Advice on a Long-term Strategy on Energy and Climate Change

SUMMARY OF KEY FINDINGS

This document addresses opportunities and challenges facing Canada in relation to its long-term energy and climate change future. Specifically, it deals with how to, by 2050:

- **Meet the energy needs of a growing economy**
- **Achieve substantial reductions in carbon emissions**
- **Improve the quality of Canada's air**

The following key findings are derived from an examination of a 2050 scenario developed by energy consultants ICF International. The National Round Table on the Environment and the Economy (NRTEE) members approved all recommendations in this advisory note.

These findings suggest a possible path for how Canada can meet its future energy needs and address the pressing environmental challenges of climate change and clean air.

1. **There <u>can</u> be a domestic solution to making significant greenhouse gas (GHG) reductions by mid-century**, but significant reductions can be achieved only if energy is used more efficiently *and* if energy is produced while emitting less carbon. Energy and climate change policy in the 21st century means addressing both energy *use* and energy *production*. The question is not *which* technologies to deploy, but how to deploy *all* of the potential GHG reduction technologies. How to effectively deploy many different technologies in several sectors is an important policy issue.

- Energy use: <u>Increasing energy efficiency is key</u> – by doing so we could achieve approximately 40 per cent of our goal of a 60 per cent reduction in GHG emissions.
- Energy production:
  - i) Oil and gas sector: Canada's growing role as a major energy exporter is compatible with deep GHG emissions, but only if <u>carbon capture and sequestration</u> (CCS) is perfected. Resource extraction in the 21st century needs to take into account GHG reduction and adaptation to a carbon-constrained world economy – this benefits Canada both environmentally and competitively as a leading provider of world energy.
  - ii) Electricity generation: To reduce GHG emissions by 60 per cent, the electricity sector will need to be transformed between now and 2050. As with the oil and gas sector,

clean coal technology involving CCS plays an important role — this study assumes that all coal-fired generation in Alberta, and Saskatchewan will use CCS by 2050. After CCS, the largest reductions pertaining to electricity generation are from co-generation and renewables (particularly wind).

2. **Urgent need for a long-term signal** — The chief difficulty in significantly reducing GHG emissions is not the lack of relevant technologies – rather it is the lack of a long-term signal. Such a signal is needed to help the private sector make shorter-term investment decisions that take GHG reductions into consideration. These decisions, affecting Canada's energy use and production infrastructure, are taken now, every day. It is important to send the appropriate signal as soon as possible. The longer we wait, the more difficult it will be.

3. **Significant co-benefits** — Air pollution reductions and other co-benefits in key areas will occur along with the reduction of GHG emission reduction. For instance, significant economic co-benefits through the marketing of clean energy technologies will occur. However, domestic platforms, especially for areas such as carbon capture and sequestration, need to be made a national priority.

Section I: Introduction

This study is a first.

While other studies have raised general issues about how climate change will affect Canada's economy and environment, this study is the first to focus on what a low carbon future might look like for Canada over the next 45 years. In this analysis, NRTEE members focused on two questions. How can Canada protect and enhance its national interest with regard to energy and climate change issues between now and the mid-21st century? And what do we need to do right now to achieve this?

Canada can meet multiple goals at the same time

The scenario developed as part of this study examines one way that Canada can reduce energy-related greenhouse gas (GHG) emissions by 60 per cent by 2050 (compared with current levels). This exercise allowed the NRTEE to explore what would likely be involved if Canada were to contribute to global stabilization of GHG emissions by significantly reducing energy-related emissions by mid-century. This challenge is considerable, given that Canada has a growing population, an economy that is growing faster than the population, and an oil and gas sector that is growing faster than the economy.

The first and perhaps most important finding of the analysis is that it can be done, at least from a technological standpoint. In other words, a scenario using existing and near-term technology only was developed in which energy-related greenhouse gas emissions are reduced to less than half their current levels, even with a future that includes a larger population (45 million), a larger economy (more than double in real terms) and growth in oil and gas production that outstrips growth in domestic demand.

Although reductions of this magnitude provide significant challenges, the necessary technologies can also bring significant opportunities for the Canadian economy and its environment. Along with reducing the threat of catastrophic climate change and meeting the energy needs of a growing economy, they will also lead to major improvements in the quality of Canada's air. These actions will also provide opportunities for Canada to develop a more sustainable economy, to become a world leader in sustainable technology and to continue its role as a major energy exporter. With environmental technology representing a global growth area, a robust domestic market will provide a solid base for Canada's exporters.

A dual focus on increasing the efficiency of how we use energy and on reducing carbon intensity in energy production

An important finding of the scenario is that there can be a Canadian solution to making significant GHG reductions by mid-century, but significant reductions can be achieved only if energy and climate change policy addresses both energy *use* and energy *production* – in other words increasing energy efficiency and reducing carbon intensity.

Developing this scenario also helped to focus on some priorities. While the analysis shows that the contribution of all existing GHG reduction technologies associated with energy use and production will be necessary to achieving a 60 per cent GHG reduction for 2050, there are some priority areas whose contributions are so large that they become fundamental to setting Canada on a trajectory towards sustained and significant GHG emission reductions. The priority areas (falling in both the energy use and energy production categories) are:

- Energy use: Increasing energy efficiency is key – by doing so we could achieve approximately 40 per cent of our goal of a 60 per cent reduction. The question is not which technologies to deploy, but how to deploy nearly all of the potential greenhouse gas (GHG) reduction technologies. How to effectively deploy many different technologies in several sectors is an important policy issue.
- Energy production:
  i) Oil and gas sector: Canada's growing role as a major energy exporter is compatible with deep GHG emissions, but *only* if carbon capture and sequestration (CCS) is perfected. Resource extraction in the 21st century needs to take into account GHG reduction and adaptation to a carbon-constrained world economy – this benefits Canada both environmentally and competitively as a leading provider of world energy.

  ii) Electricity generation: To reduce GHG emissions by 60 per cent, the electricity sector will need to be transformed between now and 2050. As with the oil and gas sector, clean coal technology involving CCS plays an important role. After CCS, the largest reductions pertaining to electricity generation are from co-generation and renewables (particularly wind, but including all other forms of renewable energy).

As noted above, GHG reduction in these priority areas would also provide substantial co-benefits. Carbon capture and storage and "clean coal" technology virtually eliminate other forms of air pollution, such as emissions of SO2, NOx, mercury and particulate matter. Similarly, renewables and other non-emitting electricity sources have a beneficial effect on air quality. Energy efficient buildings such as the new Manitoba Hydro headquarters in Winnipeg provide better indoor air quality and therefore a healthier work environment that can increase productivity. Increasing efficiency in transportation also addresses one of the most enduring problem areas with regard to improving air quality.

Urgent need for a signal showing that GHG reduction remains a priority over the long-term

The chief difficulty in significantly reducing GHG emissions is not the lack of relevant technologies – rather it is the lack of long-term signals indicating that ongoing GHG reduction will remain a priority.

Such signals are needed to help the private sector make short-term and long-term investment decisions that take GHG reductions into consideration. Investment decisions are being made every day on new equipment, new processes, new facilities and new buildings, many of which will still be operational in 2050. These investments will have to be revisited later at a higher price if they do not take into account the sustainable options that are currently available. A clear commitment to long-term GHG reductions will provide the signal that will allow investment decisions to be made in the context of sustainable growth and capital stock turnover, so that reductions can be achieved with a minimum of disruption.

The NRTEE suggests that the government examine how to convey an enduring commitment to significant GHG emissions reductions that will contribute to global stabilization of atmospheric carbon levels. This overall goal can be implemented through many different policy signals that can be adjusted over time (e.g., short-term technology and GHG reduction targets, regulation, voluntary initiatives). The overarching commitment, however, must be clearly stated very soon.

The bottom line that the NRTEE wants to convey through this report is it that addressing the challenge of climate change opens up opportunities that can be accomplished with benefits for Canada's economy, environment, and society. The broad deployment of existing and near- term technologies, taken together, can in fact achieve long range and significant reductions in energy-related GHG emissions even in the face of growth in Canada's population, economy and oil and gas sector.

Section II: Protecting Canada's National Interest

Canada is in a unique position

As a major producer and exporter of energy, Canada has a national interest in climate change that is unique among the highly industrialized countries.

Canada's domestic and international policy response to climate change needs to be firmly rooted in a clear assessment of its national interest, which encompasses its economy, its environment and the quality of life of its citizens. Only in this way will Canada be in a position to effectively mitigate and adapt to climate change, while pursuing significant opportunities that may lie ahead.

