Taking Care of Business

It is not that they cannot see the solution.
It is that they cannot see the problem.

G.K. Chesterton

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Scenario Context

Rapid innovation, open markets and low environmental etiquette have led to a world driven by economics and profit.

The world is dominated by a system of interconnected transnational companies (TNCs) aimed at furthering their own corporate as well as economic interests. This is a world of rapid capital stock turnover and strong economic interdependence between companies and nations. Expanded economic growth and prosperity has led to a reduced focus on social and environmental issues. It has also led to a growing gap between developed and developing nations. Transnational companies exert not only economic power, but also exert political power in their dealings, particularly with less powerful economies. This is a world in which TNCs locate plants in industrial enclaves within developing countries where reduced costs increase the overall profit base on the TNCs. Available land in these regions was quickly acquired by these TNCs, and in some cases, countries, particularly those with rapid population growth found themselves in a position where rural poverty and worsening urban environments created health as well as social tensions. The international issue in this world is not climate change but wealth distribution. This is a mid-grey world that has turned somewhat greener due to technological advances that have reduced GHG emissions.

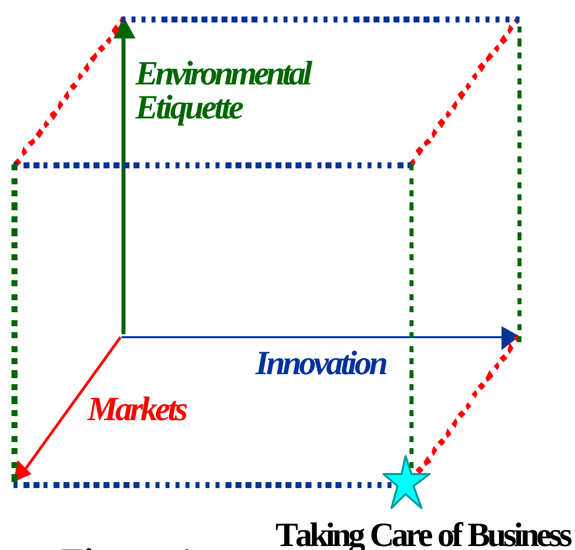

Figure 1

Taking Care of Business

Geo Political Situation

The world has seen the continuation of the strong economic growth that characterised the early part of the 21st Century. From this unprecedented growth emerged a system of new transnational companies more interconnected, and more willing to flex their economic as well as political powers. Strong linkages between TNCs and developed and near developed countries were established. TNCs were seen as the source of capital, jobs and industrial prosperity by many of the developing economies as they provided the infusion of capital to help start up local industries for exporting goods. Some of these countries have become "flags of convenience" for the TNCs who, in exchange for locating their operation in these countries and providing it with an economic and tax base, receive in exchange influence over the economy and foreign policy of that country. In developed and near developing economies, TNCs continue to push for greater market access and more liberalised trade arrangements. By 2015, free trade zones were established in the Americas, Europe, and Asia. The Americas zone included Canada, the US, Mexico, Chile, Brazil, and other Latin American countries. The European Union free trade zone gradually captured Eastern Europe and Russia. The Asian free trade zone consisted of Japan, China, a United Korea, Taiwan, and other South Asian countries. As a result, the benefits of the long economic boom became highly concentrated, causing a growing gap between richer and poorer nations. Large parts of Asia, Latin America, and Africa were left untouched by the economic boom and their growing populations coupled with the stresses on available land and resources led to serious social and economic instability.

North America, Japan and parts of Europe saw the economic booms of the early part of the 21st Century continue at unprecedented rates. Technological innovation and a set of expanding and open markets fuelled this growth. World economic wealth was quickly concentrated within these areas, with TNC employees dispersed throughout the globe into areas of company activity or interest. The interdependence of these TNCs was based on a well-developed information and telecommunications systems that enabled world-wide access to employees, headquarters, and branch plant operations. The system of TNCs focused efforts on developing the comparative advantages of all countries within its sphere of influence, maximising both the corporate good as well as the economic good of the host country. In many instances, to ensure the continuity of their workforce, these TNCs set up satellite communities for their employees that consisted of housing, commercial units and recreational facilities.

China and India were two centres of TNC dominance. China's economic growth continued at a rapid rate, but as this growth continued, China also saw the distribution of its population shift from rural to urban. By 2010, approximately 70% of China's population lived in urban areas. This reverses the demographics of the 1990's. People flocked to urban centres in search of jobs brought about by the presence of TNCs, but also the modernisation of the agricultural system left many Chinese youth seeking employment. Chinese emigration also increased during this period, with many Chinese seeking out citizenship in developed countries such as Canada, the USA, Australia and other Pacific Rim nations. Russia was also a major point of landing for these emigrants.

