Life Goes On

If you don't change course, you'll end up where you're headed

Ancient Chinese Proverb

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Scenario Context

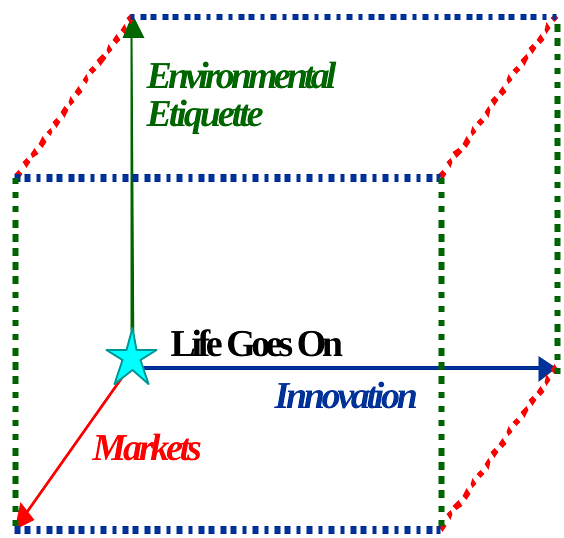

Figure 1

This is a business as usual world, with a slow pace of innovation, closed markets and grey environmental etiquette.

The various conferences of the parties to the Framework Convention on Climate Change failed to elicit the participation of developing economies as was hoped for. As a result, discussions of environmental issues faded from the international scene. Both developed and developing countries reverted from late 20th Century trade liberation practices and sought greater protectionist policies. Operating in a shell, countries had little incentive to innovate, and environmental issues, while listened to, generally received lip service. Internal political goals of increased standards of living, education, and full employment dominated the agendas of developing countries. While globalisation was a positive goal for these economies the main tenant was that it would be achieved on their terms. Environmentally, this is an increasingly grey world building on existing technologies, with few immediate prospects of becoming greener.

Life Goes On

Geo Political Situation

Throughout the early part of the 21st Century, the United States remained the only true dominant super power. In this position, it was looked to by international organisations as the world's policeman, and was called upon to address several conflicts internal to, and between countries. This role brought with it substantial benefits of using military expenditures to fuel industrial growth, but the US also incurred substantial costs. By the 2020 period, the US found itself in a situation where its budget could no longer be balanced. Continued pressures for military hardware and the growing size of the military put pressures on expenditures in other areas. However, public demands for health care, education, and other social service fields caused the US to re-think its priorities and its role internationally. By 2030, the US had adopted a more conservative approach in its international role, due in part to a strong Republican government. This conservative approach was also reflected in the stance that the US government took regarding trade issues. The strong political religious right pushed the Republicans for a more protectionist stance on trade and the full use of its rules-based trade arrangements under NAFTA as a means of ensuring that US trade interests were well protected. Countries in Latin America that had considered joining in an Americas-based trading arrangement decided against doing so; and as a result, NAFTA was not expanded.

Figure 2

Market transition and reform was taking place slowly in many of the developing countries. In the early part of the 21st Century, strong nationalistic sentiments also emerged in developing countries. These sentiments also brought with them more internal disruptions and violent conflict between those aggressively pushing reform, and those seeking continuation of past practices. Most developing countries viewed globalisation as a necessity for long term economic and social growth but nationalistic views directed a lot of attention inward, and many governments in developing countries took a cautious, 'swadehsi' [1] approach, seeking safeguards and frameworks that ensured the benefits of globalisation accrued to all citizens. Greater focus on internal objectives such as an improved standard of living, full employment and sustainable development took precedence over an aggressive push to liberalisation. Moreover, growing gaps between developed and developing economies started to emerge during this time period. Many of developing countries (including India and China) saw moves by the WTO to include governance and social issues as part of the Seattle Round as means of stemming trade between developed and developing countries. Some of these economies, notably India initiated moves in the early 2010's to limit the entrance of MNCs and to protect domestic trade through a new set of protectionist tariff barriers aimed at reducing imports.

The rapid growth in population and the economic strength of the south-eastern portion of the country drove China to international prominence, but China was unable to maintain its place in the international community. Many Chinese states sought their own autonomy, and ultimately the tensions between the highly centralised political system and the decentralised economic system caused declining economic growth and decreased foreign investment. The on-going and still unresolved conflict with Taiwan over its status as China's 23rd state and the territorial issues surrounding the Spratly Islands (along with Malaysia, the Philippines and Vietnam) erupted into a broader conflict in the mid-2030's. Taiwan's push for high-technology industries brought continued economic growth to the region, and it saw that a break with Beijing was necessary if it were to continue this trend. By the year 2050, the China and Taiwan conflict remained unresolved.

In Russia, progress towards liberalisation was slowed as the Kremlin bloc (remnants of Boris Yeltsin and former Soviet old guard) held on to power in the 2000 elections and continued to do so despite political and social unrest. The "transition recession" in Russia lasted well into the mid 2010's, and even then, there was a slow emergence as many companies held on to the 'collectivist ethos' which prevented the free flow of labour to new sectors of the economy. As well, the extended period of high business and value added taxes further reduced outputs causing firms to have 'official' and 'unofficial' output figures and products. The situation bred corruption as reduced official outputs were reduced to avoid taxes, and unofficial outputs, which had non-product related costs, were often overlooked by local tax inspectors.

Europe did not fare well in this world. Despite efforts to expand its membership to include some Eastern European states, the Union itself started to crumble under its own weight of regulations, protocols and legislative arrangements. Innovation was slowed by the weight of this administration, as was the overall rate of economic growth. The demographics of Europe also played against the Union. Ageing populations, and a shrinking labour force meant higher dependency rates and greater burdens of those Europeans working. The EU soon found itself uncompetitive in many product areas and with the flood of cheap goods from Asia and other countries flooding its markets soon

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[1] The policy of Swadeshi aims at strengthening indigenous industry and accepting liberalisation in the field of specialised higher technology, laying due emphasis on setting up requisite infrastructures. The term refers to a protectionist, cautionary approach often used in Indian politics.

introduced high tariffs and taxes to protect EU industries. This action was the final piece in the isolation of most of the world's economies.

