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CHAPTER

Canadian Policies for Deep Greenhouse Gas Reductions

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Prepared for the IRPP Canadian Priorities Agenda project

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The IRPP's *Canadian Priorities Agenda* project is designed to initiate a broad-based and informed public debate on policy choices and priorities for Canada over the medium term. Research papers on the following eight broad policy challenges have been undertaken to examine the most effective ways to address them:

- Aging and demographic change
- Climate change
- Economic security
- Health outcomes
- Human capital
- Natural resource management
- Productivity performance
- Trade and globalization

Six judges will each craft a policy package from the specific recommendations put forth in the eight papers that in his or her view will best enhance the economic and social well-being of Canadians.

Canadian policies for deep greenhouse gas reductions

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1. Description of the policy challenge

The litany of potential impacts associated with climate change is becoming familiar to anyone who regularly reads a newspaper or watches the news on television. Global average temperatures are expected to increase by 2 to 6°C over the coming century. Temperature increases will continue to melt glaciers throughout the world as well as increase the rate of evaporation and precipitation, which will reduce water availability in many areas already facing potable water shortages. Melting glaciers and thermal expansion of sea water are expected to gradually increase sea levels and potentially damage cities, infrastructure, and populations worldwide. Rapid changes in temperature are also expected to significantly affect biological diversity and distribution, with as many as 20 to 50% of all species potentially facing extinction. While many species may be negatively impacted, others may thrive as a result of a warming climate; thus many scientists foresee expansion in the range of tropical diseases like malaria and dengue fever as a result of climate change.

In addition to these and other gradual changes, scientists are particularly worried about abrupt, non-linear changes resulting from increases in average global temperature. Key among these is the potential for rapid irreversible melting or collapse of the Greenland and West Antarctic ice sheets. In 2002, part of the Antarctic ice shelf known as Larsen B, an area over half the size of Prince Edward Island and 200 metres thick, collapsed into the ocean, likely as a result of warming temperatures. Although the direct effects from this “small” collapse were limited, a similar collapse of larger parts of the West Antarctic or Greenland ice sheets could catastrophically raise sea levels by over 1 metre this century and up to 12 metres over several centuries. Researchers have also examined the potential for dramatic changes in ocean circulation as a result of climate change. New evidence suggests that ocean circulation patterns can change very quickly (on the order of decades) and that this can dramatically alter land temperatures.

Although many impacts of climate change are expected to be felt most strongly in low-lying and developing countries, Canada is by no means immune from direct impacts. Temperature changes will likely be most significant at the Earth’s poles, which are predicted to warm at about double the average rate. A 4°C average global warming, near the central estimate for 2100, would therefore be expected to warm northern Canada by roughly 8°C. Obviously such a change would have dramatic effects on natural systems and human inhabitants of Canada’s north. Other parts of Canada would likely suffer from more prolonged water shortages and extreme weather events. Smog could be exacerbated due to higher temperatures in urban areas, and some pests like the mountain pine beetle could become endemic. Over

the long term, agriculture and forestry output would likely suffer, even though productivity could actually increase in the short term.

Because of the emissions that have already been released and because the greenhouse gases (GHG) that cause climate change stay in the atmosphere so long, the world may be committed to significant climate warming over the coming century (unless technological advances enable us to extract GHGs from the atmosphere). The Intergovernmental Panel on Climate Change (2007) reports that to stabilize emissions at 550 parts per million (ppm) – roughly double the earth's pre-industrial concentration, and the upper end of what most scientists consider acceptable – global GHG emissions have to reach their peak by 2020 to 2030 and decline quickly thereafter. With global emissions currently growing and with the rate of growth still increasing in step with rapid economic growth particularly in developing countries, a significant effort will be required by the global community to stabilize emissions at 550 ppm. Some economists project that such an effort will impose costs of 1-3% of gross world product (Stern, 2006).

Compounding the technical difficulty and high costs of action are the long timescale and global nature of climate change. While costs of climate change abatement are borne today by whatever party undertakes an action, most benefits of abatement are decades or even centuries in the future, and spread throughout the entire world. Seen in this light, climate change represents the ultimate public good problem, which explains the effort that has been invested into coordinating international action and also helps explain negligible progress by national governments in the absence of an effective and truly global agreement (the current Kyoto Protocol to the United Nations Framework Convention on Climate Change sets targets for 2008 to 2012 that do not include less developed countries).

Canada produces over 2% of global GHG emissions, more than all but six other countries in the world, and produces more emissions per capita than virtually any other country (UNFCCC, 2004; Marland, Boden, and Andres, 2006). Canada's emissions are also growing faster than most other industrialized countries; emissions grew by 27% between 1990 and 2004 (Canada, 2006), primarily as a result of an increasing population, economic growth, and growing fossil fuel production (Rivers and Jaccard, 2007). Since these are all expected to increase substantially over the coming decades, Canada's emissions will continue to rise quickly in the absence of strong policies to increase energy efficiency, switch to non-emitting fuels, and capture and store emissions resulting from continued fossil fuel production and use.¹

The challenge of dramatically changing the course of GHG emissions given growth in these factors is substantial. Politically, Canada is in the difficult situation of having jurisdiction over environmental problems ambiguously divided between the provinces and federal government. As an export-driven economy, Canada also faces pressure from businesses not to adopt environmental regulations that will place its companies at a competitive disadvantage compared to other commodity producers. And because of its cold climate and vast geography, reducing Canada's space heating and transportation emissions even to current European levels represents a formidable challenge (Bataille et al., 2007).

Despite these challenges, any international agreement designed to tackle climate change will certainly require substantial GHG reductions from Canada. If rich countries such as Canada do not take action, it will be impossible to convince poorer countries like China and India to take action. This paper therefore analyzes a scenario in which Canada reduces its domestic GHG emissions by about 60% from

¹ Changing agricultural, forestry, and land use practices can also help to reduce emissions, but we do not address these in this paper.

today's level by 2050. This level of reduction is roughly consistent with emission targets articulated by all of Canada's main political parties, with recent analysis conducted by the National Roundtable on the Environment and Economy, and with national targets set by the United Kingdom, Sweden, the European Union, California, and other jurisdictions. The objective of this paper is to describe a set of appropriate domestic policies for meeting this long-term goal of deep GHG reductions.

2. Description of appropriate policy response

2.1. Criteria for choosing climate change policies

Climate change policy must provide strong long-run signals to motivate technological innovators, companies, and consumers, while avoiding unnecessary economic costs (Jaccard, Nyboer, and Sadownik, 2001). The relative emphasis on certain policy tools to achieve this end, and the ultimate design of a policy package, involves many considerations and tradeoffs. For instance, what may be most economically efficient or effective in realizing environmental benefits may be difficult from a standpoint of administrative feasibility or political acceptability.

Policy evaluation criteria have been forwarded in different contexts and by different organizations to assist environmental policy design (Canada, 2005; IPCC, 2001; Jaccard, Rivers, and Horne, 2004). In this paper, policies are evaluated based on the following criteria, which are common to most evaluative frameworks:

- **Effectiveness at Achieving Environmental Target**
 - To what extent will the measure will deliver its environmental objective? More specifically, how will the measure result in long-term sustainable reductions in GHG emissions in 2050?
 - Does the policy directly target the generation of GHG, or does it do so indirectly (i.e., through improving energy efficiency)?
- **Economic Efficiency**
 - To what extent will emission reductions be reached with the lowest economic costs, considered from the perspectives of the government administrator and the firms/households subject to the measure? This should include a realistic consideration of consumer preferences, which is often ignored in cost analyses.
- **Political Acceptability**
 - Will politicians find sufficient support to implement a policy?
 - Will Canada maintain the international competitiveness of industries producing goods that are traded in the international marketplace?
- **Administrative Feasibility**
 - Is the burden of administration, reporting, monitoring and enforcement at an acceptable level?

