Grasping At Straws

We tend to do the things we know how to do,
instead of trying to do the things we ought to do

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

Scenario Construct

This scenario is one of green environmental etiquette and a slow pace of innovation. It is a world of reasonable economic growth and wide-open global markets.

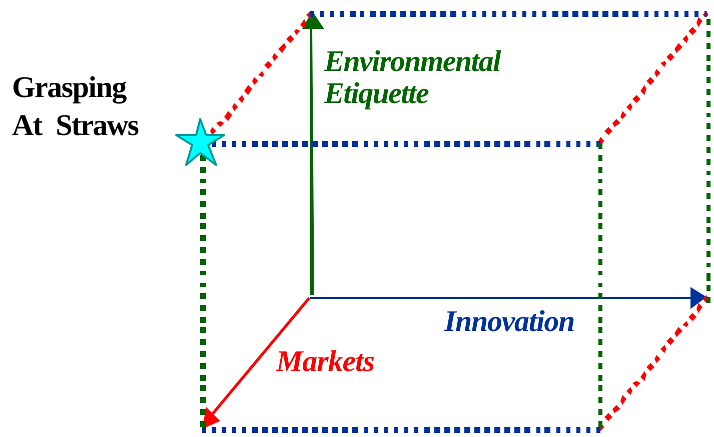


Figure 1

Pressure for immediate action on the climate change issue led governments of developed countries, including Canada, to rapidly deploy a variety of off-the-shelf technologies in the hope of finding a quick fix solution to the climate change issue. The near term advantages of moving technologies that had previously been developed off the shelf and into the market were well received in this world. Not only did they generate benefits, both economic and environmental, from their application, but they also enabled politicians to demonstrate that concrete action was being taken to reduce emissions to both the public and environmental groups. Unfortunately, this focus on deployment and nearer term activities resulted in a very uneven pattern of investment along the innovation chain. The lack of commitment to longer-term planning and far-sighted R&D left countries with limited pools of technologies from which to draw. By about 2030, very few and innovative technologies were available to address the climate change issue. This is light to mid green in the near term, but starts to turn grey as few new technologies are being developed.

Grasping At Straws

Geo-Political Situation

As the international community moved closer to the 2010 target date for the Kyoto protocol, there was a growing pressure for developed countries to put in place policies and measures aimed at meeting their Kyoto commitments. The main focus of these actions was to commercialise and deploy existing technologies that had the potential to reduce GHG emissions. Also included in this approach was the more effective utilisation of flexibility mechanisms such as the Clean Development Mechanism (CDM), and other joint implementation provisions of the Kyoto protocol. While designed to bring developing countries into the agreement, they also assisted developed countries' efforts to meet their own GHG reduction targets.

Most developed countries relied on a combination of off-the-shelf technologies and various regulatory and policy instruments to 'find a solution' to the GHG problem. This resulted in developed countries investing significantly in the deployment portion of the innovation cycle, causing them to forego investment in broader, longer-term technology R&D. The near term advantages of moving technologies that had previously been developed off the shelf and into the market were well received in this world. Not only did they generate benefits, both economic and environmental, from their application, but they also enabled politicians to demonstrate that concrete action was being taken to reduce emissions to both the public and environmental groups. Many of the latter welcomed the long-pushed for application of technologies that they felt would make a contribution to the GHG issue. Using off-the-shelf technologies was also seen as a means of avoiding public backlash to higher risk investments in such areas as advanced nuclear or controversial biotechnologies. Even closer government ties with environmental groups were forged as cleaner, more environmentally friendly

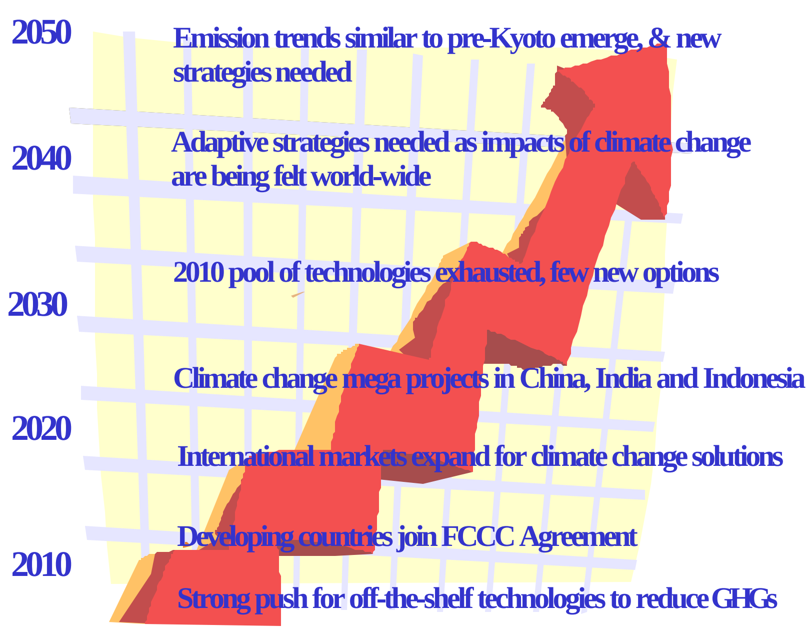


Figure 2

technologies and approaches to the climate issues (as well as other environmental concerns) were adopted.

By the year 2015, these ties were further strengthened as many nations were forced into a purely reactive mode, attempting to manage smog issues in larger industrial cities, adapting to an increasing number of climate related natural catastrophes, and coping with massive shifts in agriculture and food production.

