Peak Energy and its Implications for the City of Edmonton

J. David Hughes

June, 2010

Abstract:

Hydrocarbons (oil, gas and coal) represent a one-time legacy of fossilized sunshine that has fuelled an unparalleled expansion of population, industrial output and food production over the past two centuries. Cheap energy from hydrocarbons has underpinned the development of infrastructure in cities like Edmonton. Urban sprawl, supply chains that stretch around the World and unprecedented levels of personal energy consumption, place Canadians at the top of food chain in terms of per capita energy consumption globally. Cities like Edmonton, which also relies on fossil fuel extraction for a part of its economic livelihood, are highly vulnerable from a sustainability point-of-view to the end of cheap energy. Conventional oil and gas production in Alberta, including unconventional sources such as coalbed methane, has peaked. The only growth in the medium- and longer-term in the energy sector in Alberta is the oil sands. Global oil production is at or near peak production levels. Alternatives to oil and gas such as coal-to-liquids or gas-to-liquids are not scalable to current levels of energy throughput, nor are the multitudes of renewable energy sources purported by some. This mandates a new paradigm of radically reduced energy footprint for cities like Edmonton. Hydrocarbons will continue to be important of necessity, but renewable energy must make up an increasing share of an overall downsized demand. Rethinking energy at the end of the era of cheap energy is crucial and is not optional – the laws of Thermodynamics cannot be repealed and Mother Nature has a way of settling such issues for those who choose to ignore them.

Biography:

David Hughes is a geoscientist who has studied the energy resources of Canada for nearly four decades, including 32 years with the Geological Survey of Canada as a scientist and research manager. He developed the National Coal Inventory to determine the availability and environmental constraints associated with Canada's coal resources. As Team Leader for Unconventional Gas on the Canadian Gas Potential Committee, he coordinated the recent publication of a comprehensive assessment of Canada's unconventional natural gas potential. Over the past decade, he has researched, published and lectured widely on global energy and sustainability issues in North America and internationally. He is a board member of the Association for the Study of Peak Oil and Gas – Canada and is a Fellow of the Post Carbon Institute. He recently contributed to "Carbon Shift", an anthology edited by Thomas Homer-Dixon on the twin issues of peak energy and climate change, and his work has been featured in Canadian Business, Walrus and other magazines, as well as through the popular press, radio, television and the internet. He is currently president of Global Sustainability Research Inc., a consultancy dedicated to research on energy and sustainability issues.

Introduction

Fossil fuels have provided a unique, one-time energy subsidy for the World, which has allowed a multi-faceted explosion of growth in population, industrial output, food production and per capita- and total-energy consumption. In just 160 years, per capita energy consumption has increased more than eight-fold, global population has increased more than five-fold, and total energy consumption has increased by forty-six times. The exploitation of fossil fuels underlying these growth trends accounted for 86% of global energy consumption in 2008[1]. Unfortunately, fossil fuels are finite. There are no scalable alternatives to the energy throughput of fossil fuels at current consumption levels: not nuclear, not wind, not photovoltaics, not geothermal, not any of the other alternatives purported by various advocates, nor can these alternative sources come close to current rates of fossil fuel energy throughput even in aggregate. Fossil fuels represent the conversion of millions of years of "fossilized sunshine" to a dense form of energy that has proven to have no substitute at the scale of current rates of energy consumption. The recoverable oil that now provides 35% of global primary energy, for example, represents a consumption throughput equivalent to 14,000 years of fossilized sunshine each day. Coal and natural gas similarly represent vast amounts of fossilized sunshine. These energy dense resources are non-renewable, yet the infrastructure of much of the World, and particularly North America, including the City of Edmonton, has been built around them, assuming their continual abundance. It is therefore crucial to understand the future of fossil fuels in planning for the sustainability of a city like Edmonton.

The Current State of Edmonton's dependency on hydrocarbons

North America's infrastructure was largely built after the advent of cheap fossil fuels and was based upon them. This resulted in the need for long distance commuting, lengthy supply chains, inefficient building stock and other energy wastefulness. As a result, Canada's per capita energy consumption is higher than that of the United States, and nearly three times that of Industrialized Europe[2], which was in large part built before the advent of cheap energy. In an era of declining availability of fossil fuels and likely dramatically increasing prices in the longer term, this infrastructure is unsustainable and highly vulnerable to disruption.

The City of Edmonton, unfortunately, has been built around the growth paradigm of the ever expanding availability of cheap energy. The City far outstrips its capacity to sustain its citizens from locally produced food and other commodities. Suburban sprawl mandates lengthy commutes and massive investments in ring roads and other automobile-based transportation infrastructure, although investments in light-rail- and other mass-transit that have been made are very important in reducing this requirement. Supply chains for the City extend to the southern United States and further for food, and around the World for other necessities, and hence are dependent on cheap energy and therefore are vulnerable to a variety of geopolitical and other

[1] BP Statistical Review of World Energy 2009
[2] Energy Information Administration, International Energy Outlook, 2009

disruptions. The City's northern climate also makes it extremely dependent on a continuous supply of fossil fuels for residential and commercial heating. Moreover, given Alberta's status as the Number One producer of fossil fuels in Canada, a significant proportion of the City's economy is based on oil and gas extraction.

The City has experienced a population growth profile which parallels growth in global oil consumption and global population growth (Figure 1). This growth has been made possible in large part by the availability of cheap fossil fuels, including Alberta's role as Canada's dominant oil and gas producer.