In addition to these criteria, there are other important considerations that should be considered in the context of GHG policy development in Canada.

First, policy development will evolve from the interests and rights of multiple players within the political system and their relative power or influence in shaping policy. In the Canadian context, this is particularly critical because of the multiple jurisdictions required to enact climate change policy (Bell et al., 2005). Of particular relevance is provincial jurisdiction over natural resources such as oil and gas, energy, mining, forestry and agriculture. A realistic assessment of policy must involve this dimension and should

include a consideration of the options available for developing buy-in and mitigating transitional impacts that may accompany policy implementation.

Second, while the focus of this article is on domestic policies, Canadian policies will be more effective if they are consistent with those of other countries and with international coordination mechanisms, with the relationship to developments in the US being especially important. While ambitious policies in Canada may be hampered by the absence of such efforts in the US, innovative policy design and careful target setting may be able to reduce the importance of this constraint.

Third, setting GHG policy is a classic case of decision-making under uncertainty and this reality should be embraced instead of ignored or used as an excuse for inaction. This means that policies should be selected based on how well they perform (their robustness) under highly variable outcomes and even highly variable reference cases. How might the economy evolve? What kind of international agreement might eventually follow Kyoto? What will the US do and how will its economy be affected? How will the pace and character of technological evolution change? How will our understanding of the costs and benefits of abating climate change evolve? Policies must be well positioned to incorporate unexpected technologies, to adapt to shifting targets, and to anticipate and mesh with international policy instruments. There is a high likelihood that policies developed today will need to be changed sometime in the future to accommodate an unexpected event or development and they should be designed with this in mind.

2.2. Description of policies in terms of their compulsoriness

Environmental policies should be chosen from the suite of available options based on their ability to satisfy each of these criteria. Policy options can be categorized in different ways. In this paper, policies are described in terms of their degree of compulsoriness, an important consideration because it expresses the extent to which a certain behaviour is required by government, which in turn helps determine the efficiency, effectiveness, and political acceptability of a policy. Policies that are non-compulsory involve government providing information or using moral suasion to encourage behaviour changes, while policies that are compulsory involve government mandating a particular choice or outcome, or using fiscal measures to change the market incentives facing businesses and consumers. The following survey of policy options starts with the most compulsory and progresses towards less compulsory policies. Each policy is briefly described and a discussion follows about how it performs relative to the policy evaluation criteria described in the previous section.

Command-and-control regulations are technology or performance standards enforced through stringent financial or legal penalties. This approach dominated environmental policy in the 1970s and is still important today, although economists critique regulations on the grounds of economic efficiency (Hausman and Joskow, 1982). In particular, regulations can be costly where they require identical equipment choices or management practices by participants whose costs of emissions reduction differ considerably (Newell and Stavins, 2003), and regulations provide no incentive for companies or individuals to find emissions reductions beyond the legal requirement (Millman and Prince, 1989). This traditional regulatory approach is therefore not ideal for stimulating large emissions reductions throughout the economy. Regulations that eliminate a subset of equipment choices may be justified where information or search costs are particularly high, and research has found that application of this type of regulation can lead to net benefits to consumers and society in certain situations (Moxnes, 2004). Regulations are often used to address market conditions associated with a lack of information; for example over 50 countries, including Canada, use

appliance efficiency standards that are periodically reviewed to account for new technological developments (Nadel, 2002).

Market-oriented regulations set an aggregate regulatory requirement on the entire economy or on a sector of the economy. Unlike traditional command-and-control regulations however, this policy approach allows individual participants to choose whether they will take actions or whether they will instead pay others to take actions on their behalf. This negotiation is conducted through a permit or certificate market, and can result in an economically efficient outcome if the permit market works smoothly. Two general types of market-oriented regulations can be distinguished based on the breadth of the policy and the focus of the regulation:

- **Emission cap and permit trading** was first proposed as an environmental policy instrument in the 1960s and has recently been used in several countries for control of local air pollutants, greenhouse gas, and other pollutants (Stavins, 2001). An emission trading system sets an aggregate cap on emissions from a sector or multiple sectors of the economy, and allocates tradable emission permits to all emitters covered by the program. The total number of permits allocated to emitters is equal to the overall cap on emissions. Permits are allocated by government either using an auction or through free distribution to emitters.² At the end of each period (usually a year), each emitter must remit permits to the government sufficient to cover all GHG emissions emitted during the year. Permits can be traded from one emitter to another (and in some designs, can be purchased from entities outside the covered sectors), which should result in cost effective emissions reductions provided transaction costs are not prohibitively high and the market functions well.

Emission cap and trading schemes are a form of regulation in that the aggregate emissions cap cannot be exceeded, participation is compulsory, and penalties for non-compliance are severe. Unlike traditional command-and-control regulations, however, the policy allows participants to determine their level of emissions and whether they will buy or sell in the emission permit market. In theory, emission trading should result in exactly the same cost as a GHG tax for a given level of emissions reductions. In practice, emission trading guarantees a certain amount of emissions, while costs are uncertain – in contrast to a GHG tax, which guarantees a certain maximum cost, while the level of emission reduction is uncertain. Like a tax, a GHG emission trading system that focuses on CO₂ emissions from the fossil fuel industry can be applied upstream on fossil fuel producers according to the carbon in the fuels they produce or downstream on CO₂ emissions at the point of end-use technologies.

- An **obligation and certificate trading** system sets an aggregate obligation for a sector of the economy to produce a minimum amount of some desirable good – for example a low-GHG technology like a zero-emission vehicle or a process that captures and stores carbon. Certificates are allocated to firms for units of the desirable good or process that are produced in each period. Certificates are tradable between firms, and the system can be designed to allow certificates to be banked for use in a future period, or borrowed from a future period for use in the present; a safety valve can also be integrated to allow

² Economists that study emission trading systems generally favour distribution of at least some of the permits by auction as opposed to 100% free allocation, since an auction system reduces windfall profits to particular firms, reduces barriers to entry, and reduces opportunities for gaming (Grubb and Neuhoff, 2006).

unlimited certificate purchases from government at a certain price, thereby ensuring an upper limit for the cost of this policy. At the end of each period, each firm must remit enough certificates to government to meet its obligation. This approach to environmental policy is very similar to an emission cap and tradable permit system, except while the emission cap and trade regulates a maximum amount of an undesirable product (emissions), an obligation and certificate trading system requires a minimum amount of a desired product or process.

Examples of the obligation and certificate trading approach include the California vehicle emission standard, which specifies a minimum aggregate level of zero- and low-emission vehicles in the California vehicle fleet, but allows vehicle manufacturers to trade certificates amongst themselves in meeting the targets. Similarly, renewable portfolio standards for electricity, which exist in Australia, many European countries and about half the states in the US, require a minimum market share for certain forms of renewable energy production, and allow trading between electricity generators to achieve the aggregate outcome. While both the emission cap and trade and the obligation and certificate trading system should cost-effectively meet their goal because of the flexibility resulting from trading provisions, there are notable differences between the two systems. First, while an emission cap and trade system allocates emission permits to emitters at the beginning of each period in correspondence to the emissions cap, no certificates are allocated to firms in an obligation and certificate trading system (certificates are generated by firms when they produce a unit of the desirable good or process). Consequently, the obligation and certificate system avoids the politically sensitive issue of permit allocation, which can stall the implementation of an emission cap and trade system. However, it also means that revenue is not generated for government through permit auction, which reduces potential government revenue, but may improve political acceptability. Second, while the emission cap and trade system focuses on emissions, the obligation and certificate system can focus on other targets. If the policy objective is emissions reductions, this may be less effective, but may also more effectively target market failures and barriers in particular markets.

