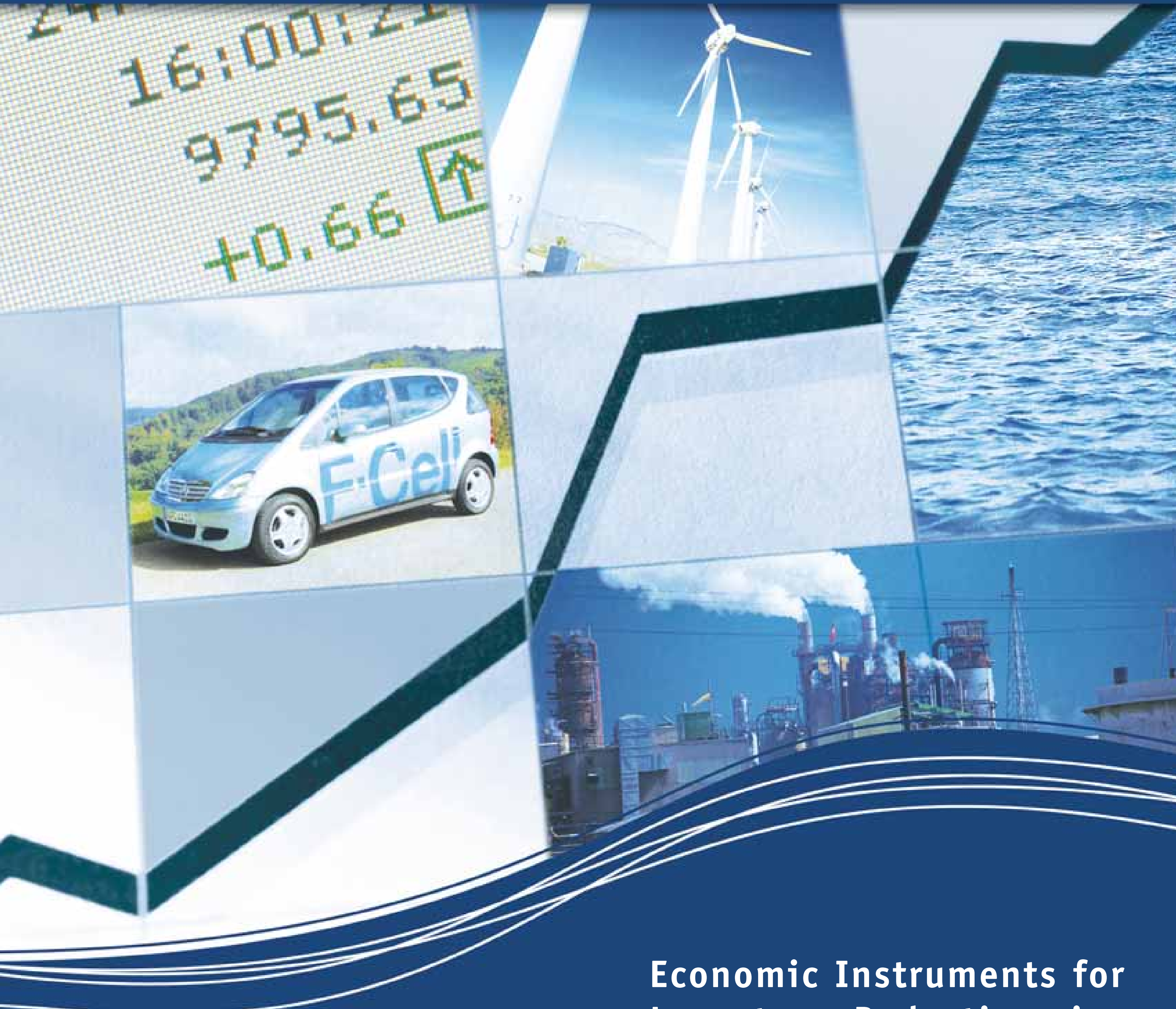
State of the Debate



Economic Instruments for Long-term Reductions in Energy-based Carbon Emissions

National Round Table on the Environment and the Economy

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Economic Instruments for Long-term Reductions in Energy-based Carbon Emissions

MANDATE

About Us

The National Round Table on the Environment and the Economy (NRTEE) is dedicated to exploring new opportunities to integrate environmental conservation and economic development, in order to sustain Canada's prosperity and secure its future.

Drawing on the wealth of insight and experience represented by our diverse membership, our mission is to generate and promote innovative ways to advance Canada's environmental and economic interests in combination, rather than in isolation. In this capacity, it examines the environmental and economic implications of priority issues and offers advice on how best to reconcile the sometimes competing interests of economic prosperity and environmental preservation.

The NRTEE was established in 1994 as an independent advisory body reporting to governments and the Canadian public. Appointed by the Prime Minister, our members are distinguished leaders in business and labour, universities, environmental organizations, Aboriginal communities and municipalities.

How We Work

The NRTEE is structured as a round table in order to facilitate the unfettered exchange of ideas. By offering our members a safe haven for discussion, the NRTEE helps reconcile positions that have traditionally been at odds.

The NRTEE is also a coalition builder, reaching out to organizations that share our vision for sustainable development. We believe that affiliation with like-minded partners will spark creativity and generate the momentum needed for success.

And finally, the NRTEE acts as an advocate for positive change, raising awareness among Canadians and their governments about the challenges of sustainable development and promoting viable solutions.

We also maintain a secretariat, which commissions and analyses the research required by our members in their work. The secretariat also furnishes administrative, promotional and communications support to the NRTEE.

The NRTEE's State of the Debate reports synthesize the results of stakeholder consultations on potential opportunities for sustainable development. They summarize the extent of consensus and reasons for disagreements, review the consequences of action or inaction, and recommend steps specific stakeholders can take to promote sustainability.

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PREFACE

This State of the Debate report marks the conclusion of the National Round Table on the Environment and the Economy (NRTEE)'s Ecological Fiscal Reform (EFR) and Energy Program. It describes the Program's research findings and details the final recommendations stemming from the stakeholder consultations.

The EFR and Energy Program represents the second phase of the NRTEE's EFR Program. Whereas Phase 1 explored the general potential of economic instruments to advance sustainable development—looking at EFR measures in Europe, the United States and Canada, as well as the use of EFR in specific sectors of the economy—Phase 2 has focused on the use of economic instruments in achieving long-term reductions in greenhouse gas emissions, specifically carbon emissions.

Phase 1 of the EFR Program was launched in 2000 and concluded with the publication in 2002 of *Toward a Canadian Agenda for Ecological Fiscal Reform: First Steps*. Work on Phase 2, the EFR and Energy Program, began shortly afterwards, early in 2003.

The NRTEE will continue to work on the broader topic of climate change and energy. This work has been mandated by Prime Minister Paul Martin, who requested on February 16, 2005, that the NRTEE "provide advice and recommendations on the development of a long-term energy and climate change strategy for Canada."

As well, in the Federal Budget 2005, the NRTEE was asked to develop options for a vehicle feebate, to consult, and to make recommendations to the government prior to the next federal budget. This request reflects the fact that the National Round Table has established capacity in the use of economic and fiscal instruments for environmental objectives.

Glen Murray
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Introduction:
The EFR and Energy Program

Concerns about climate change will clearly be among the many factors driving a coherent energy strategy. The real debate is about how much weight should be given to climate change considerations in energy policy and about the appropriate tools for doing so. To provide more context for this critical issue, the National Round Table on the Environment and the Economy (NRTEE) has explored a scenario in which economic instruments are used as a key tool to promote long-term carbon emission reductions. The operating assumption of our Ecological Fiscal Reform (EFR) and Energy Program was that long-term reductions in energy-based carbon emissions will be one of the main priorities shaping energy strategy.

The EFR and Energy Program's objective was "to develop and promote fiscal policy that consistently and systematically reduces energy-based carbon emissions in Canada, both in absolute terms and as a ratio of gross domestic product, without increasing other pollutants." The rationale for this focus was twofold:

1. Fiscal policy is one of the most powerful means at the government's disposal to influence outcomes in the economy, but it is not typically employed in a consistent and strategic manner to promote objectives that have simultaneous economic and environmental benefits.

2. The related issues of climate change and energy present substantial challenges and opportunities for Canada, and fiscal policy—employed in a consistent and strategic manner—is a key but underutilized[1] element of the government's response. Although taxation and tax credits have, for example, been used to support wind power production or to promote the expanded use of ethanol as a transportation fuel, these efforts have been piecemeal.

The Program examined the role of economic instruments in supporting technologies with the potential to reduce energy-based carbon emissions on both the demand and supply sides of the energy equation, as well as at three different stages of development: *mature technologies*, using a case study of industrial energy efficiency; *emerging technologies*, using a case study of renewable power technologies in the demonstration to market-ready stages; and *longer-term new technologies*, using a case study of hydrogen fuel technologies. The choice of these specific case studies should not be interpreted as assigning any priority to these technologies: they are understood to fit within a broad mix of supply sources and demand sectors, now and in the future, including other equally significant low-carbon energy sources and mitigation technologies, as well as carbon fuels.

The findings and recommendations of the Program draw not only on the specific analysis carried out in the three case studies (and their general lessons for the use of economic instruments), but also on the consultation process conducted as part of the Program's work.

Three questions formed the starting point of inquiry:

- What role can economic instruments play in reducing energy-based carbon emissions in Canada over the next quarter century?
- What are the constraints that will determine the design and application of such instruments?
- How can we undertake a coordinated transition toward a lower carbon emission energy system?

A 25-year perspective was adopted, inspired by the conviction that focusing on the Kyoto timetable alone would not allow a sufficient time horizon for the optimum, orderly development and implementation of mitigation and adjustment strategies. In adopting this time horizon, the NRTEE is in no way suggesting that Canada should ignore its current commitments under the Kyoto Protocol. Rather, we are recognizing that the development and deployment of new technologies can take decades: the energy system is complex and involves myriad decision makers; it is also capital-intensive and will change most easily at the rate at which long-lived capital stock is retired.[2] Research has shown that the cost of environmental improvement can be sensitive to timing—that policies matching the pace of technological change to the rates of capital stock turnover will reduce compliance costs.[3] Since turnover rates will vary by sector and technology, environmental improvement requires a long-term agenda.

Investment decisions are being made now about capital stock that may last for several decades. Without a clear, long-term direction for climate change policy, long-lived carbon-inefficient new stock will continue to be installed, complicating future mitigation efforts. Our long time horizon allows for fundamental shifts in the energy system, reflecting the advice of bodies such as the NRCan Advisory Board on Energy Science and Technology, which recommended that "to encourage the sustained and sustainable efforts required to meet the threat of climate change, both reduction of emissions and response to its effects, a long term focus on the 2015-2050+ time-frame will be required, including stable and sustainable policies."[4]

This report is organized into two parts plus appendices:

- Part 1 covers high-level themes and general findings and recommendations. Section 1 gives background on the purpose and context of the report, and on EFR. Section 2 outlines Canada's unique opportunities in an emerging, more environmentally conscious global energy economy, and Section 3 describes the connections between a long-term energy-based carbon emission reduction strategy and other societal priorities. Section 4 reviews the general findings on the use of economic instruments for carbon emission reductions, including an overview of what we know about the macroeconomic impacts of fiscal policies for carbon emission reductions from other studies. Section 5 proposes a generic strategy for coordinating mature, emerging and longer-term technologies in a deliberate framework for carbon emission reduction. Section 6 describes the general lessons learned (regarding methodologies, data, etc.) while assessing economic instruments.
- Part 2 summarizes the findings, macroeconomic impacts, policy implications and recommendations from each of the three case studies.
- The appendices contain executive summaries of the case studies.

An executive summary of this State of the Debate report, as well as copies of the full case study reports, can be obtained from the NRTEE website at <**www.nrtee-trnee.ca**>.

PROJECT SCOPE

One part of our research was based on case studies focusing on different stages of technology development, and some of the recommendations focus on the specific technologies studied. The following discussion is intended to clarify the project boundaries and to highlight relevant issues outside its scope:

- *The technologies examined are understood to be part of a broader mix of energy sources and demand sectors:* While they hold potential to change the profile of energy demand and supply (industrial energy efficiency through reduced pressure for new supply, emerging renewable power as a growing source of primary energy, and hydrogen through far-reaching applications as a secondary energy source), the dominant sources of primary energy in the country will remain fossil fuels, nuclear and large hydro well into the foreseeable future.[5]
- *These technologies are not the only low-carbon energy sources available:* Low-carbon energy sources already account for almost 75 percent of Canadian electrical generation. Over 90 percent of the electricity supply comes from hydroelectricity in British Columbia, Manitoba, Quebec, and Newfoundland and Labrador, while 31 percent comes from nuclear in Ontario. Hydroelectricity and nuclear energy continue to be the foundation of a low-carbon energy mix. Other emerging

low-carbon energy sources and technologies were also outside the scope of this study: for example, off-grid renewable energy technologies such as ground-source heat pumps, solar water heaters and passive solar, and transportation technologies such as hybrid vehicles.

- *Some of the case studies' findings are regionally specific:* The electrical generation mix and associated carbon emissions are regionally dependent in Canada. Accordingly, some of the case studies' findings—for example, that hydrogen pathways using electrolyzer technology could lead to net increases in greenhouse gas emissions—are specific to regions where the marginal source of generation has a higher carbon content than the base load. These findings may not be relevant to other generation mixes.
- *The recommendations in this report deal with only a few of the technologies, initiatives and measures that will be needed in a comprehensive climate change action plan for Canada:* The intention of the EFR and Energy Program is not to present a comprehensive climate change plan—the combined magnitude of direct and indirect reductions from the proposed instruments in the three case studies is 23 to 42 Mt by 2010 and 53 to 77 Mt by 2030; these reductions pale in comparison to the forecast emissions gap of 238 Mt by 2010.[6] Rather, the intention has been to bore down on the design of specific elements of a potential package of measures.

Part I:
General Findings and Recommendations

1. BACKGROUND

1.1 PURPOSE OF THE REPORT

In 2000, the NRTEE launched a program of work to explore the role that economic instruments can play in advancing sustainable development objectives. The initial phase of this program, the Ecological Fiscal Reform (EFR) Program, yielded some broad lessons about the application of economic instruments to economy–environment issues. Its findings were published in *Toward a Canadian Agenda for Ecological Fiscal Reform: First Steps*.

The results from the first phase convinced the NRTEE to continue the project and, in particular, to explore the use of economic instruments in reducing greenhouse gas emissions. Thus the second phase of the EFR Program—the EFR and Energy Program—was launched early in 2002 with a mandate to focus on the use of economic instruments in achieving long-term reductions in energy-based carbon emissions.

This State of the Debate report synthesizes the major conclusions of the EFR and Energy Program, drawing in particular from case study experience but also on the broader research and consultation conducted as part of the Program's work. The report defines the major points of agreement and disagreement, explores questions surrounding the use of fiscal policy in the specific sectors addressed by the case studies (industrial energy efficiency, emerging renewable power and hydrogen fuel technologies), and examines the broader context for the use of economic instruments in encouraging reductions in energy-based carbon emissions (including some aspects of the linkages between greenhouse gas emission reductions, energy policy and broad societal priorities).

1.2 ECOLOGICAL FISCAL REFORM

The NRTEE has defined EFR as "a strategy that redirects a government's taxation and expenditure programs to create an integrated set of incentives to support the shift to sustainable development."[7] Unlike the ecological tax reform or tax-shifting approach being implemented in many jurisdictions, the NRTEE's approach to fiscal reform embraces a broad suite of instruments in a reinforcing package. This package includes:

- redirection or introduction of new taxes or tax incentives;
- redirection or introduction of targeted direct expenditures, such as targeted government program expenditures, government procurement, cash subsidies and grants; and
- other economic instruments, such as tradable permits, permitting charges and user fees.

