Come Together

The problems that exist in the world today
cannot be solved by the level of thinking that created them

The views and opinions expressed in this Scenario do not reflect in any way the policy thinking or policy direction of Natural Resources Canada.

The Scenario contains fictional representations of the future that are used strictly for illustrative purposes.

Scenario Context

This is a GHG responsive world, with open markets, rapid innovation, and high levels of environmental etiquette.

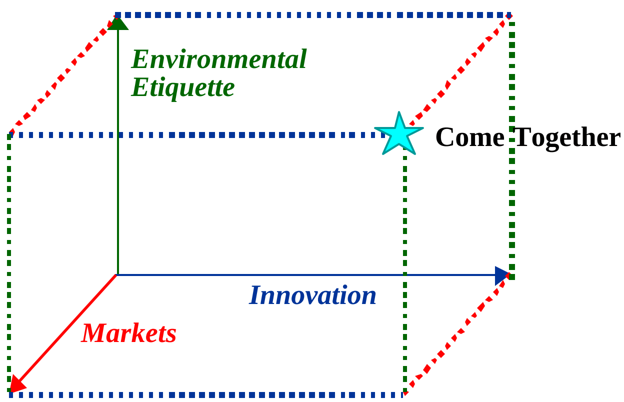

Figure 1

There is a strong cohesion of views amongst government, industry, and the public over environmental issues, and this is shared internationally. Multinational companies exert political as well as economic power, and press governments on environmental, trade and monetary issues. The expanded interconnectedness of the world allows new technology to be openly developed, traded, and applied in innovative ways across all sectors.

Canada was well placed in this global market, and Canadian business has been able to capitalise on its expertise and products, and to re-invest in improvements and establish new areas of competence readily demanded in these open and expanding global markets. This world, despite its strong environmental ethic, is mid-green in colour. Reduced GHG emissions realised through technology gains are somewhat offset by expanded industrial activity through continuing word wide economic growth

Come Together

Geo Political Overview

This is a world of rapid high technological change, high capacity computing and modelling systems, and worldwide interconnectedness. A new and dynamic slate of world leaders emerged during the middle part of the 2020's. Notable changes in leadership have taken place in Central and Eastern Europe, as well as in China, and Japan. These leaders stressed the continued need for economic and social reform. Markets were freely opened and transnational corporations (TNCs) developed strong links across trade blocks and directly with governments. Their desire to maintain growth has led to greater worldwide economic and political integration.

Figure 2

All was not ideal in this high paced and technology based world. The droughts and the flooding South East Asia and the Philippines that were prevalent in the latter part of the 20th Century became more widespread and severe in the mid-2010's. The economic disruptions and the growing costs of business insurance resulting from the several years of climate change-related extreme events, led industry and voluntary groups to align and approach the newly formed US government[1] to restart the climate change talks. These negotiations were put on hold after the 2005 Conference of the Parties[2] when several countries recognised that the 1997 protocol agreed to in Kyoto would not attain the Intergovernmental Panel on Climate Change (IPCC) proposed GHG stabilisation levels of 550 ppm. With the support of business which was beginning to flex its political influence and voluntary groups, the US government led the way, along with several other MNC influenced countries, to develop a set of stringent climate change emission reduction targets. These targets, applied to both developed and developing

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1 Starting in the year 2000, the US political landscape was dominated by a strong republican base that was closely aligned with the religious right. This resulted in a very conservative approach to US policy making with limited climate change interest. In 2015 the landscape changed with the emergence of a new democratic president supported by an equally strong House and Senate.

2 Date for reporting on Kyoto progress.

nations (who recognised the industrial advantages of participating) were negotiated and agreed to under the Global Climate Change Framework (GCCF) of 2024.

Business also recognised the financial benefits that the environmental challenge afforded. Opportunities to create and expand markets and develop new products resulted in businesses continuing their close working relationship with governments to open markets and improve accessibility. As a result, in the 10 years following the international accord on climate change, the slow and steady growth of multinational companies that took place in the 2000 to 2020 period accelerated dramatically and encompassed companies of all sizes and in all industrial, manufacturing and service areas. These TNCs were not only developed and integrated, but they also had established strong ties with their host governments, which aided in the ratification and maintenance of the 2024 global agreement. By 2035, TNCs were flexing even more political and economic power and pushing for the establishment of broader and freer trade zones.

Throughout this period, China began to emerge as a dominant force in international politics. The economic growth witnessed in the late 1990's (twice as fast as Japan's and three times as fast as the US economy) continued in the early part of the 21st Century. Modernisation of the banking and tax systems opened the economy to an influx of capital investment that drove a major boom in construction of new housing and commercial properties that provided much needed jobs and income for its huge population base. This increased standard of living and prosperity brought demands for improved goods and services, and for cleaner and healthier cities. Coupled with these demands came the demands for political reform. These demands led China into a more democratic form of government with its first democratic elections taking place in 2022, the year of the Tiger[3].

Other economies followed a similar pattern of trade liberalisation, development of human capital (through social programs and investments in education), and de-regulation of their industrial base. These moves and the strong role of the TNCs as suppliers, and deliverers, of technology resulted in a period of long and sustained economic boom. Information technology with its continuing refinement and the exponential growth in interconnectedness had linked the world economy in ways that we had never seen before. Through this medium, technology was widely available and employed. Open markets and rapid systems of innovation fed each other leading to revolutionary advances in DNA- and quantum computing and sub-sonic air transport of people, goods, and resources. By 2050, global economic integration was moving towards reality, with TNCs again exercising their political influence and pushing for a global currency that would facilitate trade and investment even further.

