Canadian Energy Research Institute

Potential Effects of Energy MegaTrends on the City of Calgary: A Long Term View

Prepared for the City of Calgary

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EXECUTIVE SUMMARY

This report, "Potential Effects of Energy MegaTrends on the City of Calgary: A Long Term View" was commissioned by the City of Calgary to study long-term energy megatrends that will dynamically and significantly affect Calgary. Cognizant of tremendous uncertainties that characterize the future, CERI applies a scenario-driven conceptualization of three future energy worlds and describes their ramifications for Calgary. While each scenario embodies cyclical oscillations that will invariably affect the energy industry and economy of Calgary, CERI did not attempt to identify the probable timing or the duration of cycles, nor their intervening impacts.

Broad findings indicate, that by and large, the future energy megatrends will sharply enhance the growth potential in Calgary throughout the period 2005 to 2035. During this period, the city grows remarkably over space and in terms of population, employment and the economy. Yet, energy-driven growth will produce challenges in several areas, including the built environment, governance, the social fabric and culture.

Some of the salient transformations that the city undergoes include rapid population growth that is surpassed by faster growth in productivity and employment: By the end of the period, CERI anticipates employment to have doubled and real GDP in the city is forecasted to reach levels that fall between double and triple the current levels. A large segment of the population will consist of immigrants originating from foreign countries. Newcomers will be attracted into the city because of Calgary's advancing economy as well as the unfavourable job prospects in their countries of origin. In general, differential international population dynamics and disparities in living standards will fuel future international migration.

The report is organized in five chapters and two appendices. After the introductory *first chapter*, global economic and energy scenarios are presented in *chapter two*. CERI considers three scenarios, based on business, environmental and political views of the future.

The scenario of *Business World* represents a Liberal world in which tolerance, open-mindedness and cooperation drive the international political scene. The world energy market is fairly dynamic in this scenario because of a 3.5 percent global economic growth rate. World energy demand growth averages 1.8 percent annually through 2035, similar to the 1971 to 2002 period, while energy intensity declines (improves) on an average 1.7 percent per year—compared to a 1.3 percent average over the comparison period. Improved efficiencies due to the spread of newer technology and the shift towards knowledge-based industries somewhat mitigate environmental deterioration.

In the scenario of *Environmental World* environmental awareness and concerns dominate the economic world Economic growth is solid at average 3.0 percent per year, reflecting moderate capital accumulation, the rapid spread of new knowledge and technology, and a modified version of globalization gaining sway. World energy demand growth averages 1.1 percent per year, and

technological change specific to the energy industry tends to be revolutionary in nature as energy intensity declines (improves) an average 1.9 percent per year.

The scenario of *Political World* is a dark Orwellian world, where life is viewed as a zero-sum game. Countries behave as if they can't win unless someone else loses. Collaboration is not high on policy agendas anywhere. A major global recession in the second half of this decade engenders the collapse of globalization, and a breakdown in international cooperation. The world economy only grows by 2.5 percent per year through 2035. World energy demand growth averages 1.1 percent annually over the projection period. Improvements in energy intensity decline (improve) slightly to 1.5 percent per year. The level of environmental destruction in Political World is severe, due to slow technological advancement, slow economic growth and a lack of international cooperation. Table ES.1 summarizes the major drivers for the three global energy-economic scenarios.

Table ES.1
Major Drivers for the Global Scenarios

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

Chapter three addresses the challenges that energy megatrends represent to the energy industry which is critical to Calgary and Alberta. The chapter illustrates how the Alberta energy industry is a vital engine of economic growth and job creation for the province and for Calgary. On the one hand, the anticipated declines in the conventional oil and natural gas production are expected to significantly slow the growth and prosperity of the economy. On the other hand, attracting investments into other energy resources secures a strong and prosperous long term future for the economy.

The chapter includes discussion of the future challenges and opportunities in the energy industry that CERI identifies. It concludes that evolving energy opportunities will not only offset the impact of declining conventional oil and natural gas industries but will also help attract more investments in other energy resources and thereby can secure a prosperous future for Calgary. The challenges include, but are not limited to, investments in the oil sands industry, expanding bitumen production and exports, construction of more oil sands upgrading capacity for producing more synthetic oil (SCO) and exports, expansion and conversion of oil refineries to utilize more SCO feedstock and converting it to refined petroleum products. Other challenges include ushering in an era of coalbed methane production, building more natural gas and oil pipelines from BC, Yukon, Northwest Territories, and Alaska for converting their energy resources into value-added products and shipping them outside of Alberta markets, changing the supply mix of

electricity generation by building nuclear power plants, or integrated coal and biomass gasification, windmills and other renewables, and upgrading the transmission infrastructure.

Under all three energy megatrend scenarios, the Alberta energy industry will attract extensive amounts of human capital and financial investments for enhancing energy production and converting the energy resources into value-added products, and exporting to other provinces and the US market. Furthermore, in the next 30 years the United States, the world's largest consumer of energy will be the largest importer of energy from Alberta. However, under the three scenarios, the Alberta energy industry and the economy in Calgary will be influenced differently by energy megatrends, energy prices, and global economy.

Somewhat ironically, CERI foresees that forces that slow down world economic growth might concurrently stimulate economic growth in Calgary. For instance, under the political scenario, $60 per barrel for international crude oil prices is the highest oil price and 2.5 percent global economic growth is the lowest growth rate among the scenarios, yet, on average, Calgary's economic growth proceeds at a handsome rate of 4 percent per year. Under this scenario energy companies are more likely to invest in Alberta's oil sands and coalbed methane due to insufficient oil and gas resources elsewhere.

By contrast, in the *environmental scenario* international crude oil prices are assumed to hit the lowest levels of ($40 per barrel) along with a robust global economic growth rate of 3 percent. In spite of relatively strong world growth, the low level of international crude oil prices leads to the economic growth rate in Calgary slowing down to 2 percent per annum, the lowest among the scenarios. Calgary's economic growth is held back by several forces including the high carbon mitigation costs that its primary industry encounters.

In the *business world* scenario international crude oil prices are mid-range estimates at $50 per barrel. Under this scenario, the Calgary economy grows at an average rate of 3.5 percent per year throughout the period 2005-2035. Business-friendly conditions that characterize this scenario give strong momentum to a robust global energy demand that is sustained over the whole period.

In chapter four, CERI establishes a quantitative anchor between energy megatrends and economic performance in the province of Alberta as well as in the city of Calgary. The chapter shows that international oil price increases contribute positively to the robust growth in Alberta and in Calgary. The chapter empirically validates such causality and delineates that the elasticity of international oil prices with respect to real GDP growth in Calgary is in the vicinity of (.3). That is, for each 10% increase in oil prices Calgary's GDP increases by 3%. The chapter findings indicate that in the political scenario, employment in the city grows from nearly 630,000 workers in 2004 to 1.26 millions in 2035. In the business world scenario, the employment approaches 1.19 million and in the environmental scenario employment approaches 1 million workers. Overall, the city of Calgary experiences high levels of net immigration primarily due to the rapid growth of the local economy and to the factors at play in the countries of origin in the source countries and regions. CERI anticipates that future immigrants into Calgary will be major sources

for satisfying the anticipated job growth as immigrants occupy between 30 percent and 50 percent of all job slots that are created during the period under study.

In *chapter five*, CERI discusses the ramifications of global megatrends to the city of Calgary in the areas of built environment, social issues and governance. In addition to affecting population and labour and financial markets, CERI envisages that emerging energy megatrends will strongly influence the built environment and natural environments. In order to take advantage of the opportunities that energy megatrends avail, refinery activities will need to be restructured as many new companies will be formed around new products and new services. Such changes foster job growth and boost tax proceeds and enhance demands for existing and emerging governmental services.

In the transportation sector, governmental agencies that depend on gasoline tax dollars will probably be strongly impacted. As the oil and gasoline consuming automobiles, trucks, planes, and ships are replaced with vehicles powered by new energy systems, the taxes collected for roads, highways, waterways, and airports will decline appreciably. While existing internal combustion engine vehicles will still need servicing, many gasoline refuelling stations may become obsolete. Furthermore, distribution systems for gasoline and fuel oil will gradually be reduced as electric and hydrogen-powered cars increase in numbers. Therefore, modifications will have to be introduced on the regulatory structures governing the vehicle licensing and taxing activates.

The highest level of global environmental damage occurs under the political World scenario, closely followed by the business World scenario, with Environmental World being the most environmentally benign scenario. Traditionally, the infrastructure supporting the natural environment (e.g. water supply, and air) has been designed on the assumption of a static climate; it may have difficulties dealing with climatic changes that depart from design criteria. The process of designing new infrastructure should allow for extreme climatic events of the past and the foreseeable future. Since addressing such contingencies is not costless, it can be expected that infrastructure costs will rise in anticipation of climate change.

A noteworthy conclusion is that the accelerating population and employment rates that CERI foresees, particularly under the political scenario, call for congruent and prudent planning in several areas, notably in the public, preventive and curative health provisions as well as in the education and transportation sectors.

Likewise, the growth that the three scenarios induce calls for strengthening governance measures by improving the processes and systems under which Calgary operates. The objectives would be to improve overall prosperity, reduce the degree of disparities among city residents, and develop Calgary into a more culturally diversified and egalitarian world-class city.

While we expect Calgary's economy and population to experience robust growth, this growth could be volatile due to the assumed scenarios and unexpected boom – bust nature of the energy economy upon which Calgary's economy is based. The inevitable occurrence of business

cycles will require the city to put in place policies and measures that are more scientifically-founded and with more flexibility than is normally found in other global cities.

CHAPTER 1
INTRODUCTION

Since the industrial revolution, there has been a gradual rise in the hydrogen-to-carbon ratio of fuels as the world's focus has moved from wood to coal to oil to natural gas and uranium. This megatrend is environmentally benign, as it has served to mitigate the rise in carbon dioxide production and has produced cleaner fuels.

Oil retains a central role in transportation, while coal still finds a niche in steel-making and in electricity generation. Many believe that hydrogen is the fuel of the future, as it contains no carbon and leaves only water as the product of combustion.

Until recently, natural gas has largely served continental markets, with most of the world's liquefied natural gas (LNG) supply going to Japan. With North American natural gas supply failing in recent years to keep up with growing demand, prices have soared, making LNG along the U.S. coastline competitive with North American natural gas supplies. As a result, a number of relatively low-cost natural gas deposits around the world that have hitherto lain untapped for want of a significant market within pipeline reach are now being developed for LNG supply.

Another possible fuel of the future which offers the prospect of enormously large supplies is gas hydrates (individual molecules of methane that are trapped in cage-like structures associated with frozen water), found in Canada's Arctic, Pacific and Atlantic regions. So far, however, no production method for gas hydrates has been fully commercialized.

In Alberta, the average rate of initial production from natural gas wells has fallen year after year, while the annual rate of production decline from existing wells has become steeper. As a result, record levels of drilling have barely been sufficient to keep Alberta gas production constant. Increasingly, coalbed methane will be called upon to replace declining conventional gas production.

Under regulated electricity supply, Alberta traditionally enjoyed some of Canada's lowest electricity prices despite a relative lack of hydro resources because of its use of low-cost sub-bituminous coal. Although combined-cycle technology has enhanced the comparative advantage of natural gas over coal as a primary energy source in electricity generation, the move to gas-fired generation sparked by deregulation has been accompanied by a rapid rise in the natural gas price, resulting in substantially higher electricity prices than Albertans enjoyed prior to deregulation.

Alberta light and medium oil production peaked in 1973 and has since fallen to less than half of the 1973 rate. In the meantime, rising oil sands output has more than offset this decline.

Foreseeable energy trends that pose potentially significant challenges and opportunities for Alberta and Calgary would include accelerated development of coal bed methane and oil sands in

Alberta. Development of production and pipeline facilities for northern natural gas and northern oil as well as gas hydrates in the more distant future add to the challenges.

1.1 Objective and Scope

The report "Imagine Calgary: Energy MegaTrends"[1] was commissioned by the City Calgary, to assess the energy global trends that Calgary has little influence over, but that affect Calgary a great deal. The report seeks to identify the long-run impact of global energy trends on the energy sector and economy of Calgary under three distinct scenarios. Although in each scenario the energy industry and economy of Calgary will encounter various cycles, no attempt was made to identify the timing or the length of cycles within the next 30-year period. The three scenarios reflect a worldview based on alternative business, environmental and political views of the future.