Canada in a Life Goes On World

Canada continued to be looked upon as a resource/commodity based economy in this world. As a result, the economy and the value of the dollar continued to move in relation to the markets for resources and resource-based commodities. The economy continued to grow, but many viewed that its growth was below expectations mainly due to the resource-based value of the Canadian dollar. Canada's increasing population and its growing age dependency caused governments to focus investment on the health, education and social service portfolios. The government also made some strategic decisions to invest in areas of Canadian competency that included information systems, wireless communication, electronics and some areas of resource extraction and use.

Canada did not fare well in its dealings with the US under the free trade agreement. US companies continued to take over Canadian natural gas companies throughout the period through to 2010. By that time some 65% of Canada's natural gas supply was being exported to the US. With growing concerns over long-term gas supply, Canada attempted to roll back the ratio of domestic to export gas to the levels closer to those at the turn of the Century (about 48% Canadian to 52% export), but this move was considered to be contrary to NAFTA, and was disallowed. Moves to further expand rules-based trade were looked on with some scepticism.

As for Canada's energy system, it remained fragmented, with the overall system fairly similar to that of the late 20^{th} Century. The combination of gradual replacement and simple efforts to extend the life of the energy infrastructure proved to insufficient. By 2010, inattention to systematic maintenance and replacement of the infrastructure led to major degradation problems. Pipelines, power plants, dams, transmission lines, roads and rail networks all showed significant wear and tear. The major focus became technologies designed to alleviate wear, corrosion-related problems, and to retrofit the existing infrastructure.

The technologies used for retrofit or repair demonstrated marginal improvements to late twentieth century technology. The impact of newly developed technology was low. Four reasons for this were:

1. A lack of a strategy for technology development and innovation with no formal network to link together potential technology partners domestically and internationally.
2. No mechanism to optimise Canadian capabilities in industry, government and universities.
3. A lack of investment in basic research and development.
4. A lack of progressive science education and public outreach.

Canadian industry, was slow to adopt new technology, and instead focused on cutting costs through downsizing and incremental attempts to automate and increase process efficiency. Capital stock turn over was slow throughout the period, as few new technologies and products found their way into the marketplace. There were some efficiency gains as improvements to existing technologies were gradually incorporated into the manufacturing system, but these were generally been low cost and introduced on an ad hoc basis. As a result, Canada's GHG emissions were reduced slightly from levels forecast at the turn of the century, but no significant step-changes were exhibited. If the trend line from the year 2000 were extended (-2.0% per year decrease) the GHG budget for the year 2050 would be about 248 Megatonnes of CO_2 equivalent. Table 1 shows that in a "Life Goes On" world, Canada misses that mark by over 450%.

Table 1

GHG Emissions (CO_2 Equivalent)		
CEO* 2000	**Kyoto Trend line 2050**	**Life Goes On ETF 2050**
694 Megatonnes	**248 Megatonnes****	**1125 Megatonnes*****

*Canada Energy Outlook, published by Natural Resources Canada in 1997 with an update in 1999.
** Based on a –2.0% decrease per year from the year 2000 to meet the Kyoto Protocol
*** See Model Assumptions for ETF Scenarios

The flow of product and process information world-wide has been limited due to the closed nature of international markets and strong moves for intellectual property protection. The convergence of computer systems, telecommunications and information services never took place to the point that a global information infrastructure was created, but Canada built on its technology base in this area through its continued investment in the telecommunications field.

Canada continued to rely on liquid and gaseous fuels throughout the first half of the 21st Century. Heavy oil and oil sands provided the bulk of Canada's supplies, and natural gas, despite pressures from growing US demand, found increased applications in cogeneration and electricity generation until 2020. Oil and natural gas pipelines, many of which were 50-100 years old, started to be replaced gradually on a 'needs' basis starting in the early 2000's. More attention was paid to the natural gas pipeline transmission system than the oil system due to the increased US demands for natural gas, and the growth in natural gas for cogeneration purposes in Canada. System design investments were needed to augment flow capacity to meet the continued growth of US demand for Canadian natural gas, but these were slow forthcoming.

De-regulation of the electricity industry saw a huge influx of independent power producers in the early 2000's, but over time, several of these producers simply left the market and the larger energy companies filled the shortfall they created. Electricity generation using combined cycle technology had made significant market penetration by the mid 2010's with the introduction of integrated natural gas combined cycle units, and had started to move to integrated coal systems to augment base-load demand by 2020. Canada's nuclear generating system came back on line following the lay up of the main reactors in the early 2000s, with these refurbished plants operating until 2030. Improvements were made to reduce system losses in transformers and interconnects, but large electricity system losses remained in transmission lines.

A. The Way We Live

Lifestyle patterns have not changed much since the early 2000s, between the turn of the century and 2050 the number of households almost doubled. While the main areas of development surrounded large cities, particularly Toronto, Edmonton, Calgary, and Vancouver, an attempt was made to infill these cities with pedestrian-friendly communities wherever possible. While somewhat successful, the design pattern could not fully offset the increased energy service demands from reduced occupancy rates (less than two people per household–many of them seniors), and the increased day-to-day mobility needs of the elderly.

Little significant change took place in building design. New buildings (those built since 2020) exceeded R-2000 design criteria and included temperature, humidity and ventilation control using low-cost solid state sensors and actuators. Canadian-designed modular housing was deployed in some regions of Canada as a means of meeting the rapid expansion of the market, plus its demands for greater building functionality (multiple and year round uses). Some changes in building operations did take place in the 2000 to 2010 period. These included the change over from incandescent to fluorescent lighting, which started in 2000 and continued as stocks turned over. More natural lighting is used through passive solar techniques and the use of solar tubes.