Due to the competitive pressures that were created in this global market environment, companies adopted a strong environmental etiquette that is reflected in their day-to-day

[3] The Year of the Tiger symbolises strength, vitality and fortune. It will also be a time for sweeping changes, with the introduction of bold, new and often challenging ideas that could nevertheless help to clean out the cobwebs. A fiery year, perhaps, as befits the Tiger's nature but one which could bring great achievements.

dealings. Zero waste and zero GHG emissions were the norm in business decisions and practices as wastefulness was seen as a sign of poor management that could affect market positioning. This was particularly the case in the dealing with eastern trading partners. As a result, pollution abated substantially.

However, climate change still was an international concern. A portion of the reduced GHG emissions resulting from improved efficiencies, process integration, the wide spread use of artificial intelligence, robotics, and information technologies were been balanced by increased industrial activities and international distribution of resources and products as well as travel. Strategies to adapt to climate change were employed in the agricultural, forestry and fisheries sectors as well as in areas susceptible to the effects of climate change such as islands, coastal areas, and low lying regions. Much of the response to stationary and mobile emissions focused on mitigation using advanced technologies and applications.

Canada and the Come Together World

Canada was well placed in this global market. The Canadian economy continued to lead the old OECD group of countries in terms of population increase and growth of GDP. Innovation was accelerated through a series of regional technology centres operated by industry, government and university researchers. These areas became technology nodes where research, development, and product marketing took place in close proximity. These nodes encouraged the development and adoption of new technologies by providing a facility for university based researchers to expand on new ideas and concepts with support from both government and industrial investors. These nodes were well linked internationally through the growing network of TNCs, and the expanded Internet. This system of technology development had contributed to Canada becoming a world leader in several high tech areas. These included: biotechnologies, intelligent information management systems, wireless communication and transmission systems, designer materials (materials designed for specific applications), nano-technologies for computer based applications, sensors and actuators, and a host of energy efficient consumer products.

The benefits of Team Canada missions to China and its allies, as well as to Latin America started to pay off in the mid 2010's, and have continued to date. These linkages, and the wealth they created, enabled Canadian business to capitalise on its expertise and products, and to re-invest in improvements as well as establish new areas of competence that were readily demanded in these open and expanding global markets. Economic growth in Canada continued to flourish with the expansion of existing businesses that led to the formation of several transnational companies and with the creation of new and rapidly growing firms. As part of this world of extreme competition Canadian firms also embraced an enhanced form of environmental etiquette that marked world economies. Improved efficiencies and new innovative technologies yielding near zero wastes and emissions characterised all industrial and manufacturing operations. These improvements were accelerated by the application of high-speed computing systems, large-scale simulations, and the application of total system life cycle analysis techniques to the design of products and processes. Much of Canadian energy use was characterised by the fertilisation of technology across sectors, and on the use and application of common computer hardware and software that minimise energy and materials input.

As a result, GHG reduction had accelerated dramatically across all sectors. 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 emissions. Table 1 shows that under 'The Come Together World', Canada would still be above that budget for GHG emissions.

Table 1

GHG Emissions (CO_2 Equivalent)		
CEO 2000*	**Kyoto Trend Line 2050**	**Come Together ETF 2050**
694 Megatonnes	**248 Megatonnes****	**324 Megatonnes*****

*Canada's Energy Outlook, published by Natural Resources Canada in 1997 and updated 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 tax and other revenues that were generated by these expanded export markets, and increased profits enabled the Canadian government to re-fuel and expand its investments in technology development and industrial expansion and encourage personal savings and investment through the reduction of personal and corporate taxation levels. This wealth also allowed Canada to adopt new and innovative technologies and practices within its own sphere of economic activity and placed Canada as a world class leader in several areas of environmentally related technology. It also permitted Canada to heavily re-invest in its system of innovation with increased investment in on-line education and training systems that ensured Canadians were capable of, and had the competencies to excel in, this high-paced technical world. Extensive government - industry (automotive and energy for example) apprenticeship programs were developed that further supported the university research programs and the innovation processes of the technology centres. Canada was not immune, however, from the deterioration of the global biosphere. The proven linkages to health concerns caused by GHG emissions (respiratory, air quality, and others) and climate change (heat-related illnesses and new disease carriers) further supported the more rapid introduction of new and innovative technologies. It also increased investment in health care and related services, along with climate change adaptation strategies.

