabling access to untapped sources. Contingent on access to capital for the expansion of extraction, processing and refining, as well as transportation and distribution, these resources flow through the fuel supply chain and lower prices. If resource reserves are perceived to be large enough that lower prices are likely to remain in effect, energy consumers have an incentive to make the capital investments in new machinery and equipment necessary to alter demand patterns for inelastic energy consumers.

This is precisely what happened in 2002. At the time, natural gas prices were relatively high and plans were drafted to establish LNG terminals for the import of natural gas to the United States from off-continent markets, and Canadian natural gas exports to the United States were climbing. By 2012, technology had brought more natural gas to market and prices fell. Both Canada and the United States considered LNG terminals for the *export* of natural gas, and some coal-fired generating facilities were retrofitted to substitute natural gas as fuel. In 2002, nuclear power was under consideration to meet rising electricity demand after a lengthy period during which the United States saw no new nuclear power plant construction. The change in the natural gas fuel supply equation enabled by technology forced nuclear power plans to reconsider the opportunity cost of investing in nuclear generation with low-cost natural gas availability increasing.

Although the timing of certain technological breakthroughs cannot be estimated with any certainty, it is possible to speculate on the potential impact of technology shocks that have yet to occur. For example, what would be the impact of a breakthrough in battery technology that would permit motor vehicles to run on electrical power with competitive performance to liquid-fuel powered vehicles on the road today?

The dynamics of energy demand reveal that the key to shifts in consumption patterns is the acquisition of new capital equipment: for a new battery technology to have an impact on energy consumption, the technology must become widespread within the driven fleet, a process that under normal conditions would take at least 10 years and could take as many as 25 years to replace older liquid fuel vehicles.

That delay would be valuable for the economy, as the shift from liquid-fuels consumption for transportation would place demands on power generation to increase supply. Reduced demand for liquid-fueled vehicles would lower prices for these fuels. This might lower the incentive for consumers to purchase motor vehicles with the new batteries and suppress the pace of transition to a situation to broader use for the new battery technology. Lower liquid fuel prices might lead to a reversal of the surprise-free scenario expected trend away from liquid fuel use in power generation.

Since adjustment through capital equipment replenishment requires ready access to capital, several projections can be made about the impact of the new battery technology: (1) industry would adjust before households; (2) fleet purchasers for commercial transportation would adjust before households; (3) wealthier households would adjust before poorer ones; (4) due to their relative per capita wealth, prevalence of the new technology would be attained more quickly in Canada and the United States than in Mexico; (5) liquid fuel- and electric-powered vehicles would coexist on roadways for a quarter century at least, with the effects on fossil fuel production and consumption experienced gradually and, during this period, fossil fuels and the entire infrastructure supporting the fuels supply chain would remain necessary; (6) this transition would delay the attainment of production economies of scale sufficient to lower the unit price of the new batteries (and therefore of the cars that employ them); and, (7) the prevalence of legacy technology abroad would assure a market for fossil fuel exports even when the North American market demand shifts decisively. These speculations are only a beginning. Further hypotheses could be generated and then tested or challenged.

For now, an initial conclusion is possible; a period of transition of 25 years should allow for supply and demand patterns to adjust with only minor upheaval in the near term following the invention of a new battery technology. It would be a shock different from the impact of slant drilling and fracking, since these altered supply for existing demand rather than altering demand expectations and challenging the dynamics of energy supply, which are relatively more elastic.

B.3 Considering Effects of an Instability Shock

Instability shocks can scramble assumptions about expected behavior in supply and demand markets. The 2007-2008 financial crisis included a housing market collapse, as the value of subprime mortgages fell and credit contracted. Unemployment rose sharply and remains high. Commodity prices rose, including energy prices for most modes. It was unclear how long these conditions would remain in effect.

At the time, there were questions about the effect that this shock would have on consumption behavior: it was expected that energy consumption would fall in a recessionary economy, but would consumers and businesses find the means to adjust by investing in energy efficiency – more fuel efficient cars, home improvements, adjustments to commutes, relocation to higher density cities?

The dynamics of energy demand discussed here would predict the opposite: with constrained access to capital, industrial, commercial and residential consumers reduced spending on other items and made other economies. The transportation segment continued to consume as it had been doing, but passed on higher fuel and power costs on to consumers.

What about a significant exogenous shock due to instability abroad, such as war with Iran over its nuclear program, or civil collapse in a major oil supplier such as Russia, Nigeria or Venezuela? The effects of these shocks are predictable based on the dynamics of energy supply, which exhibit greater elasticity than energy demand. Price increases would follow a disruption of oil markets abroad, and these would provide a strong incentive for increased production of petroleum elsewhere. The transportation and refining infrastructure constraints would limit the ability of some sources of supply to reach consumers, and the lead time for the construction of such infrastructure would be too long to meet short term surges in demand.

Oil supplies from Alberta, dependent upon pipeline transportation capacity, would have a limited opportunity for expansion of exports to world markets, while suppliers reliant upon more flexible and scalable infrastructure, such as ocean shipping, would have a greater potential to capitalize on the situation. These constraints would likely result in sustained high prices for consumers in the near term.

B.4 Shocks Versus Alternative Scenarios

The nature of shocks is that they alter conditions and trajectories of dependent and independent variables within the surprise-free scenario model. The next step in considering the alternative energy futures for North America is to reconsider the underlying assumptions of the surprise-free scenario and generate alternate scenarios.

Section 3: Scenarios

C.1 The Limits Scenario

The surprise-free scenario operates on the assumption that supply and demand will adjust to find a new equilibrium naturally. An alternate scenario can be developed assuming the imposition of hard limits on the adjustment of supply or demand, perhaps through events and perhaps though policy, that shift the trajectory of this natural adjustment by changing the relationship between independent and dependent variables.

A minor recent example was the U.S. law that mandated the phasing out of incandescent light bulbs in favor of more energy efficient alternatives. This limit forced consumers to make an adjustment that would, in the near term, lower their energy consumption and the cost of energy to households and businesses, but at the upfront cost of new and more expensive bulbs and in some cases new lighting fixtures.

Another type of hard limit might be a carbon emissions cap imposed on industrial consumers. Although an offset market can mitigate adjustment costs in the short term, industrial users should have the capital to make the adjustment through the purchase of new capital equipment. This limitation will increase operating costs in the short run also, though it might reduce the costs of waste and byproduct management to industrial users.

C.2 Fuels and Power Capacity under the Limits Scenario

As demand shifts, gradually, through the purchase and replenishment of capital equipment, prices for fuels and power will change. This is the mechanism by which suppliers will be signaled as to the need to alter capacity.

Energy efficient light bulbs will reduce demand for power very marginally, and this reduction will be spread across demand segments quickly since the capital required for adjustment is modest and can be absorbed by a larger proportion of consumer demand.

Since industrial users account for half of current demand in Canada and the United States, carbon caps imposed on industrial users will have a significant potential impact on demand. This would lead to surplus capacity in the production of some fuels and of power, which would be redirected to meet new energy demands or, as fuel or power prices fall in response to lower demand, fuels with higher extraction costs and power with a higher generation cost would be shut down, reducing the supply available at the new price.

C.3 Demand under the Limits Scenario

The nature of both examples of limits imposed by policy is that they are involuntary for consumers, who must adjust to the new limits. In both examples, capital investments are necessary at some scale in order to make the adjustment; this capital is no longer available to the consumer for other purposes, and represents an economic loss. To a certain extent, this drain on available capital resources in response to the limit will reduce the short-term demand elasticity further.

If existing fuel or power capacity is shut down in the face of reduced demand, this too is an economic loss to the economy. Reduced supply capacity will also reduce the supply elasticity of energy in the short term, even presuming an energy supply shuttered in the face of reduced demand can be brought back on line in a short amount of time if demand rises or conditions change. While each limit aims to achieve a public purpose and benefit, limits impose costs that are distributed through the economy, affecting price and the ability of energy markets to respond to exogenous shocks.

Section 3: Scenarios

D.1 The Choice Scenario

The surprise-free scenario makes no allowance for changes in demand preferences (as opposed to changes in demand or consumption patterns) such as a preference for low-carbon energy or renewable energy sources. Adjustment to the energy supply mix are expected to come on the basis of price and the sunk cost in capital equipment that conditions demand and changes only gradually.

Yet consumers in other markets exercise the option to choose based on such preferences. For example, they can pay a premium for “fair trade” coffee, or conflict-free diamonds. Other commodity markets exhibit this pattern: in order to differentiate a commodity from other, fungible products that may be substitutes.

Consider a scenario that gave greater opportunity for consumer preferences to shape demand patterns. For example, smart grid technology could enable power consumers to opt for a certain percentage of the power they purchase to come from renewable sources at a premium price per kilowatt hour. The distributor would deliver fungible electrical power to the consumer but would have a mandate to purchase power from renewable generators to meet consumer demand.

In another example, gasoline stations could offer fuels that were certified to be lower in carbon content (such as biofuel blends), as well as fuels that are sourced from countries whose governments do not sponsor terrorism. Each of these would be offered at a price premium. Assume that neither fuel choice would require the purchase of a new vehicle.

D.2 Fuels and Power Under the Choice Scenario

The premium price for renewable power would send a clear price signal to power supply chains as to how much renewable power generation capacity is needed and should be developed. Variation over time would play a role, and it is possible that the costs to install renewable generation capacity would require adjustments to the premium attached to the power it generates that would be in excess of what consumers are willing to pay. Yet policymakers could rely on this market mechanism to send clear signals via price to develop the renewable power supply at the pace that the community will support and avoid a wasteful investment of public funds that might raise power prices for all consumers.

A similar dynamic would occur in the fuel choice example. Refiners would receive a signal from consumers indicating the type of gasoline that is preferred and the price that consumers will pay for it. In the absence of fuel market mandates imposed by governments on distributors, the response from refiners would determine the extent of support for “eco-fuels” or “patriotic gas.”

D.3 Demand Drivers Under the Choice Scenario

Consumers empowered to make choices about their energy consumption mix would be free to factor in preferences based on individual situations and needs. University students in shared housing would be likely to opt to purchase the cheapest power available; their parents might expand their purchases of premium power. Senior citizens on fixed incomes might prefer low-cost fuels, while drivers with more disposable income could use their purchases to express their values.

This result appears chaotic when compared to the limits scenario, where governments send clear signals for energy supply and demand to adjust. However the operation of the market mechanism in the choice scenario lowers the economic loss to consumers due to forced adjustments and the idling of affected capacity. Choice is appealing because it enhances the supply and demand elasticities operating within the energy market.

However, some would criticize the choice scenario not on the grounds of efficiency but on the grounds that it might allow consumers to opt for consumption at the expense of environmental goals.

Section 4: Planning for Alternative Futures

Albertans have set clear goals for the development of energy supplies in a manner that is responsive to the needs and preferences of the people of the province and consumers. The problem identification at the outset of this study – the reason for the development and discussion of the dynamics of energy supply, demand and climate policy and the elaboration of alternative scenarios for North America's energy future – stated that according to the Alberta government's Provincial Energy Strategy (Launching Alberta's Energy Future, December 11, 2008) the Province of Alberta intends to:

- remain a global energy leader
- be recognized as a responsible world-class energy supplier
- be an energy technology champion
- develop as a sophisticated energy consumer
- earn a reputation a solid global environmental citizen

To do so, Alberta is committed to:

- continue to encourage responsible clean production of fossil fuels
- promote development of complementary alternative and renewable energy
- and foster the wise use and conservation of energy

Taking this list of objectives and aims as its starting point, this study has presented a tool for the consideration of the possible future conditions in which Alberta's energy leadership will be exercised, and its reputation will be judged by its customers.