As these currently available technologies were deployed, some were shown to be more effective than initially thought, while others did not achieve the expected results or market penetration. Overall, however, there was the view that these technologies were having an appreciable impact on emissions. The technologies that did succeed were in high demand, and as developing countries continued to press for the transfer of technologies as a 'bargaining chip' in the negotiations to bring them under the agreement, companies involved in these technologies found open markets for their products. The flexibility mechanisms under the Kyoto protocol were well utilised and many countries established international components of domestic activities to further push their environmental technologies.

During the first half of this 21st century world markets became almost completely open and 'globalised'. The expanding regional and hemispheric trade blocs of the 2000-20 era were well enough organised so that they were able to negotiate integration with other blocs so that by the year 2040 virtually all of the major international markets were integrated. That global market has led to vigorous competition and collaboration in the deployment of energy technologies all around the world.

Throughout the period to 2010, the growth of Chinese manufacturing (to rival that of the EU and USA) was fuelled by coal. However, by around 2015, it was becoming clear that there were limits on the capability of the Chinese to work and live in the increasingly brown urban air, China's small supply of fresh water, and its growing inability to feed itself. Similar air and water limits were reached in the biggest cities around the world such as Lagos, Mexico City, Rio and Taipei. The demand for immediate solutions from these countries translated directly in greater demands for off-the-shelf technologies. Companies in developed countries scrambled to meet these demands, and in doing so pushed for more liberal trade arrangements. However, this short-term 'solution based' focus led companies to invest mainly in product differentiation and product innovation to secure markets, and to keep competitors at bay. Little in the way of new product development took place as companies were emphasising the on-time manufacture and delivery of products.

The unplanned and uncoordinated approach to technology deployment, while somewhat beneficial in the short-term, proved to have longer-term implications. By around 2035, the pool of technologies developed in the early part of the 21st Century was starting to become depleted, and countries no longer had quick fixes to the problems at hand. The reliance on these technologies lulled the world into a sense that it could manage the GHG emissions of a growing and more energy consuming world economy. The efficiency and market for most of these technologies had peaked out, and scientists again raised cautions over rising GHG emissions. As it turned out, deteriorating air quality was just an early sign of the real impacts of climate change. Throughout the period, the scientific foundation of the climate change issue became stronger, and a continuous series of world-wide natural disasters had more than just casual links drawn to climate change. Adaptive strategies had to be relied upon, and by the year 2050, most countries realised that the growth in GHG emissions was quickly returning to pre-Kyoto levels, and a fundamental rethink of GHG management approaches was urgently needed.

Canada in a Grasping at Straws World

In this world in 2050 Canada's economy and international niche still relies heavily on its natural resource base. Overall Canada remained a regionally diverse country, with fuels and technologies pocketed in areas of capability or interest. Hydrogen based technologies such as fuel cells were centred in Western Canada, while the Prairies and parts of Ontario, and the east had interest in biomass derived liquid fuels. Canada's information and communication technologies, resource production technologies, as well as re-manufacturing and resource recovery technologies flourished. This regional diversity, while reflecting the concerns and interests of the various parts of the country, also reflected the lack of cohesive planning that was necessary to manage GHG emissions.

Canada followed the international trend and adopted a 'no regrets'[1] approach to the GHG issue. Standards and regulations (harmonised on an international basis) combined with labelling of all energy using appliances, as well as technology deployment were the main instruments used to commercialise cost-effective technologies. Regionally balanced efforts were made to demonstrate and deploy technologies available at that time were aimed at a quick fix to the GHG issue. Additional R&D investment was limited to near term applications, and as a result, the innovation system was not spurred by the early flurry of GHG reduction spending. The application of the available technologies did reduce GHG emissions in Canada, and coupled with credits from the CDM and other emission credit schemes saw GHG levels fall through to the 2020-2030 period. From then through to 2050, emission levels experienced a steady and rapid climb, as new technologies were not available to balance the GHG implications of a growing population and economy. By the mid-2040's emission levels were reaching rates similar to those witnessed in the pre-Kyoto period.

The strong environmental etiquette and the developing ties with environmental groups led to the introduction and wide spread adoption of a number of recycling and re-use efforts and technologies. Much was done to integrate these efforts with industry's ability to use and adapt re-cycled materials so that some of the demand-supply discontinuities of the early 1990's were not repeated (for example, the problems associated with paper recycling). Initially these schemes were introduced in the residential sector and quickly

[1] Refers to policies and measures that do not harm the competitive position of one country vis à vis its trading partners.

spread to other sectors and applications. By 2010, virtually all solid waste from the residential sector was recycled, reused or composted. Only a few household products (mattresses, furniture, tires, etc) were destined for the landfill, and starting in 2015 companies started to more effectively use these products and create new products from them. Recycling of tires, for example, led to the recovery of incinerator steels and of rubber granulate for use in the athletic tracks, industrial mouldings, and parts of new rain drainage road surfaces. Recycling efforts were enhanced in the steel and aluminium industries where it was proven to reduce energy input costs as well as GHG emissions.

Wide-open global trading and environmentalism furthered the deployment push. Information technologies flourished and governance, technology choices, education, work, nutrition, recreation and other consumer choices were all undertaken in a better informed environment than ever before. That information environment has been one of the primary drivers of changes in consumer and producer management of materials, processes and products.