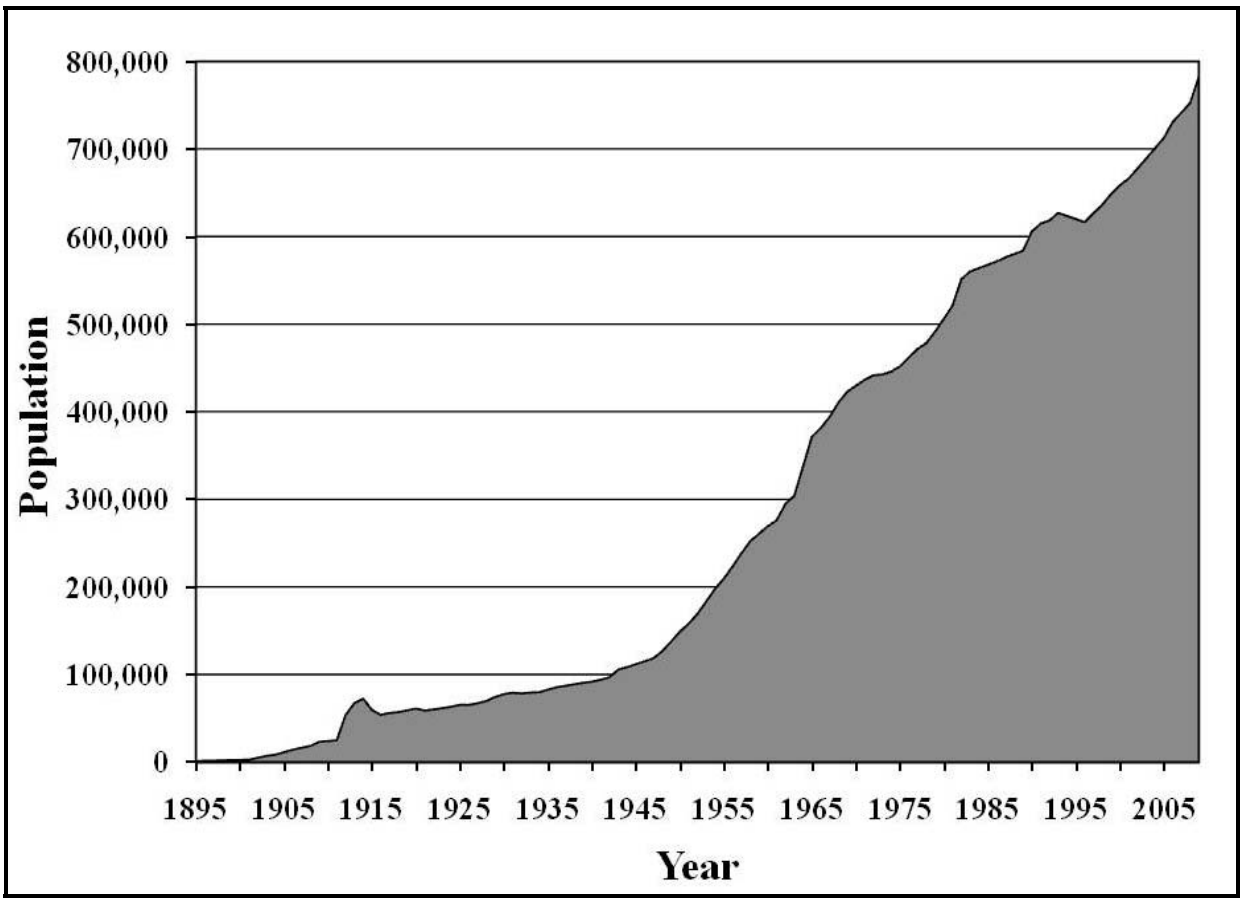

Figure 1 – Population of the City of Edmonton from 1895 to 2009[3].

Given the vulnerability of the City of Edmonton to the availability of a cheap and reliable supply of fossil fuels, as well as their production being an important input to its economy, it is prudent to examine the outlook for their availability in the longer term.

[3] http://www.edmonton.ca/business/economic_demographic/economic_information/population-and-employment-fore.aspx

Oil

Oil is a globally priced commodity, so no matter what the production levels in Canada happen to be, Canadians will be subject to global prices and the economic fallout of price volatility. The outlook for global oil production is a subject of controversy. Many economists state there is not a problem, and the "invisible hand" of the markets will provide energy as needed through price signals. Others suggest that many main stream economists represent the court jesters of yesteryear, making comforting forecasts by projecting consumption trends from the past into the future assuming that energy supplies will be there to meet requirements. Certainly, the failure of most mainstream economists to predict the economic recession of the past couple of years represents the latter, and as such justifies the representation of much of mainstream economics as the "Dismal Science". The major problem with economists who assert we have centuries to millennia of fossil fuels is they do not differentiate "peak production" from "running out" – we are unlikely to ever "run out" of fossil fuels, however "peak production" will be a watershed in an economic paradigm based on growth.

Geoscientists who are engaged in actually finding and producing oil, on the other hand, are much more reserved in the prospects for future growth in oil production. Several recent studies point to a near term peak in World oil production[4], including a 2010 study by the United States military[5] which states:

> *"By 2012, surplus oil capacity could entirely disappear, and as early as 2015, the shortfall in output could reach nearly 10 million barrels per day [about 12% of current global consumption]."*

The International Energy Agency (IEA) produced an unprecedented report in 2008[6] in which they studied the decline rates in 800 of the World's major oil producing fields. They estimated overall decline rates in post-peak fields at 6.7%/year. An average depletion rate overall including new fields coming on to production is in the order of 5%/year, which means, as stated by Dr. Fatih Birol, the Chief Economist of the IEA, in the Independent in August 2009[7]:

> *'"One day we will run out of oil, it is not today or tomorrow, but one day we will run out of oil and we have to leave oil before oil leaves us, and we have to prepare ourselves for that day," Dr Birol said. "The earlier we start, the better, because all of our economic and social system is based on oil, so to change from that will take a lot of time and a lot of money and we should take this issue very seriously," he said.'*

In this interview Dr. Birol also stated:

[4] http://www.ukerc.ac.uk/support/Global%20Oil%20Depletion
[5] http://www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf
[6] http://www.worldenergyoutlook.org/ click 2008 report.
[7] http://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html

'Even if demand remained steady, the world would have to find the equivalent of four Saudi Arabias to maintain production, and six Saudi Arabias if it is to keep up with the expected increase in demand between now and 2030, Dr Birol said.'