Some of the leading indicators of the future that bear attention from Alberta policymakers that arise from this study include:

- Transportation infrastructure is the key bottleneck between fuel and power and customers. Lead times for planning, permitting and construction mean that the transportation constraint cannot be overcome quickly, and represents a significant source of inelasticity of supply.
- Technologies that would shift demand from fossil fuels to electricity will take a generation to become prevalent, and the adjustment period can be anticipated to a certain degree.
- There is no scenario in which petroleum will not play a part in the near term future for North American energy markets. However, price volatility can alter assumptions about future demand.
- Climate policy dynamics are complex, favoring global solutions that maximize environmental benefits that are much more difficult to negotiate and enforce.

Frustration at the lack of global progress, irrespective of public appreciation of its difficulty, will spur action at other levels. Because of the nested or hierarchical nature of the levels of potential climate policy action, the lower the level of action taken, the more disruptive the action is likely to be to the efficient operation of energy markets with the effect that energy will become more costly and the elasticity of supply and demand will be reduced.

- Policy interventions that impose limits on consumers or producers impose costs on the energy supply chain and the demand segments.
- Policy interventions in energy markets that empower consumer choice increase the elasticity of markets by giving clear price signals about consumer preferences that can guide the development of capacity.

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Appendix 1: Energy Production and Reserves/Capacity in North America

Chart 1A: Oil (conventional and unconventional separated) reserves and production, latest year; Canada, Mexico and the United States

Crude Oil Production (Thousand Barrels per Day)						
Year	**Field Production**					**Renewable Fuels and Oxygenates**
	Crude Oil			Natural Gas Plant Liquids	Total	
	48 States	Alaska	Total			
2008	4268	683	4950	1784	6734	NA
2009	4715	645	5361	1910	7270	746
2010	4913	599	5512	2001	7513	902

Crude Oil Production (Thousand Barrels per Day)						
Year	**Trade**					**Production (Field +Renewable +NetImports)**
	Imports			Exports	Net Imports	
	Crude Oil	Petroleum Products	Total			
2008	9783	3132	12915	1802	11114	17848
2009	9013	2678	11691	2024	9667	17683
2010	9163	2590	11753	2312	9440	17855

*Lease Condensate (Category including oils from tar sands/oil sands) has been collaborated with Crude oil from 1982. Hence Renewable Fuels & Natural Gas plant liquids are the sole "unconventional" petroleum.

Chart 2A: Natural Gas (conventional and unconventional, separated) reserves and production, latest year); Canada, Mexico and the United States

Natural Gas Production (Billion Cubic Feet)							
Year	**Field Production**						
	Origin		State				Total
	Conventional	Unconventional	Texas	Louisiana	Other States	Federal Gulf of Mexico	
2008	21365	4270	7801	1388	14118	2330	25636
2009	20652	5361	7654	1559	14357	2444	26013
2010	20542	6317	7547	2258	14793	2259	26858

Natural Gas Production (Billion Cubic Feet)				
Supplemental Gaseous Fuels	**Trade**			**Production (Field + Supplemental +Net Import)**
	Imports	Exports	Net Imports	
61	3984	963	3021	28718
65	3751	1072	2679	28757
67	3737	1136	2601	29526

*Neglected Decimals might leave +/- 1 error
*Conventional: Natural Gas Wells + Crude Oil Wells
*Unconventional: Coalbed Wells + Shale Gas Wells

Chart 3A: Coal, reserves and production, latest year; Canada, Mexico, United States

Coal Production (Million Short Tons)							
Year	**Field Production**			**Trade**			
	Location		Total	Imports	Exports	Net Imports	
	East of the Mississippi	West of the Mississippi					
2008	493.3	678.5	1171.8	34.2	81.5	-47.3	
2009	449.6	625.3	1074.9	22.6	59.1	-36.5	
2010	446.5	638.8	1085.3	19.4	81.7	-62.3	

Chart 4A: Electricity (by mode: coal, gas, nuclear, alternatives) capacity and actual generation; Canada, Mexico, United States

Electricity Generation (Billion Kilowatthours)							
Year	**Generation**						**Total**
	Fossil Fuels				Nuclear Electric Power	Renewable	
	Coal	Petroleum	Natural Gas	Fossil Total			
2008	1985.8	46.2	883	2915	806.2	380.9	4102.1
2009	1755.9	38.9	921	2715.8	798.9	417.7	3932.4
2010	1850.7	36.9	981.8	2869.4	807	425.2	4101.6

*Renewable Energy: Biomass (Wood +Waste), Geothermal, Solar, Wind
* Capacity: EIA provides inconsistent data. Further research needed.

Chart 5A: North American energy trade: U.S. imports and exports of oil, natural gas, coal, electricity from Canada, Mexico, and Rest of World.

North American Energy Trade							
Year	**Type**	**Productions**			**US Imports from**		
		United States	Canada	Mexico	Canada	Mexico	Others
2009	Petroleum (Thousand Barrels per Day)	5,361	2,579	2,646	2,479	1,210	8,002
2009	Natural Gas (Billion Cubic Feet)	20,580	5.634	1.722	3,271	28	452
2010	Natural Gas (Billion Cubic Feet)	21,577	5,390	1,722	3,276	30	431
2010	Coal (Million Short Tons)	1,085	75	12	2	0	18
2009 Electricity	Nu clear (Billion Kilowatthours)	799	86	10	-	-	-
	Alternatives (Billion Kilowatthours)	424	374	34	-	-	-
	Conventional Thermal (Billion Kilowatthours)	2,734	144	195	-	-	-
	Total Net Generation (Billion Kilowatthours)	3,953	604	239	51	-	1

Source: U.S. Energy Information Administration - International Energy Statistics

Chart 6A: North American energy reserves of oil, natural gas

Energy Reserves						
Year	**Crude Oil and Lease Condensate** (Billion Barrels)			**Natural Gas (Dry)** (Trillion Cubic Feet)		
	Cumulative Production	Proved Reserves	Estimated Ultimate Recovery	Cumulative Production	Proved Reserves	Estimated Ultimate Recovery
2008	197.8	20.6	218.3	1082.6	244.7	1327.3
2009	199.8	22.3	222.1	1103.2	272.5	1375.7

Source: U.S. Energy Information Administration - International Energy Statistics

Appendix 2: Lead times for addition of energy supply capacity

I. Amount of time it takes to build energy infrastructure

A. Pipelines

i. The duration of pipeline construction tends to differ on the project. Details describe different pipelines established.

ii. (Pipeline & Gas Journal - Keystone Pipeline Phase 1) Mobilization of equipment and services, including construction, for the project started in 2008. Site of first construction was in North Dakota at the U.S.-Canadian border in May 2008 with Canadian construction getting under way during June 2008. Completion on the pipeline section to Cushing is scheduled for the fourth quarter of 2010. (2 years) (http://www.pipelineandgasjournal.com/keystone-pipeline-project-moving-toward-completion?page=show)

iii. (Alaska Pipeline) Construction for the Trans-Alaska Pipeline System began March 27, 1975 and was completed May 31, 1977. (2 years) The cost to build the pipeline was $8 billion in 1977, largest privately funded construction project at that time. (http://www.alyeska-pipe.com/pipelinefacts.html)

B. Offshore Drilling

i. (OPEC) An offshore oil field in deep water can take much longer than 3-10 years to discover and test, due to the challenging technical requirements. Drilling in deep water is also difficult and can be very expensive, so the explorers need time to raise the necessary money as well as meet the new technical challenges. (http://www.opec.org/opec_web/en/press_room/179.htm)

C. Introduction of New Supply

II. Time it takes for electric power plants to convert from coal to natural gas

A. (APPA: Implications of Greater Reliance on Natural Gas) Currently, coal powers half the nation's electric generation. The changeover would cost roughly $1 million per megawatt, Elder claims. "Replacing 335,000 MW of coal-fired generation thus should cost in the range of $335 billion," the study said. Further, it would require an additional $348 billion of new pipeline capacity — if anything close to that scale is even possible. *Inside Climate News* (http://insideclimatenews.org/news/20100711/natural-gas-boom-not-worth-costs-and-risks-study-warns). APPA report: (www.publicpower.org/store/ProductDetail.cfm?ItemNumber=28507)

III. How long it takes to build nuclear power plant

A. Although it would depend on the size of the generator, recently it is taking up to 5-10 years to build a nuclear power plant.

B. (Council on Foreign Relations) Cost projections for building a single nuclear power plant range from $5 billion to $12 billion, with construction times estimated between 6 and 10 years. (http://www.cfr.org/united-states/nuclear-power-expansion-challenges/p16886)

C. (US Nuclear Regulatory Commission) The proposed time line for construction is from September 2010 through May 2016. Nine Mile Point Nuclear Station, Development of Evacuation Time Estimates, Future Year Construction Annex: (http://pbadupws.nrc.gov/ docs/ML0909/ML090970659.pdf)

D. (World Nuclear Association) Construction of the second stage of Qinshan Phase II was formally inaugurated in April 2006, though first concrete had been poured for unit 3 in March. Concrete for unit 4 was poured in January 2007. Local content of the two 650 MWe CNP-600 reactors will be more than 70 percent, and scheduled construction time is 60 months. (http://www.world-nuclear.org/info/inf63.html)

E. (Nuclear Energy Information Service) The nuclear industry claims that nuclear-generated electricity costs 11õ/kilowatt-hour (kwh); electricity from the newest nuclear plants costs 15-25õ/kwh. It takes from 7 to 12 years to build a nuclear power plant. Yet conservation and efficiency programs cost between 0.5-4.0õ/kwh, and can be implemented in between 6 months to 2 years.

F. (Nuclear Energy Information Service) Construction of each nuclear power plant costs between $3 and 5 billion. The U.S. would need over 400 additional nuclear reactors to replace its coal plants. Total construction alone would therefore cost between $1.2 and $2.0 trillion.

IV. What it takes to build LNG terminals

V. Transmission power lines (i.e. smart grid)—time, cost, other factors

* * *

Key Concerns and Relevant Citations

The NEIS makes public adequate information regarding the nuclear power plant, but the relevant webpage, *per se*, raises questions of currency, as the upload date is April 1997. (Link included, *supra* page 48, under "References.") Further concerns include:

1. Energy: Rise of Electricity Demand. (Nuclear Energy Institute) The U.S. Department of Energy projects that electricity demand will rise 21 percent by 2030. (http://www.nei.org/resourcesandstats/documentlibrary/newplants/brochures/nuclearpoweringamericasfuture/)

2. Nuclear Power Plant: Inefficient. (Nuclear Energy Information Service)

A. Since its beginning, nuclear power has cost the U.S. over $492 billion, nearly twice the cost of the Vietnam War and Apollo moon missions combined. In return for this investment, the U.S. has an energy source that, until the mid-1980s, gave us less energy than did the burning of firewood. In the U.S., nuclear power contributes only 20-22 percent of our electricity, and only 8-10 percent of our total energy consumption. In Illinois these percentages are much greater due to Commonwealth Edison's over-reliance on nuclear power.

