ISEEE Energy Outlook

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PREFACE

The energy sector has been a dominant factor in Alberta's development and growth over the last half-century. The large capital investments and operating expenditures associated with finding and producing oil and gas have directly provided a major stimulus to the economy. But the indirect and induced impacts have been equally important. The development of many other industries supplying inputs to the energy sector, the generation of substantial export and government revenues, and the stimulus for large inflows of people have resulted in large 'multiplier' effects. In combination, these have also played a major role in shaping Alberta's 'character' which is generally distinguished by its highly educated, adjustable and entrepreneurial labour force, low unemployment and high labour force participation rates, strong work ethic and sense of self reliance, and its optimistic outlook.

In recent years the energy sector has become even more dominant and has increasingly made Alberta a key driver of the national economy. In a world with a rapidly growing demand for energy, having one of the largest concentrations of energy resources in the world might seem to translate into an assured, prosperous future. There is clearly huge potential associated with unconventional oil and gas, coal, remaining conventional resources and with alternative and renewable energy. However, translating this potential into reality will be daunting. Increasing constraints related to resource access, environmental impacts, infrastructure requirements, and availability of highly qualified people need to be addressed. Other challenges include the massive long-term investments in developing and implementing new technologies and making the right changes in the policy and regulatory framework. Indeed, the fact that relatively few nations have managed to convert resource wealth into high standards of societal welfare is a useful reminder of the magnitude of the challenges.

Alberta is in many respects at a crossroads. On the one hand complacency will almost certainly mean a dimming of the province's long-term prosperity. Declines in the conventional oil and gas sector will significantly dampen growth and prosperity. There are no other sectors of the province's economic base that could realistically expand sufficiently to offset significant declines in the dominant energy sector. On the other hand, visionary, strategic investments today can unlock non-conventional and other energy resources critical to securing a strong and prosperous long-term, sustainable future for the province.

It is in this context that ISEEE has undertaken a series of papers focused on Alberta's energy futures. The intent is to take a longer term look at the challenges, opportunities and choices and what they mean for Alberta's future.

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	Business World	Political World	Environmental World
Environment (Action)	Medium	Low	High
Demography (Population)	Medium	High	Low
Economics (Economic Growth)	High	Low	Medium
Anti-Culture (Globalization)	High	Low	Medium
Geopolitics (Coop/Conflict)	Medium	Conflict	Cooperation
Technology/Knowledge	High	Low	High

Business World is a Liberal World. Political World is a very dark, Orwellian world, where life is viewed as a zero-sum game. Environmental World envisages a pragmatic environmentalism beginning to permeate the planet by the 2020s.

Global Energy Scenarios

CERI's three global scenarios affect the major uncertainties for the world energy market in highly divergent ways. The world energy market through 2030 is characterized by five major areas of uncertainty that impact energy demand and fuel mix:

	Business World	Political World	Environmental World
Economics (Growth)	High	Low	Medium
Resource Availability	Medium	Low	High
Energy Policy (Action)	Low	High	High
Market Structure (Freedom)	High	Low	Low
Technology/Knowledge	High	Low	High

The major assumptions for our three global energy scenarios relate to the level of economic growth, rate of improvement in energy intensity (energy consumption per unit of output), and level of energy consumption. They are as follows (expressed in annual average percentage change):

	Historical	Scenarios (2004 - 2030)		
	1971 to 2004	Business World	Political World	Environmental World
Economic Growth	3.4	3.5	2.5	3.0
Energy Intensity	-1.3	-1.4	-1.6	-1.8
Energy Consumption	2.1	2.1	0.9	1.2

Our assumptions on oil, gas and coal prices, in 2004 US dollars, are as follows:

	Historical	Scenarios (2004 - 2030)		
	2004	Business World	Political World	Environmental World
WTI at Cushing ($/bbl)	41.49	50.00	60.00	40.00
Gas at Henry Hub ($/MMbtu)	6.18	6.75	7.25	7.75
US coal imports ($/tonne)	40.10	55.00	75.00	40.00

Primary Energy Market

- In the Business World, energy consumption increases almost 70 percent, from 11,230 MTOE in 2004 to 18,888 MTOE in 2030. Consumption increases about half as much in Environmental World (34 percent) and by 24 percent in Political World.
- Gas and "other alternatives" (which include biomass and waste, wind, geothermal, solar, tide/wave) tend to gain market share across the scenarios, while coal and oil tend to lose market share. The major exceptions are oil in Business World and coal and gas in Political World, whose shares remain flat over the projection period.

The Oil Market: Business World Scenario

- World oil demand rises by 55.8 MMbpd, from 81.6 MMbpd in 2004 to 137.4 MMbpd in 2030; an average 2.1 percent per year.
- Alberta oil revenues, production and market share are second highest.
- Alberta's oil production increases by 4.1 MMbpd (4.3 percent per year) to 6.4 MMbpd in 2030.
- Alberta contributes more than three-quarters of the increase to continental oil production. Despite Alberta's oil production coming to cover 18 percent of North America oil demand coverage, double its 2004 share, North America's oil import dependency rate remains fairly flat (43 to 45 percent) through the projection period.
- Alberta's share of world oil supply increases from 3 to 5 percent.

The Oil Market: Political World Scenario

- World oil demand increases by 13.4 MMbpd between 2004 and 2030; a sluggish average 0.7 percent per year.
- Alberta oil revenues, production and market share are highest.
- Alberta's oil production increases from 2.3 MMbpd to 7.5 MMbpd (4.9 percent per year).
- Alberta oil production comes to cover 31 percent of North American demand in 2030, compared to 9 percent in 2004, and contributes to a 27 percentage point drop (to 16 percent) in North America's oil import dependency rate. This 5.2 MMbpd increase in Alberta oil production represents about 80 percent of the total increase in North American production.
- Alberta's share of world oil supply increases from 3 to 8 percent under this scenario.

The Oil Market: Environmental World Scenario

- World oil demand grows 22.0 MMbpd through 2030, or 1.0 percent per year.
- Alberta oil revenues, production and market share are lowest.
- Alberta's oil production increases from 2.3 MMbpd to 4.8 MMbpd over the projection period (3.4 percent per year).
- The 2.5 MMbpd increase in Alberta oil production fails to compensate for the 5.3 MMbpd decline elsewhere in North America. Alberta oil production comes to cover 17 percent of

North American demand in 2030, while North America's oil import dependency rate rises by 16 percentage points to 59 percent.
- Alberta's share of world oil supply increases from 3 to 5 percent.

The Oil Market: Alberta Oil Production, by Type

- Crude bitumen production increases to between 4.5 to 7.0 MMbpd (5.6 to 7.5 percent per year) in 2030, compared to 1.1 MMbpd in 2004.
- Conventional oil production declines from 0.60 MMbpd to between 0.14 and 0.24 MMbpd (3.5 to 5.5 percent per year) over the period, while NGLs production declines from 0.62 MMbpd to between 0.16 and 0.28 MMbpd (3.0 to 5.0 percent per year).
- Crude bitumen's share of Alberta oil production doubles in all three scenarios to 93 to 94 percent in 2030, compared to 47 percent in 2004.

The Gas Market: Business World Scenario

- World gas demand rises strongly by 77.5 Tcf, from 91.0 in 2004 to 168.5 Tcf in 2030; an average 2.4 percent per year.
- Alberta's gas revenues, production and market share are fairly weak, despite world economic and gas demand growth being the highest in this scenario.
- Alberta's gas production declines by 0.6 Tcf (0.5 percent per year) to 4.4 Tcf in 2030.
- Alberta contributes about a quarter of the decline in North America's gas production. Alberta gas production comes to cover only 12 percent of North American gas demand in 2030, compared to 20 percent in 2004.
- Alberta's share of world gas supply halves to 3 percent in 2030.

The Gas Market: Political World Scenario

- World gas demand grows slowly by 24.1 Tcf, an average 0.9 Tcf per year.
- Alberta gas revenues, production and market share are strongest.
- Alberta's gas production increases slightly, from 5.0 Tcf in 2004 to 5.3 Tcf in 2030 (0.3 percent per year).
- The 0.3 Tcf increase in Alberta gas production represents about 30 percent of the total increase in North America production. Alberta gas production continues to cover 20 percent of North American demand in 2030.
- Alberta's share of world gas supply slips one percentage point to 5 percent.

The Gas Market: Environmental World Scenario

- World gas demand increases substantially by 56.3 Tcf between 2004 and 2030, or an average 2.2 Tcf increment per year.
- Alberta's gas revenues, production and market share are extremely weak.
- Alberta's gas production declines from 5.0 Tcf in 2004 to 3.0 Tcf in 2030 (2.0 percent per year).
- This 2.0 Tcf decline in Alberta gas production contributes to a 9.0 Tcf decline in North America as a whole. The share of Alberta's gas production in North America gas demand coverage slips more than half to 9 percent over the projection period.
- Alberta's share of world gas supply declines to 2 percent.

The Gas Market: Alberta Gas Production, by Type

- Coalbed methane production increases to between 1.64 and 3.01 Tcf per year (18.2 to 21.0 percent per year) in 2030, compared to 0.02 Tcf in 2004.

- Conventional gas production declines from 5.00 Tcf to between 1.32 and 2.27 Tcf (3.0 to 5.0 percent per year) over the period.
- Coalbed methane's share of Alberta's gas production increases from a negligible amount in 2004 to between 55 and 60 percent.

The Coal Market: Business World Scenario

- World coal demand rises to 9,134 Mt in 2030; an average 2.0 percent per year.
- Alberta coal production is the highest, while revenues and market share are second highest.
- Alberta's coal production increases by 13 Mt (1.5 percent per year) to 41 Mt in 2030.
- Alberta contributes about 3 percent of the increase in continental coal production. In 2030, Alberta's coal production covers 26 percent of North America coal demand.
- Alberta's share of world oil supply declines 0.1 percentage point to 0.4 percent in 2030.

The Coal Market: Political World Scenario

- World coal demand increases to 7,262 Mt in 2030; an average 1.0 percent per year.
- Alberta coal revenues and market share are highest and coal production second highest.
- Alberta's coal production increases from 28 to 38 Mt (1.2 percent per year).
- The 10 Mt increase in Alberta coal production represents about 4 percent of the total increase in North American production. Alberta coal production covers 2.6 percent of North American demand in 2030, compared to 2.3 percent in 2004.
- Alberta's share of world coal supply remains steady at 0.5 percent over the period.

The Coal Market: Environmental World Scenario

- World coal demand increases slowly to 5,767 Mt in 2030; an average 0.1 percent per year.
- Alberta coal revenues and production are lowest, while market share mimics that of Business World.
- Alberta's coal production declines from 28 to 24 Mt (0.5 percent per year).
- The 4 Mt decrease in Alberta coal represents about 1.5 percent of the total North America production decline. Alberta coal production covers 2.6 percent of North American demand in 2030.
- Alberta's share of world oil supply declines from 0.5 percent to 0.4 percent.

Conclusions

- The Alberta energy industry should perform quite well no matter what the future holds for the world energy industry as a whole, primarily due to oil sands development.
- Under the three global scenarios, total hydrocarbon revenues should continue to rise, despite gas and coal revenues declining under Environmental World, and gas revenues declining slightly under Business World.
- What is good for the global economy and oil industry is not necessarily good for Alberta's oil industry (and vice versa).
- Alberta energy performs the best in Political World, second best in Business World, and the worst in Environmental World.
- Under Political World, Alberta revenues, production and market share are the highest for all three hydrocarbons, except coal production, which comes in second place.
- Alberta energy revenues, production and market share are second highest for all three hydrocarbons in Business World, except coal production, where it is the highest.

- Under Environmental World, Alberta's energy revenues, production and market share are extremely weak, the exception being market share for coal which mimics those in Business World.

CHAPTER 1
INTRODUCTION

1.1 Background

The Institute for Sustainable Energy, Environment and Economy (ISEEE) is implementing a series of projects under the initiative called *Alberta's Energy Futures*.

1.2 Purpose

The purpose of this project is to delve into Alberta's potential role in the future world and North American energy markets and provide recommendations for further research and modeling activities.

1.3 Approach

Our approach for looking into Alberta's energy future is to develop three plausible scenarios based on global drivers and to analyze how these differing worlds would impact the world and North American energy markets through 2030.

1.4 Data

Data for the world and North America's energy markets come from the International Energy Agency's historical database. Alberta energy data comes from various sources, the most important of which is Statistics Canada.

1.5 Report Layout

In Chapter 2, we discuss the three global scenarios, including their major drivers, and how we deal with global business cycles. In Chapter 3, we discuss the major uncertainties for the global energy market, and provide an overview of the energy markets under the three scenarios. In Chapter 4, we discuss historical developments for economic growth, energy intensities, and primary energy demand for the world, North America and Alberta. In addition, we present the outlook for these factors for the three scenarios to 2030. In Chapter 5, we discuss historical developments and the future outlook for the three scenarios for the world oil market, including oil consumption, OPEC and non-OPEC supply, intra-regional trade, and oil prices. In Chapters 6 and 7, we cover similar topics for the gas and coal markets, respectively. In Chapter 8, we present our concluding remarks about Alberta's future role in the North American and global energy market. In Chapter 9, we provide recommendations for further research and modeling to provide a deeper understanding of Alberta's energy future.

CHAPTER 2
THE GLOBAL SCENARIOS

> "Old men and comets have been reverenced for the same reason; their long beards, and pretences to foretell the future."
>
> — Jonathan Swift

Attempting to predict long-term developments in the world energy market is a mug's game. The market has undergone massive changes in terms of energy demand and fuel mix in the past 200 years, many of which were unexpected. In 1800, non-commercial energy sources (e.g., wood and biomass) dominated, since most people continued to live in agrarian or hunter-gathering societies. By 1900, coal had come to dominate the energy mix due to the spread of the Industrial Revolution and rail travel. Since that time, the victory of the internal combustion engine over other technologies and the rise of private transportation have propelled oil to the number one spot. However, oil's share in the energy mix has declined since OPEC became a price setter in 1973. Natural gas, nuclear and hydropower have been the primary beneficiaries of oil's relative decline.

Growth in world energy demand has reverted to the 1860 to 1945 average since 1973, about 2 percent per year, compared to a 5 percent annual average between 1945 and 1973. Numerous factors have contributed to this shift including higher oil and other energy prices, an increased concern about energy security due to the Arab oil embargo, rising concerns over the environment, a movement towards service and knowledge industries in the more developed countries, and slower world economic growth. Since uncertainty is the rule in the longer term, and another paradigm shift could be right around the corner, CERI has adopted a scenario approach in developing our energy outlook to 2030.

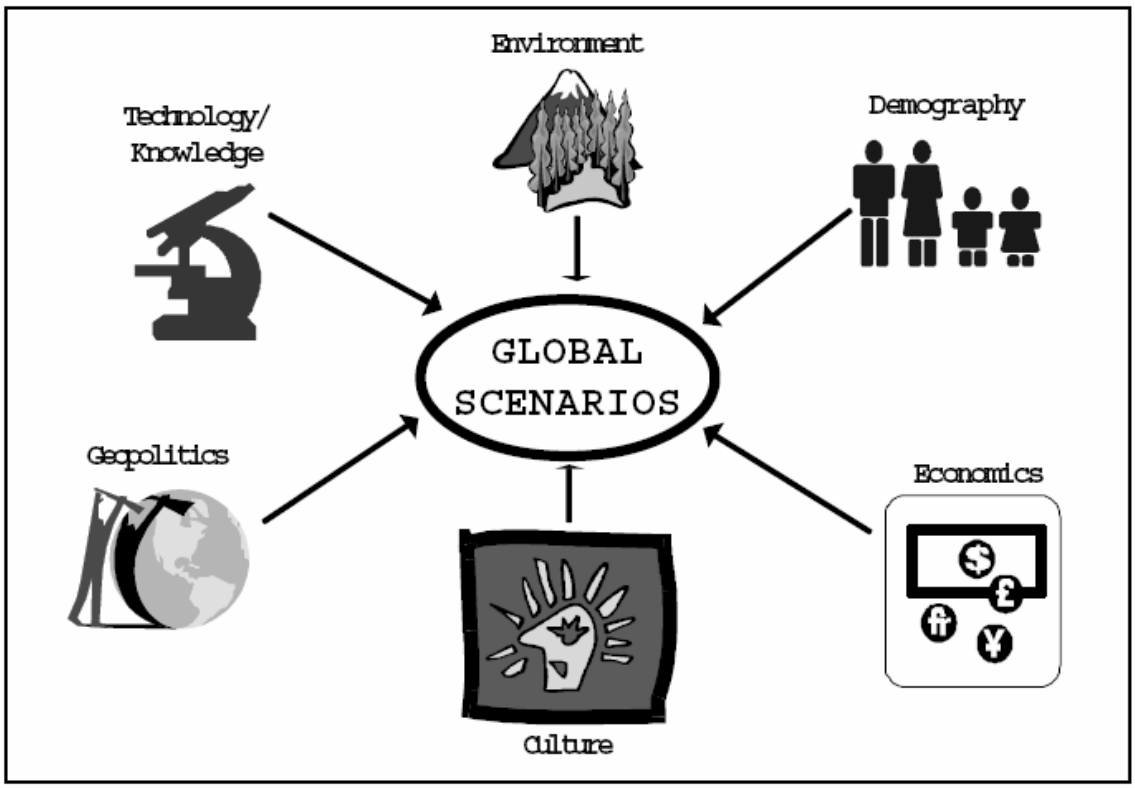
Scenarios are not predictions, but rather plausible stories about the future. Scenarios can widen perceptions of possible futures because they allow one to disentangle from any of the three worldviews (optimism, pessimism, idealism) that tend to dominate perceptions of the future at a given point in time. All of these views have made an appearance in the past fifteen years alone. An idealistic worldview prevailed following the international effort to push Iraq out of Kuwait and the collapse of the Soviet Union early in the 1990s, leading President George H. Bush to declare a New World Order. The record-long economic expansion in the United States through the 1990s, which benefited most countries, contributed to a relatively optimistic worldview becoming common. Even Allan Greenspan, the pragmatic, former Chairman of the US Federal Reserve, became a New Economy adherent. With the terrorist attacks on New York and Washington on September 11th, and the subsequent "war on terrorism", the consensus view has become decidedly pessimistic.