The report also highlights how Calgary's economic, social, environmental and governance aspects will potentially be affected by large-scale energy megatrends in the next 30 years.

1.2 Organization of the Report

This report is organized as follows:

Chapter 1 presents background, objectives and organization of the report. In chapter 2, three key secnarios of long term global energy-economic trends that Calgary has little control over, but that could affect Calgary siginificantly are presented. The major drivers for the global scenarios and uncertainties will be discussed briefly in chapter 2, but more details are presnted in Appendix A.

The energy sector is an engine of growth and job creation in all cities of Alberta including Calgary. Howerver, the declining reserves of conventional cude oil and natural gas raise the question of whether this sector can maintain its position in Calgary's future econmy. In chapter 3 we discuss, qualitatively, the challenges of the domestic energy sector and their potential to attract exetnsive investments in physical and human capital thereby enhancing future energy production and exports. This chapter also discusses the impact of the three global energy-economic scenarios on the Alberta enrgy sector and Calgary's econmic growth.

In Chapter 4, CERII focuses on developing a qunatitative link between energy megatrends and and economic performance of Alberta and Calgary. Technical details of the relationship between energy and economic are presented in Appendix B.

In Chapter 5, the implications of energy megatrends for Calgary's economic performance, built environment, social & natural environment and governance.

[1] The term "mega-trends" was coined by futurist John Naisbitt, and became the title of his 1982 best-seller. Although the United States was then in recession, he correctly assessed that it was about to have an unprecedented run of economic success. The term has entered the popular lexicon to characterize a large social, economic, political, environmental or technological change that is slow to form and yet has enormous implications.

CHAPTER 2
GLOBAL ECONOMIC AND ENERGY 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 very difficult game because the market has undergone massive changes in terms of energy demand and fuel mix, many of which were unexpected. 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 energy outlook to 2035. 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 different points in time. All of these views have made an appearance since the early 1990s.

The major drivers for our global scenarios relate to the three types of complex systems in the world—natural, social and technological. Conceptually, society itself can be further sub-divided into demographic, economic, cultural, and political spheres which are described in Appendix A. The potential overlap and interplay amongst all these systems is the basis for our global scenarios. At the same time, the world energy market through 2035 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 which are also described in Appendix A.

Considering the major and uncertainties of global scenarios, CERI's long-term energy outlook reflects the three alternative worldviews of "Business World", "Environmental World", and "Political World". These global scenarios embody different assumptions about the six major drivers that are illustrated in table 2.1. These in turn affect the major uncertainties for the world energy market in highly divergent ways which is also shown in table 2.2. Energy-economic assumptions for the scenarios are shown in tables 2.3 and 2.4.

It should be noted that what is good for the world as a whole might not be good for Alberta (and vice versa). For example high energy prices tend to slow global economic growth, but bolster Calgary's economic growth due to its energy-dependent economy.

2.1 Business World

The Business World (BW) is a Liberal world in which Liberalism drives the international political scene in Business World. Economic considerations re-assert their role in the international

landscape in the second half of this decade. World economic growth averages 3.5 percent per year over 2002 to 2035, compared to about 3.3 percent over the previous thirty years (Table 2.3). 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. Knowledge-based and service industries become a greater proportion of gross world product (GWP) as time passes.

Liberalism drives the international political scene in Business World. The Major powers tend to cooperate on issues of international security 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 fairly great between have and have-not countries in this scenario.

Due to rapid economic growth, environmental destruction is fairly high, 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.

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 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 environmental concerns.

World energy demand growth averages 1.8 percent annually through 2035, similar to the 1971 to 2002 period, while energy intensity declines (improves) an average 1.7 percent per year—compared to a 1.3 percent average over the comparison period.

The gradual shift away from high carbon fuels continues in the Business World. Oil and coal each lose some market share by 2035. The key to oil's relative success is its continuing dominance in the fastest-growing end-use sector, transportation. 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.

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; see Figure 2.4). The availability of oil and gas resources is assumed to be moderate in this scenario, despite plentiful resources worldwide, because conflict in some major producing countries hinders development and production. The price for natural gas averages $7.70 per MMbtu at Henry Hub.

Among the less carbon-intensive primary fuels, natural gas gains substantial market share, renewable energy sources gains a small amount, while nuclear holds it own. Gas demand is supported by major inroads into the power market (combined-cycle gas turbine and some

distributed fuel cells) and minor ones into the transportation market (gas-to-Liquids, compressed natural gas and methanol).

Among renewable energy resources, hydropower's market share stagnates while other renewables (i.e., wind, solar, biofuels, geothermal, etc.) gain a small amount of share. Hydro's share increases in the developing countries but declines in the OECD[2] countries (rich ones), where the best sites for large-scale dams have already been used and the large dams face major opposition. Other renewable resources gain market share, especially in developed countries. Governments in the developed countries provide incentives to renewable energy for energy security and environmental reasons, while some consumers are willing to pay a price premium for branded "green" energy. In the developing countries, renewable energy makes solid inroads into remote regions based on price alone—conventional sources of power in off-grid regions tend to be very expensive.

Nuclear maintains its market share in the Business World because of relatively high cost of competitive fuels for electric power, especially natural gas, and despite safety concerns, including fear of terrorist attacks.

2.2 Environmental World

Environmental World envisages a pragmatic environmentalism permeating the planet by 2035. As environmental degradation worsens 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. 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.

Economic growth is solid in Environmental World. The world economy grows an average 3.0 percent per year through 2035, 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

[2] The Organization for Economic Co-operation and Development (OECD) grew out of the Organization for European Economic Co-operation (OEEC), which was set up in 1947 with support from the United States and Canada to co-ordinate the Marshall Plan for the reconstruction of Europe after World War II. Created as an economic counterpart to NATO, the OECD took over from the OEEC in 1961 and, since then, its mission has been to help governments achieve sustainable economic growth and employment and rising standards of living in member countries while maintaining financial stability, so contributing to the development of the world economy. The thirty members of the OECD are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark,Finland,France,Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

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 consumer culture. While Environmental World is a high-technology world, R&D tends to be directed towards environmental sustainability.

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. While the world moves toward greater environmental sustainability by 2035, it still has a long way to go.

The world energy market is very dynamic in Environmental World. Growth in energy demand is fairly low because of major improvements in energy intensity. De-carbonization of the energy mix and electrification of final consumption continues 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.

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 the middle of the projection period.

World energy demand growth averages 1.1 percent per year in Environmental World, since energy intensity declines an average 1.9 percent per year. This major improvement is fuelled by concerted government action, including substantial funding for conservation programs, research and development 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 increases at a rapid pace in Environmental World. Natural gas, the bridging fuel to the hydrogen economy, is the big winner. Gas gains market share due to major inroads into the power sector and solid inroads into transportation. Among renewable energy technologies, hydropower maintains its share of the primary energy market while other renewables gain some market share. Major improvements in battery technology post-2020, supported by government funded R&D, gives distributed power from intermittent sources (e.g., wind and solar) a fairly substantial share of the power market. Nuclear power gains a small amount of market share through 2035. Surprisingly, nuclear power performs better in Environmental World than in Business World because of the greater concern about global warming in the former than the latter.

On the other side of the carbon shift ledger, both oil and coal lose substantial market share. The primary reasons for their steep declines are taxation policies favouring less carbon-intensive fuels and major technological advancements partially funded by governments. Nuclear power remains cost competitive throughout the projection period. 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.

The average WTI price of $40 per barrel (US$ 2004) in this scenario is at a discount to natural gas prices—average $8.90 per MMbtu at Henry Hub. Gas becomes the fuel-of-choice in the second half of the next decade due to environmental legislation and technological advancement. Seeing an opportunity to maximize revenue, several major gas exporting countries agree to retard development of their resources, just as the so-called Seven Sisters retarded development of oil resources from the early 1930s to the early 1970s. Despite this, energy prices are relatively low in Environmental World as a whole, because energy demand is fairly weak and resource availability is high. Oil and gas resources are assumed to remain plentiful, while conflicts in major producing countries are a rarity.

2.3 Political World

Political World is a very dark Orwellian world, where life is viewed as a zero-sum game. A major global recession in the second half of this decade engenders the collapse of globalization, a rise in terrorism and a breakdown in international cooperation. The world comes to be characterized by three major powers (US, Europe and Japan), three emerging ones (China, Russia and India), and increasing Islamic power.

The world divides into two major blocs. China, Russia and their Islamic allies attempt to balance against US hegemony, despite Chinese and Russian repression of Islamic groups in their own countries; Japan bandwagons with America. As time passes, India moves firmly into the US orbit, while Europe (besides Britain) shifts into the other camp.

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 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”.

The world economy only grows by 2.5 percent per year through 2035 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. Capital formation also is retarded by destruction caused by warfare and terrorism. Heavy industries, especially ones related to the defence industry, maintain their share of GWP.

The world energy market is fairly stagnant in Political World. Growth in world energy demand is relatively weak, and improvements in energy intensity through 2035 are relatively unimpressive. Liberalization flies into reverse (along with globalization) due to security of supply concerns. On the other hand, the processes of electrification and de-carbonization continue, the latter due to security of supply concerns.

World energy demand growth averages 1.1 percent annually over the projection period. Improvements in energy intensity increase slightly to 1.5 percent per year, despite relatively slow technological progress, except in areas related to national defence.

The shift away from carbon intensive fuels continues in Political World. The decline in oil's share of the energy mix in 2035 more than makes up for a small increase in coal's share. The transportation sector continues to buoy world oil demand, despite biofuel and coal-to-liquids gaining market through the projection period due to security of supply concerns. Internal combustion engines (ICEs) continue to dominate the transportation market, with only gradual efficiency improvements.

Despite relatively slow energy demand growth, WTI averages $60 per barrel (US$ 2004) over the projection period, because resource availability is low. In Political World, oil and gas resources are assumed to be relatively far along the resource triangle, while conflicts in many major producing countries and resource nationalism hinders development and production. Since oil remains the fuel-of-choice, other primary fuel prices are relatively weak on an energy equivalency basis. Natural gas at Henry Hub averages $8.55 per MMbtu.

Despite the continuing carbon shifts in Political World, gas actually loses a small amount of market share. The international gas trade requires a fair degree of political stability to encourage market players to sign the long-term contracts required to undertake capital intensive LNG and long-distance pipelines. Hydropower maintains its market share, despite security concerns, while other renewables are the big winners. Non-hydro renewables benefit from security of supply concerns in major consuming countries and a desire for quality power in remote regions in the developing world.

Overall, nuclear's share of the primary energy market remains constant through 2035. Its share declines slightly in established markets (OECD and FSU) and increases fairly substantially in new ones (non-OECD countries).

Table 2.1
Major Drivers for the Global Scenarios

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

Table 2.2
Major Uncertainties for the World Energy Market

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

Table 2.3
Major Assumptions for the Scenarios
(annual average percent change)

	Business World	Environmental	Political World
Economic Growth	3.5	3.0	2.5
Energy Intensity	-1.7	-1.9	-1.5
Energy Consumption	1.8	1.1	1.0

Table 2.4
Average Prices for the Scenarios (US$ 2004)

	Business World	Environmental	Political World
WTI at Cushing OK ($/bbl)	50.00	40.00	60.00
Gas at Henry Hub ($/MMbtu)	7.70	8.90	8.55
OECD coal imports ($/tonne)	75.00	60.00	100.00
WTI at Cushing OK ($/MMbtu)	8.60	6.90	10.35
Gas at Henry Hub ($/MMbtu)	7.70	8.90	8.55
OECD coal imports ($/MMbtu)	5.75	4.60	7.65

CHAPTER 3
ENERGY MEGATRENDS AND CHALLENGES FOR THE ENERGY INDUSTRY

The Alberta energy industry is a vital engine of economic growth and job creation for all cities in Alberta including Calgary. On the one hand the declines in the conventional oil and natural gas production are expected to significantly detract from the growth and prosperity of the economy. On the other hand, attracting investment into other energy resources secures a strong and prosperous long term future for the economy of Calgary.

The objective of this chapter is to review and identify the challenges of the energy sector that will stimulate capital investment, production, and exports in the long run. In this chapter we will also look at how the Alberta energy and Calgary economy might fare under the three scenarios described in Chapter 2.

3.1 Conventional and Synthetic Crude Oil

Prior to start-up of the first oil sands upgrader in 1967, much of Alberta's economic activity was devoted to conventional crude oil investment, production and export. However, over the past 38 years with declining operation costs of oil sands, declining reserves of conventional crude oil, and rising energy prices the oil sands industry since 2001 has usurped the leading role of conventional oil in output and job creation.