In previous work on climate change, the NRTEE determined that the following special features of Canada's national interest are directly relevant to the question of climate change:

- As a major consumer, producer and exporter of energy, Canada is unique among the highly industrialized countries and the signatories to Kyoto. In essence, Canada faces the climate change challenge from both the energy-producing and energy-consuming perspectives.
- Canada is likely to experience greater impacts than any other industrialized nation, given its northern continent-wide geography and resource-based economy.

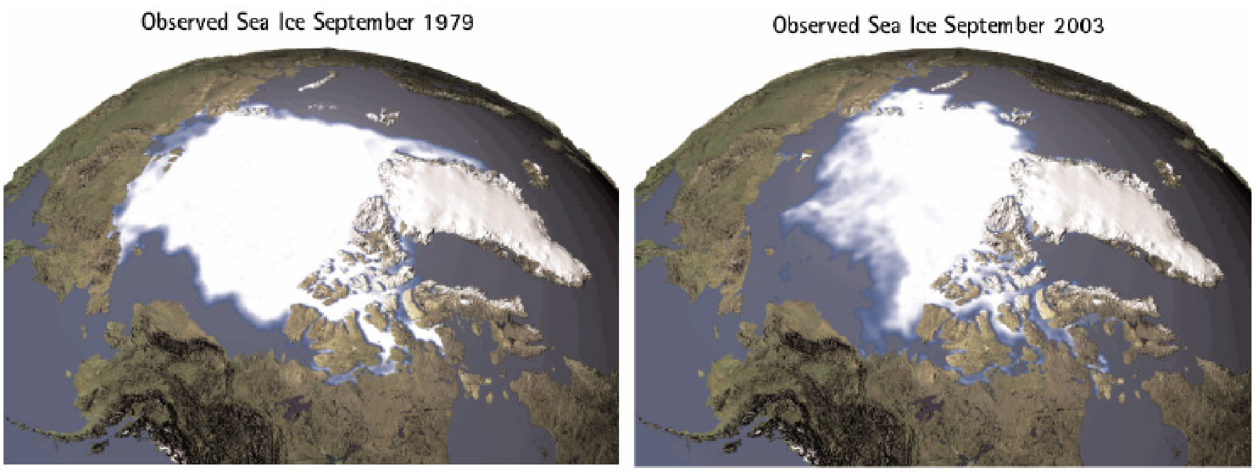
For these reasons, Canada is uniquely motivated to mitigate its contribution to climate change and to take advantage of the real economic opportunities that will arise from a strategic response.

The Dangers of Inaction

The NRTEE members believe that working to mitigate and adapt to climate change should figure as one of the federal government's chief policy priorities. Urgent action is required. Recent reports measuring the rate of increase in melting of the Greenland ice cap and the Antarctic ice cap suggest that previous studies may have underestimated the speed of the deterioration in both cases.

As an Arctic nation, Canada has first-hand experience with the implications of climate change. These changes have implications for our sovereignty as the Northwest Passage becomes easily navigable and increasing challenges arise to the traditional way of life of the Inuit, as their natural food sources diminish with the degradation of habitat. It also has significant implications for the

Ekati and Diavik diamond mines and the proposed Mackenzie Valley Pipeline. In the absence of permafrost, entirely new construction technologies will need to be developed to realize the potential of these resources.



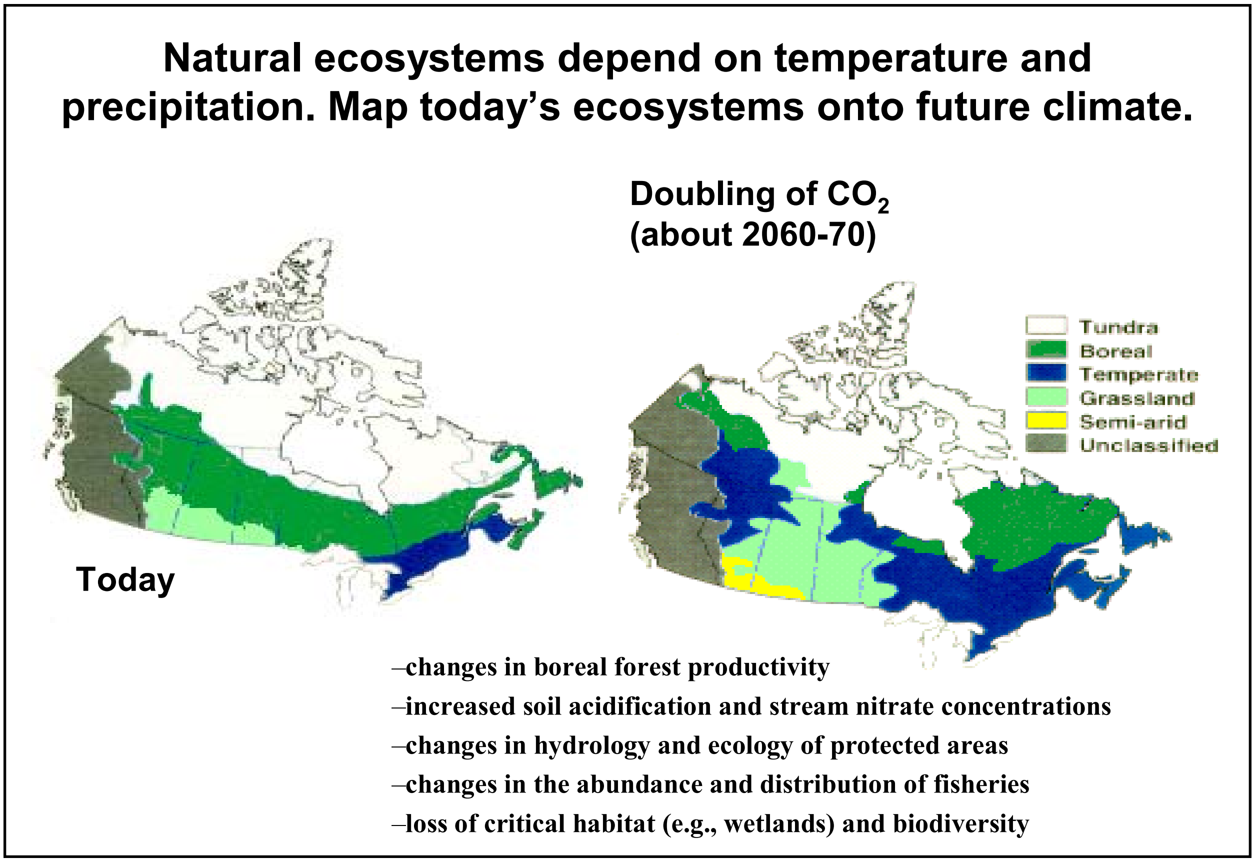
But the North is not the only area that will undergo negative consequences.

Water and the Hydrological Cycle

Several regions of Canada are already facing water stresses, and these are likely to increase as the result of projected climate change. While sea levels may rise, water levels could fall in the Great Lakes and in many rivers and streams, creating economic and environmental impacts. Agriculture, industry, oil sands development, hydroelectric generation and communities could find themselves competing for the reduced water flows. Where snowmelt is currently an important part of the hydrological regime (such as in Alberta), seasonal shifts in runoff are likely, potentially reducing summer flow. Possible changes in the frequency, intensity and/or duration of heavy precipitation events may require significant investments in land use planning and infrastructure to avoid damage arising from flooding, landslides, sewage overflows and releases of contaminants to natural water bodies.

Key Ecosystems and Related Natural Resource Sectors

The forestry sector has always had to manage for climate variability. However, the magnitude of the climate changes likely to face the sector over the coming decades may be unprecedented within the history of the industry. As the map shows, the area favourable for the boreal forest – which sustains an industry responsible for about half of Canada's annual wood harvest – shifts northward by several hundred kilometres in a scenario where atmospheric levels of carbon dioxide increase to about 550 parts per million (compared to current atmospheric levels of 375 ppm). Over the next century, the existing boreal forest throughout the Prairies and Northern Ontario could come under severe stress and would likely experience significant dieback. Compounding the problem would be the increases in insect, disease and fire-related losses expected with climate change.



Section III[1]: Details of the Study

Characteristics

The NRTEE requested the development of a scenario that shows one way in which Canada can achieve a significant reduction in energy related GHG emissions by 2050. In order to provide a quantifiable definition of what a "significant" reduction would look like, the NRTEE decided to select for illustrative purposes a long-term domestic reduction of energy-related GHG emissions by 60 per cent by 2050. This level of reduction is roughly consistent with similar targets adopted or being considered by other OECD countries (for example, the United Kingdom).

There is no denying that there is uncertainty associated with thinking about how Canada's energy use will evolve to the year 2050. One need only to think back to the late 1950s and imagine at that point trying to comment on what Canada's energy use and GHG emission patterns might look like in 2005.