The global scenarios for CERI's long-term energy outlook reflect the three worldviews discussed above. "Business World" is based on an optimistic view of the future, "Political World" on a pessimistic one, and "Environmental World" on an idealistic outlook. The major drivers for the global scenarios are discussed in Section 2.1, we deal with global business cycles in Section 2.2, and the scenarios themselves in Section 2.3.

2.1 Major Drivers for the Global Scenarios

Our world consists of three types of complex systems—natural, social and technological (see Figure 2.1). Conceptually, society itself can be further sub-divided into demographic, economic, cultural, and political spheres. The potential overlap and interplay amongst all these systems is the basis for our global scenarios.

Figure 2.1: Major Drivers for the Global Scenarios



2.1.1 Environment

The natural environment obviously underpins all human existence. Although humankind depends absolutely on the natural world, human activities have imperiled the basic sources of life since earliest times. Over the last half century, our negative impact on the planet has become increasingly apparent. Rising populations and production suggest we are only at the "leading edge" of the planet's environmental problems.

The global environmental movement began gathering steam, especially in developed countries, in the 1960s. In 1972, the United Nations (UN) convened the Stockholm Conference on Human Environment. The UN's World Commission on Environment and Development, chaired by Gro Harlem Brundtland, released "Our Common Future" in 1987. This report, a clarion call for action, coined the phrase "sustainable development". In 1992, the UN convened the Conference on Environment and Development in Rio de Janeiro, the so-called Earth Summit, which placed the issue of sustainable development at the heart of the global agenda. The delegates at the conference rubber-stamped Agenda 21, a blueprint for setting human activities onto an environmentally sustainable path. In 2002, delegates at the 2002 World Summit on Sustainable Development in Johannesburg attempted to adopt concrete steps and identify quantifiable targets for better implementing Agenda 21.

Commercial sources of energy are a prerequisite for economic progress, but most of them (especially hydrocarbons and nuclear) cause environmental impacts all along the energy chain—from extraction to refinement to end-use to spent-fuel abandonment. The contribution of hydrocarbon consumption to local air pollution has long been known.

The Kyoto Protocol, signed in December 1997, shifted the burning of hydrocarbons from a local to a global issue. Most scientists believe the buildup of carbon dioxide (and some other chemicals) in the atmosphere is contributing to global warming and climate change. The implementation of the Kyoto Protocol and other initiatives to put us on an environmentally sustainable path would have a major impact on the energy sector.

As the US government's rejection of the Kyoto Protocol makes clear, however, a scientific consensus (or near consensus) does not necessarily mean a political accord. One of the major uncertainties for our energy scenarios is the response of major governments to the environmental threat.

2.1.2 Demography

Population growth on the planet began to accelerate in the middle of the 18th century, in conjunction with the Industrial Revolution and improved agricultural productivity. World population has since skyrocketed, from around 800 million to some 6.5 billion, despite Malthusian predictions to the contrary. However, if fertility rates continue to decline in developing countries, the consensus view among demographers, the world's population should stabilize at between 9 and 12 billion people sometime in the second half of the 21st century.

Unfortunately, a large chunk of the remaining population increase is expected to occur in the next twenty-five years, and especially in many regions that can least afford it (e.g., sub-Saharan Africa and South Asia). The UN Population Division projects world population will increase to between 7.6 and 8.8 billion by 2030, with a mid-range forecast of 8.2 billion. The population in the developed world will remain around 1.2 billion over this period, including approximately two million immigrants each year from the poorer regions—fertility rates are below replacement level in some developed countries. Despite fertility rates declining from six to three in the developing world since 1960, populations in many of these countries will continue to surge due to the high proportion of women entering childbearing years. The population in developing countries is expected to increase to between 6.4 billion and 7.5 billion by 2030, compared to about 5.3 billion currently.

Although greater population growth generally leads to higher economic growth and energy demand, two other demographic factors can disrupt this relationship. First, the size of the potential workforce is affected by the age composition of the population. The "graying" of the developed world will shrink its workforce in the future. Meanwhile, the "youth bulge" in developing countries will continue to decrease the proportion of people available for work so long as the fertility rate remains above the mortality rate. Second, the size of the potential workforce depends on the general health of the population. Unhealthy people tend to be relatively unproductive workers. People in developing countries are more likely to suffer from ill health compared to those in the developed world because the latter can better afford medications and public health measures to thwart the spread of disease. The people in developing countries also are much more likely to suffer from poor nutrition or malnutrition. Antibiotic-resistant diseases in the developed world would level the playing field somewhat, however.

The relationship between population, economic growth and energy demand also can be disrupted if populations become too great for their renewable resource base. Thomas Homer-Dixon, at the University of Toronto, argues that scarcities of renewable resources, such as water, soil, forests, and fish, due to rapid population growth and environmental degradation, will become a more common cause of wars and civil violence in the future. These sorts of disturbances are already apparent in developing countries as geographically diverse as Sierra Leone and the Ivory Coast (West Africa), Somalia (East Africa), Pakistan and India (South Asia), the Philippines (Southeast

Asia), and Haiti (Caribbean). As a rule, violent conflict destroys productive assets and disrupts economic activity.

2.1.3 Economics

The march of economic history was a slow one until the Industrial Revolution began in Britain in the mid-1700s. World output per head increased by a meager 0.1 percent per year during the Agricultural Revolution (the previous 10,000 years). As a result, the world economy grew only slightly faster than world population. Living standards finally began to take off in the late 18th century, with growth in labor productivity (output per man-hour) accelerating to average 1.2 percent annually. Some economic theorists believe we are on the verge of a third economic revolution, propelled by knowledge and information technologies.

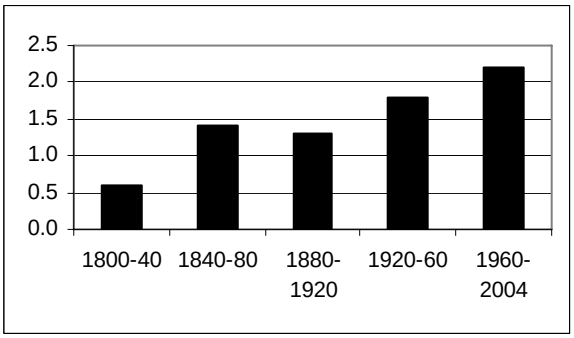
Numerous theories attempt to explain the rise in living standards since the Industrial Revolution. The most important early ideas were developed in the late 18th and early 19th century in Britain. Adam Smith, an economic optimist, believed the combination of labor specialization, technological change and accumulation of capital would lead to "universal opulence", so long as governments allowed markets a free reign—a rather large caveat for those mercantilist times. Smith believed the government's role should be limited to providing social order and national defense, basic infrastructure and public education.

His countrymen, David Ricardo and Thomas Malthus, were more pessimistic. Ricardo argued that diminishing returns to land, labor and capital would block the path to prosperity. Building on this, Malthus believed population growth eventually would outstrip agricultural productivity. In the end, "natural checks" (disease, famine and war) would be needed to control population size. He failed to foresee that capital accumulation, technological change and migration would save Britain from his "Malthusian solution".

Between the early 1800s and the mid-1950s, economists paid scant attention to economic growth theory, preferring to believe that changes in labor productivity were due simply to the amount of capital (especially industrial machinery) per worker. However, Robert Solow eventually proved that only 20 percent of the improvements in labor productivity were due to capital accumulation. The remainder, the so-called "Solow residual", he attributed to technological change.

Since the 1980s, New Growth theorists, such as Stanford's Paul Romer, have gone one step further. These theorists argue that knowledge (discovery, invention and innovation) is a factor of production in its own right. Moreover, knowledge exhibits increasing returns over time. The more humankind discovers the better we become at the process of discovering. Romer's assertion is supported by changes in output per head in the US over the past two hundred years (see Figure 2.2). Per capita gross domestic product (GDP) growth has increased in each of the 40-year time spans since 1800, except between 1880 and 1920. The standard of living in the US increased by 2.2 percent per year between 1960 and 2004, compared to about one quarter this amount over 1800 to 1840.

Figure 2.2: Per Capita GDP Growth in the US
(Annual average percent change)



New Economy zealots believe information technology (IT), including computers, software, telecoms, and the Internet, is supercharging growth in knowledge. This is expected to lead to greater gains in labor productivity in two ways. First, IT is expected to contribute to capital deepening by opening the door to new industries in areas as diverse as biotechnology (including genetics), fuel cells and nanotechnology (engineering devices at the molecular level). These industries would not be possible without low-cost computer processing power.

Second, IT is expected to increase efficiency in all industries, including old and new economy ones, by increasing innovation. For example, IT is allowing many industries to flatten their organizational structures, doing away with large segments of middle management by increasing peoples' capacity to store, analyze and communicate information.

Globalization, having been born with the collapse of the Soviet Union in 1991, is another important factor for economic growth. The driving force behind globalization is free-market capitalism (free markets, free trade and free movement of capital and multinational corporations). The major economic rules of globalization include free trade and competition, deregulation and privatization. Globalization refers to the spread of free-market capitalism to virtually every country in the world.

Globalization boosts the world economy through a more efficient use of the world's resources. To Ricardians, free trade allows states to focus their efforts where they have a comparative advantage relative to others. As a result, the national income of every state rises under free trade. The same holds true for the free flow of capital, technology and knowledge.

Obviously, there are important synergies between IT and globalization. IT helps integrate production and capital markets around the world by reducing the cost of information and communication. In turn, globalization boosts productivity gains from IT by increasing the spread of these technologies.

The nature and rate of world economic growth are extremely important factors for energy demand. Economic activity is the primary driver for energy demand growth, although a shift towards knowledge and service industries makes human activity relatively less energy (and resource) intensive.

2.1.4 Culture

Cultures differ greatly across the planet, but all are amalgams of religions, myths, traditions, art, and languages. While culture helps define the members of a particular group, and thereby contributes to social cohesion, it also may foster conflict with other groups.

The process of modernization, which has accompanied economic development over the past two hundred years, is eroding cultural (and other) differences across societies. Modernization, including industrialization, urbanization, increasing levels of education and wealth, and more complex occupational and social structures, causes traditional societies to become more "modern". In terms of culture, religion tends to decline in importance (reason versus emotion), while the role of women tends to expand (brainpower versus muscle power). Globalization has taken place under a number of different ideological systems, including communism, fascism and liberal democracy. Globalization is a supercharged version of modernization, based on liberal democratic (especially capitalist) ethos.

This homogenization process has spawned critics of globalization, many of whom claim the entire world is being colonized by America's consumer culture. The result is a backlash against globalization, especially among some religious fundamentalists and more extreme environmentalists.

2.1.5 Geopolitics

The US became the sole superpower on the planet with the collapse of the Soviet Union in 1991. Although there has been a great deal of cooperation between the major powers over the past fifteen years, including the UN-sanctioned war against Iraq in 1991, the future shape of the international political system is a matter of great debate between two schools of thought—Realists and Liberals.

Realists believe national interest drives state behavior within the anarchical international system. The primary interest of states is survival; when this is ensured, interest shifts to power and wealth. To ensure survival, and possibly freedom of action, states tend to form coalitions to balance the power of a threatening alliance or hegemon—a dominant global or regional power. Based on Realpolitik thinking, it is inevitable that some of the world's other major powers (Europe, Japan, Russia, China, and India) will form new alliances to counter the clout of the United States in the coming years.

Liberals, on the other hand, recognize the international system has been dominated by power politics in the past, but believe it is being tamed through the gradual spread of liberal economic and political thought (liberal democracy). According to Liberals, the liberal democratic mentality promotes cooperation between states, rather than conflict. They point to global institutions, such as the UN and its sister institutions (World Bank, IMF and WTO) as evidence of this cooperation.

The world appeared to be moving towards a more liberal international system in the 1990s, when the US government tended to cooperate with the UN and other international institutions to maintain political and economic order. In contrast, power politics has been making a comeback since 2001. Despite many major powers (including Europe, Russia and China) considering the 1972 Anti-Ballistic Missile treaty to be the cornerstone of international nuclear stability, the US government decided to scrap the treaty to allow it to build a missile defense system.

The primary reason for the different approaches to world politics by recent US government's lies in differing perceptions of the greatest long-term threat to American supremacy—China. China has a large population and tremendous economic potential. In addition, an impressive pre-

colonial history, the people's incredible suffering under colonialism (both Western and Eastern), years of hardcore propaganda during the Maoist era, and recent economic success have made China a highly xenophobic nation.

The Clinton administration believed China would be de-fanged through the benefits of free markets and trade. They expected economic liberalization eventually would lead to political liberalization in China, which in turn would keep China from becoming a belligerent superpower. In contrast, the Bush administration is concerned about China's recent military buildup and a lack of progress on the democratic front.

The primary goal of the Bush administration's foreign policy prior to September 11th was to isolate China and prematurely force it into an arms race. The US was seeking closer ties with India and Russia, so as to encircle China with democratic allies—although Bush was losing Russia to the Chinese prior to the terrorist attacks on Washington and New York. A major goal of the missile defense system is to push China into an arms race it cannot yet afford. China currently has only a few dozen nuclear missiles capable of striking the continental US. Its economy is still relatively undeveloped, although largely due to its huge population base. This scheme was a throwback to the Reagan administration's arms race strategy that bankrupted the Soviet Union, although in the current case, it is meant to pre-empt a superpower rather than destroy one.

Round one and two of the Bush administration's "war on terrorism", the military attack on Afghanistan and the latest Iraq war, play into Harvard Professor Samuel P. Huntington's "clash of civilizations" thesis, a variation of the Realist school. As Huntington wrote about the post-Cold War World in 1993:

> *"It is my hypothesis that the fundamental source of conflict in this new world will not be primarily ideological or primarily economic. The great divisions among humankind and the dominating source of conflict will be cultural. Nation-states will remain the most powerful actors in world affairs, but the principal conflicts of global politics will occur between nations and groups of different civilizations. The clash of civilizations will dominate global politics. The fault lines between civilizations will be the battle lines of the future."*

In the follow-up book to this Foreign Affairs article, "The Clash of Civilizations and the Remaking of World Order" (1996), Huntington discusses eight major contemporary civilizations and the likely interrelationship among them in the coming decades. The eight civilizations and the core states that dominate each (in brackets) are as follows: Sinic (China), Japanese (Japan), Hindu (India), Islamic (none), Western (US and EU), Orthodox (Russia), Latin America (none), and African (none).

The primary combatants in Huntington's multi-polar, multi-civilization world are the West and a Sinic-Islamic alliance. By the mid-1990s, a de facto coalition had formed between China, Pakistan and Iran, with missile and other military technology flowing westward and oil flowing to the east. Huntington believes this "strategic alliance" will broaden and deepen, so long as Muslim populations and Asian economies continue to surge. Islamic and Sinic societies resent Western interference in their affairs more than most, since they assume cultural superiority over the West (as does Japan).

The major "swing" civilizations in Huntington's clash thesis are Japanese (Japan), Orthodox (Russia) and Hindu (India). These civilizations may bandwagon with the West or balance against it depending on threats posed by neighboring civilizations and cultural affinities.

Huntington believes Islam will cause the greatest problems for the West (and some of the other civilizations) in the shorter term. Islamic societies have been involved in the majority of the fault-line wars (where different civilizations meet) since the end of the Cold War. Huntington attributes this to the Islamic civilization lacking a core state to intimidate other civilizations and maintain discipline within its own, and the youthful vigor of most Muslim societies. In contrast, demographically mature societies, such as Europe, Japan and Russia are expected to be relatively pacifistic in coming years.

Huntington believes China will threaten Western global hegemony in the longer term due to its tremendous economic and military potential. He compares the emergence of China to the rise of Wilhelmine Germany as the dominant power in Europe in the late 19th century. Huntington concludes, "In the clash of civilizations, Europe and America will hang together or hang separately."

Whether the global political system plays a Realist or Liberal tune will have important ramifications for the world energy market in coming decades. Realists tend to place energy security near the top of their policy agenda, whereas Liberals are far less concerned about the nationality of their energy supply. These differences are apparent in energy policies emanating from the Bush administration, with "energy security" at its foundation, compared to the Clinton administration's more laissez-faire approach.