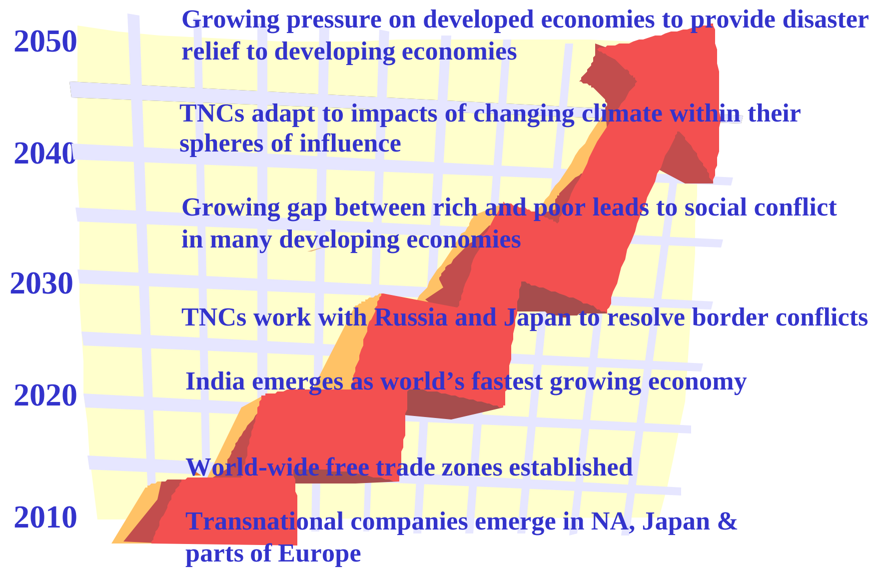

Figure 2

India also benefited from the presence of TNCs. The growing and impatient middle class pushed hard for economic reform, and many of the state owned companies were sold off, regulations on company ownership and operations rescinded, and India started to emerge around 2015, when its markets opened, to be the world's fastest growing economy. The influx of capital for infrastructure development, the strong and directed moves to eliminate corruption and TNC investment in new plant, processes, and construction led India out of its economic doldrums.

Unfortunately, in the case of both China and India, the economic boom that they experienced was not shared by all. In China, the huge growth in urban population created a surplus of labour even for the TNC operations in the country. Housing, food, water, and sewage concerns were prevalent in most of the major cities. The urban unrest was held in check as economic growth continued and conditions gradually improved. Nonetheless, China was not able to feed itself, and the strong international linkages of the TNCs secured much of the needed supplies. In India the case was somewhat different. India did not experience the population shift from rural to urban as was seen in China. Economic reforms intensified the pressure on the country's agricultural and land resources. Demands for power, wood, paper and transmission right of ways left the bulk of India's population that was living outside its main cities in 'have not' positions. The presence of the TNCs that brought the economic power also caused an ever growing split between the rich and the poor within these countries.

The Russian economy benefited from the strong economic direction of the Fatherland Party that held on to power for over two decades from the turn of the Century. The solid base of economic reform, the movement away from the collective system, and the general solidification of political parties moved the economy steadily forward. Around 2020, the revitalisation of the Russian manufacturing system was complete, and exports soared and its skilled workers found employment within the growing network of TNCs. Encouraged by strong TNC links in the area, Japan and Russia resolved their dispute over the Kuril Islands, and investment flowed into the resource rich Russian economy. Russia became a major target market for TNC activity as the growing economy brought with it growing demand for durable and non-durable goods, and infrastructure investments.

Most Asian economies, Africa and part of Latin America were pretty much left out of this blossoming world economy. These countries prospered very unevenly in a world of rapid technological change with workforces that did not have the basic skills which TNCs could utilize. Many of the rich, upwardly mobile realised many of the expectations of the economic upswing, but the vast majority of people in these areas did not, leaving behind large discontented masses of the population.

Pressures on natural resources, the growing demand for energy to fuel these expanded markets and the additional stresses on the climate led to greater frequency of extreme events. Mitigation of climate change took a back seat to adaptation measures in this world, with the TNCs focussing their efforts on those areas where the climate impacts had significant impact on their business activities. In those developing countries not in the TNC sphere of influence, dealing with climate change placed even greater demands on cash short governments, and by 2050, these countries were regularly seeking aid from developed countries to assist in disaster relief efforts.

Canada in a Taking Care of Business World

Canada was swept up in the long economic boom of the early part of the 21st Century, and saw its share of TNC emergence within its borders. Canada and Canadians focused on the pursuit of wealth through technological innovation and open markets. Information technology and other influences made rapid innovation possible and the capital stock turnover of the economy sped up. Environmental issues like climate change were not considered relevant to people's every day lives.

The nature of Canadian business and work was much different in 2050 compared to the turn of the century. The corporate sector consisted mainly of large TNCs and a few smaller niche companies. The rise of TNCs as entities with no allegiance to any nation made business transportable, with a reliance on world trade and international markets. TNCs were based in Canada because of the availability of resources, be they human capital or material, and in industries where we had a comparative advantage. There were also many corporate branch plants located in Canada that ran some continent wide services. Canada's comparative advantages in natural resources, telecommunications, pharmaceuticals, biotechnologies, high voltage electricity transmission, and pipelining were maximised in this world. Canada saw much of its industrial base rationalised and focused on key products that generated substantial value-added to the economy.

Western Canada had TNC industries concentrated in forestry, pulp and paper, coal, oil and natural gas. The prairies specialised in fertiliser, coal and agricultural biotechnology industries. Central Canada built on its aerospace, biotechnology, information technology, and automotive industries. In large manufacturing areas, robotics industries had taken root. Eastern Canada specialised in offshore undersea mining, and oil and gas production. Other major Canadian industries included mining, exploration, and advanced hydroelectric technologies.

Like most economies in this world, the growth of TNCs led to a blurring of Canada's borders. Alliances of individuals to their TNC were equally, if not more important, than nationalistic ties. There is a strong economic interdependence between Canadians and TNCs located within its borders as international trade and large, powerful (economically and politically) companies dominate the industrial fabric of the country.

Canada's demographics were similar to those of the rest of the developed world; ageing population, shrinking labour pool (despite being the only former OECD countries with a growing population), and a large youth population. Canada invested heavily in social and health areas as well as in education and re-training schemes. The declining labour force in Canada placed increasing demands for skilled and educated labour. Retraining programs and investment in skills development by governments provided a stream of talent that was quickly absorbed into the growing system of TNCs and niche corporations. These companies worked with this stream of talent, and moulded it to meet its own particular needs through additional on-the-job training, apprenticeship programs, and targeted education schemes. Employment of the elderly increased, as they formed a pool of resources that could continue to work beyond the older, more traditional retirement age of 65. These people were involved in education, re-training and business development programs run in small part by the government, but with most of the investment coming from TNCs.