But looking at deep GHG reductions in the long term allows us to take a fresh look at how our energy production and consumption patterns give rise to greenhouse gas emissions. Such an exercise reveals opportunities and possibilities that expand the menu of immediate policies and strategies for

1 The following section is based on the paper "Energy Related Greenhouse Gas Emissions in Canada in 2050-A Low Emission Scenario". Prepared by ICF International for the NRTEE.

responding to the threat of climate change, providing insights that can help Canada plan for significant GHG reductions. Looking at the "big picture" presented by this study can help with large-scale decisions that will be necessary to set direction, but which will undoubtedly require fine-tuning.

Scope of the analysis

The scope of this analysis is limited to "energy-related" GHG emissions. These are the emissions of GHG (primarily carbon dioxide, but also methane and nitrous oxide) that result from the production and consumption of fossil fuels.

Non-Energy Emissions Excluded. In 2003, GHG emissions in Canada totalled 740 Megatonnes (Mt) CO_2 equivalent of which 600 Mt CO_2 equivalent, or 81 per cent, were directly related to the production and consumption of fossil fuels.[2] The remaining 140 Mt CO_2 equivalent of emissions come from sources that are not energy-related. These emissions consist primarily of carbon dioxide from some industrial processes, methane from enteric fermentation in livestock production, nitrous oxide from agricultural soils and methane from solid waste landfills. These non-energy emissions are beyond the scope of this study, but achieving a low-emission future in Canada would require that they also be reduced. Further, in a future in which energy-related emissions are reduced to less than half their current levels, the relative importance of the non-energy sources would become much greater unless they could also be reduced by the same percentage or more.

Land Use Related Impacts Excluded. Another way we affect the level of greenhouse gas emissions in the atmosphere is through the impact of human activities on the rate of photosynthesis and respiration of plant material. The way in which we manage our forests and agricultural lands, and the extent to which we change land use patterns (for example, through urbanization) affects the rates at which carbon is transferred between the terrestrial ecosystems and atmosphere. These anthropogenic influences on the photosynthetic cycle are referred to under the rubric of "Land Use, Land Use Change, and Forestry" (LULUCF). Compared with energy-related and most of the non-energy-related emissions, there is a high degree of uncertainty surrounding our understanding of LULUCF impacts on atmospheric carbon levels. The potential strategic scope of the LULUCF sector is briefly discussed in Section IV of this document.

Assumptions

Several key assumptions were made at the start of this exercise that had a strong impact on the resulting 60 per cent GHG reduction scenario. The first was to limit the study to existing technologies or to those can likely be perfected in the near term (for example, carbon storage technology). This is not to say, however, that new, as yet unproven technologies should not be pursued.

2 CO_2 equivalent signifies "carbon dioxide equivalent." While carbon dioxide itself comprises most energy-related greenhouse gas emissions, there are also emissions of methane and nitrous oxide from the production and consumption of fossil fuels. To facilitate analysis and comparison, the relative effectiveness of these other gases in causing global warming can be used to express emissions of these gases in terms of the equivalent amount of carbon dioxide it would take to cause the same amount of global warming. For example, with the generally accepted convention used here, a tonne of methane emissions is equivalent to 21 tonnes of carbon dioxide emissions and a tonne of nitrous oxide emissions equate to 310 tonnes of carbon dioxide emissions, or 310 tonnes CO_2 equivalent.

The second important assumption was to allocate the emissions associated with the production of electricity and the exploration and production of oil and gas to the domestic end-use consumer. This approach highlights the importance of Canada's energy use infrastructure (e.g., transportation, buildings) and helps to us to think about the long term possibilities for achieving significant GHG reductions. Also, this approach significantly modifies the regional distribution of emissions, placing less emphasis on the oil and gas producing regions of Canada.

Another consequence of allocating emissions to end use is that it separates and therefore highlights the important GHG emission impact of Canada's energy exports on Canada's overall GHG emissions.

Emissions from the production of energy for export are also the subject of one of the key assumptions made at the outset of the analysis; that Canadian energy production will grow at rates that are determined less by the internal dynamics of the Canadian economy and more by continental and global markets for these commodities. This means that decreases in domestic energy use will not likely impact energy exports. For this reason, the production scenario for the oil and gas industry is based on the mid-term growth rates of the Natural Resources Canada (NRCan) production forecast.

It was also necessary to make a set of broad assumptions regarding Canada's economic structure and the size and nature of its population in 2050 in order to develop a "Business as Usual" (or non-interventionist) scenario for that time period. In terms of the underlying demographic and economic base, the non-interventionist scenario is in many ways just a larger version of the Canada of today. The scenario implies sustained growth — in some cases exponential growth — of population, labour productivity and per capita GDP. This scenario looks quite a bit like today, in that:

- The personal automobile and the truck would still dominate the transportation of people and freight, with trucks still consuming around 80 per cent of the energy used for freight transportation.
- While there is a slight shift from suburban to urban in location and lifestyle, the predominant urban form resembles the downtowns of today's cities, except that there are considerably more people living in the cores of these cities in 2050.
- Service sector workers continue to work in offices and the other sorts of commercial and institutional buildings in which they work today, but there are many more of these buildings.
- Except for the fossil fuel industry itself, there is a further drop in the relative share of Canada's economic output generated by the energy intensive primary producers (mining and smelting, steel, pulp and paper, industrial chemicals, etc.), but these industries all continue to grow in absolute terms.
- Output of the tar sands doubles and redoubles to five million barrels a day, and natural gas reserves continue to be delineated and developed at a pace sufficient to maintain Canada's role as a gas exporter from now until 2050.

In short, it is a scenario that takes as its reference point a Canada in 2050 in which energy-related greenhouse gas emissions reach 1,300 Mt CO_2 equivalent per year, about twice today's level (which is currently at 600 Mt CO_2 equivalent per year for energy related emissions).

A 60 per cent reduction of GHG emissions needs to be viewed in the context of the unique Canadian situation: our population is growing, the size of the economy is growing faster than the population, and the petroleum industry is growing faster than the economy.

Presentation of results

The NRTEE's development and analysis of a 60 per cent GHG reduction scenario is based on a method developed by Robert Socolow and Stephen Pacala[3]. The objective of their study was to show in a simple way that it was possible to envisage a transition to a global energy system by 2050 that used existing technologies to stabilize global GHG emissions, at levels widely believed able to avert major climate change impacts. The NRTEE's scenario is a Canadian adaptation and an extension of this method.

Like Socolow and Pacala's original study, the NRTEE's analysis idealizes the emissions curves and depicts them in a linear way, creating a simple diagram that shows:

- A top line showing the GHG trajectory associated with the non-interventionist 2050 scenario described above.
- A bottom line showing the GHG trajectory if Canada reduced GHG emissions to 60 per cent below current levels.
- A triangular space between the two lines, which defines the size of the GHG reduction challenge. This space is then filled by a variety of GHG reduction "wedges". Each wedge represents a different type of GHG reduction technology or strategy. The size of the wedge illustrates graphically the extent to which this measure could plausibly contribute to the overall reduction. A total of 31 individual GHG reduction technologies and strategies were identified as possible wedges (see Appendix A).