2.1.6 Knowledge and Technology

Three waves of innovation have swept the planet since the Industrial Revolution, while a fourth wave currently upon us may represent a whole new revolution. The first wave (1780s to 1840s) was fueled by steam power, the second (1840s to 1890s) by railways, and the third (1890s to 1950s) by electric power and the automobile. The fourth wave (1950s to ????), the so-called Knowledge Revolution, is being driven by the microchip and Internet at the present time.

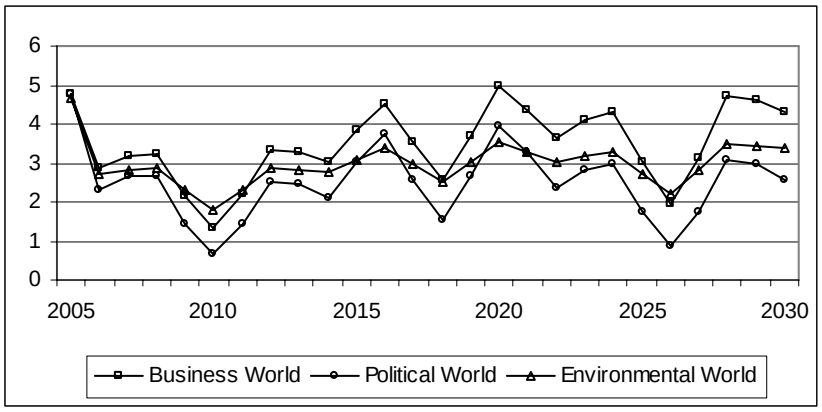
Four other emerging technologies with the potential to help fuel new investment cycles over the next twenty-five years are biotechnology, hydrogen fuel cells, solar photovoltaic, and possibly nanotechnology (although the latter may remain on the fringe through 2030). Biotechnology is on the runway, stationary fuel cells and solar photovoltaic are being taxied to the runway (especially in developing countries that lack energy infrastructure), mobile fuel cells are in the hangar undergoing flight preparations, while nanotechnology is still in the Boeing or Airbus plant. The combination of IT and these other technologies have the potential to create a very powerful "long wave" of economic growth.

A widespread backlash against Enlightenment thinking is unlikely because technological advancement gives major powers an economic and military edge over their rivals. In "Guns, Germs, and Steel: The Fates of Human Societies", Jared Diamond discusses (among other things) how China threw away its technological lead over the rest of the world in the 15th century, as the Chinese equivalent of Luddites gained control over the Court. By 1400, China already had many of the innovations that triggered the Industrial Revolution in Britain more than 300 years later, including moveable-type printing, the blast furnace and water-powered spinning machines. In addition, China was a maritime power, with a huge fleet and pre-eminent navigation. But their Luddites banned transoceanic travel around 1433 and retreated from mechanical devices and other technology later in the century. The Chinese believed they could afford to step off the technological treadmill because they did not foresee any external threats to their domain. Considering the price China subsequently paid for this mistake, any other major power is unlikely to do likewise. However, a reaction against specific technologies, possibly due to a cataclysmic event (e.g., a biotechnology disaster), is another matter. President Bush recently limiting stem cell research in the US in response to Christian Fundamentalist opposition is an example.

2.2 Global Business Cycles

Before discussing our three global scenarios, an explanation of how we deal with business cycles is warranted. In a nutshell, the economic growth assumptions underlying the scenarios build in cyclical behavior in order to make the trajectories more realistic. Flat-line economic growth assumptions simply fail to supply the curve balls the real world throws out. The typical business cycle has four stages: prosperity, transition, recession or depression, and recovery. As the global economy showed early this decade, the business cycle has not yet been banished, despite predictions to the contrary by the most extreme New Economy zealots. Business cycle theorists have identified four distinct cycles of varying lengths—Kitchin (3-5 years); Juglar (7-11 years); Kuznets (16-18 years); and Kondratieff (46-60 years). Each of these cycles marches to their own drummer, and as a result, they can either reinforce or counteract one another.

Figure 2.3: Economic Growth for the Global Scenarios (Annual percent change)



A major world recession is assumed to hit all three global scenarios in 2009-11, with the four cycles simultaneously hitting their trough in 2010 (see Figure 2.3). Four simultaneous peaks do not occur through our projection period. The Kondratieff cycle's trough is assumed to occur 76 years after the previous one (1934), whereas the other three cycles are assumed to behave fairly true to form. Greater international financial cooperation since World War Two, due to the house John Maynard Keynes built (World Bank, IMF, WTO), along with the development of central banks on the domestic front, makes for a longer Kondratieff cycle. In Political World, additional recessions occur in 2014, 2018, 2022, and 2025-27. In contrast, 2026 is the only other year that economic growth in the Business World and Environmental World meet the IMF's definition of a world recession (global growth below 2.5 percent per year). Political World suffers the greatest economic volatility, due to a breakdown in international cooperation. For the opposite reason, Environmental World enjoys the greatest economic stability.

2.3 Global Scenarios

As previously mentioned, CERI's global scenarios reflect three major worldviews. "Business World" is based on an optimistic view of the future, "Political World" on a pessimistic one, and "Environmental World" on an idealistic outlook.

2.3.1 Business World

Business World (BW) is a Liberal World (see Table 2.1). Economics re-asserts its role in the international landscape later this decade, with the New Economy driving the global economy.

Table 2.1: Major Drivers for the Global Scenarios

	Business World	Political World	Environmental World
Environment (Action)	Medium	Low	High
Demography (Population)	Medium	High	Low
Economics (Economic Growth)	High	Low	Medium
Anti-Culture (Globalization)	High	Low	Medium
Geopolitics (Coop/Conflict)	Medium	Conflict	Cooperation
Technology/Knowledge	High	Low	High

World economic growth averages 3.5 percent per year over 2004 to 2030, compared to about 3.4 percent over the 1971 to 2004 period. The world economy suffers a relatively deep, and prolonged recession from 2009 to 2011, and a milder one in 2026. Otherwise, economic growth trends higher through 2030. This economic strength reflects strong capital accumulation, the rapid increase and diffusion of new knowledge and technology and continuing globalization. World population growth is neither too fast nor too slow in this scenario, helping to drive economic growth higher.

Information technology, knowledge and globalization reinforce one another, supercharging labor productivity and economic growth, and feed into other industries and around the world. R&D spending focused on consumer goods, including IT, biotechnology, fuel cells (especially stationary), and solar photovoltaic encourages new investment cycles, increasing capital accumulation over the next twenty-five years. Knowledge-based and service industries become a greater proportion of gross world product (GWP) as time passes.

A rapidly growing world economy creates increased opportunities for the wave of young people entering the workforce and rising living standards. The former encourage Global Teenagers, especially in the developing world, to become entrepreneurial, while the latter help lower fertility rates in most developing countries. As a result, world population follows the trajectory of the UN's "medium" projection (8.2 billion by 2030).

Liberalism drives the international political scene in the Business World. Economic liberalism leads to greater prosperity and an increasingly liberal political system. As a result, China is co-opted into the international political system in the second half of the 2010s, and morphs into a relatively benign superpower rather than a belligerent one. Major powers tend to cooperate on issues of international security (including new ones such as environment, terrorism, narcotics, etc.), as well as international financial matters, although some geopolitical wrangling continues. Regional and domestic strife is fairly common in the developing world, due to ethno-nationalism, religious extremism and environmental degradation. Tensions tend to be great between have and have-not countries in this scenario.

Terrorism (including cyber- and bio-terrorism), the weapon of the weak, occasionally rears its ugly head, and is especially directed at targets in developed countries. Due to rapid economic growth, environmental destruction is fairly severe, despite moderate efforts to counter it. Improved efficiencies due to the spread of newer technology and the shift towards knowledge-based industries somewhat mitigate environmental deterioration.

2.3.2 Political World

Political World (PW) is a very dark, Orwellian world, where life is viewed as a zero-sum game (see Table 2.1). A trade war breaks out between the US and China late this decade, leading to a collapse in Sino-American relations. The new Cold War leads to increased geopolitical rivalry and proxy wars, and relatively slow economic growth. Realpolitik dominates this scenario.

The major world recession of 2009-11 engenders the death of globalization, a rise in terrorism and a breakdown in international cooperation. Another prolonged recession occurs in 2025-27, and milder ones in 2014, 2018 and 2022. The world comes to be characterized by two major powers (US and Europe), three emerging ones (China, Russia and India), and widening Islamic extremism. The aging Japanese society remains under the US nuclear umbrella.

All five of the major powers aspire to global leadership, as do Islamic countries and militants. To begin with, China and its Islamist allies, along with Russia, attempt to balance against US hegemony; Europe bandwagons with America, and India marches to its own drummer. The Islamists, especially in the Arab world, continue their uncomfortable alliance with China, given continuing efforts to eradicate Islamic separatists (Uighur people) in the western part of the country (Xinjiang Province). India moves firmly into the US orbit in the 2010s, to counter the rising power of China.

Nuclear arms, other weapons of mass destruction and the missiles systems to deliver them keep the competition between the two blocs cold rather than hot, since both sides wish to avoid the devastation of a major exchange. Instead, the two blocs fight "proxy" wars in developing countries, similar to the last Cold War, stirring the ethnic, religious and environmental pot in the process.

The world economy only grows by 2.5 percent per year through 2030 in Political World. This slow growth reflects excessive population growth, sluggish capital formation, a relative lack of new knowledge and technology, and the collapse of globalization. R&D efforts focus on military applications rather than commercial ones, while greater effort is placed on minimizing risk rather than capital formation. Heavy industries, especially ones related to the defense industry, maintain their share of GWP.

The major world recession beginning in 2009 leads the major powers to implement "beggar thy neighbor" economic policies (e.g., competitive exchange rate depreciation, trade barriers and capital restrictions) in an attempt to bolster economic growth in their own countries. The ensuing decline in international trade and capital flows causes the economic slowdown to deepen. The collapse of international financial cooperation, including the Bretton Woods economic system, increases global economic volatility.

The implosion in globalization and the decline in R&D slow the creation and spread of new technologies and knowledge, except in areas related to national security (including energy security). In addition, since societies seem to have greater respect for military rather than intellectual pursuits, the pool of scientists and engineers tends to be relatively shallow.

Increased military spending has a negative impact on the world economy through a second channel, capital formation. Relatively high government spending, driven by military expenditures and anti-terrorist measures, crowds out productive investment. In addition, proxy wars lead to widespread capital destruction in many developing countries, especially once the new Cold War begins in earnest (post-2010). Terrorist attacks cause destruction primarily in the developed world.

Contributing to this capital destruction is excessive population growth, which, along with relatively slow economic growth, turns Global Teenagers into Teenage Warriors. Given the lack of economic opportunity, proxy wars aplenty, and the proliferation of terrorist networks, the youth in many developing countries conclude the best way to get ahead is through the barrel of a gun.

The world population is assumed to follow the path of the UN's "high" projection (8.6 billion by 2030), despite warfare and major plagues periodically striking the developing world. Population growth is retarded in developed countries because the fear of plagues leads to severe restrictions on immigration and travel. Social Darwinism (survival-of-the-fittest) becomes a respectable doctrine. Life is "nasty, brutish and short" for a large segment of the world's population.

The level of environmental destruction in Political World is severe, due to slow technological advancement, slow economic growth (and hence limited diffusion of new technologies), a lack of international cooperation, and environmental protection being viewed as a "luxury good". Developing countries cannot afford to protect the environment because their primary concern is to provide basic necessities for their people, including national defense. The major powers cannot afford it because of their geopolitical commitments and efforts to combat terrorism.

2.3.3 Environmental World

Environmental World (EW) envisages a pragmatic environmentalism beginning to permeate the planet by the 2020s (see Table 2.1). As environmental degradation and climate change worsen over time, the major powers become increasingly serious about achieving sustainable development. The 20th century comes to be viewed as the "free" century for economic development; the 21st century is time to pay the environmental piper.

Environmental World is neither a Realist nor a Liberal world. The major powers crawl onto the environmental bandwagon over time, as they perceive environmental degradation becoming a greater threat to their security than their traditional foes. Relatively "green" Europe, with its large population and comparatively small territory, leads the pack. The second major power to embrace the new environmentalism is the US. Russia, China and India begin to cooperate with the West in the second decade of the 21st century, as living standards rise and the environmental consequences of growth increase in these countries.

A global social contract gradually evolves based on collective security and economic justice (meaning better distribution of wealth achieved primarily through market mechanisms), with the UN family of organizations at the epicenter. Collective security is important because extravagant military spending comes to be seen as a luxury an environmentally constrained world can no longer afford. Economic justice is needed to help raise living standards in the poorest countries so that environmental problems can be tackled. The combination of collective security and economic justice contribute to a relatively low-conflict world.

Economic growth is solid in Environmental World, while economic volatility is low due to strong international financial cooperation. The world economy grows an average 3 percent per year through 2030, reflecting moderate capital accumulation, the rapid spread of new knowledge and technology and a modified version of globalization gaining sway. Slow population growth and aging populations are a relative drag on the world economy. The committed environmental effort, along with increasing services and knowledge-based industries, leads to a significant de-materialization of GWP.

Although globalization is alive and well in Environmental World, it is driven by pragmatic environmentalism rather than US consumer culture. Free trade and capital flows, and the spread of new technologies and knowledge lead to a better distribution of income and wealth on a global basis and rising living standards. The trade barriers that most harm developing countries, such as those affecting agriculture and textiles, are primary targets of the WTO.

While Environmental World is a high technology world, R&D tend to be directed towards environmental sustainability rather than consumer products. The combination of globalization, and efforts by the international community to entrench sustainable development, lead to the widespread diffusion of new technology and knowledge.

Capital investment also is high in Environmental World, but capital accumulates relatively modestly because some investment is directed towards the early retirement of "dirtier" plant and equipment. On the other hand, there is relatively little destruction of physical capital due to warfare or terrorism.

The environmental threat helps temper divisions among humans, and as a result, there is less ethno-national and religious conflict. Local and international efforts towards sustainable development alleviate a third cause of conflict, environmental degradation. Rising living standards evolving from the global social contract allow more Global Teenagers to work towards idealistic goals. Finally, a powerful UN, with a strong police force, is better able to mediate, and make and keep the peace.

Higher living standards in developing countries and UN support for countries wishing to lower their fertility rates lead to relatively slow population growth in Environmental World. World population follows the trajectory of the UN's "low" growth projection (7.6 billion by 2030).

While the world moves toward greater environmental sustainability by 2025, it still has a long way to go. The major reasons for superior environmental performance are committed governments working in concert to achieve sustainable development, rapid technological advancement and only moderate economic growth.

CHAPTER 3
GLOBAL ENERGY SCENARIOS

CERI's three global scenarios affect the major uncertainties for the world energy market in highly divergent ways. In Section 3.1, we discuss the five major uncertainties facing the world energy market. In Section 3.2, we provide an overview of the energy markets under our three global scenarios.

3.1 Major Uncertainties for the Global Energy Market

The world energy market through 2030 is characterized by five major areas of uncertainty that impact energy demand and fuel mix. These are the economy, technology, energy policy, resource availability, and market structure (see Table 3.1).

Table 3.1: Major Uncertainties for the Energy Market

	Business World	Political World	Environmental World
Economics (Growth)	High	Low	Medium
Resource Availability	Medium	Low	High
Energy Policy (Action)	Low	High	High
Market Structure (Freedom)	High	Low	Low
Technology/Knowledge	High	Low	High

3.1.1 Energy Demand

World energy demand depends on economic growth and energy intensity. Several factors contribute to economic growth—land, labor, capital, technology/knowledge, and globalization. The most important wildcards for the nature and rate of future economic growth relate to technology/knowledge and globalization.

The potential impact of information technology on long-term economic growth is a matter of heated debate. New Economy zealots believe IT will continuously ratchet labor productivity higher by supercharging growth in knowledge. In contrast, New Economy sceptics believe higher labor productivity, seen primarily in the US (where IT is most prevalent) in recent years, is a temporary phenomenon. They argue that IT is not contributing to the development of new products as other significant inventions have done in the past (for example, the way electricity contributed to the creation of all sorts of household appliances). In addition, the New Economy sceptics do not believe IT is contributing to innovation outside the IT industry. As a result, they claim the recent increase in labor productivity growth will disappear as the pace of IT investment in the rest of the economy slows, and the rapid rate of innovation in the IT industry itself abates.

In addition, globalization is not necessarily irreversible, despite claims to the contrary. This is actually the second era of globalization. In terms of volumes of trade and capital flows relative to total world output, the world economy also was highly globalized from the mid-1800s to the late 1920s. This era collapsed under the weight of World War One, the Russian Revolution and the Great Depression of the 1930s. These caused colonial empires to crumble and major powers to adopt protectionist policies in an attempt to "save" their economies. Since the world has not yet experienced another serious economic downturn, it would seem premature to assume globalization is irreversible.

Energy intensity (energy consumption per unit of output) depends on several factors, including the rate and nature of economic growth, energy prices, the rate of technological advancement, and energy policy. The rate of economic growth affects the turnover of the world's capital stock. Since newer technologies are more energy efficient than older ones, a faster rate of turnover lowers the amount of energy needed to fuel an economy, per unit of GDP. The nature of world economic growth also matters since knowledge-oriented and service industries tend to be relatively less energy intensive than industrial ones. For example, steel production consumes far more energy per each dollar of output than does software design. As basic energy needs are met, consumer priorities shift towards other less energy-intensive goods and services.