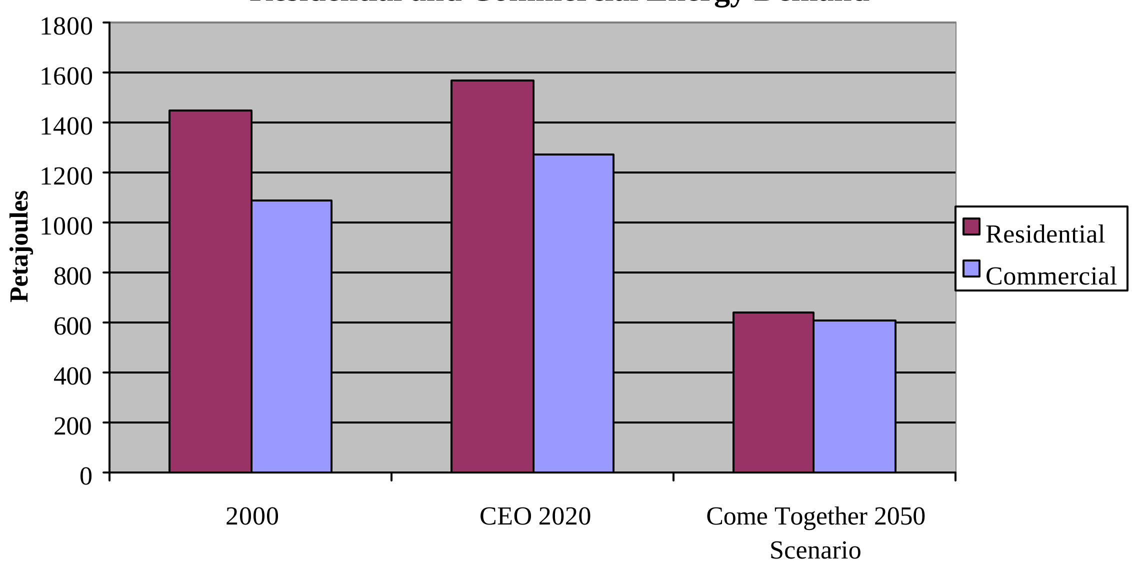
These investments in health coupled with the biotechnology revolution allowed Canadians to live longer lives. The residence became the focal point for work, education, and relaxation activities for Canadians. Work at home with visual conferencing was commonplace and enabled Canadians to conduct business transactions, participate in business conferences, manage factories and actively participate in the day-to-day decisions of government from their homes without the demands and stresses of commuting. The Net provided most of the day-to-day communication and commercial needs. Electronic commerce became a multi-billion dollar per year business and continued to grow. As well, the Net provided the information and on-line texts for all primary and secondary educational levels, thus facilitating the work-at-home ethic. The expanded use of the information systems and artificial intelligence resulted in some lost employment, but directed, on-line learning programs facilitated re-training more rapidly and effectively than previously employed approaches. The growth in interconnectedness of the economy provided greater time for developing innovative ideas and concepts or adapting technologies available in other markets to Canadian needs, for high-speed international business travel or for vacationing. Vacations in bio-engineered environments ("artificial-nature" in temperature controlled buildings), or vacations in virtual space (experiencing all aspects of the environment) became the preferred option for most Canadians. Agricultural products were bio-engineered to meet product specifications for domestic and international consumption, and to ensure their pest and drought resistance. Aquaculture and deep-sea and mining operations flourished off the east and west coasts and the Great Lakes.

A. The Way We Live

The use of buildings in Canada evolved markedly from the early 21st century work at home environment to one directly influenced by the demographic structure of Canada in 2050 and the rapid expansion of the information network and integration of world wide computer networks. In this world, the expanded use of residential buildings and the adaptable use of other non-residential structures resulted in consumer demand for more flexible building environments that can provide the space conditioning, lighting and hot water needs on demand. This led to the development and heavily reliance on integrated and intelligent energy management systems using a range of sensors and intelligent controls to manage the building’s energy requirements in response to weather conditions. Passive solar and solar thermal strategies provided natural lighting, ventilation, and water heating in a more integrated and overall more energy efficient building design. Designer materials such as crystal-structure or phase-change materials were used in the wallboards and flooring to capture and gradually release heat or water vapour for temperature and humidity control. Waste heat from “grey water” that was previously used by appliances or bathing was recycled for improved efficiency or used in low-grade applications. Excess heat has been virtually eliminated from lighting systems by photoluminescent wall lighting or through the use of fibre optic light pipes, which distribute illumination to the building from a single light source.

By 2050, buildings were part of an integrated electrical system and supplying energy to the grid. The use of photovoltaic (PV) shingles, or paints enabled buildings to generate electricity when loads from the unit were low. In applications where these technologies were coupled with stationary fuel cells, all building space conditioning, lighting and water needs were met without excessive demands on external fuel supplies. Pollutants in the building air and excess carbon dioxide were managed through the use of biologically based purification/revitalisation systems, and wastewater was treated and purified using similar techniques. Many buildings and residential units had living walls incorporated into the building design, avoiding investment in the more energy intensive and cumbersome HVAC systems. These walls of selected plants, microbes, and other living materials provide biological purification of building air, literally breathing in dirty air, and emitting clean air to the building environment. Municipal solid waste was substantially reduced through extensive recycling programs and waste to energy systems such as pyrolysis systems. Buildings in 2050 have low emissions and clean environments that have formed part of a more integrated energy system within Canada.

Figure 3
Residential and Commercial Energy Demand



B. The Way We Work

The industrial sector underwent a fundamental change in its operations from the 1990's. Overall manufacturing systems became more flexible and agile, responding quickly to changes in international market needs and domestic consumer demands, as well as to changes in new materials, energy technologies and other factors of production. Strong international and domestic competition required that industry was capable of providing rapid continuous 'one-off' manufacturing of unique products as opposed to the mass-produced products that were commonplace at the turn of the century.

Flexible manufacturing cells with fast retooling, multi-processing and rescheduling, replaced turn of the century production lines. These cells were comprised of chains of machines capable of multi-tasking and making production changes quickly and easily. Combining micro-machines with computing power has given manufacturers the ability to build small or microscopic precision devices with the ability to sense, react and communicate. These are applied in controls, biological systems design, electronics and other sectors. Nano-manufacturing operations emerged which enabled molecule-by-molecule construction of microscopic devices that had widespread application in the computing field, medicine, and in the manufacture of sensors, controls, and actuators.

By 2050, manufacturers had made tremendous leaps in process improvements and with the aid of high-speed and high-capacity computing. Automated systems had eliminated several steps in old production processes so that they can now move from design to product in one step. Products were designed with tailored energy and GHG properties (based on intensive modelling and life cycle analysis of the product, its materials and compatible manufacturing processes) built-in. All to ensure optimisation of the overall system and minimisation of GHG emissions.