There was a close linking of home and work environments. TNCs tended to establish gated, company communities that were self-sufficient, fully integrated satellites of larger cities. Employees lived, worked, shopped, and had their entertainment and recreational needs all met within these gated environments. The closed nature of these communities allowed flexible work arrangements, in part to match the global nature of the TNC business, reduced commutes to and from the workplace, and strengthened individual and company ties. They also secured a voice by the TNC in local government decisions.

The reliance on information technology and the Net furthered the link between the at-work and at-home activities of individuals. The level of interconnectedness within TNC enabled employees to do business world-wide from either their home or office. Indeed, the globalisation of business required flexibility in working arrangements to video conference, tour new plants in a virtual space, and to make on-line modifications in plant design and process flow configurations.

Environmental etiquette did not find a solid place in the decision-making processes of the Taking Care of Business world. The aggressive profit orientation meant that environmental concerns were addressed only if they impacted on the bottom line issues of the company. Companies preferred to follow the least cost route to either resolve environmental issues or adapt to them. There was no conscious decision to incorporate environmental concerns into day-to-day decisions. Nonetheless, some reductions in GHG emissions were brought about simply by the introduction of new, less energy intensive technology and the expanded use of nuclear energy to meet the needs for reliable and high quality power.

Table 1

GHG Emissions (CO_2 Equivalent)		
CEO* 2000	**Kyoto Trend Line 2050**	**Taking Care of Business ETF 2050**
694 Megatonnes	**248 Megatonnes****	**586 Megatonnes*****

* Canada's Energy Outlook, published by Natural Resources Canada in 1997, 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

A. The Way We Live

Through the period to 2050, Canadian households continued to decline in size. About two-thirds of Canadians continued to live in urban areas, with several satellite communities springing up around major cities, the largest of those being Toronto with a population of over 8 million[1]. Downtown cores of most of these cities were mainly dedicated to commercial enterprises and high-density residential buildings.

The energy needs of these satellite communities were usually met by multipurpose energy plexes. These plexes provided electricity, hot water, and heat to the community through high efficiency combined cycle power generators and waste heat utilisation. Natural gas delivered by underground piping was the preferred fuel for these energy plexes because of its reliability of supply. If additional power was needed, an energy plex could use grid electricity provided by utilities. Energy plexes were used for the quality of power they provided and the security they gave to the community.

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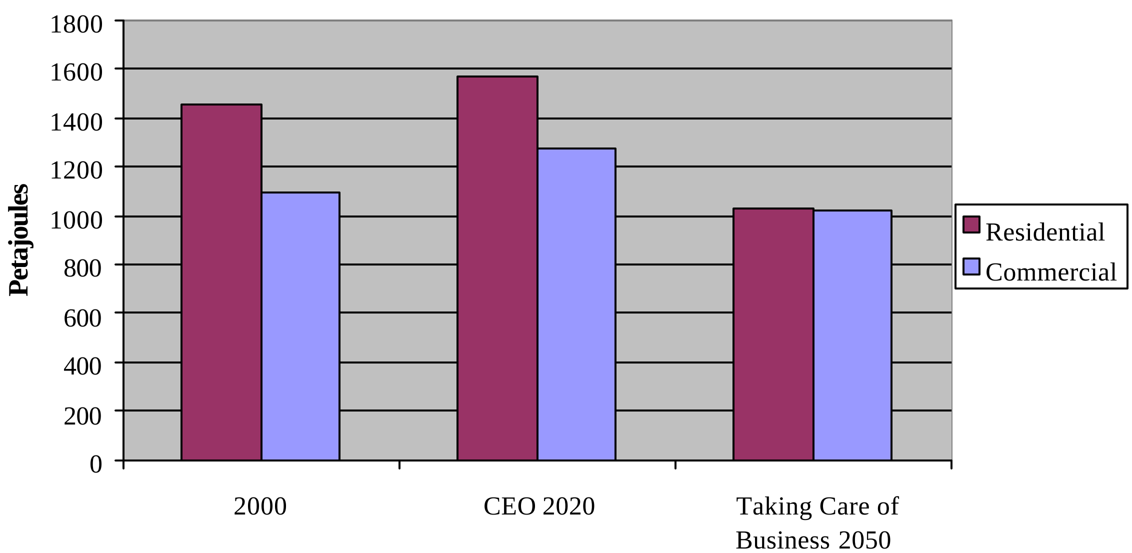
1 Energy Technology Futures, *Global and Domestic Long-range Demographic and Economic Projections*, 1999

These communities usually included a range of building types and sizes. Corporations usually placed a large work campus in the centre of the community. In many corporate communities, employees tended to work longer hours and discuss work-related issues in their spare time. Virtual reality technologies allowed virtual mini vacations or interactive entertainment that could maximize leisure time. The occupants rarely needed to leave their communities and did so infrequently. Building technology was mainly derived from other technology sectors like computer science, telecommunications, materials science, and biotechnology to meet its needs.

Buildings were more aware of their environment, active, and comfortable than they were 50 years ago. Consumer electronics had been integrated into new and retrofitted buildings starting in 2020, giving them more functionality. Sensors placed around the home or office were built into the building materials from about 2030, and could detect leaks in the building envelope. These sensors were connected to the building's central control software that controlled interior climate, security, and energy management functions. Precision controlled heating and cooling improved the energy efficiency of most buildings with no trade-offs in comfort to occupants.

Figure 3
Residential and Commercial Energy Demand



Most buildings, either new or built at the turn of the century, had energy management systems that allocated power evenly during a day to reduce peaking. Electricity could also be stored through reversible fuel cells producing hydrogen and oxygen for later use. Dry battery technology such as lithium batteries or other advanced battery systems were also used to provide portable power and were recharged in off peak times. Ultracapacitors provided short-term electrical storage needs to ensure a continuous power supply to appliances.

Other systems like SMES[2] systems provided diurnal or longer-term storage in large industrial settings. These technologies significantly reduced the daily power peaking and evened out the baseload requirements. Less peak generation made smaller energy plexes more viable because of the consistency of demand. Energy plexes and electric utilities were also able to run at maximum efficiency.