GHG taxes require domestic emitters to pay a fixed fee per unit of GHG (carbon dioxide equivalent – CO₂) released to the atmosphere. The emitter's response to the tax is to either pay the fee or reduce emissions to avoid payment. In this sense, a GHG tax is not as compulsory as a regulation because it does not specify a particular action; the business or consumer chooses between taking no action to reduce emissions or reducing emissions. In theory, emitters will reduce emissions up to the point where the marginal abatement cost is equal to the tax. Since every emitter covered by the tax faces a uniform fee per tonne of CO₂, a tax system theoretically results in the lowest cost to the economy for a given level of emissions reduction (Baumol and Oates, 1988). An emission tax, unlike emissions trading, does not guarantee a particular level of emissions because emitters have flexibility to pay the tax or to reduce emissions (Weitzman, 1974). As a result, it will likely be necessary to adjust the level of the tax to meet a given emissions target. A key economic advantage of GHG taxes is that they limit costs by allowing overall emissions to rise if abatement costs are higher than expected. GHG taxes can be applied upstream (on producers and importers of fossil fuels and other GHG) or downstream (on final consumers of fossil fuels that produce emissions). GHG taxes raise revenue for the government, which government can use to offset other taxes, transfer to other regions or governments, increase spending, or pay back in lump sum to emitters. If government uses GHG tax revenue to offset other taxes that distort the economy (e.g., income taxes, corporate taxes), there is potential that the economy could benefit while GHGs are reduced. GHG taxes (and other green tax

variations such as environmentally-motivated energy taxes) have been instituted in a number of European countries and are considered, for example, to have played a role in the development of carbon capture and storage technologies in Norway. In practice, tax design has used included refunds of taxes to vulnerable industries, differentials in the tax rates applied to industry and households, and exemptions to address equity and competitiveness concerns. Although GHG taxes are considered by most economists to be the optimal policy for deep GHG reductions in terms of economic efficiency, the public in Canada has to date been reluctant to consider new taxes (although there has been little opportunity for real public debate on GHG taxes). Even propositions to impose a revenue-neutral GHG tax, in which revenue from the GHG tax would be used to offset other taxes have been successfully portrayed by opponents as attempts by government to increase the overall tax burden (Svendson, Daugbjerg, and Pederson, 2001).

Subsidies, such as rebates, grants, low-interest loans, and tax credits, improve financial returns to businesses and consumers who take specified actions to reduce emissions. While this approach appears non-compulsory, governments generally acquire their funds from various types of compulsory taxes. As a result, while subsidies to low-emission technologies can influence behaviour of consumers and businesses, governments generally lack the financial resources to induce large changes in GHG emissions through this method alone. Also, it is difficult to design subsidy programs to exclude free-riders – participants who qualify for the subsidy even though they would have undertaken the action anyway. When free-rider effects are calculated, some subsidy programs are a lot less effective and thus a lot more expensive than anticipated (Loughran and Kulick, 2004). Finally, subsidies do nothing to discourage the development and dissemination of new technologies and products that emit GHGs, so this approach cannot be successful by itself.

Voluntary programs, based on labelling and other forms of information provision, moral suasion, and voluntary agreements, allow individual companies and consumers to determine their own level of effort for environmental protection, and cast government in the role of information provider, facilitator, role model, and award giver. Voluntary programs for GHG reduction and energy efficiency have formed a major part of past policy efforts, with programs directed at public outreach, industry energy efficiency, and information provision to consumers and businesses. However, while the use of voluntary programs has been widespread and while participating industry offers much anecdotal evidence of voluntary actions to improve the environment, it is difficult to estimate the aggregate effect of such programs (IPCC, 2001; Harrison, 1999). Recent empirical reviews of voluntary programs suggest that both their environmental effectiveness and their economic efficiency are poor (OECD, 2003).

2.3. Using the criteria to choose policies from the menu

Each of these policies performs differently compared to the criteria listed above. While no policy performs perfectly against all criteria, some do better against the suite of criteria than others. In developing GHG policy for Canada, it is important to choose policies that do not fare badly against any single evaluation criterion.

In this vein, voluntary policies in general do not satisfy the environmental effectiveness criterion. Significant research has been conducted to determine the cost of deep GHG reductions, both in Canada and internationally (EIA, 1998; MKJA, 2003). Most peer-reviewed models predict long-run marginal costs of at least CDN\$100/t CO₂ for deep emissions reductions: a substantial cost. Because of the high cost, it is

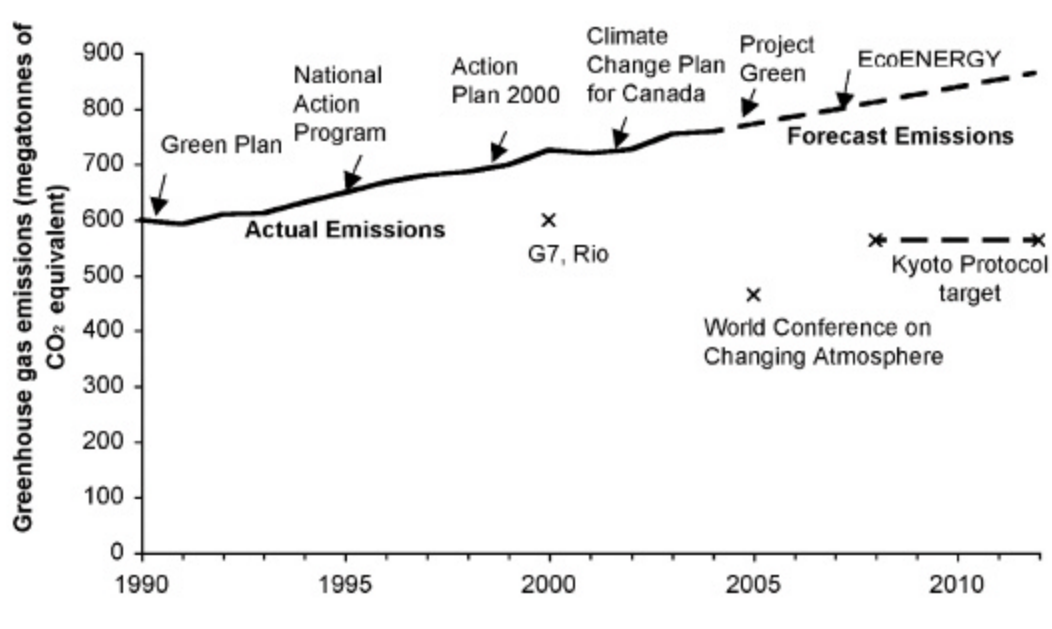
extremely unlikely that businesses and consumers will voluntarily reduce emissions on a large scale, even with government provision of information, education, or moral suasion (Jaccard and Bataille, 2003).

Even for small GHG reductions, voluntary policy may be relatively ineffective, based on evidence from international experience and within Canada. For example, the Voluntary Challenge and Registry that was used in Canada in the 1990s to encourage businesses to reduce GHG emissions has been criticized as being ineffective (Bramley, 2002; Takahashi et al., 2001). In Europe, the European Union negotiated a modest voluntary agreement with automobile manufacturers, which are now falling short of their commitment (OECD, 2005).

Like voluntary policies, subsidies are inappropriate for achieving deep GHG reductions. First, it is impossible to exclude free-riders from a subsidy program, and these can often represent more than 60% of total subsidy recipients (Loughran and Kulick, 2004). Cost effectiveness is further compromised by the presence of the rebound effect. By making a service cheaper, subsidies encourage increased consumption, which can offset some of the energy efficiency gains (Greening, Greene, and Difiglio, 2000). Subsidies to energy efficient or low emission technologies also fail to curtail the development of new technologies, products, and services that produce GHG emissions. New products and services in the economy are developing at an accelerating rate. Finally, a subsidy approach generally places government in the position of choosing specific technologies to support; most analysis suggests that governments have a poor track record in this.