So what does this mean for Alberta and the City of Edmonton? Conventional production of light and heavy oil in Alberta has long since peaked and is in terminal decline. The only growth is in the oil sands as illustrated in the June 2009 forecast from the Canadian Association of Petroleum Producers (CAPP) in Figure 2. And the production increase in this forecast beyond 2012 is totally dependent on as yet unknown projects in the oil sands, which may never happen. The message here is that the old paradigm of ever increasing energy abundance is over. Peak global oil production may have occurred in 2008 according to many analysts, and will certainly occur before 2020 according to the majority of reports. This will profoundly impact the liveability of cities like Edmonton as energy prices rise and supply limitations become an issue.

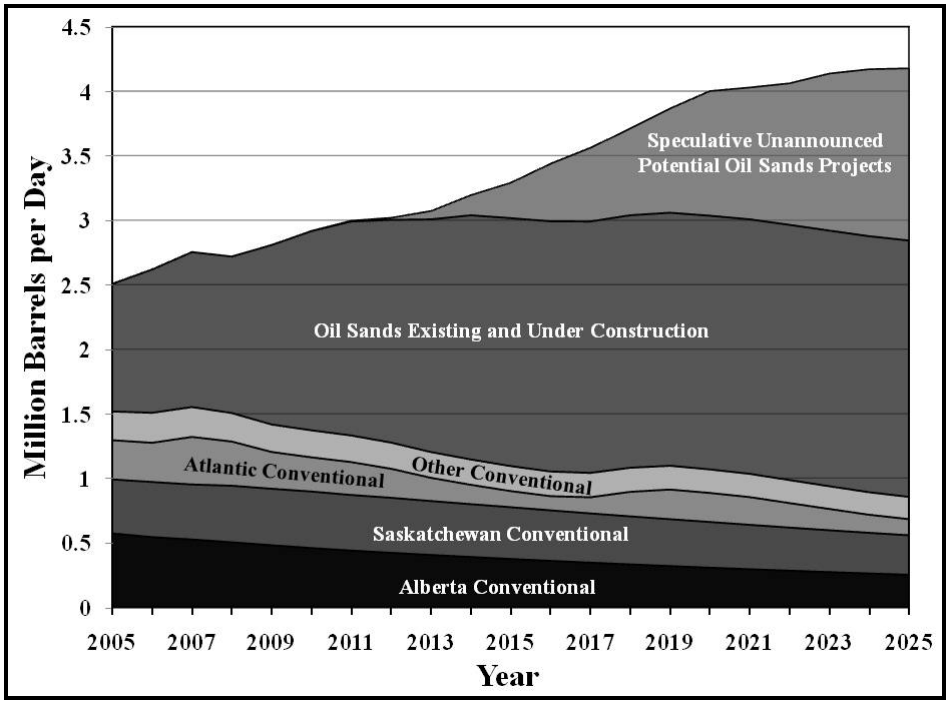

Figure 2 – Potential growth in Canadian oil production as forecast by CAPP in June 2009[8].

It is interesting to note that even if CAPP's unannounced oil sands projects come to fruition, oil sands and all other sources of unconventional liquid fuels (eg.Venezuela extra heavy oil, biofuels, coal-to-liquids, gas-to-liquids, oil shale etc.) will make up less than 13% of projected global demand by 2030 according to the U.S. Energy Information Administration[9]. Unconventional oil will be important to partially offset declines after peak oil production occurs,

[8] http://www.capp.ca/aboutUs/mediaCentre/NewsReleases/Pages/2009-2025CanadianCrudeOilForecastandMarketOutlook.aspx#VNTml6PQmsD5

[9] Energy Information Administration International Energy Outlook 2009.

but is no panacea in terms of allowing the continuation of the growth paradigm based on cheap energy. The message for the City of Edmonton is that all future expenditures on infrastructure must be made in the context of escalating oil prices and directed towards reducing the energy footprint of the average citizen, as well as shortening supply chains based on cheap energy to ensure greater resilience in the event of potential disruptions in the flow of energy.

Natural Gas

Natural gas is the number one source of royalty revenue for the Province of Alberta. The recent decline in drilling and the resultant falloff in production has been a major factor in the current government budget deficits. The fact of the matter is that geological limits to available production have been reached, and Alberta is now on an "exploration treadmill" in which more and more drilling is required to maintain production. This treadmill is illustrated in Figure 3. Alberta gas production peaked in 2001 and is now 30% below peak, despite record gas prices in early 2008. Meanwhile, the number of gas well connections required to produce that reduced production in 2009 was nearly 117,000, up 312% from 1990. The average productivity per gas well connection has declined by 73% since 1993, meaning that nearly four wells have to be drilled today to equal the production of one average well in 1993.