1.2.1 Broad Conclusions from Phase 1 of the EFR Program

Phase 1 of the NRTEE's EFR Program reviewed international experience with EFR and undertook three case studies to assess the applicability of EFR within the Canadian context.[8]

This research indicated that, in theory, there is a role for EFR in Canada and that EFR can be a uniquely appropriate tool in implementing sustainable development. EFR is an integrative tool that is easier to adapt to the complexity of sustainable development objectives than are other policy tools. It is more amenable to a continuous improvement approach than are exclusive command-and-control models, and it allows for more flexibility because parties can determine their own response. Analysis for the case studies revealed the vital importance of precisely targeted instruments and clearly defined policy objectives, as well as a thorough understanding of Canada's unique regulatory, market and jurisdictional profiles. The effectiveness, impacts and experience with EFR measures in some limited existing applications showed these to be promising approaches. However, conclusive evidence on the efficiency and effectiveness of EFR measures in Canada will require broader applied experience and the passage of sufficient time to judge their performance.[9]

According to the Organisation for Economic Co-operation and Development (OECD):

> *Economic instruments have been playing an increasing role in the environmental policies of OECD countries over the last decade, including environmentally related taxes. All OECD countries have introduced environmentally related taxes to some extent and an increasing number are implementing comprehensive green tax reforms. Green tax reforms have been identified as a key framework condition for sustainable development in the OECD report* Sustainable Development: Critical Issues *and as a powerful tool in implementing the OECD* Environmental Strategy for the First Decade of the 21st Century *adopted by OECD environment ministers in May 2001.*[10]

Such successes have stimulated interest in the use of market-based instruments in Canada, as evidenced by the emphasis on fiscal instruments in the 2002 Climate Change Plan for Canada.[11] Nonetheless, regardless of our understanding of the potential of EFR instruments, as well as international experience in their design, these instruments have not been widely adopted in Canada.

This deficiency was noted in the OECD's 2004 review of Canada's environmental performance, which concluded:

> *Despite [the introduction of a number of economic instruments for environmental policy purposes, mainly at the provincial level], limited use has been made of economic instruments for environmental management at any level of government. A* number of constraints *affect greater uptake of economic instruments.* Industry *is concerned about day-to-day competitiveness pressures, especially in relation to cost competitiveness with the US. It has difficulty understanding how to implement new instruments such as trading. Within* governments*, economic agencies have supported economic instruments in principle, but resisted specific proposals for targeted incentives on allocative efficiency grounds. The* public *is wary of new fees and charges, and of the allocation of "right to pollute". There is a general resistance to external pressure to change consumption patterns. Small but influential groups have blocked some proposals….*
>
> *Increasing the use of economic instruments is a* matter of urgency *in view of the need for affordable solutions and appropriate cost sharing to reduce environmental degradation.*[12]

One objective of the NRTEE's EFR Program was to determine why these instruments are not used more.

1.2.2 Long-term Benefits of EFR

Under regulatory approaches based on command and control, compliance decisions are made by the regulator. With fiscal instruments, however, this decision making shifts to the regulated community (i.e., firms or individuals). In theory, this shift provides increased flexibility for the targeted community, enabling it to make compliance decisions that minimize compliance costs and thus maximize profits. According to environmental economic theory, the ability of fiscal instruments to enable profit-maximizing behaviour gives them a major advantage over traditional command-and-control approaches. Fiscal instruments are also more attractive because, in theory, they reduce government implementation costs, raise government revenues and reduce budgetary outlays, thus reducing the costs (both to government and industry) of meeting societal objectives.

Of course, not all fiscal instruments accomplish this. Many of the benefits of EFR will depend on the specific design of the fiscal instrument, and badly designed EFR instruments, like any other badly designed policy instrument, can be inefficient, ineffective and administratively costly.

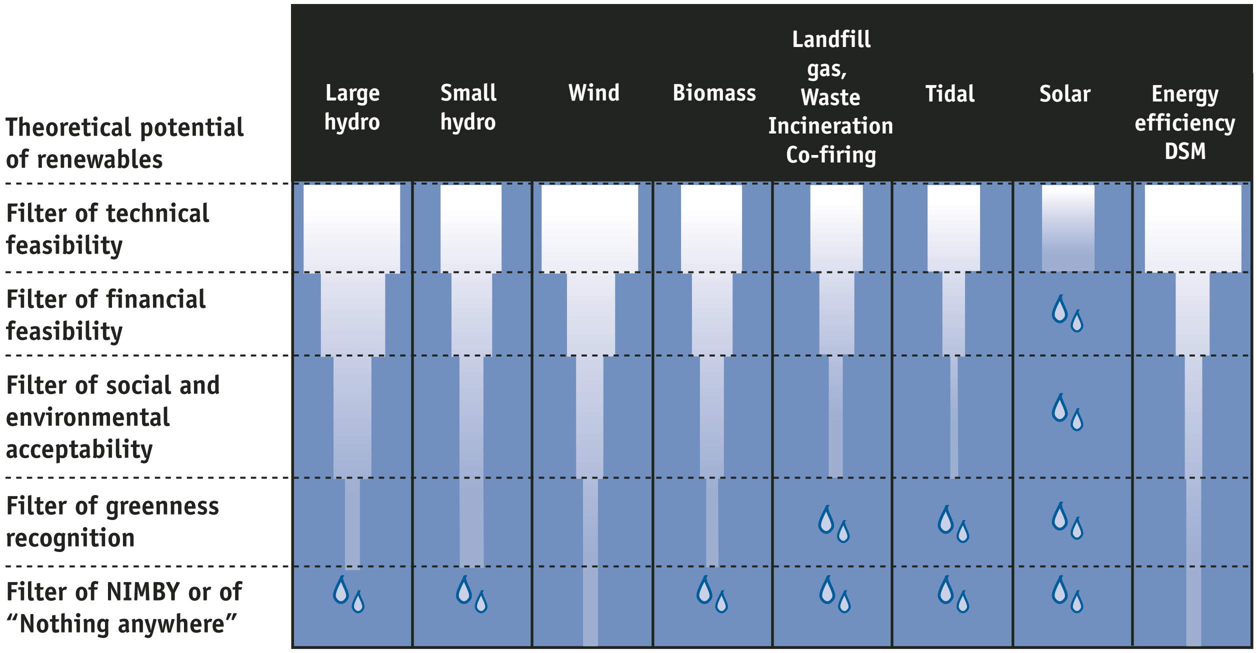
Building on this logic, the Government of Canada announced in its Budget 2005 a new set of initiatives targeting carbon emission reductions. It also indicated that it intends to "actively consider other opportunities to use the tax system to support environmental objectives, in areas where it would be an appropriate instrument."[13]

1.2.3 Fiscal Instruments Within a Mix of Policy Instruments

The focus on fiscal instruments in this report does not imply the exclusion of other policy instruments. Rather, the intent is to drill down on one set of the policy reforms necessary to enable greater deployment of carbon-reducing technologies. The intent is also to explore and highlight the possible benefits of EFR—over other policy tools—as a cost-effective, agile and integrative means of pursuing sustainable development objectives.

A recent review of alternatives for managing environmental problems compared approaches emphasizing economic instruments with those emphasizing command and control. The researchers noted that almost all of the 12 policies studied were a blend of economic incentives and command-and-control instruments, underlining the fact that the use of economic instruments does not imply the exclusion of other policy tools.[14]

Figure 1: Barriers to Renewable Energy Development and Their Potential Impact on Project Implementation Rates



DSM= demand-side management

Note: This illustration is an evocation of a principle. It does not pretend to represent accurately the relative importance of the options, nor their rate of shrinking.

Source: Y. Guérard (Hydro-Québec), Presentation at the November 3–4, 2004, Green Power Workshop in Montreal.

Promoting a long-term, coordinated strategy for long-term, energy-based carbon emission reductions will require coherent and cohesive policy reforms on many fronts, as well as engagement from every level of government. For example, factors such as pricing, market access, grid access, perceived investment risk, market demand, and social and regulatory acceptance are just some of the barriers acting as cumulative filters to these theoretically feasible projects.[15] This filtering process is illustrated in Figure 1. It is confirmed by this project's finding that, while the technical resource potential for low-impact renewable power in Canada has been estimated at 68,500–336,600 MW capacity and 244,700–1,210,400 GWh/yr supply, the actual installed base today is only 2,300 MW capacity and 12,100 GWh/yr supply.[16]

In this policy field, as in others, ecological fiscal reform is a necessary but far from sufficient instrument for meeting policy objectives.

2. CONTEXT: THE NEW ENERGY ECONOMY—CANADA'S OPPORTUNITY

2.1 GLOBAL ENERGY TRENDS

The International Energy Agency (IEA) concluded in 2002 that:

> *[30-year energy projections] raise serious concerns about the security of energy supplies, investment in energy infrastructure, the threat of environmental damage caused by energy production and use and the unequal access of the world's population to modern energy. …Governments will have to take strenuous action in many areas of energy use and supply if these concerns are to be met.*[17]

Spurred by population growth, increasing standards of living and spreading industrialization, the global energy market is projected to increase by two-thirds over the next three decades, equal to an annual demand growth of 1.7 percent. Meeting this demand will require an unprecedented investment in worldwide energy supply infrastructure: US$16 trillion of investments in new energy supply capacity and replacement are anticipated at the global level. Power generation, transmission and distribution will account for nearly US$10 trillion of this, including US$2 trillion for power generation in OECD countries.[18]

Renewable energy is expected to assume a growing role in the world's primary energy mix under both business-as-usual and alternative environmental scenarios. In the IEA's reference (business as usual) scenario, non-hydro renewables will grow faster than any other primary energy source, at an average rate of 3.3 percent over the 2002–2030 projection period. This growth will take place largely within the OECD. Wind power and biomass will grow most rapidly, again especially in OECD countries.[19] The European Union has set itself a target of 22.1 percent of electricity consumption and 12.0 percent of gross national energy consumption from renewable energy sources by 2010.[20] The United States aims to nearly double energy production from renewable sources (excluding hydro) between 2000 and 2025.[21]

Environmental policies could lead to a dramatic shift in the pattern of energy investment and reduce overall energy needs. Scenarios based on policies currently being debated in OECD countries forecast investment in renewables (including large-scale hydroelectricity) to increase from $480 billion to $720 billion over the 2000–2025 period—a shift from one-third of new investment in power generation to one-half.[22]

The IEA's reference scenario forecasts that hydrogen fuel cells will phase in slowly between 2020 and 2030—from 4 GW global generating capacity to 100 GW.[23] The IEA notes that:

> *[t]he total investment required in order to achieve a substantially hydrogen-powered transport system will depend both on the rate at which costs are reduced and the timing of the development of this system. …With optimal learning and cost reduction, a mature fuel cell vehicle market could be reached at an incremental cost of several hundred billion dollars, but if cost reductions are slow, the incremental costs of achieving a mature market could be around $5 trillion.*[24]

A PricewaterhouseCoopers study on global demand for fuel cell products projects this market to reach $46 billion per year by 2011 (stationary: $17.9 billion; portable: $17.6 billion; early phase transportation: $10.3 billion) and $2.6 trillion per year by 2021.[25]

Other forecasts echo these coming shifts. The Intergovernmental Panel on Climate Change's peer-reviewed "IS92a" scenario, a middle path that assumes significant technological change under a business-as-usual (i.e., no climate policy) scenario, assumes that the reduced costs of carbon-free technologies such as wind, solar, biomass, nuclear and hydropower, relative to fossil fuels, will lead to their supplying 75 percent of global electricity by the end of the century, up from one-third in 1995.[26]

2.2 CANADA'S OPPORTUNITY

Canada is a world leader in oil and gas, hydroelectric and nuclear energy production and technologies. Our leadership in these energy sectors has been fostered through a long history of deliberately using public policy to successfully partner and contribute to the development of new energy technologies and sources of supply. For example, Crown corporations have been instrumental in the development of Canada's hydroelectricity generation; nuclear technologies have been supported through Crown corporations, R&D and export subsidies, and capped liability in the event of accidents; oil and natural gas developments have been supported through grants and other investments in numerous megaprojects and the use of royalty structures and tax measures tailored to the development needs of this sector; and the recent development of northern Alberta's oil sands is being assisted by tax treatment designed for that industry's specific needs.

Should Canadian governments proactively pursue a similar advantage in the carbon emission reduction technologies that are defining global energy trends? A coherent Canadian energy strategy will be driven by many factors, such as energy security, economic and industrial development, employment, international competitiveness, environmental protection and sustainability. Mitigating climate change also will be one of these factors, but will it be one that limits or one that enables other objectives?

The charge for policy-makers is to design a path to a lower carbon emission future that responds to the ecological urgency of climate change impacts and to the challenge of mitigation, and that does so in a way that limits disruption to other societal priorities.

Canada enjoys unique challenges, opportunities and constraints in finding this path.

Our challenges, as a resource-based trading nation of modest economic and demographic size, come from two sides. On one side is a changing international market, in which energy supply preferences are diversifying and shifting and in which greenhouse gas performance is increasingly a factor in market access, investment decisions and assessments of corporate risk. In this market, environmental sustainability drives innovation and competitiveness. On the other side are competitiveness challenges posed by countries at different stages in their policies and level of economic development.

Fortunately, Canada has unique advantages in assembling this response. More than any other country, we combine a rich and varied mix of energy sources with the knowledge capital that can enable us to maintain our global leadership in the energy economy, even as it shifts and diversifies to mitigate climate change. Untapped wind, water, solar and biomass resources of world-class calibre abound alongside the hydrocarbon, uranium, coal and large hydro resources that have formed the basis to date of Canada's energy wealth. We are knowledge leaders in several of the new technologies—small hydro, biomass, hydrogen, and carbon capture and sequestration—that are critical elements of a lower-carbon energy future. And the geographic diversity of our communities enables experimentation with technologies for urban and remote locations, cold and moderate weather conditions. In other words, we have all the resources necessary to adapt to the coming energy revolution, provided we advance strategically and with a clear vision.

In contrast with these unparalleled opportunities on the energy resources front, on the policy front there are real constraints. Canada's confederation model introduces jurisdictional limits that establish substantive hurdles and that often require complex and significant efforts in the area of federal–provincial coordination. Unilateral federal action is possible in many areas (e.g., transport), but federal and provincial governments must work in concert for effective action in others (e.g., power production and building standards). Our dominant trading relationship with a nation that has not ratified the Kyoto Protocol, coupled with the scale of commodity-based trade, imposes inescapable international competitiveness challenges that shape the choice and design of policies available to mitigate greenhouse gas emissions.

These circumstances compel a "smart" response: a timely, no-regrets approach that pursues opportunity while enhancing economic achievement and that employs a set of dynamic and diverse means based on knowledge and innovation.

3. CONTEXT: MAXIMIZING OVERALL ADVANTAGES TO SOCIETY—LONG-TERM CARBON EMISSION REDUCTIONS WITHIN AN INTEGRATED POLICY FRAMEWORK

History records a gradual decline in the carbon intensity of energy sources over the last century. Beginning with the transition from wood to coal, and continuing with sequential shifts to oil and natural gas, each of these technology stages has resulted in less carbon being released per unit of energy produced. The primary reason for the shift to each new fuel was the promise of better-quality energy. Society invested enormous research, capital and infrastructure to bring each of these new energy sources to market.

Drivers for past shifts to new energy sources have been affordable energy, quality of energy, ease of use, reliability, regional security of supply, desire for decentralized generation and other non-ecological factors. Climate change considerations have not been a main driver for energy technology change and will not be—unless consideration of long-term carbon emission reductions is given greater priority in energy policy than it has up to this point.

But how much priority should we accord to long-term carbon emission reductions in energy policy? Some participants in the EFR and Energy Program argued that long-term carbon emission reductions and other objectives are complementary to a point, but that eventually there will need to be trade-offs. These participants proposed long-term carbon emission reductions as *the* priority of energy strategy. Yet another perspective cautioned against making long-term carbon emission reductions even the primary environmental objective in an energy strategy, noting that other environmental aspects of sustainability, such as biodiversity and toxics prevention, also need to be upheld. And, finally, some participants felt that energy policy should be primarily interested in opportunities for economic development, with any environmental objectives considered secondary.