B. Since 1950, nuclear power has received over $97 billion in direct and indirect subsidies from the federal government, such as deferred taxes, artificially low limits on liability in case of nuclear accidents, and fuel fabrication write-offs. No other industry has enjoyed such privilege.

C. According to a recent study conducted by the Citizens Utility Board, Commonwealth Edison's customers now pay the highest electric bills in the Midwest, due primarily to over-reliance on nuclear power plants.

D. Many costs for nuclear power have been deliberately underestimated by government and industry, such as costs for the permanent disposal of nuclear wastes, the "decommissioning" (shutting-down and cleaning-up) of retired nuclear power plants, and nuclear accident consequences. In January 1994, Commonwealth Edison acknowledged that it had nearly doubled its estimate for reactor decommissioning, from $2.3 billion to as much as $4.1 billion.

E. Ironically, the first year these pro-nuclear ads ran, over 40 percent of uranium fuel used in U.S. reactors was from foreign sources (http://www.neis.org/literature/Brochures/npfacts.htm).

3. Nuclear Power Plant: Massive Land Required.

A. According to (www.nucleartourist.com/areas/areas.htm), 500~1,000 acres of land is required to build a nuclear power plant.

4. Coal-Natural Gas Conversion: Excessive Amount of Cash Spent.

A. According to the Government Accountability Office's Director of Construction and Facilities Management, "[I]t costs about 4 times as much to burn natural gas at the Capitol Power Plant as it does for coal based on the amount of energy that you get out of the two energy sources.... Earlier this year, we estimated that switching from coal to natural gas costs about $139 per ton of carbon dioxide saved" (U.S. Senate Committee on Rules and Administration, *Increasing the Use of Renewable Sources of Energy, and Reducing the Carbon Footprint of the Capitol Complex*, June 18, 2008, pp. 5-6). (http://nepinstitute.org/get/CRS_Reports/CRS_Energy/Energy_Efficiency_and_Conservation/The_Capitol_Power_Plant.pdf)

5. Coal-Natural Gas Conversion: Natural Gas also releases harmful CO_2 (Union of Concerned Scientists USA). Natural gas produces 43 percent fewer carbon emissions than coal for each unit of energy delivered, and 30 percent fewer emissions than oil. (http://www.ucsusa.org/clean_energy/technology_and_impacts/energy_technologies/how-natural-gas-works.html)

Appendix 3: Selected Data and Projections from the EIA International Energy Outlook 2011 Reference Case

Note: The data tables in this appendix follow the order presented in the discussion of the surprise-free scenario, which is different from the order in which these data tables appear in the *EIA International Energy Outlook 2011*.

Table A14. World population by region, Reference case, 2006-2035
(Millions)

	History			Projections					Average annual percent change, 2008-2035
Region	2006	2007	2008	2015	2020	2025	2030	2035	
OECD									
OECD Americas	**455**	**459**	**464**	**495**	**518**	**540**	**562**	**582**	**0.9**
United States[a]	299	302	305	326	342	358	374	390	0.9
Canada	33	33	33	36	38	40	42	43	1.0
Mexico/Chile	123	124	125	133	138	142	146	149	0.6
OECD Europe	**538**	**541**	**544**	**560**	**567**	**573**	**577**	**580**	**0.2**
OECD Asia	**200**	**201**	**201**	**203**	**202**	**201**	**199**	**196**	**-0.1**
Japan	128	128	128	126	124	122	119	116	-0.4
South Korea	48	48	48	49	49	49	49	48	0.0
Australia/NewZealand	25	25	25	27	28	30	31	32	0.8
Total OECD	**1,193**	**1,201**	**1,209**	**1,257**	**1,287**	**1,314**	**1,338**	**1,358**	**0.4**
Non-OECD									
Non-OECD Europe and Eurasia	**341**	**340**	**340**	**338**	**336**	**333**	**329**	**324**	**-0.2**
Russia	143	142	141	138	135	132	129	125	-0.4
Other	198	198	199	200	200	201	200	198	0.0
Non-OECD Asia	**3,487**	**3,526**	**3,565**	**3,840**	**4,021**	**4,175**	**4,300**	**4,400**	**0.8**
China	1,314	1,321	1,328	1,385	1,419	1,441	1,451	1,450	0.3
India	1,148	1,165	1,181	1,294	1,367	1,431	1,485	1,528	1.0
Other	1,025	1,040	1,055	1,162	1,234	1,302	1,365	1,422	1.1
Middle East	**196**	**200**	**205**	**234**	**255**	**275**	**293**	**311**	**1.6**
Africa	**921**	**941**	**961**	**1,101**	**1,202**	**1,302**	**1,401**	**1,501**	**1.7**
Central and South America	**441**	**446**	**451**	**486**	**509**	**528**	**545**	**559**	**0.8**
Brazil	188	190	192	203	209	214	217	219	0.5
Other	253	256	259	283	299	315	328	340	1.0
Total Non-OECD	**5,385**	**5,454**	**5,522**	**5,999**	**6,321**	**6,613**	**6,869**	**7,095**	**0.9**
Total World	**6,579**	**6,655**	**6,731**	**7,257**	**7,609**	**7,927**	**8,207**	**8,453**	**0.9**

[a]Includes the 50 States and the District of Columbia.
Sources: **United States:** U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo. **Other Countries:** IHS Global Insight, *World Overview* (Lexington, MA: various issues).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A3. World gross domestic product (GDP) by region expressed in purchasing power parity, Reference case, 2006-2035
(Billion 2005 dollars)

	History			Projections					Average annual percent change,
Region	2006	2007	2008	2015	2020	2025	2030	2035	2008-2035
OECD									
OECD Americas	**15,755**	**16,090**	**16,125**	**18,759**	**21,457**	**24,759**	**28,305**	**32,246**	**2.6**
United States[a]	12,976	13,229	13,229	15,336	17,421	20,020	22,731	25,692	2.5
Canada	1,200	1,226	1,233	1,408	1,572	1,741	1,942	2,167	2.1
Mexico/Chile	1,579	1,634	1,664	2,015	2,463	2,998	3,632	4,387	3.7
OECD Europe	**14,469**	**14,924**	**15,007**	**16,378**	**18,241**	**20,150**	**22,126**	**24,222**	**1.8**
OECD Asia	**5,706**	**5,883**	**5,873**	**6,565**	**7,124**	**7,596**	**8,086**	**8,584**	**1.4**
Japan	3,952	4,043	3,995	4,235	4,405	4,483	4,558	4,624	0.5
South Korea	938	986	1,009	1,274	1,506	1,737	1,969	2,196	2.9
Australia/NewZealand	816	853	869	1,055	1,213	1,375	1,559	1,764	2.7
Total OECD	**35,929**	**36,897**	**37,005**	**41,701**	**46,822**	**52,506**	**58,517**	**65,052**	**2.1**
Non-OECD									
Non-OECD Europe and Eurasia	**3,171**	**3,431**	**3,612**	**4,191**	**4,847**	**5,557**	**6,418**	**7,349**	**2.7**
Russia	1,835	1,984	2,094	2,377	2,681	3,055	3,589	4,197	2.6
Other	1,336	1,447	1,518	1,814	2,166	2,502	2,829	3,152	2.7
Non-OECD Asia	**13,349**	**14,779**	**15,783**	**25,488**	**34,084**	**43,465**	**53,455**	**63,853**	**5.3**
China	6,130	7,000	7,672	13,358	18,206	23,550	28,953	34,366	5.7
India	2,759	3,025	3,180	5,207	7,147	9,121	11,255	13,433	5.5
Other	4,460	4,753	4,931	6,924	8,730	10,794	13,247	16,054	4.5
Middle East	**2,183**	**2,306**	**2,415**	**3,229**	**3,924**	**4,682**	**5,569**	**6,577**	**3.8**
Africa	**2,587**	**2,743**	**2,891**	**3,906**	**4,744**	**5,646**	**6,631**	**7,776**	**3.7**
Central and South America	**3,633**	**3,872**	**4,073**	**5,317**	**6,454**	**7,757**	**9,272**	**11,041**	**3.8**
Brazil	1,594	1,692	1,778	2,452	3,079	3,840	4,784	5,951	4.6
Other	2,039	2,181	2,295	2,865	3,375	3,916	4,488	5,091	3.0
Total Non-OECD	**24,924**	**27,131**	**28,774**	**42,131**	**54,052**	**67,107**	**81,345**	**96,596**	**4.6**
Total World	**60,853**	**64,028**	**65,779**	**83,832**	**100,874**	**119,612**	**139,862**	**161,648**	**3.4**

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding. GDP growth rates for non-OECD Europe and Eurasia (excluding Russia). China, India, Africa, and Central and South America (excluding Brazil) were adjusted, based on the analyst's judgment.
Sources: **History:** IHS Global Insight, *World Overview* (Lexington, MA: various issues). **Projections:** IHS Global Insight, *World Overview*, Third Quarter 2010 (Lexington, MA: November 2010); and U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo.

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table E1. World total liquids production by region and country, Reference case, 2007-2035
(Million barrels per day)