Many traditional building power requirements decreased because of passive means of heating and lighting. These designs also tended to be more aesthetically pleasing as well as economical. Automatic shading of windows was used to reduce air conditioning loads in the summer months and better insulation and fenestration reduced heating loads in the winter months. Fibre optic light piping combined with passive lighting reduced illumination energy demands. However, the constant introduction of new electrical appliances mitigated some of these energy reductions.

Phase change or crystal structure change materials were used in wallboard and flooring to capture and gradually release heat and water vapour to help stabilise interior temperatures. Many of these advances were based on improved materials that made buildings easier to construct and more durable.

The downtown core of major cities continued to be a mix of high-density residential and commercial properties. Most of these buildings used natural gas for heating and electricity from the utility grid. In high-density areas, commercial and residential complexes tend to use natural gas cogeneration with the waste heat used to provide heat and hot water for adjacent buildings. Some urban housing complexes and apartments used fuel cells running on natural gas to provide electricity and heat.

By 2050, building energy demand decreased by about 60% from early 21st Century levels. Most of this energy is used as electricity with small amounts of natural gas and liquid fossil fuels being used. Gains were made through the use of better materials, improved systems and controls. Some of these gains were eroded due to greater use of home electronics. The demand for natural gas has decreased by about 80% due to better designed buildings and district systems.

B. The Way We Work

Consumers and new technologies had greatly changed the industrial sector in 2050. Consumers the world over demanded unique and original products produced to their specifications and delivered quickly. New manufacturing techniques introduced around 2020 allow designs to go into production faster and for identical products to be produced from different assembly lines. Factories running small or large production runs created

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[2] SMES (Superconducting Magnetic Energy Storage) systems store energy by circulating a DC current through a superconducting coil. Normally electricity would be lost to heat due to the resistance of the wires but since a superconducting wire has no resistance to DC power, the energy can be stored indefinitely. SMES systems can rapidly accept and deploy charge, limited by the conversion from AC to DC or vice versa.

varied products for selective consumers. Microchips were place in many products for easy tracking during delivery and for identification and on-line repair and re-programming.

Most jobs have changed and become more sedentary and thought intensive in nature with work taking on a more knowledge-based role. The old blue-collar factory jobs almost completely disappeared due to a decrease in local manufacturing in Canada and the continued rise of robotics. Displaced workers found new work in the expanding service industry or retrained at many TNC-run technical schools. Changes to the education system in the early part of the century involved major employers outlining the skill sets required for graduates from schools or universities. Today the bulk of the workforce is highly skilled and has no desire to do “a robot’s job”.

By 2050, many jobs have flexibility in where and when they are done. Nine-to-five jobs with no flex-time or overtime are rare. Teleworking is done by much of the workforce two to three days of the workweek and many workers have no office at all. Due to advances in virtual presence technologies, teleworking became very interactive and engaging to many people. Many industrial or commercial duties require employees to be present for a few core hours, two or three days a week. Telecommunications technology has inter-linked living and working spaces, making many homes into working spaces as well as personal living spaces.

Life cycle analysis, initially designed for energy auditing, was used from the mid-2010’s to match the most cost effective processes and materials. Designer materials with customised properties were used in products so they were not over or under designed. The high capital turnover in the economy required companies to ensure customer needs were met without excessive material and cost considerations. This was important due to the exponential pace of innovation that rendered some technologies obsolete within two to three years from their introduction.

In the early part of the century steps were taken by many TNCs to increase the rate of recycling in the economy. Due to the large amounts of energy required in the primary production process of raw materials and their tremendous global demand, recycled materials continued to become more economical to 2050. For example by 2040, most aluminium production was from recycled or reclaimed materials. Some small mining enterprises also started to mine old landfills for valuable materials. Besides recycling, waste minimisation came about through better monitoring of assembly lines, with advanced sensors and control devices creating intelligent monitoring systems. These systems did not only detect errors but also corrected them automatically. Biological interface technologies were also added to many electronic devices to improve assembly line perception. Problems could be seen, smelt or tasted in-line for many products and chemicals, corrections made and rejects were minimised.

Industrial production also minimised waste energy as well as waste materials. The use of advanced designer materials increased the efficiency of most industrial processes. Ion implantation started to be widely used around the 2010 period for surface modification of materials that needed ultra smooth, wear resistant finishes. These produced a line of 'frictionless' products that greatly reduced the energy required to run different machines. High temperature resistant metals and crack-resistant ceramic parts increased the efficiency of engines.

Many other efficiency gains were made through biotechnology. In the mining industry, bio-leaching by using microbes to extract metal from ore became a preferred method of extraction of copper, gold, uranium, and nickel. This, combined with increased recycling, reduced the need for extensive mining of virgin materials and greatly reduced the energy consumption of this industry.

The petroleum refining industry also started using biotechnology. By about 2015, bio-refining using microbes became widely used to remove impurities from fossil fuels. Hydrogen sulphide was biologically removed from natural gas (2010) and later from heavier hydrocarbons (2015). These methods were less costly than old extraction methods. Membrane filtration and separation of petroleum were used to yield higher quality gasoline and other fuels. Also, in situ processing was used where microbes worked within the oil deposit to process it before extraction. These microbes broke up long chain hydrocarbons to generate methane and lighter molecular weight fuels more useful to industry.

The chemical industry greatly changed due to the influences of biotechnology. The ability to produce complex chemicals in one or two step batch processes decreased energy and time requirements and the need for highly purified feedstock. Industries like pulp and paper and other manufacturers used bio-processing by microbes or enzymes to replace or enhance previous mechanical processes, decreasing energy input into the production of certain processes. Bio-bleaching and other enzyme reactions were also widely applied.