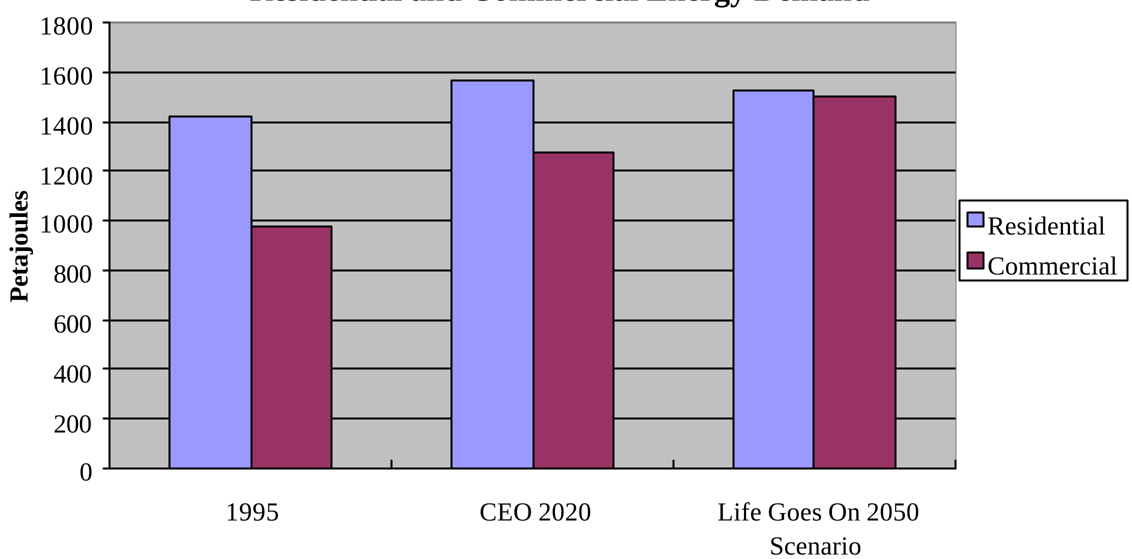
The new pipeline distribution system transporting natural gas from Sable Island, and other offshore sites, to the Maritimes led to natural gas displacing fuel oil and propane for space conditioning purposes in the Maritimes. New homes in Quebec also started to use natural gas, reflecting the general increased use of natural gas in the buildings sector. However, on average, residential heating and cooling systems remained mid-efficiency with natural gas being the prime fuel for furnaces, air conditioning, and heat pump systems. Some temperature-differential lake-based heat pump systems were developed to a limited extent in places like Toronto and Hamilton to provide community heating and cooling needs.

In the early part of the 21st Century, industry and commercial enterprises encouraged telecommuting as a means of reducing costs associated with acquiring and servicing office or other building space. From 2000 to 2020 the telecommunications industry experienced fairly rapid growth based mainly on the telecommuting push by industry and commercial enterprises. The communications industry with its associated software and hardware needs prospered. Low-loss fibre optics lines were used for the high-volume, rapid data flow needed for day-to-day remote industrial communications, and technologies for the management and security of information became quite sophisticated.

However, over the long-term it was found that working at home also brought with it reduced worker productivity. At home pressure, including care of the young and elderly, was one of the contributing factors for this reduced motivation and productivity. As well, the home was generally less conducive to work than the office. Not only did the home not offer the full range of electronic and 'Net' conveniences, it also lacked the stimulation of co-workers to generate new ideas and enthusiasm. For these reasons, companies started to abandon the idea of telecommuting around the year 2020. As a result, from that time onwards, the telecommunications infrastructure became seriously under utilised and parts of it, especially the local communal office networks developed for individual enterprises, became outdated, and were ultimately abandoned. This decline in telecommuting activities started a trend back towards day-to-day commuting so that by 2050 most people travel to and from a work location putting additional pressures on the urban transport system. As well, with little real push for the sophisticated applications and high-speed capabilities of computers, the telecommunications industry started into a downturn around 2025, and its full capabilities and applications in other sectors were never realised.

By 2020, solid oxide fuel cells made significant market penetration in areas not directly serviced by natural gas; for example, farms, remote villages in northern Canada, and off-grid locations. The proven cost-effectiveness and reliability of these cells made them ideal for co- or tri-generation. Their popularity was further enhanced by their ability to operate on many fuel types, whether they were liquid or gaseous. These fuel cells were also extensively used as back-up, non-interruptible power units for hospitals, nursing homes and critical industry facilities.

Figure 3
Residential and Commercial Energy Demand



By the end of the 2050 period, high-efficiency thin-film photovoltaics still were not in widespread use. The cost of production, limited diurnal use in many parts of Canada, and the lack of good, low-cost energy storage materials for household use were the main deterrents. Other renewable energy sources were limited to mainly passive systems and some active solar hot water heating, but again, these were in remote, off-grid applications.

By 2050, new buildings had become approximately 50% more energy efficient through the application of turn-of-the-century technologies to existing and new situations. Overall, GHG emissions in the sector decreased by about 16% as a whole from year 2000 levels, and it was not expected that any significant reductions would be seen post 2050.

B. The Way We Work

In general, the industrial sector grew very slowly in the 2000-2050 time period. Changes made to product lines were incremental and aimed at lowering production costs through, for example, eliminating process steps or incorporating on-line process control thereby decreasing the number of product rejects. Electro-technologies, such as microwave, infrared and plasma heating were in general use by 2010 because of their high efficiency and low operational costs. Better fans and motors also helped increased production efficiency. Recovery of waste heat and more efficient independent power generation systems making use of co- or tri-generation helped to reduce operational costs, but these were applied on a limited site basis.