Over the period 1990 to 2004, Alberta's remaining established reserves of conventional crude oil (light, medium and heavy) due to discoveries and additions failing to keep pace with production, declined by half, to 1.6 billion barrels. In addition, annual production of conventional crude oil, which peaked at 1.4 million bbl/d in 1973, gradually declined to approximately 600 thousand bbl/d by 2004. Production in 2004 and remaining reserves at the end of that year imply a reserves life index for conventional crude oil of only 8 years.

In contrast to conventional oil, Alberta's ultimate potential[3] and remaining established[4] reserves of crude bitumen are very large, estimated at 315 and 174 billion barrels respectively by the end of 2004[5]. The volume of oil sands established reserves are second only to Saudi Arabia's 264 billion barrels of recoverable reserves[6]. In 2004, production of crude bitumen slightly exceed 1 million bbl/d, of which about 600 thousands bbl/d was upgraded to synthetic crude oil and the remaining non-upgraded bitumen shipped primarily to the US market. The growth of synthetic oil production and the decline of conventional oil production are both expected to continue.

The abundant reserves and export potential of crude bitumen portend a bright but challenging future for Alberta's oil sands industry. The replacement of conventional with synthetic crude oil

[3] potentially recoverable under anticipated technology
[4] Recoverable under current technology
[5] Alberta Reserves 2004 and Supply/Demand Outlook 2005 – 2014, Alberta Energy utilities board
[6] hhtp://www.rense.com/general37/petrol.htm

(e.g. moves away from finding hydrocarbons to mastering processing technology) causes a major shift in the technology and business practices of the petroleum industry and impacts the growth of cities in this province. For example, the higher global energy demand necessitates construction of more refineries and pipelines for moving the non-upgraded bitumen and synthetic crude oil to markets beyond Alberta's borders.

Rising demand for oil sands output and the challenges of oil sands industry entail more investment and job creation, requiring rapid labour force growth which will put significant stress on the city of Calgary and other regions. The degree of stress depends on global energy demand, speed of response to environmental challenges and success in reducing operating costs in a competitive market. Most importantly and planning for the anticipated impacts could greatly negate this stress.

3.2 Natural Gas and Coal Bed Methane

In 2004, Alberta produced 141.7 billion cubic meter of marketable natural gas from its conventional gas and oil wells, where 28 percent of that production was used domestically, and the remainder was sent to other Canadian provinces and the united sates.

The remaining established reserves of natural gas was estimated at 1,127 billion cubic meters at the end of 2004. Under current practices of technology, energy efficiency, Production, and no additional reserve, the remaining reserves imply a reserves life index for Alberta's natural gas of only 8 years.

In recent years with declining natural gas reserves, coal bed methane (CBM) has come into vogue in Alberta. The CBM industry has long been established in the United States. Exploitation of methane from coal beds is technically challenging, and has generally been undertaken by large firms.

The Alberta Energy and Utilities Board estimates the remaining established reserves of CBM at 7.42 billion cubic meters by the end of 2004. The commercial production of CBM started in 2002, with very small volumes. In 2004, some 600 million cubic meters was produced in Alberta.

Over the next 10 years, CBM has the potential to become a significant supply source in Alberta. It is expected that the rise in CBM production will offset some part of the decline in conventional gas production.

Unlike conventional gas, CBM has essentially no natural gas liquids (ethane, propane, butanes and pentanes plus) associated with it. Although lacking in liquids, coal bed methane has the advantage of being located largely in parts of Alberta that are well served by existing gas pipelines.

3.3 Coal

The remaining Alberta established reserves of all types of coal are abundant, estimated at 34 billion tonnes by the end of 2004. In the same year Alberta produced 28 million tones of coal, most of which (sub-bituminous) was used for electricity generation and the remainder was shipped outside of the Alberta market. The remaining reserves imply a reserves life index for Alberta's coal of 1,200 years.

Coal has been the most widely used fuel for power generation. In the last two decades due to environmental pressures the electric power industry has sought to avoid bringing on more coal fired-plants and to replace coal-fired plants with natural gas turbines.

However, in recent years surging natural gas prices have undermined the competitiveness of natural gas turbines and enhanced the competitiveness of coal gasification and renewable resources such as wind, and solar.

Gasification is a proven technology currently in operation all over the world. Gasification involves heating a solid fuel material such as coal by partially combusting it with insufficient air. The result of the process is 'synthesis gas" which is the most promising route to use coal in the future to generate electricity.

3.4 Electricity

For most of the 20th century, two factors characterized the electric industry. First, from an engineering perspective, generators became larger and more centralized. Secondly, from an economic perspective, electric utility companies became vertically integrated monopolies through ownership of generation, transmission and distribution.

Recent policy and technological changes have challenged these characteristics. For example, in 1990s Alberta restructured the electric industry and separated the ownership of generation, transmission and distribution. It also separated the marketing of output from existing regulated power plants from their ownership. The objective was to develop a competitive power generation market.

Technological innovation is another factor enabling entrepreneurs to generate power at relatively small facilities more cheaply than the embedded costs of the traditional utility industry's centralized facilities. Improvements in gas-fired generation technologies shifted the electric industry toward smaller and more dispersed generators[7], which have enhanced power availability and reliability for end users.

[7] In this report, dispersed or distributed generation consists of those power plants that can produce electricity in smaller scale from renewable or non-renewable resources. They can also choose their fuel from gasification of conventional hydrocarbons such as coal, and unconventional fuels such as biomass and municipal waste. Distributed generation includes simple-cycle, and combined-cycle electricity generation as well as the combined production of heat and power which is known as cogeneration.

Distributed generation (including cogeneration plants) is located at or near the point at which the power is used. Their generation capacity in many cases is used primarily to meet on-site requirements. If there is excess capacity then they are connected to the grid at either transmission or distribution level[8].

Alberta led the country in cogeneration capacity in 2004 with 2.58 GW (2,584 MW). The oil sands industry, with a 40.7 percent share (1,100 MW) in 2004, has more operational cogeneration capacity than any other industry in Alberta, followed closely by petrochemical plants.

The key advantage of cogeneration is its efficiency in generating electricity and steam[9]. For example, in oil sands in-situ operations high-pressure steam is used for bitumen production[10]; in petrochemicals and oil sands upgrading it is employed in steam reforming of methane.

Another factor that should be considered in the electric industry is fuel choice. In 2004, Alberta generating capacity was approximately 12,000 MW[11]. The mix of primary energy associated with this capacity is coal (5,617 MW), natural gas (5,060 MW), hydro (899 MW), wind (282 MW), biomass and other (148 MW). Approximately 1,500 MW of the total serves on-site industrial needs. In 2004, peak demand was 9,236 MW- up from 8,967 MW in 2003. Thus, the Alberta electricity generating system is highly dependent on fossil fuels with 88% coming from coal and natural gas. Hydropower and other renewable resources provide the remaining 12%.

Overall, the recent policy and technological changes is expected to facilitate the speed of shifting from the centralized power plants to smaller-scale operations, and increased diversification of the fuel sources for the electricity generation.

3.5 Petrochemical Plants

Alberta's petrochemical industry, the largest in Canada as measured by shipments, is primarily gas-based. Its nameplate capacity stands at 8.6 billion lb/yr (3.9 million tonnes/yr). The province's earliest large petrochemical plants were methane-based ammonia plants, serving the needs of agriculture. The ammonia was used in the manufacture of solid fertilizers: ammonium phosphates, ammonium nitrate and later urea.

In recent years the direct application of ammonia to the soil has become a popular method of fertilization. In the late 1970s and early 1980s world-scale plants producing methanol (methane-based), ethylene (ethane-based) and their derivatives were constructed in Alberta. Smaller

[8] Traditional power plants are connected to the grid at the transmission level (the high-voltage portion of the delivery network)

[9] Total fuel consumed by a cogeneration system is less than the total fuel that would be consumed by two separate systems -one produces electricity and one steam. Therefore, the gain in thermal efficiency reduces emissions of greenhouse gases and ozone precursors.

[10] In oil sands jargon "extraction" is a mining term that refers to the separation of sands and bitumen subsequent to actual mining.

[11] Export capacity to BC and Saskatchewan in 2004 was 800 and 150 MW respectively.

plants were constructed utilizing propane and butanes as feedstocks. Ethylene and aromatics derived from bitumen are feedstocks for styrene production in Alberta and elsewhere.

Although there has been a turnaround very recently, Alberta's petrochemical industry has gone through a number of difficult years. Its methane-based industries have been faced with high natural gas prices that have undermined its costs relative to competitors with access to inexpensive gas from nearby gas reserves that are not within reach of large consuming markets. Its ethylene industry has suffered from both a decline in provincial gas-based ethane supply and decreased competitiveness relative to oil-based competitors, who have been enjoying attractive prices for oil-based ethylene's co-products.

Although Alberta's methane-based petrochemical producers have been insulated from offshore competition to some extent by their inland location, the emergence of North American natural gas prices set by competition with liquefied natural gas will foster imports of methane-based petrochemicals from producers located in regions where the alternative use of their feedstock gas is either to produce LNG or to shut it in. As Alberta moves increasingly to coal bed methane for gas production, natural gas liquids supplies will dwindle. Fortunately alternative feedstocks will become available from the oil sands industry, both from upgraders' off-gases and from direct cracking of bitumen. Increasingly, therefore, Alberta's petrochemical industry will be oil-based.

3.6 Summary and Energy MegaTrends Scenarios

The energy sector accounts for more than one half of the Alberta economy when direct and indirect linkages are taken into account. In recent years, the energy sector has become more dominant in the economy of Calgary and Alberta. A summary of the short and long run energy challenges and opportunities is as follows:

- bringing on production of conventional oil and gas deposits,
- expanding bitumen production, and applying advanced technology for reducing the operating costs of bitumen extraction,
- construction of more oil sands upgrading capacity for producing more synthetic oil (SCO),
- expansion and conversion of oil refineries to utilize more SCO feedstock, converting it to refined petroleum products,
- Ushering in an era of coal bed methane production,
- building more natural gas and oil pipelines from BC, Yukon, Northwest Territories, and Alaska for converting their energy resources into value-added products and shipping them outside of Alberta markets.

- changing the supply mix of electricity generation by building nuclear power plants or integrated coal and biomass gasification, wind power and other renewable electricity generating resources, and

- upgrading the transmission infrastructure in order to export more electricity.

As noted earlier, what is good for the world as a whole is not necessarily good for Calgary. The Alberta energy industry, and hence Calgary's economy, is quite robust in the **Business World.** The Calgary and Alberta economy grows an average 3.5 percent per year through 2035, the same rate as the global economy. The major reasons Alberta's energy industry is quite strong in this scenario are:

- Fairly high energy prices, especially for resources it has in abundance, ample opportunities for international investment by Alberta-based companies, and strong development of Northern gas. Oil and coal prices are the second highest among the scenarios ($50.00 per barrel and $75 per tonne). Natural gas prices ($7.70 per MMbtu) are the lowest among the three scenarios, but still quite high in historical terms.

- Only moderate geopolitical instability contributes to a fairly high degree of resource availability around the world.

- Business-friendly environment leads to strong global energy demand growth over the long run.

- Carbon mitigation costs are lower for conventional oil production than for oil sands and coal production. Although these costs are assumed to be relatively low in the Business World compared to Environmental World, they are an extra cost all the same.

- Strong demand growth for natural gas contributes to the rapid development of Northern gas which leads to additional business opportunities for Alberta-based companies, including pipeline toll or tariff for already established pipelines.

The Alberta energy industry and economy struggle somewhat in **Environmental World.** The Calgary economy grows an average 2.0 percent per year through 2035, compared to 3.0 percent growth for the global economy. The major reasons that Alberta's energy industry will not perform strongly are:

- Relatively low prices for oil and coal ($40.00 per barrel and $60 per tonne, respectively). In contrast, natural gas prices ($8.90 per MMbtu) are the highest among the three scenarios.

- High carbon mitigation costs. Since the Federal government, under this scenario, imposes the carbon costs onto the energy industry in the 2010s, the increasing cost to

mitigate against carbon causes growth in Alberta's oil sands and coal production to slow over the projection period.

- Energy companies have a wide range of options to invest around the world rather than just in Alberta. Conventional oil and gas resources are plentiful in Environmental World, partly due to the rapid rate of technological advancement. In addition, a lack of warfare and other strife in this geopolitically-benign world tends to keep resource rich oil and gas producing countries open for business.