Table 1

GHG Emissions (CO_2 Equivalent)		
CEO* 2000	**Kyoto Trend Line 2050**	**Grasping at Straws ETF 2050**
694 Megatonnes	**248 Megatonnes****	**810 Megatonnes*****

*Canada's 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

Canada made some improvements in GHG emissions reductions during the period 2010-2030 through the wider demonstration, refinement and wider application of currently available and Canadian-made technologies such as tri-generation, fuel cells, and ethanol production technologies. The overall pace of new energy product development was slow. Without the development of more fundamental longer-term technologies, and the nurturing of new creative ideas, the pool of available technologies started to become seriously depleted. Canada was not isolated from the growing concerns over climate related issues, and by 2035, found itself with a limited range of new technology options that could address the growing GHG issue.

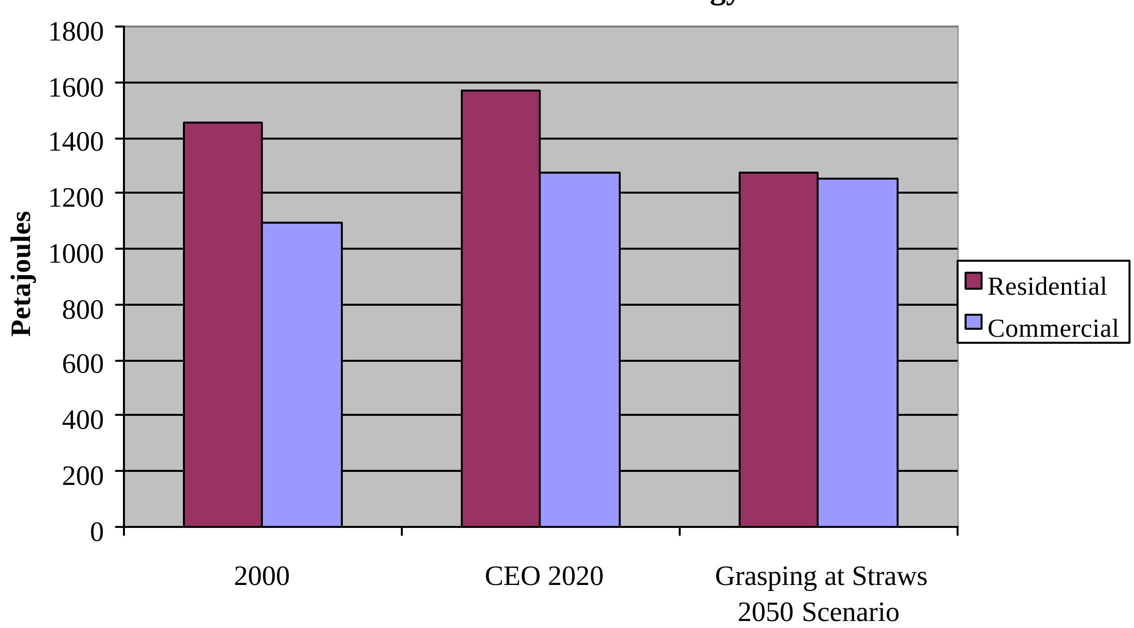
A. The Way We Live

Demographic considerations and the rapid growth and interconnectedness of information technologies led to more individuals working at home. This placed greater demands for high quality and reliable power for computer and telecommunication applications, lighting and appliances, and for space heating and hot water needs. These would be met by improvements in existing technologies (greater efficiency systems and furnaces) and electricity displacing oil and natural gas for most residential applications.

The 'Net' became pervasive in the period around 2010. More and more people flocked to the electronic shopping mart for its convenience and speed of delivery. Nearly all consumer purchases of well known branded products, groceries, basic commodities and even entertainment were done over the Internet. 'High-touch' products such as furniture, do-it-yourself, hobbies, speciality foods, and restaurant meals remained the principal face-to-face market experiences. In reality, e-commerce and its reliance on branded products proved to be an impediment to smaller companies with limited product lines who found it difficult to build a sufficient web market base from which to operate.

The downtown core of most urban centres continued as the primary commercial workplace but starting around 2015, a large amount of business shifted locations to a growing array of nearby satellite communities making up the edges of large cities. These communities became hubs for residential housing and a growing number of remote offices. Businesses, to avoid high rents and other costs of operating in the city, rented 'communal' office space in these communities thus providing employees the flexibility of limited commutes, while still providing the interconnectedness and social interactions of the office.

Figure 3
Residential and Commercial Energy Demands



Heightened environmental etiquette led to substantial networks of commuter and recreational bikeways in most southerly communities. Increased periodic warming in winters in our major cities (one of the impacts of climate change) encouraged more people to have their bicycles ready for use throughout the year. While this led to more difficulties for predicting public transit loads, it did reduce particulate emissions in cores, and some congestion. To facilitate the mobility of the elderly in the downtown core, a set of well maintained (year round) pedestrian walkways and networks started to become a basic part of the infrastructure of all communities starting in about 2015.

Working with the construction industry and building on the success of programs and measures introduced in the early part of the 21st Century, Canada was able to lower the energy use and GHG emissions of buildings by almost 30% by the year 2015. Since 2010 nearly all newly constructed buildings are well above the old R2000 standard through improvements in insulation, windows, passive solar heating, HVAC, and more intelligent sensors and controls. Reduction of GHGs related to the operation of buildings had also been successful, driven mainly by the introduction of ratcheted appliance efficiency standards and regulations. As re-manufactured products were being used in the construction industry, several builders concerned over air quality issues introduced a variety of mechanisms for air purification such as carbon filtration or biological filters.