Energy prices affect energy intensity through conservation efforts by consumers. During the 1973 to 1985 energy price boom, driven by higher oil prices, consumer preference shifted away from gasoline-guzzling "Detroit steel" to more energy-efficient automobiles, such as those made by the major Japanese auto-makers (e.g., Toyota, Nissan, Mitsubishi, Honda). In addition, there was a major drive by homeowners over these years to better insulate their homes against cold and heat. Since oil and other energy prices declined in 1986, the importance of conservation has declined in the minds of consumers, especially in countries that have not masked these declines completely with higher product taxes. For example, many American and Canadian consumers began their love affair with SUVs and "monster" homes in the second half of the 1990s.

Technological advancements decrease energy intensity because they tend to improve energy efficiency. Possibly the best recent example is the development of combined-cycle gas turbine (CCGT) technology for power generation which has increased thermal efficiencies to 55 to 60 percent, compared to about 35 percent in conventional steam-raising plants.

Finally, energy policies affect energy intensity by promoting conservation programs in the shorter term and funding research and development (R&D) for more efficient technologies in the longer term. The Weatherization Assistance Program in the US, which has been helping low-income Americans improve the energy efficiency of their homes since 1976, is an example of the former. In terms of the latter, the US (and other governments) funds numerous R&D programs aimed at improving energy efficiency in building, industry and the transportation industries.

The primary drivers for energy policy, besides high prices, tend to be geopolitical and environmental concerns. For example, the basis of the Bush Administration's "National Energy Policy" and the European Union's "Towards a European Strategy for the Security of Energy Supply" (Green Paper) is "energy security". Based on forecasts by their respective energy agencies, US dependence on foreign sources of energy will rise from about one-quarter to over 40 percent between 2000 and 2020, while European dependence will increase from one-half in 2000 to around 70 percent in the 2020-30 period. While the primary goal of the proposed US and EU energy policies is to mitigate this "over-dependence", an important secondary goal for the latter is a shift towards sustainable development. As a result, the EU plan tends to concentrate on conservation and developing renewable sources of energy, while US policy focuses greater attention on developing domestic supplies of oil, coal and nuclear power.

3.1.2 Energy Mix

The three major factors affecting the mix of fuels are end-use technologies, the marginal cost of primary fuels and their relative prices. The marginal cost and price of a fuel may not always coincide due to market imperfections and government interference in the market place. In addition, the process of electrification has led to changes in the energy mix since coal and gas tend to dominate power generation. Electricity is becoming the energy carrier of choice due to its combination of convenience, quality and cleanliness (at least at the point of use). Electricity's

share of final consumption has increased to 16 percent by 2004, compared to a 9 percent share in 1971. Meanwhile, there has been a gradual shift away from carbon-intensive fuels over time.

The dominant end-use technologies in different sectors of the economy have a major impact on demand for primary fuels (oil, gas, coal, nuclear, hydro, biomass and waste, and other alternatives). For example, oil has dominated the transportation sector over the past century because of the widespread use of the internal combustion engine.

However, end-use technologies will continue to change in response to both commercial and technological forces. Coal was under siege from gas, at least until the recent run up in gas prices due to the adoption of CCGT technology from the mid-1990s. CCGT plants are cheaper than conventional steam raising operations, much quicker to build and far more efficient. In the future, with advances in hydrogen fuel cell and micro-turbine technologies, coal could face an even greater challenge from gas, as power generation becomes more distributed. Solar photovoltaic are another potential source of competition, especially in regions without access to established gas and power grids.

The last bastion of world oil demand, the transportation sector, also could come under siege in the coming decades. As Paul Mlotok wrote in the February 1999 issue of *Geopolitics of Energy*,

> *"The current paradigm for the automobile is basically the best the 1890s had to offer: a steel box, on a steel frame, with an internal combustion engine ... The automobile has continued in its present form primarily because of the huge capital investment required to shake the old paradigm loose and a lack of alternate technologies—until now."*

There are two ways new transportation technologies, such as Mitsubishi Motor's direct-injection engines, hybrids (gasoline/battery powered) and fuel cell technologies eventually will reduce growth in world oil demand. First, substantially better fuel economy will be achieved than is possible with current technologies. Direct-injection engines currently achieve 20 percent better fuel economy than conventional engines, while hybrids and other "future cars" are shooting for 70-80 miles per gallon. Fuel economy for the average passenger vehicle in the US is currently around 27 miles per gallon. Second-generation "future cars" are expected to achieve at least 100 miles per gallon.

Second, fuel demand will shift away from gasoline and towards methanol (natural gas), and eventually, hydrogen. Hybrids generally run on a combination of battery power and gasoline, whereas fuel cells run on gasoline, methanol or hydrogen. The automakers tend to prefer methanol or direct hydrogen, whereas the oil industry prefers gasoline. Fueling infrastructure is a major economic asset, but also a major barrier to change. For now, methanol currently appears to be the most likely fuel to power fuels cells because of cleanliness, portability and cost (gasoline stations can be converted to methanol for a reasonable investment).

Another emerging competitor to oil is gas-to-liquids (GTL) technology, which produces transportation fuels using the Fischer-Tropsch three-stage conversion process. This process was discovered in 1923, and used primarily for coal-to-liquids conversion by the Germans during World War Two and by Afrikaners during the apartheid era. Spurred on by the environmentally-friendly nature of its products, GTL technology is nearing commercial take-off stage, with operating and capital costs falling by one-half in the past four years. The two-stage process of this technology can produce a high quality "white crude"; the third stage produces primarily middle distillates free of sulfur, aromatics and metallic contamination. GTL plants also have the potential to drastically reduce greenhouse gas emissions from flaring "stranded gas" associated with oil production.

Energy policies can affect fuel choice by funding R&D for specific end-use technologies and through subsidies to consumers purchasing specific technologies. Initiatives under the US government's Office of Energy Efficiency and Renewable Energy to support the development of advanced transportation vehicles (and fuels) that will reduce energy demand, particularly for oil, are an example of the former. An example of subsidies is US government Federal income tax incentives for the purchase of hybrid vehicles in the Energy Policy Act of 2005.

Major factors affecting the marginal cost of primary fuels include resource availability, technology and energy policy. British Petroleum's assessment of proven conventional oil and gas reserves, the US Geological Survey's most recent assessment of undiscovered resources, and the opening up of non-conventional oil and gas resources indicate that future physical constraints for these fuels should not be a concern over our projection period. However, the world is moving down the resource pyramid for oil and gas, especially in the OECD countries. Despite technological advancements such as 3-D seismic, horizontal and deep offshore drilling, and in situ techniques such as SAGD (for the development of Alberta's oil sands), the marginal costs of oil and gas are rising.

In addition, access to the physical resource is also extremely important for resource availability. The NIMBY factor has closed substantial oil and gas resources from development in North America, while rising resource nationalism among the major oil and gas exporting countries is increasing costs and slowing development of their resources. In contrast, ample physical supply and access to coal and uranium is likely in most major, energy consuming countries over our projection period.

Energy policies also can affect the relative cost of a fuel by funding R&D for specific ones. For example, the US government's Office of Fossil Energy includes several R&D programs directed at coal, including the Advanced Clean/Efficient Power Systems program, which is attempting to increase the efficiency and decrease the cost of "clean coal" technology.

Two major factors affecting the relative prices of primary fuels, besides marginal costs, are market structure and energy policy. The gradual liberalization of energy markets has increased competition amongst primary fuels and energy carriers (e.g., gas versus power). Nonetheless, consumers are willing to pay a premium price for fuels with superior attributes, despite competitive markets. For example, the convenience of natural gas makes it the preferred heating fuel despite generally costing more than heating oil or coal.

In addition, so long as oil remains the fuel-of-choice in the energy market as a whole, OPEC will be able to continue to manipulate world oil prices. However, if gas becomes the fuel-of-choice, major gas exporting countries may decide to collude to influence gas prices, with oil (and other fuel) prices becoming a function of gas prices.

The main policy tools governments have at their disposal for adjusting relative fuel prices are taxes and subsidies. The former is especially prevalent in Europe due to energy security and environmental concerns.

3.2 Global Energy Scenarios

The future world energy market differs substantially under our three global scenarios. In what follows, an overview of these different energy markets will be provided.

3.2.1 Business World

The world energy market is fairly dynamic in the Business World. Growth in world energy demand is very strong, especially in non-OECD countries, and despite moderate improvements in energy intensity over the projection period. De-carbonization of the fuel mix, electrification of final consumption and liberalization of energy markets continue, although the latter is mitigated somewhat by security of supply and, to a lesser extent, environmental concerns. The developed world becomes more serious about combating climate change in the second decade of the 21st century; developing countries are co-opted into the process in the 2020s.

Technological change related to the energy industry tends to be relatively rapid, although the technologies that actually diffuse around the world are more evolutionary in nature. The dominant technologies generally improve on the incumbents rather than being radical new ones. For example, the internal combustion engine (ICE) continues to dominate the transportation sector while combined-cycle gas and coal turbines make inroads into the power market throughout the projection period. Major exceptions to this trend are stationary fuel cells and solar photovoltaic. The former are sold primarily to businesses willing to pay a premium for high reliability power in developed countries, while the latter find a receptive market in remote regions of developing countries, especially later in the projection period.

World energy demand growth averages 2.1 percent annually through 2030, while energy intensity declines an average 1.4 percent per year—both similar to the 1971 to 2004 comparison period (see Table 3.2). The rate of decline in energy intensity increases from 1.2 percent in 2004 to 1.6 percent in 2030 primarily due to technological advancements, rapid turnover of capital (strong economic growth) and a shift towards more knowledge-based and service industries. Governments, especially in developed countries, add programs over time to encourage conservation and fund R&D to improve efficiency of end-use technologies.

Table 3.2: Major Assumptions for the Energy Scenarios (Annual average percent change)

	Historical	Scenarios (2004 - 2030)		
	1971 to 2004	Business World	Political World	Environmental World
Economic Growth	3.4	3.5	2.5	3.0
Energy Intensity	-1.3	-1.4	-1.6	-1.8
Energy Consumption	2.1	2.1	0.9	1.2

Although the shift away from high carbon fuels continues in the Business World, the pace slows. Coal loses one percentage point of market share by 2030 (25 to 24 percent), while oil's share of the primary energy market remains flat (35 percent). The key to oil's relative success is its continuing dominance in the fastest-growing end-use sector, transportation. Because of their inherently higher manufacturing costs, fuel cell vehicles (methanol and gasoline) make only minor inroads into the transportation market by 2030, mainly in fleet sales in OECD countries, while hybrids (gasoline/battery powered) and diesels capture an increasing share of the global market. Governments generally are assumed to be unwilling to provide sufficient incentives, such as direct subsidies or high gasoline taxes (relative to natural gas), to cover the difference until near the end of the projection period.

As a result, oil continues as the fuel-of-choice in the Business World, with other fuels priced at a discount to it based on energy equivalency (see Table 3.3). Strong residual demand for OPEC oil allows the cartel to keep crude prices high (relative to their marginal cost), translating into relatively high fuel prices across the board. The $50 per barrel average price for WTI (US$ 2004)

encourages incremental technological advances that allow the continued economic exploitation of crude further down the resource pyramid (lower quality and more remote), as well as non-conventional sources of supply such as Canada's oil sands and Venezuela's Orinoco belt. The price for natural gas averages $6.75 per MMbtu at Henry Hub.

Table 3.3: World Energy Price Assumptions (US$ 2004)

	Historical	Scenarios (2004 - 2030)		
	2004	Business World	Political World	Environmental World
WTI at Cushing ($/bbl)	41.49	50.00	60.00	40.00
Gas at Henry Hub ($/MMbtu)	6.18	6.75	7.25	7.75
US coal imports ($/tonne)	40.10	55.00	75.00	40.00

Coal would lose substantially more market share in the Business World were it not for security of supply concerns. Import dependency rates for oil and gas rise substantially through the projection period in all the major energy consuming regions (OECD and non-OECD Asia), despite these regions having large coal reserves. In an attempt to temper dependence on foreign supplies of energy, OECD countries continue to subsidize coal production, while funding R&D in clean coal and carbon sequestration technologies. Coal continues to dominate the power markets in China and India due to relatively fewer concerns about the environment.

Among the less carbon-intensive primary fuels, natural gas gains the most market share (21 to 23 percent), while renewable energy resources are flat. Gas demand is supported by inroads into the power market (CCGT and some distributed fuel cells), despite the relatively high cost of gas to coal, and minor ones into the transportation market (GTL, CNG and methanol). OECD governments (especially European ones) provide generous incentives for fuel cell vehicles late in the projection period. The LNG trade skyrockets and inter- and intra-continental pipeline projects proliferate in the Business World.

Among the renewables, biomass and waste lose some market share (11 to 10 percent), hydropower's share is flat (2 percent), while so-called other alternatives gain share (1 to 2 percent). The major reason biomass and waste lose share is because traditional fuels become a relatively less important fuel source as countries develop.

"Other alternatives" gain market share, especially in OECD countries. Governments in these countries provide incentives for energy security and environmental reasons, while some consumers are willing to pay a price premium for branded "green" energy. In the developing countries, other alternatives make solid inroads into remote regions based on price alone—conventional sources of power in off-grid regions tend to be very expensive. Wind power initially drives the growth in other alternatives, especially with costs falling substantially as turbines come to exceed 3 megawatts (MW). The completion of a world-scale photovoltaic manufacturing plant in 2020 substantially reduces the cost of solar energy, making it the alternative of choice for the rest of the period.

Nuclear power loses some market share (from 6 to 5 percent) in the Business World, primarily because of continuing safety concerns (including fear of terrorist attacks), especially in developed countries. Few new plants are built in OECD countries through 2030, although licenses tend to be extended, but several developing countries commission new plants.

3.2.2 Political World

The world energy market is relatively stagnant in Political World. Growth in world energy demand is weak, partly due to fairly substantial improvements in energy intensity through 2030 due to security of supply concerns. De-carbonization grinds to a halt, while liberalization shifts into reverse (along with globalization) due to security of supply concerns. The process of electrification continues, although the source of power tends to be relatively conventional, coal plants. The Kyoto Protocol and sustainable development become dead issues under this scenario.

World energy demand growth averages 0.9 percent annually over the projection period (see Table 3.2). Improvements in energy intensity average 1.6 percent per year, despite relatively slow technological advancement and capital turnover, and heavy industries (including defense industries) tending to dominate growth. Security of supply concerns come to dominate energy policy in the major consuming countries as the New Cold War progresses and political instability increases in many major oil and gas producing countries.

The shift away from carbon intensive fuels slows in Political World. Coal's share of the energy mix increases one percentage point (to 26 percent) between 2004 and 2030, whereas oil's share declines from 35 to 33 percent due to a concerted effort by major consuming countries to slow their dependence on foreign (re: Middle East) oil.

Although WTI averages $60 per barrel over the projection period, oil prices are significantly lower during the five economic recessions (see Table 3.3). Since oil remains the fuel-of-choice in Political World, prices for other primary fuels are pulled higher. Natural gas at Henry Hub averages $7.25 per MMbtu.

Although non-OPEC producers lose market share through 2030, their share remains above 50 percent due to relatively strong oil prices and government policies supporting security of supply. Major consuming governments fund R&D to improve upstream technologies, while providing royalty relief and direct subsidies to boost domestic production. Similar government policies also support the coal market, as does a lack of concern about the environment, especially in developing countries such as China and India.

Since the carbon shift fizzles in Political World, neither gas, renewables nor nuclear gain substantial market share. The share of natural gas in the fuel mix is flat (21 percent), with coal regaining share in the power market through the projection period. Biomass and waste lose one percentage point (to 10 percent), hydropower's share of the market remains steady at 2 percent, while other alternatives gain a single point (to 2 percent). Other alternatives benefit from security of supply concerns in major consuming countries and a desire for quality power in remote regions in the developing world.

Nuclear's share of the primary energy market increases one percentage point (to 7 percent) through 2030. Its share declines slightly in the FSU, holds steady in the OECD and increases fairly substantially in non-OECD countries. Security of supply concerns drive the commissioning of new plants and extensions of existing ones in OECD and developing Asia, while the desire to produce nuclear weapons drives nuclear plant construction in some non-OECD countries.

3.2.3 Environmental World

The world energy market is very dynamic in Environmental World, despite fairly weak growth in energy demand. Improvements in energy intensity are extremely strong, while de-carbonization of the energy mix and electrification of final consumption continue full speed ahead—power

becomes much more distributed under this scenario. However, the liberalization of energy markets is tempered by environmental concerns, especially about global climate change. The world community eventually agrees to stabilize atmospheric carbon levels below 550 parts per million, the oft-cited safe maximum level. This initiative is supported by substantial government efforts, as well as a global carbon trading system. Energy security declines in importance through the projection period because of increasing international cooperation and a lack of geopolitical rivalry.