The Alberta energy industry, and hence Calgary's economy, booms in **Political World.** The Calgary economy grows an average 4.0 percent per year through 2035, compared to 2.5 percent growth for the global economy. There are several reasons that Alberta is prosperous in this scenario.

- Energy prices are high across the board. Oil and coal prices are the highest in Political World ($60.00 per barrel and $100 per tonne, respectively) among the scenarios, while natural gas prices ($8.55 per MMbtu) lag only those in Environmental World.

- Energy companies are more likely to invest in Alberta's oil sands and coal bed methane due to insufficient oil and gas resources elsewhere. The global oil and gas resource base is assumed to be low in Political World, partly due to a slow rate of technological advancement, while political instability in many major oil and gas producing countries decreases the opportunity to invest in them.

- Security of supply is a significant issue to major energy consuming countries. US demand encourages the development of oil sands and Northern gas through tax incentives and other measures. Alberta-based companies benefit from the exploration, development and production of Northern gas, the construction of pipelines to Alberta and elsewhere, and new supply sources for already established pipelines. Alberta-based pipeline companies receive pipeline toll since most Northern gas will pass through the province, while Alberta-based companies should benefit from the construction of Northern gas pipelines.

- Finally, oil sands and coal producers do not have to bear additional costs to mitigate against carbon, due to geopolitical concerns trumping environmental ones.

Table 3.1
Major Assumptions for Three Scenarios

	Business World	Environmental	Political World
WTI at Cushing OK ($/bbl)	50.00	40.00	60.00
Calgary Economic Growth	3.50	2.00	4.00
World Economic Growth	3.50	3.00	2.50

CHAPTER 4
ENERGY MEGATRENDS, AND ECONOMY OF CALGARY

This chapter focuses on establishing a quantitative anchor between energy megatrends and the economy of Calgary. Validating the anchor statistically reinforces the structural foundations of Calgary's future economic growth trajectories which CERI conceptualizes. Utilizing anchored growth trajectories, CERI then proceeds to envisage three future employment profiles that are likely to ensue. Therefore, this chapter is divided into two parts. In the first CERI establishes a quantitative anchor between energy megatrends and economic performance in the city of Calgary. In the second, CERI presents three scenarios of future employment paths and delineates their attendant labour productivity trajectories. The underlying approach and statistical estimates between energy megatrends and economic growth are presented in Appendix B.

4.1 Significance of Energy MegaTrends to Calgary

Understanding the anchor between economic growth and energy megatrends is crucial for Calgary's long-term strategic planning because of the multi-faceted dimensions that the anchor reverberates. Invariably, Calgary's strategic plans and vision would address the implications of future growth scenarios for the dynamics of the city's future revenues and expenditures as well as for its ability to expand spatially in order to meet future employment and population growth. The timely development of growth-responsive policies becomes crucial for ensuring the long-term sustainability of the city.

Calgary has been growing and rising rapidly to join the league of global cities. Its rapid rise can also be gleaned from anecdotal evidence which suggest that the city benefited from energy megatrends that occurred in past decades. Specifically, the city's economy has been driven mainly by resource endowments such as energy and human capital that are amalgamated by growth-conscious policy apparatus and location-specific factors. The amalgam of endowment and policy variable has enabled Calgary to gain growing significance as headquarter of a large number of corporate offices. Because of favourable spatial and local fiscal variables, corporations and companies that locate in Calgary enjoy the lowest head office operating costs amongst 52 cities in North America[12]. Moreover, the city of Calgary has the highest concentration of head office employment in Canada on a per capita basis, 38.2 per 1,000 populations[13]. A recent survey by the influential *Economist* magazine of the 100 best cities for business travel in the world ranked Calgary as the close second city next to Vancouver. The highest ranks received by Vancouver and Calgary were attributed to their excellent transportation and infrastructure as well as safety records[14]. Therefore, a key result of the factor endowment-cum growth-friendly environment and policies is gauged by increasing agglomerations of high-tech and services industries who contribute more than thirty percent of the city's gross domestic product.

[12] Michael Lau (2004): "Head office costs lowest in Calgary: San Francisco most expensive" *Calgary Herald* October 8.
[13] Western Canada Business Center (2004): "*Calgary Heart of the* West", November.
[14] Calgary Herald (2005) "*Margin Calls: Calgary No.2 for Business Travel*" Friday November 18.

4.1.1 Energy MegaTrends and Economic Growth in Calgary

In order to quantify the relationship between energy megatrends and economic growth in Calgary, CERI applies simple statistical tests to available data. The problem however is that energy megatrends encompass a large number of fuels, technologies, policies and prices, to name a few only. Therefore, selecting a single variable whose information content can be used to proxy the dynamics of energy trends becomes a critical matter. In essence, policy makers and researchers must pick a proxy whose path drives the dynamics of energy megatrends and CERI opted to apply the movements in international oil prices as such proxy. The rationale is that oil prices have historically been the catalyst of energy policy formulations in Europe, the United State, Canada and elsewhere. This is apparent, for instance, by the wide variety of energy efficiency and conservation programs in the transportation and electricity generation sectors and by the infusion of public and private R&D investments in renewable energy technologies and fuels programs. Most of these policies were driven primarily by concerns over uncertainty of international oil price movements. Closer to home, recent oil price increases, combined with technology cost reductions, have provided strong momentum to the tar sands industry in Alberta[15].

It should be noted that Calgary's economic growth will invariably be affected by other institutional, trade and policy variables. For instance, world economic growth rates as well as growth rates in world trade volumes, composition and direction are powerful growth drivers. Other growth-impacting factors include Canada's future growth profile and particularly the profiles of provinces that have significant trade flows with Calgary[16]. Therefore, CERI is cognizant of the strong influence that other growth drivers have on the economic growth of both the city and the province[17].

Relying on historical trends, the next section focuses on establishing a quantitative anchor between energy megatrends and economic performance in the city of Calgary. In particular, it tests the hypothesis that international oil price movements have had discernible effects on economic growth in Calgary. If statistically validated, it would buttress our conceptualized scenarios that economic growth in the city is positively and strongly influenced by energy megatrends. Looking forward, the information will then be utilized in order to develop employment growth trajectories for Calgary that are powerfully impacted by future global energy megatrends.

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[16] Discerning the causality direction, the relative magnitude and the dynamic impact of these variables on the historical and future growth rates of the city of Calgary falls outside the immediate scope of the present study. However, they are issues are extremely significant for city planning purposes and deservedly merit further probing and analysis in future research.

[17] A full-fledged analysis of growth drivers is typically conducted within the framework of growth accounting approaches. This is an extremely warranted topic that for the city and the province that should be implemented in future research.

4.1.2 Direction of Causality Test

CERI applied causality tests in order to gain further insights about the direction of causality between oil prices and economic growth in the city. Specifically, we are interested in validating the hypothesis that oil prices do indeed cause economic growth in the city of Calgary. In performing the causality tests, we applied a variety of lag structures that range between one and three years. In all cases, we found evidence supporting that international oil price movements directly influence economic growth in the city of Calgary. Hence, the findings corroborate our next statistical test.

4.1.3 Statistical Test - Estimation of Elasticity

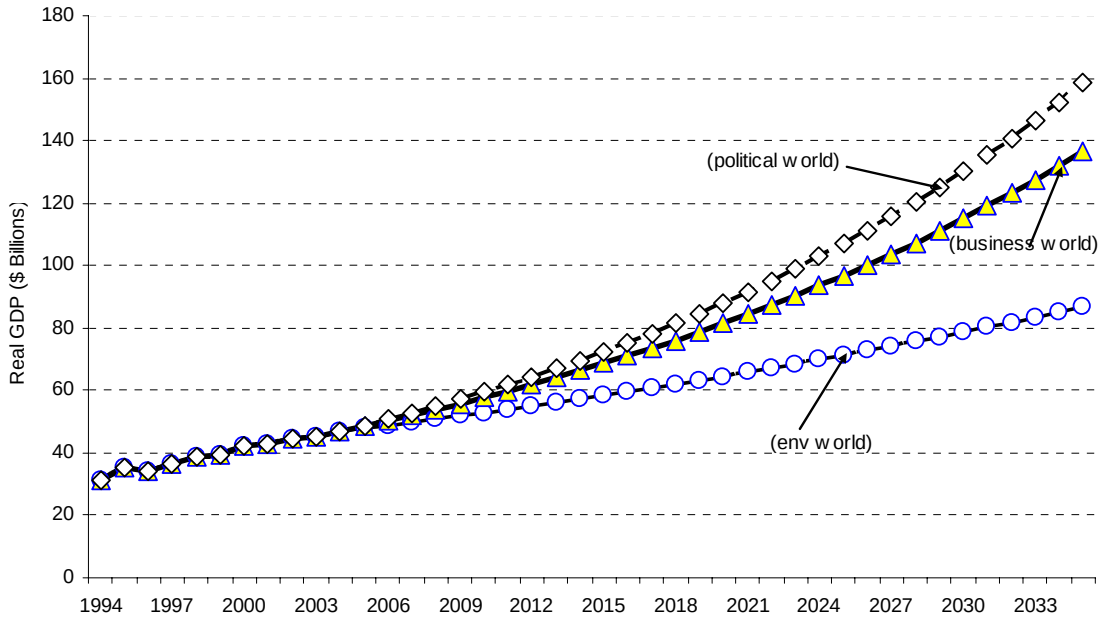
Intuitively, establishing a robust relationship between energy prices and economic growth requires long time data series that properly tests for integrity and consistency. However, city-published data in the case of Calgary is both scant and short. For instance, available data show Calgary's real GDP for eleven years only, 1994-2004. Statistical inference under these conditions will usually be less robust.

CERI tested the hypothesis that energy price movements influence GDP growth in Calgary by performing a simple regression analysis in which oil prices are the explanatory variable of real GDP variations in Calgary. The statistical function in logarithmic scale is interpreted as the elasticity of GDP with respect to oil price movements.

The findings indicate that during the period 1994-2004, a change in world oil prices of, say, 10 percent resulted on average in a 3 percent change in Calgary's real GDP. That is, the underlying elasticity between oil prices and GDP is positive at (0.3). To illustrate the implications, suppose that oil prices increased by fifty percent from say, 30 dollars to 45 dollars, then real gross domestic product growth rate in the city would increase on average by 15 percent from, say 3 percent, to 3.45 percent per annum. Therefore, oil prices appear to act as a driver of economic growth in province of Alberta as well as in the city of Calgary.

Figure 4.1 plots Calgary's future levels of real gross domestic product under the three global scenarios developed in chapter 2 for the period 1994 to 2035.

Figure 4.1
Calgary Economic Growth Scenarios
Real GDP 1994- 2035



4.2 Calgary's Economic Growth and Employment

The focus of this section is on future employment trends in Calgary. In conformity with the literature, CERI proposes that future energy megatrends which condition economic growth in the city will also impact the city's employment generation profiles. The section starts with simple validations of important indicators such as the general impact of economic growth on employment in Calgary. It then develops three future employment trajectories for Calgary.

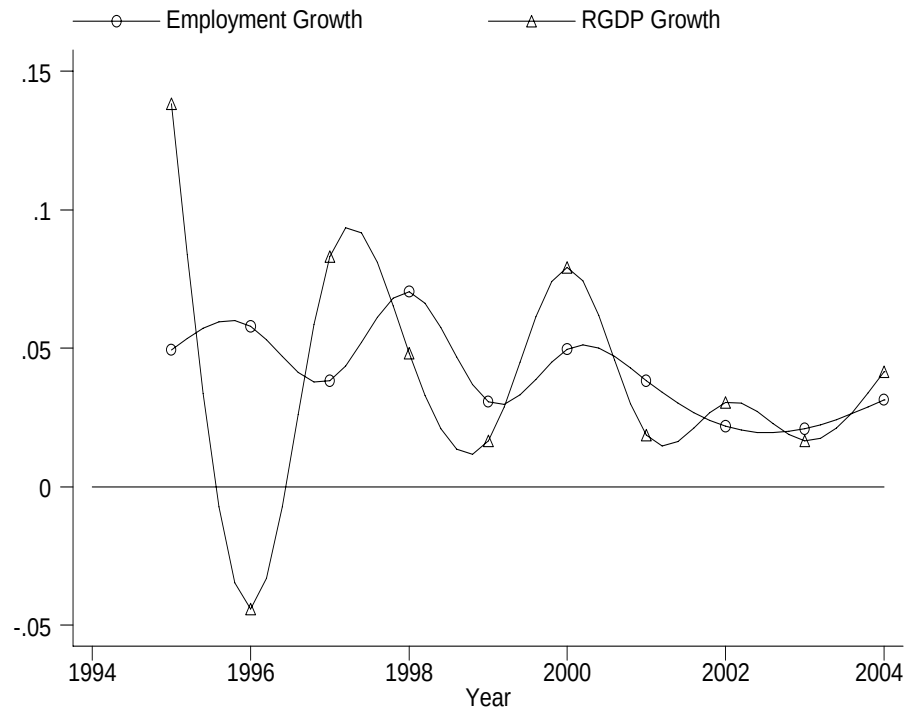
4.2.1 The GDP-Employment Relationship

Historical data indicate that growth in the city of Calgary is associated with new job creation according to the following ratio: each one percentage increase in real economic growth leads to the creation of 5,000 new jobs. Thus during periods of real GDP growth of 2 percent per year, nearly 10,000 new jobs were created in Calgary.