The major introduction of integrated automated systems designed to optimise manufacturing processes and to operate with zero feedstock waste, which started around 2025, had expanded to virtually all corners of the industrial complex within Canada. Advanced technologies such as robotics, artificial intelligence, high-speed computing, wireless communications, power electronics and photonics were now generally applied. These systems provided alerts for maintenance and repair, energy management control, GHG emission levels, production standards and quality control. Industrial and manufacturing processes typically used closed emission systems, and the recycling of energy, in fact, most are operated as ‘dark factories’ requiring few staff and little heating and lighting.

Biotechnologies have made huge strides since their early applications in medical science. Some prime examples of 2050 applications included:

- Bio-remediation
  - Bio-membranes operating on stable substrates for use in the separation of pollutants from effluent or emissions streams (CO_2 capture is a very typical example of this application)
  - Bio-refining to de-sulphurise petroleum products
  - Bio-purification of industrial waste steams using genetically engineered organisms
  - Biofloculating agents for charge neutralisation of suspended particles in effluents to cause their aggregation and subsequent precipitation
- Biotechnology for in-situ processing and upgrading of heavy oil and tar sands, extremophiles being used in conventional oil wells to enhance oil recovery by decreasing the viscosity of the oil underground thereby facilitating its movement through the rock.
- Bio-catalysis: Microbial enzymes acting as catalysts to accelerate reactions in the processing and treatment of certain products; and
- Bio-sensors to artificially ‘smell’ or ‘taste’ for pollutants or for impurities for impurity detection e.g. detection of sulphides in oil and gas pipelines

Genetic engineering was used to alter microbes and their enzymes for adaptation to different industrial environments. Biologically based sensors were also applied to detect certain chemicals used in industry and in buildings as part of the overall intelligent management system. Other applications of these sensors were to detect pollutants or other gases, or to help 'fine tune' processes. Other biologically derived tools were also widely available for product creation and process intensification, monitoring, and control.

Breakthroughs in DNA computing in the 2030 period led to the design of artificial-intelligence control systems that imitate human brain's processes. Simultaneous advances in quantum computing, and its integration with DNA computing, allowed high-speed and high-capacity chips to be combined with intelligent algorithms. This enabled fast, adaptive learning systems to be developed that were far superior to turn-of-the-century expert systems. This new generation intelligent computing was capable of quickly assimilating data from multiple sources, model complete systems, identifying problems and formulating a range of probable solutions along with the advantages and disadvantages of each. Biosensors mounted on semiconductor substrates were used to trigger mechanical responses in robots giving them a sensory dimension (for example, proximity recognition and environmental status information) which facilitated improved human/machine interaction in the workplace and the home.

Robots using these biological/computer interfaces were part of an array of smart and intelligent machines that used biological sensors to trigger mechanical responses. Such systems were applied in both energy production and use industries. For example, they were common place applications involving oil and gas pipelines where they are used to detect impurities such as sulphides.

Based on the technologies outlined in the 'Come Together' World, industrial energy demands (with the exception of electricity) could be reduced as follows.

Table 2

Come Together Industrial Energy Demand in 2050	
Industrial Sector	*Percent reduction in non-electric energy demand from trend*
Pulp and Paper	40%
Chemical	75%
Iron and Steel	40%
Smelting and Refining	40%
Mining	40%
Other Manufacturing	60%
Construction	30%
Forestry	25%
Cement	50%
Petroleum Refining	60%
Non combustion	30%
Total energy reduction	**36%***

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

C. Our Mobility

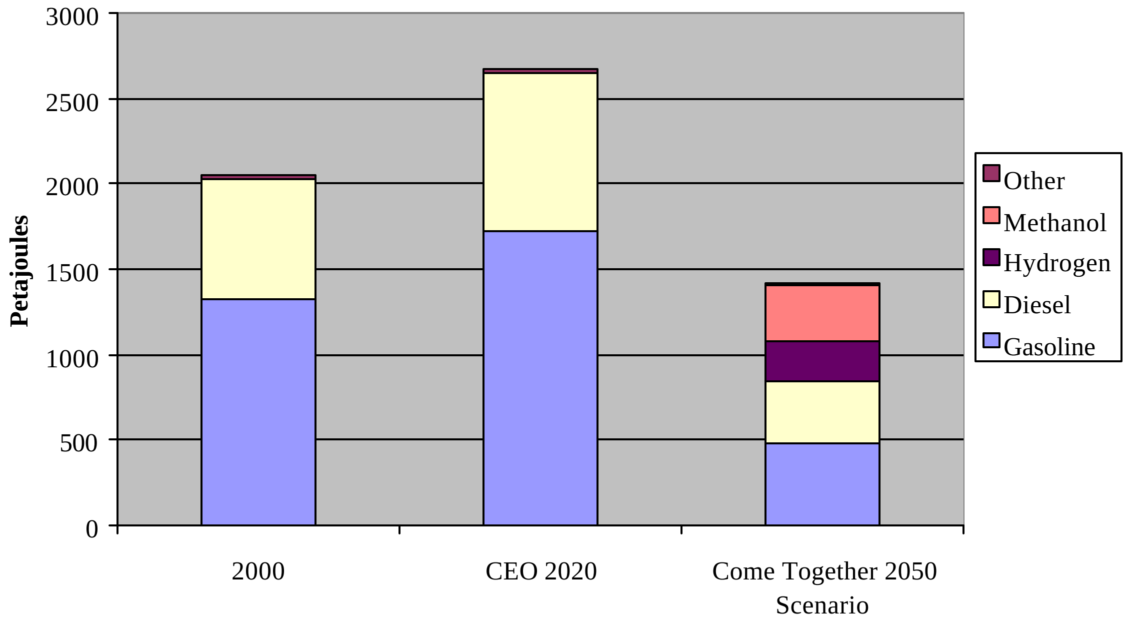
In 2050, mobility remained a priority for Canadians. Consumer demands in this area were remarkably similar to those of 1990's; i.e., reasonably sized vehicles, 600+ kilometre range, with a full range of consumer amenities. While work at home was a reality for Canadians, the use of personal vehicles remained high and dominated energy use. More importantly, Canadians and North Americans in general, still had a preference for liquid transportation fuels. Modelling traffic flow and implementing intelligent traffic-control systems had largely solved the problem of excessive congestion in urban areas, which once carried a high environmental cost. Urban design and infill projects were also developed to be pedestrian friendly and to minimise mobility needs.