Technological change specific to the energy industry tends to be revolutionary in nature, although the diffusion of the more disruptive technologies does not occur until later in the projection period. In the power sector, for example, stationary fuel cells displace CCGT as the best selling technology by 2015, while solar photovoltaic begin to make major inroads into the power market after 2020. Improvements in fuel cells, including production processes, drive down the cost of the mobile applications. The combination of lower costs and increased government subsidies, especially in developed countries, help fuel cells become the best selling automotive power source in OECD countries by 2030—although most fuel cell vehicles are fueled by extremely high-quality gasoline and onboard hydrogen converters.

World energy demand growth averages 1.2 percent per year in Environmental World, while energy intensity declines an average 1.8 percent annually (see Table 3.2). A steady improvement in energy intensity—from 1.6 in 2004 to 2.0 percent in 2030—is fueled by concerted government action, including substantial funding for conservation programs, R&D for more energy efficient end-use technologies and the transfer of more energy efficient technologies to the developing world.

The shift away from high carbon fuels continues at a fairly rapid pace in Environmental World. Natural gas, the bridging fuel to the hydrogen economy, and renewables (besides hydropower) are the winners. Gas gains four percentage points of market share (to 25 percent), due to major inroads into the power sector (e.g., CCGT, fuel cells) and solid inroads into transportation (e.g., GTL, CNG, methanol).

Among the renewables, biomass and waste lose one percentage point of market share (to 10 percent), hydropower maintains its share of the primary energy market (2 percent), while other alternatives gain two percentage points (to 3 percent). Wind power leads the growth in other alternatives until around 2015, at which time solar photovolataic become the primary driver. Major improvements in battery technology post-2015, supported by government funded R&D, help distributed power from intermittent sources (e.g., wind and solar) win a fairly substantial share of the power market. The World Bank establishes micro-credit programs to encourage the spread of wind and solar power to remote regions in the developing world. Within biomass and waste, traditional fuels lose market share while biofuels gain share.

Nuclear power gains one percentage point (to 7 percent) of the world energy market through 2030. Declining market share in the FSU is overshadowed by increasing share in the non-OECD—market share is flat in the OECD. Nuclear power performs better in Environmental World than Business World because of the greater concern about climate change in the former than the latter.

On the other side of the carbon shift ledger, coal and oil lose six (to 19 percent) and two (to 33 percent) percentage points of market share, respectively. The primary reasons for these declines are taxation policies favoring less carbon-intensive fuels and major technological advancements partially funded by governments. In regards to the transportation sector, oil's last bastion, super-efficient ICE vehicles and hybrids in the first half of the projection period and fuel cell vehicles (methanol and gasoline) in the second whittle demand away from oil. In regards to the

power sector, coal's primary market, CCGT, stationary fuel cells, and solar photovoltaic erode demand for coal in successive waves. Coal would lose even more market share, especially in China and India, were it not for government funded R&D on liquid coal and carbon sequestration. Clean coal technologies become cost effective at the end of our projection period.

The average WTI price of $40 per barrel (US$ 2004) in this scenario is at a slight discount to natural gas prices—average $7.75 per MMbtu at Henry Hub (see Table 4.3). Gas becomes the fuel-of-choice in the second half of the 2010s due to environmental legislation and technological advancements. Seeing an opportunity to maximize revenue, several major gas-exporting countries—including Russia, Iran and Qatar, three countries that account for over 40 percent of proved reserves—collude to slow the pace of capacity expansion to bolster prices. This strategy is akin to the one followed by the Seven Sisters to bolster oil prices and revenue from the 1930s to the early 1970s.

CHAPTER 4
PRIMARY ENERGY MARKET

The world energy market differs greatly under the three scenarios through 2030 in terms of major trends such as consumption growth, de-carbonization, electrification, and market liberalization. In terms of the latter, energy markets continue to liberalize under Business World, but the process is constrained by security of supply concerns in Political World and environmental concerns in Environmental World. In North America, differences in the major trends tend to be more pronounced for the three scenarios, since North America is a major consuming region.

In this chapter, we discuss global energy markets in Section 4.1, regional energy markets in Section 4.2, and the North America energy market in Section 4.3.

4.1 Global Energy Market

In this section, we discuss the major assumptions for global energy markets, and world energy consumption trends for the three scenarios.

4.1.1 Major Assumptions

The major assumptions for our three global energy scenarios relate to the level of economic growth, rate of improvement in energy intensity (energy consumption per unit of output), and level of energy consumption. These, along with degree of resource availability, translate into different energy prices for the three scenarios.

As discussed in more detail in Chapter Two, economic growth varies in our three scenarios, depending upon the rate of population growth and capital accumulation, the diffusion of new knowledge and technologies, and globalization (see Table 4.1). As a result, economic growth is strongest in Business World (3.5 percent), moderate in Environmental World (3.0 percent) and weakest in Political World (2.5 percent).

As discussed in more detail in Chapter Three, several factors affect energy intensity including the rate and nature of economic growth, energy prices, the rate of technological advancement, and energy policies. Improvements in energy intensity are greatest in Environmental World (1.8 percent per year) and Political World (1.6 percent per year), primarily because energy policies in major consuming countries are most active in these scenarios for environmental and geopolitical reasons, respectively. In contrast, in Business World, where these factors are relatively minor concerns, energy policy tends to be more laissez-faire and improvements in energy intensity is lower (1.4 percent per year).

The combination of economic growth and improvements in energy intensity provide us with the rate of energy consumption for the three scenarios. It is assumed that energy consumption is very strong in Business World (2.1 percent), and relatively weak in Environmental World (1.2 percent) and Political World (0.9 percent). In comparison, energy consumption increased an average of 2.1 percent per year between 1971 and 2004.

Table 4.1: Major Assumptions for the Energy Scenarios (Annual average percent change)

	Historical	Scenarios (2004 - 2030)		
	1971 to 2004	Business World	Political World	Environmental World
Economic Growth	3.4	3.5	2.5	3.0
Energy Intensity	-1.3	-1.4	-1.6	-1.8
Energy Consumption	2.1	2.1	0.9	1.2

Hydrocarbon (and other energy) prices tend to be highest in Political World, the lowest in Environmental World, and fall in between these two extremes in Business World (see Table 4.2). The major exception is gas prices which are highest in Environmental World. The primary reason energy prices tend to be the highest in Political World, despite the slowest rate of energy demand growth, is resource availability is the lowest in this scenario. Although we assume the same amount of hydrocarbons in the ground under our three scenarios (as mentioned in Chapter 3), a high degree of conflict in major exporting countries and a high level of resource nationalism constrain the development of oil, and to a lesser extent gas resources, in Political World. The major driver for mid-level energy prices in the Business World is high energy demand. We assume a moderate level of resource availability, since conflict and resource nationalism are more subdued in this scenario. Finally, a high level of resource availability and fairly slow energy demand growth are the major reasons for (relatively) low prices in Environmental World, except gas where demand is relatively high.

Table 4.2: World Energy Price Assumptions (US$ 2004)

	Historical	Scenarios (2004 - 2030)		
	2004	Business World	Political World	Environmental World
WTI at Cushing ($/bbl)	41.49	50.00	60.00	40.00
Gas at Henry Hub ($/MMbtu)	6.18	6.75	7.25	7.75
US coal imports ($/tonne)	40.10	55.00	75.00	40.00
WTI at Cushing ($/MMbtu)	7.15	8.62	10.34	6.90
Gas at Henry Hub ($/MMbtu)	6.18	6.75	7.25	7.75
US coal imports ($/MMbtu)	1.76	2.41	3.29	1.75

The volatility of energy prices is the most extreme under Political World, the least extreme under Environmental World, and moderate under Business World. The major reason for these differences is due to the degree of cooperation versus conflict in the three scenarios. In the Political World, geopolitical competition rather than international cooperation in the political and economic spheres contributes to more pronounced business cycles, and hence, greater price volatility. In contrast, a high level of international political and economic cooperation in the Environmental World leads to relatively subdued business cycles and price volatility. Since Business World falls in between these extremes in terms of political and economic cooperation, its business cycles and price volatility fall into the mid-range.

In the three scenarios, oil tends to be the most expensive, gas the second most, and coal a distant third through the projection period. The primary reason for oil's continuing premium relative to the other fuels is its predominant role in the transportation sector. The only exception is under the Environmental World, where gas becomes the fuel of choice in the mid-2010s because of energy policies that support its environmentally favorable qualities. On the other

hand, coal is priced at a substantial discount to the other fuels because it is environmentally unfriendly and relatively inconvenient for end-use.

Historically, gas prices are the most volatile of the hydrocarbon prices, with oil prices about two-thirds as volatile, and coal prices about one-third. We have assumed similar relative price volatilities under Political World, somewhat lower price volatilities for oil, gas and coal under Business World, and even lower volatilities under Environmental World.

4.1.2 World Energy Consumption

In the Business World, energy consumption increases almost 70 percent, from 11,230 MTOE in 2004 to 18,888 MTOE in 2030 (see Table 4.3). Consumption increases about half as much in Environmental World (34 percent) and by 24 percent in Political World. In terms of relative winners and losers among the primary energy sources, gas and "other alternatives" (which include biomass and waste, wind, geothermal, solar, tide/wave) tend to gain market share across the scenarios, while coal and oil tend to lose market share. The major exceptions are oil in Business World and gas in Political World, whose shares remain flat over the projection period, and coal in Political World where it gains one percentage point. Nuclear loses a small amount of market share in Material World, but gains a small amount in both Political World and Environmental World. The share of hydro power remains flat across the scenarios. Biomass and waste loses a small amount of share in the three scenarios, but the performance of traditional biomass compared to modern biomass (e.g., biofuels) differs in each. Hence, de-carbonization of the primary fuel mix tends to continue, but at a faster pace in the Environmental World than the other two scenarios.

Table 4.3: World Energy Consumption

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
Energy Consumption	11230	100	18888	13921	15014	2.1	0.9	1.2	100	100	100
Coal	2756	25	4497	3576	2840	2.0	1.0	0.1	24	26	19
Oil	3880	35	6562	4527	4945	2.1	0.6	1.0	35	33	33
Gas	2322	21	4299	2900	3758	2.5	0.9	1.9	23	21	25
Nuclear	709	6	950	945	1047	1.2	1.1	1.5	5	7	7
Hydro	240	2	429	323	370	2.3	1.2	1.7	2	2	2
Biomass & Waste	1264	11	1862	1430	1552	1.5	0.5	0.8	10	10	10
Other Alternatives	59	1	289	220	501	6.4	5.2	8.8	2	2	3

Electrification increases across the three scenarios, due to its convenience and safety as an energy carrier compared to other end-use fuels (see Table 4.4). Electric power's gain is at the expense of coal, biomass and waste (especially traditional sources), and rather surprisingly, gas. Oil tends to hold or gain (Business World) market share, because of its dominant role in the fastest growing sector, transportation (see Table 4.5).

Table 4.4: Total Final Consumption

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
World	7697	100	12728	9177	10087	2.0	0.7	1.1	100	100	100
Coal	613	8	704	543	449	0.6	-0.5	-1.2	6	6	4
Oil	3213	42	5638	3879	4241	2.2	0.8	1.1	44	42	42
Gas	1214	16	1893	1283	1678	1.8	0.2	1.3	15	14	17
Electricity	1225	16	2488	1978	2030	2.8	1.9	2.0	20	22	20
Heat	258	3	351	253	281	1.2	-0.1	0.3	3	3	3
Biomass & Waste	1164	15	1606	1206	1309	1.3	0.1	0.4	13	13	13
Other Alternatives	9	0	48	35	100	6.7	5.4	9.8	0	0	1

Table 4.5: Total Final Consumption, by Sector

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
World	7697	100	12728	9177	10087	2.0	0.7	1.1	100	100	100
Industry	2451	32	3871	2839	3070	1.8	0.6	0.9	30	31	30
Transportation	1922	25	3691	2547	2834	2.6	1.1	1.5	29	28	28
Other Sectors	3033	39	4773	3517	3869	1.8	0.6	1.0	37	38	38
Non-Energy Use	291	4	393	274	315	1.2	-0.2	0.3	3	3	3

4.2 Regional Energy Markets

Among the major regions, growth in primary energy consumption is fastest in the developing countries, especially the non-OECD ones, in all three scenarios (see Table 4.6). The primary reason for relatively strong demand growth in the non-OECD, and less so the FSU, is relatively strong economic growth in these regions (see Table 4.7).

Table 4.6: Total Energy Consumption, by Region

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
World	11230	100	18888	13921	15014	2.1	0.9	1.2	100	100	100
OECD	5494	49	7560	5992	6320	1.2	0.3	0.5	40	43	42
Non-OECD	4509	40	9442	6555	7150	3.0	1.5	1.8	50	47	48
FSU	1080	10	1665	1209	1367	1.7	0.4	0.9	9	9	9
Bunker Fuel	147	1	221	165	177	1.6	0.5	0.7	1	1	1
North America	2762	25	3946	3095	3320	1.4	0.4	0.7	21	22	22

Table 4.7: Economic Growth Rates, by Region (Annual average percent change)

	Historical	2004 - 2030		
	1971 to 2004	Business World	Political World	Environmental World
World	3.4	3.5	2.5	3.0
OECD	2.9	2.4	1.7	2.1
Non-OECD	4.8	4.6	3.3	3.8
FSU	1.2	4.0	3.0	3.6
North America	3.1	2.6	1.9	2.3

Energy demand growth in non-OECD countries tends to be about 50 percent above the global average in the three scenarios. FSU growth tends to be about four-fifths the global rate, except under Political World (less than a half), where domestic demand is retarded by a lack of transportation demand for export gas. OECD energy demand growth ranges between 45 (Environmental World) and 55 (Business World) percent of the global average.

4.3 North America Energy Market

Economic growth in North America varies in the three scenarios in a similar fashion as for the world, although it tends to be somewhat less volatile. The major reason for less volatile economic growth is because North America (and the OECD as a whole) is assumed to have greater economic and political stability than other regions under all three scenarios. Economic growth in North America is 2.6 percent in the Business World, 2.3 percent in Environmental World, and 1.9 percent in Political World (see Table 4.8).

Table 4.8: Major Assumptions for North America
(Annual average percent change)

	Historical	Scenarios (2004 - 2030)		
	1971 to 2004	Business World	Political World	Environmental World
Economic Growth	3.1	2.6	1.9	2.3
Energy Intensity	-1.7	-1.2	-1.4	-1.6
Energy Consumption	1.4	1.4	0.4	0.7

Improvements in energy intensity are lower across the board for North America compared to the world, since developing countries tend to have more room for improvement. As a whole, developing countries are less energy efficient than developed ones. Improvements in energy intensity average 1.6 percent per year in Environmental World, 1.4 percent per year in Political World, and 1.2 percent in Business World.

As a result, it is assumed that energy consumption in North America is relatively strong in Business World (1.4 percent), and relatively weak in Environmental World (0.7 percent) and Political World (0.4 percent). In comparison, energy consumption increased 1.4 percent per year between 1971 and 2004. North America energy consumption tends to be somewhat stronger than total OECD for the three scenarios, since economic and population growth rates are assumed to be stronger in the former (see Tables 4.6 and 4.7).

The pattern of change in North America primary energy consumption for the three scenarios tends to be fairly similar to that of the world. Other alternatives tend to gain market share across the scenarios, while coal (except in Political World) and oil tend to lose market share (see Table 4.9). The major exceptions are gas losing market share in Political World, and a relatively strong performance by biomass and waste in North America, due to efforts to increase the production and use of bio-fuels. Biomass and waste and other alternatives tend to perform better than gas in North America compared to the world as a whole because North American gas resources are assumed to be relatively mature.

Table 4.9: North America Energy Consumption

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
Energy Consumption	2762	100	3946	3095	3320	1.4	0.4	0.7	100	100	100
Coal	584	21	790	712	465	1.2	0.8	-0.9	20	23	14
Oil	1131	41	1616	1111	1261	1.4	-0.1	0.4	41	36	38
Gas	646	23	908	681	863	1.3	0.2	1.1	23	22	26
Nuclear	238	9	276	279	299	0.6	0.6	0.9	7	9	9
Hydro	54	2	79	62	66	1.5	0.5	0.8	2	2	2
Biomass & Waste	92	3	179	172	217	2.6	2.4	3.3	5	6	7
Other Alternatives	16	1	99	77	149	7.2	6.2	8.9	3	3	4

De-carbonization of the primary fuel mix continues at a faster pace across the three scenarios in North America than the world; the reverse is true for the process of electrification. De-carbonization occurs at a faster pace because developed countries tend to be more committed to combating climate change over our projection period, partly due to greater resources to do so. In terms of electrification, the process is slower in North America because the electric power sector is already well developed (see Table 4.10). Transportation is the fastest growing sector in North America, as in the world, except in Political World (see Table 4.11). In this scenario, stringent policies are implemented by the US government to thwart rising dependency on foreign oil.