4.2.2 Employment Scenarios for Calgary

The response of employment growth to output growth is a key determinant of the future employment growth in Calgary. In Figure 4.2 CERI plots the relationship between real GDP growth and employment growth in Calgary during the period 1994-2004. The figure suggests that employment and real GDP growth rates tended to co-move with real GDP leading employment growth in the city.

Figure 4.2
Growth Rates in Real GDP and Employment Calgary
1994-2004



Growth rates of real GDP and employment Calgary 1994-2004

In order to quantify the relationship between real GDP and employment in Calgary, CERI utilizes data published by the city of Calgary and applies a simple OLS regression model in order to gauge employment response to economic growth in the city of Calgary. The findings imply that the elasticity of employment is quite high, 1.02; suggesting that in response to an increase of 10% in real GDP, employment grows on average by 10.2 percent.

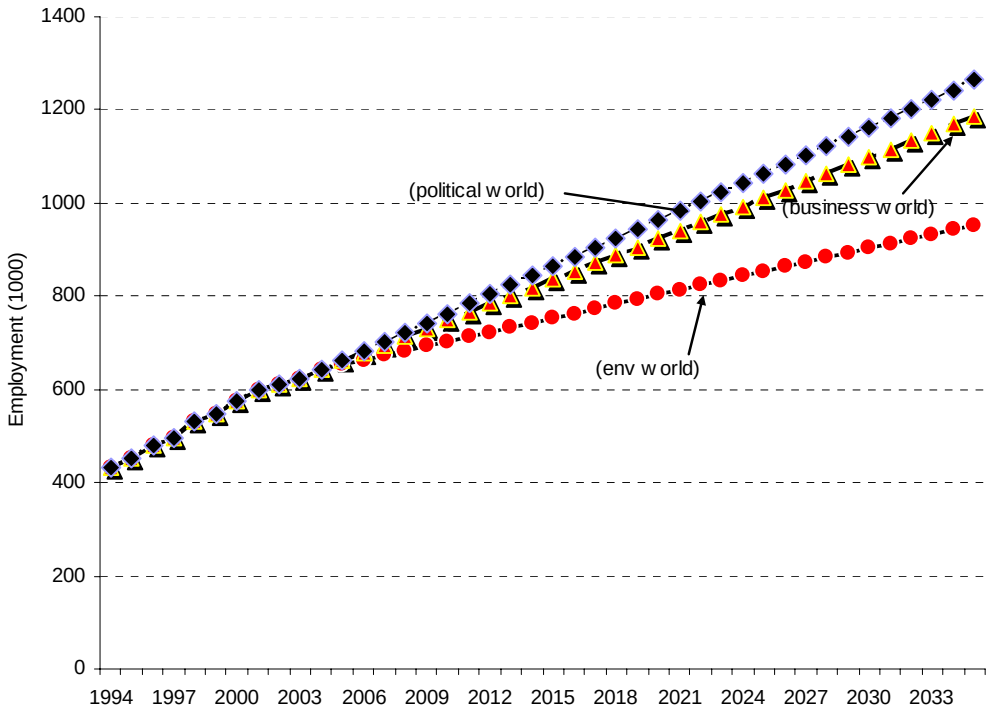
Having validated the direction and magnitude of the employment elasticity, CERI applies next a simple approach in order to estimate future employment in the city of Calgary. The approach is based on assumptions regarding the following variables:

1. Future growth path of the Calgary economy;

2. Historical and assumed trajectories of the growth-employment relationships; and
3. Estimates of population forecasts that were officially published by the city[18].

Figure 4.3 shows the employment growth under the three scenarios of business, environmental and political worlds.

Figure 4.3
Employment Scenarios
Calgary 1994 - 2035



As Figure 4.3 portrays, under the high economic growth trajectory which the political scenario embodies for Calgary, employment increases to 760,000 workers in the year 2010 and to 925,000 in 2020 and leaps to 1.26 million workers in 2035. In the business world scenario, the number of employed workers approaches 748,000; 925,000 and 1.19 million in the respective years 2010, 2020 and 2035. In the environmental scenario, the employment which corresponds to low GDP growth inches up to 700,000 by 2010 and to 800,000 in 2020 and approaches 1

[18] City of Calgary (2005): "Calgary Economic Region Map: Calgary & Region Economic Outlook 2005-2010"

million in 2035. CERI anticipates that Calgary will attract large numbers of future immigrants in order to fill the jobs that develop. While local entrants will provide a significant fraction of future incremental labour supply, CERI anticipates the city will rely on new waves of immigrants in order to satisfy between 30 and 50 percent of Calgary's future employment growth needs.

In the three scenarios, CERI lowers historical estimates of the employment elasticity. That is, the response of employment to GDP growth is assumed to decrease as the economy becomes more capital intensive.

4.2.3 Labour Productivity

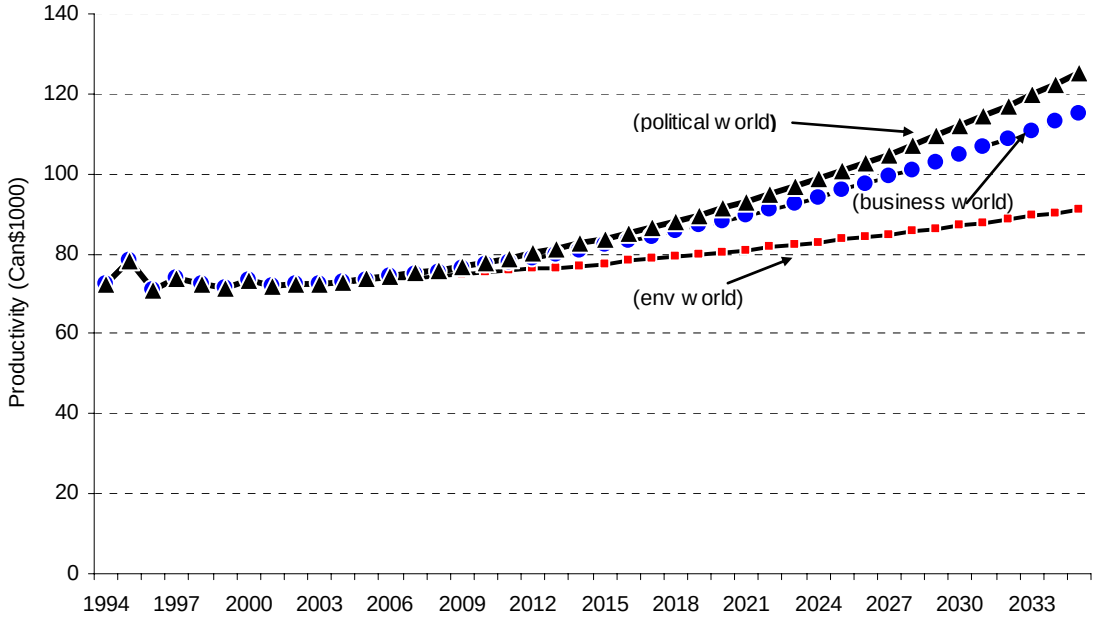
Average labour productivity levels which had prevailed in the past are used as benchmark estimates. These are simply the real dollar amounts of GDP per worker; that is (real GDP/employment). Historical data gleaned from official city publications indicate that average labour productivity in Calgary hovered around CAN$73,000. However, marked deviations from this average have occurred in the past. For instance, in 1996, when the city's real economic growth was lagging, average labour productivity dipped to less than 71,000 from its high level of over 78,000 in 1995. Moreover, for consistency checks, CERI used the city's official population projections as a benchmark for comparing and contrasting its employment forecasts with official population projections.

Historical figures indicate that the unadjusted employment rate (the number of employed individuals relative to the total population of all ages) has increased from 51% in 1994 to 57.5% in 2005. Invariably, the increase reflects the impact of cumulative waves of immigrants into the city who tend to be selective in terms of working age and who are typically gainfully employed.

It is worth noting that in its scenario-driven approach, CERI expects that the unadjusted employment ratio to increase significantly reflecting the high economic growth which induces more migratory waves. In conducting its forecasts, CERI followed the literature by assuming that temporal waves of (international) immigrants into Calgary will have lower dependency rates as a result of selective immigration policies on one hand and because of reduced fertility rates in the source countries on the other. Furthermore, economic growth is envisaged to result in luring more native people who are "not in the labour force" to join the ranks of the "actively employed".

The employment scenarios above imply three different future paths of labour productivity that are depicted in Figure 4.4. In each path, CERI envisages labour productivity would increase due to an amalgam of factors that include improved technology, improved quality of high school and university graduates, increased training opportunities, immigration of highly educated and skilled workers. The introduction of more business friendly governance at the city and province levels and better organization and management of human and non-human resources is expected to further bolster productivity improvement.

Figure 4.4
Labour Productivity Estimates,
Calgary 1994 - 2035



CHAPTER 5
ENERGY MEGATRENDS: ENVIRONMENTAL, SOCIAL AND GOVERNANCE IMPLICATIONS

In this section we will review the impact of mega energy trends and economic growth in the city of Calgary on built environment, social aspects, natural environment, and governance. A case study is presented in the last section.

5.1 Built Environment and Natural Environment

In this section, no attempt has been made to quantify how the pace of climate change may be advanced or retarded under the three scenarios (chapter 2). Intuitively, one would expect the most global environmental damage under Business World, followed closely by Political World; with Environmental World being most environmentally benign. Apart from the climate change impacts illustrated below, the impacts on Calgary's built environment and natural environment under the three scenarios are realized indirectly through their impacts on Calgary's demography and prosperity. The following treatment illustrates how climate change could affect the conduct of civic business in a variety of ways. It does not purport to be exhaustive.

5.1.1 Built Environment

Climate change would have both negative and positive impacts on infrastructure such as roads, buildings, and bridges. An increase in temperature would affect the structural integrity of pavement through increased pavement deterioration. On the other hand, increased temperature reduces damage to pavement from freeze-thaw events and also reduces costs and accidents associated with winter storms. Climate change could affect precipitation patterns, which in turn, could increase the intensity and frequency of heavy rainfall events. Consequently, costs associated with constructions and maintenance of roads, highways, bridges and culverts (storm water management) would increase. Deterioration of transportation infrastructure, such as bridges and parking garages, accelerates in areas where precipitation events become more frequent. In the summer of 2005, heavy rainfall affected infrastructure in Calgary and High River areas.

Climate change scenarios project increased frequencies of heavy rainfall events that could result in flash flooding. This would obviously have implications for infrastructure, such as more frequent overflow of storm drainage facilities. The vulnerability of the Bow River Basin, from which Calgary derives its water supply, to flash flooding is well known. In the summer of 2005, pressure on the Glenmore Reservoir dam on the Elbow River necessitated the release of water that caused flooding further downstream.

Traditionally, infrastructure has been designed on the assumption of a static climate; it may have difficulties dealing with climatic changes that depart from design criteria. While designing new infrastructure, extreme climatic events of the past and the foreseeable future need to be taken in

to account. Since addressing such contingencies is not costless, infrastructure costs may rise because of climate change.

High temperatures cause damage to roadway materials' heat tolerance levels because they depend upon the type of material, duration of the temperature and the loading on the material. In the southern United States, asphalt roads soften and concrete roads have been known to "explode" lifting three to four foot pieces of concrete (Adams 1997).