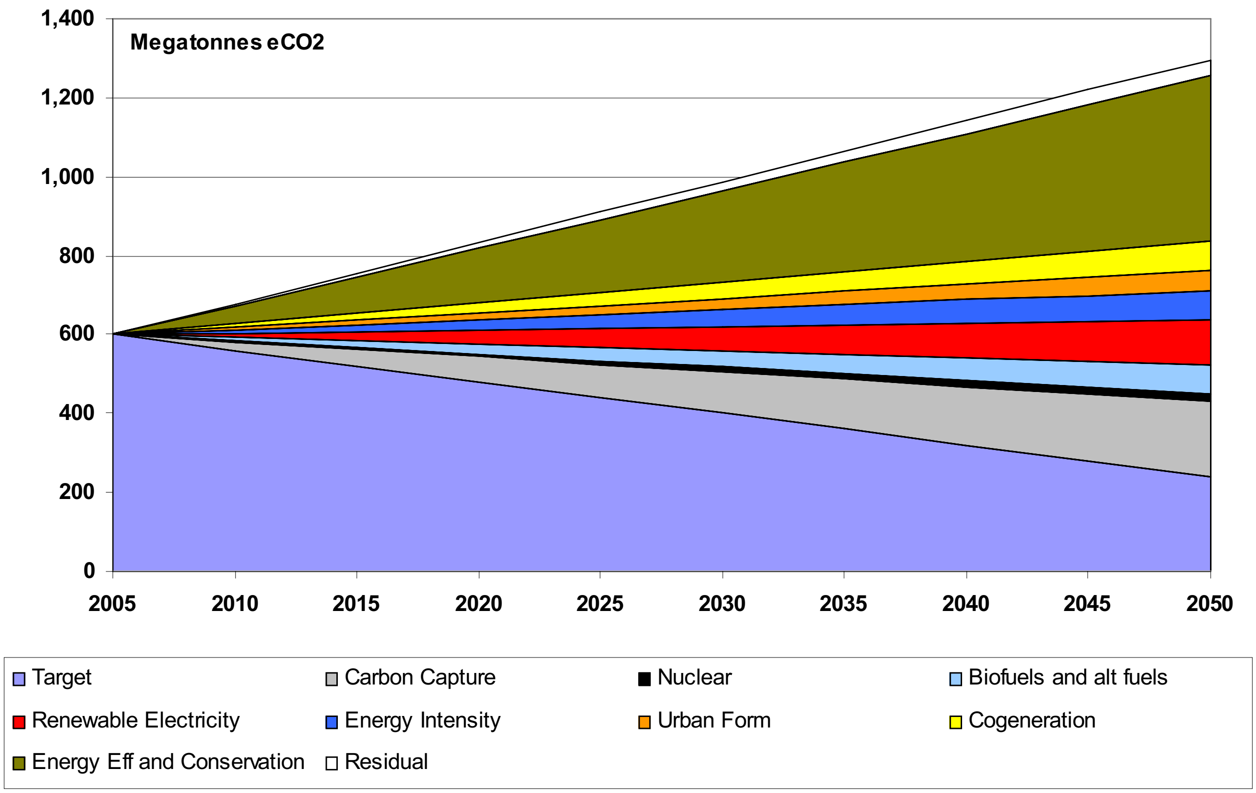
3 "Stabilization Wedges: Solving the Climate Problem for the Next Fifty Years with Current Technology", *Science*, Vol. 305, 13 August 2004, pp.968-972

Section IV: Picturing a Low-Carbon Canada in 2050

The 60 per cent GHG reduction wedge diagram

The figure below summarizes the main findings of the 60 per cent GHG reduction 2050 scenario for energy-related sources developed by the NRTEE. This figure is designed to show how existing technology, if more broadly deployed, can meet the climate change challenge. Further it depicts graphically the extent to which different GHG reduction technologies can contribute to the overall reduction goal.

GHG Reduction Diagram for Canada -- Aggregate Wedges



What does Canada look like under this scenario?

It is important to note that this scenario was developed with stringent criteria. It required the reduction of greenhouse gas emissions in 2050 to less than half their current levels while limiting the analysis to existing technologies. The analysis also specified a future that is similar to the present only with a larger population (45 million), a larger economy (more than double in real terms) and growth in oil and gas production that outstrips growth in domestic demand.

This scenario would create a Canada that in 2050 would look like this:

Personal use of energy

Housing densities have increased to the point where 70 per cent of Canadians live in some form of multiple dwelling. With the majority of jobs in services and light manufacturing, these land uses are integrated into residential developments so that it has become common to live and work in the same "walkable" neighbourhood or work at home for several days each week. The average Canadian travels much less than at mid-century; reserving travel more for pleasure than for commuting. Where it is necessary to travel to work, Canadians are now twice as likely to use public transit, which has become more efficient and convenient as a result of higher density and improved design.

Personal vehicles are also more efficient, averaging close to 80 mpg (3.6 L/100 km), and are generally fuelled by ethanol mixed with 15 per cent gasoline. One in five vehicles continues to use propane or compressed natural gas. Canada has developed an ethanol production industry, distributed across the nation, supporting production from western farmers as well as northern communities impacted by the slow reduction in the forestry and pulp and paper industry.

Canadian homes are much more efficient, as well as being more comfortable and durable as a result of efforts over the past several decades to inspect and upgrade the building stock. Solar heating and power systems are viewed as the norm, with one in three single family homes using a solar water heating system and one in 10 now using photovoltaics. Solar systems are associated with progressive new designs as the majority of systems are located in new subdivisions that have been designed to maximize solar access. An active local network of home renovation and energy services business has developed to provide insulation, air sealing and installation and maintenance of solar energy systems.

Energy to drive the economy

Electricity is made by a much more diverse and widely distributed set of generators, including a greatly expanded role for local co-generation and micro-turbine systems, wind power and other renewable sources of power. Canada continues to rely heavily on its hydroelectric resources, and a grid with increased east-west connectivity allows the delivery of a highly reliable power supply that combines the output of the new, distributed sources with some remaining central power plants. Where coal is still used to produce electricity, CO_2 capture and sequestration has been designed into the plants. Where possible this captured CO_2 is used to enhance oil recovery. Existing nuclear plants are replaced, and an additional 9,200 MW capacity is added in Ontario.

Freight distribution has not changed dramatically since the turn of the century, though reliance on trucks has declined back to 1990 levels with marine and rail transport picking up the difference. The efficiency of the trucks used to move freight has doubled or tripled over the past four decades and on average bio-diesel now provides about 20 per cent of the energy required for the sector.

The industrial structure in Canada has continued its gradual shift to manufacturing, service and high technology manufacturing. Energy intensive industries, while accounting for a declining portion of overall industrial output, have continued to increase their energy efficiency and the value of product produced per unit of energy used.

While domestic energy demands have fallen, the oil and gas industry continues to produce at rates similar to those achieved at the turn of the century, exporting oil and gas to the US and the rest of the world.

As noted above, the LULUCF impacts are beyond the scope of this study, but there could be a strategic role for the LULUCF "sector" on a low-emission strategy with a time scale of 2050.The anthropogenic influence on the total photosynthetic cycle in Canada is on the order of tens of megatonnes of GHG per year. It can be a source or a sink, and in recent years is estimated to have been a net sink in the range of 40 Mt CO_2 equivalent per year.

This is a significant amount when compared with the current level of energy-related greenhouse gas emissions (600 Mt CO_2 equivalent) and non-energy emissions (140 Mt CO_2 equivalent). In a scenario such as the one developed here, in which Canadian energy-related greenhouse gas emissions are in the range of 250 Mt CO_2 equivalent by 2050, a successful effort to sustain a 40- or 50-year period in which LULUCF impacts contribute a net sink effect on the order of 100 Mt CO_2 equivalent (a very rough estimate based on the assumption of moderately increased levels of biological sequestration) could make a significant contribution to achieving overall climate change policy objectives.

Section V: Strategic Priorities – Near-term action for long-term impact

The first and perhaps most important finding of the NRTEE's analysis is that existing technology is sufficient for Canada to significantly reduce GHG emissions by mid-century even if the future examined here is similar to the present and takes into account population and economic growth.

The second major finding is that both energy use and energy production activities must be involved. Doing only one or the other is not sufficient for Canada to make a significant dent in its GHG emissions.

The final set of findings deals with identifying which technologies must be encouraged now. The wedge diagram shows that the broad deployment of all potential GHG reduction technologies – at heretofore unseen levels – will be necessary to achieve the 60 per cent reduction target. Because this scenario is only one potential pathway to achieve this level of GHG reductions, the relative size of many wedges could be varied to achieve the same result. However, a few of these wedges are of such great importance that they effectively become "make or break" issues for Canada – failure to start implementing the technologies associated with these wedges would greatly impede Canada's ability to significantly reduce GHG emissions, even in the long run.

Therefore, the NRTEE recommends that near-term action on these strategic priorities is needed to help set Canada on a long-term trajectory towards a low emission energy future.

These key "must have" measures have been grouped into three areas which will be discussed below:

- With respect to energy use: Energy efficiency improvements in the industrial sector, the transportation sectors, and to residential and commercial buildings.
- With respect to energy production:
  - Carbon sequestration and storage in the oil and gas sector
  - Reducing the carbon intensity of electricity generation

Strategic Priority 1 – Energy Efficiency Improvements

Prior to the oil shock of the 1970s, increases in energy consumption and therefore emissions of greenhouse gases grew in tandem with growth in GDP. Since the 1970s GDP growth has often grown faster than the rate of GHG emissions, reflecting the productivity gains that have been achieved in the economy. The good news is that the dollar value of goods and services produced in the Canadian economy is growing faster than our energy consumption-related emissions. But as this study clearly shows, to achieve the necessary reductions in emissions, the energy efficiency of the Canadian economy will have to improve at a much greater rate than in the past.

The area of energy efficiency highlights two key differences that emerge when examining significant GHG reductions on a longer time frame. This first is that unlike the current debate on climate change, the question is not which technologies to deploy, but how to deploy nearly all of the potential GHG reduction technologies. How to effectively deploy many different energy efficiency technologies in several different sectors then becomes an important policy issue.