Household appliances, including HVAC, have become lighter, more energy efficient in their operation, more durable, and modular, making for easier consumer replacement of parts or remote control fixes (re-programming) by suppliers. Sources for such appliances became fewer and with greater dependence on e-commerce, more dependent on goods delivery systems. On the other hand, the production technologies to make these appliances and other building components were almost as energy and GHG intensive as they were at the turn of the century.

Passive solar techniques became an integral part of new building design. Active solar for hot water applications proved not to be as popular due to the availability of a number of devices for air and waste-water heat recovery. Active solar systems but did find some market niches in off-grid and remote locales. Around 2015, ground and water based heat pumps became more widely applied. These were site specific and mainly larger commercial or remote applications. Toronto's lake-based downtown municipal cooling system which started in 1997, is a prime example of this application, and by 2020 served approximately 80% downtown core. The other cities on large lakes and rivers, including Montreal, developed similar systems with about a 10 to 15 year lag time.

Other schemes to promote renewable energies were attempted, and some suffered from the ad hoc and random approach to technology investment planning that characterised this 'solutions based' environment. For example, by the year 2010, late 20th Century investments in methane recovery from landfill sites and to gasify waste products demonstrated some early success, but as recycling and re-use schemes took hold and the materials destined for disposal reduced significantly, these applications soon were abandoned.

B. The Way We Work

Looking back it has been a half-century of relatively low innovation in Canada and around the world. Most technology advances in the industrial sector have been marginal. Companies have been more interested in advancing their products in the open market, and changes to production lines have been made generally to reduce costs, or improve overall performance of the production process. Little innovation has taken place in industry as a whole.

Nevertheless, Canadian industry has managed to make some gains in GHG reduction through better waste reduction techniques, process simplification, the wide use of sensors and controls, wireless communication systems, and software programs to simulate manufacturing processes. More efficient appliances, pumps, turbines, motors, bearings, lubrication, and the use of controls and sensors, membranes and catalysts being applied in the market during the first decade of the century led to improvements in energy efficiency, and a better matching of process and related energy load requirements. Industry also continued its use of natural gas and renewable fired co-generation, membranes and other advanced separation technologies and of electro-technologies such as microwave and plasma heating.

Product re-manufacturing and resource recovery built on comprehensive recycling, reuse, and separation technologies became a standard practice around 2015. Re-manufacturing technologies changed the composition of many end products, and several value-added products based on recycling appeared on the market in large-scale quantities around 2020. Some of these included: artificial lumber made from a mix of recycled plastics and glass; synthetic concrete from used concrete, recycled plastics, fly-ash, metals and woods; wall board using fly-ash from coal-burning electricity plants; and marble composites from recycled plastics and industrial aggregate. This re-manufacturing and resource recovery approach paid off as significant improvements in energy use and reduced GHG emissions were realised. For example, the concrete industry has managed to reduce energy consumption and emissions by about 30% through the use of fly-ash aggregate, and a further 20% through planned recycling of concrete components in lieu of energy intensive demolition.

Other key technologies such as closed loop-processes, on-site energy generation from wastes, and advanced heat recovery became attractive options for manufacturers. By the year 2030, approximately 60% of heat that was wasted in year 2000 industrial processes was being captured for re-use in manufacturing systems or for use in nearby applications. There was no wide spread systems integration. However, some individual plants tended to link production systems through the use of miniaturised sensors and control systems to manage energy use and actual production processes.

Around the same time, ambient temperature biotechnologies had replaced a few heat-driven processes and helped lower energy requirements. This was done by using enzymes as catalysts for reactions or in treating materials. Biotechnological processes also reduced water and air emissions in all fossil fuel based industries including pulp and paper, distilleries, chemical and food industries. Bioprocessing of waste streams transformed waste products into other chemical forms. This turned previously detrimental emissions into harmless by-products or even useful feedstocks for other industries. Biotechnology processes were incorporated in the mining industry to improve separation and conversion processes. This allowed for lower environmental impacts near mines and easier cleanup of the sites upon closing.

However, the rate at which technological improvements were introduced in the industrial sector started to slow from about 2035 onward. The slow and uneven nurturing of the innovation system, and the resulting slow capital stock turnover were being felt throughout the economy, and the industrial sector, while continuing to invest in product differentiation, and process improvements, no longer had a stream of cost-effective new technologies and applications to draw on.

Table 2

Grasping at Straws Industrial Energy Demand in 2050	
Industrial Sector	*Percent reduction in non-electric energy demand from trend*
Pulp and Paper	20%
Chemical	30%
Iron and Steel	30%
Smelting and Refining	20%
Mining	10%
Other Manufacturing	25%
Construction	20%
Forestry	10%
Cement	40%
Petroleum Refining	15%
Non combustion	20%
Total energy reduction	**18%***