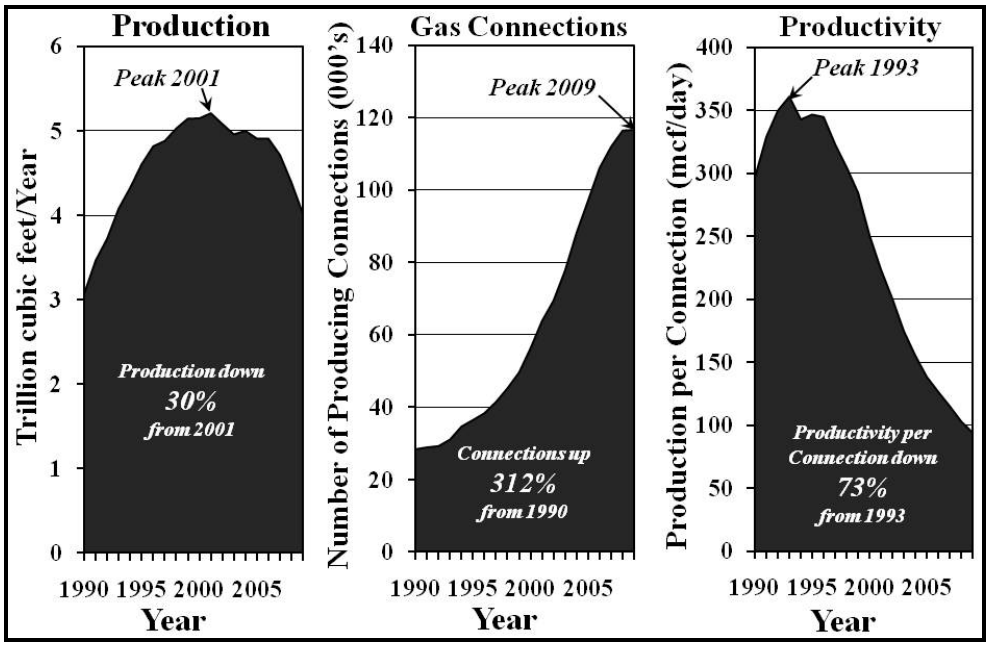

Figure 3 – Alberta's Gas Exploration Treadmill, 1990-2009 (ERCB, 2010[10]). Production is down 30% from a 2001 peak, gas well connections are at a record high, and productivity per gas well connection is down to a record low (gas well connections are slightly higher than the number of producing gas wells as a small minority of gas wells may have more than one connection).

[10] http://www.ercb.ca/docs/products/STs/st98-2010-ds-conventionalng.xls

Canadian gas production is now declining at a rate of 8.2%/year (Figure 4), and Alberta gas production, which constitutes 80% of Canadian production, peaked in 2001 (Figure 5).

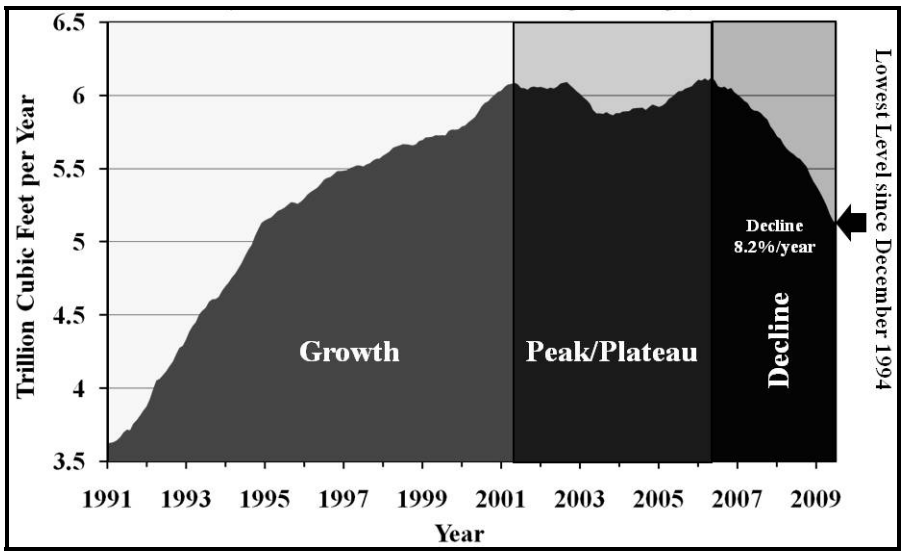

Figure 4 – Canadian marketable gas production including data through December, 2009 (12 month centered moving average). Source Statistics Canada[11].

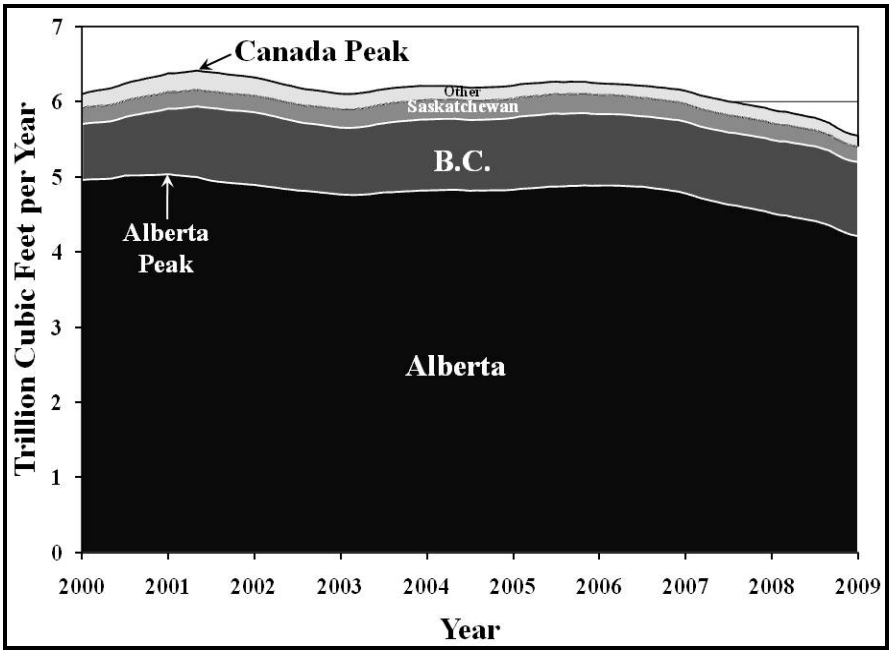

Figure 5 – Marketable gas production by province illustrating 2001 peaks in Alberta and Canadian production (12 month centered moving average), and the fact that Alberta accounts for 80% of Canadian production. Source National Energy Board[12].

[11] http://cansim2.statcan.ca/cgi-win/cnsmcgi.pgm?Lang=E&ArrayId=1310001&Array_Pick=1&RootDir=CII/&ResultTemplate=CII\CII

The Alberta Energy Resources Conservation Board's 2010 forecast suggests that this decline in production will continue through 2019 (Figure 6), and given recent production figures this chart could by too optimistic.