The slow pace of the innovation system slowed capital stock turnover, and companies and consumers undertook means to extend product lives[2]. Efforts expended in extending product lives usually translated into making products more durable and using improved traditional engineering materials with better wear-, or corrosion resistance and/or high strength-to-weight ratios. Developments in designer materials were restricted by and large to electronics applications for the computer industry, and in sensors and controls. The sensor and control industry became an increasingly important means for manufacturers to cut production costs and to monitor product quality on existing assembly lines. However, few industries undertook major investments in new production lines or multi-tasking manufacturing cells. The advances in computer capacity and electronics manufacturing capability that did occur did have some effect on energy conservation. However, major impacts that could have been realised through complete system simulation or one-step computer design-to-product manufacturing did not take place.

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[2] Not only did this make good environmental sense because it meant less recycling and disposal, but smaller production runs required less energy and less material. However, slow turnover also meant smaller industrial profit margins and little incentive to make substantive improvements in energy- or GHG-reduction technologies.

However, between 2010 and 2020, the auto industry did invest heavily in production line improvements, particularly in assembly and joining technologies, with 'just-in-time' manufacturing being brought on-line to reduce inventory costs. In part, this was spurred by increasing vehicle demand, and the advances being made in US automotive plants. Power electronics to increase fuel efficiency and micro-electromechanical systems (MEMS) became particularly important in the automotive industry around 2010 as MEMS sensors could be produced at low cost using semiconductor fabrication techniques for mass production. Most automotive production line improvements were made following acceptance of the recommendations of the Partnership for a New Generation of Vehicles[3] (PNGV) program. However, because people were keeping their cars for longer, the industry never fully realised the return on its investment and was unable to make any subsequent improvements after 2020. Some manufacturing advances, for example multi-tasking manufacturing cells, did spill over into the suppliers of automotive parts as a means of ensuring compatibility with the design standards and the changing operational needs of the automotive manufacturers.

The ability to model new molecular structures and design effective catalysts to improve chemical reactions, thereby cutting costs, started to be of importance to the chemical and plastics industries in about 2010. About the same time, computer design was also used to evolve better chemical separation techniques based on molecular/membrane interface modelling. By the year 2050, membranes could be designed to separate different chemical constituents quickly and easily. One of the main beneficiaries for catalysis and membrane technology was the petrochemical industry where both are used in the refining process.

In the "Life Goes On" world the main performance improvements were made in traditional engineering materials. Two of the most important materials: steel and aluminium, were often in competition for the same market which spurred similar process improvements in both industries. At the turn of the century, steel and aluminium producers focused on cutting production costs by using tight on-line process control to enhance efficiency and reduce rejects, and process-step elimination to reduce energy consumption. Both the steel and aluminium industry saw wider introduction of net shaping technologies and recycling and re-manufacturing technologies to eliminate some fabrication steps and enhance savings in energy and product costs.

Secondary recovery of all energy intensive materials from primary production processes became extremely important to cut costs. This was particularly the case for aluminium

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[3] The Partnership for a New Generation of Vehicles, established in 1993, is a partnership between the United States Government and the U.S. Council for Automotive Research (USCAR) which represents DaimlerChrysler, Ford and General Motors. The goal of PNGV is to develop technology that can be used to create environmentally friendly vehicles that can achieve up to triple the fuel efficiency of today's mid-size cars with very low emissions without sacrificing affordability, performance or safety. The timeline for this "Supercar "goal is:

- By year-end 1997 to finish the evaluation of competing technologies
- In 1998-2000 each car company produces concept vehicles
- By 2004 each company produces production prototypes (the last stage before a car goes into production)

and steel because of the aggressive competition between them for the same markets. Aluminium recycling had always been of critical importance because primary production of aluminium was, and in 2050 still is, particularly energy (and GHG) intensive and therefore more costly compared to steel. By 2040, 50% of the total aluminium supply was comprised of recycled product.

In the early 2000s, to retain market share and break into markets traditionally belonging to the aluminium industry, such as beverage cans, steel manufacturers invested heavily in mini-mill technology for steel recycling. By 2040, steel's overall recycling rate was 80%. Steel mini mills, using electric arc furnace melting, decreased the need for primary production using coke-fired blast furnaces. New generation high-strength steels, engineered using multi-phase microstructural design, and produced by these mills, were used in new pipeline construction and for structural applications.

Table 2

Life Goes On Industrial Energy Demand[4] in 2050	
Industrial Sector	*Percent reduction in non-electric energy demand from trend*
Pulp and Paper	15%
Chemical	30%
Iron and Steel	20%
Smelting and Refining	15%
Mining	10%
Other Manufacturing	20%
Construction	10%
Forestry	15%
Cement	20%
Petroleum refining	10%
Non combustion	20%
Total energy reduction	**11%***

Assume the industrial sectors decrease their energy needs from all sources except for electricity.
*Refers to total energy demand including electricity.

As part of the PNGV Program, auto manufacturers designed and manufactured an ultra-light steel autobody that was 36% lighter than the mid-sized cars on the highways in the year 2000 and did not compromise safety. Again, steel and aluminium competed for the automotive market. Despite continued reliance on steel for its weight and crash durability features, aluminium still managed to increase its market share because of its

4 All of these technologies have influenced the energy demand of different sectors within industry. Energy demands have been reduced from interpolated data provided by Natural Resources Canada[4] under the Business as Usual base case. Improving processes and reducing waste has made most of the energy savings. Improved catalysis and membranes had a significant impact in the chemical industry. Iron and steel energy demands were decreased through the use of mini mills and electric arc furnaces. These technologies developed in the late 20th century allowed smaller scale production of steel that enabled more scrap steel to be recycled. Enhanced aluminium and other metal recycling reduced energy demands in the smelting and refining sector.

inherent lightness. By the year 2020 it also demonstrated some market penetration in infrastructure applications.