Region/country	History (estimates) 2007	2008	2009	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OPEC[a]	34.4	35.6	33.4	38.6	40.8	43.1	45.0	46.9	1.0
Middle East	23.1	24.2	22.5	27.0	28.9	31.2	33.3	35.2	1.4
Iran	4.0	4.2	4.1	4.0	3.8	3.7	3.8	3.9	-0.3
Iraq	2.1	2.4	2.4	2.9	3.6	4.5	5.5	6.3	3.7
Kuwait	2.6	2.7	2.5	3.0	3.1	3.3	3.7	4.0	1.4
Qatar	1.1	1.2	1.2	1.9	2.1	2.3	2.5	2.5	2.7
Saudi Arabia	10.2	10.7	9.6	11.6	12.8	13.9	14.6	15.4	1.4
United Arab Emirates	2.9	3.0	2.8	3.6	3.5	3.5	3.3	3.2	0.2
North Africa	4.0	4.1	3.9	3.5	3.4	3.4	3.3	3.2	-0.9
Algeria	2.2	2.2	2.1	2.6	2.7	2.6	2.5	2.3	0.3
Libya	1.8	1.9	1.8	0.9	0.7	0.7	0.8	0.8	-3.0
West Africa	4.1	4.2	4.1	5.3	5.5	5.5	5.4	5.4	1.0
Angola	1.8	2.0	1.9	2.2	2.3	2.2	2.1	2.0	0.0
Nigeria	2.4	2.2	2.2	3.0	3.2	3.3	3.3	3.4	1.7
South America	3.2	3.1	2.9	2.9	3.0	3.0	3.0	3.1	-0.1
Ecuador	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	-0.3
Venezuela	2.7	2.6	2.4	2.4	2.5	2.5	2.5	2.6	0.0
Non-OPEC	50.5	50.0	50.5	54.7	56.8	60.1	63.0	65.3	1.0
OECD	21.6	21.0	21.3	21.5	21.7	22.4	23.5	24.9	0.6
OECD Americas	15.4	15.0	15.6	16.9	17.7	18.5	19.7	21.1	1.3
United States	8.5	8.5	9.1	10.4	11.2	11.7	12.2	12.8	1.5
Canada	3.4	3.4	3.6	4.2	4.7	5.4	6.0	6.6	2.6
Mexico	3.5	3.2	3.0	2.3	1.8	1.4	1.5	1.7	-2.4
OECD Europe	5.4	5.1	4.8	3.8	3.3	3.2	3.1	3.0	-2.0
OECD Asia	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	-0.3
Japan	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.6
South Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Australia and New Zealand	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	-0.6
Non-OECD	28.9	29.0	29.2	33.2	35.1	37.6	39.5	40.4	1.2
Non-OECD Europe and Eurasia	12.8	12.7	12.9	14.6	15.5	16.6	17.4	18.0	1.3
Russia	9.9	9.8	9.8	10.8	11.4	12.2	12.8	13.3	1.1
Caspian Area	2.6	2.6	2.8	3.5	3.8	4.2	4.4	4.5	2.1
Other	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	-1.2
Non-OECD Asia	7.9	7.9	7.7	7.8	7.8	8.3	8.6	8.5	0.3
China	4.1	4.0	4.0	4.0	4.2	4.8	5.2	5.3	1.0
India	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.1	0.8
Other	2.9	2.9	2.8	2.8	2.6	2.4	2.2	2.0	-1.3
Middle East (Non-OPEC)	1.5	1.5	1.5	1.6	1.4	1.3	1.1	1.1	-1.3
Africa	2.7	2.7	2.6	3.0	3.2	3.4	3.5	3.5	1.0
Central and South America	4.1	4.3	4.5	6.2	7.2	8.1	8.9	9.4	3.0
Brazil	2.3	2.4	2.6	3.8	4.7	5.5	6.0	6.5	3.7
Other	1.8	1.9	1.9	2.5	2.5	2.7	2.9	2.9	1.7
Total world	84.9	85.7	83.9	93.3	97.6	103.2	108.0	112.2	1.0
OPEC share of world production	40%	42%	40%	41%	42%	42%	42%	42%	
Persian Gulf share of world production	27%	28%	27%	29%	30%	30%	31%	31%	

[a]OPEC=Organization of the Petroleum Exporting Countries (OPEC-13).
Note: Conventional liquids include crude oil and lease condensates, natural gas plant liquids, and refinery gains.
Sources: **History:** U.S. Energy Information Administration (EIA), Office of Energy Markets and End Use. **Projections:** EIA, Generate World Oil Balance Model (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table E2. World conventional liquids production by region and country, Reference case, 2007-2035
(Million barrels per day)

	History (estimates)			Projections					Average annual percent change, 2008-2035
Region/country	2007	2008	2009	2015	2020	2025	2030	2035	
OPEC[a]	**33.8**	**35.0**	**32.8**	**37.6**	**39.5**	**41.7**	**43.4**	**45.2**	**1.0**
Middle East	**23.1**	**24.2**	**22.5**	**26.8**	**28.7**	**31.0**	**33.0**	**35.0**	**1.4**
Iran	4.0	4.2	4.1	4.0	3.8	3.7	3.8	3.9	-0.3
Iraq	2.1	2.4	2.4	2.9	3.6	4.5	5.5	6.3	3.7
Kuwait	2.6	2.7	2.5	3.0	3.1	3.3	3.7	4.0	1.4
Qatar	1.1	1.2	1.2	1.7	1.9	2.1	2.2	2.2	2.3
Saudi Arabia	10.2	10.7	9.6	11.6	12.8	13.9	14.6	15.4	1.4
United Arab Emirates	2.9	3.0	2.8	3.6	3.5	3.5	3.3	3.2	0.2
North Africa	**4.0**	**4.1**	**3.9**	**3.5**	**3.4**	**3.4**	**3.3**	**3.2**	**-0.9**
Algeria	2.2	2.2	2.1	2.6	2.7	2.6	2.5	2.3	0.3
Libya	1.8	1.9	1.8	0.9	0.7	0.7	0.8	0.8	-3.0
West Africa	**4.1**	**4.2**	**4.1**	**5.2**	**5.5**	**5.5**	**5.4**	**5.4**	**0.9**
Angola	1.8	2.0	1.9	2.2	2.3	2.2	2.1	2.0	0.0
Nigeria	2.4	2.2	2.2	3.0	3.2	3.3	3.3	3.4	1.6
South America	**2.6**	**2.5**	**2.4**	**2.1**	**1.9**	**1.8**	**1.7**	**1.7**	**-1.5**
Ecuador	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	-0.3
Venezuela	2.1	2.0	1.9	1.6	1.5	1.4	1.3	1.2	-1.9
Non-OPEC	**47.8**	**46.8**	**46.9**	**49.6**	**50.3**	**51.9**	**53.1**	**53.9**	**0.5**
OECD	**19.6**	**18.6**	**18.6**	**17.7**	**17.1**	**16.7**	**16.5**	**16.8**	**-0.4**
OECD Americas	**13.6**	**12.8**	**13.2**	**13.4**	**13.3**	**13.0**	**13.0**	**13.3**	**0.1**
United States	8.0	7.8	8.3	9.3	9.8	9.8	9.7	9.9	0.9
Canada	2.1	1.8	1.9	1.8	1.8	1.8	1.8	1.8	0.0
Mexico	3.5	3.2	3.0	2.3	1.7	1.4	1.5	1.6	-2.5
OECD Europe	**5.2**	**5.0**	**4.6**	**3.6**	**3.1**	**2.9**	**2.8**	**2.8**	**-2.1**
Denmark	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	-1.5
Norway	2.6	2.5	2.3	1.9	1.6	1.5	1.4	1.3	-2.2
United Kingdom	1.7	1.6	1.5	0.9	0.7	0.6	0.6	0.6	-3.4
Other	0.7	0.6	0.6	0.5	0.5	0.6	0.6	0.6	-0.1
OECD Asia	**0.8**	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**-0.3**
Japan	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.6
South Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Australia and New Zealand	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	-0.7

[a]OPEC=Organization of the Petroleum Exporting Countries (OPEC-13).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table E2. World conventional liquids production by region and country, Reference case, 2007-2035 (continued)
(Million barrels per day)

	History (estimates)			Projections					Average annual percent change, 2008-2035
Region/country	2007	2008	2009	2015	2020	2025	2030	2035	
Non-OECD	**28.2**	**28.2**	**28.3**	**31.8**	**33.2**	**35.2**	**36.5**	**37.1**	**1.0**
Non-OECD Europe and Eurasia	**12.8**	**12.7**	**12.9**	**14.6**	**15.5**	**16.6**	**17.4**	**18.0**	**1.3**
Russia	**9.9**	**9.8**	**9.8**	**10.8**	**11.4**	**12.2**	**12.8**	**13.3**	**1.1**
Caspian Area	**2.6**	**2.6**	**2.8**	**3.5**	**3.8**	**4.2**	**4.4**	**4.5**	**2.1**
Azerbaijan	0.8	0.9	1.0	1.3	1.3	1.2	1.1	0.9	0.3
Kazakhstan	1.4	1.4	1.5	2.0	2.2	2.6	2.9	3.1	2.9
Turkmenistan	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	3.2
Uzbekistan	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	-5.0
Other	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**-1.3**
Non-OECD Asia	**7.7**	**7.7**	**7.6**	**7.6**	**7.5**	**7.6**	**7.6**	**7.3**	**-0.2**
China	3.9	4.0	3.9	4.0	4.1	4.3	4.5	4.3	0.3
India	0.9	0.9	0.9	1.0	0.9	1.0	1.0	1.0	0.5
Brunei	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	-1.1
Malaysia	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	-0.7
Thailand	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5
Vietnam	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.2	-1.3
Other	1.3	1.3	1.3	1.0	0.9	0.8	0.7	0.6	-2.7
Middle East (Non-OPEC)	**1.5**	**1.5**	**1.5**	**1.6**	**1.4**	**1.3**	**1.1**	**1.1**	**-1.3**
Oman	0.7	0.8	0.8	1.0	0.8	0.7	0.6	0.6	-1.1
Syria	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	-1.9
Yemen	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	-3.3
Other	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.6
Africa	**2.5**	**2.5**	**2.4**	**2.8**	**2.9**	**3.0**	**3.1**	**3.1**	**0.9**
Chad	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-3.0
Congo (Brazzaville)	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	-0.5
Egypt	0.8	0.7	0.7	0.6	0.7	0.7	0.8	0.8	0.2
Equatorial Guinea	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	-0.1
Gabon	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	-2.5
Sao Tome and Principe	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	--
Sudan	0.5	0.5	0.5	0.5	0.5	0.6	0.7	0.8	2.1
Other	0.3	0.3	0.3	0.7	0.8	0.8	0.8	0.7	3.4
Central and South America	**3.7**	**3.8**	**3.9**	**5.3**	**5.9**	**6.7**	**7.3**	**7.6**	**2.7**
Brazil	1.9	2.0	2.0	2.9	3.5	4.1	4.5	4.8	3.4
Argentina	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	-1.2
Colombia	0.5	0.6	0.7	1.1	1.0	0.9	0.9	0.8	1.3
Peru	0.1	0.1	0.1	0.3	0.3	0.4	0.4	0.4	4.5
Trinidad and Tobago	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.6
Other	0.2	0.2	0.2	0.2	0.3	0.5	0.8	0.8	6.0
Total world	**81.5**	**81.7**	**79.7**	**87.2**	**89.8**	**93.6**	**96.5**	**99.1**	**0.7**
OPEC share of world production	41%	43%	41%	43%	44%	45%	45%	46%	
Persian Gulf share of world production	28%	30%	28%	31%	32%	33%	34%	35%	

Note: Conventional liquids include crude oil and lease condensates, natural gas plant liquids, and refinery gains.
Sources: **History:** U.S. Energy Information Administration (EIA), Office of Energy Markets and End Use. **Projections:** EIA, Generate World Oil Balance Model (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table E3. World unconventional liquids production by region and country, Reference case, 2007-2035
(Million barrels per day)