Table 4.10: North America Final Energy Consumption

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
North America	1891	100	2761	2078	2327	1.5	0.4	0.8	100	100	100
Coal	31	2	37	34	22	0.7	0.3	-1.4	1	2	1
Oil	1023	54	1494	1029	1166	1.5	0.0	0.5	54	50	50
Gas	404	21	512	379	488	0.9	-0.2	0.7	19	18	21
Electricity	363	19	582	511	487	1.8	1.3	1.1	21	25	21
Heat	7	0	10	8	9	1.5	0.5	0.8	0	0	0
Biomass & Waste	60	3	112	108	136	2.4	2.2	3.2	4	5	6
Other Alternatives	2	0	13	10	20	7.5	6.4	9.1	0	0	1

Table 4.11: North America Final Consumption, by Sector

	2004		2030 (MTOE)			2030 (Ann % Ch)			2030 (% Share)		
	MTOE	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
North America	1891	100	2761	2078	2327	1.5	0.4	0.8	100	100	100
Industry	498	26	690	551	609	1.3	0.4	0.8	25	27	26
Transportation	747	39	1199	824	954	1.8	0.4	1.0	43	40	41
Other Sectors	572	30	764	628	675	1.1	0.4	0.6	28	30	29
Non-Energy Use	75	4	107	75	87	1.4	0.0	0.6	4	4	4

CHAPTER 5
THE OIL MARKET

The world oil market under the three global scenarios differs greatly through 2030 in terms of oil prices, market structure and fundamentals—oil demand, and non-OPEC and OPEC supply. These in turn lead to very different levels of import dependency among the major consuming regions. The role of Alberta's oil industry in the context of the North America and global oil markets also differ under the scenarios, especially crude bitumen production.

In this chapter, we discuss the world oil market in Section 5.1 and the Alberta oil supply in Section 5.2.

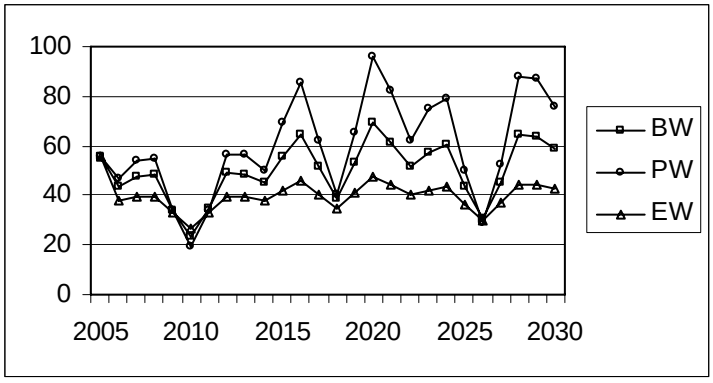
5.1 World Oil Market

In this section, we discuss the world oil market under the three global scenarios.

5.1.1 Business World

Business World is the most attractive scenario for OPEC. Strong oil demand, and relatively high market share, leads to the highest oil revenues for the organization. In addition, the average real price for WTI, which tends to be moderately volatile in this scenario, is $50 per barrel (US$ 2004; see Figure 5.1).

Figure 5.1: WTI Prices
(US$ 2004 per barrel)



Strong world energy demand translates into strong oil demand in the Business World, with each increasing 2.1 percent per year (see Table 5.1). World oil demand rises by 55.8 MMbpd, from 81.6 MMbpd in 2004 to 137.4 MMbpd in 2030. Most of this growth comes from the booming developing countries, with non-OECD and FSU demand increasing an average 3.4 percent and 2.0 percent per year, respectively. In contrast, OECD oil demand grows 1.1 percent per year on average, resulting in a slide in market share from 60 percent to less than a half.

Table 5.1: World Oil Market

	2004		2030 (MMbpd)			2030 (Ann % Ch)			2030 (% Share)		
	MMbpd	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
Oil Demand											
OECD	49.1	60	65.6	46.7	50.8	1.1	-0.1	0.2	48	49	49
Non-OECD	27.2	33	63.2	42.0	46.0	3.4	1.8	2.1	46	44	44
FSU	5.2	6	8.6	6.3	6.8	2.0	0.8	1.1	6	7	7
Total Demand	81.6	100	137.4	95.0	103.6	2.1	0.7	1.0	100	100	100
North America	25.0	31	35.5	24.5	27.8	1.4	0.0	0.5	26	26	27
Oil Supply											
Non-OPEC	48.8	59	68.7	56.0	45.9	1.3	0.6	-0.1	50	60	44
OECD	20.8	25	23.2	24.6	13.5	0.4	0.7	-1.4	17	26	13
Non-OECD	15.2	18	19.9	16.0	15.0	1.0	0.3	0.0	15	17	14
FSU	10.9	13	21.4	12.7	14.3	2.6	0.6	1.1	16	14	14
Process Gains	1.8	2	4.1	2.8	3.1	3.3	1.9	2.2	3	3	3
OPEC	32.1	39	68.7	37.4	56.2	3.0	0.7	2.3	50	40	54
Gulf	19.9	24	43.3	20.7	34.9	3.0	0.2	2.3	31	22	34
Non-Gulf	8.0	10	14.3	8.3	12.6	2.2	0.2	1.9	10	9	12
NGLs	4.2	5	11.2	8.3	8.7	3.9	2.8	3.0	8	9	8
Total Supply	81.6	100	137.4	93.4	103.6	2.0	0.6	1.0	100	100	100
North America	14.2	17	19.5	20.6	11.4	1.2	1.5	-0.7	14	22	11

The combination of fairly high crude oil prices (relative to other scenarios) and rapid technological advancement leads to strong non-OPEC supply growth through 2030. Non-OPEC oil supply grows by 19.9 MMbpd, from 48.8 MMbpd in 2004 to 68.7 MMbpd in 2030. Despite increasing an average of almost 0.8 MMbpd per year, non-OPEC's share of the world oil market drops from 59 percent to 50 percent. OECD production increases an average 0.4 percent per year, non-OECD output by 1.0 percent and FSU production by 2.6 percent. Oil production in the FSU, Africa and Latin America increases at similar rates as OPEC, while production contracts in OECD Europe, non-OECD Asia (China, India and other Asian countries) and non-OECD Middle East. Although this, along with high oil demand, contributes to a fairly substantial increase in oil import dependency among the major oil consuming countries, (especially OECD Europe and non-OECD Asia), this is not a major concern for their governments under this scenario (see Table 5.2).

Table 5.2: World Oil Import Dependency (percent of regional demand)

		2030		
	2004	BW	PW	EW
OECD	58	65	47	73
North America	43	45	16	59
Europe	61	85	78	88
Pacific	93	93	91	95
Non-OECD Asia	51	84	74	87
China	47	84	67	88
India	72	92	83	94
Other Asia	45	80	77	80

As a result, there is plenty of residual demand for OPEC oil in the Business World. OPEC oil production increases by 36.6 MMbpd, from 32.1 MMbpd in 2004 to 68.7 MMbpd in 2030. With an average increase of 3.0 percent per year, OPEC remains a very cohesive organization in the future. However, Gulf producers increase crude oil production by 3.0 percent per year, faster than OPEC non-Gulf suppliers (2.2 percent). NGL production continues to race ahead; increasing by 3.9 percent annually (NGLs are not included in production quotas). OPEC's share of the rapidly expanding oil market increases from 39 to 50 percent. Iraq returns to the OPEC fold later this decade.

5.1.2 Political World

Political World is the least attractive scenario for OPEC. Despite the real price of WTI averaging $60 per barrel, weak oil demand and low market share lead to the lowest OPEC oil revenues—similar to those in Environmental World. In addition, prices and revenues are the most volatile in this scenario due to extreme business cycles and supply disruptions.

Weak energy demand growth translates into sluggish oil demand growth in Political World (0.9 percent per year and 0.7 percent, respectively). World oil demand increases by 13.4 MMbpd between 2004 and 2030. Oil demand growth is relatively slow in the developing countries, compared to the Business World, due to slower economic growth ensuing from the collapse of globalization and the proliferation of regional and domestic conflicts. FSU oil demand increases an average 0.8 percent per year, non-OECD demand by 1.8 percent per year and OECD demand contracts slightly (0.1 percent per year). The OECD's share of world oil demand drops from 60 percent to 49 percent over the period.

Non-OPEC oil supply grows fairly slowly over 2004 to 2030 in Political World, despite high oil prices. Security of supply concerns shift to the forefront in this geopolitically-driven world, while technological advancements are slow. As a result, major consuming countries adjust their royalty and tax regimes to promote domestic production, while encouraging their international oil companies to re-direct spending to "secure" sources of supply (especially OECD producers). Growth in FSU production tends to be relatively low in this scenario because Russian production comes to be viewed as an insecure source of supply by Europe. Oil import dependency rates decrease somewhat in all the major consuming countries, with the major exception of North America, where rates decline substantially.

Non-OPEC supply increases by 7.2 MMbpd through 2030, an average of 0.6 percent per year. OECD production increases an average 0.7 percent per year, non-OECD production increases by 0.3 percent per year, and FSU output by 0.6 percent. Besides OECD Europe, production declines in non-OECD Asia and non-OECD Middle East.

As the residual supplier to the world oil market, OPEC pays the price in terms of volumes, with its oil production increasing a mere 5.3 MMbpd by 2030 (0.7 percent per year). Oil revenues are only about two-thirds those in Business World. OPEC's share of the slowly growing world oil market stagnates in this scenario at around 40 percent. OPEC crude oil production increases about 0.2 percent per year; NGL output increases substantially faster (2.8 percent per year) primarily because of rising natural gas use in the region.

5.1.3 Environmental World

From a revenue perspective, Environmental World is an equally unattractive scenario as Political World, despite OPEC having the highest market share. The major reasons are relatively weak demand growth and the real price of WTI averaging only $40 per barrel. However, OPEC oil

revenues tend to be the least volatile in this scenario, due to greater international financial and economic cooperation.

World oil demand grows 22.0 MMbpd through 2030 in Environmental World, or 1.0 percent per year, compared to 1.2 percent for world energy demand. In the OECD countries, oil demand growth slows substantially to 0.2 percent per year due to new environmental initiatives and the relatively rapid diffusion of revolutionary transportation technologies. In contrast, non-OECD demand increases 2.1 percent per year and FSU demand by 1.1 percent. As a result, the OECD's share of world oil demand declines from 60 percent to about a half.

Non-OPEC producers are under pressure in Environmental World, especially the high-cost ones. Non-OPEC supply drops by 2.9 MMbpd between 2004 and 2030, an average decline of 0.1 percent per year. OECD producers are especially hard hit, with output declining an average 1.4 percent annually, with growth in non-conventional production from North America retarded somewhat due its high environmental costs. Non-OECD production is basically flat, with only two regions experiencing positive growth—low-cost Africa and Latin America. Relatively low-cost FSU production grows by 1.1 percent per year. Oil import dependency rates for the major consuming countries substantially increase in this scenario, but this does not pose a serious concern for their governments in this cooperative world.

Oil production in OPEC countries increases 24.1 MMbpd between 2004 and 2030, or an average 2.3 percent per year. Gulf producers increase crude oil production by 2.3 percent per year, somewhat faster than OPEC non-Gulf suppliers (1.9 percent). NGL production continues its rapid rise, increasing by 3.0 percent annually. As a result, OPEC's share of the world oil market increases from 39 to 55 percent through 2030. The bulk of this increase goes to Gulf producers (10 points), and another three points to NGLs.

5.2 Alberta's Oil Supply

In this section, we discuss Alberta's role in the world oil market, as well as Alberta oil production by type for the three scenarios

5.2.1 Alberta's Role in the World Oil Market

Alberta's oil performs at least quite well under the three energy scenarios. However, what is good for the global economy and world oil industry is not necessarily good for Alberta's oil industry (and vice versa). Alberta oil performs the best in Political World, second best in Business World, and the worst in Environmental World.

Since Alberta oil is considered a secure source of supply by the US and environmental issues are considered relatively unimportant, Alberta oil revenues, production and market share are highest under Political World. This is despite global economic and oil demand growth being the lowest. Alberta's oil production increases from 2.3 MMbpd to 7.5 MMbpd over the projection period (4.9 percent per year). This 5.2 MMbpd increase in Alberta oil production represents about 80 percent of the total increase in North American production. Alberta oil production comes to cover 31 percent of North American demand in 2030, compared to 9 percent in 2004, and contributes to a 27 percentage point drop (to 16 percent) in North America's oil import dependency rate. Alberta's share of world oil supply increases from 3 to 8 percent under this scenario.

Under Business World, Alberta oil revenues, production and market share are second highest, despite world economic and oil demand growth being the strongest in this scenario. Alberta's oil production increases by 4.1 MMbpd (4.3 percent per year) to 6.4 MMbpd in 2030. As a result, Alberta contributes more than three-quarters of the increase to continental oil production.

Despite Alberta's oil production coming to cover 18 percent of North America oil demand coverage, double its 2004 share, North America's oil import dependency rate remains fairly flat (43 to 45 percent) through the projection period. Alberta's share of world oil supply increases from 3 to 5 percent under this scenario.

Since environmental concerns are the major driver for energy policies in Environmental World, and security of supply concerns are considered relatively unimportant, Alberta oil revenues, production and market share are lowest—despite global economic and oil demand growth being moderate in this scenario. Alberta's oil production doubles from 2.3 MMbpd to 4.8 MMbpd over the projection period (3.4 percent per year). This 2.5 MMbpd increase in Alberta oil production fails to compensate for the 5.3 MMbpd decline elsewhere in North America. Alberta oil production comes to cover 17 percent of North American demand in 2030, while North America's oil import dependency rate rises by 16 percentage points to 59 percent. Alberta's share of world oil supply increases from 3 to 5 percent.

Table 5.3: Oil Production

	2004		2030 (MMbpd)			2030 (Ann % Ch)			2030 (% Share)		
	MMbpd	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
World	81.6	100	137.4	93.4	103.6	2.0	0.6	1.0	100	100	100
North America	14.2	17	19.5	20.6	11.4	1.2	1.5	-0.7	14	22	11
Alberta	2.3	3	6.4	7.5	4.8	4.3	4.9	3.4	5	8	5

Table 5.4: Alberta Oil Production (percent of demand)

		2030		
	2004	BW	PW	EW
World Demand	3	5	8	5
North America Demand	9	18	31	17

5.2.2 Alberta Oil Production, by Type

As the projection period progresses, crude bitumen production comes to dominate Alberta oil production in all three scenarios. Crude bitumen production increases to between 4.5 to 7.0 MMbpd (5.6 to 7.5 percent per year) in 2030, compared to 1.1 MMbpd in 2004. In contrast, conventional oil production declines from 0.60 MMbpd to between 0.14 and 0.24 MMbpd (3.5 to 5.5 percent per year) over the period, while NGLs production declines from 0.62 MMbpd to between 0.16 and 0.28 MMbpd (3.0 to 5.0 percent per year). As a result, crude bitumen's share of Alberta oil production doubles in all three scenarios to 93-94 percent in 2030, compared to 47 percent in 2004. For further details, see Appendix A.

Table 5.5: Alberta Oil Production, by Type

	Historical		Business World			Political World			Environmental World		
	2004		2030		2004-2030	2030		2004-2030	2030		2004-2030
	MMbpd	% share	MMbpd	% share	% per year	MMbpd	% share	% per year	MMbpd	% share	% per year
Alberta Oil	2.31	100	6.40	100	4.0	7.52	100	4.7	4.80	100	2.9
Conventional	0.60	26	0.18	3	-4.5	0.24	3	-3.5	0.14	3	-5.5
Crude Bitumen	1.09	47	6.00	94	6.8	7.00	93	7.5	4.50	94	5.6
NGLs	0.62	27	0.21	3	-4.0	0.28	4	-3.0	0.16	3	-5.0

CHAPTER 6
NATURAL GAS MARKET

The world gas market under CERI's global scenarios differs greatly through 2030 in terms of market structure and fundamentals. On the other hand, gas prices are less variable due to counteracting shifts in market structure and the movements in fundamentals. Gas demand growth is relatively strong in Business World and Environmental World, exceeding overall energy demand growth in each case. In contrast, gas demand growth in Political World simply matches energy demand growth. These scenarios in turn lead to very different levels of import dependency among the major consuming regions. In addition, the role of Alberta's gas industry in the context of North America and global gas markets will also differ under the scenarios, especially non-conventional gas.

In this chapter, we discuss the world gas market in Section 6.1 and Alberta gas supply in Section 6.2.

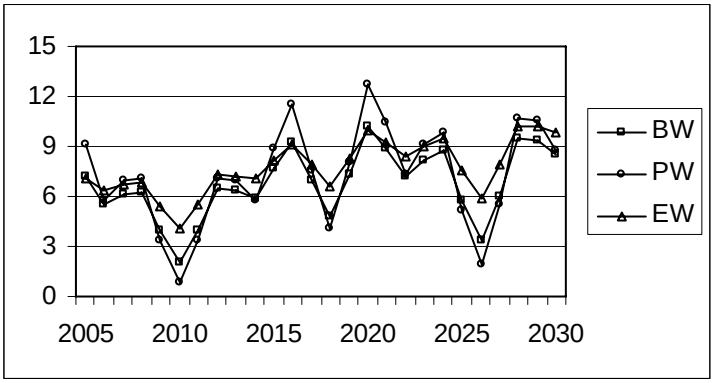
6.1 World Gas Market

In this section, we discuss the world gas market under the three global scenarios.

6.1.1 Business World

The world gas market is very strong in the Business World. Gas tends to sell at a slight discount to oil in North America (see Figure 6.1), with an average real price of $6.75 per MMbtu at Henry Hub (US$ 2004).