C. Our Mobility

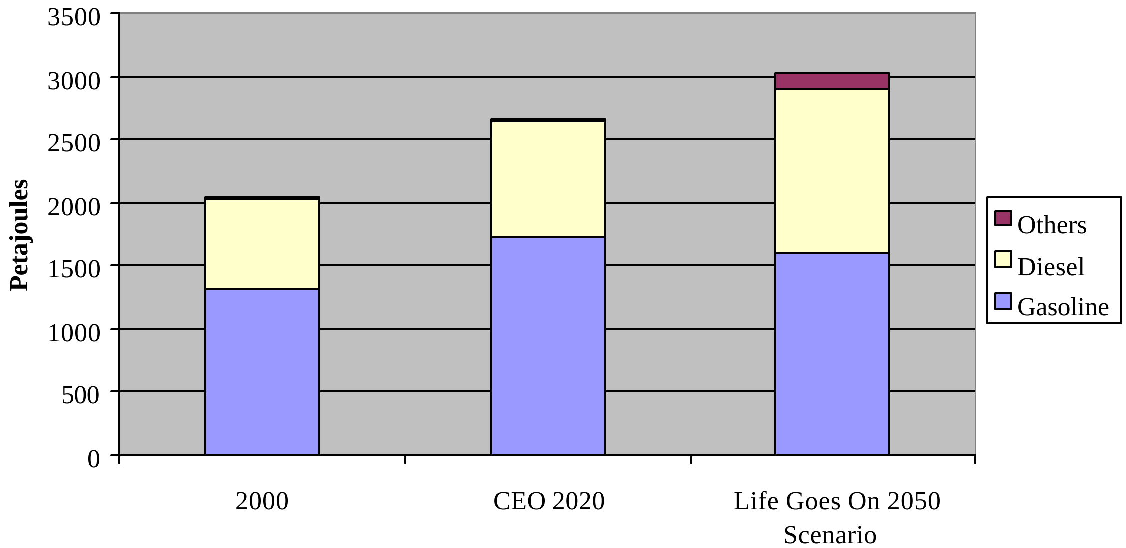
Throughout the period, gasoline remained the fuel of choice for personal vehicles due to its high-energy density, ease of distribution, and consumer's preferences for liquid fuels in general. While there had been some blending of liquid fuels using ethanol and other liquid fuels, other 'designer gasoline' fuels did not emerge as viable alternatives. Most research efforts in the gasoline field dealt with particulate and fuel quality issues. Natural gas also failed to make significant market inroads as the cost involved in changing the transportation and distribution infrastructure mitigated against the use liquid natural gas as a transportation fuel.

Throughout the period, consumer demands for personal vehicles continued to rate convenience, range, affordability, quality and safety as priorities. Vehicle retention was about eight years on average so turn over of the vehicle stock was slow. Personal vehicles continued to be 2-6 passenger, wheeled vehicles with a cruise speed of about 100 km/h and a range between 300-500 km.

The number of vehicle kilometres travelled continued along historical trends with its rate of increase roughly proportional to the growth in population. By the year 2050, with the unsuccessful attempts at telecommuting, people had returned to their cars to commute to and from work. Commuting accounted for about 30% of the total vehicle kilometres travelled. Moreover, non-commuting travel rose significantly with seniors making small trips and accounted for more person kilometres travelled than the commuting population. Combined, these vehicle uses increased congestion and accelerated the deterioration of the road infrastructure.

The fuel efficiency of vehicles improved radically throughout the period to 2050 mainly due to efforts under the PNGV program. Lightweight and frictionless materials, reduction of fluid drag through use of computational fluid dynamics both internal and external to the vehicle, and higher temperature, increased efficiency internal combustion engines (ICEs) were all part of the new generic design. Although many different power trains were considered for personal vehicles, manufacturers made improved-efficiency ICEs their first choice in the "Life Goes On" world. Gasoline ICEs power ninety eight percent of the cars on the road in Canada. It took almost ten years to make the changes in production lines to achieve the fuel efficiency standards of PNGV. By about 2020 the large auto manufacturers were all at about the same level as far as product quality and performance. Since that time the average PNGV vehicle gasoline consumption had remained at about 34 km/l (80 mpg). By 2030 approximately 20% of the vehicle fleet met PNGV, or equivalent, standards, that proportion doubled by 2040 and about 80% of vehicles met the standard by 2050. Sports utility vehicles, minivans and pick-up trucks retained almost 50% market share by 2050. The improvements to these vehicles have been marginal, they continued to be gasoline powered, and although engines efficiencies have increased, the main focus of the design has been on increased comfort levels adding weight and offsetting some of the efficiency gains made.