Examining GHG emissions on a longer time frame also shifts the relative importance of different energy use sectors. While the industrial sector (excluding the oil and gas sector) remains an important source of emissions, the influence of residential, transportation and commercial/service-related activities all become greater over the course of the next 45 years. The emphasis on reducing energy use in these three sectors therefore becomes more and more important.

Increasing energy efficiency in all of these sectors is key. In this section we will look at the implications for the industrial, commercial and residential and transportation sectors that are the primary energy consumers in Canada. These findings are based on an historical analysis of Canadian energy use that examined the period between 1990 and 2003.

Industrial sector

The industrial sector, which in this study includes mining, manufacturing and agriculture[4], is normally front and centre when there is a discussion of reducing GHG emissions because of the volume of their emissions and the visibility of their operations. The track record of this sector has been quite good. From 1990 to 2003 GDP for the sector grew at 24 per cent, while energy use grew by only 11.7 per cent and emissions grew by only 1.3 per cent. These accomplishments represent a combination of energy efficiency improvements and fuel switching, particularly in the pulp and paper sector, where wood waste has become an increasingly important fuel source for firing boilers.

4 The oil and gas sector is examined separately in this study.

These improvements have been driven generally by issues of competitiveness rather than government regulation, since it is not unusual for companies in this sector to have energy represent 20 per cent of their operating expenditures. For companies that are selling their products on the international market, managing these operating costs is often the difference between profitability and not. This is also an area where there has been investment in co-generation and more conventional combined heat and power (CHP) to maximize the benefit of fuel combustion.

There are, however, additional gains that can be made. This study assumed that energy intensive industry continues to improve its efficiency at rates similar to those achieved between 1990 and 2003. Specifically:

- Pulp and paper – Energy intensity increases 10 per cent/tonne/yr. By 2030, 80 per cent of energy comes from wood wastes.
- Iron and steel – energy use per tonne declines 20 per cent by 2050
- Smelting and refining – as above
- Chemicals – energy intensity declines 2.5 per cent per year.
- Cement – energy intensity declines 0.1 per cent per year.
- Mining (excluding oil and gas) – energy intensity declines 1 per cent per year.

From a policy perspective the important factor to note is that major technology investments are aligned with capital stock turnover. Most plants have an operating life of 25 to 40 years, and although upgrades and improvements are made constantly, the kinds of investments that will contribute to an 80 per cent reduction in emissions (as envisioned with pulp and paper) are made when the plant is replaced. Decisions are being made continually to replace and upgrade facilities. It is important that these decisions be informed by a clear policy framework designed to optimize the energy efficiency of new facilities.

It is also important to realize that heavy industry as defined in this study will play a smaller role in terms of energy consumption in the future, since it has been assumed that domestic based industry will need to produce higher value-added products in order to grow and prosper. For example, Dofasco Inc. produces the same volume of steel that it did 15 years ago but its sales volume has tripled because of changes to its product line. This is a trend that will prevail in Canadian heavy industry with the result that energy consumption in this sector will remain largely static and will decrease as a percentage of overall energy consumption.

Service and residential sectors – Renewing Canada's building stock

Canada's building stock is a long-lasting component of its energy use infrastructure: 66 per cent of the buildings that will be standing in 2050 are already built. This means that there will be a major renovation effort needed to bring these buildings up to the standards necessary. It also means that 34 per cent of the buildings have not been built yet, and these provide the opportunity to improve building codes and standards so that they will not be additions to the inventory that needs to be retrofitted. The results of this study show that while Canada's building stock can be renewed and improved over the years, setting better standards soon is key.

In the residential sector there is good news and bad news with regard to the history of energy use and energy efficiency. On the good news side there have been improvements of 13 per cent in energy use per square foot over the period from 1990 to 2003. This, however, has been offset by the increase in average living space as our affluent society opts for larger homes. Also, home entertainment, information technology and appliances are increasing the electricity load. Air conditioning is still a relatively small load, but is increasing rapidly. The net effect is that residential energy use increased over that same time period.

The 60 per cent reduction scenario made several assumptions with regard to the residential sector. Some of major assumptions, listed below, illuminate the need for early action:

- That 90 per cent of the existing 6.6 million single family homes and the 5.6 multi-family dwellings will undergo an energy audit over the next 50 years and that the identified savings can be made through air sealing, insulation upgrades and other will be carried out. This implies that 2.5 to 3 per cent of Canadian homes will need to be audited and retrofitted each year, or approximately 165,000 homes per year.
- That virtually every furnace in service today will be replaced by 2050 with high efficiency furnaces (greater than 90 per cent) becoming standard equipment by 2008. Of the approximately 3.5 million homes in Canada using electricity to heat their homes, some 520,000 electrically heated homes in Alberta, Saskatchewan and the Atlantic provinces (which all use a large proportion of coal to generate electricity) will need to be converted at a rate of about 26,000 homes per year. In areas where natural gas is not accessible, these homes would be converted to high efficiency propane furnaces.
- That the 4.1 million new single family dwellings projected to be built by 2050 will be 30 per cent more efficient than current standards by 2010. Similarly, the 3.4 million multi-family dwellings projected to be built between 2010 and 2050 will be 60 per cent more efficient.

New homes would be better insulated and sealed, with higher quality windows and doors. They would be heated with high efficiency furnaces where setback thermostat controls are standard and designed to take greater advantage of available solar gain in winter. It is expected that many of these upgrades are already cost effective for homeowners and result in more comfortable homes – and energy bills – with homeowners enjoying energy costs at least 30 per cent lower than they would otherwise have been.

The service sector referred to in this study consists of office, commercial and institutional space. As Canada has become increasingly a service-based economy it is not surprising that the service sector grew by 36 per cent between 1990 and 2003 while GDP only grew by 25 per cent over the same period. There was no correlation between changes in the price of energy and demand: over the period of the study, gas prices rise significantly but there is no corresponding decrease in demand. This speaks to the demand being structural and once the decision is made to use gas for space heating it is both expensive and disruptive to change. This furthers the argument that it is important to influence these decisions on buildings before they are built.

The service sector is therefore growing rapidly and must therefore become a key focus for reducing GHG emissions in the long term. Some of the assumptions that have implications for short-term action include:

- A heavy emphasis on renovation, since commercial buildings are renovated more frequently than residential homes: some commercial buildings may undergo several major renovations between now and 2050. This study assumes that over the next 40 years, 50 per cent of buildings are retrofitted to reduce energy use by 25 per cent. The balance are renovated to the equivalent of the LEED platinum standard, which reduces energy use by 50 per cent.
- All new buildings constructed after 2010 are required to meet the LEED Platinum standard which reduces energy use by 60 per cent over current standards.

Transportation Sector

As with the residential and service sectors, the trend in personal transportation between 1990 and 2003 shows that energy intensity per passenger-kilometre improved modestly, by 8 per cent. But the overall level of activity (in this case kilometres traveled) increased by 27 per cent, creating an overall increase in GHG emissions. This trend has been further driven by the popularity of light trucks and SUVs. The 60 per cent reduction scenario shows that significant gains in this sector coming from new technologies such as hybrids that increase the efficiency of personal vehicles. To a lesser extent, it also emphasizes improved access to and use of public transit.

One of the assumptions that has implications for short-term action is related to a gradual increase of the average energy efficiency of the fleet:

- 2005-2014, efficiency increases 2.25 per cent/year
- 2015-2020, efficiency increases 2.40 per cent/year
- 2021-2050 efficiency increases 2.55 per cent/year.

This results in an average energy efficiency of 3.01L/100km by 2050 (78 mpg).

The role of freight transportation is of great importance in this study. The evolution of just in time manufacturing as the norm has placed increased pressure on freight transportation. This is borne out by an increase of 46 per cent in volume in tonne/kms compared to a GDP growth of 26 per cent from 1990 to 2003. This growth in volume was only somewhat offset by energy efficiency improvements that reduced trucking energy intensities. The result was a significant 42 per cent increase in GHG emissions during this time period.

Truck efficiency improvement is the second largest single GHG reduction wedge in this study, after carbon capture and sequestration. The study assumes that light and medium trucks will triple their fuel efficiency by 2050, and that heavy trucks will double fuel efficiency by 2050.

These assumptions are based on the US 21st Century Truck Program that has set the goal to develop by 2010 the technologies to triple, among other things, the fuel efficiency of light and medium trucks. In its 2005 annual report, this group seemed to be reporting reasonable progress; however, this is not currently demonstrated technology.

In the meantime, a number of existing, demonstrated and cost-effective technologies exist today that could increase energy efficiency of small and medium trucks by 50 per cent.