Region/country	History (estimates) 2007	2008	2009	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OPEC[a]	**0.6**	**0.7**	**0.5**	**1.0**	**1.3**	**1.4**	**1.6**	**1.7**	**3.6**
Biofuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Extra-heavy oil (Venezuela)	0.6	0.7	0.5	0.8	1.1	1.2	1.3	1.4	3.0
Coal-to-liquids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Gas-to-liquids (primarily Qatar)	0.0	0.0	0.0	0.2	0.2	0.3	0.3	0.3	16.0
Non-OPEC	**2.8**	**3.2**	**3.6**	**5.1**	**6.5**	**8.2**	**9.9**	**11.4**	**4.8**
OECD	**2.0**	**2.4**	**2.7**	**3.7**	**4.6**	**5.8**	**7.0**	**8.1**	**4.6**
Biofuels	0.6	0.9	1.0	1.3	1.6	2.0	2.4	2.5	4.1
Oil sands/bitumen (Canada)	1.4	1.5	1.7	2.3	2.9	3.5	4.1	4.8	4.4
Extra-heavy oil (Mexico)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	8.5
Coal-to-liquids	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	26.3
Gas-to-liquids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Shale oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	--
Non-OECD	**0.7**	**0.9**	**0.9**	**1.4**	**1.9**	**2.4**	**3.0**	**3.3**	**5.2**
Biofuels	0.5	0.6	0.7	1.1	1.4	1.7	2.0	2.1	4.6
Extra-heavy oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Coal-to-liquids	0.2	0.2	0.2	0.2	0.4	0.7	0.9	1.1	7.5
Gas-to-liquids	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	1.3
Shale oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
World									
Biofuels	1.2	1.5	1.7	2.4	3.0	3.8	4.4	4.7	4.3
Oil sands/bitumen	1.4	1.5	1.7	2.3	2.9	3.5	4.1	4.8	4.4
Extra-heavy oil	0.6	0.7	0.5	0.8	1.1	1.2	1.4	1.5	3.1
Coal-to-liquids	0.2	0.2	0.2	0.3	0.5	0.8	1.3	1.7	9.0
Gas-to-liquids	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.3	7.4
Shale oil	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	12.1
World total	**3.4**	**3.9**	**4.1**	**6.1**	**7.8**	**9.7**	**11.5**	**13.1**	**4.6**
Selected country highlights									
Biofuels									
Brazil	0.3	0.5	0.5	0.9	1.1	1.4	1.5	1.7	4.8
China	0.2	0.0	0.0	0.0	0.1	0.1	0.2	0.3	7.4
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
United States	0.5	0.7	0.8	1.1	1.4	1.8	2.1	2.2	4.6
Coal-to-liquids									
Australia and New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
China	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.7	--
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
India	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	--
South Africa	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	2.0
United States	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.5	--
Gas-to-liquids									
Qatar	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	15.5
South Africa	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	1.0

[a]OPEC=Organization of the Petroleum Exporting Countries (OPEC-13).
Sources: **History:** U.S. Energy Information Administration (EIA), Office of Energy Markets and End Use. **Projections:** EIA, Generate World Oil Balance Model (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table G1. World total natural gas production by region, Reference case, 2008-2035
(Trillion cubic feet)

Region	History 2008	History 2009	Projections 2015	Projections 2020	Projections 2025	Projections 2030	Projections 2035	Average annual percent change, 2008-2035
OECD								
OECD Americas	**28.0**	**27.5**	**31.3**	**33.0**	**34.0**	**35.8**	**37.6**	**1.1**
United States[a]	20.2	20.1	22.4	23.4	24.0	25.1	26.4	1.0
Canada	6.0	5.6	7.0	7.7	8.3	8.7	9.0	1.5
Mexico	1.7	1.8	1.9	1.7	1.7	1.8	2.1	0.8
Chile	0.1	0.0	0.1	0.1	0.1	0.1	0.1	2.9
OECD Europe	**10.6**	**10.1**	**8.1**	**7.5**	**7.5**	**7.9**	**8.3**	**-0.9**
North Europe	10.3	9.7	7.7	7.0	7.0	7.3	7.6	-1.1
South Europe	0.3	0.3	0.4	0.4	0.5	0.5	0.6	2.2
Southwest Europe	0.0	0.0	0.0	0.0	0.0	0.1	0.1	19.4
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
OECD Asia	**1.9**	**2.0**	**2.8**	**3.3**	**4.0**	**5.0**	**5.9**	**4.3**
Japan	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0
South Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Australia/NewZealand	1.7	1.8	2.6	3.1	3.8	4.8	5.7	4.5
Total OECD	**40.6**	**39.6**	**42.3**	**43.7**	**45.5**	**48.7**	**51.8**	**0.9**
Non-OECD								
Non-OECD Europe and Eurasia	**30.4**	**26.3**	**30.5**	**32.6**	**35.4**	**38.3**	**40.4**	**1.1**
Russia	23.4	20.6	23.0	24.9	27.3	29.6	31.2	1.1
Central Asia	5.9	4.5	6.4	6.7	7.0	7.5	7.9	1.1
Non-OECD Europe	1.2	1.2	1.1	1.0	1.1	1.2	1.4	0.5
Non-OECD Asia	**12.7**	**13.3**	**15.6**	**17.4**	**19.7**	**22.2**	**24.5**	**2.5**
China	2.7	2.9	3.1	3.7	4.7	6.0	7.3	3.8
India	1.1	1.4	2.5	3.0	3.3	3.6	3.9	4.6
LNG exporters	5.1	5.0	5.5	6.1	6.8	7.6	8.2	1.8
Other	3.8	3.9	4.5	4.6	4.8	5.0	5.2	1.2
Middle East	**13.5**	**14.3**	**19.7**	**22.3**	**24.6**	**26.7**	**28.8**	**2.8**
Arabian producers	3.5	3.5	3.7	3.7	3.8	3.9	4.1	0.5
Iran	4.1	4.6	5.7	6.9	7.8	8.6	9.4	3.1
Iraq	0.1	0.0	0.1	0.2	0.4	0.7	0.8	9.8
Qatar	2.7	3.2	6.3	7.0	7.4	7.8	8.1	4.1
Saudi Arabia	2.8	2.8	3.3	3.7	4.2	4.6	5.2	2.3
Other	0.3	0.3	0.6	0.9	1.0	1.1	1.2	5.8
Africa	**7.5**	**7.1**	**9.7**	**11.1**	**12.2**	**13.3**	**14.1**	**2.4**
North Africa	5.8	5.8	7.4	8.5	9.3	10.0	10.4	2.2
West Africa	1.5	1.1	2.1	2.3	2.6	2.9	3.3	3.1
South Africa	0.1	0.1	0.1	0.1	0.2	0.2	0.2	5.1
Other	0.1	0.2	0.1	0.2	0.1	0.2	0.2	1.1
Central and South America	**5.1**	**4.9**	**5.8**	**6.6**	**7.5**	**8.5**	**9.5**	**2.3**
Brazil	0.4	0.4	1.0	1.4	1.8	2.3	2.7	6.9
Northern producers	2.4	2.5	2.7	2.9	3.1	3.4	3.7	1.5
Southern Cone	1.6	1.5	1.3	1.3	1.5	1.8	1.9	0.8
Andean	0.7	0.6	0.8	0.8	0.9	1.0	1.0	1.7
Central America and Caribbean	0.0	0.0	0.1	0.1	0.1	0.1	0.2	5.0
Total non-OECD	**69.3**	**66.0**	**81.3**	**90.0**	**99.4**	**109.1**	**117.4**	**2.0**
Total world	**109.9**	**105.6**	**123.6**	**133.8**	**145.0**	**157.8**	**169.2**	**1.6**
Discrepancy[b]	**-1.0**	**-1.2**	**0.4**	**0.3**	**0.6**	**1.0**	**0.5**	

[a]Includes the 50 States and the District of Columbia. Production includes supplemental production, less any forecast discrepancy.
[b]Balancing item. Differences between global production and consumption totals results from independent rounding and differences in conversion factors derived from heat contents of natural gas that is produced and consumed regionally.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, April 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and International Natural Gas Model (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table G2. World tight gas, shale gas and coalbed methane production by region, Reference case, 2008-2035
(Trillion cubic feet)

Region	History 2008	History 2009	Projections 2015	Projections 2020	Projections 2025	Projections 2030	Projections 2035	Average annual percent change, 2008-2035
OECD								
OECD Americas	**12.9**	**13.7**	**17.5**	**19.0**	**21.1**	**22.9**	**24.9**	**2.5**
United States[a]	10.9	11.7	14.8	15.6	17.1	18.4	19.8	2.3
Canada	2.1	2.0	2.7	3.4	3.9	4.3	4.6	3.0
Mexico	0.0	0.0	0.0	0.0	0.0	0.2	0.4	–
Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.1	–
OECD Europe	**0.0**	**0.0**	**0.1**	**0.3**	**0.9**	**1.7**	**2.3**	**19.1**
North Europe	0.0	0.0	0.1	0.3	0.9	1.6	2.1	18.7
South Europe	0.0	0.0	0.0	0.0	0.1	0.1	0.1	–
Southwest Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Turkey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
OECD Asia	**0.1**	**0.1**	**0.5**	**1.0**	**1.6**	**2.5**	**3.3**	**13.3**
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
South Korea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Australia/NewZealand	0.1	0.1	0.5	1.0	1.6	2.5	3.3	13.3
Total OECD	**13.1**	**13.8**	**18.1**	**20.3**	**23.7**	**27.1**	**30.5**	**3.2**
Non-OECD								
Non-OECD Europe and Eurasia	**0.0**	**0.0**	**0.2**	**0.7**	**1.3**	**2.1**	**3.0**	–
Russia	0.0	0.0	0.2	0.7	1.1	1.5	2.0	–
Central Asia	0.0	0.0	0.0	0.0	0.1	0.4	0.7	–
Non-OECD Europe	0.0	0.0	0.0	0.0	0.1	0.2	0.4	–
Non-OECD Asia	**0.0**	**0.0**	**0.6**	**1.5**	**2.8**	**4.3**	**5.8**	–
China	0.0	0.0	0.5	1.4	2.6	3.9	5.2	–
India	0.0	0.0	0.0	0.1	0.1	0.2	0.2	–
LNG exporters	0.0	0.0	0.0	0.0	0.0	0.0	0.1	–
Other	0.0	0.0	0.0	0.0	0.0	0.1	0.2	–
Middle East	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.3**	**0.7**	–
Arabian producers	0.0	0.0	0.0	0.0	0.0	0.1	0.2	–
Iran	0.0	0.0	0.0	0.0	0.0	0.1	0.3	–
Iraq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Qatar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.1	0.1	–
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Africa	**0.0**	**0.0**	**0.0**	**0.1**	**0.3**	**0.7**	**1.0**	–
North Africa	0.0	0.0	0.0	0.1	0.2	0.3	0.4	–
West Africa	0.0	0.0	0.0	0.0	0.0	0.2	0.4	–
South Africa	0.0	0.0	0.0	0.0	0.1	0.2	0.2	–
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Central and South America	**0.0**	**0.0**	**0.2**	**0.4**	**0.9**	**1.5**	**2.0**	–
Brazil	0.0	0.0	0.0	0.0	0.2	0.4	0.6	–
Northern producers	0.0	0.0	0.0	0.0	0.1	0.2	0.3	–
Southern Cone	0.0	0.0	0.2	0.4	0.6	0.9	1.1	–
Andean	0.0	0.0	0.0	0.0	0.0	0.0	0.1	–
Central America and Caribbean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–
Total non-OECD	**0.0**	**0.0**	**1.0**	**2.8**	**5.3**	**8.7**	**12.5**	–
Total world	**13.1**	**13.8**	**19.0**	**23.1**	**28.9**	**35.8**	**43.0**	**4.5**

[a]Includes the 50 States and the District of Columbia. Production includes supplemental production, less any forecast discrepancy.