Figure 6.1: Henry Hub Gas Prices
(US$ 2004 per MMbtu)



Strong world energy demand translates into very strong gas demand in the Business World, with the former increasing an average 2.1 percent annually and the latter by 2.5 percent (see Table 6.1). World gas demand rises by 77.5 Tcf, from 91.0 in 2004 to 168.5 Tcf in 2030. Although this represents a large 3.0 Tcf increase per year overall, the increment is significantly smaller earlier in the projection period. Demand for gas grows especially briskly in the relatively immature non-OECD markets, rising an average 4.2 percent per year. Gas demand increases at a third this rate in the OECD and by 2.0 percent per year in the FSU over the projection.

Table 6.1: World Gas Market

	2004		2030 (TCF)			2030 (Ann % Ch)			2030 (% Share)		
	TCF	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
Gas Demand											
OECD	47.2	52	69.1	50.9	64.7	1.5	0.3	1.2	41	45	44
Non-OECD	23.3	26	65.4	40.0	54.1	4.2	2.1	3.4	39	35	37
FSU	20.5	22	34.1	22.8	28.5	2.0	0.4	1.3	20	20	19
Total Demand	91.0	100	168.5	113.7	147.3	2.5	0.9	1.9	100	100	100
North America	25.3	28	35.6	26.7	33.8	1.3	0.2	1.1	21	23	23
Gas Supply											
OECD	36.8	40	31.0	35.6	22.3	-0.7	-0.1	-1.9	18	31	15
Non-OECD	28.7	31	88.9	48.3	78.3	4.5	2.0	3.9	53	42	53
FSU	25.6	28	48.6	29.8	46.7	2.5	0.6	2.3	29	26	32
Total Supply	91.0	100	168.5	113.7	147.3	2.4	0.9	1.9	100	100	100
North America	24.6	27	22.3	25.6	15.6	-0.4	0.2	-1.7	13	23	11

As a result, the non-OECD share of world gas demand increases from 26 to 39 percent through the projection period, with the OECD losing the bulk of the share. Within the OECD, gas demand grows faster in Asia-Pacific than the other regions primarily due to availability of untapped indigenous supplies. The most dynamic non-OECD gas markets are China, India, and Africa, whose markets are relatively immature at the present time. Security of supply and environmental concerns tend to drive up gas consumption in China and India, whereas the rapid development of gas reserves feeds growth in Africa. Natural gas demand growth is relatively slow in the FSU, primarily because these markets are already well-developed, and the continuing turnover of highly inefficient Soviet-era machinery (earlier in the period).

Although the major driver for natural gas supply was domestic demand in the past, since it is relatively expensive to transport gas long distances, declining OECD gas production cannot meet 38.1 Tcf of regional demand in 2030. In the Business World, rapid technological advancement cannot counter relatively mature gas basins in the OECD, especially North America and Europe. OECD gas supply declines by 5.8 Tcf (0.7 percent per year), from 36.8 Tcf in 2004 to 31.0 Tcf in 2030. The OECD's share of world gas supply declines from 40 percent to 18 percent. Since North America becomes a major gas importer through the projection period, joining the other two OECD regions, a global LNG market develops in this scenario (see Table 6.2).

Table 6.2: World Gas Import Dependency (percent of regional demand)

		2030		
	2004	BW	PW	EW
OECD	22	55	30	66
North America	3	37	4	54
Europe	38	72	57	79
Pacific	69	80	64	76
Others				
China	0	68	10	74
India	9	65	11	72

Non-OECD gas supply increases substantially in Business World, more than tripling from 28.7 Tcf in 2004 to 88.9 Tcf in 2030. With the annual increase averaging 4.5 percent, the non-OECD share of world supply rises from 31 to 53 percent. All regions experience strong supply growth, except India and China, who become major gas importers through the period. In contrast, Africa and the Middle East, and to a lesser extent other Asia and Latin America, become major gas exporters. Excess production allows the non-OECD to cover almost two-thirds of the OECD's shortfall in 2030.

The FSU makes up the other third of the OECD's shortfall, despite relatively slow production growth compared to the other developing countries (2.5 versus 4.5 percent). FSU gas supply almost doubles from 25.6 Tcf in 2004 to 48.6 Tcf in 2030, maintaining a stable share of the world gas market (around 29 percent).

In the Business World, trans-regional exports rise from 10.5 Tcf in 2004 to 45.7 Tcf in 2030. This translates into an average 1.4 Tcf increase in long-distance pipeline, LNG and GTL infrastructure per year. The rate of growth in infrastructure is significantly smaller in the first half of the projection period.

6.1.2 Political World

The world gas market is fairly weak in Political World. Natural gas continues to sell at a discount to oil in North America through 2030 since oil continues to be the fuel-of-choice. The average real price for gas is $7.25 per MMbtu at Henry Hub (US$ 2004).

Weak world energy demand growth translates into sluggish natural gas demand growth in Political World, at 0.9 percent each. World gas demand grows by 22.7 Tcf over the period, or an average 0.9 Tcf per year. Non-OECD gas demand increases an average 2.1 percent per year, FSU demand by 0.4 percent per year, and OECD demand by 0.3 percent. As a result, non-OECD share of world gas demand increases from 26 to 35 percent, while OECD share declines 7 percentage points and the FSU by 2 points.

In Political World, OECD gas production declines slightly (to 35.6 Tcf), an average 0.1 percent per year, compared to a 0.3 percent per year increase in demand. As a result, the OECD's share of world gas supply slips nine percentage points. Growth is strongest for Asia-Pacific gas production, mildly positive for North America, and declines in Europe. A world LNG market does not develop in this scenario because relatively sluggish demand growth in North America does not translate into a major need for gas from outside the region.

Non-OECD gas supply grows by 19.6 Tcf through 2030. The non-OECD share of world gas supply increases 11 percentage points, fueled by average annual increases of 2.0 percent per year. Neither India nor China becomes major gas importers through the period, because security of supply retards the development of their markets. The non-OECD covers half of the OECD's shortfall by 2030.

As a result, the FSU fails to gain additional market for its natural gas in the OECD under this scenario. FSU gas (especially Russian gas) comes to be viewed as insecure supply by Europe as the great power rivalry intensifies through the projection period, and the FSU creeps deeper into the Chinese camp. FSU gas supply grows by 4.2 Tcf by 2030, compared to a 2.3 Tcf increase in domestic demand. The FSU's share of world gas supply declines slightly over the projection period (28 to 26 percent).

In Political World, trans-regional exports rise by only 5.2 Tcf through 2030, which translates into an average increase of 0.2 Tcf per year.

6.1.3 Environmental World

The world gas market is very strong and dynamic in Environmental World. Following the US jumping onto the environmental bandwagon, natural gas becomes the world's fuel-of-choice in the middle of next decade. This opens the door for a number of major gas exporting countries to slow capacity expansion to manipulate gas prices to a premium to oil and above its marginal cost. The average real price for gas is $7.75 per MMbtu at Henry Hub (US$ 2004).

World gas demand growth is substantially stronger than energy demand growth in Environmental World, with the former averaging 1.9 percent per year, compared to 1.2 percent per year for the latter. World gas demand increases 56.3 Tcf between 2004 and 2030, or an average 2.2 Tcf increment per year. Non-OECD gas demand rises an average 3.4 percent per year, OECD demand by 1.2 percent per year, and FSU demand by 1.3 percent. The non-OECD share of world gas demand increases 11 percentage points, with OECD losing eight percentage points and the FSU losing three points.

Despite relatively high gas prices in Environmental World, OECD supply declines substantially through 2030 due to environmental concerns related to the production of non-conventional gas. Gas production drops by 14.5 Tcf, an average 1.9 percent per year. As a result, OECD share of gas supply declines by 25 percentage points. Asia-Pacific is the only region to experience production growth, while relatively mature North America and Europe suffers substantial annual declines. The combination of relatively weak production and fairly strong demand growth forces the OECD to cover a 42.4 Tcf production shortfall by 2030. A world LNG market develops in this scenario since North America becomes a major gas importer over the period.

Non-OECD gas supply almost triples in Environmental World, from 28.7 Tcf in 2004 to 78.3 Tcf in 2030. This 3.9 percent average annual increase pushes the non-OECD share of the world gas market from 31 to 53 percent. China and India become major gas importers over the period. Excess production allows the non-OECD to cover about 57 percent of the OECD's shortfall by 2030.

As a result, the FSU again makes up about 43 percent of the OECD's shortfall in Environmental World. FSU gas supply grows by 21.1 Tcf between 2004 and 2030, dwarfing domestic demand growth of 8.0 Tcf. The FSU's share of world gas supply slips three percentage points in this scenario.

In Environmental World, trans-regional exports rise by 39.3 Tcf through 2030, which translates into an average 1.5 Tcf increase per year. Of course, the annual increment is significantly smaller earlier in the projection period.

6.2 Alberta's Gas Supply

In this section, we discuss Alberta's role in the world gas market, as well as Alberta gas production by type for the three energy scenarios.

6.2.1 Alberta's Role in the World Gas Market

Alberta's gas does not perform overly well in any of the three global scenarios, primarily due to the mature nature of conventional gas in the region. All the same, what is good for the global economy and world gas industry is not necessarily good for Alberta's gas industry—as is the case for Alberta's oil industry. Alberta's gas performs the best in Political World, second best in Business World, and the worst in Environmental World.

In the Political World, Alberta gas revenues, production and market share are strongest, because Alberta is considered a secure source of supply by the US, and environmental issues are considered relatively unimportant. This is despite world economic and gas demand growth being the lowest. Alberta's gas production increases slightly, from 5.0 Tcf in 2004 to 5.3 Tcf in 2030 (0.3 percent per year). This 0.3 Tcf increase in Alberta gas production represents about 30 percent of the total increase in North America production. As a result, Alberta gas production continues to cover 20 percent of North American demand in 2030, helping to keep North America's gas import dependency rate static at 3 percent. Alberta's share of world gas supply slips one percentage point to 5 percent over the projection period (see Tables 6.3 and 6.4).

Table 6.3: Gas Production

	2004		2030 (TCF)			2030 (Ann % Ch)			2030 (% Share)		
	TCF	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
World	91.0	100	168.5	115.1	147.3	2.4	0.9	1.9	100	100	100
North America	24.6	27	22.3	26.0	15.6	-0.4	0.2	-1.7	13	23	11
Alberta	5.0	6	4.4	5.3	3.0	-0.5	0.3	-2.0	3	5	2

Table 6.4: Alberta Gas Production (percent of demand)

		2030		
	2004	BW	PW	EW
World Gas Demand	6	3	5	2
N. America Gas Demand	20	12	20	9

Alberta's gas revenues, production and market share are fairly weak under Business World, despite world economic and gas demand growth being the highest in this scenario. Alberta's gas production declines by 0.6 Tcf (0.5 percent per year) to 4.4 Tcf in 2030. As a result, Alberta contributes about a quarter of the decline in North America's gas production. Alberta gas production comes to cover only 12 percent of North American gas demand in 2030, compared to 20 percent in 2004. Since continental gas production declines in this scenario in the face of strong regional gas demand, North America's gas import dependency rate surges 34 percentage points to 37 percent in 2030. Alberta's share of world gas supply halves to 3 percent in 2030.

In Environmental World, Alberta's gas revenues, production and market share are extremely weak, since environmental concerns are considered paramount, and security of supply concerns relatively unimportant. This is despite global economic and gas demand growth being moderate in this scenario. Alberta's gas production declines from 5.0 Tcf in 2004 to 3.0 Tcf in 2030 (2.0 percent per year). This 2.0 Tcf decline in Alberta gas production contributes to a 9.0 Tcf decline in North America as a whole. The share of Alberta's gas production in North America gas demand coverage slips more than half to 9 percent over the projection period. North America's gas import dependency rate skyrockets to 54 percent in 2030, partly due to Alberta's share of world gas supply declining to 2 percent.

6.2.2 Alberta's Gas Production, by Type

As the projection period progresses, coalbed methane overtakes conventional gas production in all three scenarios. Coalbed methane production increases to between 1.64 and 3.01 Tcf per year (18.2 to 21.0 percent per year) in 2030, compared to 0.02 Tcf in 2004 (see Table 6.5). In

contrast, conventional gas production declines from 5.00 Tcf to between 1.32 and 2.27 Tcf (3.0 to 5.0 percent per year) over the period. As a result, coalbed methane's share of Alberta's gas production increases from a negligible amount in 2004 to between 55 and 60 percent. For further details, see Appendix B.

Table 6.5: Alberta Gas Production, by Type

	Historical		Business World			Political World			Environmental World		
	2004		2030		2004-2030	2030		2004-2030	2030		2004-2030
	Tcf	% share	Tcf	% share	% per year	Tcf	% share	% per year	Tcf	% share	% per year
Alberta Gas	5.02	100	4.35	100	-0.5	5.27	100	0.3	2.96	100	-2.0
Conventional	5.00	100	1.73	40	-4.0	2.27	43	-3.0	1.32	45	-5.0
Coalbed Methane	0.02	0	2.62	60	20.4	3.01	57	21.0	1.64	55	18.2

CHAPTER 7
THE COAL MARKET

The world coal market under the global scenarios differs greatly through 2030 in terms of coal prices, market structure and the fundamentals. In particular, the world coal market is greatly impacted by energy policies in major energy consuming countries, and whether these policies are driven by security of supply or environmental concerns. The production of coal follows similar regional patterns as coal demand in the global scenarios, since it is expensive to transport coal and coal is the most geographically dispersed hydrocarbon. In Political World, and less so Business World, coal tends to be promoted by major energy consuming countries to help minimize dependence on foreign oil and gas. Alberta's coal industry in the context of North America and global oil markets also differ under the scenarios.

In this chapter, we discuss the world coal market in Section 7.1 and Alberta coal supply in Section 7.2.

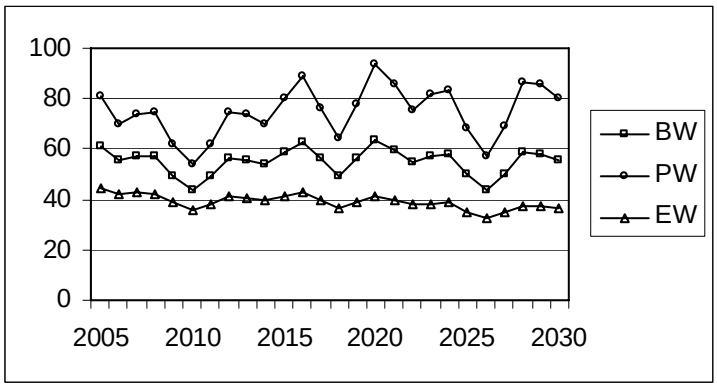
7.1 World Coal Market

In this section, we discuss the world coal market under the three global scenarios.

7.1.1 Business World

The world coal market is very strong in Business World. Although coal continues to sell at a substantial discount to oil, the average real price of US coal imports equals $55.00 per metric tonne (US$ 2004) over the projection period (see Figure 7.1).

Figure 7.1: US Coal Import Price
(US$ 2004 per Mt)



Strong world energy demand contributes to strong coal demand in Business World, with energy increasing 2.1 percent annually and coal increasing by 2.0 percent (see Table 7.1). World coal demand rises from 5,597 Mt in 2004 to 9,134 Mt in 2030, or 63 percent. Demand for coal grows especially quickly in the non-OECD, about 2.8 percent per year, whereas the rate of growth in OECD and FSU is only about a quarter this level.

As a result, the non-OECD share of world coal demand increases 13 percentage points to 64 percent in 2030. In contrast, OECD loses about 10 percentage points (to 31 percent) and FSU loses two points (to 5 percent). Within the OECD, coal demand grows fastest in North America, primarily due to the regional availability of high quality coal, and at a moderate rate in Asia-Pacific. Coal demand stagnates in Europe due to greater concern about the environment and the

low quality of their coal resource. The most dynamic non-OECD coal markets are other Asia, Latin America and India. Coal demand growth is relatively low in the FSU due to an abundance of oil and gas resources in the region.

Table 7.1: World Coal Market

	2004		2030 (Mt)			2030 (Ann % Ch)			2030 (% Share)		
	Mt	Share	MW	NBS	UT	MW	NBS	UT	MW	NBS	UT
Coal Demand											
OECD	2302	41	2804	2546	1658	0.8	0.4	-1.3	31	35	29
Non-OECD	2883	51	5838	4285	3800	2.8	1.6	1.1	64	59	66
FSU	413	7	493	431	309	0.7	0.2	-1.1	5	6	5
Total Demand	5597	100	9134	7262	5767	2.0	1.0	0.1	100	100	100
North America	1186	21	1604	1446	944	1.2	0.8	-0.9	18	20	16
Coal Supply											
OECD	2027	36	2336	2182	1362	0.5	0.3	-1.5	26	30	24
Non-OECD	3070	55	6180	4542	4017	2.7	1.5	1.0	68	63	70
FSU	501	9	618	538	388	0.8	0.3	-1.0	7	7	7
Total Supply	5597	100	9134	7262	5767	1.9	1.0	0.1	100	100	100
North America	1215	22	1633	1476	944	1.1	0.8	-0.9	18	20	16

In Business World, OECD coal production increases by 309 Mt (0.5 percent per year), from 2,027 Mt in 2004 to 2,336 Mt in 2030. The OECD's share of world coal production drops by 10 percentage points to 26 percent by the end of the period. Due to the low quality of its resource, Europe is forced to import additional volumes of coal as the projection period progresses.