Strategic Priority 2 – Carbon capture and sequestration in the oil and gas sector

This study showed that Canada's growing role as a major energy exporter is compatible with deep GHG emissions reductions by mid-century, but only if the carbon intensity of oil and gas production is reduced through the use of carbon capture and sequestration (CCS). However, while carbon capture technology is mature, carbon storage with permanent sequestration is not yet a widely proven technology. The development and use of this and other emission reducing technology is possibly the single greatest issue determining whether or not Canada can significantly reduce GHG emissions in the long-term.

In the Canadian oil and gas industry, the oil sands are the dominant factor in future development. Currently producing just over a million barrels a day, that production is forecast to grow five-fold over the next 45 years. The potential emissions implications of that level of production would dwarf all other considerations in trying to reach the GHG reduction target explored in the NRTEE scenario. At the same time, there is a global demand for the output of the oil sands, and the billions of dollars of investment in developing these properties is critical to the health of the Canadian economy.

Fortunately carbon capture and geological storage holds the potential to virtually eliminate these emissions and also has a series of important collateral benefits. From a "wedge perspective", the 191 Mt/yr of emissions that could be reduced represents 18 per cent of the overall target and is the largest single wedge in Figure 3. This assumes that CCS reduces emissions from the oil and gas industry by 30 per cent by 2030, and by 60 per cent by 2050.

Once the CO_2 is separated it can be used for enhanced oil recovery in the Western Sedimentary Basin. Conventional drilling will only recover about 40 per cent of the oil, at which point the pressure in the formation is insufficient to continue production. The carbon dioxide can repressurize the well and increase recovery. A similar approach can be taken to enhanced gas recovery. The key point is that not only are emissions being reduced by pumping the CO_2 back into the geological formations but a valuable resource is being recovered. In addition, water is currently being used for enhanced oil and gas recovery and water is a limited resource in Alberta and Saskatchewan. This technique can also be important for recovering coal bed methane, tight gas and other non-conventional reserves.

The potential value of carbon capture and storage is widely recognized for many of the reasons noted above. Canada has the opportunity to be on the leading edge of deploying this technology. This not only has significant benefits for Canada in terms of resource development but it also becomes an important exportable expertise. Given the outlook for growth in the production and consumption of fossil fuels internationally, and in particular the impending development of the vast coal reserves of China and India, carbon capture and storage technology will also have a critical role to play in global scenarios for GHG emission stabilization. There will be significant global opportunities for those who can demonstrate the ability to deliver effective carbon capture and storage technology.

This is one of the key underlying themes of this paper, that environmental and economic objectives can achieved in a manner that produces incremental economic and export benefits for Canadian industry.

Strategic Priority 3 – Electricity generation

As noted above, the NRTEE's scenario implies that that the electricity sector will be transformed between now and 2050.

The measures with the greatest immediate strategic importance are:

Co-generation

Canadian industry requires significant volumes of process steam provided by industrial boilers. That same steam can drive a turbine producing electricity before it is used for process purposes. The emissions associated with the fuel used to fire the boiler are already occurring so the power generation occurs with no net increase in fuel consumption. Historically, difficulties in interconnecting to the electricity grid have discouraged the full development of combined heat and power (CHP) potential but advances in control technology combined with standardization and downsizing of co-generation technology expand the potential contribution of this option.

The large proportion of co-generation implies that the Canadian electricity sector will become a much more distributed one. Industrial co-generation, as well as micro turbines and CHP in the residential sector (apartment and condominium buildings) and commercial sectors must all be deployed. The increase in capacity – a total of 2010 MW *per year* between now and 2050 – provides a sense as to the urgency surrounding this measure.

Clean coal with carbon storage

Canada has sufficient proven deposits of coal to fuel our coal fired power generation fleet for the next 500 years. "Clean coal" technology offers the potential to exploit these coal reserves and at the same time to minimize the environmental impact. In the clean coal process, the coal is first gasified, the sulphur is removed, the gas is burned in a turbine in an oxygen enriched atmosphere and the NO_x is removed. The exhaust gas is almost pure CO_2 that can be captured and stored as discussed previously. This technology can result in a 95 per cent reduction in GHG emissions, and the virtual elimination of SO_2, NO_x and mercury emissions with the resulting benefits of cleaner air.

One of the by-products of coal gasification is hydrogen produced in an environmentally sustainable manner. If our transportation sector moves towards hydrogen as a future fuel source this production method will be important.

This study assumes that all coal-fired generation in Alberta, and Saskatchewan will use clean coal and CCS by 2050.

Wind

All renewables feature in the 60 per cent scenario, including wind, solar, bio-mass, hydro, geo-thermal, ground source heat pumps, and tidal power. The contribution by wind is particularly important. In May 2006, Quebec Hydro announced that it plans to build 4,000 MW of new wind capacity, in addition to the 3,000 MW already committed. Ontario has indicated its intention to acquire 5,000 MW of wind by 2025. This wedge envisions just over four times that amount of capacity being added in the next 40 years, in other words 40,000 MW of wind by 2020 rising to 50,000 MW of capacity by 2050.

This additional capacity would result in approximately 33,000 additional turbines to be installed (assuming 1.5 MW turbines, which is currently a common size, but which are rapidly being replaced by larger turbines on wind farms being built today).

Section VI: Conclusions and Key Findings

The greatest value of re-examining climate change through a long, rather than a short-term lens is that looking forward to 2050 helps to take a fresh look at the most effective strategies for reducing greenhouse gas emissions in a way that is responsive to Canada's unique circumstances. Some of the changes in focus and some key messages are:

Focus on Canada's role as an energy producer and exporter, since achieving significant GHG emissions necessitates developing energy resources in a sustainable manner. For the oil and gas industry that means incorporating carbon capture and storage into future development plans. On the power generation side it means a combination of clean coal technology including carbon capture and storage and a national strategy for the deployment of renewable energy.

There are significant opportunities to sell this type of technology in international markets. But Canada should be cautious about promoting solutions for other countries that are not yet solutions at home. These technologies should continue to be tested domestically through technology platforms to demonstrate commercial success and export viability. Coupled with international demonstration projects in "receptor" countries, the technology platform concept can be instrumental in the demonstration of commercial potential and provide a focus for investment leading to expanded trade in climate-related technologies and services, for example the International Test Centre for CO_2 Capture at the University of Regina and the affiliated Boundary Dam field test facility.

Focus on technology deployment. Although this analysis shows that existing and near commercial technology hold the potential to "bridge the gap" if widely deployed, there must be a broad portfolio of initiatives, as there is no one "magic" wedge. In contrast to the debate that has swirled around the achievement of the Kyoto targets, the question is not *which* technologies to deploy, but how to deploy many or even *all* of the potential GHG reduction technologies at unprecedented levels of implementation. This is particularly true in the area of energy efficiency.

Combine long-term certainty and short-term action. A focus on affecting decisions being made now on capital stock investments must include policy certainty on climate change policy. This analysis suggests that there is a need for urgency, since all three of the strategic priorities are expected to undergo significant expansion and renewal. An estimated $36 billion in investment is planned for the oil sands in the next six years – an investment that will last at least 40 years. During these four decades, 34 per cent of Canada's housing stock will be new, and within 20 years, the Canadian Electricity Association estimates that at least $150 billion of electricity infrastructure will be constructed. New, long-life capital stock provides once-in-a-generation opportunities for GHG reductions through the adoption of best available technologies and structures. What we plan and begin now will influence our emissions in 2050 and beyond.

Important co-benefits. Lowering GHG emissions can lead to many additional environmental and economic co-benefits. Many of the GHG reduction wedges also have significant clean air advantages. This is particularly true of the measures associated with the three strategic priorities, since they encompass some of the more enduring problems areas with regard to criteria air pollutants such as transportation and fossil-fired electricity generation.

Section VII: Next Steps for the NRTEE

As noted at the start of this document, this work constitutes one of the first examinations of Canada's long-term approach to energy and climate change policies. As such, the NRTEE sees this work as a first step towards helping Canadian develop effective approaches as to how the climate change challenge can be faced.

To further thinking on a long-term strategy for energy and climate change, the NRTEE is planning two separate but related activities:

Going from the "What" to the "How" (Program to be initiated in Summer 2006)

Wedge diagrams such as the one featured in this study provide a good visual representation of which technologies and actions can be combined to achieve a particular greenhouse gas reduction target. They do not, however, describe how these changes can be achieved. The NRTEE freely admits that implementing the levels of change represented by the wedges will be a huge challenge and success will be contingent on the development of significant policies.

For this reason, the NRTEE plans further analysis to supplement the Canadian "wedge analysis". This analysis will examine:

- The costs and benefits associated with technologies associated with key wedges;
- Policies to encourage the dissemination and adoption of these technologies at the levels suggested in the current analysis; and,
- Practical, realistic, feasible ways to provide long-term policy signals with respect to GHG reduction.