Sources: **History:** *United States:* U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. *Canada:* National Energy Board, *Short-term Canadian Natural Gas Deliverability, 2010-2012*, Appendix C.1. Canadian Gas Deliverability by Area/Resource--Mid-Price Scenario (March 2010), p. 63, website www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/ntrlgs/ntrlgs-eng.html. *Australia:* Australian Bureau of Agricultural and Resource Economics (ABARE), *Energy in Australia 2010* (Canberra, Australia, April 2010), Table 22, "Australian Gas Production by State," p. 44. *Note:* The 2008 number in this table is ABARE's 2007-2008 number (Australia's fiscal year is from July 1, 2007, to June 30, 2008); and the 2009 number is ABARE's 2008-2009 number. **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, April 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo; and International Natural Gas Model (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table 8. World coal production by region, 2008-2035 (quadrillion Btu)

Region	2008	2010	2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD Americas	**25.7**	**24.6**	**23.4**	**24.4**	**26.6**	**27.4**	**29.0**	**0.4**
United States	23.8	22.6	21.5	22.4	24.5	25.3	26.5	0.4
Canada	1.6	1.7	1.7	1.8	1.9	2.0	2.1	1.1
Mexico/Chile	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.7
OECD Europe	**7.1**	**6.4**	**5.3**	**5.4**	**5.1**	**4.9**	**4.8**	**-1.4**
OECD Asia	**9.2**	**10.2**	**11.2**	**11.3**	**12.4**	**14.1**	**15.6**	**1.9**
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
South Korea	0.1	0.1	0.1	0.0	0.0	0.0	0.0	-0.3
Australia/New Zealand	9.1	10.1	11.1	11.3	12.3	14.1	15.6	1.9
Total OECD	**42.0**	**41.2**	**39.9**	**41.1**	**44.1**	**46.4**	**49.4**	**0.6**
Non-OECD Europe and Eurasia	**11.0**	**10.3**	**10.6**	**10.4**	**10.3**	**10.5**	**11.1**	**0.0**
Russia	6.4	6.4	6.7	6.7	6.7	7.0	7.6	0.6
Other	4.6	3.9	3.9	3.7	3.6	3.5	3.5	-1.0
Non-OECD Asia	**80.7**	**89.8**	**96.9**	**102.1**	**113.7**	**125.4**	**135.1**	**1.9**
China	62.2	70.5	76.8	81.4	91.5	100.9	107.6	2.0
India	9.4	9.1	9.3	9.8	10.9	12.3	13.8	1.4
Other	9.1	10.2	10.8	10.9	11.2	12.2	13.7	1.4
Middle East	**0.0**	**0.1**	**0.1**	**0.0**	**0.0**	**0.1**	**0.1**	**1.7**
Africa	**6.0**	**6.0**	**7.2**	**7.6**	**8.0**	**8.6**	**9.6**	**1.7**
Central and South America	**2.3**	**2.0**	**2.9**	**3.7**	**4.1**	**4.5**	**4.8**	**2.7**
Brazil	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-0.4
Other	2.2	2.0	2.9	3.6	4.1	4.4	4.8	2.7
Total Non-OECD	**100.1**	**108.2**	**117.6**	**123.9**	**136.2**	**149.1**	**160.8**	**1.7**
Total World	**142.0**	**149.4**	**157.5**	**164.9**	**180.3**	**195.5**	**210.1**	**1.4**

Note: With the exception of North America, non-seaborne coal trade is not represented in EIA's forecast scenarios. As a result, the projected levels of production assume that net non-seaborne coal trade will balance out across the IEO2011 regions. Currently, a significant amount of non-seaborne coal trade takes place in Eurasia, represented by exports of steam coal from Kazikhstan to Russia and exports of coking coal from Russia to Ukraine.

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table F1. World total installed generating capacity by region and country, 2008-2035
(Gigawatts)

Region/country	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD							
OECD Americas	**1,207**	**1,293**	**1,320**	**1,378**	**1,457**	**1,539**	**0.9**
United States[a]	1,009	1,075	1,085	1,119	1,170	1,221	0.7
Canada	128	136	143	153	167	180	1.3
Mexico/Chile	70	82	92	105	120	137	2.5
OECD Europe	**864**	**946**	**1,018**	**1,063**	**1,098**	**1,133**	**1.0**
OECD Asia	**425**	**444**	**460**	**476**	**492**	**510**	**0.7**
Japan	281	283	288	294	299	306	0.3
South Korea	80	89	95	103	111	119	1.5
Australia/New Zealand	65	72	77	79	82	85	1.0
Total OECD	**2,495**	**2,684**	**2,798**	**2,917**	**3,047**	**3,181**	**0.9**
Non-OECD							
Non-OECD Europe and Eurasia	**405**	**408**	**423**	**437**	**460**	**487**	**0.7**
Russia	224	227	235	242	258	277	0.8
Other	181	181	188	194	202	210	0.6
Non-OECD Asia	**1,207**	**1,633**	**1,920**	**2,184**	**2,446**	**2,695**	**3.0**
China	797	1,118	1,313	1,492	1,666	1,817	3.1
India	177	240	290	332	371	411	3.2
Other	233	275	317	360	408	466	2.6
Middle East	**165**	**182**	**202**	**221**	**240**	**264**	**1.8**
Africa	**123**	**149**	**169**	**191**	**214**	**238**	**2.5**
Central and South America	**228**	**256**	**284**	**320**	**363**	**408**	**2.2**
Brazil	104	122	144	172	205	242	3.2
Other	124	134	141	148	158	165	1.1
Total non-OECD	**2,128**	**2,628**	**2,998**	**3,352**	**3,722**	**4,091**	**2.5**
Total world	**4,623**	**5,312**	**5,796**	**6,269**	**6,769**	**7,272**	**1.7**

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: History: Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. Projections: EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, May 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table F2. World installed liquids-fired generating capacity by region and country, 2008-2035
(Gigawatts)

Region/country	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD							
OECD Americas	**137**	**120**	**113**	**112**	**111**	**106**	**-0.9**
United States[a]	116	101	94	94	94	90	-0.9
Canada	4	4	3	3	3	3	-1.0
Mexico/Chile	17	16	15	14	14	14	-0.8
OECD Europe	**48**	**44**	**42**	**40**	**38**	**36**	**-1.0**
OECD Asia	**58**	**54**	**51**	**49**	**46**	**44**	**-1.0**
Japan	52	49	46	44	42	40	-1.0
South Korea	4	4	4	4	4	3	-1.0
Australia/New Zealand	1	1	1	1	1	1	-1.0
Total OECD	**242**	**219**	**206**	**201**	**195**	**187**	**-1.0**
Non-OECD							
Non-OECD Europe and Eurasia	**27**	**25**	**24**	**23**	**22**	**21**	**-1.0**
Russia	5	5	5	4	4	4	-1.0
Other	22	20	19	18	18	17	-1.0
Non-OECD Asia	**46**	**43**	**41**	**39**	**37**	**35**	**-1.0**
China	12	12	11	10	10	10	-0.9
India	4	4	3	3	3	3	-1.0
Other	30	28	26	25	24	23	-1.0
Middle East	**35**	**33**	**31**	**30**	**28**	**27**	**-0.9**
Africa	**14**	**13**	**13**	**12**	**11**	**11**	**-1.0**
Central and South America	**26**	**25**	**23**	**22**	**21**	**20**	**-1.0**
Brazil	5	5	5	4	4	4	-1.0
Other	21	20	19	18	17	16	-1.0
Total non-OECD	**148**	**139**	**132**	**125**	**119**	**114**	**-1.0**
Total world	**391**	**357**	**338**	**326**	**315**	**301**	**-1.0**

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: History: Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. Projections: EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, May 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table F3. World installed natural-gas-fired generating capacity by region and country, 2008-2035
(Gigawatts)

Region/country	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD							
OECD Americas	**382**	**414**	**428**	**464**	**515**	**573**	**1.5**
United States[a]	338	368	373	395	436	482	1.3
Canada	16	15	14	18	20	24	1.5
Mexico/Chile	29	31	40	51	60	68	3.3
OECD Europe	**190**	**191**	**196**	**205**	**228**	**251**	**1.0**
OECD Asia	**118**	**115**	**119**	**128**	**133**	**135**	**0.5**
Japan	79	74	74	76	78	78	-0.1
South Korea	24	26	28	31	33	33	1.1
Australia/New Zealand	14	15	17	20	23	25	2.3
Total OECD	**690**	**720**	**744**	**797**	**876**	**959**	**1.2**
Non-OECD							
Non-OECD Europe and Eurasia	**141**	**132**	**129**	**132**	**143**	**150**	**0.2**
Russia	97	91	87	84	91	96	-0.1
Other	43	40	42	47	53	54	0.9
Non-OECD Asia	**153**	**208**	**242**	**284**	**312**	**327**	**2.9**
China	31	52	58	64	67	68	2.9
India	19	42	52	62	65	67	4.9
Other	103	114	132	158	180	192	2.4
Middle East	**113**	**129**	**144**	**159**	**178**	**200**	**2.1**
Africa	**42**	**51**	**66**	**81**	**94**	**99**	**3.3**
Central and South America	**51**	**54**	**61**	**66**	**73**	**89**	**2.1**
Brazil	9	12	19	23	28	43	6.0
Other	42	42	42	43	45	46	0.3
Total non-OECD	**499**	**575**	**642**	**722**	**800**	**866**	**2.1**
Total world	**1,189**	**1,295**	**1,386**	**1,519**	**1,676**	**1,825**	**1.6**

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: History: Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. Projections: EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, May 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table F4. World installed coal-fired generating capacity by region and country, 2008-2035
(Gigawatts)

Region/country	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD							
OECD Americas	**334**	**342**	**342**	**346**	**351**	**360**	**0.3**
United States[a]	313	322	323	326	329	334	0.2
Canada	16	12	12	12	12	13	-0.8
Mexico/Chile	6	8	8	8	10	14	3.3
OECD Europe	**200**	**189**	**182**	**176**	**171**	**169**	**-0.6**
OECD Asia	**106**	**101**	**98**	**97**	**99**	**103**	**-0.1**
Japan	48	45	44	42	41	40	-0.7
South Korea	27	26	26	28	31	37	1.2
Australia/New Zealand	31	30	28	27	27	26	-0.7
Total OECD	**641**	**632**	**622**	**618**	**620**	**633**	**0.0**
Non-OECD							
Non-OECD Europe and Eurasia	**104**	**98**	**95**	**92**	**95**	**102**	**-0.1**
Russia	50	47	46	44	46	52	0.1
Other	54	51	49	48	49	50	-0.3
Non-OECD Asia	**707**	**857**	**902**	**1,038**	**1,185**	**1,314**	**2.3**
China	557	695	733	848	962	1,043	2.4
India	99	111	116	131	149	171	2.0
Other	50	51	53	58	75	100	2.6
Middle East	**4**	**4**	**4**	**4**	**4**	**4**	**-0.1**
Africa	**40**	**47**	**47**	**49**	**54**	**65**	**1.8**
Central and South America	**7**	**8**	**8**	**8**	**9**	**11**	**1.6**
Brazil	2	3	4	4	4	4	2.8
Other	5	4	4	4	5	6	1.0
Total non-OECD	**862**	**1,014**	**1,056**	**1,191**	**1,347**	**1,496**	**2.1**
Total world	**1,503**	**1,646**	**1,677**	**1,810**	**1,968**	**2,129**	**1.3**

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: History: Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. Projections: EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, May 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table F5. World installed nuclear generating capacity by region and country, 2008-2035
(Gigawatts)