The advanced internal combustion engine powered about 60% of the vehicle fleet with the remainder powered by fuel cells. Dependence on the liquid fuels infrastructure prompted large investments in the maintenance and re-design of the pipeline system starting in 2010 and continuing for the next 10 years. This long-lived and capital intensive infrastructure benefited from advances in materials that allowed for a more flexible, durable system that were less susceptible to corrosion, and that incorporated self-maintaining characteristics such as cartridges that emitted corrosion inhibiting substances at the early signs of material degradation.

Designer materials also played a significant role in the design of new vehicles and engines. Lightweight, crash resistant materials, composites, advanced alloys, hybrid materials and strong, lightweight steels were used in the design of vehicle frames and bodies. Some manufacturers started to use large-scale metal powder, or semisolid injection moulding for custom shaped vehicle parts and frames, but this technique was not widely applied until the year 2030. High temperature and lightweight ceramic engines, operating more efficiently than the older conventional engines made from aluminium, established a solid share of the market. The mechanical efficiency of ICEs benefited greatly from advances in the design and development of frictionless materials, using either surface modification techniques or hybrid, layered materials that eliminated the need for lubricants that vaporised and added to the emissions burden.

Preferences of Canadian and US automobile consumers and the flexibility, convenience, and acceptance of a liquid fuels infrastructure pushed automotive manufacturers to continued to rely on the internal combustion engine (ICE) for drive power. However, this was not the same ICE seen at the turn of the century. Several key advances in the design and performance of the ICE as well as in the fuels used have been developed and widely introduced. The largest percentage of the 2050 vehicle fleet used homogeneous charge, with self- or radical-ignition to increase gas mileage, lower exhaust emissions, and cyclic variation. Coupled with improvements such as variable valve timing (VVT) or continuously variable timing (CVT) meant that newer vehicles would have improved maximum power and torque, higher all-around efficiency, and improved emissions performance. Computer aided design and life cycle modelling (including combustion modelling, and computational flow dynamics), played an important role in establishing optimal vehicle operating conditions and in the design of the materials and fuels for the new vehicle fleet.

Figure 4
Road Transport Energy Demand by Fuel



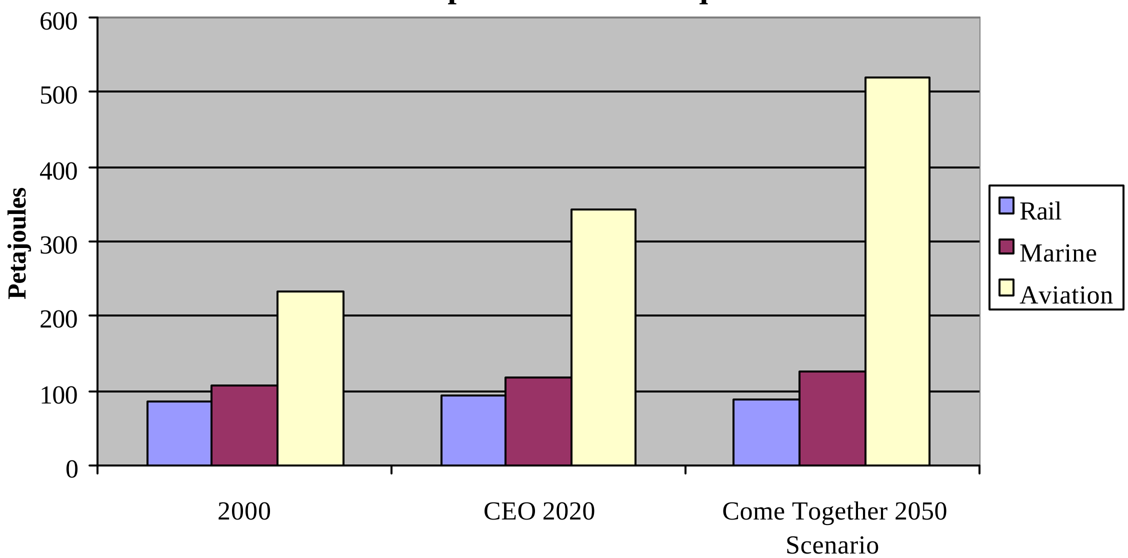
The impact of changes in mobility under the 'Come Together' world resulted in a shift in its fuel mix. Overall fuel demand is reduced, and hydrogen and methanol fuels have taken a larger proportion of the fuel mix from gasoline (albeit 'cleaner' gasoline).

ICE and other powered vehicles continued to require fuels of high power density, thus, the continued emphasis on a liquid fuels infrastructure. To meet this need, and to balance the emission reduction targets under the GCCF, alternative fuels, as well as cleaner gasoline derived from fossil fuels emerged. These gasolines were derived from the use of bio-engineered processes, enhanced hydrocracking, advanced membranes and catalysts, and the development of hybrid fuels e.g. hydrogen and gasoline, hydrogen and diesel were widely used. Advances in fuel cell vehicles from the early work on the Ballard system allowed for the emergence of fuel cells that met the energy density and fuel convenience demanded by consumers. Direct methanol or gasoline reforming fuel cells were the clear choice for consumers. Fuel cells using on-board hydrogen were used for mainly for commercial fleets and for road-based urban transport systems where off-peak bulk fuelling was a more convenient option. Solid oxide fuel cells have been the main stay of underground urban rail systems since 2030. These systems use low temperature fuel cells operating on liquid fuels to meet most 'metro' high speed commuting needs with less noise, and with virtually no emissions; a positive benefit for most commuters.