Canada's GHG policy approach thus far has been dominated by voluntarism and subsidies, an approach that while politically attractive has been largely ineffective at stemming the rising tide of fossil fuel exploitation in Canada and the growing consumption of fossil fuel products (natural gas, gasoline, diesel, jet fuel, heating oil) that emit GHGs. Figure 1 matches the evolution of Canada's emissions since 1990 with the voluntary and subsidy policy initiatives launched by a succession of Canadian governments, including the most recent EcoEnergy initiative of the Conservative government. Independent research suggests that the past policies had little or no effect and it is obvious from the figure that they did not lead to declining emissions. The figure also shows the targeted emission levels that Canadian governments were trying to achieve with their policies. An important lesson is that government statements about emissions targets are not credible if they are not accompanied by policies that have a high probability of being effective in reducing emissions, namely policies that include substantial financial penalties or regulatory constraints on emissions.

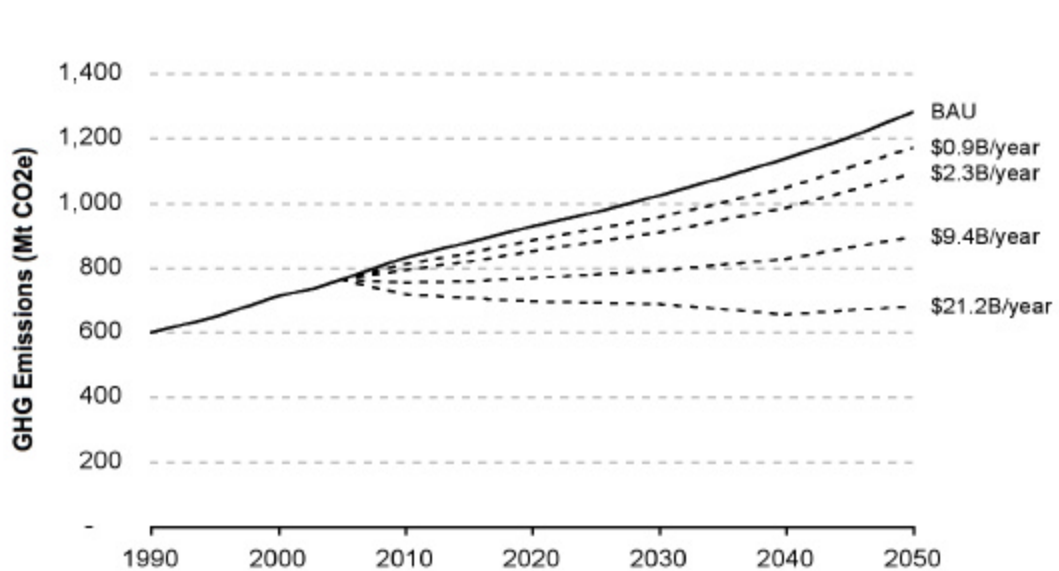
Figure 1: Canadian Targets, Policies and Emissions: 1990 - 2007



In order to assess the likely effect on emissions of a continued reliance on the voluntary approach, we used the CIMS energy-economy model to simulate rising subsidy levels for GHG emissions reductions actions across the Canadian economy. This is a model that uses empirical estimates of how firms and households respond to the financial costs, risks and qualitative attributes of technology options for energy services. Subsidies reduce financial costs of low emission technologies, which should reduce emissions. But, as noted, there are important countervailing effects. First, much of the subsidies are captured by free riders. Second, efficient technologies have lower operating costs, which can cause some increase (rebound) in the demand for certain energy services and, more generally, a long-term development of energy using devices whose proliferation is in part stimulated by the gains in energy productivity from the subsidy programs.

The parameters in the CIMS model are estimated from empirical research assessing 25 years of government and energy utility subsidy programs in North America, including estimating free-riders. Figure 2 provides the simulation of ever higher subsidy levels on GHG emissions in the Canadian economy over the 45-year period from 2005-2050. The simulation shows that even with a massive annual expenditure of \$21.2 billion dollars (\$1995), Canadian emissions are unlikely to fall below their 1990 levels by 2050. Even this level of reduction might not be achieved since the simulation does not include a full estimate of the development and penetration of new energy using and GHG-emitting technologies and services like backyard patio heaters and roof de-icers. Yet this is a likely development in the absence of emission caps, GHG taxes or regulatory prohibition of these technologies, especially as subsidy programs improve the rate of energy productivity innovations.

Figure 2: Projected GHG Reductions in Canada Resulting from a Subsidy Approach



The solid line shows projected business as usual greenhouse gas emissions in Canada. The dashed lines show projected GHG emissions corresponding to different levels of government subsidy for emissions reductions. Calculations were performed using the CIMS energy economy model. Monetary values are presented in CDN\$1995, and costs are discounted using a social discount rate of 7%.

In designing our set of three key policies to meet the terms of this policy exercise for the Institute for Research on Public Policy, we therefore exclude voluntary and subsidy policies as being largely ineffective.³ We also rely only to a minor extent on traditional command-and-control regulations as these would prove administratively infeasible and economically inefficient when applied to a myriad of technologies across the economy. By specifying particular technologies and processes for all firms or consumers whose cost of abatement and preferences differ significantly, government imposes large costs on some consumers, which can significantly reduce the political acceptability and increase the cost of command-and-control regulations. In addition, specifying regulatory standards for thousands of products throughout the economy is an enormous administrative task. Finally, command-and-control regulations provide little incentive for firms to develop innovative new technologies with dramatically lower GHG emissions, which will be critical in the future.

Although traditional command-and-control regulations are not appropriate as the dominant policy approach for dramatic GHG reductions throughout the economy, some of these regulations can be cost effective, administratively feasible, and politically acceptable when they are used to consolidate gains that are achieved through other policies (Moxnes, 2004). As a result, they play a minor role in the policy package described below.

³ Subsidies could be used as a complementary measure to a limited extent to help fund key public infrastructure, for building retrofits (particularly for low-income households), and possibly for research and development. Because of the scope of this paper, we do not provide a discussion of these policies, which are less important to GHG emissions than the ones covered in the paper.

The policy approaches that perform best in terms of effectiveness and economic efficiency are ones that prohibit or financially penalize technologies and activities that emit GHGs. In other words, the only hope for substantially reducing GHG emissions in a market economy is to ensure that the atmosphere can no longer be treated as a free waste receptacle. The atmosphere must be valued. The policy options of interest therefore are either GHG taxes or market-oriented regulations on emissions, technologies and processes that force reductions in GHG emitting activity.

There are many design options for these policy approaches. A GHG or carbon tax could be applied at the point of emissions. Greenhouse gas emissions from both large and dispersed sources can be accurately estimated based on the amount of fossil fuels consumed, since there is a direct chemical relationship between the amount and type of fuel and the greenhouse gas emissions released when it is burned. Instead of the carbon tax, an emissions cap and tradable permit system can be applied to the emissions of large industries and energy supply facilities like oil refineries, thermal electricity generating stations and natural gas processing plants. This, in effect, is the “large final emitters” policy that Canada’s previous Liberal government tried to negotiate for almost 10 years and which the subsequent Conservative government resurrected in 2007 as proposed new air emission regulations for industry. Since large final emitters represent about 50% of Canadian GHG emissions, a cap and trade policy for these industries begs the question of how to provide the equivalent financial or regulatory signal to smaller emitters in light industry, the commercial sector, the residential sector and transportation. One option is a GHG tax for smaller emission sources. Again, it would be fairly easy to link a tax to the carbon content in fuels used in smaller devices. And possibly, the cap and trade system might be extended to all energy-related carbon emissions and perhaps even to other non-energy GHG emissions. Yet another way to apply the cap and trade approach is to apply a cap on the carbon content in fuels used by and produced by the fossil fuel industry. This is referred to as “upstream cap and trade” in that the regulatory constraint is applied to the upstream components of the fossil fuel industry. The advantage of this approach is that the costs of constraining carbon flows are passed down through the economy, so that the cap and trade system simultaneously affects large final emitters and all smaller emitters. This means, however, that the price of fossil fuel products would rise, just as they would with the carbon tax. This poses political acceptability challenges.