Outreach strategy (To begin in Fall 2006)

The NRTEE wishes to initiate a national discussion on Canada's long-term response to energy and climate change. For this reason it is planning a series of half-day seminars for relatively small but influential groups of key players in the business, provincial, municipal and non-governmental organization (NGO) sectors.

These sessions will use the wedge analysis described in this document as a starting point to discuss Canada's long-term approach to energy and climate change, and to discuss the potential roles of government and non-governmental players. In particular, this process will be designed to engage key players in a constructive dialogue on how the wedges in which they have an interest might become a reality.

The input gained through these sessions will greatly assist in the NRTEE's policy work on deploying GHG reduction technologies as described above. This input and any subsequent analysis will be forwarded to the Minister of the Environment.

These sessions will take place in eight to 10 major cities across Canada between September 2006 and April 2007.

Appendix A: Wedge Summary
Scenario Descriptions and Implications

This is a table that shows the impact of each wedge measure.

The first column shows the independent impact of each wedge measure, which represents the measure's impact when measured by itself against the Business as Usual baseline with no other wedges acting.

The second column shows the contribution of the individual wedge measure in the 60 per cent GHG reduction scenario featured in this report, in which the interactive effect of all the wedge measures acting together is taken into account.

The main reason that the individual contribution of the wedges is reduced when combined in an interactive scenario is that many of the measures are acting on the same target emissions. To take an example from transportation, efficiency improvements in the passenger vehicle stock would reduce emissions in 2050 by 89 Mt CO_2e (Wedge 10) if this measure were to be implemented against the mostly gasoline-powered vehicle fleet assumed in the Business as Usual baseline. In a similar way, the switch to gasoline containing 85% ethanol (Wedge 16) would on its own reduce emissions by 53 Mt CO7 pte measured against that same Business as Usual scenario. But when both of these measures are carried out simultaneously, along with others that also target personal vehicle emissions (e.g. switch to transit, other alternative fuels, urban densification) the combined impact is less than the sum of the individual impacts than when they are evaluated singly and independently.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
1. Residential – Existing Buildings – Energy Retrofits *Single Detached made 30% more efficient, Multiple dwellings made 20% more efficient and all oil and gas furnaces converted to 90% efficient.*	27	13	There are about 6.6 million single-family homes in Canada in 2003, along with 5.6 multi-family dwellings. Over the next 50 years it is assumed that roughly 90% of existing homes are inspected (an energy audit) to identify where savings can be made through air sealing, insulation upgrades, etc. and that these improvements are carried out. This implies that 2.5-3% of Canadian homes will need to be audited and retrofitted each year; that is approximately 165,000 homes per year. Virtually every furnace in service today will be replaced by 2050. Current standards represent