For the year 2050, the average vehicle fleet fuel economy had increased from 9.7 litres per 100 kilometres for cars in the year 2000 to 3.0 litres, an increase of over 50%.

Similar increases also occurred in light duty trucks where average economy rose from 13.3 litres per 100 kilometres in the year 2000 to 6.8 litres per 100 kilometres in 2050. Priority was given to developing an efficient system for transport of heavy goods in the early part of the century. The main emphasis was to substantially reduce the number of heavy goods transport road vehicles. These vehicles continued to be responsible for significant road degradation and environmental pollution well into the early part of the 21st Century. Rail companies relied on lighter weight materials to containerise the goods being shipped and for lightweight stainless steel rolling stock to minimise wear damage on the rails and to improve efficiencies. High-speed electrified rail systems, travelling between 200-500 km/h, linking the heavily populated and industrialised areas across Canada and providing easy access to the United States for passenger and goods, were just starting to emerge by the year 2045. The necessary track upgrades and other infrastructure modifications will need to be completed within the next 10 to 15 years before we see full electrified rail within Canada.

Figure 5
Other Transportation Fuel Requirements



Aircraft designs markedly improved; again due in large part to advanced computer aided design and simulation systems. However due to cost considerations, major new engine designs still take in the order of 25 years to implement. As a result, aircraft companies relied on advances in materials and changes in design parameters to improve the efficiency, durability, and reliability of planes. In 2050, transcontinental aircraft typically travelled at Mach 0.98 or thereabouts and were generally used for stage lengths greater than 1,000 km. They used high turbo and propeller fans and made use of high strength-to-weight ratio materials such as super-alloys or nickel-based inter-metallics.

D. Our Energy Mix

Canada's energy mix in 2050 consisted to a large extent of the same fuels that were employed in 2000; however, the energy system became more integrated, with a variety of fuels being used to meet service demands. However, the processing, refining and transmission of these fuels underwent significant changes. Strong market forces were at play in this sector as in other components of the Canadian economy; thus, industries needed to be flexible, adaptive and ensure their product was highly competitive. Canada was in a favourable position as its energy resources remained plentiful, reasonably priced, and highly valued internationally.

Fossil Fuels

The state of the industry in 2050 was very similar to that of 2000.

- Canada continued to be a world producer of hydrocarbons,
- Energy consumption patterns did not change dramatically, as consumers still demanded the services energy provided, and
- Canadians continued to demand and use a "liquid fuels" infrastructure.

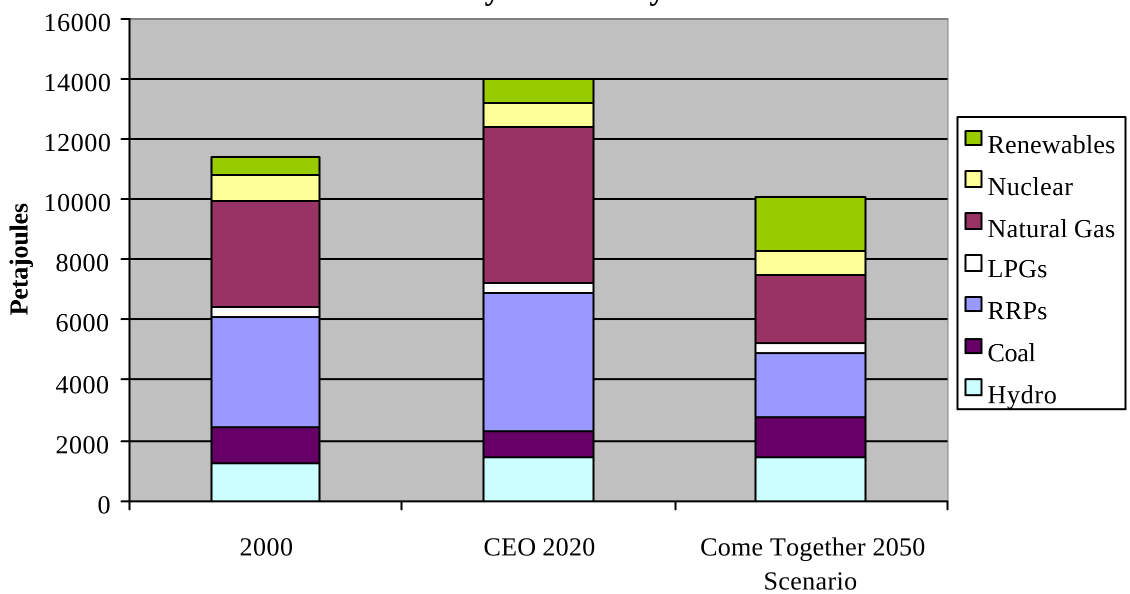
Diversity and integration of energy sources did relieve considerable domestic pressures from fossil fuels use. As forecast in the year 2000, conventional crude production from Western Canada's Sedimentary Basin (WCSB) dropped off significantly starting in 2010. This coincided with the deterioration of the pipeline infrastructure that started to become a concern towards the end of the 1990's. Security of energy supply remained an issue, and the economic disruptions that would be associated with failure of the pipeline system raised concerns and prompted large investment in the area. The Governments of Canada, Alberta, and Saskatchewan joined forces with industry and invested heavily over the ten years from 2010 to not only upgrade but extend the Western Canadian pipeline system using new, stronger and more durable pipes manufactured domestically. Upgrade and extension of the lines was necessary to balance throughput capacity for domestic as well as export markets, but also to bring into the system the unconnected gas in the WCSB (about 35% of established reserves in 2010) and northern sources of supply. Other technologies to transport natural gas were also examined including the use of compressed gas tubing that proved to be viable for handling small quantities of gas for near-source delivery, and dual phase pipelines for greater and more diverse product density.
By the year 2025 production from conventional sources of gas had fallen off from its peak in 2015. This brought into play offshore Scotian shelf deposits and northern frontier sources.