Forestry companies planted genetically modified trees and other fibre crops in near mills and industries. Fibre growing plants were improved and new ones produced materials such as spider silk for high tensile strength fabric and as a reinforcing material for composites.

Biotechnology made a tremendous change in agriculture due to the genetic modification of many crops. By 2030, many crops make there own pesticides and herbicides as well as grow faster to yield quicker more plentiful crops. Climate change adaptation strategies included changing the plants to grow better in a higher concentrated CO_2 environment and to be more immune to unpredictable weather patterns.

Table 2

Taking Care of Business 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	**37%***

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

C. Our Mobility

As Canadians living and working patterns changed, so did their mobility requirements. Transport systems were designed to be both quick and efficient. Local mobility relied mainly on hybrid or electric vehicles. Car usage was limited more for pleasure or short distance trips as increased income of many professionals increased their demand for quick, comfortable, travel. Rapid rail transport was used between many communities and major cities. These consisted of solid oxide fuel cell trains running on traditional tracks or superconducting magnetic levitation systems for shorter distances. Air traffic grew significantly over the last 50 years carrying people, goods, and other resources.

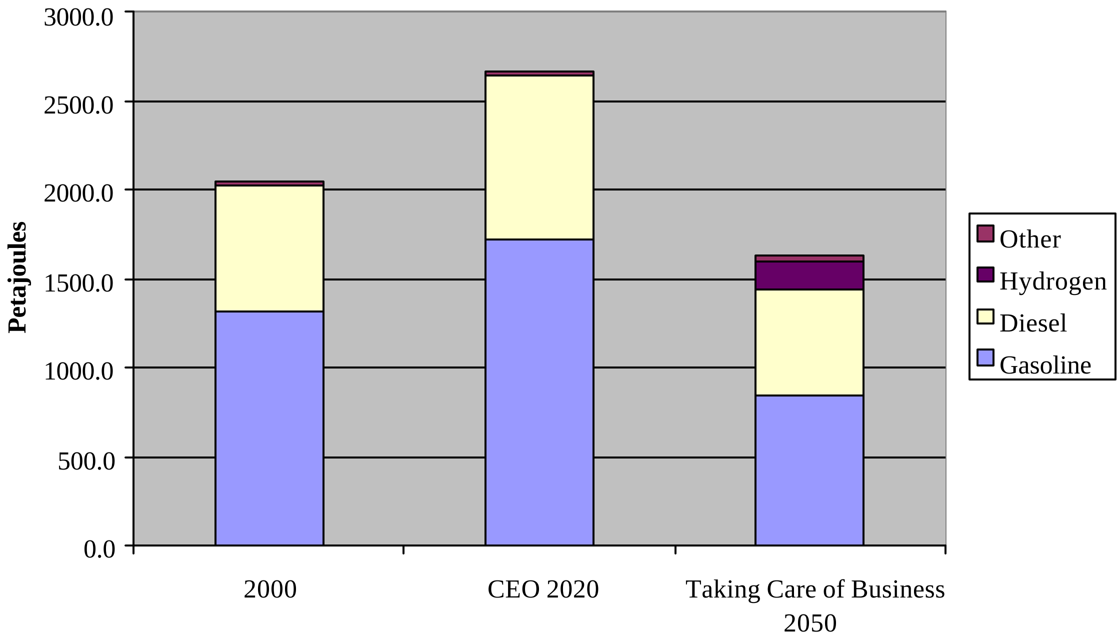
The average number of cars per household remained about the same, but since the amount of people per household has decreased, there are more cars per capita now than in the year 2000. Flexible hours, virtual presence technologies and corporate communities had a significant effect on reducing congestion on highways by spreading out peaks and reducing overall traffic volume. The addition of active traffic management technologies on roads directed traffic more efficiently and helped to prevent traffic jams. All of these factors combined have decreased the annual average kilometres travelled per car by 25% less than trend.

Technologies emerging from turn of the century programs[3] were used to extract more energy out of fuels as opposed to reducing gasoline consumption. These advances

[3] The Partnership for a New Generation of Vehicles is a joint effort between the United States Government, Ford Motor Company, General Motors, and DaimlerChrysler established in 1993. The goal of the PNGV program is to develop technology to create environmentally friendly vehicles that can achieve

benefited sport utility vehicles (SUVs) and trucks where significant increases in fuel efficiency over average year 2000 consumption levels. The trend towards SUVs and high-powered vehicles continued into the 21st century. As the Baby Boom generation became older, these trucks became lower and more comfortable and were not replaced by cars. Currently, almost half of personal vehicles on the road are classified as SUVs or light trucks.

Figure 4
Road Transport Energy Demand by Fuel



Both cars and trucks are now more easily disposable and most parts and components almost fully recyclable. As cars got smaller over time, they became more affordable and less energy and material intensive. In response to city and community design, newer personal vehicles were lower in emissions of hydrocarbons, particulates, and NOx than their older counterparts. With successive improvements in small motors and batteries, hybrid cars became very popular from about 2015 on. Hybrid vehicles still relied mainly on high-octane gasoline fuel, with many models incorporating regenerative braking or flywheels into their design. Developments in battery technology spun off from the rapid use of hybrids and started to make small electric car technology more viable, particularly for local transport in communities. After their introduction in the late 2010's these vehicles improved significantly in range and power, and were used frequently as station cars for individuals living in enclosed communities.