Many in the EFR and Energy Program stressed that societal priorities such as quality jobs, regional and community development, productivity and energy security animate society more than carbon reductions. These participants feared that the call for a single-minded pursuit of long-term carbon emissions reduction, in isolation from other public priorities, will fall by the wayside, as it currently has. However, if the benefits and opportunities arising from long-term, energy-based carbon emission reductions can be shown to align comfortably with these societal priorities, there will be more champions for and broader interest in the agenda.

Wherever they stood on the priority of carbon emissions in energy strategy, participants in the EFR and Energy Program agreed that public investments in a long-term carbon emissions reduction strategy would yield many additional benefits, including those described below.

3.1 CO-BENEFITS: NINE REASONS FOR AN INTEGRATED POLICY FRAMEWORK

3.1.1 Energy Security

3.1.1.1 Overcoming the Supply Shortage

By 2020, approximately 15 percent of Canada's current electrical generation capacity will be more than 40 years old. Incremental generation requirements by 2020 for both plant replacement and demand growth are expected to be 42,000 MW or 40 percent of the current stock of approximately 105,000 MW.[27]

This statistic accents the enormity of one dimension of the nation's looming energy security challenge; it also underscores the importance of the decisions that will soon have to be made for a long-term carbon emission reduction strategy.

Deep shifts in energy policy are underway in most provinces, which will affect the context for decisions regarding energy and long-term carbon emission reductions at the national level. British Columbia, Alberta, Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia face changes in how they handle electricity generation and supply, and some provinces are looking to private sector, independent producers to provide much of their new supply. For example:

- Ontario faces a supply shortage that could become serious as early as 2007 and worsen over the longer term. Driving this shortage are a combination of factors: growing population and economy, aging generating infrastructure and insufficient planned new capacity. Furthermore, for health and environmental reasons, the government has committed to shutting down five coal-fired electricity-generation plants (which produce one-third of Ontario's power) by 2008. As much as $5 billion in new generating capacity is needed. Aggressive conservation measures and a growth in independent generation, including from renewable sources, are recognized as vital components of meeting future demand.[28]
- Manitoba has been emphasizing its hydropower as a competitive advantage. The province is exploring new hydroelectric power capacity and an east–west grid to export this power to Ontario. Moreover, it has identified hydrogen development, using a carbon-efficient hydropower feedstock, as an attractive future energy option.[29]
- In New Brunswick, a transition to a deregulated electricity market is underway. Some retail competition will be allowed: large industrial and wholesale customers will be able to choose their providers, and decentralized facilities will be able to re-sell the electricity they produce back into the grid. The provincial government has recently introduced a renewable portfolio standard (RPS), and in the meantime New Brunswick Power has set its own target of 100 MW from wind by 2010.[30]
- In British Columbia, BC Hydro forecasts that energy demand will increase by 1.7 percent per year over the next decade. This demand will be met by a combination of energy efficiency (demand-side management), generation efficiency and independent power generation, including low-impact green power. There is a voluntary commitment to meet at least 10 percent of new electricity demand through green energy by 2010, and 16 projects representing 1,764 GWh were recently commissioned. A new corporation, the BC Transmission Corporation, was created in 2003 to provide transmission services that will enable independent generators to sell into the grid. BC Hydro has also targeted hydrogen, in particular the hydrogen-fuelled transportation market, as a future business opportunity.

Provincial renewable portfolio standards are also being discussed in Alberta and Prince Edward Island and have been announced in Ontario and Nova Scotia. British Columbia, Ontario, Nova Scotia, New Brunswick and Prince Edward Island are considering the introduction of net metering. Several provinces have also announced targets for renewable energy procurement.[31] Several provincial Crown utilities have also committed to targets for emerging renewable energy technologies; for example, while Quebec's generation profile is already composed of 93 percent hydro, Hydro-Québec has committed to buying 1,000 MW of new wind-power capacity from independent producers by 2013.

3.1.1.2 Improving Security of Supply

The September 11 terrorist attacks, combined with the rolling California brownouts in the winter and spring of 2001 and the August 2003 eastern North America blackout, have renewed public interest in the security of energy supplies.

More diverse sources of fuels, a more responsive supply mix (including renewable energy sources) and greater energy efficiency are key ingredients of a more robust energy model:

- Hydrogen fuels can be a carrier for low-carbon primary energy sources, creating the potential to replace the fossil fuels being used in transportation.
- Distributed generation, for which hydrogen and many renewable energy technologies are well suited, increases the resilience of a system otherwise characterized by large centralized power plants, pipelines and long transmission distances—all of which contribute to the system's vulnerability.
- Energy efficiency can also contribute to grid stability through reduced loading of transmission systems.
- Conservation and efficiency programs can reduce pressure on supply more quickly than can the construction of new facilities. The lead times for many low-impact renewable power sources are shorter than those for many traditional sources of supply. The McBride Lake Wind Farm in southern Alberta, for instance, was brought on-line in under a year. Large hydro projects may take 10 or more years to complete, due in part to federal and provincial regulatory processes.[32]

3.1.1.3 Improving Price Stability

Stability of energy pricing has also become a priority following recent experience with rising crude oil prices and significant price volatility in the natural gas and deregulated electricity markets. There is some concern that the increased demand for natural gas (in part due to environmental reasons) will lead to continuing price volatility and that the increased presence of gas-fired electricity generation has led to a closer correspondence between gas and electricity prices.[33] Integrating emerging renewable power sources into the supply mix can offer a buffer against price volatility: these sources have higher upfront costs but generally more stable operating costs. Improved stewardship of existing sources of supply, through increased energy efficiency, reduces overall demand, making energy more affordable for all Canadians.

New energy sources and technologies for distributed generation are particularly attractive for remote communities that are currently subject to high energy prices.

3.1.2 Clean Air and Improved Quality of Life

The largest sources of human-created air pollution are energy generation, transportation and energy-intensive industries. Emissions from these sources contribute to increases in the concentration of particulates, smog-forming gases and acid rain precursors, all factors that lead to respiratory problems and impaired lung function as well as other health issues. Smog alerts have become a familiar summer occurrence in Canadian urban centres. Energy efficiency programs that reduce the quantity of fossil fuels burned, zero-emission renewable energy sources and hydrogen technologies with zero emissions at the point of combustion can all reduce emissions of smog precursors in Canadian urban centres and improve the quality of life.

3.1.3 Reduced Health Care Costs

Air pollution causes respiratory ailments, exacerbates cardiovascular disease and contributes to higher mortality rates from a number of conditions. The associated hospital admissions, emergency room visits, doctor visits and medication costs impose a large cost on the health care system—$600 million in 2000 in Ontario alone, according to research by the Ontario Medical Association.[34] These costs could be lowered by reducing smog.

3.1.4 Industrial and Manufacturing Capacity in New Environmental Technologies

The domestic economic benefits of large investments in long-term carbon emission reductions would be amplified if Canada were able to supply the requisite technology and expertise.

At present, however, many of the energy technologies required for carbon mitigation would need to be imported. Analysis conducted by Industry Canada for the AMG Working Group in 2002[35] concluded that, given present Canadian manufacturing capacities, one-third or more ($25 billion of $75 billion) of the machinery and equipment required to satisfy Canada's Kyoto targets would need to be imported.[36] The same study noted that under normal circumstances, foreign countries provide 60 to 70 percent of Canada's machinery and equipment requirements. The level of imports required to satisfy Canada's Kyoto targets could be as high as 95 percent if the timeline for investment were too short for Canadian manufacturers or if the demand were perceived to be a one-time opportunity, with declining requirements once the Kyoto target was achieved.

Canada already has well-developed knowledge and manufacturing clusters in some emission reduction technologies such as hydro turbines and biomass and an emerging industrial cluster for fuel cells. Other vital technologies are not supported by strong manufacturing capacity in Canada. These include technologies such as wind turbines, solar panels, geothermal heat pumps and micro-turbines for landfill gas recovery. More aggressive Canadian commitments to specific technologies, such as a sizable renewable power portfolio standard, would stimulate European companies to locate manufacturing plants in Canada—and possibly even to use this country as their entry point into the North American market. This would create an entire ripple effect of benefits through the supply chain. In Germany, for example, the wind industry now stands second only to auto manufacturing as a consumer of steel. The benefits would apply both to sectors where Canada is considered a "technology taker" (such as wind turbines) and sectors where it is a "technology maker" (such as proton exchange membrane fuel cells).

Industry participants in the EFR and Energy Program confirmed that manufacturing facilities for some technologies and equipment now supplied by other countries would locate in Canada if the domestic market passed certain demand thresholds. Leading wind industry manufacturers, for example, are actively developing North American manufacturing strategies to take advantage of the positive long-term market outlook, U.S. production tax credits, emerging renewable portfolio standards, competitive labour costs (25 percent lower in Canada than in Europe) and the elimination of import duties. North American production would also mitigate against currency risks, the high costs of shipping large machines (5 to 10 percent of project costs) and customer preferences for North American goods. According to the Canadian Wind Energy Association, "manufacturers regard North America as a single market from a manufacturing strategy point of view. Any plants located in Canada will have significant export potential to the U.S.…"[37] Locating in the United States would obviously yield similar benefits.

A deliberate emphasis on promoting domestic manufacturing capacity in these emerging industrial sectors would permit Canada to expand its share of the booming global markets for energy management and renewable energy technologies. It would also keep the economic benefits of substantial expenditures on machinery and equipment within Canada.

3.1.5 Targeting Growing Export Markets and Developing Country Needs

Nearly 70 percent of the increase in world primary energy demand between 2001 and 2030 will be in the developing and transition economies; half of total global energy investments during this period, US$7.9 trillion, will be directed to developing countries.[38] At the global level, renewable energy, and wind and biomass in particular, are projected to grow faster than any other primary energy sources, at an average rate of 3.3 percent a year even under business-as-usual scenarios. Environmental scenarios would increase the investment in renewables by 50 percent to $720 billion, forming half of all investment in new power generation.

The primary energy sources and energy use efficiencies that are used to meet this ballooning demand will determine the ecological future of the planet, as well as environmental and health effects at regional and local scales. Thus a Canadian focus on assisting the commercialization of cleaner, reduced-carbon technologies could also benefit developing countries. Moreover, it would be in line with the stated federal objective of developing "a strategy specifically focused on learning technologies, life sciences and the environment to help those in developing countries to benefit from Canadian expertise" and the long-term plan of providing "at least 5 per cent of research investment to those who are developing new ways of dealing with international problems."[39]

3.1.6 Commercializing and Leveraging Government-funded Research

Government fiscal involvement in the development of new energy technologies has historically focused mainly on the idea generation and conceptual stages of product development. The recent establishment of the Sustainable Development Technology Fund aims to address the gap in funding at the demonstration and pre-commercialization stages, just prior to venture capital investment. These stages are often characterized as the "valley of death" for new technologies.

Many experts believe that despite these efforts, there remains a backlog of market-ready carbon mitigation technologies. This "innovation backlog" is cited as evidence of the need for ecological fiscal reform at new stages of the innovation chain, to reduce financial risks to investors and to create the market pull needed to get new technologies off the shelf.[40] The tax treatment of certain renewable energies (e.g., through accelerated capital cost allowances or the ethanol excise tax exemption) helps support the market entry of these technologies from the demand side.

Others also note that different technologies have different pathways to the market and that their specific context must be taken into account when designing fiscal instruments to encourage their adoption. Such a context might be the lack of a domestic manufacturing capacity for a low-carbon energy technology, which would put Canada in the role of technology taker. Representatives of the wind industry, for example, argued that Canadian R&D investment in wind would have little impact on cost curves since these technologies are largely manufactured elsewhere. The EFR focus for this technology, therefore, should be on instruments to expand demand. A related point was made regarding breakthrough technologies and/or step changes in the energy efficiency of industrial processes: these will likely be determined in the international marketplace and are unlikely to be stimulated by Canada in isolation. This consideration must inform the choice of fiscal instrument for these technologies.

3.1.7 New Jobs and Regional Development

Other countries are achieving worthwhile employment benefits from the R&D, manufacturing and servicing of carbon emission reduction technologies. In Germany, for example, 45,000 jobs have been created in the wind industry alone; the United Kingdom expects that 20,000 jobs will be created through the development of 6,000 MW from offshore wind, much of this in rural and remote areas.[41]

The macroeconomic study commissioned for the EFR and Energy Program was not able to quantify employment impacts from the policies proposed in the case studies, other than to conclude that the aggregate macroeconomic impacts of the proposed instruments are insignificant from a national perspective.

Other Canadian data on employment potential from the three technologies studied is limited. A recent assessment of employment potential from Canadian development of low-impact, renewable electricity sources, commissioned by the Clean Air Renewable Energy Coalition, concluded that:

> *Low-impact, renewable electricity sources currently employ an average of six people per 10 MW of capacity. If the federal government were to encourage the development of these energy sources with a 1¢ per kilowatt-hour incentive paid to power producers, they would leverage significant job creation.*
>
> *The Clean Air Renewable Electricity Coalition has proposed that there is the potential in Canada to develop approximately 31,875 MW of low-impact renewable electricity between 2004 and 2020. Depending on the assumptions used, building and operating this capacity would create between 12,700 and 26,900 jobs by 2015, and would sustain these jobs through to 2020.*[42]

Ninety-nine percent of these jobs would be approximately evenly distributed between onshore wind, run-of-river hydro and biomass facilities. Over time, the job mix would steadily shift away from manufacturing and development and toward operations and management. By 2020, 54 percent of jobs would be dedicated to keeping existing facilities operational. The employment created from low-impact renewable electricity would be comparable to or greater than that created by an equivalent capacity of fossil fuel–based generation.[43]

Renewable energy sources offer employment potential in rural and remote locations, including First Nation communities, and energy efficiency–related jobs are distributed across all regions of the country. OECD research confirms that conventional energy supply sectors tend to create employment at centralized sites or regions or in banking, trade and other services clustered in densely populated regions. In contrast, energy efficiency investments are more often serviced by small and medium-sized enterprises, and tend to stimulate employment that is more geographically and sectorally dispersed, at least for a while. Therefore, the regional distribution of net employment from these types of investments is more equitable, a co-benefit for underdeveloped regions or regions with high unemployment.[44]

3.1.8 Innovation and Development of Value-added and Intellectual Property–Intensive Secondary Industries

Emerging, low-carbon energy technologies are a natural element of the innovation agenda. This was recognized at the National Summit on Innovation and Learning in November 2002, where specific discussions on environment, clean energy and eco-efficiency identified several strong connections.[45] Canadian leadership in new, knowledge-based industries—such as hydrogen fuel cells or carbon sequestration—can supplement commodity-based energy sector exports to diversify our economy.

3.1.9 Maintaining Canadian Competitiveness

International markets are changing. While demand for conventional energy commodities and technologies will persist and grow, markets are increasingly interested in the environmental impact of production, favouring new, environmentally conscious offerings that can meet the same needs. A long-term carbon mitigation strategy is a pre-emptive response on two fronts: to ensure the continued acceptance of conventional Canadian commodities—heavy crude from oil sands, electrical power and minerals—into international markets; and to position Canada to participate in new growth sectors such as the production of hydrogen-fuelled vehicles. Improved energy efficiency in the industrial sector will also enhance the productivity of Canadian firms.