Figure 4
Road Transport Energy Demand by Fuel

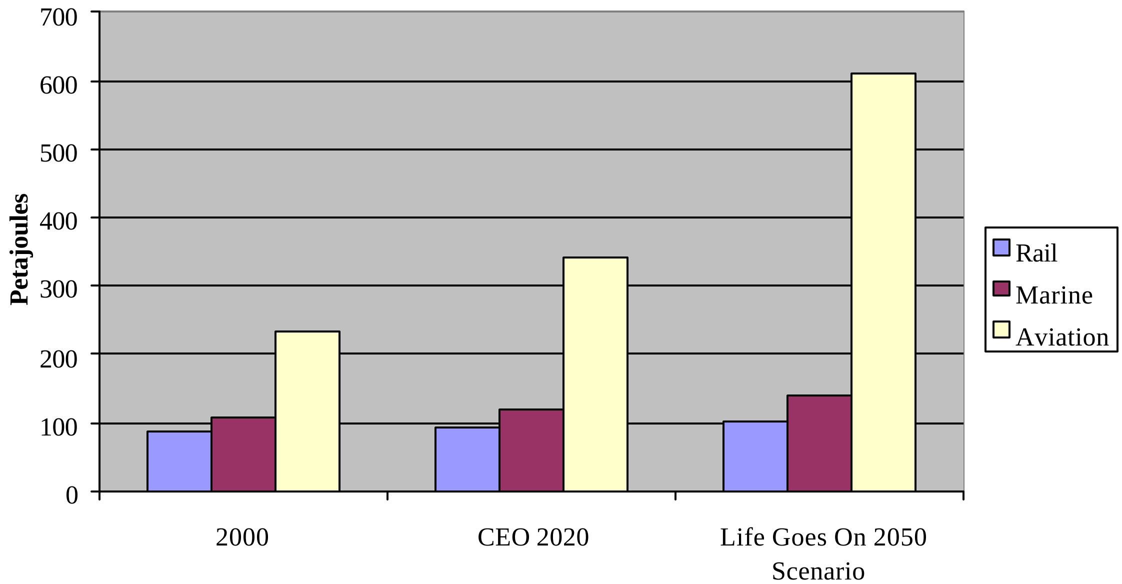


In urban areas little was done to ameliorate the traffic flow problems apart from building some by-pass roads. The main mode of mass in-city public transport remained the bus. Buses became lighter weight and were made from stainless steel for better corrosion resistance. Most commuters, though, still preferred the flexibility of using their own cars and local authorities subsidised bus systems to keep them operational.

Some proton exchange membrane (PEM) fuel cell (FC) vehicles did find their way into the market in western Canada. FC vehicles did not achieve significant market penetration in the rest of the country because of the complexities and cost of designing these cars for cold climatic conditions, hydrogen storage, and the costs and technical issues surrounding the infrastructure needed to transport and distribute hydrogen. The main application of fuel cells for transportation has been in public transit applications in western Canada. By 2020, only one or two cities in British Columbia were running fuel cell bus fleets based on hydrogen-fuelled PEM fuel cells. In total, the number of personal FC vehicles accounts for about 2% of the 2050 vehicle fleet.

The transport of goods across the country continued to rely on the rail system. Unfortunately, the problems facing rail in the latter part of the 20th Century continued to plague the industry into the first half of the 21st Century, and the system was not expanded. However, some system refurbishing did take place. By the year 2000, more durable head-hardened rail being was introduced as a replacement to worn sections, by 2010, low-cost energy management systems were widely used for winter switch protection to prevent freeze up. Portable in-field welding units using electromagnetic stirring were used to ensure the integrity of welded joints in the rail network. Heavy goods vehicles continued to be relied on to carry goods from railway distribution points to their final destination. These heavy trucks continued to be fuelled by diesel, but some biomass-derived diesel had penetrated the market by 2025.

Figure 5
Other Transportation Fuel Requirements



Demands for both passenger air travel and airfreight increased along with increases in population. Airports, long faced with increased congested and frequent delays, did little in the way of automated on-ground aircraft control management. Aircraft design did, around 2020, start to make more use of high turbo fans and propeller fans, but changes in engine design continue to take about 25 years to introduce as design and testing costs have risen dramatically. The fuel efficiency of aircraft did not improve greatly and nor was there any major attempt to improve the quality and emission characteristics of aviation fuel.

D. Our Energy Mix

Despite growing electrification of the economy, Canada's energy mix remained heavily reliant on fossil fuels. Oil remained to be the main energy source for transportation fuels and for the petrochemical industry. Since 2030, heavy oil wells and tar sands displaced much of the conventional liquid hydrocarbon feedstock. The use of oil had virtually been eliminated from space heating or power production uses.

Since the turn of the Century, and following the general North American trend, there has been a steady increase in the use of natural gas for power production, largely in British Columbia, Ontario and the Maritimes–as the offshore supply became available. There was also increased demand for natural gas for electricity generation in larger utilities and in a number of independent power production facilities using natural gas cogeneration (mainly in Ontario). Nonetheless, there continued to be concern over the longer term availability of natural gas as export levels continued to rise.

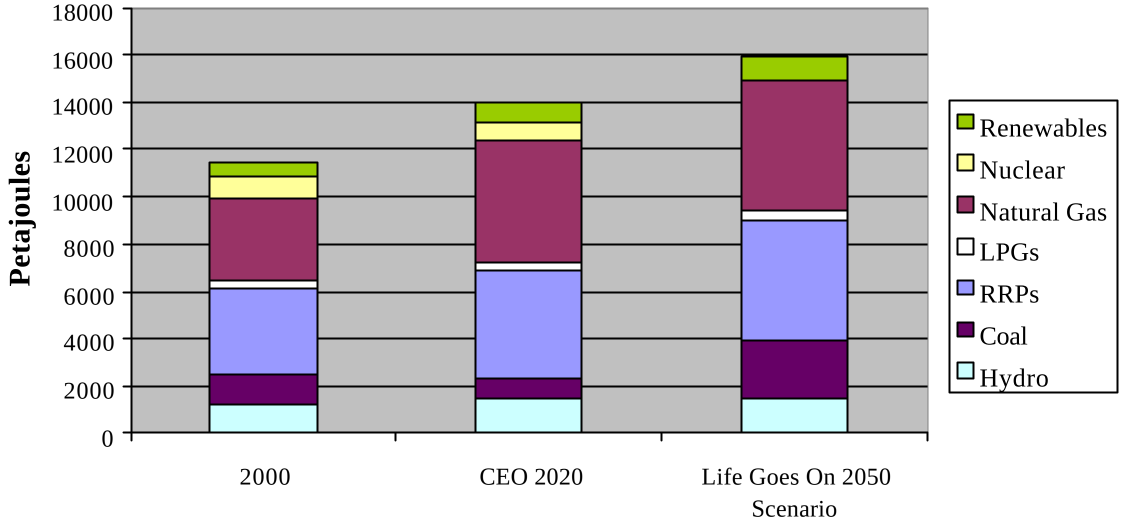
By 2015, a number of small independent power producers, that entered the electricity generation market following deregulation, unfortunately, were not able to negotiate non-interruptible gas contracts and started to leave the market. The larger utilities had to meet these additional requirements. Although hydroelectric facilities were maintained, dams were repaired, and turbines replaced as required, most economical hydroelectric sources were tapped by 2020. Larger utilities had to look for other options to supply the base load necessary to meet the increased demands for electrification. In 2015 when Alberta successfully demonstrated high-efficiency, combined-cycle coal gasification plants for power generation utilities developed renewed interest in coal for base-load electrical power supply, and invested in integrated coal gasification combined cycle (IGCC) power generation to augment and maintain supply.