Although these policies can cover all energy-related GHG emissions in Canada, there is evidence that the political acceptability (and perhaps even economic efficiency) of such a profound long-term technological transformation could be improved if these economy-wide policies were complemented with sector-specific, market-oriented regulations to support the development of key technologies, energy forms and processes that will need to be commercially-available as businesses and consumers are confronted with rising costs for GHG emissions. There is also evidence that even some well-designed command-and-control regulations can improve consumer welfare in some circumstances.

Finally, another objective in policy design is to ensure that the policy does not force premature retirement of existing infrastructure, buildings and equipment as this would expose firms and individuals to substantial costs (Jaccard and Rivers, 2006). To minimize these costs, policies should be designed in a way that provides the correct long-run signals to stimulate low-GHG innovations and technology adoption without significantly changing the operating costs of buildings and equipment that are likely to be renewed in any case over the coming decades.

3. Our proposed policies and their simulated impacts

While other policy packages could certainly also be effective, we believe that the package we present below best satisfies the criteria outlined above. It involves only three key policies: a carbon management standard that is very similar to the upstream cap and trade approach, a vehicle emissions standard, and a limited application of appliance and building regulations. We describe each in some detail, including simulation of its impact on emissions.

3.1. Carbon management standard for fossil fuel producers and importers

The central policy requirement is an economy-wide instrument that imposes on GHG emissions a financial charge (a GHG tax) or a regulatory constraint (a market-oriented regulation). While the options for this have their pros and cons, our position is that it is more important to emphasize the need for at least one of these than to argue excessively about the relative superiority of one or the other policy. Canadian policy makers still do not appear to have learned this lesson, in spite of all the evidence of past policy failures. Both the recent Liberal federal government (and now while in opposition) and the current Conservative federal government presume the imposition of some form of emissions cap and trade regulations on large industrial and electricity generation sources, but neither is considering effective and efficient market-based mechanisms like GHG taxes or cap-and-trade for the remaining 50% of emissions in the economy. And the cap and trade policies have numerous loopholes which allow industries to do something other than reduce emissions.

We believe that a GHG tax is the best policy for environmental effectiveness and economic efficiency. So this is our default policy recommendation. However, economists have been suggesting GHG taxes for 15 years in North America with absolutely no success and meanwhile emissions keep rising. If a carbon tax is simply unacceptable for political reasons, then some form of market-oriented regulation can be designed that approximates the environmental and economic effects of a GHG tax. Therefore, this is what we focus on in this proposal.

While major effort has been expended on trying to establish a large final emitters cap and trade system over the last 8 years, an effective market-oriented GHG regulation has yet to be implemented in Canada. In April of 2007, the Conservatives proposed yet another version of the large final emitters regulation, but this latest incarnation contains several so-called “flexibility mechanisms” that allow industries to do something other than actually reduce their emissions. The policy includes opportunities to pay into a technology fund (that may or may not succeed in lowering the cost of future emission reductions), subsidize unregulated emitters to reduce their emissions (an offsets program) and subsidize emission reductions in other countries using flexibility mechanisms of the Kyoto Protocol. It is our assessment that the flexibility mechanisms in the initial Liberal version and the subsequent Conservative version of the large final emitters policy will severely limit the amount of emission reduction that occurs in Canada. Industry will look to emission reduction actions elsewhere in the economy if these are the cheaper option. These reductions may appear cheaper, but given that they rely on subsidies (from regulated firms to actions in transportation, agriculture, forestry, residences and offices), they are subject to the same ineffectiveness challenges that we have already described for subsidy programs.

For these and other reasons, our key policy proposal is a variant on the upstream emission cap and trade policy – with a wrinkle. Our policy borrows from the philosophy of other obligation and certificate

trading programs such as the vehicle emission standard and the renewable portfolio standard. We call this policy a carbon management standard.

Our carbon management standard is a form of market-oriented regulation that would require fossil fuel producers and importers to ensure that a growing fraction of the carbon they extract from the earth's crust does not reach the atmosphere.⁴ This obligation would rise over time according to a preset schedule that allows the economy enough time to adopt the required technologies to achieve the standard. It would apply to fossil fuel producers and importers, and would likely be based on measures and estimates from oil, gas and coal extraction activities, as well as directly on importers when their fossil fuel-based product enters Canada.⁵ (Fossil fuel exporters could receive partial exemptions from the obligation for exported carbon in order to limit the impacts on their international competitiveness.)

The carbon management standard is different from an upstream cap and trade system in that it sets an obligation for a growing share of processed carbon to be captured and safely stored, whereas a conventional cap and trade system on fossil fuel producers sets a cap on the overall amount of carbon-based fuels they can sell. Rather than allocating permits to emitters in accordance with the cap, government collects certificates from firms that must match their aggregate obligation. At the end of each year, each producer and importer of fossil fuels would be required to remit certificates to government in accordance with its overall obligation to ensure that a percentage of the carbon it extracted from the earth is permanently stored. Substantial financial penalties would be levied on firms that failed to comply with the system. Firms participating in the system would be able to trade certificates amongst themselves in an established market. For increased efficiency, the system should allow firms to bank certificates acquired in one period for use in a future period and borrow from future time periods for use in the present.⁶

By using this obligation and certificate approach rather than the conventional cap and permit approach, government avoids politically and economically complex negotiations over initial permit allocation. Unlike a carbon tax, the policy generates no revenue for government, thereby increasing its political acceptability when compared with the tax approach. But like the "upstream" cap and trade system, the policy covers all carbon flows in the economy. There are no loopholes that allow regulated entities to subsidize unregulated entities; all carbon emissions in the economy are covered by the policy.

⁴ Other GHGs could also be covered with the carbon management standard, including HFCs, PFCs, and sulphur hexafluoride (SF₆), by using a project-based approach, in which projects proving emissions reductions would be allocated certificates by government that could then be sold into the certificate market. In total about 80-90% of total Canadian GHG emissions could be covered by the carbon management standard, depending on how effectively fugitive emissions from the upstream oil and gas sector and other key sectors were addressed.

⁵ Applying the carbon management standard at bulk collection and shipment points would be less economically desirable than applying the system at the wellhead, since a significant and rising amount of fugitive emissions (about 70 Mt in 2004) are released at wellhead and would be outside the scope of the system. However, because of the large number of oil and gas wells (over 100,000 in Canada and increasing) and because of the difficulty in measuring fugitive emissions, it would be administratively more feasible to apply the system at bulk collection and transshipment points. Firms undertaking verified emissions reductions upstream of the carbon management standard certificate requirement points could receive certificates that could be sold to firms directly regulated carbon management standard. For a discussion of the point of application of an upstream system in Canada, see NRTEE (1999).

⁶ Borrowing of permits/certificates is contentious and requires a credible institutional arrangement to ensure future permit/certificate deficits are not forgiven by the regulator. However, borrowing of certificates is likely to significantly lower costs of compliance (Richels and Edmonds, 1995).

Table 1 presents the carbon management standard in terms of the percentage of total carbon that must be prevented from entering the atmosphere. Being stipulated in percentage terms, this means that the carbon management standard functions in part like an intensity target. Rapid growth of the fossil fuel industry could offset in whole or in part the fact that a growing percentage of the carbon it processes is captured and stored. Only when the standard reaches closer to 100% would its effect be closer to that of an absolute cap.