Transportation

Existing studies on the impact of climate change on transportation suggest that there is a likelihood of a reduction in winter maintenance and snow removal costs in the populated areas of southern Canada. It is predicted that winters will be shorter and have variable precipitation amounts. A shorter winter accompanied by continually less snow may encourage cities to reduce their stock of snow-removal and related equipment. If winters are accompanied by more extreme snowfall events, there will be more equipment breakdowns, resulting in the need to maintain a higher inventory of replacement parts. If winters are accompanied by more freezing rain, cities will have to keep more sand and salt inventory in stock and carry out more sanding and salting. Salt mixtures work effectively at or above -6°C, but below -12°C they cannot melt and break down the ice-pavement bond. Alternative, more expensive road salt formulations could be needed in such an event.

Climate change may affect driving habits. Warmer winter temperature would cause less warming up of vehicles in the winter months, leading to savings to the cities' and residents' vehicle operations. Since climate change has the potential for more extreme weather hazards, there could be major impacts on the transportation systems and on the risk of accidents.

Waste Management

Calgary has invested millions of dollars in waste management infrastructure. The effects of climate change on the infrastructure that was designed and installed more than 30 years ago could be potentially significant. Climate change would impact waste management under either increased or reduced precipitation. Increased frequency of high-intensity rainfall may increase the amount of urban runoff, exceeding the capacity of storm sewer systems and thereby leading to localized flooding. In the event of low precipitation, water flow in rivers is likely to decline. Treatment of raw water, its distribution and the treatment of sewage effluent depend upon volume of water flow in rivers where the effluents are released. Sewage effluent needs adequate water-supply levels to assimilate it; low water flow reduces a river's waste-water assimilation capabilities.

Energy Demand

Since climate change is projected to result in warmer temperatures, there would be shifting of some energy demand from winter to summer because of a decrease in winter heating and an

increase in summer air conditioning. This shift would result in higher demand for electricity and lower demand for natural gas in the residential and commercial sectors. However, if natural gas is used to generate electricity in response to increased demand, total consumption of natural gas might increase.

Recreational Activities

The number of days suitable for golfing could increase due to climate change. For example, it has been suggested that the number of days suitable for golfing in Quebec could increase by 20 to 50 percent. This change would obviously affect the golfing industry. On the other hand, shorter winters due to the climate change would negatively impact skiing and outdoor skating activities. Considering the impact of climate change, there would be more demand for outdoor sports activities such as soccer, football as compared to indoor sports activities such as ice hockey.

5.1.2 Natural Environment

Climate change could result in changes to Calgary's natural environment arising from the continued melting of glaciers that provide a source of water to the Bow River Basin, as well as rising average temperatures and increasing frequency of severe weather conditions.

Water supply in the Bow River Basin has benefited from the melting of the Athabasca Glacier and from (by historical standards) heavy precipitation during the twentieth century. Continued shrinking of the Athabasca Glacier could result in lower melt volumes within the next 30 to 100 years. Lower flows would imply reduced oxygen concentrations in the water as well as a lessening of the dilution of pollutants. Rising average temperatures give rise to increased losses of water through evapotranspiration. Agriculture is the largest user of water drawn from the Bow River; the City of Calgary takes only three per cent of its flow and proposes to meet the water needs of growth in population and economic activity through conservation measures rather than rising water consumption.

Calgary may experience a more rapid rise in average temperatures than the surrounding countryside due to the combined effects of climate change and enhanced "urban heat island" effect[19]. From a global perspective, higher average temperatures tend to be associated with higher rates of disease, elevated mortality and problems of pest control. Such problems do, however, lend themselves to mitigation. In the United States, for example, the two states with the highest life expectancies are Hawaii (a warm state) and Minnesota (a cold state); the two states with the lowest life expectancies are Louisiana (a warm state) and Alaska (a cold state).

[19] The urban heat island effect is a phenomenon that causes higher temperatures in the cities as compared to the surrounding rural areas. It is a result of replacing "natural land cover" (e.g., grasslands, trees) with urban land surfaces (e.g., buildings, pavement). This land surface alteration changes the way solar radiation is absorbed and distributed across the land with the ultimate result an increase in air temperature (Quattrochi et al. 2000). The impact on ambient temperature arising from heat emitted by buildings and vehicles is surprisingly minor by comparison.

Measures to reduce greenhouse gas emissions within municipal boundaries will also generally reduce sulphur emissions and thereby improve ambient air quality. Although ambient air quality in Calgary is better than in most Canadian metropolitan areas, portions of the city are somewhat exposed to the danger of toxic levels of sulphur emissions as the city is ringed by sour gas plants. Development of very sour natural gas reserves in the eastern slopes of the Rocky Mountains, particularly under the Political World and Business World, would tend to increase this exposure. Because of limestone blowing into Calgary from the mountains, soils in this city are more alkaline than would be optimal for gardening, so the acidifying influence of sulphur compounds and oxides of nitrogen actually benefits Calgary's soils. Oil sands developments in northern Alberta have no significant environmental impact on Calgary because Calgary is not normally downwind from them.

5.2 Social

Social issues and their complex inter-links with economic, cultural and technology issues along the city space, represent an integral part of any future vision that Calgary planners must deal with. Unequivocally, anticipating and planning for social issues is imperative in view of the fact that 75% to 90% of all economic assets of nations are located in cities[20]. Social scientists use emerging S-shaped curve in order to identify social issues along a continuum may or may not eventuate 10-20 years forward. Anticipating these issues is crucial for providing decision-makers ample lead time to prepare for them by creating cultural, economic and knowledge capacity for learning, intervening and inventing[21]. Because of the complexity of issues involved and given time and resource constraints, CERI identifies below a few salient issues only and "imagines" their significance for Calgary's future.

Salient Social Issues

Rapid population and employment growth rates: the accelerating population and employment rates call for adequate planning in several social areas, particularly as they strongly and positively impact future demands for health, education and transportation.

In the health area, it is noteworthy that the World Health Organization projects that during the span of next thirty years, all countries of the world will encounter a large deficit in the availability of medical doctors and paramedical staff. In order to mitigate the impact of future global medical deficit, Calgary needs to develop long-term strategic plans for the health sector in ways that ensure improved future provisions of public, preventive and curative health for future city residents.

In addition to medical doctors, Calgary must ascribe to attract the *best talent* in engineering, in finance, in international law, in arts and education. Calgary must also try to lure the *best business and entrepreneurial skills* that can help it increase its spatial share of business

[20] Weissbourd R. (2004) "CEO's for Cities: the Changing Dynamics of Urban America" RW Ventures.

[21] Inayatullah S. (2002) Scanning for City Futures: a report to Asia-Pacific Cities Summit management Committee": www.paymate.com.au/PayMate.

agglomerations. In this context, reference should be made to empirical evidence that amply demonstrate that cities that attract highly educated human capital can also influence the location decisions of firms and corporations and therefore can contribute not only to economic growth but also to the city's fiscal balance[22]. The work of Florida also supports the argument that cities that manage to attract the "creative class" will succeed more than cities that fail on this count[23].

Schooling: The trend towards accelerated immigration poses additional challenges to the city by way of providing adequate schooling for dependents of future skilled workers. Calgary must ensure that teaching facilities and capacities are adequate to meet future demands by local and immigrant segments of the population. Beyond that, Calgary will want to emphasize the quality dimension of learning by competing with other cities in order to become a world-class center for knowledge, education and learning.

Cultural factors: The city must enhance and augment the cultural diversity and richness of its amenities and recreational facilities. Notice however that the rapid immigration rates will invariably lead the city to have temporal increases in ethnic minorities. In turn, its rising ethnic diversity will require Calgary to put in place additional measures and guidelines to help enhance its efficiency-cum-tolerance philosophy. Such measures include allowing identity-group differences to persist, to be recognized and to be respected without resort to prejudice or coercive action.[24]

Negative spillover effects: Finally, city planners are fully cognizant that rapid population growth will induce negative spillover effects most notably in the areas of congestion and environmental imprints. Therefore, in order to maintain its sustainable outlook, Calgary will need to encourage the business sector to innovate and introduce technologies that can reduce pollution and improve overall environmental quality.

5.3 Governance

Governance deals with processes and systems by which a city or society operate. The process usually entails a strategic planning and scenario approach. The objective of strategic planning is to improve the economic prospects of the city, reduce the degree of disparities among residents and make the city more human and more equal. The objective of a scenario approach is to provide flexibility to the planners due to unexpected changes that affect city expansion.

While we expect Calgary's economy and population to experience robust growth, this growth could be volatile due to the unexpected boom – bust nature of the energy economy upon which Calgary's economy is based. This will require flexibility from Calgary city planners beyond that which is normally required from there counterparts in most other cities. The difficulty will lie in determining whether the change the city is experiencing is merely cyclical or whether actual

[22] Matouschek N. and Robert-Nicoud F. (2005): "The Role of Human Capital Investments in the Location Decisions of Firms". *Regional Science and Urban Economics* Vol. 35: 570-583.
[23] Florida: xxx.
[24] The World Bank (2005) *Efficient Labor Markets and Economic Growth:* Washington D.C.

growth trend has changed. In the case of the former, the impact on planning might be minimal; whereas the later case may lead to major planning revisions.

Under all three scenarios the fundamentals of good governance and funding growth are essential and are discussed below.

Fundamentals of Good Governance

According to the World Bank, there are four priorities that must be simultaneously achieved if cities are to meet their objectives of providing for the welfare of their citizens. Cities must be liveable, well governed, competitive, and well financed. All four elements are interdependent; all four are to a meaningful extent influenced by factors beyond the control of local decision makers, and all four needed to be continually balanced and readjusted as their dynamic environment changes.

Governance, of the four elements, is the mechanism that translates the democratic action and subjective values of voters into policies and projects designed to make a city liveable, competitive and bankable. While some priorities are (nearly) universal, citizens of different cities will have differing values, sensitivities and definitions as to what constitutes a good quality of life, a competitive local economy, and the level of taxation from local governments they are willing to support.

Good planning requires an understanding not only of the circumstances and environment the city is currently operating in but an informed evaluation of how the city is likely to evolve in the future. In addition, effective governance requires knowing and focusing on those factors that are within its ability to control or influence (land zoning) and a flexibility to respond to the changing factors outside its control (energy megatrends and macroeconomic conditions). Proper governance therefore necessitates a developed information system that allows the planners to stay appraised of what is happening in the city. In addition, information technology will be an important channel for citizens to access and interact with the city.

In order for regional management to be effective, services will have to be delivered uniformly across the metropolitan area. Regional authorities will therefore need to conduct a certain amount of redistribution of revenues from richer areas to poorer areas. Because of the typical uncertainties that surround global economic growth, regional management needs to be established around a framework that has guiding principles but allows for flexible strategies and instruments of regulation to adjust to a changing environment.

Maintaining and improving Calgary's business-friendly governance policies is imperative. Such policies include city procedures for starting business and licenses; codes for registering and building property. International literature shows that cities that have a small number of requirements in terms of rules and regulations for setting up businesses tend to thrive more than cities that have long lists of regulations and business set up requirements. There are obvious benefits for business-friendly governance: more business entry implies more investment and

higher economic growth. More business entry also implies more tax base for Calgary's tax revenue and as more companies move into the city boundaries, the city can lower the corporate tax burden which gives more incentive for business to locate and produce in Calgary. Making property registration simple, fast and low in cost allows entrepreneurs focus on their business and encourage formal title which in turn makes it easier for businesses to get credit from banks[25].

Two conditions need to be met in order to sustain Calgary as an engine of growth for the Alberta economy. First, the provincial government will have to proactively partner with Calgary to help optimize and manage growth in the region. Second, a mechanism must be put in place to make sure that the benefits and costs of growth over the region are redistributed to the areas in which they are actually generated. For example, if Calgary restricts its perimeter expansion and moves to zoning laws that favour housing that is denser, its efforts will be thwarted if surrounding cities and municipalities do not simultaneously adjust there zoning policies as well. Optimally, Calgary would coordinate policies with neighbouring jurisdictions. [26]

Funding Growth

As in many other cities, Calgary is built around the "car" and future physical limits will cause more traffic congestion to occur. Calgary needs to prepare to relieve itself from such future traffic congestions in the center by building a combination of beltways and fast track mass transit systems. The mass transit systems are not just to ease traffic congestion, but also to change the shape of the city[27].

Building major transportation systems will require huge funding that could affect the temporal balance of the city's purse. As identified in the Calgary City Council report 'Righting the Balance', the 25 percent increase in Calgary's population over the last 10 years has already placed significant pressure on the city's finances. The city's main revenue source is property tax which does not grow in lock step with the economy, but rather must be increased by vote of city council. Moreover, the city has to share its property tax revenue with the province (education system).