By the year 2040, attention started to turn to the development of offshore gas hydrates as a source of energy. However, given the abundance of more readily available natural gas, this new source was not exploited by 2050. The more rapid declines in conventional WCSB oil led to increased investments in oil sands and heavy oil fields and in East Coast oil deposits. Until about the year 2030, Canada's sources of supply of hydrocarbons were becoming more remote, and somewhat more energy intensive. By that time, however, oil from conventional wells that had ceased production or were seen to be uneconomic given the continued flat world oil prices, started to become more viable thanks to the growing use of extremeophiles and CO_2 injection. In fact, the value of CO_2 disposal in these wells led to a virtual re-birth of the WCSB conventional oil regime.

Throughout the period to 2030, the oil and gas industry relied mainly on the application of technologies available and economically attractive (drilling technologies, especially offshore), and the application of some of innovative drilling and production techniques for East Coast offshore regions where large potential discoveries had been made.

Biotechnology applications that process crude oil in situ into shorter chained hydrocarbons like methane did not really start to emerge until about 2040, and are now widely employed. Natural gas, while cleaner than other hydrocarbon fuels, continued to maintain a premium, with its use and price matching this higher value. Biotechnologies such as algae and other micro-organisms were now in wide use to produce gaseous and liquid fuels. Hydrogen was also produced using bioprocessing as well as through electrolysis using sub-surface PV applications, the processing of alcohols, glucose, or while fixing nitrogen.

Figure 6
Primary Demand by Fuel



The coal industry changed dramatically. The growing demands for coal slurries forced the industry to re-tool and abandon turn of the century coal mining practices and use of water jet systems of mining. These systems were more efficient and used robotics to mine the coal. Sensors were being tested to manage and control the slurry mix so that it met user specifications as it left the coal mouth and thus improved the overall utilisation process.

Electricity

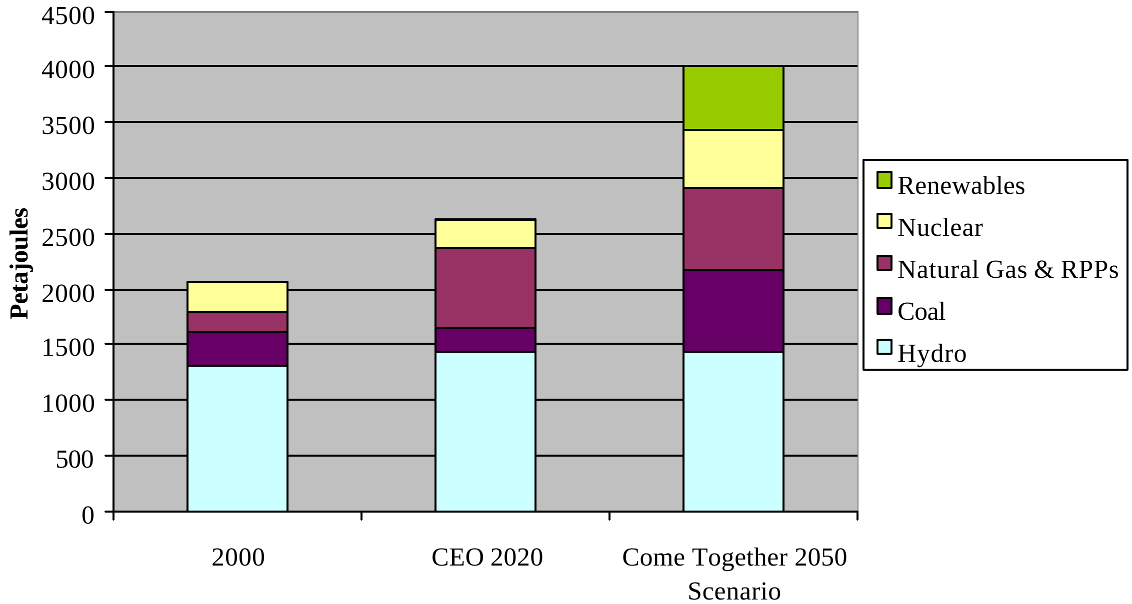
With the lay up of several of the nuclear facilities in Ontario and Québec during the 1990 to 2007 period, interest in nuclear as a viable electricity source waned. Coupled with the on-going perceptions of the public over the nuclear waste issue and the controversy over mixed oxide fuels (MOx, or weapons grade plutonium), the Canadian nuclear industry continued to experience its downward trend that began in the 1980's. The growing use of natural gas combined cycle, other gas technologies for electricity generation as well as the emergence of cleaner coal technologies served to provide the electricity that would have otherwise been produced from nuclear sources.

Despite the growth in natural gas and coal as sources of electricity generation, the second decade of the 21st Century saw the entire electrical system entering a period of extended turmoil. The generation stock was ageing, the distribution system had been ravaged by service disruptions due to extreme weather events in summer and winter, and hydro companies were unable to maintain the levels of peak service demanded by customers. At that point in time, the integration of renewable energy technologies was limited to situations where they were competitive with conventional generating sources. For the most part, the focus of attention was placed on cost-effective means to diversify and broaden the generation mix and the use of more efficient fossil fuelled electrical generation technologies. This included the retrofit of existing facilities as a means of dealing with its ageing generation stock.