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
			a significant improvement compared to the efficiency of equipment typically installed even a decade ago. This wedge assumes that these standards will be upgraded to require high-efficiency (>90%) furnaces as the new standard by 2008 so that every home heating with fossil fuels will be equipped with a high-efficiency furnace. There are over 3.5 million homes in Canada that heat using electricity. In provinces which use a significant amount of coal to produce electricity, we have assumed 5% of these homes are converted to other sources each year. This means that some 520,000 electrically heated homes in Alberta, Saskatchewan and the Atlantic provinces will need to be converted at a rate of about 26,000 homes per year. In areas where natural gas is not accessible, these homes would be converted to high-efficiency propane furnaces. Similar efforts have been successful in the past to encourage homeowners to transition away from oil heating (Canada Oil Substitution Program). As a result, homes without basement insulation would be upgraded, air sealing would be upgraded to improve home comfort and windows upgraded where appropriate. Every home that could benefit from one will have an automatic setback thermostat installed over the next 10 years. It is expected that many of these upgrades will be cost-effective for homeowners and result in more comfortable homes – and energy bills – with homeowners enjoying energy costs at least 30% lower than they would otherwise have been.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
2. Residential – Lighting, Equipment & Appliances Efficiency	12	6	The average Canadian home has 40 light bulbs, of which about 16 are used regularly. The majority of lamps today are 60 watt incandescent. Twenty years from now, virtually all household lighting will be provided by compact fluorescent lamps and the use of LED lighting will be as common as CFLs are today. By 2050, a combination of CFLs and LED will be used in most homes. Over the past decade, the average efficiency of major household appliances has increased dramatically. The average energy consumption for fridges and freezers has dropped by over 40%. Over the next 50 years, we assume that electrical appliance efficiency will increase by a further 25%, while appliances such as stoves and dryers will become only 20% more efficient. In 2001 the average new refrigerator used 559 kWh per year compared to 950 kWh per year in 1993. By 2050, we assume this will drop to 419 kWh which is within the range of appliances available today. Residential lighting energy use per household will be reduced by 60% by 2025 and by 75% by 2040; non-substitutable appliance efficiency increases 25%, substitutable appliances by 20%.
3. Residential – New Building Shell Efficiency (heating/cooling)	28	14	4.1 million new single-family dwellings and 3.4 million multi-family dwellings are projected to be built by 2050. To create this new building stock, at least 102,000 new single-family homes and 85,000 new multi-family units will be built each year across Canada, with actual new starts being somewhat higher to replace existing homes that are demolished or replaced for various reasons. Roughly 40% of the housing stock in 2050 will have been built after 2003.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
			This wedge assumes that new single detached homes will be 30% more efficient and new multiple dwellings 60% more efficient than current standards by 2010. New homes would be better insulated and sealed, with higher quality windows and doors, heated with high-efficiency furnaces with setback thermostat controls as a standard and designed to take greater advantage of available solar gain in winter.
4. Residential – Air Conditioning Efficiency	0.3	0.15	Current standards require that all new central AC units have a SEER of at least 10. Higher efficiency equipment is available today with a SEER of 15. This wedge assumes that improvements to building envelopes as well as higher SEER units will reduce AC use by 40%.
5. Residential – Water Heating (Efficiency, Water Conservation & Fuel Choice)	11	7	By 2050, virtually every home that has a washing machine will use a front-loading design, while all showerheads, taps and toilets will be water efficient reducing overall water heating demands. As natural gas water heaters are retired over the next 40 years, they will be replaced by new 78% efficient devices. There are 6.5 million electric water heaters in Canada. This wedge assumes that over the next 15 years, half of these units can be converted to tankless systems now available on the market, reducing energy use (standby losses) by 15%. All of the approximately 500,000 oil-fired water heaters are assumed to be converted to natural gas by 2020. In both instances these changes could occur as the existing tanks are retired at the end of their useful lives.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
6. Economic/Structure Changes			
a) Urban Form/ Neighborhood Planning – dwelling type mix, mobility requirements, district energy potential *2% annual shift from Single Detached to Multi-Family dwellings. Passenger transportation PKT assumed to be 33% lower for multi-family households.*	105	52	In 2003, 54% of Canadians lived in single-family homes and travelled an average of 9,674 km/year. By 2050, we assume that 71% of Canadians will have transitioned to multi-family homes (apartments, condominiums or row housing). As a result of higher housing densities and more integrated land uses, the average Canadian will have less need of private modes of transportation, significantly reducing their vehicular travel.
b) Shift from Energy Intensive Industry to Manufacturing	20	11	Gross output from energy intensive industries will declined by an average of 0.5% per year with compensating growth in other industrial sectors.
c) Continued historic structural and/or process changes for all sectors, including transportation	144	65	Continues historic changes in energy intensity across all sectors reflecting both structural and process changes.
7. Commercial – Existing Building Retrofits and Energy Management	28	14	Commercial buildings are renovated more frequently than residential homes. Some commercial/industrial buildings may undergo several major renovations between now and 2050. Over the next 40 years, 50% of buildings are retrofitted to reduce energy use by 25%. The rest are renovated to the equivalent of the LEED platinum standard, reducing energy use by 50%, all by 2050.
8. Commercial – New Buildings – Integrated Building Systems for Energy Efficiency	26	13	All new buildings constructed after 2010 required to meet LEED Platinum standard, reducing energy use by 60% over current standards. Impact equal over all equipment categories.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
9. Commercial – Lighting and Equipment Electrical Efficiency	20	11	Lighting – reduced by 30% by 2015 and by 50% by 2025 (High-efficiency T8 systems with electronic ballasts, occupancy sensors and day lighting become standard). Auxiliary Equipment – reduced by 25% by 2020, slightly exceeding current Energy Star standards. Water heating – reduced by 35% by 2020, largely due to reduced demand supported by improved efficiency of water heating systems. Auxiliary Motors – reduced by 20% by 2020, due to combination of improved controls and design. Cooling – reduced by 30% by 2020, largely due to reduced internal loads plus improved building shell.
10. Personal Transportation – Vehicle Fuel Efficiency	89	46	2005-2014, efficiency increases 2.25%/year. 2015-2020, efficiency increases 2.40%/year. 2021-2050 efficiency increases 2.55%/year. Results in efficiency of 3.01L/100km by 2050, or 78 mpg in US measurements. Also assume transit bus efficiencies triple by 2050.
11. Personal Transportation – Public Transit, Non-Motorized Modes	11	5	Increased public transportation usage by 1.39% per year, approximately doubling its share of PKM from 4.2% to 8.03% by 2050. Personal vehicle travel declines by an assumed 0.2% per year due to 2% increase per year in non-motorized modes of travel.
12. Personal Transportation – Mobility, Improved Access & Trip Reduction	5	2	Light vehicle use reduced by 0.28% per year due to increase in telecommuting and substitution of communications for travel.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
13. Freight Transportation – Vehicle Efficiency	158	126	Light & Medium trucks triple fuel efficiency by 2050. Heavy Trucks double fuel efficiency by 2050. Rail and Marine sectors decrease energy intensity by 50% and 25% respectively.
14. Freight Transportation – TKT Reduction & Mode Split (rail vs. truck)	13	7	Modal splits return to 1990 levels. Rail & Marine each increase by 5%, Trucking declines 10%.
15. Alternative Fuels/Vehicles For Transport – Bio-diesel	7	3	By 2050, 50% of diesel used is a 20% (B20) blend with the result that bio-diesel supplants 10% of all diesel use.
16. Alternative Fuels/Vehicles For Transport – Ethanol	53	28	Under Canada's Ethanol Expansion Program, Canada expects to produce 1.4 billion litres of ethanol per year by 2007, seven times what it was prior to the launch of the program, and enough to meet the Government of Canada's climate change target for ethanol production two years ahead of schedule. *More on Ethanol Expansion Program and Government's ethanol targets and support programs*: http://news.gc.ca/cfmx/view/en/index.jsp?articleid=158789. This wedge envisions 172.5 PJ of ethanol use in 2050 equal to 8.2 billion L of ethanol with much of this produced from cellulose-based materials. This is roughly half the level of current Brazilian production of 14 Billion L or US production of 15 Billion Litres. Fifty to sixty plants will be required to produce this volume, providing local employment across Canada, with an opportunity to locate some of these jobs in northern areas. Gasoline production falls to 109 PJ per year compared to 2,433 PJ in the Base Case.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
			By 2010 - 100% of all gas contains 10% ethanol By 2030 - 50% of all gas contains 85% ethanol By 2050 - 100% of gas contains 85% ethanol
17. Alternative Fuels/Vehicles For Transport – Hydrogen	8	4	Sales of hydrogen vehicles grow over period. By 2050 5% of passenger vehicles and buses and 6% of fleet vehicles sold use hydrogen.
18. Biomass Fuels – Direct Burning	–	–	See 30 a below.
19. Hydrogen as Carrier – Overall potential in stationary applications	n.a.	n.a.	Impact of hydrogen assumed to occur primarily in transportation. Use of fuel cells for stationary heat/power assumed to be fueled by natural gas rather than hydrogen.
20. Carbon Capture and Storage	191	191	All fossil fired generation in Alberta and Saskatchewan use CO_2 capture by 2040, reducing emissions by 90% from what they would otherwise be without CO_2 capture. 30% of all oil and gas emissions (extraction and refining, etc.) are captured by 2030 rising to 60% capture by 2050.
21. Energy Intensive Industry (excluding electric power and oil & gas sectors) – targeted emission reductions, industrial energy efficiency	50	26	Energy Intensive industry continues to improve its efficiency at rates similar to those achieved between 1990 and 2003: Pulp & Paper – Energy intensity increases 10%/tonne/yr. By 2030, 80% of energy comes from wood wastes. Iron & Steel – energy use per tonne declines 20% by 2050 Smelting & Refining – as above Chemicals – energy intensity declines 2.5% per year.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
			Cement – energy intensity declines 0.1% per year. Mining (excluding Oil &Gas) – energy intensity declines 1% per year.
22. Secondary Manufacturing – energy efficiency	42	27	Energy intensity/$GDP declines by 2.8% per year.
23. Oil and Gas Industry:			
a) Reduction of Emission Intensity per Unit of Energy Produced	97	74	Oil Sands energy intensity per dollar of gross output declines by 1% per year. Pipelines reduce energy intensity per dollar of gross output by a modest 0.5% per year. Petroleum Refining industry reduces energy intensity by 0.6% per cu. m. of product per year.
b) Fugitive Emissions	27	22	Fugitive emissions are reduced by 30% by 2020 and by 60% by 2030.
24. Electricity Supply Wedges:			
a) Nuclear Re-tubing			Included with new nuclear (see below)
b) New Nuclear	44	20	All existing nuclear replaced plus an additional 9,200 MW capacity added in Ontario.
c) Large Hydro	18	8	In May 2006, Quebec Hydro announced its intention to build 4,500MW of new hydraulic capacity based on sites in northern Quebec (*Globe & Mail*, May 4, 2006, page B1). This exceeds the increase envisioned in this wedge. 2025 – 2000 MW installed in Manitoba 2020 – 2800 MW installed in Labrador 2030 – 2000 MW installed in Quebec/Ontario
d) Wind	105	50	In May 2006, Quebec Hydro announced that it plans to build 4,000MW of new wind capacity, in addition to the 3,000 MW already committed. Ontario has indicated its intention to acquire 5,000 MW of wind by 2025. This wedge envisions just over four times that amount of capacity being added in the next 40 years.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
			40,000 MW of wind by 2020 rising to 50,000 MW of capacity by 2050
e) Photovoltaic	4	2	5,000 MW of solar capacity installed by 2050 This assumes a 5KW solar array on less than 10% of 10.7 million Canadian homes. Starting in 2010, 2.7% of homes are assumed to install Solar PV systems each year with an average of 25,000 homes per year across Canada install PV arrays.
f) Biomass	–	–	See Wedges 30a and 30b below
g) Small Hydro	11	5	7,500 MW of capacity installed by 2040
h) Tidal/Wave/OTEC	23	10	Tidal = 4,000 MW; 3/4 in BC balance in Maritimes. Wave = 10,000 MW by 2050.
25. Electricity – East West Connectivity	3	2	Interconnections increased by 2000 MW between Quebec & Ontario, Manitoba & Ontario, and Alberta & BC flowing in both directions starting 2020.
26. Electricity – Cogeneration (industrial cogeneration, micro turbines and CHP)	116	73	Growth in Cogeneration capacity: Industry – 875 MW per year Commercial – 440 MW per year Residential – 695 MW per year added to apartments and condos
27. Landfill Gas Recovery and Utilization	6	5	50% of current landfill gas is captured and recovered as heat or electricity by 2050.
28. Solar Water Heating	8	4	Residential – 30% of all single detached homes are retrofitted with solar DHW (domestic hot water) heating supplying 50% of needs by 2050 with most of this occurring in new construction as subdivisions are designed to maximize solar opportunities. Commercial – 50% of water heating needs in the Health Care & Social Services, Education and Accommodation and Food sectors is supplied by solar in 2050. Virtually all commercial and institutional buildings that can accommodate one is equipped with a solar DHW system by 2050.

Wedge Name	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Independent Impact	Emission Reductions Relative to Baseline (Mt CO_2e per year) – Interactive Scenario	Description
29. Geothermal Energy	13	6	Geothermal energy to provide1.6% of total electric generation capacity by 2050. Ground source heat pumps to supply 1% of national heating and air conditioning, using 2/3 less energy than systems that they replace.
30. Alternative Fuel Wedges:			
a) Wood & Biomass Fuel	37	17	Residential use of wood heating assumed to double by 2050. Biomass assumed to supply 90% of Pulp & Paper and 75% of Forestry sector stationary energy needs. Municipal energy from waste assumed to supply 60 PJ of heat to residential and commercial sectors.
b) Biogas	2	1	By 2050, 800 MW of power is supplied by biogas generation with half of the available waste heat from generation captured to displace on-farm stationary fuel use.
c) Peat	n.a.	n.a.	No provision is made for the use of peat. Burning peat could reduce emissions if allowance is made for reductions in natural emissions from peat lands.
31. Switch to Lower Carbon Fossil Fuels	82	43	By 2050, 20% of passenger transportation is supplied by propane; 50% is supplied by CNG. In the Freight sector, CNG displaces the 23% of energy now supplied by gasoline.
TOTAL	**1,644**	**1,013**	