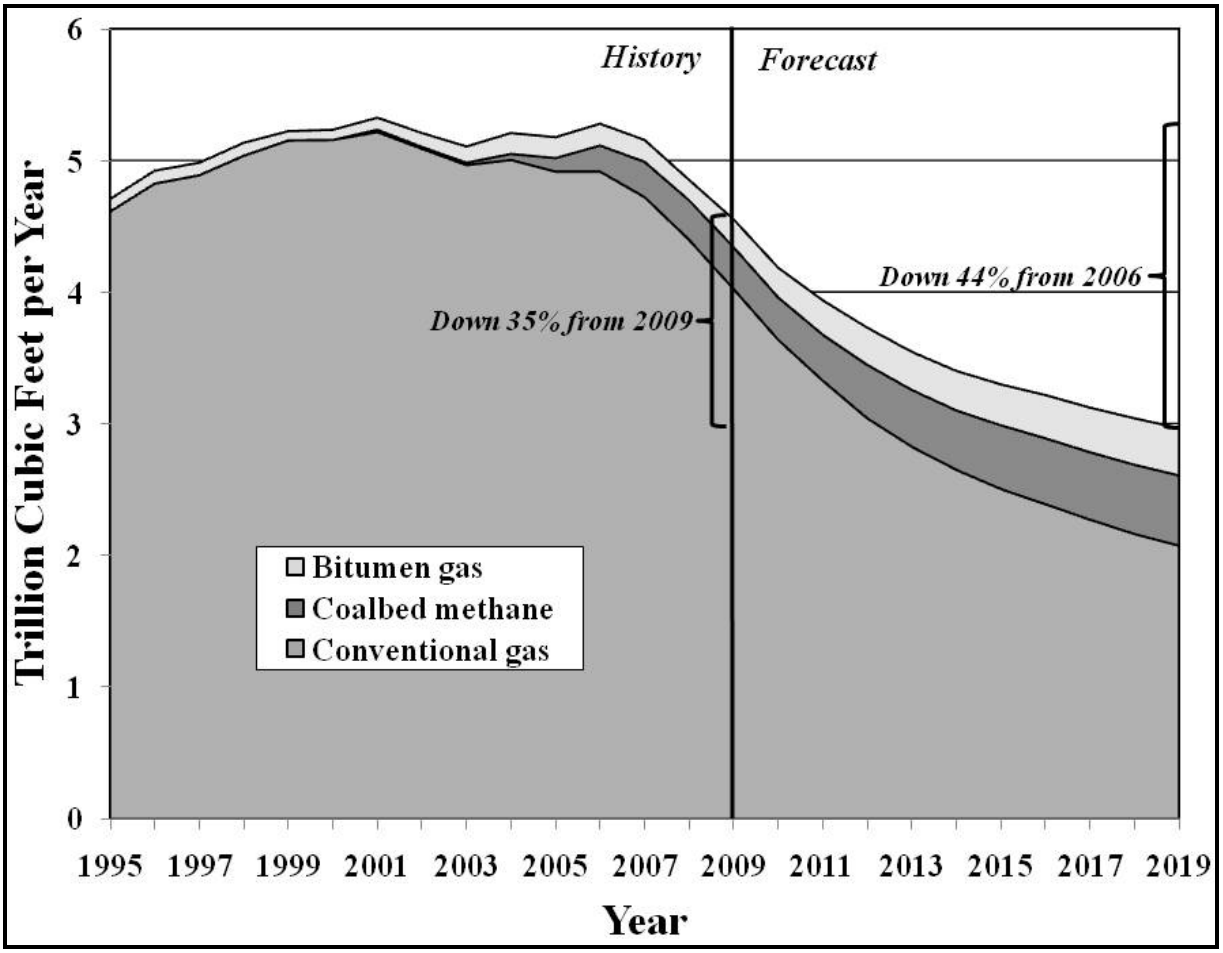

Figure 6 – Forecast of Alberta gas production from the Alberta Energy Resources Conservation Board (2010)[13].

There has been great enthusiasm for a dramatic increase in North American gas production from shale plays recently. This is based primarily on the success of the Barnett shale in eastern Texas, which accounts for 60% of U.S. shale gas production. Results from the Barnett have been extrapolated to shale formations all over the U.S. and Canada. Investors such as T. Boone Pickens and Aubrey McClendon, CEO of Chesapeake Energy, have suggested natural gas will become so abundant that America's vehicle fleet (or at least trucks and buses) can be repowered with natural gas, radically lowering the U.S. need for oil imports. The bottom line is that this rhetoric is likely totally overblown. All shale plays are different from a geological perspective, and the Barnett experienced a peak in production in early 2009. U.S. gas production peaked in

[12] http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/sttstc/mrktblntrlgsprdctn/mrktblntrlgsprdctn-eng.html
[13] http://www.ercb.ca/docs/products/STs/st98_current.pdf

1973 and although gas production has been rising due to the near quadrupling of drilling effort since the late 1990's, the collapsed gas drilling rig count since late 2008 will soon take its toll on U.S. gas production. Notwithstanding the declines in Canadian gas production illustrated in figures 4 and 5, and the projections for further declines in gas production in Figure 6, plans are afoot to build an export terminal for Canadian gas at Kitimat and connect it by pipeline to Alberta and northeast B.C[14]. The logic behind these proposals escapes me.

The message here for the City of Edmonton is that the natural gas industry is in decline owing to the exploration maturity of the Western Canada Sedimentary Basin, and hence so is the economic activity that is to be derived from this sector. Price volatility will increase going forward barring a miraculous bonanza from shale gas, which I class as a long-shot. Investments and policies must be directed to energy conservation and efficiency to reduce requirements for natural gas and diversify from the proportion of economic activity that depends on it.