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

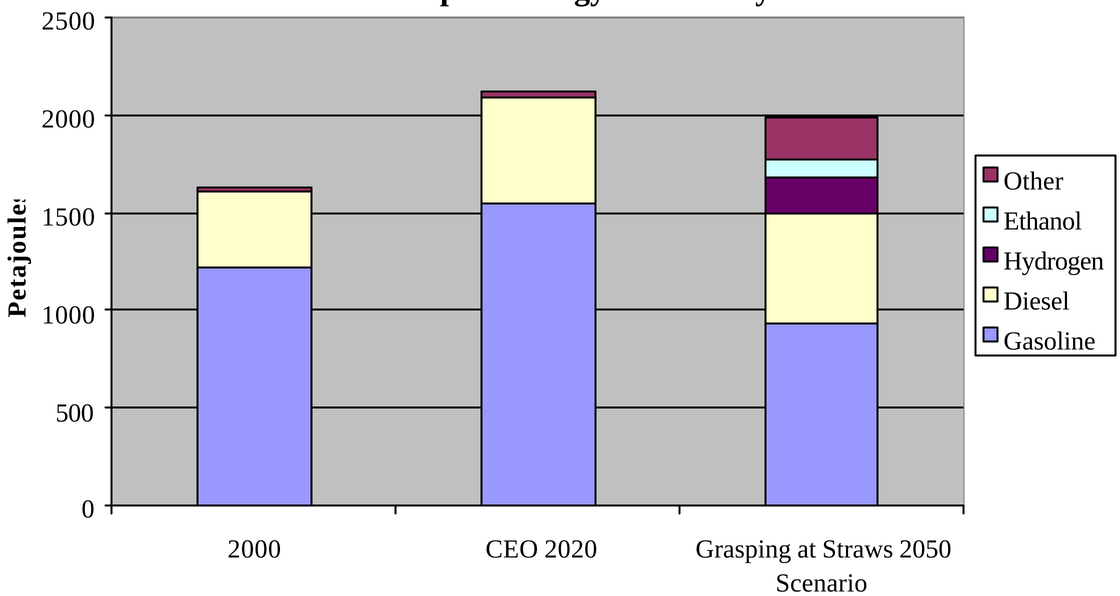
C. Our Mobility

The transportation sector best reflected the regional diversity of the economy, and the unplanned approach to GHG management. Road-based vehicles were fuelled by a wide variety of sources, neat gasoline with somewhat improved emission levels, ethanol blended gasoline, hybrid (gasoline-electric) systems, bio-diesel, and natural gas and propane fuels, and hydrogen and methanol fuel cell systems.

Canada benefited greatly from the Partnership for a New Generation Vehicle (PNGV) Program promoted by the United States. Not only were advanced internal combustion engines developed under the Program, but hybrid systems also emerged as cleaner, more cost-effective options, especially in areas of carbon free electricity supply. Advances in lightweight and self lubricating materials, improved vehicle design, and more efficient internal combustion engines (ICEs) were all part of the new-look vehicle. While it took some time for these vehicles to be produced in sufficient quantities, they were widely available in Canada by 2020.

Canada's vehicle stock remained mainly liquid fuelled. In the year 2050, 60% ICEs used neat gasoline or ethanol blends, 30% hybrid vehicles (some of which have incorporated flywheels for acceleration and energy absorption during braking), the remainder was split between different fuel cell powered units. The average liquid fuel powered PNGV vehicle efficiency had been about 34 km/l (80 mpg) since 2015. By 2020 approximately 10% of the vehicle fleet met the PNGV, or equivalent, standards, and by the year 2050, most liquid fuel powered vehicles met the standard. Sports utility vehicles, minivans and pick-up trucks held one third of the market share in 2050. In general improvements to these vehicles have been marginal, but some PNGV structural and engine design changes started to seen around the 2030 model year.

Figure 4
Road Transport Energy Demand by Fuel

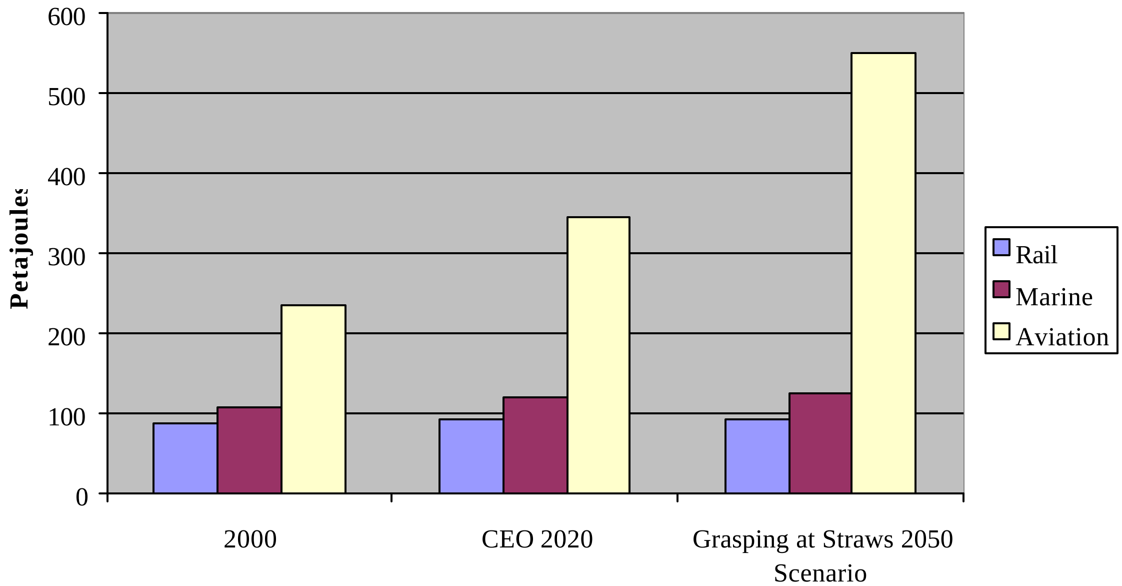


The high expectations of the 2000-2010 period in hydrogen fuel cells as the successor to the ICE did not materialise. On-board hydrogen vehicles continued to be limited to urban transit and some fleets. Issues regarding hydrogen generation, storage and distribution infrastructure, as well as the relatively low energy density of hydrogen compared to gasoline made penetration of the personal vehicle market difficult.