Table 1: Design of carbon management standard for fossil fuel producers and importers

	2010	2011- 2015	2016- 2020	2021- 2025	2026- 2030	2031- 2035	2036- 2040	2041- 2045	2046- 2050
Zero-emission GHG Requirement (%)	0%	6%	11%	17%	25%	34%	43%	52%	56%

Using the numbers of Table 1 as an example, consider a coal mining company that extracts 1,000 tonnes of coal per year. In each of the years 2011-2015 it must remit to government certificates to indicate that 6% of the carbon in the coal it produces will never reach the atmosphere. (If the coal were pure carbon, the certificates would be for 60 tonnes of carbon.) It can get these certificates by capturing itself some or all of the carbon as a solid or as CO₂ gas. More likely, it would purchase certificates from a coal-fired electricity plant, an industry that uses coal for thermal purposes, or perhaps a coal-to-hydrogen gasification plant in future. These latter industrial activities are likely to have lower costs for capturing the carbon in solid or gaseous form and then for permanently storing it. In any case, if the costs of capturing carbon are high relative to energy efficiency and fuel switching alternatives (to nuclear or renewables), then the coal mining industry will gradually lose market share over the coming decades. Society will have gradually determined that shifting away from fossil fuels is cheaper than using fossil fuels without emissions. More likely, the outcome will vary depending on the resource endowments of each particular region.

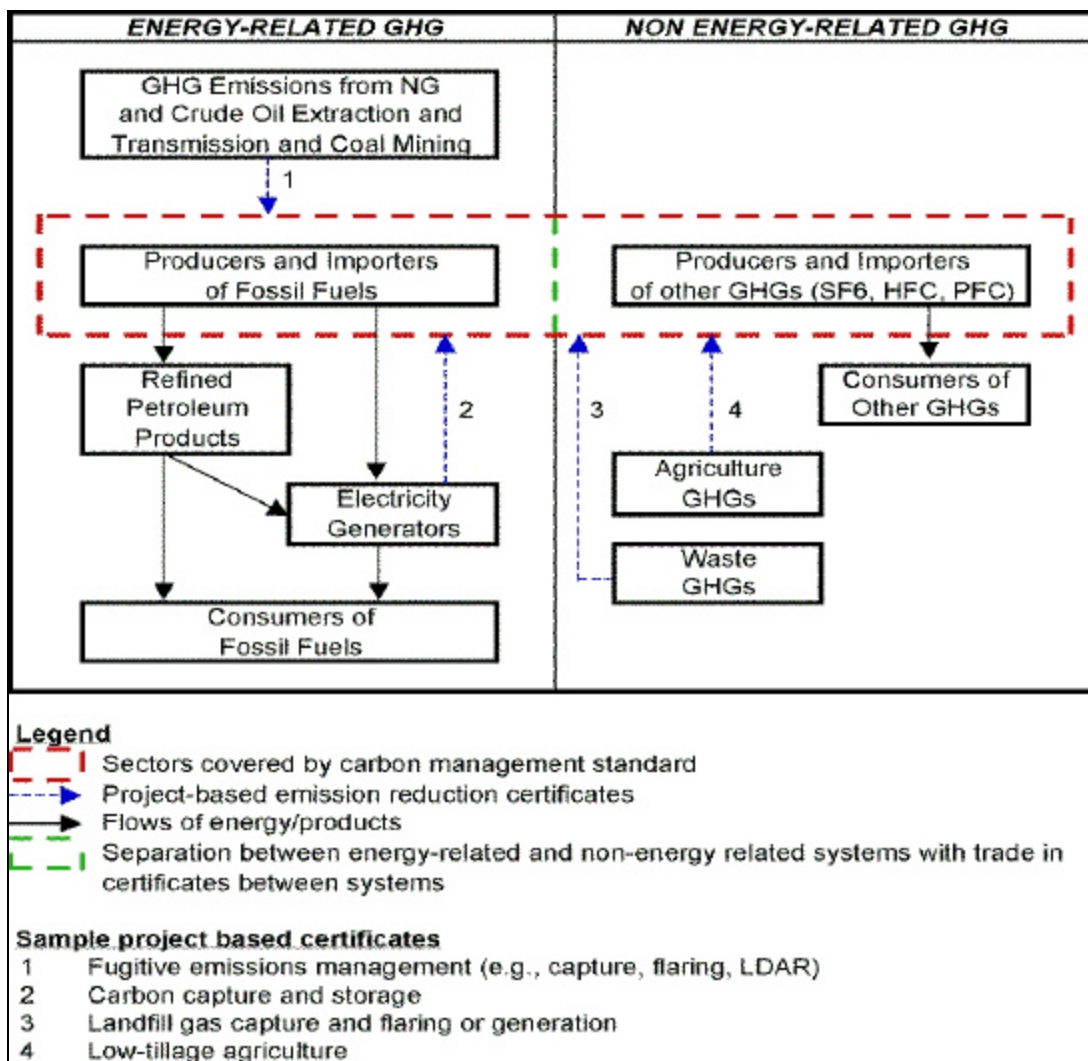
The carbon management standard would cover all carbon contained in fossil fuels, and could also directly cover emissions of HFC, SF₆, and PFC on the basis of their equivalent global warming potential (the values presented in Table 1 would change if these gases were included). The system could also allow non-covered sources to sell project-based certificates to firms directly covered by the carbon management standard. Potential projects would include carbon capture and storage projects throughout the economy, as well as projects to reduce fugitive emissions from oil and gas wells, and reduce methane emissions from coalmines and the agricultural sector. Projects would need to be certified through government or third-party audits, and certificates could be marketed through a central emissions exchange. Figure 3 shows the basic design features of the carbon management standard.

Careful design of the carbon management standard, including incorporation of a safety valve, monitoring, and certificate banking and borrowing, is critical if the policy is to function effectively and efficiently.⁷ We do not address these issues in detail, but significant experience with design issues for

⁷ The safety valve is a guarantee by government to sell an unlimited number of permits or certificates at a predetermined price, to ensure that market prices for permits or certificates never exceed that price. The safety valve can be used in a cap and tradable

economy-wide market-oriented regulations is available to draw upon through the Emissions Trading Scheme of the European Union, the SO₂ trading provisions under US Clean Air Act, the California RECLAIM program for NO_x and SO₂ emissions, the phase-out of lead from gasoline, and many other programs. In addition, there is a large theoretical and applied treatment of emission trading programs in the economics literature. As discussed above, the carbon management standard shares many similarities with an emissions cap and trading system applied to fossil fuel producers.

Figure 3: Design of Carbon Management Standard



permit system or an obligation and tradable certificate system to limit the exposure to very high abatement costs by sectors affected by the policy.

3.2. Zero-emission vehicle standard for vehicle manufacturers

A vehicle emission standard (VES) is an obligation and certificate trading system that requires vehicle manufacturers and importers to sell a minimum number of zero-emission vehicles by a target date as a percentage of total vehicle sales. This market share percentage grows over time, thus creating and expanding an artificial niche market for low or zero-emission vehicles. The goal is for production of the vehicles to reach a critical threshold where their costs of production fall significantly and consumer acceptance is widespread. A VES therefore accelerates the process of developing, commercializing, and disseminating low emission vehicles, while letting industry pick the specific technologies that will meet the emission criteria in accordance with customer preferences. A per-vehicle penalty is charged to manufacturers who do not sell the required number of zero-emission vehicles, but manufacturers can trade amongst themselves to meet the overall target. A VES is therefore designed to give manufacturers significant flexibility in meeting the aggregate market outcome, while bringing down the cost of innovative low emission vehicles.