Coal

Coal is often credited with virtually infinite resources, capable of lasting for millennia. Here again, as with oil and gas, the issue is not resources, it's deliverability – rate of supply. Some economists suggest that even if we experience declines in oil production, we can make liquids from coal as a substitute. This is only true to a very limited extent. Coal-to-liquids requires major capital investments in infrastructure and is very carbon intensive. Even if global coal-to-liquids capacity were to increase by twelve-fold by 2030, it would only be about one percent of projected world demand[15]. There is no chance that liquids or gas from coal can hope to replace that from current sources.

Nonetheless coal will be important for Alberta going forward. Coal is not a versatile fuel like oil or natural gas without building very expensive and wasteful conversion infrastructure. On the other hand it is well suited as a source of heat for electricity generation and, in higher rank forms, for metallurgy. On a fuel cost basis, coal is a fraction of the cost of natural gas for electricity generation. Given the versatility and necessity of natural gas for distributed heat, petrochemicals and fertilizers, it makes sense to conserve it for those uses and utilize coal for base load electricity where it is best suited.

That said, coal is a finite resource. Alberta has enjoyed the benefits of some of the cheapest mineable coal anywhere, feeding mine mouth power plants for several decades, which has provided low cost base load electricity. Some of these deposits (eg. Sheerness) are now nearly exhausted. The outlook for Alberta coal production is basically flat through 2019, according to

[14] http://www.kitimatlng.com/code/navigate.asp?Id=2
[15] http://www.eia.doe.gov/oiaf/ieo/index.html

the Alberta Energy Resources Conservation Board (Figure 7)[16]. Canadian coal production peaked in 2001[17].

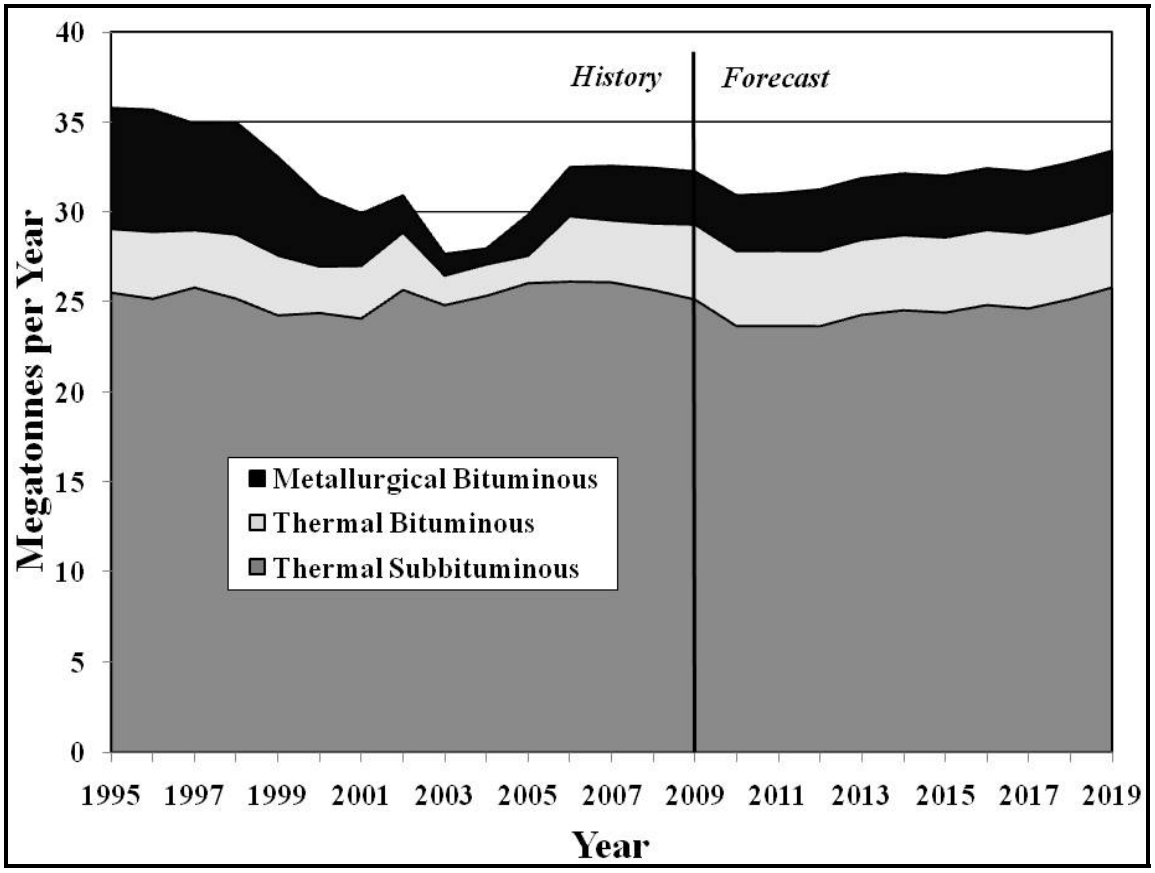

Figure 7 – History and forecast of Alberta production of coal by Alberta Energy Resources Conservation Board (2010).

The concept that coal can miraculously replace oil and gas, as purported by some, is a non-starter owing to the intrinsic properties of this fuel and the fact that it is mined, transported and burned with infrastructure built by and using oil.