Non-OECD coal supply increases substantially in Business World, doubling from 3,070 Mt in 2004 to 6,180 Mt in 2030. With the annual increase averaging 2.7 percent, the non-OECD share of world supply rises from 55 to 68 percent. All regions experience strong production growth.

Despite a large resource base, FSU coal production increases by only about a quarter (0.8 percent per year), to 618 Mt in 2030. As a result, FSU share of global coal production declines two percentage points to 7 percent at the end of the projection period.

7.1.2 Political World

The world coal market is fairly strong in Political World. As a result, the average real price of US coal imports equals $75.00 per Mt (US$ 2004) over the projection period.

Despite weak energy demand, coal demand is quite strong in Political World, with coal demand growth edging out energy demand growth (1.0 versus 0.9 percent per year). World coal demand increases about 30 percent to 7,262 Mt in 2030. Demand for coal grows relatively quickly in the non-OECD, about 1.6 percent per year, whereas the rate of growth in OECD (0.4 percent per year) and FSU (0.2 percent) is substantially lower.

As a result, the non-OECD share of world coal demand increases eight percentage points to 59 percent in 2030, with the OECD losing most of this share. Among the OECD regions, coal demand grows fastest in North America, and at a fairly slow rate in Asia-Pacific. Coal demand declines in Europe. Other Asia and Latin America experience the strongest demand growth among non-OECD regions. As previously mentioned, coal demand growth is relatively low in FSU.

In Political World, OECD coal production increases by 155 Mt (0.3 percent per year) to 2,182 Mt in 2030. The OECD's share of world coal production drops by 6 percentage points to 30 percent by the end of the period. Due to the low quality of its resource, Europe is forced to import additional volumes of coal as the projection period progresses.

Non-OECD coal production increases fairly substantially in Political World, increasing by almost a half to 4,542 Mt in 2030. With supply increasing an average 1.5 percent per year, the non-OECD share of world supply rises from 55 to 63 percent. Other Asia experiences especially strong growth in coal production.

FSU coal production increases from 501 Mt in 2004 to 538 Mt in 2030 (0.3 percent per year). As a result, FSU share of global coal production declines two percentage points to 7 percent at the end of the projection period.

7.1.3 Environmental World

The world coal market is very weak in Environmental World. As a result, the average real price of US coal imports equals $40.00 per Mt (US$ 2004) over the projection period.

Coal demand growth is substantially weaker than energy demand growth as a whole, 0.1 percent versus 1.2 percent per year, respectively. World coal demand increases a mere 3 percent, from 5,597 Mt in 2004 to 5,767 Mt in 2030. Non-OECD is the only region to experience positive growth in this scenario (1.1 percent per year). In contrast, coal demand contracts 1.1 percent per year in FSU and 1.3 percent in OECD due to international commitments to counter carbon emissions.

As a result, non-OECD share of world coal demand increases 15 percentage points to 66 percent in 2030, with the OECD losing 12 percentage points and FSU losing 2 points. Within the OECD, coal demand contracts at the fastest rate in Europe (2.4 percent per year) and about a third this rate in North America and Asia-Pacific. Demand growth is relatively strong across the non-OECD regions, except Africa where it is flat. As previously mentioned, coal demand growth is negative in FSU.

In Environmental World, OECD coal production declines by 665 Mt (1.5 percent per year) to 1,362 Mt in 2030. The OECD's share of world coal production declines by 12 percentage points to 24 percent by the end of the period. Due to the low quality of its resource, European coal production declines at a substantially higher rate than the other OECD regions.

Non-OECD coal production increases moderately in Environmental World, increasing about 30 percent to 4,017 Mt in 2030. With the annual increase averaging 1.0 percent, the non-OECD share of world supply rises from 55 to 70 percent. Production growth is relatively strong in all the non-OECD regions except Africa.

Despite a large resource base, FSU coal production declines by 23 percent to 388 Mt in 2030 (1.0 percent per year). As a result, FSU share of global coal production declines 2 percentage points to 7 percent at the end of the projection period.

7.2 Alberta's Role in the World Coal Market

Alberta's coal industry plays a relatively minor role in the world and North America coal markets compared to oil and gas in the three global scenarios, primarily due to the large quantity of high-

quality coal elsewhere in the world, especially the US. Alberta's coal performs the best in Political World, second best in Business World, and the worst in Environmental World.

Alberta coal revenues and market share are highest and coal production second highest in Political World. Alberta's coal production increases from 28 Mt to 38 Mt over the projection period (1.2 percent per year). This 10 Mt increase in Alberta coal production represents about 4 percent of the total increase in North American production. Alberta coal production covers 2.6 percent of North American demand in 2030, compared to 2.3 percent in 2004. Alberta's share of world coal supply remains steady at 0.5 percent over the period.

Under Business World, Alberta coal production is the highest, while revenues and market share are second highest. Alberta's coal production increases by 13 Mt (1.5 percent per year) to 41 Mt in 2030. As a result, Alberta contributes about 3 percent of the increase in continental coal production. In 2030, Alberta's coal production covers 26 percent of North America coal demand. Alberta's share of world oil supply declines 0.1 percentage point to 0.4 percent in 2030 under this scenario.

Alberta coal revenues and production are lowest in Environmental World, while market share mimics that of Business World. Alberta's coal production declines from 28 to 24 Mt over the projection period (0.5 percent per year). This 4 Mt decrease in Alberta coal represents about 1.5 percent of the total North America production decline. Alberta coal production covers 2.6 percent of North American demand in 2030. Alberta's share of world oil supply declines from 0.5 percent to 0.4 percent over the period. For further details, see Appendix C.

Table 7.2: Coal Production

	2004		2030 (Mt)			2030 (Ann % Ch)			2030 (% Share)		
	Mt	Share	BW	PW	EW	BW	PW	EW	BW	PW	EW
World	5597	100.0	9134	7262	5767	1.9	1.0	0.1	100.0	100.0	100.0
North America	1215	21.7	1633	1476	944	1.1	0.8	-0.9	17.9	20.3	16.4
Alberta	28	0.5	41	38	24	1.5	1.2	-0.5	0.4	0.5	0.4

Table 7.3: Alberta Coal Production (percent of demand)

		2030		
	2004	BW	PW	EW
World Coal Demand	0.5	0.4	0.5	0.4
N. America Coal Demand	2.3	2.6	2.6	2.6

CHAPTER 8
CONCLUDING REMARKS

The Alberta energy industry should perform quite well no matter what the future holds for the world energy industry as a whole, primarily due to oil sands development. Under the three global scenarios, total hydrocarbon revenues should continue to rise, despite gas and coal revenues declining under Environmental World and gas revenue declining slightly under Business World. Interestingly, what is good for the global economy and oil industry is not necessarily good for Alberta's oil industry (and vice versa). Alberta energy performs the best in Political World, second best in Business World, and the worst in Environmental World.

Under Political World, Alberta revenues, production and market share are the highest for all three hydrocarbons, besides coal production, which comes in second place. In terms of oil, Alberta's production increases from 2.3 MMbpd to 7.5 MMbpd (4.9 percent per year) over the projection period. Crude bitumen comes to dominate Alberta oil production (as it does in all three scenarios), with its share of Alberta oil production increasing from 47 percent in 2004 to 93 percent in 2030. Alberta's gas production increases slightly in Political World (0.3 Tcf) to 5.3 Tcf (0.3 percent per year). In this scenario, as well as the others, coalbed methane overtakes conventional gas production later in the projection period. Finally, Alberta's coal production increases from 28 Mt in 2004 to 38 Mt in 2030 (1.2 percent per year).

Alberta energy revenues, production and market share are second highest for all three hydrocarbons in Business World, except coal production, where it is the highest. Alberta's oil production increases by 4.1 MMbpd (4.3 percent per year) to 6.4 MMbpd in 2030, with crude bitumen production reaching 6.0 MMbpd. Alberta's gas production declines by 0.6 Tcf (0.5 percent per year) to 4.4 Tcf, despite coalbed methane production increasing from 0.02 Tcf in 2004 to 2.6 Tcf in 2030. Alberta's coal production increases by 13 Mt (1.5 percent per year) to 41 Mt at the end of the projection period.

Under Environmental World, Alberta's energy revenues, production and market share are extremely weak, the exception being market share for coal which mimics that in Business World. Alberta's oil production increases from 2.3 MMbpd in 2004 to 4.8 MMbpd in 2030 (3.4 percent per year), with crude bitumen production increasing to 4.5 MMbpd. Alberta's gas production declines from 5.0 Tcf in 2004 to 3.0 Tcf (2.0 percent per year), with coalbed methane reaching a 55 percent share in 2030. Finally, Alberta's coal production declines from 28 to 24 Mt over the projection period (0.5 percent per year).

CHAPTER 9
RECOMMENDATIONS FOR FURTHER RESEARCH AND MODELING

The following research areas are suggested in order to fill the gaps and to enable both the private and public sectors to enhance their understanding of the global and Alberta energy markets.

Alberta Energy Balance & Database (AED): The creation of a multilayer, hierarchical and comprehensive database to monitor all movements in Alberta primary and secondary energy markets and to allow the calculation of Alberta's energy balance. This database would record and process all relevant energy data, including supply, demand, inter-provincial and international energy trade, inventories, prices, etc. It would also keep track of and monitor all inter-sectoral energy flows. In addition, it would enable the users to retrieve various reports on historical trends and the current status of energy markets in Alberta. It could be used by private and public sector analysts, scientists and researchers. Special built-in modules would allow for regular data updates and software maintenance. Highly advanced database management software would ensure maximum data and report exchange and transportability. The project to construct such a database and energy balance is expected to take about 30 months. The initial budget estimate including personnel, software, hardware and administrative costs would be about $2,700,000 (Cdn).

Alberta Energy Model (AEM): The creation of econometric and statistical analysis tools to construct a modular energy model to study the interactions among energy market fundamentals such as supply, demand, stocks, prices, and trade as well as economic, monetary and fiscal variables such as GDP, interest rate, money supply, etc. in Alberta. The Alberta Energy Balance & Database (AEB) would provide the input data required by the Alberta Energy Model. The model would cover both primary and secondary energy sources. The users would be able to conduct in-depth studies on historical trends and to perform scenario analysis about the future based on a variety of market and economic assumptions. The model could be used as a tool in policy and strategy formulation by decision-makers in both the public and private sectors. In addition, it could be used by scientists and researchers. This project can be defined and implemented on a phase-by-phase basis. Project implementation could start 12 months after the start date of AED project and could continue in three phases of 12 months each. Initial estimate of the cost would be around $3,150,000 (Cdn).

Global Energy Balance & Database (GED): The GED would track data for the world primary energy markets and would allow for the calculation of global energy balance. It would record past data on economic growth, energy demand, energy intensity, energy supply, energy reserves, energy prices and energy trade dependency on country and regional levels. In addition, the GED would track the changes in world energy mix as well as sectoral energy demand trends. It would enable the users to retrieve various reports on historical trends and the current status of world energy markets, including regional and country-level energy balances. It could be used by private and public sector analysts, scientists and researchers. Special built-in modules would allow for regular data updates and software maintenance. Highly advanced database management software would ensure maximum data and report exchange and transportability. The project to construct such a database and energy balance is expected to take about 24 months. The initial budget estimate including personnel, software, hardware and administrative costs would be about $2,300,000 (Cdn).

Global Energy Model (GEM): The GEM would encompass the creation of econometric and statistical analysis tools to construct a modular energy model. The model would study the interactions among energy market fundamentals such as supply, demand, stocks, prices, and trade as well as economic, monetary and fiscal variables such as GDP, interest rates, money

supply, etc. The GEM would utilize a bottom-up approach starting at country level and would provide regional and world-level analysis by integration and consolidation of lower level results. The Global Energy Balance & Database (GED) would provide the input data required by the Global Energy Model. The model would cover only primary energy sources. The users would be able to conduct in-depth studies on historical trends and to perform scenario analyses about the future based on a variety of market and economic assumptions. The model could be used as a tool in policy and strategy formulation by decision-makers in both the public and private sectors. In addition, it could be used by scientists and researchers. This project can be defined and implemented on a phase-by-phase basis. Project implementation could start twelve months after the start date of GED project and could continue in three phases of twelve months each. Initial estimate of the cost would be around $2,750,000 (Cdn).

APPENDIX A
OIL

Table A1: Alberta Oil Production and Reserves

Oil[#]	Business world	Political world	Environmental world
Production volume; million barrels per day			
Actual 2004	2.311	2.311	2.311
Expected 2030	6.395	7.517	4.800
Average 2005-30	4.261	4.851	3.434
Production change rate; %			
Average 2005-30	4.01	4.66	2.86
Remaining reserves volume; million barrels			
As of end 2004	184,786	184,786	184,786
As of end 2030	144,347	138,751	152,194
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	78.12	75.09	82.36

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

[#]Oil includes conventional crude oil, crude bitumen, and natural gas liquids (NGLs)

Table A2: Alberta Crude Oil Production and Reserves

Conventional crude oil	Business world	Political world	Environmental world
Production volume; million barrels per day			
Actual 2004	0.600	0.600	0.600
Expected 2030	0.181	0.238	0.138
Average 2005-30	0.342	0.385	0.306
Production change rate; %			
Average 2005-30	-4.50	-3.50	-5.50
Remaining reserves volume; million barrels			
As of end 2004	4,493.131	4,493.131	4,493.131
As of end 2030	1,247.468	844.092	1,593.108
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	27.76	18.79	35.46

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

Table A3: Alberta Crude Bitumen Production and Reserves

Crude bitumen	Business world	Political world	Environmental world
Production volume; million barrels per day			
Actual 2004	1.093	1.093	1.093
Expected 2030	6.000	7.000	4.500
Average 2005-30	3.546	4.046	2.796
Production change rate; %			
Average 2005-30	6.84	7.51	5.63
Remaining reserves volume; million barrels			
As of end 2004	174,075	174,075	174,075
As of end 2030	140,419	135,675	147,537
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	80.67	77.94	84.75

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

Table A4: Alberta NGLs Production and Reserves

Natural gas liquids (NGLs)	Business world	Political world	Environmental world
Production volume; million barrels per day			
Actual 2004	0.617	0.617	0.617
Expected 2030	0.214	0.280	0.163
Average 2005-30	0.373	0.420	0.332
Production change rate; %			
Average 2005-30	-4.00	-3.00	-5.00
Remaining reserves volume; million barrels			
As of end 2004	6,217.385	6,217.385	6,217.385
As of end 2030	2,680.553	2,231.930	3,064.362
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	43.11	35.90	49.29

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

APPENDIX B
GAS

Table B1: Alberta Gas Production and Reserves

Natural gas[#]	Business world	Political world	Environmental world
Production volume; million cubic feet per year			
Actual 2004	5,023,402	5,023,402	5,023,402
Expected 2030	4,350,673	5,274,303	2,958,186
Average 2005-30	3,610,824	4,064,962	3,096,373
Production change rate; %			
Average 2005-30	-0.47	0.25	-1.96
Remaining reserves volume; million cubic feet			
As of end 2004	596,428,800	596,428,800	596,428,800
As of end 2030	502,547,389	490,739,776	515,923,098
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	84.26	82.28	86.50

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

[#]Natural gas includes conventional natural gas and coalbed methane (CBM)

Table B2: Alberta Conventional Gas Production and Reserves

Conventional natural gas	Business world	Political world	Environmental world
Production volume; million cubic feet per year			
Actual 2004	5,002,222	5,002,222	5,002,222
Expected 2030	1,730,673	2,265,834	1,318,186
Average 2005-30	3,019,891	3,402,944	2,692,180
Production change rate; %			
Average 2005-30	-4.00	-3.00	-5.00
Remaining reserves volume; million cubic feet			
As of end 2004	102,228,800	102,228,800	102,228,800
As of end 2030	23,711,627	13,752,252	32,232,119
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	23.19	13.45	31.53

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

Table B3: Alberta Coalbed Methane Production and Reserves

Coalbed methane	Business world	Political world	Environmental world
Production volume; million cubic feet per year			
Actual 2004	21,180	21,180	21,180
Expected 2030	2,620,000	3,008,469	1,640,000
Average 2005-30	590,932	662,018	404,193
Production change rate; %			
Average 2005-30	20.36	21.00	18.21
Remaining reserves volume; million cubic feet			
As of end 2004	494,200,000	494,200,000	494,200,000
As of end 2030	478,835,761	476,987,524	483,690,979
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	96.89	96.52	97.87

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections

APPENDIX C
COAL

Table C1: Alberta Coal Production and Reserves

Coal	Business world	Political world	Environmental world
Production volume; million tonnes per year			
Actual 2004	27.8	27.8	27.8
Expected 2030	40.9	37.9	24.4
Average 2005-30	34.2	32.8	26.0
Production change rate; %			
Average 2005-30	1.50	1.20	-0.50
Remaining reserves volume; million tonnes			
As of end 2004	33,600	33,600	33,600
As of end 2030	32,711	32,748	32,924
Remaining reserves ratio; %			
As of end 2004	100.00	100.00	100.00
As of end 2030	97.35	97.46	97.99

Source: 2004 data from Alberta Energy and Utilities Board (EUB); 2005-30 data are CERI projections