World-class Cities

The rise of Calgary as a world class city can be discerned from several areas. First, world-class cities such New York, London, Tokyo, Paris, Frankfurt, Zurich, Amsterdam, Los Angeles, Sydney and Hong Kong are fast-growing locations of international services, primarily as international financial, information and business centers that have strategic concentrations of resources and

[25] World Bank (2006): *Doing Business in 2006*, World Bank, Washington D.C.

[26] The following is an excerpt from the November 8th Rocky View Weekly "Municipal Affairs Minister Rob Renner acknowledged that dismantling the Calgary Regional Planning Commission a decade ago may have had unintended consequences for local jurisdictions in the Province of Alberta. 'We see conflicts beginning to arise.' Renner said, speaking at an assembly of about 100 representatives to the Calgary Regional Partnership."

[27] Phones D. (2005) "Western Sprawl: The Octopus and the Tortoise" *The Economist*, November 11.

infrastructure.[28] On this count, Calgary clearly stands shoulder to shoulder with global cities. Because of its mature infrastructure and excellent transportation and low tax rate, Calgary was ranked second to Vancouver among 100 international business travelers. [29] It also enjoys the lowest head office operating costs amongst 52 cities in North America.[30] Second, the downtowns of cities and metropolitan business centers receive massive investments in real estate and telecommunications. Calgary has had some impressive infusions of resources and growth in real estate and telecommunications. Finally, global cities attract highly educated and skilled workers from all over the world and Calgary's community of highly educated immigrants is also impressive

5.4 How a City Manage Growth – Case Study

The challenges of rapid, if at times sporadic, economic and population growth over a sustained time frame have occurred in cities around the world, from Sao Paulo, Brazil to San Francisco, USA to Shanghai, China. At a national level, we have the example of the Greater Toronto Area (GTA) which grew from a population of 2.1 million in 1961 to 4.6 million in 1996. In the future, we expect Calgary, like Toronto in the 1960s to 1990s, will grow due primarily to an influx of relatively high skilled immigrants.

A full treatment of the growth of Toronto is beyond the scope of this paper. We focus instead on several public - sector decisions that were crucial in their implications for Toronto's future growth and the evolution of the city. The following discussion draws heavily from '*Designing a Metropolitan Region: The Lessons and Lost Opportunities of the Toronto Experience'* by Larry S Bourne.[31]

An important decision was the creation, in 1953, of the Municipality of Toronto (Metro). A provincial government act combined the City of Toronto and twelve municipalities into a two – level government organization responsible for the entire region. Responsibilities were divided between Metro and the local municipalities; perhaps most importantly Metro was given taxation powers and the ability to exercise planning powers over the sparsely populated bordering rural municipalities.

This governing structure was the first of its kind in North America. The expanded tax base allowed for investments in infrastructure, transportation and social services all over the locality. In addition, the structure allowed for a uniformity of services across the region by allowing tax transfers from high income areas to low income areas. Public housing was built across the region instead of being localized in a single area. Metro was able to control new growth in the surrounding suburbs, leading to an urban region with a denser population base.

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[28] Sassen S. "Urban Economies and Fading Distances" http://www/megacities.nl/lecture_sassen.htm

[29] Michael Lau (2004): "Head office costs lowest in Calgary: San Francisco most expensive*"* *Calgary Herald* October 8.

[30] Calgary Herald (2005) "*Margin Calls: Calgary No.2 for Business Travel*" Friday November 18

[31] A submission to '*The Challenge of Urban Government Policies and Practices'* edited by Mila Freire and Richard Stren,. World Bank Institute 2001

The establishment of the Metropolitan Toronto and Regional Conservation Authority (MTRCA), in part created as a response to a hurricane 1954, represents another vital public - sector decision. The MTRCA, initially intended to afford flood protection for the watershed, has also implemented policies resulting in the conservation of the region's ravine systems as parkland. These ravines became the foundation of the metro Toronto park system.

Lastly, we highlight the creation of a mass transit system. Its first branch, a 4 kilometre underground subway line stretch, was built along Yonge Street and opened in 1954. The Toronto Transit Commission (TTC) system has over 390 million riders a year and is the second largest in North America. A top quality transportation system allowed for a higher population density as Toronto grew.

These aforementioned decisions, made in the 1940s and 50s, prepared a way for Toronto's sustainable growth in the 1960s and beyond. If growth is to be managed correctly, a "systems thinking" approach is required that takes into account the interconnectedness of the various elements of city life: employment, the natural environment, transportation, the types of housing, .and the quality of services, etc. The city must have some mechanism to direct housing and growth not only with in its immediate borders buts also in its neighbouring jurisdictions. Otherwise lower tax rates or looser zoning in adjacent regions will draw population to the bordering municipalities. This could result in a migration from the city to the suburbs outside city limits (a hollowing out) that would put an increased pressure on the remaining tax base. The creation and management of a city's transportation infrastructure is one of the most critical elements to its long term success.

Over the years the powers granted to Toronto's municipal government structure have changed substantially. This is reflective of the policies and attitudes prevailing at the time. In the 1970s, the province took away Metro Toronto's planning influence in areas directly outside their political authority. Instead of allowing Metro's jurisdictional boundaries to grow, the province created 4 new two-tiered regional governments. This led to a boom, which continued into the early 1990s, in the development of suburbs outside of Toronto. This boom was not coordinated with Metros' own service or development standards. In 1998, Metro Toronto and its six bordering municipalities were amalgamated, against popular opinion in all jurisdictions, into a new single tier city of Toronto.

According to Bourne, present day Toronto is made up of three cites or worlds. The core of Toronto is the portion that grew into being before the Second World War. The second world of Toronto are the older suburbs created and shaped by the three policy decisions articulated earlier. The third world of Toronto is the post - 1970s explosion of the suburbs surrounding Toronto. This growth to the periphery is similar to what many cities, especially in the US, have experienced and, more recently, to what Calgary is experiencing.

Some view the old inner city of Toronto and its neighbouring suburbs as a success because they possess a higher population density, a pedestrian friendly transit orientation and because the costs and benefits of growth were split more or less equally across neighbourhoods. According to

this view, the outer suburbs of Toronto are a social and planning failure. The relatively low population density of the suburbs means that public transportation is poor, residents must drive to work and shop and social services are strained by rapid growth. Development was conducted without coordination with the Metro area.

On the other hand, many of the residents of the outer ring of new (er) suburbs in Toronto view them as a success. The suburbs represent a place of safety, high quality affordable housing complete with recreational facilities, and employment opportunities. They view the older parts of the city as polluted, congested, dangerous and unattractive.

APPENDIX A
MAJOR DRIVERS AND UNCERTAINTIES FOR THE GLOBAL SCENARIOS

A.1 Major Drivers

Our world consists of three types of complex systems—natural, social and technological. 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.

A.1.1 Environment

The natural environment obviously underpins all human existence. Although humankind depends absolutely on the natural world, human activities have imperilled 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. One of the major uncertainties for our energy scenarios is the response of major governments to the environmental threat.

A.1.2 Demography

Human population growth 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 6.4 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.

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 is already shrinking its workforce; and the "youth bulge" in developing countries could provide a source of people available for work worldwide. 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 the developing world tend to live in less sanitary conditions, while those in the developed world can better afford medications and public health and thus remain more productive.

A.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 meagre 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 labour 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.

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.

A.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 societies.

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". 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 religious fundamentalists and more extreme environmentalists.

A.1.5 Geopolitics

The future shape of the international political system is a matter of great debate between two schools of thought—Realists and Liberals. Based on Realist 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. According to Liberals, on the other hand, 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, International Monetary Fund and World Trade Organization) as evidence of this cooperation.

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.

A.1.6 Technology and Knowledge

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 fuelled 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 thirty years are biotechnology, hydrogen fuel cells, solar photovoltaic, and possibly nanotechnology. Biotechnology is already taking-off, stationary fuel cells and solar photovoltaic are about to (especially in developing countries that lack energy infrastructure), and mobile fuel cells are being tested, while nano-technology is still on the drawing board. The combination of information technology (IT) and these other technologies have the potential to create a very powerful "long wave" of economic growth.

A.2 Major Uncertainties

The world energy market through 2035 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.

A.2.1 Energy Demand

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

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. Technological advancements decrease energy intensity because they tend to improve energy efficiency. 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 primary drivers for energy policy tend to be high energy prices, and geopolitical and environmental concerns.

A.2.2 Energy Mix

The major factors affecting the mix of fuels are end-use technologies, the marginal cost of primary fuels and their relative prices and energy policy. 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). 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, and other renewables). For example, oil has dominated the transportation sector over the past century because of the widespread use of the internal combustion engine (ICE). However, end-use technologies will continue to change in response to both commercial and technological forces.

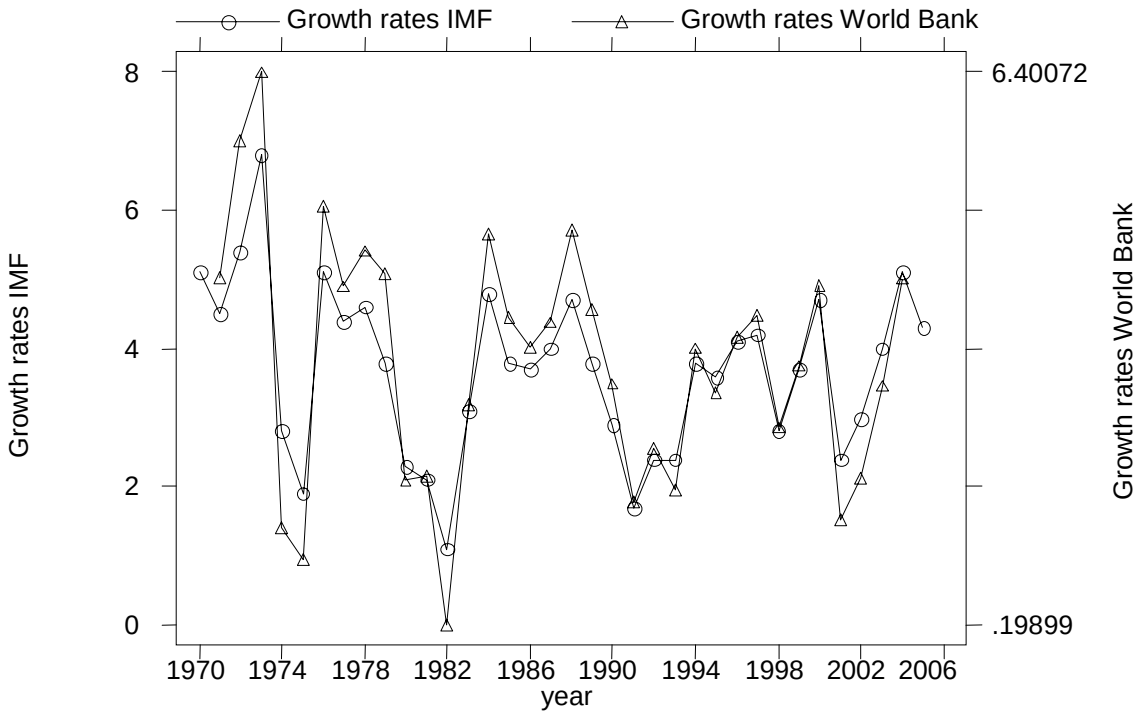
In addition, energy policies can affect fuel choice by funding R&D for specific end-use technologies and through subsidies to consumers purchasing specific technologies.

APPENDIX B
ENERGY MEGATRENDS AND ECONOMIC GROWTH: ECONOMETRIC CAUSALITY

B.1 MegaTrends In The World Economy

Below, we test the causality between international oil spot prices and global economic growth. Pragmatically, the oil-prices-to-economic growth hypothesis draws on two literature records. The first relates to the positive impact that oil prices exert on the economic performance of oil-exporting economies such as Saudi Arabia, Iran, Kuwait, Norway and Russia. The second concerns the widely-acclaimed negative correlation between international oil prices and economic growth in the world economy. Utilizing the World Bank and the IMF data files which utilize different benchmark base years, Figure B.1 shows the annual growth rates that the world economy realized during the period 1970 to 2005[32].