Heavy goods and personal vehicles still shared the road, causing huge congestion problems and delays. Although roadways had become 'smarter', to a degree, through the implanting of sensors, controls and management systems, problems still continued. In some areas of major congestion (e.g. Toronto) high priced toll roads and qualified user access privileges were introduced. While these systems increased vehicle ridership and reduced congestion somewhat, they contributed only slightly to dampening per capita energy use for travel. Road materials, construction and repair remained energy and GHG intensive.

Pushed by the emphasis of business on just in time delivery, heavy goods transport and larger vehicle fleet managers adopted technologies first introduced in luxury automobiles around 2000. By the year 2010, wireless modem transponders and computer systems in these vehicles provided remote monitoring of vehicle location, but also of vehicle emissions and maintenance needs. GPS and onboard communications coupled with central systems enabled drivers, traffic managers to optimise routes to avoid congestion and traffic tie-ups.

Figure 5
Other Transportation Fuel Requirements



Rail kept its share of long distance goods transport, but trucking was still required to move goods to their final destination. Solid oxide fuel cells were introduced in some heavy use rail systems, but in the main, diesel remained the prime locomotive fuel with some bio-diesel being used. On the passenger side, light rail transit systems in Vancouver and Calgary expanded to meet the growing population base of these two cities. In the Golden Horseshoe area including Toronto, where population growth accelerated, the GO System was refurbished and expanded to meet the needs of the Toronto-St. Catherine's and Toronto to Belleville region. This expansion involved converting to electrically powered trains, new wheel-on-rail designs, investment in new rail-bed, some of which used remanufactured plastic rail ties, new track, and computerised, weatherproof control systems.

Small gains in the energy efficiencies of larger commercial aircraft and engine design have barely kept pace with the additional energy requirements flowing from consumer demands for safety, quiet, and legroom. North-South commuting has led to the introduction of newer aircraft design. Tiltrotor designs became popular around 2015 (despite the concept being around since 1950). These and other Vertical Short Take-Off and Landing, (VSTOLs) used a variety of electronic based fly-by-wire systems for reduced weight, and more corrosion resistant composite materials for the frame, fuselage, tail and wings.

D. Our Energy Mix

Over the past 30 to 50 years there has been modest reduction in GHG emissions, but the range of technologies used was not significantly different from that available at the turn of the century. The deployment of many of the 'off-the-shelf' technologies circa 2010 has made some difference, but they have not formed the basis of any "C" step change in emission levels. The fossil fuels used in the transportation and industrial sectors were derived from more efficiently refined crude, based on recycled refinery catalysts, and synthetic crude oil. Deregulation of the electricity system resulted in short-term increased demands for natural gas for co-generation, and electricity generation needs.

Canada and other oil producers did make some impressive early progress in reducing some major GHG leakage in the fossil fuel system. Leakage, flaring and evaporation of hydrocarbons in the energy generation, storage and distribution system that were rampant and even undetected in 2000 were 90% eliminated by 2030 through better monitoring, maintenance, CO_2 capture, re-use as well as better pumps and seals.

Early investments in CO_2 sequestration at the well and mine head and down hole did not yield the results anticipated. Considerable funds were invested in the 2010-20 period on developing electrical generation using coal bed methane, scrubbers and mid-process, as well as CO_2 sequestration. These were wound down by the year 2025 as they proved to be technically difficult and costly compared to natural gas usage.