Development of zero-emission vehicles is critical for generating deep GHG reductions over a long time period. Incremental price signals, as generated by the carbon management standard, are unlikely to quickly stimulate demand for zero-emission vehicles. The VES policy is designed to create a market for zero-emission secondary sources of energy in the transportation sector, namely electricity and hydrogen as well as biofuels like ethanol, methanol and biodiesel. The VES ensures that vehicles with engine platforms that use these sources of energy are available to consumers as a policy like the carbon management standard gradually increases the cost of using fossil fuel based fuels, like gasoline and diesel, to power vehicles.

California has had a VES in place since 1990, called the Zero-emission Vehicle (ZEV) program. As part of the state's larger Low Emission Vehicles (LEV and LEV II) programs to reduce smog-causing emissions, the ZEV program aimed to commercialize vehicles with zero exhaust emissions under all operating conditions (a vehicle with zero local air emissions would also have zero GHG emissions at the point of end-use). Although the California program has been amended several times and has faced legal challenges from vehicle manufacturers, the ZEV requirements still exist, and have been increased for future years, rising to 16% of new vehicle sales by 2018 (CARB, 2003). Because a VES is already in place in California, as well as a number of other north-eastern US states that automatically adopt California's regulations, the introduction of a Canadian VES should not cause competitiveness problems with the US. California, New York, Massachusetts, and Vermont alone represented 18% of the US auto market in 2000, and vehicle manufacturers are already required to produce low and zero-emission vehicles to meet VES in those states (Larrue, 2003).

Based on our simulations with the CIMS model, a schedule for specific requirements under the VES is presented in Table 2. For the policy that was simulated here, an aggregate target was set for vehicle manufacturers; in practice, government may distinguish between different classes of vehicles (e.g., cars, light trucks) in setting the standard. The VES could also be designed to allow manufacturers of low emission vehicles to qualify for partial ZEV credits. This is done in California where exceedences of the Ultra-Low vehicle requirements are granted partial VES credit. The VES designed and modelled in this report only applies to passenger transportation because of experience with passenger transport VES in the US; in a comprehensive policy approach, it should also be applied to freight transportation, especially since zero-emission freight transportation vehicles may be more easily achieved in the medium-term (Keith and Farrell, 2003).

Table 2: Design of zero-emission vehicle standard

	2010	2015	2020	2025	2030	2035	2040	2045	2050
ZEV percentage in sales	0%	1%	5%	10%	20%	35%	50%	65%	80%

3.3. Residential and commercial building codes and appliance and equipment standards

The application of the carbon management standard will result in relative price increases for carbon-intensive energy forms which in turn will motivate more efficient buildings and equipment, as well as fuel switching to cleaner energy for end-uses in the residential and commercial sectors. However, the existence of split incentives in rental housing and many commercial buildings (a separation between those who pay the investment costs of efficiency improvements and those who would receive the operating cost benefits via lower energy costs) as well as incomplete information in consumer decision making provide the rationale for a more targeted approach to improving energy efficiency and reducing emissions.

The most cost-effective way to lower the GHG emissions in the building stock (through energy efficiency and fuel choice) is in design and construction, which strongly influences energy use in space heating, lighting, cooling, ventilation, and water heating, during the life of a building. Currently, Canadian provinces have a diversity of energy-related requirements in their buildings codes, with some of these quite lax.

In our policy proposal, new buildings are required to meet strengthened performance standards, either in terms of energy efficiency or GHG emissions. Both could be related to other 'green' building requirements.⁸ Standards would either eliminate the least energy efficient (or GHG intense) new buildings, or be set as an average standard to encourage a shift across the entire market. Flexibility mechanisms could also be used to set developer average sales standards, or to specify shares of sales that must meet a desired performance level, with trading between developers permitted to meet the requirement.

Table 3: Design of residential and commercial building code

	<i>% energy reduction in 2050 relative to current new building practices</i>
Residential Buildings	Apartments and Attached: 40% Single family detached: 35%
Commercial and Institutional Buildings	All Buildings: 55%

The federal government stipulates minimum energy performance standards under the Energy Efficiency Act for more than thirty products. Because standards restrict consumer choices, an important

⁸ In this regard, interest as grown in the LEED (Leadership in Energy and Environmental Design) rating system which ranks a building's environmental performance in different categories and awards points for achieving specific goals clearly outlined in each.

consideration in policy development is whether they lower consumer utility. However, if consumer research indicates that consumers would make different decisions with additional information, there can be a social benefit to eliminating the least energy-efficient products (Moxnes, 2004).

Canada has relatively strong efficiency standards for some equipment, for instance cooking appliances, commercial cooling equipment, fridges and freezers. However, based on standards that have been accepted in the European Union and Australia, there is substantial opportunity to achieve stronger standards in washing machines, dishwashers, and commercial lighting while still finding political acceptance. No mandatory standards have been introduced in relation to domestic electronic equipment and lighting. Energy consumption from the former has been growing considerably in Canada (and other countries), and there is some momentum internationally to develop limits for standby power use in small appliances.

Table 4 shows representative appliance and equipment efficiency standards that we propose for adoption over the next decades. The standards as presented will not drive technological change, since regulations are inefficient in that role, but will follow and consolidate changes pushed by market conditions.

Table 4: Design of equipment and appliance minimum energy performance standards

<i>Minimum Efficiency in 2050</i>	
Furnaces	AFUE 92
Gas water heaters	EF 0.86
Water fixtures	Low flow
Air conditioning	central: SEER 15.5; room: EER 10.8
Clothes washers	MEF 46
Freezers	efficiency improvement of 10% upright, 50% chest
Minor appliances	1 kW standby loss
Lighting	overall luminous efficiency: 6%

Note: AFUE is annual fuel utilization efficiency, EF is energy factor, SEER is seasonal energy efficiency rating, EER is energy efficiency rating, MEF is modified energy factor. Luminous efficiency refers to the percentage lighting flux in total power (Incandescent lighting is typically about 2-3%; Compact fluorescent lamps 7-9% and prototype LEDs 25%).

3.4. Projected results of policies

We used the CIMS energy-economy model to quantitatively estimate the effects of the policy package because it integrates three key dynamics: (1) it competes technologies to provide end-use services based on realistic consumer and firm decision making, (2) it integrates the energy demand and supply sides of the economy, and (3) it estimates changes in the demand for final goods and services based on changes in energy prices and costs of production (Bataille et al., 2007; Nyboer, 1997). CIMS also allows modelling of sector- and technology-specific policies, unlike more aggregated models.

In a business-as-usual simulation, CIMS projects that energy-related greenhouse gas emissions will rise from over 700 million tonnes (Mt) in 2010 to almost 1,200 Mt in 2050, an increase of 65% (Table

5).⁹ Much of the increase in emissions comes from the oil and gas industry, especially due to surging exports of crude oil from the oil sands. The transportation sector is also expected to grow significantly by 2050, primarily as a result of increased population and demand for mobility.

Table 5 also shows the projected emissions in Canada in 2050 resulting from the implementation of our policy package. A few sectors make major contributions to a 60% reduction of GHG emissions from Canada's 2010 levels. The electricity sector is highly responsive to GHG policy over the long-term; CIMS projects a reduction of almost 90% compared to 2010 emissions. This conclusion is similar to other analyses, and reflects the relatively lower cost opportunities for dramatic GHG reductions in the electricity sector. Oil and gas production is also quite responsive to aggressive GHG policy over the long-term. Emissions fall about fourfold compared to business as usual. Other sectors reduce emissions relatively less because the cost of emissions reduction in these sectors is somewhat higher.