3.2 WHY LONG-TERM CARBON EMISSION REDUCTIONS CANNOT BE AN IMPLIED OR SECONDARY OBJECTIVE

Opinions differ on where long-term carbon emission reductions should rank in energy strategy. What is clear, though, is that we cannot simply assume that such reductions will come about as an implied or secondary effect of other policies. This point is significant because the present policy debate often tends to assume an inherent substitutability between sustainable energy initiatives—such as energy efficiency, renewable energy deployment, development of hydrogen technologies and carbon mitigation—and this assumption may not always hold true. Findings from our case studies, which form the basis for this report, reveal that:

- attempts to improve industrial energy efficiency can sometimes increase the greenhouse gas intensity of production. For instance, a coal-fired boiler is more efficient than a wood-fired or even a natural gas–fired boiler (depending on coal quality). Increasing energy efficiency by using a coal boiler instead of the other options would result in higher carbon emissions. (In corollary, focusing on industrial carbon efficiency alone could result in the use of methods such as sequestration that would increase energy consumption);
- an exclusive emphasis on maximizing the output of emerging renewable power technologies would neglect the two other factors determining the carbon intensity of the electricity market: the carbon intensity of fossil fuel generation and total electricity demand; and
- the carbon intensity of hydrogen fuels depends on their primary energy source. Hydrogen production technologies that use electricity as a fuel source, such as electrolyzers, can increase greenhouse gas emissions if the marginal electricity used to produce the hydrogen comes from a higher carbon source (e.g., natural gas) than the base load. Therefore, an undiscriminating "diversity" approach to primary energy sources and production technologies for hydrogen fuels could lead to some pathways that increase greenhouse gas emissions. Carbon capture and sequestration technologies, which are currently under development, may offer a companion technology to address this issue, but the introduction of this mitigation technology would come at a significant cost to the energy balance of hydrogen fuels.

Thus a major lesson arising from our case studies is that the pursuit of other objectives of a sustainable energy strategy, without a specific long-term carbon emission reduction objective, may lead to perverse emission impacts.

4. ECONOMIC INSTRUMENTS FOR LONG-TERM CARBON EMISSION REDUCTIONS AND TECHNOLOGY DEVELOPMENT

4.1 ECONOMIC INSTRUMENTS AND CANADA'S CLIMATE CHANGE PLAN

Climate policy in this country has largely been implemented through voluntary programs and expenditure instruments. But experience is revealing the weakness of this approach: voluntary methods will not achieve Canada's Kyoto targets, and the per-tonne reduction expenditures are proving costly since subsidies go to actors who would have reduced emissions without a subsidy as well as to those who needed the incentive.

This reality underscores a perplexing question: if economic instruments are apparently so effective and efficient, why do they not have a larger presence in Canada's national climate change strategy? And, in an environment of tight fiscal space, can we afford not to adopt those measures that hold the greatest promise for achieving carbon reductions?

4.1.1 A Piecemeal Plan

The November 2002 Climate Change Plan for Canada (CCPC) contains a plethora of small initiatives—over 90 federal and provincial programs to date. These have spread both the burden and the benefits across regions and sectors, but they have also led to piecemeal results and high administrative costs.[46]

If Canada continues to follow this piecemeal model rather than a plan composed of fewer, more rigorous and innovative elements, it risks falling far behind in the climate race; it will be a policy and technology taker in the sustainable energy field, with attendant competitiveness concerns.

4.1.2 A Largely Voluntary Emphasis

The CCPC is heavily weighted to information, suasion and voluntary action approaches.[47] The main exception to Canada's largely voluntary approach is the domestic emissions trading system being established for large final emitters (LFEs); there is widespread confidence that real emission reductions will be achieved under this program. There are also some targeted subsidy programs, but other sources of emissions are still primarily addressed through voluntary means.

Evaluations of the environmental effectiveness of voluntary initiatives have been inconclusive. Surprisingly, the economic efficiency of such initiatives has also been found to be generally low,[48] due to administrative costs and to the high proportion of actors who choose not to take action. Both of these factors can to some extent be addressed through rigorous criteria for use and robust design.[49]

Possible reasons for the ongoing reliance on voluntary and suasive approaches are set out below:

- The knowledge and information infrastructure for managing and monitoring economic instruments and other regulatory systems is large and complex, requiring a long lead time to design and establish it.
- The CCPC's goal is "to reduce greenhouse gas emissions in the most cost-effective way possible." This creates a preference for policy instruments that place a priority on achieving low cost or least cost at the firm level. Voluntary programs and expenditure instruments do this best. The CCPC's goal reflects competitiveness priorities, which have dominated effectiveness considerations.
- The concern with competitiveness has also made policy-makers reluctant to use instruments that put a price on emissions (whether through a tax or a tradable emissions permit system); there is a feeling that this would hurt the competitiveness of Canadian industry, particularly in the absence of any equivalent price signal in the U.S. market. The scale and extent of this effect, however, is not known.
- Another key factor in the design of policy instruments has been concern to manage federal–provincial relations in an area of contested jurisdiction. Federal leadership on voluntary initiatives and federal willingness to subsidize expenditure instruments face less provincial resistance than regulatory measures (including various types of emission charges and market-based regulations).

This is not to say that there is no role for voluntary initiatives in managing an environmental issue. But voluntary initiatives are best undertaken at an early, learning stage in the management of the issue. We have moved beyond this stage in managing greenhouse gas emissions.

4.1.3 Project Green

Project Green is a set of policies and programs from the federal government, aimed at supporting a sustainable environment and a more competitive economy. Project Green's groundwork was established by the October 2004 Speech from the Throne and Budget 2005. Launched on April 13, 2005, *Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment*, is Project Green's first instalment.

4.2 MACROECONOMIC IMPACTS OF FISCAL POLICY TO PROMOTE LONG-TERM CARBON EMISSION REDUCTIONS

This following discussion presents a qualitative review of findings from other studies that have attempted to quantify the macroeconomic impacts of climate change and energy policies, with an emphasis on insights related to targeted policies. The review is limited mostly to studies in developed countries and, in particular, to studies related to the Canadian context such as those conducted from 1998 to 2003 by the Analysis and Modelling Group (AMG) of Canada's National Climate Change Process (NCCP).[50]

4.2.1 What Are Macroeconomic Impacts?

Macroeconomic impacts are the economy-wide effects of a policy (i.e., the direct and indirect changes in prices and output throughout the economy), created by the backward and forward linkages among sectors and markets. Allowing for these dynamic and economy-wide effects can increase or decrease the overall costs (and benefits) of climate and energy policies.

One of the most comprehensive and common measures of the macroeconomic impact of policy is the percentage change in real gross domestic product (GDP) relative to a reference case or business-as-usual (BAU) case without the policy. However, GDP has some disadvantages as an indicator of long-term effects and overall societal well-being:

- the measure does not include changes in non-marketed goods and services such as the quality of goods, environmental amenities and leisure;
- changes in real GDP can also mask distributional effects (i.e., differences in the incidence of costs and benefits) among different sectors, regions, firms and individuals; and
- long-term impacts on GDP are difficult to predict and are sensitive to many different and controversial assumptions, such as the rate of technological change with and without the policy.

For these reasons, many impact studies report effects on both short- and long-term GDP growth, together with distributional consequences and effects on specific determinants of long-term growth or structural change, such as the rate of technological change (innovation) and competitiveness. Some studies also consider other non-market costs and benefits such as the effects of energy or carbon policies on local air quality.

4.2.2 Evaluating Macroeconomic Impacts: It's Not So Simple

The macroeconomic impacts of energy and greenhouse gas policies are very uncertain. Impact studies conducted after a policy has been implemented are complicated by the difficulty of unravelling the effects of the specific policy from changes caused by a multitude of other factors that affect the overall economy. Estimating macroeconomic impact prior to the implementation of a policy requires complex models and numerous assumptions.

Numerous competing models exist for assessing macroeconomic impact, and different models yield different results depending upon model structure and input assumptions. Even using the same model, the magnitude and duration of macroeconomic impact associated with the same mix of policies can also vary across economies and over time, due to differences in various factors that include initial resource endowments, economic structure, and labour and capital markets.

Regardless of the model or modelling approach, precise quantitative assessments of macroeconomic impact are often resource- and time-intensive. Furthermore, many models of macroeconomic impacts are too aggregated to capture the impact of smaller, more targeted policies (i.e., policy instruments directed at specific sectors and technologies), and they do not necessarily provide an adequate "story" of the macroeconomic impact or long-run dynamics for decision makers. In practice, the design and analysis of targeted policies can benefit from the use of more qualitative approaches such as simple screening techniques and rules of thumb for predicting possible macroeconomic impact.

The recently released Project Green provides the following information on the Large Final Emitters (LFE) system:

The purpose of the LFE system is to secure emission reductions from Canada's largest emitters in the mining and manufacturing, oil and gas, and thermal electricity sectors. These sectors are large contributors to Canada's GHG emissions — just under 50 percent of the total. The LFE system will cover about 700 companies operating in Canada; 80–90 of these companies account for approximately 85 percent of the LFE GHG emissions.

The system that is being introduced respects all previous commitments that have been made concerning the LFE system, including that the cost of compliance to industry will not be more than $15 per tonne of carbon dioxide equivalent. Appropriate mechanisms will be implemented to achieve that price cap commitment.

The overall target established for the LFEs is for 45 Mt of annual reduction during the 2008–2012 Kyoto commitment period. The 45 Mt target is based on a BAU baseline to which methodological improvements have been made to the electricity component.

LFE companies will have a number of options for compliance:

- Investment in in-house reductions. This is likely to be the first priority of LFE companies, since it allows them to invest in their own facilities and profit from increased productivity and reduced waste associated with such investments in emission reductions and modernization.
- The purchase of emission reductions from other LFE companies that have done better than their target.
- Investment in domestic offset credits (credits attesting that a real emission reduction or carbon sequestration has been generated outside the LFE system — these credits may be purchased by LFE companies and used for compliance with their obligations).
- The purchase of international credits provided that these represent verified emission reductions — i.e., only "green" international credits will be recognized for Canadian compliance purposes. Investment in international credits may be linked to sales of Canadian technology and provides LFEs with experience in an international trading market that is likely to be of increased importance over time.

In addition to these options, LFEs would be able to invest in technology developments and count those investments for purposes of compliance. Legislation has been introduced in the House of Commons to establish a Greenhouse Gas Technology Investment Fund. The Fund would support the development and deployment of innovative domestic technologies that can reduce GHG emissions. For the most part, investments in the Fund would not generate emission reductions until after the Kyoto period of 2008–2012. However, it is important to provide this additional compliance option to LFE companies so as to promote investment in Canadian technology and facilitate Canada's long-term transformational change.

4.2.3 What Do Recent Studies Suggest About the Macroeconomic Impacts of Carbon Fiscal Policies?

There are hundreds of estimates of the costs and benefits of environmental protection in the literature. In recent years, considerable analysis has been directed toward the costs (and in some cases benefits) of meeting emission reduction targets under the Kyoto Protocol. Many of these analyses consider price or quantity instruments (i.e., taxes or tradable permits) applied on an economy-wide basis to encourage the least-cost mix of investments that will achieve the desired target. A few examine more targeted sector- or technology-specific instruments. In all cases, the macroeconomic impact of fiscal instruments related to greenhouse gases and energy is still very uncertain and controversial.

In 2000, the NCCP's Analysis and Modelling Group conducted a macroeconomic analysis of the national and provincial effects of greenhouse gas reduction options. That analysis showed that, depending upon assumptions about microeconomic costs and international actions, meeting the Kyoto targets reduces real GDP by 0 to 3 percent by 2010 (equivalent to a one-year recession), if all necessary policies are implemented by 2000. Although there is a small increase in activity in the short term as a result of increased capital spending, GDP declines after a few years as a result of the higher production costs, lower productivity, trade effects and reduced disposable incomes. Provincial impacts are generally within 1.5 percent of the national average. However, the relative impacts on each province vary depending on the reduction path. If Canada acts alone, Saskatchewan and Ontario are the most negatively affected. With international action, Alberta, Saskatchewan and New Brunswick are the most negatively affected.

The AMG's analysis also showed that, if Canada acts alone, the marginal costs of all measures to meet the Kyoto target range from $40 to $120/tonne in 2010. If passed through to energy prices, these costs raise gasoline prices by 13 to 35 percent, natural gas prices (for residential use) by 30 to 75 percent and coal prices by 300 to 800 percent. The impact on electricity prices varies greatly across regions depending on the dominant sources of supply and the pricing regime. Assuming average cost pricing, price increases vary from a low of 2 percent in Quebec to almost 84 percent in Alberta.[51]

In general, the aggregate macroeconomic costs of the various instruments proposed in the NRTEE's case studies are likely much smaller than the estimates produced by the AMG. The reasons are threefold:

- For the most part, the marginal costs of emission reductions in the case studies are lower than those assumed by the AMG to meet the Kyoto targets.
- Total emission reductions by 2010, even without adjusting for possible double-counting among the case studies (e.g., both the renewables and energy efficiency case studies include reductions in the electricity sector), are 3 to 10 times lower in the case studies than those assumed by the AMG.
- Even in the case of instruments such as emission prices, the estimated impact on energy and other product prices is smaller than that estimated by the AMG, suggesting more limited demand feedbacks.

The AMG analysis strongly supports the view that costs can be lowered by moving from sector-specific targets to economy-wide targets. This effect allows marginal costs to converge across sectors. Sector-specific emission targets are also shown not to distribute the burden any more evenly across the country. As well, the analysis suggests that the design of instruments such as permit trading can greatly affect the distribution effects.

Studies in other countries have produced results with similar ranges of impact. However, there is no strict correlation between the carbon price necessary to reach a certain emission target and the GDP loss faced by a country. For example, higher carbon taxes are required in Japan than in the United States, but GDP impact is lower in Japan than in the United States. This result is explained in part by pre-existing differences in energy supply, economic structure and the tax system. For example, if a country relies more on renewable energy and specializes in low-energy-intensive industry, a higher carbon price may be required to achieve a given target but the aggregate impact on output will be lower. However, in these cases, the burden of emission reductions likely also falls only on a few sectors. The macroeconomic impact can sometimes be positive for individual countries in an international implementation framework. In addition, the impact is often non-linear; that is, the impact on GDP may increase more or less rapidly than the increase in carbon prices or permit values.

4.3 GENERAL FINDINGS: USING ECONOMIC INSTRUMENTS FOR LONG-TERM CARBON EMISSION REDUCTIONS AND TECHNOLOGY DEVELOPMENT

Economic instruments (including charges, tradable permits, tax measures and government expenditure) are a favoured policy tool for driving emission reductions because of the broad-based and diversified nature of greenhouse gas emission sources.

There is also an important place for other tools, such as regulations, disclosure requirements and educational programs, but these were outside the boundaries of the EFR and Energy Program. The efficiency and effectiveness of economic instruments should always be tested against regulatory and stringent voluntary alternatives. Many experts believe that regulatory approaches are more efficient and effective for low-intensity, "non-industrial" applications. Examples include building codes, appliance standards and auto-efficiency standards. In addition, economic instruments often need to be complemented by other policy measures in order to be effective. For instance, access to transmission grids is essential for renewable energy deployment.

4.3.1 Introduction to Economic Instruments

Economic instruments can be grouped into three broad categories according to their effect on government finances:

1. *Revenue-raising instruments* such as taxes and auctioned permits that increase the relative cost of emission-intensive technologies and products. These instruments create a continuous incentive for innovation to improve emission efficiency or to shift to lower-emission substitutes, as well as providing revenues to the government.

2. *Budget-neutral instruments* that increase the relative cost of emission- and/or energy-intensive technologies and products but do not raise revenues for government. This category includes market-based regulation, which requires firms to meet certain standards but allows them to trade with other parties in meeting this commitment. Budget-neutral instruments can focus on technology (e.g., a renewable portfolio standard or California's Vehicle Emission Standard) or on performance (e.g., an LFE domestic emissions trading program, discussed above).

3. *Expenditure instruments* such as subsidies and other incentives that reduce the relative cost of technologies and products with lower emission and/or energy intensity, making them more competitive with incumbent technologies. They may target current decisions (e.g., through accelerated depreciation for tax purposes or mail-in rebate programs) or long-term cost competitiveness through funding for research, development and commercialization of new technologies. Financing these subsidies requires governments to either increase other taxes or reduce other expenditures.

Another perspective on economic instruments groups them according to the scope of application: are they broad-based, sending signals across the economy and letting the market determine the nature of the response? Or are they targeted to a specific sector, technology or action? This perspective will be further discussed below.