The Achilles heel of coal using old coal-burning technology of course is carbon emissions, which are roughly double those of combined-cycle natural gas. Utilizing ultra-supercritical coal-burning technology can increase efficiency and lower CO_2 emissions by 25%, and if coal can be further burned where waste heat can be captured and utilized an overall 50% reduction in CO_2 emissions can be achieved. This makes much more sense than a massive investment in carbon capture and storage technology, which is not only expensive, increasing the capital cost of a

[16] http://www.ercb.ca/docs/products/STs/st98-2010-ds-coal.xls
[17] http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/nrgyftr-eng.html#s4

plant by 50% or more, and energy wasting, requiring about 30% of a power plant's output for capturing and compressing the CO_2, but is also unproven at scale. As Vaclav Smil points out[18]:

> *Carbon sequestration is irresponsibly portrayed as an imminently useful large-scale option for solving the challenge. But to sequester just 25% of CO_2 emitted in 2005 by large stationary sources of the gas ..., we would have to create a system whose annual throughput (by volume) would be slightly more than twice that of the world's crude-oil industry, an undertaking that would take many decades to accomplish.*

The message here for the City of Edmonton is that coal will be an important source of energy in the medium- to longer-term but cannot be counted on to be ramped up much beyond today's levels. New coal-burning infrastructure should use distributed configurations with combined heat and power, potentially including district heating, which will lower coal input requirements, offset the need for other hydrocarbons to provide this heat, and result in much lower CO_2 emissions. Massive scale carbon capture and storage projects should be rejected in favour of investing the capital that would have been used in such projects in infrastructure that will radically reduce energy footprints.

Renewables

Renewable energy sources, including wind, photovoltaics, hydro etc. are primarily sources of electricity, although solar hot water, geothermal and passive solar building designs are also very important. It is important to understand the limitations of renewables and three key words are crucial *"Beware of Scale"*. Non-hydropower renewable forms of energy make up less than 2% of primary energy worldwide. They also have some fundamental drawbacks compared to fossil fuel-powered generation – for example wind is intermittent and unpredictable and photovoltaics are intermittent. In the U.S. if renewables are ramped up by more than five-fold by 2035, they will make up just 11% of projected electricity demand, and nearly half of this total is wood and biomass[19]. The National Energy Board's recent forecasts for Canadian and Alberta electricity generation by fuel are illustrated in Figure 8. Although wind and other forms of renewable energy are forecast to grow dramatically, they still form a small part of total requirements. And electricity is only a portion of our total energy requirements.

Incentives for renewables are important, while recognizing that renewables will have only a limited impact on current levels of energy consumption. They can make up a much larger proportion of total requirements, however, once demand is reduced by smart investments in infrastructure to lower per capita energy requirements.

[18] http://www.nature.com/nature/journal/v453/n7192/full/453154a.html
[19] http://www.eia.doe.gov/oiaf/aeo/

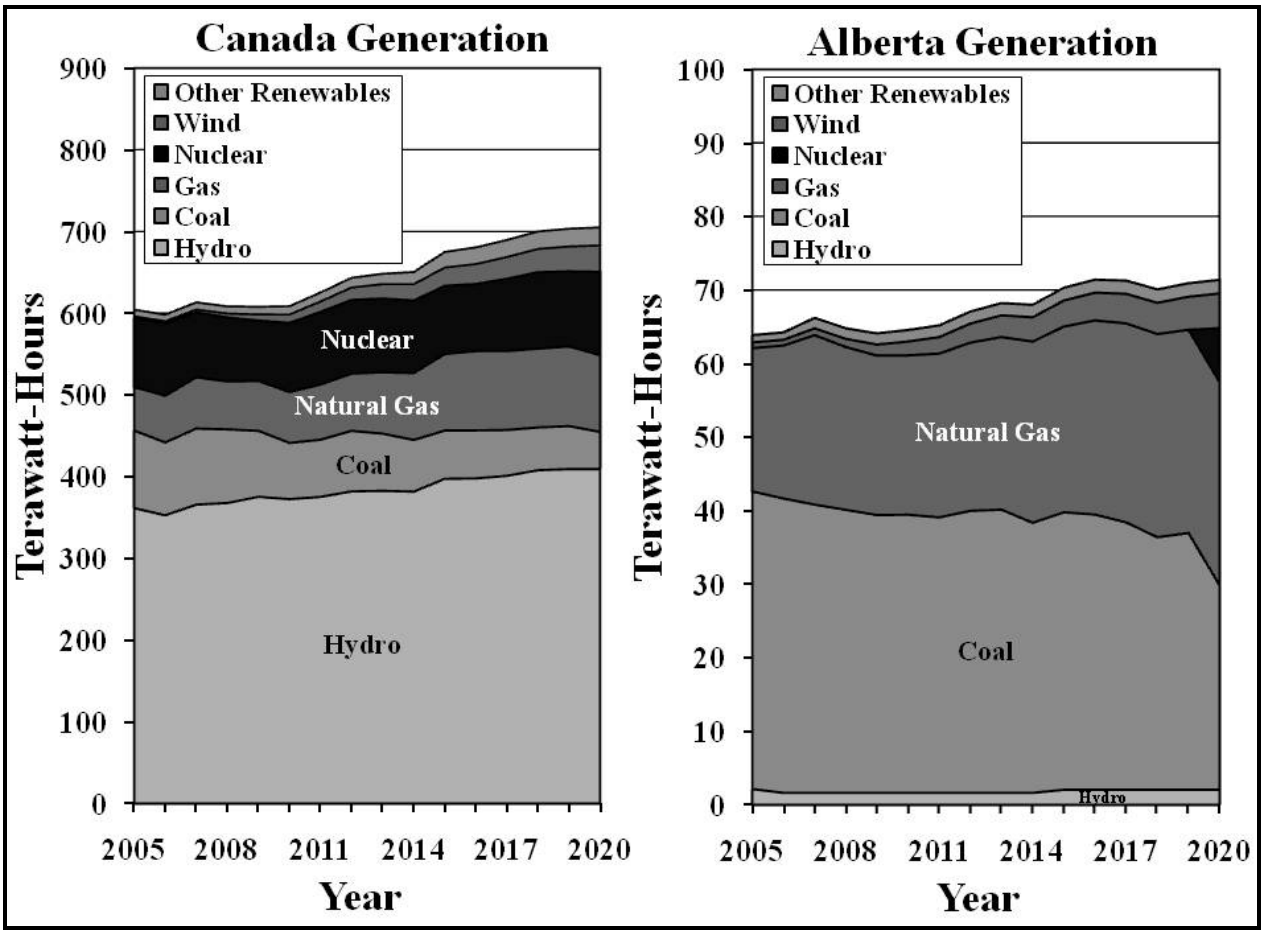

Figure 8 – Forecast electricity generation by fuel through 2020 in Canada and Alberta by the National Board[20].