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triple the fuel efficiency and produce fewer emissions than today's mid-sized cars. This must be done without sacrificing affordability, performance or safety. The timeline for the 'Supercar' goal is:

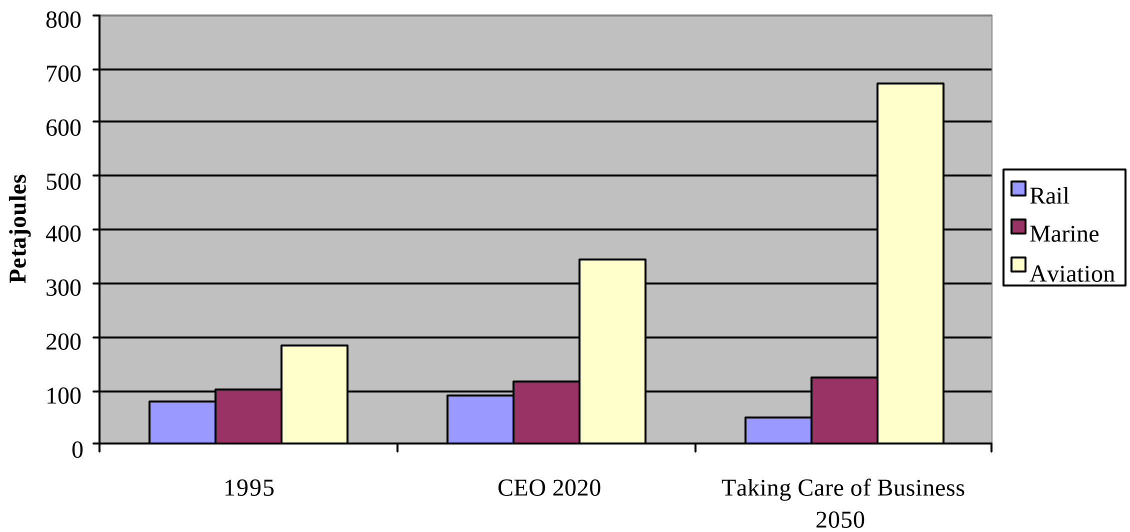
- Finish the evaluation of competing technologies by year-end 1997
- Each company produces concept vehicle between 1998-2000
- Each company produces production prototypes by 2004

Hydrogen fuel cells found uses in city buses and some commercial fleet vehicles, and some buildings generated hydrogen on site for employee use from reversible stationary fuel cells while other sources included local electrolysis at fuelling stations. Stream reforming of hydrogen was still a more cost-effective than electrolysis, but was limited to larger scale hydrogen demands. Palladium membrane pipe reactors improved the efficiency of hydrogen gas (H_2) production but they were very expensive and only useful for stationary generation. Eventually steam reforming and other thermal processes were abandoned around 2035 when genetically modified microbes were developed that produced large amounts of hydrogen biologically.

Economical long distance hydrogen transport remained a major scientific hurdle. Pipeline transport of hydrogen with natural gas proved to be impractical due to embrittlement effects on the pipeline metals and end point separation. Fuel cell technology was used in many sectors of the economy however it has not found a significant market in personal road going vehicles. Commercial transport trucks are still mainly diesel powered.

Changes in the way communities and cities were arranged, combined with demands for rapid service, created a push for the effective and rapid rail transport of people and goods. Intermodal distribution systems were placed near many industrial and city nodes. Diesel and solid oxide fuel powered trains serviced local transport needs in some gated communities and connected these communities to others and major city centres. Many of these systems were based on magnetic levitation technology. These systems did not become popular until the advent of high temperature superconductors around 2040[4].

Figure 5
Other Transportation Fuel Requirements



[4] Super-conducting magnets on the vehicle combined with conductive strips on the track to levitate the train. These super-conducting magnets required a refrigeration system in the train to keep the magnets cool. These trains sustained speeds greater than 500 km/h with fast acceleration and deceleration. Since they did not touch the tracks there was little track wear and reduced noise.

Aeroplanes and ships ran on similar fuel mixes as they did 50 years ago. Though there have been new advances in high atmosphere skimming space planes to meet demands for quicker travel between distant destinations, air travel is very technologically similar to that of the turn of the century. Marine vessels have increased in size and efficiency over time by incorporating new designs and information technologies. Fuel cells have replaced many diesel and heavy fuel oil engines.

D. Our Energy Mix

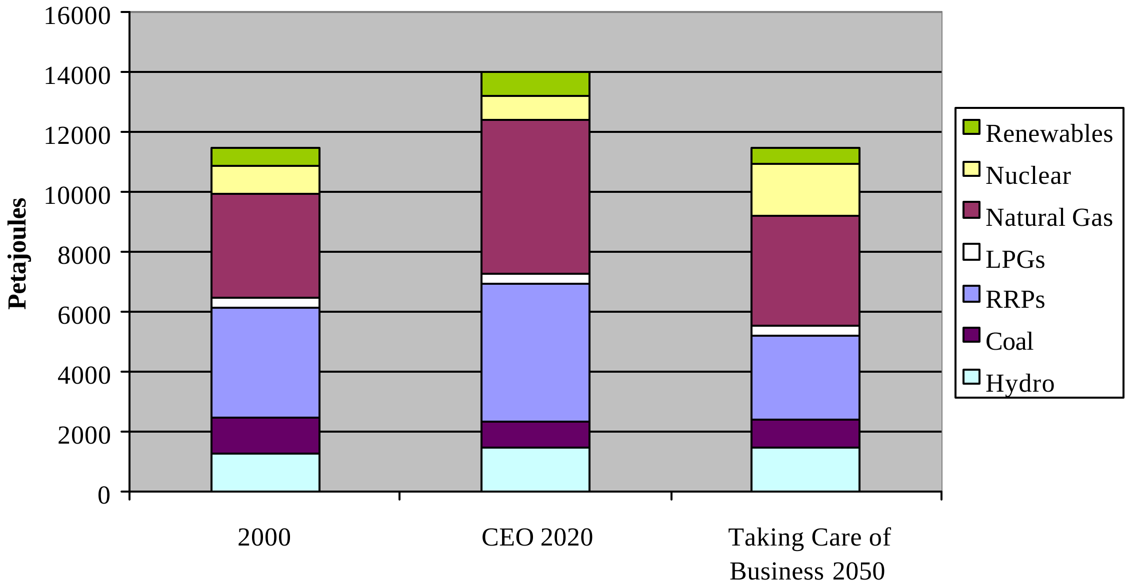
In general, Canadians continued to improve the efficiency with which they used energy, however by 2050 they use much more of it than in the past due to increased economic activity. Due to their high energy density and relative abundance fossil fuels continued to be developed and utilised throughout the economy. The fuel-switching trend from oil to natural gas continued in industry and other end use demands. Space heating and hot water demands were increasingly met by gas fired cogeneration systems. Grid electricity was provided by utilities through hydroelectricity and nuclear power. This, as well as increased demand, led to the construction of larger capacity power plants to meet power requirements. Utilities, seeing their demand on natural gas for electricity generation possibly outstripping supply, moved to nuclear generation along with hydroelectricity as their primary sources. Technologies that better balanced loads and storage mechanisms reduced the needs for peaking power allowed more base-load nuclear to be brought on line.