Regardless of the economic instrument, a few general principles apply to their design:

- The costs of fiscal policies are generally lower when they are expected, gradual, continuous and well designed.
- All things being equal, broad instruments that provide more flexibility with respect to the form of response are generally less costly than more targeted or prescriptive instruments for achieving the same reductions.
- Instruments that encourage firms and households to invest in more efficient equipment and processes (when they need to replace existing equipment or when they are considering new equipment purchases) are less costly than instruments that require them to accelerate capital replacement.
- Instruments that avoid transferring wealth between parties and/or regions are more likely to receive public support (e.g., in the absence of targeted revenue recycling or transition measures, a carbon charge would transfer wealth from fossil fuel–intensive regions to those with hydroelectric resources).

The type and magnitude of the economic impact will vary across instruments even though the environmental outcome may be the same. As well, there are many opportunities to mitigate impacts and to improve effectiveness in the detailed design of specific instruments. Often there will be some trade-off between minimizing aggregate costs and other objectives such as minimizing distributional impact.

In developing packages of instruments, it is important to consider the interactions among policies and the resulting impacts of these interactions on desired outcomes. Another key consideration in designing policy packages is staging—both to reduce costs by allowing adaptations to follow the natural rate of turnover in long-lived capital stocks and to tailor the fiscal instrument to the development stage of the technology (see Section 5).

4.3.2 Application of Broad Measures

Advocacy for and against the use of broad-based price signals (emissions charges such as taxes and broad-based tradable permits) to achieve environmental objectives is an old (some would say tired) debate. In Canada, the debate is characterized by entrenched positions and little interest on the part of politicians. And yet experience from other jurisdictions offers many examples of innovative ways to implement environmental charges—how to design these price signals to ensure effectiveness (the extent to which the measure will deliver its ecological objective), ensure efficiency (the extent to which the ecological objective will be reached with the lowest marginal economic costs), and minimize concerns about competitiveness (at firm, industry and/or sector and national levels) and distributional equity (the effects of the measures across sectors, regions, individuals and generations).[52]

In assessing the effects of broad-based measures, it is essential to compare policy instruments that have equivalent environmental outcomes. In this context, the key advantages of emissions charges emerge as greater efficiency in the allocation of abatement costs and the creation of incentives for continuous improvement. The primary appeal of broad-based measures is that they are neutral to technology choice, leaving the choice of response to the subject parties. Because these instruments are performance-based, they avoid the risks associated with picking winners and, instead, enable winners to emerge through continuous improvement and innovation. Improvement and innovation occur because it is always in a party's interest to lower its marginal cost of abatement. However, the precise response to a price signal cannot be predicted; hence, emissions charges do not guarantee the achievement of a specific emission reduction target.

These instruments have the greatest impact on market prices. They can often affect energy-intensive sectors or regions more than others, and they tend to have disproportionate effects on low-income households. However, the cost and distributional impact can be greatly reduced through revenue recycling policies. For example, costs can be reduced by lowering or eliminating other taxes that dampen economic activity. Alternatively, more focused revenue recycling policies can be used to mitigate impact on specific income groups, sectors or regions of the economy. Recycling mechanisms must be designed carefully to balance multiple objectives, such as protecting historical investments while providing incentives for new investment and encouraging desirable long-term technological changes. Recycling mechanisms for industry must also be designed carefully to minimize any possible windfalls as a result of the policy.

The impact of these instruments on the competitiveness of individual industries depends upon both their energy intensity and their trade intensity. Competitiveness is a complex concept that depends on numerous other interacting price and non-price factors such as overall tax rates, wages, productivity levels, resource availability, proximity to markets, innovative activity and exchange rates. The incremental effects of many existing energy and environmental policies are small in comparison to other factors. However, greenhouse gas reduction policies could have a more significant impact if large and rapid reductions were required.

When considering the application of broad measures, it should be noted that large fluctuations in market prices for energy, such those seen in recent years, would likely overwhelm most signals sent by policy. These fluctuations would be a stronger driver of the choice of fuel and technologies. However, the fuel switching that occurs might sometimes result in the use of more carbon-intensive fuels; thus such a market price signal should not be considered a substitute for policy action if our objective is a long-term reduction in carbon emissions.

In theory, broad-based price signals (emissions charges such as taxes and tradable permits) supplemented by targeted relief were widely acknowledged by participants in the EFR and Energy Program to offer the best combination of effectiveness and efficiency in stimulating long-term carbon emission reductions. These instruments increase the relative cost of emission-intensive technologies and products, creating a continuous incentive for innovation to improve emission efficiency or to shift to lower-emission substitutes. Broad-based measures will stimulate the most immediate response from mature technologies. However, when applied in a predictable and continuous fashion, they will also gradually stimulate the uptake of emerging technologies and investment in the development of new ones. They were considered to offer a better approach than the alternative array of complex and possibly arbitrary individual regulations and standards.

In practice, however, broad-based price signals have received virtually no thoughtful discussion, let alone application in Canada. The reasons are summarized below:

- Broad-based price signals affect energy-intensive sectors or regions more than others and, depending on their design, tend to have disproportionate effects on low-income households. This makes them unpopular in the Canadian political context. However, international experience has tested many methods to mitigate these distributional effects.
- International competitiveness concerns mitigate against the imposition of a price signal, particularly in commodity-based sectors where the market price is set internationally (such as oil) and which are not able to pass on this cost. Although revenue recycling can in theory address competitiveness impacts, there is little practical experience with this, except in the case of the U.K.'s Climate Change Levy program. While competitiveness has been a dominant concern shaping public policy in Canada, our case study on industrial energy efficiency suggests this concern may be overblown. The study looked at the effect of \$30/tonne CO_2e price signals with no mitigation policies and found that only the industrial minerals and the iron and steel sectors experienced changes in output prices high enough to reduce output.
- Revenue-generating price signals, such as taxes or auctioned permits, run counter to the prevailing political movement to lower taxes. There is widespread public distrust regarding how governments will use new revenue and, in particular, whether they will fairly redistribute it. Tax shifting can be used to ensure that the net level of taxation remains the same, but there has been little discussion of this approach in Canadian climate change policy.

On the other hand, incentive instruments, such as subsidies, are also likely to face significant resistance unless they have a funding base. Revenue-generating price signals can provide such a base. For this reason, a low energy or carbon charge, paired with incentive programs in a tax-shifting model, warrants serious discussion and attention.

Given these dynamics, is there any room for the future use of broad-based measures in Canada? Participants in the EFR and Energy Program did identify one possible application. The U.K. Climate Change Levy and companion Climate Change Agreements elicited interest due to their simplicity and targeted revenue recycling. The Levy is a tax on the use of energy in industry, commerce and the public sector. The revenue raised is recycled to business through three streams: (1) offsetting cuts of 0.3 percent in employers' National Insurance contributions; (2) additional support for energy efficiency (technical support plus a 100 percent first-year capital allowance for certain energy-saving investments, which is expected to be worth up to £70 million a year); and (3) programs to stimulate the uptake of renewable sources of energy (£50 million a year). The objective has been no net gain for the public finances and no increase in the tax burden on industry as a whole (although it may not be cost-neutral at the individual firm level). Under the companion Climate Change Agreements, energy-intensive industries receive a rebate of up to 80 percent of the Levy if they agree to a program of energy savings, negotiated sector by sector.[53]

4.4 APPLICATION OF TARGETED MEASURES

If broad-based measures cannot find political acceptance, targeted measures will continue to be the main category of economic instrument available for driving long-term carbon emission reductions. The charge for policy-makers will be to find other ways to capture the performance-based benefits of this approach.

Targeted economic measures focus on a technology, class of technologies or action. They do so in two ways:

- through subsidies, which reduce the relative cost of technologies and products with lower emission intensities, making them as or more attractive than incumbent technologies; and

Recommendation

The option of a broad-based price signal should be given serious consideration. The case study experience shows that this type of instrument (such as a charge or a permit market) is the most effective in delivering on the policy objective to which it is explicitly tied (in this case carbon emissions) and the most cost-efficient to society in that it allows for the greatest degree of flexibility in societal response. A key feature of such instruments is that they are also effective in ensuring that some of the government's other policy objectives—notably in the area of innovation and technology development—are promoted. At the same time, the consultation conducted during the Program revealed serious concerns about the competitiveness impacts of such a price signal. Another concern centred on the design and implementation challenges posed by a broad instrument of this sort and on the very high standard for "getting it right." Finally, there was acknowledgement of the lukewarm political interest in such instruments. An existing model for Canadian policy-makers, if they are to consider a broad-based signal, is the U.K.'s Climate Change Levy and companion Climate Change Agreements.[54]

- through so-called market-based regulation such as renewable portfolio standards or the planned LFE domestic emissions trading system, which requires designated firms to meet certain targets but allows them to trade with other parties in meeting this commitment.

4.4.1 Subsidies

Subsidies form the backbone of the ecological fiscal measures that are currently in place in Canada. Subsidies may target current decisions by reducing upfront capital costs or target long-term cost competitiveness through funding for research, development and commercialization of new technologies.

The precise response to subsidies, like that to emissions charges, cannot be accurately predicted, and hence neither of these instruments is able to assure a specific emission reduction target.

The total cost of subsidies often exceeds the direct costs to government because governments must raise funds through other taxes, which have dampening effects on economic activity. These effects may be partly offset by raising government funds through more targeted approaches that correct for other distortions. For example, a subsidy for hydrogen vehicles may be funded through a levy on gasoline that reflects its external costs.

Subsidies tend to require relatively large public expenditures per unit of effect, because of the presence of firms and individuals that would have undertaken the desired change in the absence of the subsidy. These costs can be large but are often underestimated. Evaluations of energy efficiency incentive programs, for example, have found that 40 to 85 percent of program recipients would have acted in the absence of the program.[55] This rate can be reduced through more discriminating methods for distributing subsidies. For example, grants can be tied to specific performance criteria rather than general tax credits for a class of technologies. The relatively high cost of subsidies per unit of reduction was observed in two of the EFR and Energy Program's case studies: on industrial energy efficiency and, on emerging renewable power technologies.

The cost of subsidies can be spread out over the entire economy, reducing, although not eliminating, negative distributional impacts. Moreover, the performance of subsidies can be improved through better policy design. The benefits of various design options must also be weighed against other considerations such as higher administrative costs.

4.4.1.1 Current Decisions

Subsidies targeting current decisions (e.g., accelerated capital cost allowances or consumer rebates) usually aim to reduce the upfront capital costs of investments in specific technologies. However, the administrative need to designate specific, qualified technologies dampens innovation, deters new market entrants and favours technology-specific responses rather than systems innovation and substitution.

Concerns about supporting higher-cost technologies and being technology-prescriptive could be addressed by designing targeted measures that are performance-based. Under this approach, subsidies would be directed more toward specific outcomes than toward specific technologies. For example, a carbon trust could be established to purchase reductions (through competitive bidding) from a wide variety of sources regardless of the technology. Such a targeted measure would share a key characteristic of broad-based instruments, notably their promotion of innovation.

This approach does raise some issues, however. In the area of emerging renewable power, for example, a performance-based subsidy on its own would skew selection toward market-ready technologies to the detriment of pre-competitive ones. From the government's perspective, verification issues are also more complex.

4.4.1.2 Long-term Competitiveness
Subsidies (e.g., grants and loans) for research and development, while a well-established category of expenditure instrument, are typically highly uncertain with regard to the scope of their impact on reductions and very long term in delivering their benefits.

4.4.2 Market-based Regulation
Market-based regulation avoids many of the weaknesses of conventional subsidies. These instruments require firms to meet certain targets but allow them to trade with other parties in meeting this commitment. Overall costs are minimized through the use of trading. The target is specified by the regulation, and depending on the design, the regulation can be performance-based and technology-neutral.

A portfolio standard is an example of a market-based regulation with a technology focus. The policy objective of a portfolio standard is rapid deployment of a technology facing a price barrier in its early stage of market entry. By design, it ensures a high penetration rate for targeted technology and/or high participation rates. The design of this instrument, including the point of application, can greatly affect performance.

Different regional targets may be developed to reflect regional differences in supplies and costs or in greenhouse gas benefits. Costs could be further reduced through a national credit trading system. A phased implementation with clear targets and timelines may also offer more opportunity for technological changes that lower the ultimate costs of the instrument.

Unique Risks

Promoting the development and adoption of new technologies may require greater incentives than suggested by economic models. There are many reasons: existing capital stock may not be ready for replacement, capital markets demand high premiums for taking risks in early commercial applications, and new technologies are not always perfect substitutes for the incumbent technology.

In very limited cases, there may be unique risks that merit an extra level of public investment, because of the public good arising from successful adoption of a high-risk technology. One approach, adopted in other countries, is the use of loan guarantees. Other fiscal examples are targeted tax credits, direct subsidies, repayable and contingently repayable contributions, and grants to university technology incubation centres.

Finally, the use of a system of penalties can provide a cap on the costs of the instrument, which are uncertain. Any revenues raised from penalties can be reinvested in the research and development of new technologies.

The planned LFE domestic emissions trading system is an example of a market-based regulation with a performance focus.

The application of market-based regulation in Canada faces a possible limitation: the need for the market covered by the regulation to have adequate supply and demand to ensure liquidity. This necessity requires that the definition of "sector" or "technology" be kept broad, which may be difficult for certain Canadian applications, particularly on the production side.

Experience with LFE domestic emissions trading to date also demonstrates that these instruments, which are based in regulation, require the same complexity of infrastructure (program design, reporting, monitoring and enforcement) as any other regulation.

Recommendation

As an alternative to broad-based price signals—and consistent with current policy approaches—economic instruments targeted to specific types of technology should be used, but they would need to be broadened. They could also be designed to link directly to the policy objective being pursued (in this case carbon emission reductions). This linkage would allow the targeted measures to share the key characteristics of broad-based instruments, notably their promotion of innovation. An example of such an instrument is the U.K.'s Enhanced Capital Allowance for vehicles with low carbon emissions.[56]

4.5 TRANSITION MEASURES

The EFR and Energy Program case studies did not examine transition issues. However, EFR literature highlights transition measures as a key factor in achieving acceptance, particularly of new charges. Transition mechanisms include:

- *Pilot projects:* These help build awareness, understanding, experience and trust.
- *Predictability and continuity:* The details of an EFR measure should be provided to affected firms and households well in advance, and policy continuity should be maintained over time so that businesses and households are confident in making the investments necessary to respond to the price signals.
- *Gradual implementation:* The introduction of new taxes or charges and the reduction or phase-out of current subsidies should proceed at a modest pace to give firms time to adjust to new costs.
- *One-time assistance:* One-time subsidies or credits can be provided to support the transition costs of implementing new technologies.

Part 2 of the present report contains further discussion of economic instruments to support the development of the specific technologies examined in the case studies.

5. A COORDINATED, LONG-TERM CARBON EMISSION REDUCTIONS STRATEGY

Energy is a basic good in society, essential for the functioning of our modern civilization. People want reliable, high-quality and affordable energy services. They care less about the source of such services, as demonstrated by the sequential shifts to new fuels over the course of history.

Energy is a dominant presence in Canadian society. We are large producers of, large consumers of and highly dependent on energy, with our cold climate and far-flung geography. For these reasons, Canada needs to think now about how to navigate the foreseeable shifts in the energy economy, as new technologies are introduced, new ecological pressures emerge and some incumbent sources ebb. The benefit of an explicit strategy will be an orderly transition and greater certainty for all actors.

Sustained and sustainable efforts will be required to avert the more extreme scenarios of climate change. Policy-makers will need to focus beyond the short-term horizon of the Kyoto Accord—and its comparatively timid first steps—and on the fundamental changes needed in the energy system to stabilize concentrations of greenhouse gases in the atmosphere at safe levels. The two levers most amenable to public policy intervention are energy intensity (the amount of energy used to create a dollar of economic output) and the carbon intensity of the energy sector (see box).[57] This will require path-breaking innovations such as those examined in this study: increasing the efficiency of energy use, removing obstacles to the wider use of existing carbon-free energy technologies, and developing and deploying entirely new low-carbon technologies. These actions could produce long-term and enduring results, positioning Canada as a winner in the shift toward a less carbon-intensive global economy.