Implications for Sustainability

The City of Edmonton is at present nearly completely dependent on cheap fossil fuels. Without them in its current configuration the City would be dysfunctional. The message from this analysis is that future availability of fossil fuels is likely to become more and more problematic and expensive. Fossil fuels will be essential for the foreseeable future but must be utilized to maximum advantage. This means assuming, in determining the economics of new projects for mass transit and other energy efficiency initiatives, that the price of energy will be much more expensive in the future. Moving towards a more sustainable city will take time, and it is unlikely that a city the size of Edmonton at its latitude could ever be completely sustainable without the energy subsidy of fossilized sunshine. But it is certain that much can be done to lessen the impact of the inevitable waning of this incredibly useful one-time energy resource.

[20] http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/nrgyftr-eng.html#s4

Provincial and Municipal Initatives

I reviewed the numerous provincial initiatives on energy provided to me. These included:

- The Provincial Energy Strategy, which stated among other things that "Ongoing development of Alberta's energy resources will be a platform for continued economic growth and success" and that "Government will encourage energy efficiency and conservation at all levels". *The facts of declining production make it unlikely that Provincial coffers will continue to be filled by energy royalty revenues as they have in the past. And the economic impact of oil and gas exploration is also likely to decline, with the exception of the oil sands. Efforts to promote efficiency and conservation are of course essential.*

- Bioenergy Initiatives including the Renewable Fuels Standard calling for 2% renewable fuel in diesel and 5% in gasoline by 2011 and the Bioenergy Producer Credit Program. I also reviewed the 9 point bioenergy plan, a $240 million program to promote innovation in bioenergy and fuels over the next five years. *The whole issue of the dubious net energy profit of biofuels and other issues associated with impacts on soil fertility, competition with food crops etc. is beyond the scope of this essay. However, because of likely very limited net energy, the use of ethanol from crops grown at this latitude in fuels will have minimal to nonexistent impact in my view. The other bioenergy initiatives are worth pursuing.*

- The Micro-Generation Regulation. *This is an excellent initiative.*

- The 2006-2011 business plan for the Alberta Energy Research Institute, which stated, among other things that "Production from conventional oil and gas resources has peaked and is declining; new technology is required to unlock the large remaining conventional energy reserves. Given the availability of the right technologies, bitumen, coal and coal bed methane have hundreds of years of production remaining". *Interestingly, few if any of the goals in this report slated for 2012 will be met (eg. doubling bitumen production to 2 million barrels per day, tripling upgraded bitumen to 1.5 million barrels per day, increasing conventional oil production by 10%, increasing gas production by one trillion cubic feet per year, as well as targets for green hydrogen, fuel cells, bioenergy and geothermal). These goals have been overruled by the law of diminishing returns imposed by geological realities, the laws of thermodynamics and rates of investment.*

- The climate change and emission management fund generated from the $15/tonne tax on industry emissions. *This is a very useful concept provided funds are applied to projects allowing reduced consumption and greater efficiency.*

- The $4 billion fund for carbon capture and storage ($2billion) and transportation ($2billion). *I have previously stated that investment in large scale carbon capture and storage is likely a lost opportunity for these funds given capital costs, energy wastage, complexity and scalability – they could be better spent on infrastructure to lower energy footprint instead. The transportation portion has not been allocated in my understanding and should be as soon as possible.*

- The Alberta Electric System Operator Future Demand and Energy Outlook 2008-2028. *A key statement in this report is "The AESO forecasts the peak Alberta internal load (AIL) demand to grow by an average 3.4 per cent per year for the next 20 years. Electricity consumption is expected to grow by 3.5 per cent per year." This is a rate of growth normally seen only in the under-electrified developing world. It is the antithesis of what is needed going forward.*

- The City of Edmonton also has some very good initiatives involving the expansion of the LRT system to the entire city by 2040, silver LEED standard buildings for city operations, more efficient street lighting, more efficient city fleet vehicles, gasification of municipal wastes and so forth. *These are laudatory initiatives, but as I said "Beware of Scale".*

My overall impression is that although there are very good directional intentions in many of these documents they are for the most part firmly grounded in the growth paradigm, believing if we substitute this energy source for that, or bury our carbon, growth can continue ad infinitum. Having studied these issues for decades I'm sorry to say I think we need to get our heads around the next paradigm, which in my view is radically lowering our energy footprint while recognizing that fossil fuels will be with us for a very long time to come.

Conclusions

The City of Edmonton, along with most other major metropolitan areas in Canada, has been built in an era of cheap and abundant energy from fossil fuels. This has resulted in infrastructure which requires high levels of per capita energy consumption as a result of urban sprawl and population densities below the threshold for efficient mass transit, as well as personal levels of energy consumption unparalleled in human history. Supply chains for the City are also long, vulnerable to disruption, and based on the availability of cheap fossil fuels.

An analysis of global energy production trends reveals that the era of cheap fossil fuels is coming to an end. Production of conventional oil and gas in Alberta, which has fuelled Alberta's and Edmonton's prosperity for decades, is in decline. The only growth in the energy sector in the near- and medium-term is likely to be in the oil sands, which has historically provided low levels of royalties compared to conventional oil and gas. The peaking of global oil and gas production will mark a watershed for the current paradigm of continual economic growth. Although energy consumption per dollar of GDP has dropped over time, real growth in overall energy consumption is highly correlated to economic growth. This growth paradigm, which after all, like fossil fuels, has been with us for only a snapshot of time in human history, is now coming to an end. The challenge for cities like Edmonton is to understand this and rethink all future investments in this context. Radically reducing the energy footprint of cities, shortening supply chains and increasing liveability will provide resilience against whatever the downslope of global energy production brings. Fossil fuels will be with us for a long time to come, but the growth paradigm they fuelled is almost over.