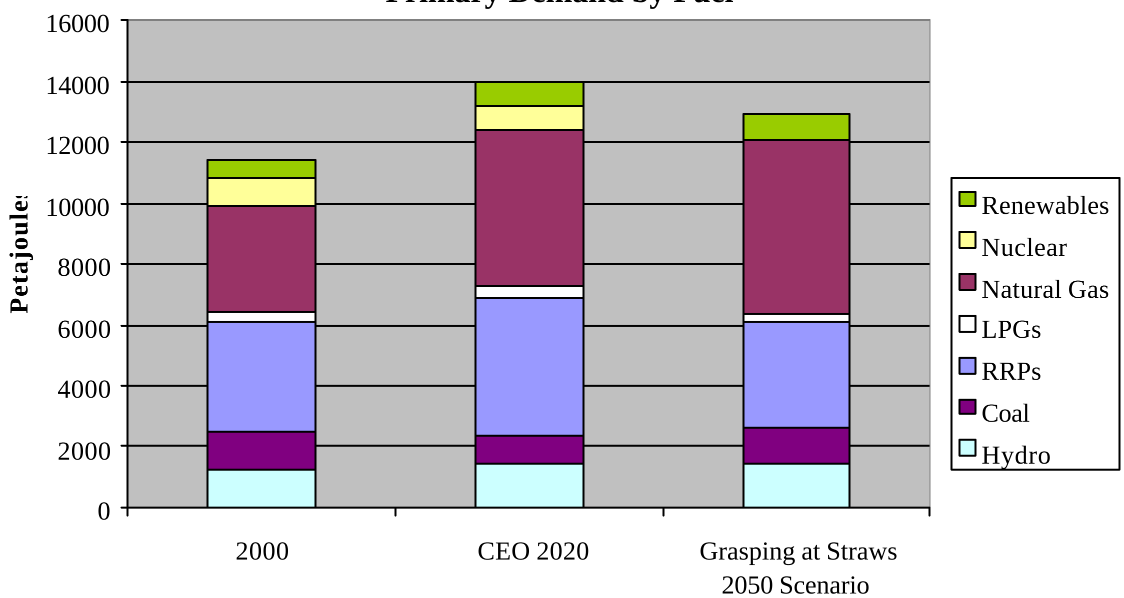
Fossil Fuels

Consumers will still demanded the services from energy that exist today. Fossil fuel continued to meet the space conditioning, lighting and mobility needs of Canadians, although in reduced quantities than witnessed at the turn of the century. Domestically, Canadian conventional oil supplies declined between 2000 and 2020. These supplies were augmented by production from heavy oil, oil sands, frontier, enhanced oil recovery techniques for conventional or medium heavy oils. Demands for cost-effective technologies designed to reduce the environmental and safety risks in the production and use of these non-conventional sources intensified throughout the period as reliance on non-conventional supplies, particularly oil sands resources, increased.

Oil, gas and coal reduced their GHG impacts, but did not manage a complete transition to sustainability in the energy economy of 2050. Supplies from oil sands and heavy-oil have kept pace with growing demand world-wide and in Canada. Production has been made more efficient through enhanced down-hole recovery techniques and new motors, sensors and controls but production of these fuels remained a major GHG problem.

Canada continues to have an abundant supply of natural gas to meet growing domestic and international demands. Off shore east-coast and northern gas sources were continually being found and developed as needed. Coal technology development continued to focus on the production of cleaner coals and more efficient, cleaner combustion. As electricity demands increased, and the continued decommissioning of nuclear plants, coal's role as source of energy for electricity grew. As with the other fossil fuels, the technologies that were employed to produce these energy sources did not change markedly from those in use at the early part of the 21st Century. The 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.

Figure 6
Primary Demand by Fuel



Environmental and economic pressures along with improvements in turbines made natural gas the fuel of choice for both distributed and central electrical generation. Biotechnologies were widely employed to produce ethanol from a variety of sources (sugars, starches, and biomass). However, further uses of biotechnologies to produce liquid fuels from other feedstocks or to transform liquid fuels into cleaner products failed due mainly to the lack of a solid S&T foundation.

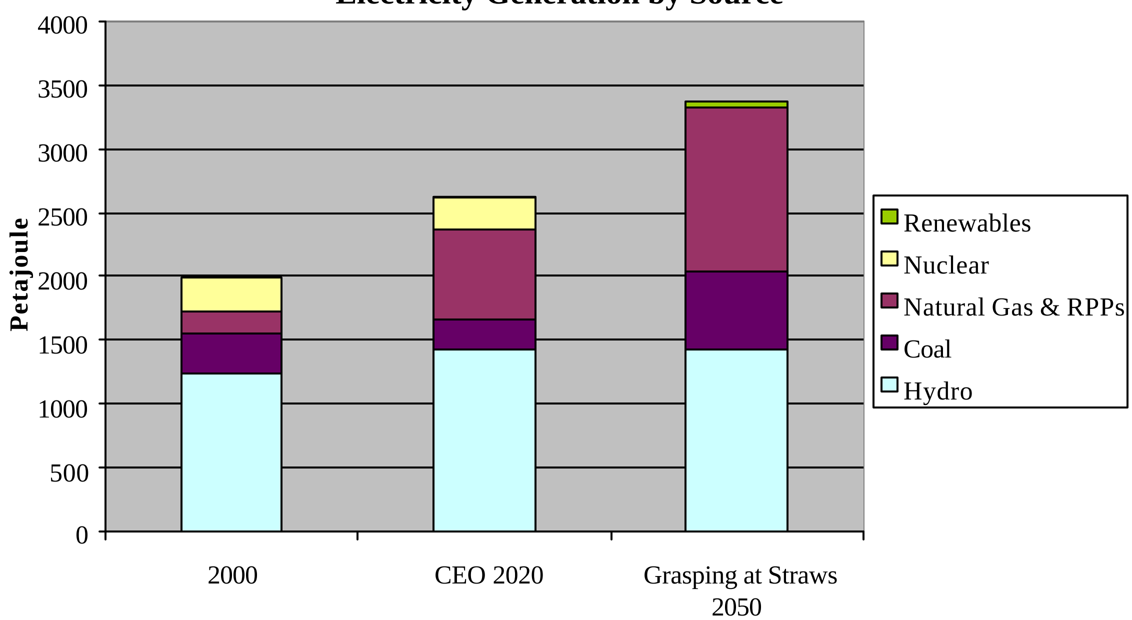
Electricity Generation

The electrical generation system became more distributed with the advent of community and industry based generation and co-generation systems. These projects started primarily in off-grid northern communities and industrial sites and extended to more southern applications, as the systems became more reliable and economical. The mix of fuel sources for the generation of electricity has shifted substantially since 2000 towards the greater use of natural gas due in part to its increased attractiveness resulting from de-regulation, and to steadily rising concerns over environmental impacts.

Electrical generation was based on nuclear (until the end of its useful life), with hydro, natural gas, cleaner coal technologies (IGCC and others), co-generation and some renewable energy sources meeting much of the remaining load. A few ‘energy-plexes’ built around large users of electrical energy such as aluminium and other smelting operations brought together large scale energy generation and use, cascades of energy use and recovery, and CO_2 capture, use and sequestration.

Hydroelectric has been able to keep its share of the growing market so far through improvements in turbines, new low head and river sites and more efficient high voltage DC long distance transmission. By the year 2020, most potential hydroelectric sites had been tapped.