These actions proved to be insufficient. Nearing the end of this period, the huge expansion of the development and use of information technologies required Canada to re-examine its investments in generation capacity. The unprecedented demands for high quality and reliable power raised serious questions concerning the overall state of the system, the role of nuclear in Canada's electricity mix, and the reliability of the electricity distribution system. It was too apparent that in order to keep pace with the growing and more competitive environment, major investments and new approaches to doing business were needed in all of these areas.

During the 2015-2025 period, standalone electrical generation systems started to be replaced by more distributed ones, and more integrated energy complexes, with on-site production from these "energy plexes" meeting the needs of smaller users. These "plexes" were co-fired systems using coal, biomass, and other fuels, as well as stationary, ceramic fuels cells. Renewable energy sources were well suited for these systems and photovoltaic systems, wind and solid waste systems were widely used. The widespread implementation of clean coal technologies (IGCC, oxygen combustion and CO_2 capture and coal bed methane production) started in the 2020 to 2030 period, but accelerated in application since then. Smaller sized IGCC units and oxygen combustion systems made them ideal candidates for distributed generation sites. Where applicable, these distributed systems used better separation technologies to ensure the capture of CO_2 produced for subsequent sequestration. By the year 2030, the larger portion of Canada's electrical generation was being produced from distributed facilities.

Figure 7
Electricity Generation by Source



This new approach to generation also helped extend the life of the remaining fossil fuel plants. By 2040, most of these plants were approaching the end of their useful life and needed to be replaced. The strong environmental push and the growing acceptance on the part of consumers of safe nuclear power, interest again shifted to expanding nuclear capacity in Canada. Canada looked offshore for a supplier of high temperature gas-cooled reactors (HTGR) that offered the higher thermal efficiency and enhanced safety considerations that were being demanded. These advanced systems used more integrated fuel cycles, higher efficiency units, and technologies for better waste management practices (transmutation and other enabling technologies) as their main selling feature. In addition, they incorporated technologies such as intelligent systems, and solid state sensors that contributed to greater overall system reliability and longer life expectancy. In part, this was the result of better predictive maintenance practices based on risk management and on data from intelligent sensor and actuator systems. Moreover, the reactor's ability to use either helium or carbon dioxide as a coolant gas proved to be an additional feature in the design. Decisions on these plants were made in 2035, and with the shorter lead times and more streamlined environmental approval processes, these plants were starting to be built in the early part of the 2040 period.

In addition to the domestic acceptability of nuclear, and the introduction of new technological approaches and innovation, there is a growing international recognition of the importance of nuclear in addressing global climate change issues. By 2050, there was increased globalisation and integration of the nuclear industry. This co-operation and the technology alliances formed, enabled the more effective development and deployment of technology advances and practices within the industry.

Electricity Transmission

In 2050 the Canadian electricity sector was a combination of a centralised and a distributed system relying on advanced transmission and electricity storage technologies to ensure a reliable and fully integrated supply of electricity. The fully integrated North American system was highly dependent on advanced computerised management systems that enabled wheeling of electricity North and South as well as East to West. Fibre optics were widely used for computer security applications as they are more difficult to tap into, and flexible AC Transmission Systems (FACTS), with increased quality and flow control sensors that allowed for a 50% greater load factor that incorporated Gate Turn Off technology were widely employed. By 2040, wireless transmission started to be utilised in remote northern communities and for both electricity supply and for transmission of electricity from remote hydro sites. Local distribution of electricity was based underground high temperature superconducting wires. Superconductor and gas insulated line technology were also used in the design of low loss transformers that further reduced overall system losses. In 2035 an international scientific team was formed to develop the first space-based solar transmission array. The prototype model is expected to be operational by 2060 providing power to Central Africa. Canada was able to provide substantial expertise in wireless transmission and rectenna design.

Energy storage systems became an integral part of the distributed electrical system incorporating wireless transmission technologies as well as storage technologies to ensure a reliable, affordable and low-loss supply of electricity. By 2025, technologies such as regenerative (reversible) fuel cells, advanced batteries, superconducting magnetic energy storage (SMES), lightweight composite flywheels, and aero-capacitors proved essential for the integration of renewable systems in to the fuel mix, and for remote renewable generation locations.

Sequestration of CO_2

Sequestration of CO_2, especially into fixed energy sources, was the essential ingredient in the development of a sustainable hydrocarbon system. There were large potentials for sequestration in the oil patch, agriculture, forestry, and ocean sectors. Key to the sequestration issue was the need for better separation technologies.

Longer-term fixation had an indirect benefit for the application of biologically derived polymers or through biomass fixation processes. Extending forested areas into marginal land or redeveloping plants to better produce biomass was one approach. Creating other GHG fixing microbes and plants proved to be another possibility. While these innovations were helpful in the short term, they did not represent long term solutions.

One innovative technique for longer-term fixation was the mineral carbonisation of CO_2 with concurrent hydrogen production through the use of a calcium oxide shift reaction. Prototype testing of the option started in the early part of 2040's, and in 2050, the approach was starting to be a widely accepted means of storing carbon dioxide at reasonable costs and on a permanent basis.

E. GHG Emissions in the Come Together World

GHG emissions are substantially reduced in this scenario. Significant reductions in emissions were seen in all areas of the economy. These reductions were due in part to due to the increased role of nuclear, the expanded use of biotechnologies, CO_2 sequestration, and the management of fugitive emissions.

Figure 8
Canadian Emissions by Source