The 25-year time frame proposed by the EFR and Energy Program would enable the exploration of a coordinated transition: phased deployment of proven mature technologies, complemented by the gradual adoption of emerging ones, and investment in the research, development, demonstration and commercialization of longer-term options.

The EFR and Energy Program used case studies to examine the use of fiscal instruments in encouraging the adoption of energy-based carbon mitigation technologies at three different stages:

1 *Mature technologies*, at the market-ready or market-entry stage of development. Industrial energy efficiency was the focus of investigation because apparently cost-effective energy efficiency investments are routinely forgone, suggesting some form of market barrier. Large hydro is another example of a mature energy-based carbon mitigation technology.

2 *Emerging technologies*, spanning the demonstration to early market-entry stages. Emerging renewable power technologies (based on the EcoLogo criteria) were examined; other examples in this category are hybrid cars and thermal renewables, which were not covered.

…the key driver of historic and future carbon emissions…is a byproduct of four interrelated factors…

+ population growth rate
+ per capita economic growth rate
+ energy intensity growth rate
+ carbon intensity growth rate

Most scenarios for the future suggest that the expected increases in population and economic growth will outweigh the continued decreases in energy and carbon intensities.…

—Battelle Memorial Institute, *Global Energy Technology Strategy: Addressing Climate Change.*

Initial Findings from an International Public–Private Collaboration (Washington, D.C.: Battelle, n.d.) pp. 14–15.

3 *Longer-term new technologies*, still in the fundamental research to demonstration stages. Hydrogen fuel technologies were the technologies of interest in this study; other examples of longer-term new technologies are carbon capture and sequestration.

It should be noted that the choice of the specific technologies for our case studies does not imply primacy for any of these technologies: they are understood to fit within a broad mix of mitigation technologies, supply sources and demand sectors, now and in the future. This mix includes mitigation technologies such as carbon capture and sequestration; other low-carbon energy sources (e.g., nuclear, large-scale hydro and thermal renewables) that, together with carbon fuels, will likely remain significant sources of primary energy in the future; and other demand sectors (e.g., residential, commercial and transportation) and technologies (e.g., hybrid and electric vehicles). All need to be addressed as part of a balanced approach to long-term carbon emission reductions. It should also be noted that the specific recommendations related to these case studies do *not* constitute a proposal for a comprehensive climate change action plan or energy strategy for Canada; other technologies, initiatives and measures will be needed. These were simply outside the scope of this program.

In presenting the findings and recommendations of the EFR and Energy Program, we draw not only on the specific analysis carried out in the case studies (and the general lessons they yield regarding the use of economic instruments), but also on the consultation process conducted as part of the Program's work.

5.1 STAGING AND CONSIDERATIONS FOR A COORDINATED TECHNOLOGY TRANSITION STRATEGY

A key consideration for policy-makers as they develop a long-term, coordinated strategy for energy policy will be how to tailor policy measures to support the different development stage of each technology. Particular consideration will need be given to creating synergies between current and future technologies, so that these technologies can reinforce one another where possible.

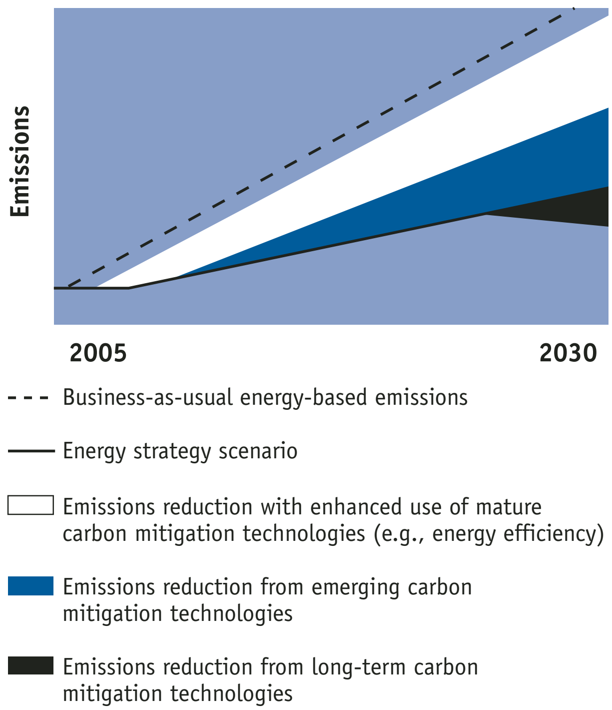
- *Mature technologies:* Many carbon emission reduction options are currently available and cost-competitive: these should form the first and major focus of a coordinated technology transition strategy.
  - The foremost emphasis should be on reducing demand through carbon-efficient energy efficiency measures—the "low-hanging fruit" in emissions mitigation. This should be the priority before any investment in new supply. Mature and cost-effective options for significant efficiency improvements are available now in all sectors, and they are the focus of some of the fiscal measures proposed in this report. The best opportunity for energy efficiency improvements comes with the turnover of capital stock; each one of these opportunities must be seized. Energy efficiency relieves the pressure to build new supply and has historically been less costly than building new supply. It frees up resources and buys time to develop alternative energy sources.
  - The synergies between incumbent technologies and future technologies identified for the strategy should be a factor in assessing incumbent supply options. For example, large hydro complements many emerging renewable power sources by providing reservoirs that can offset their intermittent nature, while enhancing the renewable power component of the electricity grid reduces the carbon intensity of electricity and is one strategy for carbon-efficient hydrogen pathways.
  - Economic instruments to support mature carbon mitigation technologies should ideally be broad-based to avoid picking winners. They should focus on reinforcing the position of these technologies by increasing the relative cost of emission-intensive technologies and products, thereby creating a continuous incentive to shift to lower-emission substitutes or to innovate to improve emission efficiency.
- *Emerging technologies:* Some of these technologies (e.g., hybrid cars, wind and solar) are commercially viable or near-viable in certain applications and ready for immediate expanded use. Other technologies (e.g., wave power) require further development and would only be commercially viable in the mid- to long term.
  - Instruments to support emerging technologies should focus on stimulating market adoption to encourage the learning by doing and economies of scale needed to close the cost gap with incumbent technologies. Examples include portfolio standards, guaranteed minimum feed-in tariffs and/or production subsidies.

Instrument Choice and Technology Stage

The fiscal instrument should be tailored to the development stage of the technology:

- Large cost differential between incumbent and new technology? Reduce difference through R&D subsidies.
- Cost differential reduced and performance improved? Focus on learning by doing and economies of scale; encourage market adoption through portfolio standards and/or subsidies.
- Cost difference eliminated? Reinforce position of new technology through broad-based instruments (e.g., emissions permits, taxes).

Emissions Impacts of Coordinated Energy Strategy Over Time (notional only; not to scale)



- *Longer-term new technologies*: By their nature, these still need to overcome technical challenges and large costs compared with incumbent technologies. Where these challenges are still significant, they are best addressed by research and development subsidies and incentives. Where the technology is more mature, demonstration and pre-commercialization assistance is important.
  - Of the economic instrument options studied, public R&D investments are the most expensive and uncertain in terms of assured carbon emission reductions. For this reason, as well as because the demand for R&D funding can be limitless and because technology development occurs within an international arena, these investments should strategically target fields in which Canada has a competitive advantage. Consideration of Canadian capacity to respond to this assistance, particularly at the pre-commercialization stage, is also needed.
  - Technology development is driven by private investment as well as public investment. Thus fiscal mechanisms for mobilizing private research and development investments must also be used. For fundamentally new technologies that are highly research-intensive and have long commercialization timelines, such as hydrogen fuel cells, new approaches to stimulating R&D investments may also be needed.

It must be emphasized that technologies can span two or more stages of development. Take, for instance, some of the technologies examined directly or indirectly in the case studies: there are certain hydrogen technologies with competitive market applications today, although most are still in a research and development or early demonstration stage. Adoption does not occur all at once; rather, technologies are gradually phased in as they become competitive, niche by niche. Similarly, even long-established, mature technologies can be revolutionized by radical new production processes, with potential breakthroughs in energy efficiency.

Assessment of technologies for their potential to reduce carbon emissions should always be done on the basis of life-cycle emissions (and life-cycle net benefits, i.e., total benefits minus total costs), not just at the final point of energy use. The significance of life-cycle assessment was highlighted in the hydrogen case study, where the choice of hydrogen pathway affected life-cycle carbon emissions by as much as 175 percent. Other research shows that zero-emission vehicles, fuelled by hydrogen and electricity, may have greater carbon emissions on a life-cycle basis than best-in-class internal combustion vehicles on the road today, depending on the electricity source and the method of producing hydrogen. Carbon capture and sequestration, another longer-term technology, may be able to moderate these results, but not without affecting the energy balance—the amount of energy required across the life cycle to produce a given unit of energy.

6. LESSONS: THE EXPERIENCE WITH ASSESSING FISCAL INSTRUMENTS

In its exploration of approaches, processes and methodologies that link the issues of energy, climate change, technology development and fiscal policy, the NRTEE has attempted to generate lessons that can inform policy development in the fiscal area.

The following discussion summarizes these general lessons.

6.1 DATA RELIABILITY AND COMPREHENSIVENESS

It goes without saying that the decision to apply fiscal measures to increase the use of emerging energy technologies should be based on information about the anticipated effectiveness of such policies. Yet the case studies showed that the ability to assess anticipated effectiveness, and hence make sound policy, is severely constrained by the absence of reliable, timely and comprehensive data.

There were several dimensions to this constraint:

- Data on many aspects of alternative energy resources have not been collected in Canada. For instance, no comprehensive, high-resolution wind resource atlas exists for Canada, presenting a considerable barrier to further development.[58] As well, accurate and up-to-date information on the technical and practical potential of many renewable energy sources, including potential hydro sites (a staple of the Canadian energy picture), either does not exist or is far inferior to that for other OECD countries. The information that is available presents widely varying estimates, reflecting different interpretations of the concept of renewable energy.
- Alternative energy technology is being installed at a rate that exceeds current data collection; hence data for the installed base of grid-connected renewable power in Canada can only be gathered through extensive personal communications, not through formal statistical sources.
- Modelling results are highly dependent on data for which there is low confidence (e.g., the future price of natural gas).

Despite these constraints, the three case studies gathered considerable original data, representing a significant contribution of new data to the public domain.

6.2 SENSITIVITIES

The case studies proved highly sensitive to the price of fossil fuels and, in particular, the price of natural gas. This sensitivity was the single most important factor in the development of all three classes of technologies examined. For example, in the hydrogen case study, the price of fossil fuels affects the final price, and hence the penetration, of hydrogen by affecting the cost of input fuels and the price of competing commodities.

Yet to provide a common baseline for calibration—and to ensure the results would be comparable with other official Canadian modelling efforts in the field of greenhouse gas reduction measures—the hydrogen case study was forced to employ estimates of natural gas pricing that are now outdated. However, there was no other reference available. The pricing estimates used in the case study were developed in the late 1990s and reported in *Canada's Emissions Outlook: An Update*.[59] Since then, the actual prices of key energy commodities have diverged significantly from those portrayed in that study. For example, the price of oil and the price of gas were, respectively, approximately 30 percent and 140 percent higher in 2000 than forecast in the 1999 study. That study also did not include price impact data from Action Plan 2000[60] and the 2002 Climate Change Plan for Canada, since these postdate the study.

There is inherent uncertainty in forecasting the price of natural gas 30 years into the future. A significant factor is expected to be the climate change policy itself, which by driving a shift to greater use of natural gas may create a significant supply gap in this commodity.

6.3 TECHNOLOGY PATHS

The path for long-term reductions in carbon emissions from energy use will involve both proven and still-emerging technologies. Some of these technologies could be adopted on a gradual and incremental basis. Other technology shifts may reflect a step change. Still other technologies are likely to be fundamentally disruptive, changing the pattern of energy use in unpredictable ways. Examples in this latter category include stationary fuel cells.

The uptake of these different categories of technology is likely to take place on different time scales: mature technologies on an immediate time scale (e.g., hydro, cogeneration and wind), emerging technologies on a medium time scale as they enter the market (e.g., certain photovoltaic technologies) and longer-term new technologies on a longer time scale as they move out of the R&D phase and into commercialization (e.g., hydrogen fuel cells). The question, from a policy perspective, is: should fiscal instruments be chosen to target potential breakthrough technologies? These promise significant carbon emission reductions on a more speculative context. They may also support the enhanced uptake of proven technologies, ready for deployment on a massive scale, and with a known impact on the output of clean or cleaner energy.

Companies are extra sensitive to the risk involved in investing in new, not commercially proven technologies. Concerns include the possible effect on product quality, process reliability, maintenance needs and general uncertainty about the performance of a new technology.[61] New technologies carry a greater potential for premature failure, and the presence of this uncertainty can prove a significant barrier to investment. Investors are tempted to postpone investment and wait for additional information to inform their decision ("option value").[62] The effect grows when energy and technology price uncertainty increases, and technology costs are falling more quickly.[63] This observation might suggest that EFR measures should focus on facilitating the market-entry phase of emerging technologies, leaving the accelerated deployment of proven technologies to existing market forces.

Another factor affecting the uptake of new technologies is the presence of less competitive energy markets. The introduction of disruptive technologies (e.g., hydrogen) is often controlled in such settings.

6.4 EXAMINING MID- TO LONG-TERM FUTURES: UNCERTAINTIES AND UNKNOWNS

The long-term perspective adopted for the case studies presents the unavoidable challenges of knowledge limitations. There are inherent uncertainties in looking two to three decades into the future, particularly in a field that will likely be characterized by unpredictable technological evolution and breakthroughs, potentially disruptive technologies and uncertain conventional energy stocks.

Many uncertainties were flagged by participants in the EFR and Energy Program. Among these is the likely impact of the anticipated depletion of non-renewable energy stocks. What will be the impact on fossil fuel pricing? What are the implications for the speed of transition to alternatives? And how will this affect the urgency of government intervention to stimulate breakthroughs in energy efficiency and a more rapid transition to low-impact renewable power sources?

Another category of uncertainties is the non-price factors that will also influence the rollout of new technologies and fuels. These include advantages of quality, convenience and reliability of supply, which may be embodied in new energy sources and drive early adoption; competition among firms to gain early-adopter advantage in a new energy economy; and social pressures related to the external costs of fossil fuel use in a world increasingly concerned about climate change and urban air quality. Any of these could speed up the transition from incumbent technologies to lower-carbon energy sources.

6.5 MARKET SETTINGS

Sub-national factors as well as the international context will influence both the effectiveness and the unintended impact of national-level fiscal measures to encourage lower-carbon energy futures.

Profound shifts underway in some provincial energy policies, including the deregulation of electrical utilities, consequent uncertainty and volatility in prices, and a new openness to independent power production, will be major influences at the sub-national level. Some provinces are also considering or introducing their own measures to encourage growth in low-impact renewable power. The accelerated deployment of all of the low-carbon technologies examined will require coordinated and collaborative arrangements between jurisdictions. Jurisdictional and governance challenges were identified in each of the case studies.

The international context also creates challenges for Canadian action. Some participants in the EFR and Energy Program felt that the use of a price mechanism in the scenarios (e.g., the $30 shadow price for carbon in the energy efficiency case study) was not appropriate for Canada in the absence of policy action by its major trading partner, because the only effect would be to encourage mobile industries to leave the country. Increasing continental trade in electricity could also influence the development of renewable supply in Canada or limit policy options.

6.6 OTHER ISSUES

As the three case studies proceeded, a number of issues emerged relating to the potential relationships between initiatives in each of the technology areas examined.

All three case studies revealed the need for technology development policies that specifically target energy and climate change considerations, while taking into account Canada's comparative advantages.