Region/country	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD							
OECD Americas	**115**	**122**	**129**	**130**	**133**	**134**	**0.6**
United States[a]	101	106	111	111	111	111	0.4
Canada	13	15	18	18	20	22	1.8
Mexico/Chile	1	1	1	1	2	2	2.0
OECD Europe	**132**	**134**	**137**	**145**	**149**	**151**	**0.5**
OECD Asia	**66**	**75**	**82**	**85**	**90**	**94**	**1.3**
Japan	48	52	55	56	59	61	0.9
South Korea	18	23	27	29	31	33	2.3
Australia/New Zealand	0	0	0	0	0	0	0.0
Total OECD	**313**	**331**	**349**	**360**	**373**	**379**	**0.7**
Non-OECD							
Non-OECD Europe and Eurasia	**42**	**49**	**63**	**74**	**77**	**82**	**2.5**
Russia	23	28	39	47	49	52	3.0
Other	19	20	24	27	28	31	1.9
Non-OECD Asia	**19**	**49**	**83**	**111**	**137**	**163**	**8.4**
China	9	30	55	75	95	115	9.9
India	4	9	16	21	25	28	7.4
Other	6	9	12	15	17	20	4.8
Middle East	**0**	**1**	**4**	**7**	**7**	**7**	**0.0**
Africa	**2**	**2**	**2**	**3**	**3**	**4**	**3.1**
Central and South America	**3**	**4**	**5**	**6**	**6**	**8**	**3.8**
Brazil	2	3	3	4	4	5	3.7
Other	1	2	2	2	2	3	4.0
Total non-OECD	**65**	**104**	**157**	**201**	**230**	**265**	**5.3**
Total world	**378**	**436**	**505**	**561**	**603**	**644**	**2.0**

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: History: Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. Projections: EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, May 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table F6. World installed hydroelectric and other renewable generating capacity by region and country, 2008-2035 (Gigawatts)

Region/country	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD							
OECD Americas	**238**	**295**	**307**	**326**	**348**	**365**	**1.6**
United States[a]	141	179	184	194	201	205	1.4
Canada	79	91	96	102	112	119	1.6
Mexico/Chile	18	26	28	30	35	40	3.1
OECD Europe	**294**	**387**	**460**	**497**	**512**	**525**	**2.2**
OECD Asia	**78**	**100**	**110**	**118**	**123**	**133**	**2.0**
Japan	53	63	69	76	80	88	1.9
South Korea	6	10	11	11	12	13	2.7
Australia/New Zealand	18	27	30	31	31	32	2.1
Total OECD	**610**	**783**	**878**	**941**	**983**	**1,023**	**1.9**
Non-OECD							
Non-OECD Europe and Eurasia	**92**	**104**	**112**	**116**	**123**	**132**	**1.4**
Russia	48	54	59	63	68	74	1.6
Other	43	49	53	53	55	58	1.1
Non-OECD Asia	**283**	**476**	**652**	**712**	**774**	**855**	**4.2**
China	187	330	456	494	532	581	4.3
India	51	74	102	115	129	142	3.9
Other	45	72	94	103	113	131	4.1
Middle East	**12**	**15**	**20**	**21**	**23**	**24**	**2.7**
Africa	**25**	**36**	**41**	**45**	**52**	**58**	**3.2**
Central and South America	**141**	**165**	**187**	**218**	**254**	**280**	**2.6**
Brazil	86	99	113	137	165	186	2.9
Other	55	66	74	81	88	94	2.0
Total non-OECD	**552**	**796**	**1,012**	**1,113**	**1,225**	**1,349**	**3.4**
Total world	**1,163**	**1,578**	**1,890**	**2,054**	**2,209**	**2,372**	**2.7**

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: History: Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), web site www.eia.gov/ies. Projections: EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC, May 2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, web site www.eia.gov/aeo; and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A1. World total primary energy consumption by region, Reference case, 2006-2035
(Quadrillion Btu)

Region	History 2006	History 2007	History 2008	Projections 2015	Projections 2020	Projections 2025	Projections 2030	Projections 2035	Average annual percent change, 2008-2035
OECD									
OECD Americas	**122.3**	**124.3**	**122.9**	**126.1**	**131.0**	**135.9**	**141.6**	**147.7**	**0.7**
United States[a]	99.8	101.7	100.1	102.0	104.9	108.0	111.0	114.2	0.5
Canada	14.0	14.3	14.3	14.6	15.7	16.4	17.6	18.8	1.0
Mexico/Chile	8.5	8.3	8.5	9.5	10.4	11.5	13.0	14.7	2.1
OECD Europe	**82.8**	**82.3**	**82.2**	**83.6**	**86.9**	**89.7**	**91.8**	**93.8**	**0.5**
OECD Asia	**39.2**	**39.4**	**39.2**	**40.7**	**42.7**	**44.2**	**45.4**	**46.7**	**0.7**
Japan	23.3	23.0	22.4	22.2	23.2	23.7	23.7	23.8	0.2
South Korea	9.4	9.8	10.0	11.1	11.6	12.4	13.1	13.9	1.2
Australia/NewZealand	6.5	6.6	6.8	7.4	7.8	8.1	8.5	8.9	1.0
Total OECD	**244.3**	**246.1**	**244.3**	**250.4**	**260.6**	**269.8**	**278.7**	**288.2**	**0.6**
Non-OECD									
Non-OECD Europe and Eurasia	**48.9**	**49.6**	**50.5**	**51.4**	**52.3**	**54.0**	**56.0**	**58.4**	**0.5**
Russia	29.1	29.7	30.6	31.1	31.3	32.3	33.7	35.5	0.6
Other	19.8	19.9	19.9	20.4	21.0	21.7	22.3	22.9	0.5
Non-OECD Asia	**121.0**	**128.6**	**137.9**	**188.1**	**215.0**	**246.4**	**274.3**	**298.8**	**2.9**
China	73.4	78.9	86.2	124.2	140.6	160.9	177.9	191.4	3.0
India	18.8	20.0	21.1	27.8	33.1	38.9	44.3	49.2	3.2
Other	28.8	29.7	30.7	36.2	41.3	46.7	52.1	58.2	2.4
Middle East	**24.0**	**24.0**	**25.6**	**31.0**	**33.9**	**37.3**	**41.3**	**45.3**	**2.1**
Africa	**17.2**	**17.8**	**18.8**	**21.5**	**23.6**	**25.9**	**28.5**	**31.4**	**1.9**
Central and South America	**25.9**	**26.5**	**27.7**	**31.0**	**34.2**	**38.0**	**42.6**	**47.8**	**2.0**
Brazil	11.5	12.1	12.7	15.5	17.3	19.9	23.2	26.9	2.8
Other	14.4	14.5	15.0	15.6	16.9	18.1	19.5	20.8	1.2
Total Non-OECD	**237.0**	**246.5**	**260.5**	**323.1**	**358.9**	**401.7**	**442.8**	**481.6**	**2.3**
Total World	**481.3**	**492.6**	**504.7**	**573.5**	**619.5**	**671.5**	**721.5**	**769.8**	**1.6**

[a]Includes the 50 States and the District of Columbia.
Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), website www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2010), website www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011) (Washington, DC: May 2011); AEO2011 National Energy Modeling System, run REF2011. D020911A, website www.eia.gov/aeo, and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A5. World liquids consumption by region, Reference case, 2006-2035
(Million barrels per day)

Region	History 2006	2007	2008	Projections 2015	2020	2025	2030	2035	Average annual percent change, 2008-2035
OECD									
OECD Americas	**25.3**	**25.4**	**24.2**	**25.2**	**25.5**	**25.8**	**26.4**	**27.2**	**0.4**
United States[a]	20.7	20.6	19.5	20.4	20.7	21.0	21.4	21.9	0.4
Canada	2.3	2.3	2.2	2.3	2.3	2.3	2.3	2.4	0.2
Mexico/Chile	2.4	2.5	2.4	2.5	2.6	2.6	2.7	2.9	0.7
OECD Europe	**15.7**	**15.6**	**15.6**	**14.4**	**14.6**	**14.8**	**14.8**	**14.9**	**-0.2**
OECD Asia	**8.6**	**8.5**	**8.3**	**7.8**	**8.2**	**8.3**	**8.3**	**8.4**	**0.1**
Japan	5.3	5.2	5.0	4.3	4.6	4.7	4.6	4.5	-0.4
South Korea	2.2	2.2	2.1	2.3	2.4	2.4	2.5	2.6	0.7
Australia/NewZealand	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	0.5
Total OECD	**49.6**	**49.6**	**48.0**	**47.5**	**48.3**	**48.9**	**49.5**	**50.4**	**0.2**
Non-OECD									
Non-OECD Europe and Eurasia	**4.9**	**4.6**	**5.0**	**5.3**	**5.2**	**5.2**	**5.4**	**5.6**	**0.4**
Russia	2.8	2.6	2.8	2.9	2.8	2.7	2.8	2.9	0.1
Other	2.1	2.1	2.1	2.3	2.4	2.5	2.6	2.6	0.8
Non-OECD Asia	**16.2**	**16.6**	**17.1**	**23.0**	**26.2**	**30.2**	**32.6**	**34.4**	**2.6**
China	7.3	7.5	7.8	12.1	13.6	15.6	16.4	16.9	2.9
India	2.7	2.8	3.0	3.8	4.6	5.7	6.8	7.5	3.5
Other	6.2	6.3	6.3	7.1	7.9	8.8	9.4	9.9	1.7
Middle East	**6.0**	**6.3**	**6.6**	**7.7**	**7.7**	**8.1**	**9.0**	**9.5**	**1.4**
Africa	**3.0**	**3.1**	**3.2**	**3.3**	**3.4**	**3.5**	**3.7**	**4.0**	**0.9**
Central and South America	**5.5**	**5.6**	**5.8**	**6.6**	**6.9**	**7.2**	**7.8**	**8.3**	**1.4**
Brazil	2.3	2.4	2.5	2.9	3.1	3.3	3.6	3.9	1.7
Other	3.2	3.3	3.3	3.7	3.9	4.0	4.2	4.4	1.1
Total Non-OECD	**35.7**	**36.3**	**37.7**	**45.9**	**49.3**	**54.3**	**58.4**	**61.8**	**1.9**
Total World	**85.3**	**85.9**	**85.7**	**93.3**	**97.6**	**103.2**	**108.0**	**112.2**	**1.0**

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), website www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo, and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A6. World natural gas consumption by region, Reference case, 2006-2035
(Trillion cubic feet)