Figure 7
Electricity Generation by Source



From 2000 to 2010 the nuclear industry lobbied hard for its use as a GHG reducing technology and as the supplier of electricity to produce hydrogen for transportation fuel cells. However, the industry failed to solve public concerns over life-cycle-cost, life of reactors, and the management of radioactive wastes. The substantial R&D required to develop a new generation of reactors to succeed CANDU was not found in the thinly spread shower of projects funded as part of the climate change initiatives that covered the 2000-2010 period. Without funding for a new generation of reactors or the R&D and capital required to solve the waste issue, the nuclear program drifted to a stop around 2030 with end of the life (albeit extended from 35 to 50 years by several massive retrofits) of its reactors.

Without electricity from nuclear, coal and natural gas started to fill the growing demand for the generation of electricity. IGCC, fluidised bed, pressurised fluidised bed, and co-firing of coal with biomass became more widely adopted throughout Eastern Canada and Alberta. Natural gas high efficiency gas turbines using advanced materials for reduced NOx and CO_2 also garnered a significant portion of the market by 2035. Natural gas became the most attractive non-renewable fuel in terms of its environmental impacts, particularly once problems were solved re flaring and distribution leakage and substantial efficiencies were gained through new combined cycle and turbine technologies.

Renewable sources other than hydro have grown to about 1% of electrical generation by utilities. The use of biomass for electricity generation increased slightly, particularly in the Maritimes where generation plants combining coal & biomass have been a success. Renewable components have been incorporated into distributed energy systems for remote communities and small off-grid requirements as well as in a few locations with particular advantages for wind and solar generation. All of these technologies were on the shelf in 2000 and saw continued improvements in production efficiencies and the lowering of initial capital costs of equipment; e.g., photovoltaics, wind turbines.

Transmission and Storage

De-regulation put pressure on utilities to manage all aspects of their business, and efforts were made starting in around 2005 to minimise transmission-line losses and transformer losses. With transmission line remaining AC for the most part, there few opportunities to make significant reductions in line loss. Options to increase the capacity of transmitted power included the testing and deployment of compact conductors for overhead lines, and underground cables. The former started to be employed around the 2010 period, with compact conductors seeing wider market penetration around 2015. Transformers using rapidly solidified amorphous powder cores replaced older units.

Some provinces did expand their high voltage (<400,000 V) DC transmission lines, and efforts were made to upgrade these lines to the 750,000 V range, but progress in this area was slow, and by 2050, the technology was deployed in only a small portion of the lines in Manitoba and Saskatchewan. Some harmonisation of inter-provincial power systems was also started, and wheeling of power around the interconnected grid started around 2030. Transmission losses account for 7% of electrical generation in 2050.

In terms of storage, most utilities continued to rely on pumped storage where possible. Until they were decommissioned, the nuclear facilities relied on hydrogen storage using regenerative fuel cells and organic liquids. Smaller, distributed units introduced chemical and battery storage starting in 2025.

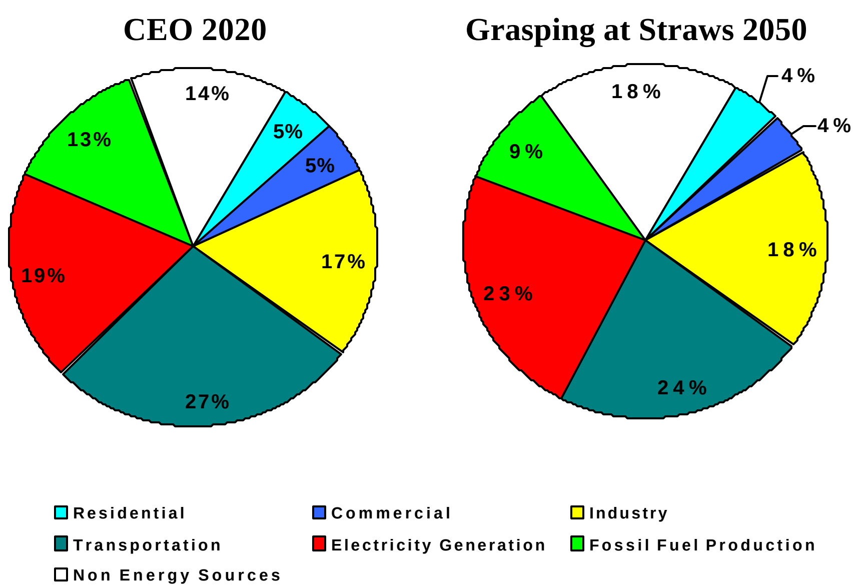
Sequestration of CO_2

In this scenario, 10% of GHG emissions are sequestered by electric utilities. Emissions of carbon dioxide are usually sequestered in oil fields or deep-water environments such as oceans and aquifers. Low cost and effective carbon dioxide separation technologies have limited the growth of these practices. Biotechnological applications to sequester carbon were attempted but found unfeasible due to a lack of knowledge and innovative technologies. The unknown effects of carbon dioxide on aquatic environments and the search for long-term options have kept sequestration marginal.

E. GHG Emissions in Grasping at Straws

GHG emissions in this world initially exhibit a downward trend from 2010, but as the world evolves into the 2030 period, GHG emissions gradually start to increase.   By 2050, GHG emissions under this scenario have returned to approximately levels forecasted for 2020 under the Canadian Energy Outlook's Business as Usual scenario.

Figure 8
Canadian Emissions by Source



Total 845 Mt   **Total 810 Mt**