In addition, the studies highlighted the variations in the cost-effectiveness of the carbon emission mitigation achieved by the different technologies, while also indicating that the options that are most cost-effective in the short term are not necessarily the ones that will yield the most significant long-term reductions.

Recommendation

The federal government should put in place a process to continuously evaluate and monitor progress in achieving the goals and to suggest adaptation of measures based on their effectiveness, as changes occur or as new opportunities start to develop.

To support a better ability to assess economic instruments for long-term carbon emissions reduction:

1. The federal government should regularly update its energy and emissions outlooks, incorporating new price forecasts and the effects of new climate change initiatives as these are adopted.

2. Governments (federal and provincial) should support the development of reliable and comprehensive mapping of the technical and practical potential of emerging renewable resources.

3. Governments (federal and provincial) should support the gathering of timely data on installed capacity and market activity with respect to emerging technologies.

4. Governments (federal and provincial) should improve the data on the current capital stock in both energy supply and use systems and on its performance characteristics.

7. SUMMARY OF FINDINGS

Our analysis and consultation on the role of fiscal policy in promoting long-term carbon emission reductions yielded four main findings:

1 **Economic instruments can make a significant contribution to achieving long-term reductions of energy-based carbon emissions.** Their full potential will only be realized, however, if:

- the government clearly restates its sustained commitment to long-term carbon emission reductions;
- fiscal policy is developed in a coherent and consistent fashion to support this commitment to long-term carbon emission reductions.
- federal action is closely coordinated with provincial strategies targeting the same objectives;
- sufficient time, and a degree of predictability, is provided for in the introduction and application of economic instruments. This will allow efficient and effective long-term investment decisions to be made and implemented; and
- all technologies being targeted with economic instruments are assessed for their life-cycle potential to reduce carbon emissions.

2 **There is no contradiction between promoting long-term carbon emission reductions through EFR initiatives and pursuing Canada's other key societal objectives** (such as energy security and economic development). Success, however, requires a framework that clearly identifies the opportunities that exist for achieving these objectives and the necessary actions for doing so.

3 At the same time, **promoting energy technology development through EFR initiatives does not necessarily equate to the long-term reduction of carbon emission**. This finding points to the critical need to integrate carbon emission objectives with technology development policies.

4 **Economic instruments designed to promote these long-term carbon emission reductions through technology need to reflect both the market and the technological maturity of the technology in question**:

- For **mature carbon emission reduction technologies** (such as those represented in our case study on industrial energy efficiency), the focus should be on demand–pull instruments that facilitate and promote the uptake of existing technologies, and on support for the development of new energy efficiency technologies, particularly those that offer radical energy efficiency benefits (e.g., through new production processes).
- For **emerging carbon-efficient energy technologies** (such as those represented in our emerging renewables case study), the focus should be on instruments that help bridge the price gap between mature technologies and the emerging ones. The operating assumption is that the price gap will close with increasing market penetration and progressively favourable economies of scale.

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- For **longer-term carbon emission reduction technologies** (such as those represented in our hydrogen case study), the focus should be on promoting research and development to address critical technical and economic barriers.

PART 2:
SPECIFIC FINDINGS FROM THE CASE STUDIES

The EFR and Energy Program carried out parallel case studies of targeted fiscal instruments to promote energy-based carbon emission reduction technologies at three stages of development:

- *Mature technologies*, represented by industrial energy efficiency technologies in Canadian manufacturing and mining industries;
- *Emerging technologies*, represented by emerging renewable power technologies (based on the EcoLogo criteria) for the integrated electricity grid; and
- *Longer-term new technologies*, represented by hydrogen energy technologies, defined as any energy system where the primary fuel, at some point within the process, is hydrogen. The focus was on transportation and stationary power production in residential and/or commercial buildings.

Highlights of the findings and discussion of the policy implications of the three studies are presented below; more extensive summaries of the findings can be found in the appendices.

8. CASE STUDY SCOPE, BOUNDARIES AND METHODOLOGIES

Several aspects of the scoping and boundary decisions made within the case studies were contentious:

- Members of the EFR and Energy Task Force emphasized that the case studies are intended to portray an illustrative sequencing of technologies, not a comprehensive energy strategy. The technologies are understood to be part of a broader mix of supply sources and demand sectors, now and in the future. Other energy sources—nuclear energy and large-scale hydroelectricity, in particular—represent a substantial share of low-carbon energy sources, and fossil fuels will likely remain a significant source of primary energy into the foreseeable future.
- Some participants were concerned that the use of the EcoLogo certification criteria in the emerging technologies case study would send the wrong signal regarding the renewability of large-scale hydro:

  The EcoLogo criteria focus on "low impact" renewable energy, excluding most large-scale hydroelectricity, although this is a renewable energy source. "Low impact" hydro is defined by a number of criteria based on protection of indigenous species and habitat, requirements for head-pond water levels, water flows, water quality and several other factors. Theoretically, an installation of any size could meet this requirement, although the general threshold is approximately 10 to 20 MW. As well, the length of time that water is retained upstream from the installation should generally be less than 48 hours. (Note: the EcoLogo criteria also screen out some biomass facilities. For more detail, see Appendix B.)

  Some hydroelectric utilities consider the EcoLogo exclusion of larger installations to be confusing and misleading. Moreover, it was pointed out that the federal government defines large-scale hydro as a renewable energy source.[64] Fiscal instruments for emerging renewable power sources should therefore be complemented by other measures designed to support renewable sources at more mature stages of development, most notably large-scale hydro. Failure to do so would eliminate 90 percent of the current renewable electricity supply in Canada, as well as risking less displacement of fossil-fuel generation.

  A related concern was that the EcoLogo, a voluntary ecolabelling program, is a marketing tool, not a regulatory standard; as such, it should not be used as the basis for fiscal instruments.

There was widespread agreement that large-scale hydro is complementary to many emerging renewable energies. Apart from geothermal energy, these resources are intermittent and require backup energy production capacity, such as that from hydroelectric reservoirs.

- The solar industry and Natural Resources Canada originally wanted the emerging renewable electricity case study to include off-grid applications (e.g., ground-source heat pumps, solar hot water heaters and passive solar), which hold considerable promise in mitigating long-term carbon emissions. These technologies could not be addressed in the computer model that was used and, for that reason only, were excluded. Although certain modelling programs do exist for such technologies (i.e., the Renewable Energy Deployment Initiative, REDI), these technologies do not lend themselves to production-related fiscal measures. Off-grid technologies can contribute more to the displacement of existing generation (in ways that are sometimes difficult to measure) than to the actual generation of electricity.
- One participant questioned the exclusive focus on hydrogen as an emerging fuel source for transportation. This person would have liked to have seen electric vehicles studied as well. The technology for electric vehicles was thought to be more commercially advanced than that for hydrogen vehicles and, in some regions of the country, to have a better energy balance.

8.1 OVERVIEW OF CASE STUDY METHODOLOGIES

The three case studies shared a similar analytical framework:

- define a business-as-usual (BAU) evolution assuming no government intervention;
- identify elements that offer an opportunity to alter development either in time or intensity;
- identify barriers that prevent opportunities from being achieved;
- define instruments that could overcome the barriers;

- assess the economic and environmental efficiency and effectiveness of the potential instruments; and
- have policy and technical experts review these modelling results, as well as validate and shape recommendations for economic instruments specific to each technology.

The hydrogen and renewable energy case studies model the period from 2010 to 2030. The energy efficiency case study models a slightly longer period from 2005 to 2030. It must be emphasized that this time horizon introduced sizable uncertainties into the technology development pathway and commodity prices, influencing the reliability of the results.

The work of the Analysis and Modelling Group of Canada's National Climate Change Process was used as a common baseline for calibrating assumptions to ensure consistency and comparability of results.[65] The BAU scenarios used in these studies do not include any of the measures committed to under Action Plan 2000.

Each case study uses a different model to evaluate the possible impact of fiscal instruments on greenhouse gas emissions in the target sectors. The case studies also differ in terms of definitions of costs, levels of regional and sectoral detail, and the scope of feedback included in the analysis. For example, in evaluating the impact of different fiscal instruments,

Table 1: Case Study Assumptions and Results

	Hydrogen energy
Fiscal instruments considered	Only subsidies are considered. Two alternative fiscal packages are examined with different levels of subsidy in each: • Producer tax credits or grants to lower the cost of hydrogen production by 10% or 25% • Producer incentives as above together with consumer incentives to reduce the price of hydrogen vehicles and stationary fuel cells by 10% or 25%
Estimated emission impacts (excluding macroeconomic feedbacks)	From an increase of 0.3 to a decrease of 1.2 Mt/year by 2030 (Note 1)
Marginal cost of emission reductions in 2030	~$800 to >$2,000/tonne (depending upon sub-sector)
Total direct costs of instrument (excluding other feedbacks)	No estimate of total costs is provided but, assuming average reduction costs of $1,400/tonne, an estimated ~$1.6 billion in government subsidies per year will be required by 2030

the energy efficiency case study considers non-price factors affecting the adoption of energy efficiency technologies. In contrast, the renewable energy case study assumes the penetration of renewable energy is related primarily to relative prices only (except in the case of a renewable portfolio standard, or RPS, which mandates a minimum level of production from renewables). Similarly, the energy efficiency case study includes limited assumptions about induced technological change (primarily in the form of a decline in technology costs with increasing market share), whereas the renewable energy case study includes the effects of policies on R&D decisions, and the effects of both R&D investments and cumulative experience on future renewable energy costs.

For this reason, comparisons of per-tonne emission reduction costs between one study and another are not possible.

None of the case studies includes feedback from changes in aggregate demand, including trade impact, or structural changes in the national economy.

Table 1 provides a summary of key assumptions and outputs for each case study. Direct comparison was not easy because each study team reported inputs and outputs in very different ways (e.g., present values vs. annual averages; aggregate impacts vs. sectoral or regional impacts). This table represents a best interpretation of the results of each case study.

Renewable energy	Energy efficiency
Five alternative packages to achieve a 12% reduction in emissions: • Renewable portfolio standard (24%) • Emission pricing ($10/tonne) • Renewable subsidy ($0.006/kWh) • R&D subsidy (61% of forecast base case R&D) • Combined renewables and R&D subsidies	Three alternative instruments with two levels of shadow cost ($15 and $30/tonne): • Greenhouse gas tax • Tradable permits (auctioned) • Subsidies (grants, loans and tax incentives)
Decrease of 9 to 24 Mt/year by 2030	Decrease of 46 to 58 Mt/year by 2030
~$10 to $40/tonne (Note 2)	~$15 to $30/tonne
Case study estimates net levelized welfare costs of $68 to $270 million/year, calculated as changes in consumer costs + changes in producer profits + changes in net government revenues. In the case of emission pricing, government revenues would equal ~$1 billion per year. In the case of subsidies, government expenditures would be $125 to $460 million/year.	In the case of emission taxes, government would raise $5 to $10 billion/year (after changes in greenhouse intensity). In the case of subsidies, government would spend $0.2 to $0.5 billion per year. This estimate assumes no free riders, which could increase costs as much as 85%. In both cases, these costs represent the cost of inducing changes in industry based on price and non-price considerations. In terms of real financial costs, industry will also save $1.9 to $2.7 billion per year in energy costs (net of capital investment).

Table 1 continued on next page

Table 1: Case Study Assumptions and Results (cont'd)

	Hydrogen energy
Price impact of instruments	Use of subsidies results in no price increases for non-participants (Note 3)
Consideration of non-price factors in the analysis	Modelling framework considers non-price factors in estimating impact of subsidies on producer and consumer decisions
Effects included	Hydrogen production costs Equipment purchases by producers and consumers Hydrogen demand
Effects excluded	Incremental effects of policies on R&D activity Effect of incremental R&D and/or penetration on rate of technology change Indirect costs of government funds for subsidies Possible changes in prices of fossil fuel generation (through technological change and changes in fossil fuel prices)
Sectors directly affected	Transportation, residential and commercial
Regional impact	Impacts modelled by region Uptake is largest in Alberta, Ontario, B.C. and Saskatchewan
Technology impact	50% increase in hydrogen demand for transportation (43 to 67% increase in hydrogen-related vehicles) by 2030 472% increase in hydrogen demand for stationary fuel cells (230% increase in number of installed fuel cells)

	Renewable energy	Energy efficiency
	No price increases with subsidies. Under emission pricing and RPS, national average electricity prices (delivered) increase 4.0 to 5.4% in 2015. Impact of RPS declines to 1.0% beyond 2015 as a result of R&D investments. (Note 4)	In case of subsidies, combined effects of subsidies and energy savings could actually lower prices in some sectors (by 0.1 to 9.0% depending upon the reduction scenario and sector). In the case of carbon taxes, prices could decline in some sectors (energy savings exceed cost of compliance) and increase in other sectors. Largest price impact occurs in industrial minerals, where additional costs exceed 5% of total value of output. The impact could be mitigated in part through revenue-recycling mechanisms.
	Modelling framework assumes all technologies/options are perfect substitutes with decisions based entirely on relative prices	Modelling framework considers non-price factors in estimating impact of instruments on producer decisions
	Uptake of renewables In the case of emission pricing, fuel switching (coal to natural gas) is included Demand feedbacks based on electricity price increases (aggregate elasticities) R&D investment and subsequent reduction in technology costs Reduction in technology costs associated with increased experience	Investments in energy efficiency equipment in target sectors as well as reductions in upstream electricity emissions (through cogeneration) Some reduction in technology costs incorporated with increased market shares
	Electricity trade Downstream impacts on output for individual sectors Aggregate demand feedbacks Indirect costs of government funds for subsidies and indirect benefits from revenue recycling of taxes	Effects of policies on R&D activity Effect of cumulative experience on technology costs Sectoral demand feedbacks Aggregate demand feedbacks Indirect costs of government funds for subsidies and indirect benefits from revenue recycling of taxes
	Electricity	Mining and manufacturing (indirect impacts on electricity sector through fuel substitution and cogeneration)
	Impacts modelled using aggregate national parameters	Impacts modelled by region but sub-regional impacts not reported separately
	58 to 80% increase in renewable production $22 to $172 million increase in annual R&D spending 13 to 26% reduction in renewable costs	Encompasses a wide variety of technologies and processes; impact is diffuse

Table 1 continued on next page

Notes:

1. Emissions may increase depending upon the source of hydrogen (e.g., SMR vs. electrolytic production).
2. The price instrument has the lowest unit cost. The other instruments are more costly on a unit cost basis. The higher value reflects the approximate cost of reductions under R&D subsidies.
3. For participants, the cost of hydrogen still exceeds the cost of gasoline and electricity. Uptake is driven by non-financial considerations. In theory, reduced demand for conventional fuels from participants could lower prices of conventional fuels for non-participants.
4. It is not entirely clear from the case study why the cost of electricity does not also decline under emission pricing with increased R&D expenditure.

Source: Trent Berry, "Macroeconomic Impacts of Fiscal Policy Promoting Long-term Decarbonization in Canada," Working paper prepared for the National Round Table on the Environment and the Economy (Vancouver: Compass Resource Management Ltd., August 2004).

9. SPECIFIC FINDINGS: INDUSTRIAL ENERGY EFFICIENCY

Energy efficiency refers to the relationship between the output (service) of a device or system and the energy put into it. This case study focused on Canadian manufacturing and mining industries,[66] seeking energy efficiency opportunities in energy-using equipment, major industrial processes, supply technologies and delivery networks. Fuel switching was considered in conjunction with efficiency options.

Economy-wide energy intensity (unit energy per unit GDP) is influenced by two factors: energy efficiency itself and other factors such as structural shifts in the economy toward new industries or value-added commodities with different energy intensities of production and interaction effects. Past reductions in the energy intensity of the economy can be attributed in part to shifts in the composition of the economy, such as the growth of the service sectors and the relocation of manufacturing facilities to other regions. The design of EFR measures may affect the structure of the economy by encouraging a move in production up the value-added chain, toward value-added products that have greater price elasticity and hence the ability to absorb new environmental costs.