Fossil Fuels

Canada's coal industry saw a revival due to growth in the export market. Coal is still used in some industries but most of these involve coal refining, gasification, or liquefaction. In some site-specific locations, such as deposits in western or eastern Canada, coal gasification for the removal of impurities like sulphur compounds was widely applied.

From the early 2020's, oil demand gradually decreased in all sectors of the Canadian economy but demand continued to grow abroad. Enhanced oil recovery (EOR) started to rely more and more on biotechnology. From about 2030, companies started using thermal, gas-miscible, chemical or microbial methods to maximise production from its conventional wells. In addition, several companies used organisms to make oil-wells more porous enabling easier flooding. Genetically modified microbes that can survive in the extreme temperature, pressure, pH conditions, and salt concentrations of oil reservoirs were also used.

Figure 6
Primary Demand by Fuel



Perhaps the largest use of biotechnology was in exploiting Canadian oil sands and heavy oils. Biological processes as well as better catalysts in production were widely used to reduce the energy intensity of processing. In situ bioprocessing of crude oil was used to remove sulphur, nitrogen, and heavy metals. Bioremediation, adding enzymes and bio-membranes to flocculation and recycling processes, was used to clean up and recover waste oils from tailing ponds. The fossil fuels used in the transportation and industrial sectors are derived from more efficiently refined crude, based on re-cycled refinery catalysts, and synthetic crude oil.

After riding a trend started in the late 20th century, natural gas usage remained the dominant fuel in this world. Most of the natural gas produced was used in energy plexes, cogeneration facilities, industrial processes, and space and water heating. Projects on natural gas enhanced recovery, based on the success of EOR projects, started around the year 2030. Coal bed methane capture was one of the components of this strategy, but it met with limited success. Offshore natural gas and deep well drilling technologies locations were widely exploited as Canadian deep well and off-shore technologies were used extensively off the East Coast as well in the northern frontier.

Natural gas delivery through pipelines became a major issue in the 2010's with an increasing number of pipeline failures. New pipe sections were installed with intelligent coatings that enabled not only the detection of minute cracks but also had the capability to take corrective, self-sealing measures. The importance of the gas distribution system led to large sections of new durable pipelines being replaced and older portions of the lines were substantially upgraded to include new technologies such as intelligent pipeline inspection gauges (PIGs) able to detect cracks in piping and make small repairs.

Advanced monitoring equipment and better materials have reduced fugitive methane emissions from pipelines as well.

Electricity Generation

The growing electrification of the economy brought demands for greater security and reliability in power supply. The surety of electricity supply was managed through a variety of generation sources and large-scale storage areas throughout the grid. Nuclear power became Canada's second largest power source, second only to hydroelectricity. These two sources accounted for over 60% of Canada's energy generation. In the early 2010's, nuclear power started replacing coal and oil in generation. As storage technologies started to reduce peaking, nuclear even started to replace natural gas for base load power. This allowed TNCs access to considerable supplies of natural gas that they used in their own operated cogeneration facilities for plant and community needs. These systems began to appear in large numbers by the 2030's.

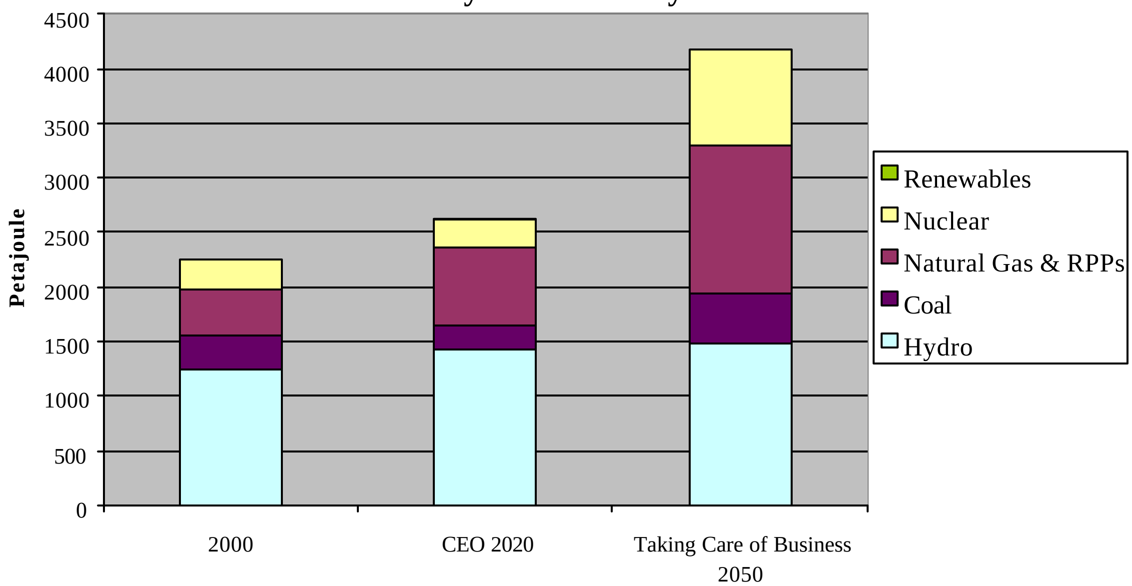
Canadian nuclear rectors had changed significantly compared to the older CANDU models. New reactor designs include hot gas reactors that can operate at an efficiency of 65%, much higher compared to older models. By 2050, there were 32×600 MWe[5] and 44×400 MWe nuclear generating plants in Canada. Much of the nuclear waste generated was handled in traditional methods like water tanks and concrete storage containers. Transmutation of nuclear waste, which became viable by 2040, transformed some elements into shorter-lived isotopes and created more fissionable products for later separation and reprocessing. This as well as old weapons grade fuel recycling ensured a long-term supply of nuclear power.