Renewable energies, apart from large hydroelectric schemes, played a very small part in the Canadian energy system their use was restricted to remote communities and niche off-grid applications. The major renewable energy technologies available near the turn of the Century underwent some improvements in production efficiencies and the lowering the initial capital costs of equipment, but no new major renewable sources emerged.

Fossil Fuels

Throughout the period, oil remained the primary fuel for transportation and as a feedstock for the petrochemical, and chemical industries where it continued to be used to make such products as: asphalt, lubricants, synthetic rubber, nylon, polymeric materials and plastics. Agricultural demand remained high for the production of herbicides, pesticides, and fertilisers. By 2020, the Western Canada Sedimentary Basin had passed its oil production peak from conventional wells and many wells were closed due to their deteriorating economics. Little oil has been produced from conventional wells since the 2020s after successful use of enhanced drilling techniques and steam-assisted gravity drainage. Early attempts to use CO_2 injection to enhance oil recovery failed because of the uncertain behaviour of the CO_2 injected into the wells and the small increases in yield relative to the cost. As conventional supplies declined, heavy oil and oil sands production increased and by the year 2040 accounted for most of the oil produced in Canada. Improved yields using froth flotation techniques and in-situ processing of oil sands, down-hole bitumen and heavy oil processing, and de-watering technologies have been continually improving and gaining greater market penetration since the late 2010's.

Figure 6
Primary Demand by Fuel



Natural gas emerged as the main fuel for residential heating and it became popular for independent power cogeneration facilities for industry in the 2010-2020 period. Although Canada continued to have a plentiful supply of natural gas from offshore, western Canada, and remote northern locations, some 65% of the total supply had been channelled to the United States since 2010. Pipelining continued to be the most effective way for natural gas to get to market. However, large parts of the transmission system[5] remained pre-twenty first Century, consisting of a mixture of lower grades of steel that make it susceptible to stress corrosion cracking. The transmission companies continued to replace pipe at the rate of about 400 km a year with high-strength linepipe steel, but had to continually monitor the system for cracking using pipeline inspection gauges (PIGS)[6]. Additional efforts to reduce corrosion have centred on removal of hydrogen sulphide and use of corrosion inhibitors in the pipeline. Flaring containment (through the use of mini-turbines for electricity generation) and management of fugitive gas emissions have been addressed to maximise the flow of product to market.

The major demand for coal in 2050 is for power production; a smaller proportion is for metallurgical use. Demand for coal has been increasing steadily since around 2015. Coal mining techniques gradually became more automated using mechanical retreat long-wall mining wherever possible to meet the increased demand. Wear-resistant materials have been developed for mining, milling, transport, drill bits etc. to extend lifetime and

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[5] In 1999 there are approximately 60,000 km of transmission pipelines in Canada. This excludes the extensive network of gathering lines and distribution lines, much of which is independently owned and operated, and is largely provincially regulated. Currently, transmission companies are replacing about 400 km annually.

[6] Although PIGS have become increasingly sophisticated, using for example, electromagnetic acoustic transducers, there is a real need for continual real-time crack monitoring systems to prevent catastrophic failures using sensors embedded in the pipe coating.

decrease operational costs[7]. Since about 2045 discussions have focussed on coal refining to maximise coal's potential for producing electricity, coke, methanol and gasoline with a minimum of waste.

Electricity

Across Canada, the domestic demand for electricity increased steadily from 2000 onwards at a rate of over 1% per year. Provincially, the demand was greater in Alberta and Ontario due to increased population and concomitant industrial development. Between 2010-2020 both provinces invested in the refurbishment (Alberta) or the conversion of coal and oil plants to natural gas (Ontario). Natural gas generation found increased popularity through to about 2015 as larger industries invested in gas cogeneration or tri-generation facilities, and independent power producers who entered the market following de-regulation found natural gas their fuel of choice. The modularity of natural gas systems allowed non utility users to bring generation on-line quickly and at relatively low-cost. The larger utilities also found natural gas a viable option during this period, and they were able to negotiate bulk purchase deals for natural gas. Unfortunately, these bulk purchases were so attractive that smaller energy companies could not compete on a price per kilowatt basis, and many were forced to leave the business at this time, selling off facilities to the larger utilities. By the year 2015 the number of utilities (offering a full range of energy services) was about the same as it was before deregulation of the industry.

The growth in electrical demand drove most utilities to refurbish or retrofit their hydroelectric plants to maintain their contribution to base-load supply. By 2020 most power plant refurbishing had taken place with more efficient turbines replacing older units. Around the same time, all potential new sites, large and small, for run-of-river or head (large and small) hydro had been exhausted. A concerted effort was also made in the early 2010s to maintain the hydroelectric infrastructure. More durable concrete for use such as in dams was developed, and ice expansion cracking and alkali-aggregate reactivity, both of which are major problems in dam deterioration were addressed by using supplementary cementing materials.

Towards the early 2020's, a couple of things started to emerge on the planning horizon for utilities. First, some utilities started to express some concern over the sustainability of the natural gas supply and were reluctant to make new investment in natural gas power plants. Second, by 2030, after having extended the lifetime of Canada's nuclear facilities in Ontario, Québec, and New Brunswick for as long as possible, a decision was taken to decommission these facilities and not to consider any new nuclear plants.