Figure B.1
World Economy: Growth Rates



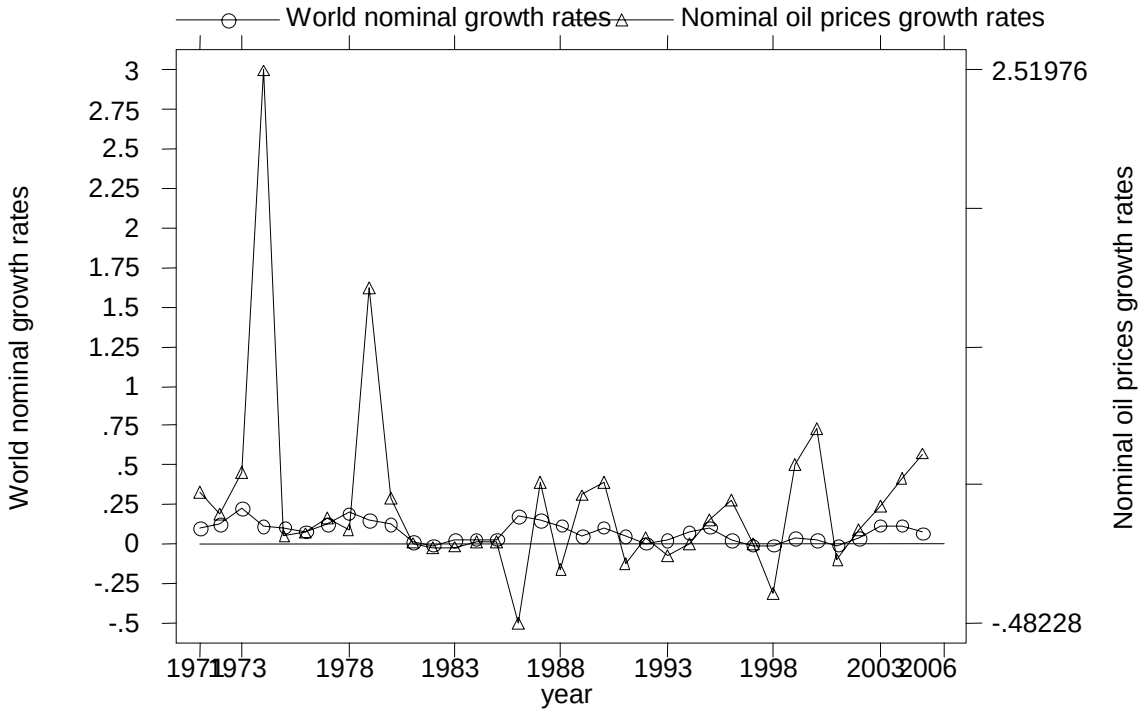
Five distinct dips in the global growth rates can be discerned from the Figure. Perhaps, expectedly, most of the dips were associated with oil price shocks. For instance, after oil prices quadrupled in 1973, economic growth dropped in 1974 to less 2 percent, well below rates that

[32] Base year is 2000.

were realized earlier[33]. Other growth-accelerating (decelerating) spells have also coincided with international oil price movements that occurred since the early 1980s.

Figure B.2 plots world nominal economic growth rates against nominal international oil spot prices. The plot shows that dips in world growth rates were generally associated with spells of oil price increases. Thus prior to the oil price shock of 1973, the world economy grew at high nominal rates while the oil price shock of 1973 induced decelerated world economic growth rate. As well, the more recent increases in oil prices of 2004 and 2005 were associated with reduced world economic growth rates in nominal terms. The pattern is verified by the significant simple correlation rate of 0.41, between the growth rates of nominal oil prices and nominal world economic growth rates.

Figure B.2
Nominal Growth Rates of World Economy and Oil Prices, 1970 - 2005



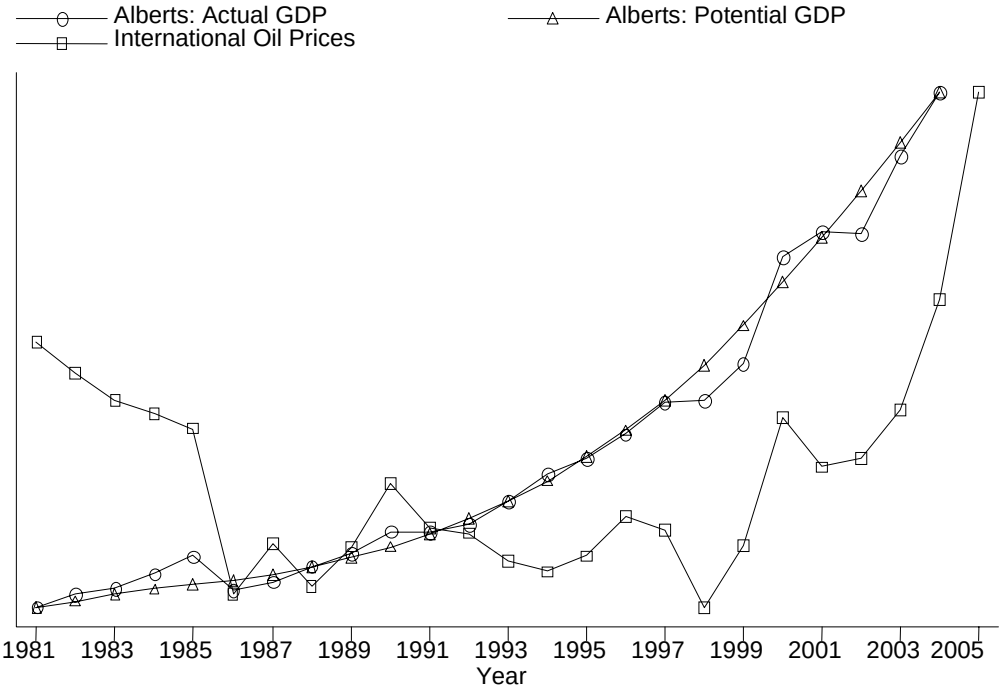
B.2 MegaTrends In The Alberta Economy

Available evidence suggests that there is a positive correlation between nominal oil prices and nominal GDP in the province of Alberta; the correlation coefficient between the two series is

[33] More accurately-speaking however, the causality is most likely two-way and strictly recursive. For instance, it is plausible that slower world economic growth would reduce the pressure on international oil prices.

highly positive at (0.65). Of course correlation does not mean causality partly because time series data often tend to move in the same direction because of a trend that is common to all of them. However, the link may also be eyeballed from contrasting oil price movements with actual and potential GDP in the province[34], Figure B.3. Particularly noteworthy is the fact that Alberta's actual GDP was higher than potential during periods of high oil prices. For several years during which oil prices were high and/or rising, Alberta's actual GDP exceeded its potential GDP. This apparent causality should not be construed that we ignore the impact of other energy prices, notably natural gas on corporate revenues, the economy or the fiscal standing of Alberta. For instance, it has been recently forecasted that Alberta's natural gas royalties will be $9.1 billion, an increase of $3.6 billion from the budget. Natural gas prices are forecast to average Cdn$8.50 per gigajoule, an increase of $2.90 from the budget estimate while total oil royalties are forecast at $2.4 billion, $1.1 billion higher than budget. The increase is based on oil prices averaging US$60 per barrel for the fiscal year, up $18 from budget and $10 from first quarter. As well, research elsewhere has identified the role of fiscal policy in influencing Alberta's economic performance[35].

Figure B.3
International Oil Prices, Actual and Potential GDP for Alberta

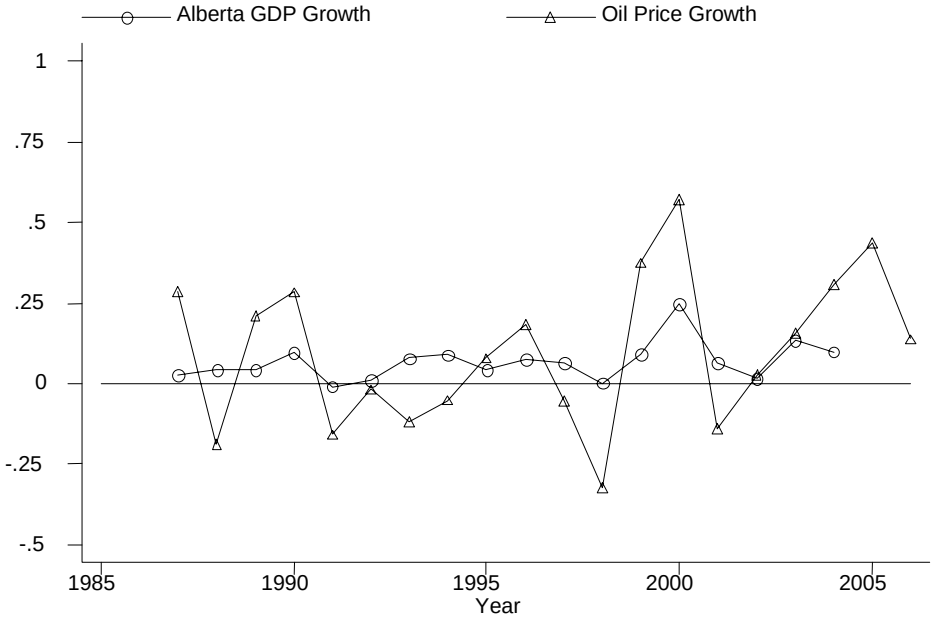


[34]Potential GDP for Alberta is estimated using the Hodrick-Prescott filter.

[35] For instance, policies that controlled budget deficits had strong impact on the economic performance of Alberta. See: K.J. Mckenzie (2003) "A tale of two provinces-tax policy in Alberta and Ontario" www.fraserinstitute.ca/asmin/books/chapterfiles

The co-movements between energy prices and GDP in Alberta can also be discerned in Figure B.4 which displays growth rates of oil prices and the growth rates of Alberta's nominal GDP.

Figure B.4
Growth Rates of Oil Prices and Alberta's Nominal GDP



A simple first differences regression was also performed. The results indicated that the series of first-differenced oil prices strongly affect first-level differences of GDP in Alberta. The findings indicate that the response of GDP to changes in oil price, the elasticity estimate in difference form, is (0.20). That is, in response to oil prices increase of ten percent, Alberta's nominal GDP growth rate would increase by 2 percent. Table B.1 shows the findings

Table B.1
Oil prices and GDP in Alberta (variables are in log of differences)

```
      Source |       SS       df       MS              Number of obs =      20
-------------+------------------------------           F(  1,    18) =   28.24
       Model |  .053755926     1  .053755926           Prob > F      =  0.0000
    Residual |  .034264247    18  .001903569           R-squared     =  0.6107
-------------+------------------------------           Adj R-squared =  0.5891
       Total |  .088020173    19  .004632641           Root MSE      =  .04363

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    D_lnalbg |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    D_lnoilp |   .2038401   .0383584     5.31   0.000      .123252    .2844282
       _cons |   .0508965   .0097707     5.21   0.000     .0303691    .0714239
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CERI tested similar relationship in the case of Calgary. Table B.2 summarizes the results gleaned from a simple regression analysis in which oil prices are the explanatory variable of real GDP variations in Calgary. The dependent variable, Calgary's real gross domestic product, and the independent variable, world oil prices, are both in logarithmic scale and hence the estimated coefficient can be interpreted as the elasticity of GDP with respect to oil price movements.

Table B.2
Impact of Oil Prices on Economic Growth in Calgary

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reg  lnrgdpcal lnoilprsp, robust

Linear regression                                      Number of obs =      11
                                                       F(  1,     9) =   10.91

                                                       Prob > F      =  0.0092
                                                       R-squared     =  0.5897
                                                       Root MSE      =  .08793

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             |               Robust
   lnrgdpcal |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lnoilprsp |   .3246284   .0982993     3.30   0.009     .1022598     .546997
       _cons |   9.584707   .3211226    29.85   0.000     8.858278    10.31114
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The coefficient of oil prices is positive (0.30) and significant at the 1% level. The elasticity indicates that during the period 1994-2004, a change in world oil prices of, say, 10 percent resulted on average in a 3 percent change in Calgary's real GDP.

Given the severe data limitations illustrated by short time series data, CERI tentatively concludes that international oil price movements seem to foster economic growth in the city of Calgary.

About CERI

The Canadian Energy Research Institute (CERI) is a co-operative research organization established through an initiative of government, academia, and industry in 1975. The Institute's mission is to provide relevant, independent, objective economic research and education in energy and related environmental issues Related objectives include reviewing emerging energy issues and policies as well as developing expertise in the analysis of questions related to energy and the environment.

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