Table 5: Business as usual and policy energy-related greenhouse gas emissions by sector, 2010 and 2050

	2010	2050 <i>business -as-usual</i>	2050 <i>policy</i>
Electricity Generation	127	178	23
Oil and Gas Production	176	325	117
Energy Intensive Industry	112	194	59
Non-Energy Intensive Industry	23	66	22
Residential	41	19	7
Transportation	193	272	95
Services	42	102	33
Total	713	1,157	357

All values in megatonnes of CO₂ equivalent

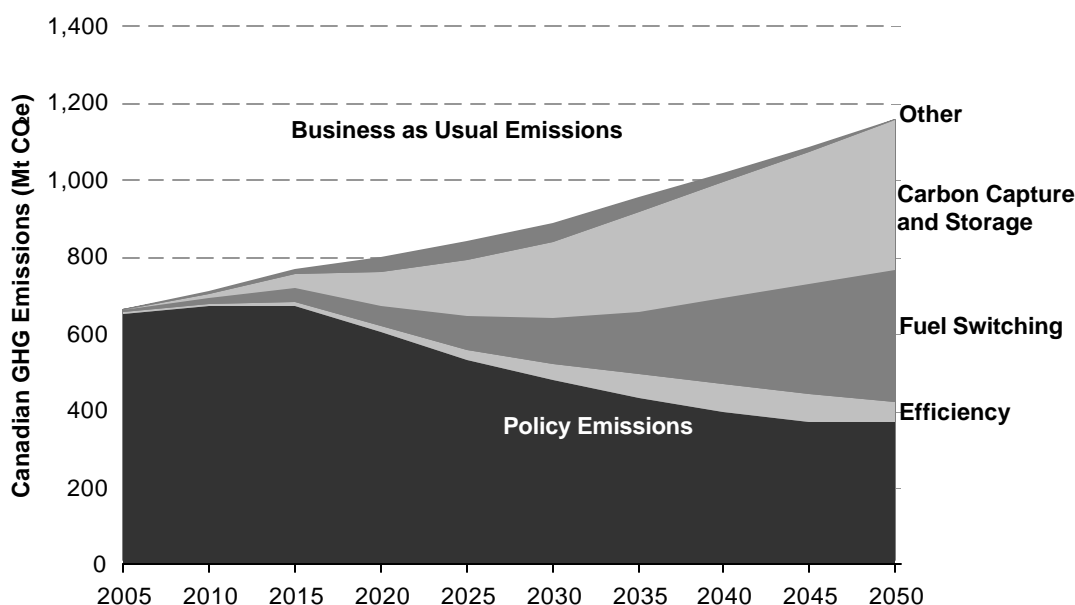
Note: Only energy-related GHG emissions are included in this figure; total GHG emissions are about 20-25% higher.

Figure 4 presents the results in the form of “wedges” of emissions reduction actions that occur under the policies but not under business-as-usual. While there are many actions, these can be assembled into three main categories and a fourth catch-all. GHG emissions will only fall because of (1) using less energy (efficiency and conservation) where fossil fuel use is substantial (which is the case in most locations), (2) switching away from fossil fuels to renewables and nuclear power, and (3) preventing emissions during the use of fossil fuels by implementing carbon capture and storage. The fourth action includes things like methane capture and use from landfills. Because the modelling conducted for this report only covers energy-related GHG emissions, actions related to afforestation and waste management are not included in the figure.

⁹ This report only considers energy-related emissions, thereby excluding emissions associated with agriculture, various kinds of urban and industrial wastes, and certain chemicals. Energy-related emissions represent just over 80% of total Canadian emissions.

It may seem surprising that the contribution of energy efficiency is small compared to fuel switching and carbon capture and storage. There are two reasons. First, when risk and consumer preferences are incorporated, energy efficiency can be more expensive than its advocates suggest. So its contribution is diminished in comparison to the other main options. Second, the figure shows “net” energy efficiency. Expanded use of oil sands and coal, on the one hand, and the extra energy needed for carbon capture and storage, will tend to increase energy use in the economy. The net effect is that much of the end-use energy efficiency is offset by declining energy efficiency in the energy supply industry.

Figure 4: Business as usual gas emissions and reductions due to policy package, 2005-2050



Note: The upper line shows projected business as usual GHG emissions (in the absence of policies specifically designed to control GHG emissions). The bottom line shows projected GHG emissions with application of the carbon management standard, vehicle emission standard, and appliance and equipment standards. The “wedges” between the two lines show emissions reductions actions resulting from the policies. Only energy-related emissions are shown.

Implementation of our three major GHG reduction policies will impose costs on the Canadian economy. Cost increases are highest by far in the industrial minerals sector, which has significant process-related GHG emissions that are hard to reduce. The pulp and paper sector and chemicals sector, both of which are energy-intensive, are also predicted to face increases in the cost of production. Other industrial sectors would face fairly minor cost increases.

The ability of firms to pass these cost increases through to consumers depends heavily on how exposed the sector is to international competition and whether other countries impose policies to curtail GHG emissions on a similar scale to the ones proposed here. For a sector that faces potentially large cost increases because emissions controls are expensive or impractical and which is exposed to competition from other countries (e.g., the industrial minerals sector), “leakage” of firms in the sector to other countries

is likely if Canada's GHG policy is much more aggressive than that of other countries and has no partial exemptions for the sector. If, however, Canada's trading partners impose GHG policies of similar stringency, costs are likely to be passed through to final consumers, and leakage of industrial activity to other countries should be minimal.

The economic impacts are also not distributed evenly by region. Although this is certainly not a prerequisite for cost-effective emission reduction, the federal government has made it a priority throughout the process of developing climate change policy that no regions should bear disproportionate costs of reducing emissions. To satisfy this self-imposed requirement, it would be necessary for the federal government to design compensatory mechanisms to at least partially share nationally the cost burden of GHG emissions reduction.

4. Conclusions

Climate change policy in Canada to date has failed because it has relied primarily on voluntary and subsidy policies, which although politically acceptable, are ineffective for producing substantial emissions reductions (Jaccard, Rivers, and Horne, 2004; Jaccard et al., 2006). In the absence of a dramatic shift in approach, it is very likely that GHG emissions in Canada will continue to grow quickly, especially as a result of the combined effects of population growth, economic growth, and growth in production of crude oil from Alberta's oil sands (Rivers and Jaccard, 2007).

This paper outlines three policies that could reverse the trend of growing GHG emissions in Canada. The main policy proposed is an economy-wide market-oriented regulation (which we call a carbon management standard), which sets an obligation for the fossil fuel industry to prevent a growing percentage of the carbon it processes from reaching the atmosphere, eventually leading to growing production of zero-emission forms of energy such as electricity and hydrogen. This policy is supplemented with a zero-emission vehicle standard that requires vehicle manufacturers to produce and sell a minimum amount of zero-emission vehicles as a percentage of total sales (eventually applied to other forms of transportation), and building and equipment standards, which require improvements in energy efficiency and emissions reduction in buildings throughout the economy.

We estimate that implementation of these three policies over a 45-year timeframe would reduce energy-related GHG emissions to 50-60% below current levels by 2050, a level of reduction that may be required of industrialized countries such as Canada if humanity is to avoid dangerous anthropogenic interference with the climate system. Along with substantial GHG reductions, these policies are certain to have economic impacts in terms of higher costs of energy services to households and firms, and some loss of industrial output if Canadian firms are hit harder than their international competitors. But careful policy design can reduce these impacts significantly.

One of the key attributes of the policy package is that it explicitly targets the penetration of zero-emission technologies through creation of artificial niche markets for these technologies (e.g., zero-emission vehicles, zero-emission fossil fuels), rather than just seeking incremental improvement in current practices. As a result, industry and consumers gain experience with these technologies without the imposition of large cost increases in the near term. Experience with these revolutionary technologies is expected to drive down costs in the longer term, making the pursuit of the dual goals of economic growth and environmental protection easier.

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