As electricity demands continued to increase, utilities looked more closely to coal gasification plants to provide base load electricity. The move back to coal started in

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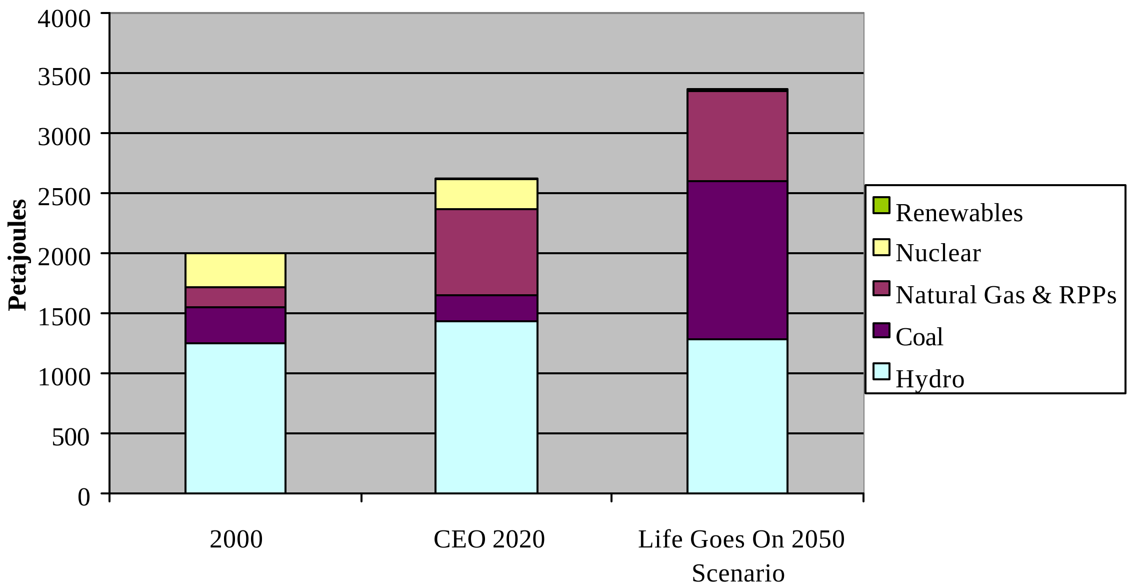
7 Materials development of high-temperature, erosion/corrosion-resistant materials (nickel-based alloys or high temperature steels, and appropriate fabrication technology and joining procedures) for superheaters, pipework, steam chests, rotors and turbines to maximise their lifetime and minimise the operational and maintenance costs was of great importance for the new coal plants.

Alberta, quickly followed by Ontario, Quebec, and the Maritimes. Between 2020-2030 the role of coal accelerated and many of the clean coal technologies developed in the early part of the century were widely employed. Although integrated coal gasification combined cycle generation (IGCC) is efficient, without sequestration, a considerable amount of carbon dioxide is still released into the atmosphere. By the year 2050, about 40% of Canada's base-load electricity was generated from coal.

Figure 7
Electricity Generation by Source



Throughout the time period from 2000-2050, remote communities used a variety of off-grid sources to generate their power that included solid oxide fuel cells running mainly on liquid fuels, and others such as wind turbines, photovoltaics or micro-turbine run-of-river hydro depending on local conditions. There was an expansion in the niche market applications for renewable energy "stand-alone" power systems, as they became more economically viable. In addition to the off-grid demand, some expansion took place because of concerns about the reliability of the power supply. However, by 2050 renewable energies, apart from large-scale hydro, only provided a small part of Canada's total electricity generation capability.

Electricity Transmission and Storage

From 2020 onwards utilities struggled to keep their own costs down and maintain their competitiveness, and they examined and tried to minimise transmission-line losses, transformer losses and resistance-interconnection losses. Based on number of units alone, transformer losses had always been high–in addition to all the substations, practically every household had a step-down transformer close by. As transformers were replaced, low-loss core units made from rapidly solidified amorphous powders were deployed.

By 2030, increased demand forced the utilities to consider the interconnectivity of provincial electrical supply-sources, transmission and storage as a whole. Saskatchewan and Manitoba were both well placed to meet their own electrical demands, and generate excess power from fossil fuel and hydroelectric sources.

Despite the majority of Canadian transmission lines remaining AC lines, some long distance, high voltage DC transmission lines were operating in the Manitoba and Quebec. By 2030, Manitoba and Quebec started to wheel power into Ontario to take advantage of the market opportunity caused by decreased supply and increased demand. They began to examine the harmonisation of inter-provincial power systems that in the past had been ignored in favour of developing connectivity between the United States and Canada.

The use of dams to store potential energy in a head of water is still considered to be the most effective way to store energy for fast electricity production in the 2050 "Life Goes On" world. Other electrical storage capability remained poor and any small-scale capacity that did exist was based on compressed-air storage.

Sequestration of CO_2

Due to low levels of environmental etiquette, no attempt has been made in the "Life Goes On" world to sequester carbon dioxide in, for example, aquifers. Carbon dioxide sequestration takes place in naturally occurring sinks or where it has been used to improve process or material performance.

In the 2020s an attempt was made to use a stream of carbon dioxide to enhance the recovery of oil from conventional wells. However, the cost of carbon dioxide was high, and the level of additional oil recovered did not warrant long-term investment in the enhanced recovery process so it was quickly abandoned.

A modest amount of carbon dioxide reduction occurred through the increased use of mini-turbines at wellhead flaring sites to produce power instead of letting the "flared" gas escape. Some attempts had been made to use supercritical carbon dioxide to enhance the durability of concrete and for dry cleaning of critical computer and other highly sensitive parts. However, the amounts are negligible.

E. GHG Emissions in the Life Goes On World

GHG emissions are not substantially reduced in this scenario. Emissions from electricity generation increased under this scenario due to the increased use of natural gas and coal throughout the period. The transportation and fossil fuel production sectors showed some decrease in emissions due in part to reduced gasoline demand and improved production processes for oil sands and heavy oil.

Figure 8
Canadian Emissions by Source