The other major generation sources for electricity were hydropower and natural gas generators. Hydropower benefited from better turbine design and gearing mechanisms. Low head hydropower had been tapped in many areas with local energy plexes, with most of these natural sites were exhausted by 2020. Larger-scale water diversion projects expanded hydroelectric capability until 2030. The additional base load power that was provided by these plants greatly outweighed any watershed or fish habitat concerns.

Natural gas usage in cogeneration systems became more popular with increases in efficiency of combined cycle systems. Turn of the century cogeneration systems were characterised by excessive waste heat compared to the electricity that was generated. These older systems were replaced with higher efficiency units with proportionately less waste heat per unit of generated power. Natural gas cogeneration facilities were used mostly in small or medium size, energy self-sufficient communities. Natural gas cogeneration also utilised solid oxide fuel cells running at high temperatures and providing high quality excess heat for distributed systems.

[5] MWe: Megawatts of electricity (1megawatt = 1,000,000 watts)

Figure 7
Electricity Generation by Source



Other electrical generation technologies used include gasification. Many municipalities used solid waste to run power generation or cogeneration facilities. Municipal waste facilities changed significantly in the later part of the 2020's in response to the need for greater recycling and the decreasing availability of landfill space. New waste facilities sorted and gasified much of the incoming solid waste to extract high value recyclable materials and reduce the volume of waste for landfill. The gas was used in single or combined cycle processes to generate power. This technology was also extended to other sectors of the economy with waste biomass such as forestry and pulp and paper. Renewable energy contributed only a small percentage of Canadian electricity needs. The relative abundance and energy density of fossil and nuclear fuels made renewable energies viable only in remote, off grid communities. Though technologies like solar and wind power played a large role in these communities, they did not make significant penetration into the Canadian electricity grid. Space based solar power was adopted by many transnational powers, but it was used only as a way of ensuring power supplies to factories or offices abroad.

<u>Transmission and Storage</u>

As electrical generation increased in complexity and scale, so did transmission and storage technologies. Transmission technologies included flexible AC transmission technologies that included a collection of high-speed controllers to dampen power oscillations, reduce overloading, and give utilities more control over the grid. Metallic glass low loss transformer cores made from rapidly solidified ferrous silicon powders were introduced in the early part of the century and have become widespread by 2050.

Technologies like high temperature superconductors increased the efficiency of urban and long-range electrical transmission. Transmission lines have been upgraded to higher voltages (750,000 V or even 1,000,000 V) using low resistant, better-insulated wires, and taller towers.

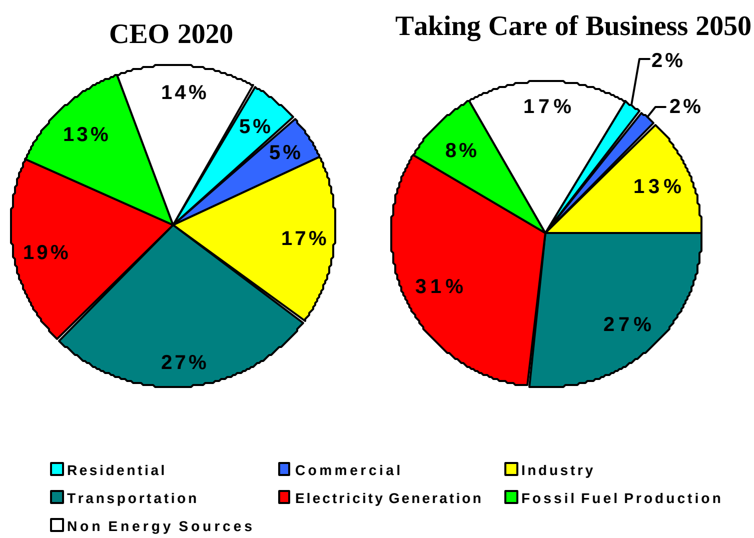
In some urban centres step down transformers using gas-insulated superconducting wires were used to minimise losses. After rectification, the electricity was fed into local superconducting grids that incorporated SMES systems. This made the grid a more effective storage medium as well as delivery medium for power. Overall losses in transmission lines were only 6% of generated electricity in 2050.

SMES, batteries or reversible fuel cells were used in conjunction with most storage systems. SMES became increasingly larger in scale, especially since the routine use of superconductors that worked at the temperature of liquid nitrogen and above. Some energy plexes also use hydrogen storage technologies through reversible fuel cells. The use of fuels cells, SMES, batteries, or even pumped hydroelectric storage were dependent on space considerations and surrounding conditions.

E. GHG Emissions in Taking Care of Business

GHG emissions in this world continue to grow in the early part of the century and then begin to decrease as new efficient technologies and nuclear technology replace GHG intensive capital. The role of improved technologies in all sectors of the economy and the rapid capital stock turnover rates exhibited under this scenario tend to reduce overall emissions by the year 2050 from the Canadian Energy Outlook forecast. Emissions of 586 megatonnes are approximately 30% below the 2020 levels forecast.

Figure 8
Canadian Emissions by Source



Total 845 Mt **Total 586 Mt**