	History			Projections					Average annual
Region	2006	2007	2008	2015	2020	2025	2030	2035	percent change, 2008-2035
OECD									
OECD Americas	**27.4**	**28.7**	**28.8**	**31.1**	**32.2**	**33.2**	**35.2**	**37.1**	**0.9**
United States[a]	21.7	23.1	23.2	25.1	25.3	25.1	25.9	26.5	0.5
Canada	3.3	3.4	3.4	3.5	3.7	4.2	4.6	5.0	1.5
Mexico/Chile	2.5	2.2	2.2	2.5	3.2	4.0	4.7	5.5	3.4
OECD Europe	**19.2**	**19.0**	**19.5**	**19.8**	**20.4**	**20.9**	**22.0**	**23.2**	**0.7**
OECD Asia	**5.8**	**6.2**	**6.2**	**6.5**	**6.8**	**7.4**	**7.8**	**8.0**	**1.0**
Japan	3.4	3.7	3.7	3.7	3.7	3.9	4.0	4.0	0.3
South Korea	1.1	1.2	1.3	1.5	1.6	1.8	1.9	1.9	1.5
Australia/NewZealand	1.2	1.2	1.3	1.3	1.5	1.8	2.0	2.2	2.1
Total OECD	**52.4**	**53.9**	**54.5**	**57.4**	**59.5**	**61.6**	**65.0**	**68.4**	**0.8**
Non-OECD									
Non-OECD Europe and Eurasia	**24.8**	**25.0**	**25.0**	**24.4**	**24.4**	**24.9**	**25.8**	**26.6**	**0.2**
Russia	16.6	16.7	16.8	16.2	16.1	16.2	16.8	17.4	0.1
Other	8.2	8.3	8.2	8.1	8.4	8.7	9.0	9.1	0.4
Non-OECD Asia	**9.5**	**10.5**	**11.3**	**17.1**	**20.8**	**25.2**	**28.9**	**31.9**	**3.9**
China	2.0	2.5	2.7	5.3	6.8	8.6	10.2	11.5	5.5
India	1.4	1.5	1.5	3.3	3.9	4.5	4.9	5.1	4.6
Other	6.2	6.6	7.1	8.5	10.0	12.0	13.9	15.3	2.9
Middle East	**10.3**	**10.7**	**11.7**	**14.7**	**17.0**	**19.1**	**21.3**	**24.0**	**2.7**
Africa	**2.9**	**3.1**	**3.6**	**4.7**	**5.9**	**7.1**	**8.3**	**9.1**	**3.5**
Central and South America	**4.3**	**4.2**	**4.6**	**5.0**	**5.7**	**6.5**	**7.5**	**8.8**	**2.5**
Brazil	0.7	0.7	0.8	1.1	1.5	1.8	2.3	3.2	5.1
Other	3.6	3.5	3.7	3.8	4.2	4.7	5.2	5.7	1.6
Total Non-OECD	**51.8**	**53.5**	**56.2**	**65.8**	**73.9**	**82.8**	**91.7**	**100.4**	**2.2**
Total World	**104.1**	**107.4**	**110.7**	**123.1**	**133.4**	**144.4**	**156.8**	**168.7**	**1.6**

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), website www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo, and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A7. World coal consumption by region, Reference case, 2006-2035
(Quadrillion Btu)

Region	History			Projections					Average annual percent change, 2008-2035
	2006	2007	2008	2015	2020	2025	2030	2035	
OECD									
OECD Americas	**24.4**	**24.7**	**24.3**	**21.3**	**22.5**	**24.3**	**25.2**	**26.5**	**0.3**
United States[a]	22.5	22.7	22.4	19.7	20.8	22.6	23.4	24.3	0.3
Canada	1.4	1.4	1.4	1.0	1.0	1.0	1.0	1.1	-0.7
Mexico/Chile	0.6	0.6	0.5	0.6	0.6	0.7	0.8	1.1	2.6
OECD Europe	**13.2**	**13.5**	**12.5**	**11.5**	**11.2**	**10.8**	**10.5**	**10.4**	**-0.7**
OECD Asia	**9.2**	**9.6**	**9.9**	**9.7**	**9.5**	**9.4**	**9.5**	**9.7**	**-0.1**
Japan	4.6	4.9	4.8	4.6	4.4	4.2	4.0	3.8	-0.8
South Korea	2.1	2.3	2.6	2.6	2.6	2.8	3.1	3.4	1.0
Australia/NewZealand	2.4	2.5	2.6	2.5	2.5	2.5	2.5	2.5	-0.1
Total OECD	**46.8**	**47.8**	**46.8**	**42.6**	**43.1**	**44.6**	**45.3**	**46.7**	**0.0**
Non-OECD									
Non-OECD Europe and Eurasia	**8.8**	**8.6**	**8.9**	**8.5**	**8.2**	**8.0**	**8.1**	**8.5**	**-0.2**
Russia	4.4	4.2	4.5	4.5	4.3	4.3	4.5	4.9	0.3
Other	4.4	4.5	4.5	4.0	3.9	3.8	3.7	3.7	-0.7
Non-OECD Asia	**66.3**	**71.4**	**77.5**	**99.6**	**106.2**	**119.5**	**132.8**	**144.1**	**2.3**
China	51.2	55.2	60.4	80.7	85.5	96.4	106.5	113.6	2.4
India	9.2	10.1	10.9	12.4	13.6	15.3	17.3	19.5	2.2
Other	5.8	6.1	6.3	6.5	7.0	7.7	9.1	11.0	2.1
Middle East	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.3**
Africa	**4.2**	**4.4**	**4.6**	**5.1**	**5.4**	**5.7**	**6.2**	**7.1**	**1.6**
Central and South America	**0.7**	**0.8**	**0.8**	**1.1**	**1.2**	**1.4**	**1.8**	**2.3**	**4.0**
Brazil	0.4	0.5	0.5	0.8	0.9	1.1	1.4	1.9	5.2
Other	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	1.1
Total Non-OECD	**80.4**	**85.6**	**92.2**	**114.7**	**121.4**	**135.1**	**149.4**	**162.5**	**2.1**
Total World	**127.2**	**133.3**	**139.0**	**157.3**	**164.6**	**179.7**	**194.7**	**209.1**	**1.5**

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), website www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo, and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A8. World nuclear energy consumption by region, Reference case, 2006-2035
(Billion kilowatthours)

	History			Projections					Average annual
Region	2006	2007	2008	2015	2020	2025	2030	2035	percent change, 2008-2035
OECD									
OECD Americas	**891**	**905**	**905**	**963**	**1,018**	**1,021**	**1,047**	**1,054**	**0.6**
United States[a]	787	806	806	839	877	877	877	874	0.3
Canada	93	89	89	113	131	134	152	162	2.2
Mexico/Chile	10	10	9	10	10	10	18	18	2.4
OECD Europe	**935**	**884**	**882**	**965**	**998**	**1,067**	**1,111**	**1,136**	**0.9**
OECD Asia	**430**	**386**	**389**	**502**	**560**	**591**	**641**	**683**	**2.1**
Japan	288	251	245	319	342	358	388	417	2.0
South Korea	141	136	143	183	218	233	253	266	2.3
Australia/NewZealand	0	0	0	0	0	0	0	0	0.0
Total OECD	**2,255**	**2,176**	**2,175**	**2,430**	**2,576**	**2,680**	**2,799**	**2,873**	**1.0**
Non-OECD									
Non-OECD Europe and Eurasia	**263**	**272**	**276**	**342**	**449**	**538**	**567**	**614**	**3.0**
Russia	144	152	154	197	275	342	366	388	3.5
Other	119	120	121	145	174	196	201	225	2.3
Non-OECD Asia	**111**	**119**	**119**	**360**	**631**	**855**	**1,063**	**1,281**	**9.2**
China	55	63	65	223	419	585	749	916	10.3
India	16	16	13	66	119	157	187	211	10.8
Other	40	41	41	71	92	113	127	153	5.0
Middle East	**0**	**0**	**0**	**6**	**24**	**51**	**52**	**54**	**0.0**
Africa	**10**	**12**	**11**	**15**	**15**	**21**	**21**	**31**	**3.8**
Central and South America	**21**	**19**	**21**	**25**	**35**	**44**	**44**	**63**	**4.2**
Brazil	14	12	14	18	22	31	31	41	4.1
Other	7	7	7	7	13	13	13	22	4.4
Total Non-OECD	**405**	**422**	**427**	**748**	**1,154**	**1,508**	**1,747**	**2,043**	**6.0**
Total World	**2,660**	**2,598**	**2,602**	**3,178**	**3,731**	**4,188**	**4,546**	**4,916**	**2.4**

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), website www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo, and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

Table A9. World consumption of hydroelectricity and other renewable energy by region, Reference case, 2006-2035
(Quadrillion Btu)

	History			Projections					Average annual percent change, 2008-2035
Region	2006	2007	2008	2015	2020	2025	2030	2035	
OECD									
OECD Americas	**10.7**	**10.7**	**11.8**	**14.2**	**15.8**	**17.3**	**18.8**	**19.9**	**2.0**
United States[a]	6.4	6.2	7.0	8.6	9.5	10.6	11.3	11.8	1.9
Canada	3.7	3.9	4.0	4.3	4.9	5.2	5.7	6.0	1.5
Mexico/Chile	0.6	0.6	0.7	1.3	1.4	1.5	1.8	2.1	4.0
OECD Europe	**7.6**	**8.1**	**8.4**	**12.0**	**14.2**	**15.8**	**16.5**	**17.1**	**2.7**
OECD Asia	**2.0**	**1.9**	**1.9**	**3.1**	**3.6**	**3.9**	**4.1**	**4.3**	**3.1**
Japan	1.2	1.1	1.1	1.6	2.0	2.2	2.3	2.4	2.9
South Korea	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	3.0
Australia/NewZealand	0.7	0.7	0.7	1.2	1.4	1.4	1.5	1.6	3.3
Total OECD	**20.4**	**20.7**	**22.1**	**29.3**	**33.6**	**37.1**	**39.4**	**41.4**	**2.4**
Non-OECD									
Non-OECD Europe and Eurasia	**3.3**	**3.1**	**3.0**	**3.6**	**3.9**	**4.2**	**4.6**	**5.0**	**1.9**
Russia	1.9	1.9	1.7	2.1	2.2	2.5	2.8	3.1	2.1
Other	1.4	1.2	1.3	1.5	1.7	1.7	1.8	1.9	1.6
Non-OECD Asia	**10.5**	**11.2**	**12.6**	**20.3**	**27.3**	**30.5**	**34.1**	**38.2**	**4.2**
China	4.7	5.3	6.4	11.2	15.8	17.8	19.7	21.8	4.6
India	2.4	2.5	2.4	3.5	4.7	5.3	6.0	6.7	3.9
Other	3.5	3.5	3.7	5.6	6.8	7.4	8.4	9.7	3.6
Middle East	**0.3**	**0.3**	**0.1**	**0.4**	**0.6**	**0.6**	**0.7**	**0.8**	**6.6**
Africa	**3.5**	**3.6**	**3.7**	**4.3**	**4.7**	**5.1**	**5.6**	**6.0**	**1.9**
Central and South America	**9.2**	**9.6**	**9.8**	**10.7**	**12.1**	**14.1**	**16.3**	**18.1**	**2.3**
Brazil	5.5	5.9	6.0	7.2	8.2	9.7	11.5	13.1	2.9
Other	3.7	3.7	3.8	3.5	3.9	4.4	4.7	5.0	1.0
Total Non-OECD	**26.8**	**27.8**	**29.2**	**39.3**	**48.6**	**54.6**	**61.2**	**68.1**	**3.2**
Total World	**47.1**	**48.5**	**51.3**	**68.5**	**82.2**	**91.7**	**100.6**	**109.5**	**2.9**

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding. U.S. totals include net electricity imports, methanol, and liquid hydrogen.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of March 2011), website www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2010), website www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2011*, DOE/EIA-0383(2011), AEO2011 National Energy Modeling System, run REF2011.D020911A, website www.eia.gov/aeo, and World Energy Projection System Plus (2011).

Source: *International Energy Outlook2011*DOE/EIA-0484 (Washington: U.S. Energy Information Administration) September 2011

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