From an analytical perspective, it is important to note that the electricity sector was not included in the study. The argument against including it was that most electricity in Canada is still produced by publicly owned utilities, and these are not subject to the same fiscal instruments as private corporations. Some participants thought the sector should be included, since it holds many opportunities for energy efficiency improvements. They also pointed out that, in many Canadian jurisdictions,[67] electricity (and, in particular, electricity at the margin) will increasingly be generated by independent producers, and their choice of feedstock will have significant environmental consequences. Excluding electricity generation from the purview of the fiscal instruments could also create unintended perversities—for example, it could motivate industries to install high-efficiency boilers rather than cogeneration units, which would be better from a system-wide greenhouse gas reduction perspective.

This case study considered the role of energy efficiency in promoting decarbonization of the energy system. At the same time, it acknowledged the multiple policy objectives served by energy efficiency. For example, a carbon reduction focus was thought to buttress steps to meet air quality standards and, as such, to be of interest to firms that would otherwise resist measures to improve energy efficiency. Furthermore, promoting energy efficiency would support other policy priorities, such as reducing energy demand.

According to OECD research, innovative energy- and material-efficient technologies have multi-functional benefits in addition to their GHG mitigation effects. Ancillary local air quality, macroeconomic and health effects are well understood. More neglected are other ancillary benefits:

- improved product quality, quality of life, capital and labour productivity from energy- and material-efficient process substitution;
- dynamic effects of learning, economies of scale and technological competition between the new and the traditional technology;
- net employment effects because of import substitution and first-mover effects; and
- regional redistribution of net employment from the more equitable distribution of jobs in a resource-efficient economy.

The benefits of these other aspects may in fact surmount the energy savings and mitigation benefits.[68]

9.1 STATUS OF INDUSTRIAL ENERGY EFFICIENCY

The industrial sector, which includes mining and manufacturing activities, is a significant GHG-producing sector in Canada. The sector produced 237 Mt CO_2e of direct GHG emissions in 2000, the majority of which were energy-consumption based.[69] Total energy consumed by industry in that same year was 3,187.2 petajoules (PJ).[70]

Energy intensity (based on GDP) in Canadian industry decreased by about 27 percent between 1990 and 2002.[71] Trends in carbon intensity are similar (as measured by GHG emissions per unit of GDP). During the same period, the carbon intensity (also based on GDP) of Canadian industry also declined, levelling off at approximately 34 percent below 1990 levels in 2002.[72] The decline in energy and carbon intensity is due to improved efficiency among energy users and to structural changes in industry (a change in product or industry mix). It is also affected by factors associated with GDP monetary units, such as costs of labour or selling price of the final product. Composite indicators computed for aggregate physical energy intensity in Canadian industry between 1990 and 1996 suggest a smaller decline in energy intensity relative to the measure based on GDP.[73]

The potential for energy efficiency improvements can still be significant, particularly for some industry sectors. For example, a 1996 study prepared for Natural Resources Canada found that the technical potential for energy conservation in six major energy-consuming industries ranged from 3 to 25 percent of projected energy consumption in 2010.[74] However, three decades of research show that consumers and firms forgo apparently cost-effective investments in energy efficiency. One reason for this is that energy efficiency projects must compete for capital within a firm and may simply not meet internal required rates of return. Another reason may be that firms hesitate to adopt new technologies, which carry a greater potential for failure. Since these investments are irreversible and can be delayed, this uncertainty can create a significant drag on investment. This so-called energy efficiency gap is a critical issue in evaluating the economic cost and potential of EFR to influence the uptake of energy-efficient technologies.

9.2 STATUS OF INDUSTRIAL ENERGY EFFICIENCY TO 2030 ASSUMING BUSINESS AS USUAL

Overall, emissions in the industry sector (as defined in this case study) grow by 50 percent over the 2000–2030 simulation period, with direct emissions increasing and indirect emissions decreasing.[75] Total emissions grow at an average annual rate of 1.53 percent, which is faster than the average annual rate of growth in energy consumption of 1.48 percent (Table 2). This growth occurs because the production in a number of carbon- and energy-intensive subsectors is expected to grow significantly. The share of electricity produced by cogeneration in the industrial sector increases over the simulation period, particularly in oil sands operations. The oil and gas sector generates the largest quantity of GHG emissions driven by strong growth in exports to the United States.

Findings

INDUSTRIAL ENERGY EFFICIENCY

- A \$15/tonne CO_2e shadow price would lead to a reduction of 46 Mt CO_2e by 2030, compared with the BAU scenario.
- A \$30/tonne CO_2e shadow price would lead to a reduction of 58 Mt CO_2e by 2030, compared with the BAU scenario.

9.3 INDUSTRIAL ENERGY EFFICIENCY SCENARIOS TO 2030 WITH GOVERNMENT INTERVENTION

The CIMS model[76] explores an achievable potential, rather than one that may be only technically feasible. Energy efficiency actions are adopted according to a technology competition that represents firm purchasing decisions based not only on minimization of annualized life-cycle costs, but also on performance preferences, cost heterogeneity, option value and failure risk.

Table 2: Baseline Forecast of GHG Emissions and Energy Consumption for Canada

	2000	2010	2020	2030	Average Annual Growth
GHG emissions (Mt CO_2e)	288	343	396	453	1.53%
Direct	237	307	358	407	1.82%
Indirect	50	36	38	46	-0.30%
Energy (PJ)	4,239	5,030	5,783	6,579	1.48%

Table 3: GHG Emissions and Energy for Alternative Scenarios, Canada

	2000	2010	2020	2030
Total GHG emissions (Mt CO_2e)				
BAU	288	343	396	453
Low Carbon I	288	322	365	407
Low Carbon II	288	316	355	395
Direct GHG emissions (Mt CO_2e)				
BAU	237	307	358	407
Low Carbon I	237	292	339	386
Low Carbon II	237	293	335	378
Indirect GHG emissions (Mt CO_2e)				
BAU	50	36	38	46
Low Carbon I	50	29	26	22
Low Carbon II	50	23	20	17
Energy (PJ)				
BAU	4,239	5,030	5,783	6,579
Low Carbon I	4,239	4,822	5,537	6,298
Low Carbon II	4,239	4,818	5,497	6,232

BAU = business as usual

The case study used two alternative forecasts, Low Carbon I and Low Carbon II, which model a shadow price for carbon of $15/tonne CO_2e and $30/tonne CO_2e respectively, to influence a shift in investment patterns over a 25-year period (2005–2030). The price was also applied to the electricity sector so that a carbon price can be reflected in the electricity price seen by the industry sub-sectors.

Table 3 summarizes the results of the Low Carbon I and Low Carbon II scenarios relative to the baseline business-as-usual scenario in Table 2. In Low Carbon I, GHG emissions are reduced by 46 Mt CO_2e; in Low Carbon II, GHG emissions are reduced by 58 Mt CO_2e. Direct emissions make up most of these emission reductions, though the response of indirect emissions to the imposition of a shadow price is stronger than the response of direct emissions (indirect emissions decline by 53 to 62 percent in 2030, while direct emissions decline by only 5 to 7 percent). Actions behind this strong indirect response include the greater adoption of cogeneration systems and actions that improve the overall efficiency of auxiliary motor systems. The metal smelting and refining sector, petroleum refining, and iron and steel sub-sectors contribute the most emission reductions because of improved energy efficiency.

Ex ante financial costs are –$17.64 billion for the Low Carbon I scenario and –$24.87 billion for the Low Carbon II scenario (2000 dollars). In other words, the value of energy savings (discounted to 2004 at a rate of 20 percent) is greater than any associated increase in upfront capital costs for all industry sub-sectors; this is revealed as a negative cost.

These estimates do not account for risk, option value, market heterogeneity and perceived quantitative or qualitative advantage of product preferences; therefore, they do not reflect the full compensation required for firms to make the technology switch (i.e., the energy efficiency gap). The total monetary incentive needed to overcome baseline technology preferences (e.g., through a subsidy) is $2.012 billion for Low Carbon I and $4.885 billion for Low Carbon II (2000 dollars). Notably, this incentive is for a program perfectly designed to target cost-effective actions; it does not include expenditures required to subsidize firms that have already undertaken the technology switch in the baseline scenario, a group that can often be in the order of 40 to 85 percent of program recipients in previous evaluations of energy efficiency programs.

Further detail on the case study findings is provided in Appendix A.

9.4 MACROECONOMIC IMPACT: INDUSTRIAL ENERGY EFFICIENCY CASE STUDY

The macroeconomic impact of the proposed instruments in the industrial energy efficiency case study can be summarized as follows:

- *Aggregate macroeconomic impact:* Insignificant from a national perspective.
- *Distributional and competitiveness impact:* Possible distributional impact varies with the specific type of instrument employed. Subsidies would produce no price increases and could even lower output prices. Emissions pricing (through taxes or tradable permits) will increase costs for industry. However, these costs will in part be offset by savings from energy efficiency and fuel switching, including cogeneration. Many industries experience cost increases of less than 1 percent of the value of output. Under a shadow price of $15/tonne, price impact varies from reductions of 0.4 percent in the chemical products and pulp and paper sectors to an increase of more than 5 percent in the industrial minerals sector. There are fewer cases of cost decreases at $30/tonne, and costs (as a percentage of the value of output) increase more than 12 percent in the industrial minerals sector. When the price responsiveness of domestic and international markets is considered, only the industrial minerals and the iron and steel sectors experience changes in output prices high enough to reduce output.

These impacts assume no mitigation policies are implemented.

- *Effects on technological change:* The impact on long-term technological change is very uncertain and will depend in part upon the types of instruments employed and the detailed design of those instruments. However, there is also empirical evidence that the energy price shocks of the 1970s clearly stimulated investment in R&D for more efficient equipment.

Further detail on the macroeconomic impact of the proposed instruments can be found in a background paper for the EFR and Energy Program.[77]

9.5 POLICY IMPLICATIONS: INDUSTRIAL ENERGY EFFICIENCY

The strategic significance of having carbon emission reductions as a priority objective is well illustrated in the energy efficiency case study, where three related policy objectives can each lead to very different actions being taken:

- An emphasis on industrial energy efficiency alone can, in some cases, result in increased carbon intensity. While improved energy efficiency in industry is closely connected to fuel switching and other means of carbon emission reduction, there are instances where increased energy efficiency can also increase carbon intensity. For instance, an efficient coal-fired boiler is more efficient than a wood-fired or certain natural gas–fired boilers. This emphasis would support other energy policy priorities, such as the need to narrow forecast gaps between energy demand and supply.
- A dual emphasis on carbon efficiency and energy efficiency, as explored in the case study, would encourage only those energy efficiency actions that also provide carbon reduction dividends.
- An emphasis on greenhouse gas mitigation alone would open the door to non-efficiency means to reduce emissions such as fuel switching, reducing fugitive emissions, reducing process emissions, and the capture and storage of carbon dioxide. These emission reductions are sometimes more cost-effective than those occurring through energy efficiency.

These findings illustrate the importance of pursuing a dual objective—an approach that will also support a broader set of public policy objectives, including narrowing the supply gap.

The underlying conclusion from the case study is that the issue of energy efficiency in the industrial sector is essentially an issue of project finance. Industrial firms are assumed to be generally more likely than households to have already pursued cost-effective options to reduce energy consumption. Nonetheless, research over the past 30 years has consistently shown that firms and consumers forgo apparently cost-effective investments in energy efficiency. The results of the energy efficiency case study's economic analysis confirm this general knowledge, identifying energy savings[78] greater than the associated capital cost investments for all of the industry sub-sectors analyzed. Why do firms not make these investments? One reason is that energy efficiency projects must compete for capital within a firm and may simply not meet internal required rates of return—or may not be as attractive as alternative investments, such as investments in productivity improvement. These situations offer a sound business opportunity for third-party engineering and/or finance firms. Another reason may be that firms hesitate to adopt new technologies, which carry a greater potential for failure.

The market setting within which a firm operates exerts a powerful influence on its energy efficiency investment decisions. In markets with strong growth and competition, efficiency with respect to energy and other inputs is necessary to survive. In contrast, stagnating markets are poor theatres for innovation and investment, and instead rely on already depreciated equipment to maintain low production costs.[79]

Projects designed to promote energy efficiency compete against a variety of other projects for corporate investment. In highly energy-intensive industries, firms have a strong incentive to invest in more energy-efficient systems. In other sectors, however, the most promising investments may lie in the development of new products or in modernization and restructuring projects that do not yield accompanying gains in energy efficiency. For small and medium-sized enterprises (SMEs) with very limited investment capital, there are especially strong economic pressures to avoid projects with the long paybacks that are typical of energy-saving measures.[80] Furthermore, SMEs often do not have the internal expertise to identify and follow up on energy efficiency opportunities.

These findings underscore the role that energy prices and market forces play in stimulating energy efficiency actions, as well as the need for a price signal given that current prices appear too low to stimulate major efficiency improvements. The choice of appropriate fiscal instrument is between targeted measures that relate to one set of technologies or one particular sector, or a broad fiscal instrument that does not assign technological or sectoral preference. In either scenario, the ultimate impact is largely a function of the level at which the instrument is set (in the case study itself, the “shadow carbon price”). This level must at the very least overcome the hurdle of the energy efficiency gap.

The case study concludes that policy intervention would be most appropriate at the two ends of the product pipeline: (1) the market uptake of existing (and eventually emerging) technologies and processes and (2) the research and development related to the development of new energy efficiency technologies, particularly those that offer significant energy efficiency benefits.

There is an obviously close relationship between the two stages, inasmuch as they involve a cycle of investment, development and market uptake, which is dynamic and ongoing. In this scenario, promoting the market uptake of “on the shelf” technologies leads to reinvestment into new generations of energy efficiency technologies, and so to a virtuous cycle of investment leading to R&D and continuous improvement in energy efficiency performance. Improvements in energy efficiency performance follow an incrementally positive trend, as seen in the cumulative impact of the 1 percent per year energy efficiency improvements observed under the Canadian Industry Program for Energy Conservation.

For the mature industrial energy efficiency technologies, policy intervention should encourage market uptake of existing technologies and processes. The choice of EFR tools to do this will be influenced by the nature of the industrial energy efficiency opportunities. Energy use in industry can be categorized into generic or auxiliary services (steam generation, lighting, HVAC [heating, ventilation, air conditioning], and electric motors) and processes unique to each specific sector and even each facility. Within this latter category of use, the energy efficiency opportunity is characterized by countless specific and differentiated technologies and processes, not only among different sectors but also among the operations within one sector.

Fiscal tools for industrial energy efficiency have been dominated by capital cost allowance tax measures, an approach that, for tax administration purposes, is technology-prescriptive. It is therefore well suited for generic and auxiliary technologies with widespread application. These tools are less suited to sector- and facility-specific processes, where the energy efficiency opportunity is characterized by countless, differentiated technologies and processes among different sectors and among the operations within one sector. They are also less suited to the system-based or sector- and/or process-specific technology opportunities, which are radical in nature. An example is process substitution using membrane techniques or biotechnology instead of thermal processes, or improvements to the material efficiency of production. These categories of opportunity are better supported through broad-based fiscal measures that are performance-based (as opposed to technology-prescriptive), such as an emissions tax or market-oriented regulation (tradable permits). Under this approach, government sets a target backed by regulation—which can be emissions-based (for certainty of environmental outcome) or technology-based (for certainty of market outcome)—and allocates tradable permits[81] (by auction and/or by gratis) to all subject parties. This approach allows individual flexibility in achieving the compulsory limit or requirement—the party can either meet the target or pay others to do so. In addition, experience with this approach indicates that it is more efficient than subsidies in preventing rebound effects and in providing a long-term signal for technological innovation.

Program participants felt that tax measures alone are unable to address the diversity of industrial energy efficiency technological opportunities or system-based improvements; in addition, there was concern about the large public expenditure per unit of effect typically experienced in subsidy programs, because of the presence of firms that would have undertaken the desired change even in the absence of the subsidy.

At a theoretical level, participants favoured the emissions tax, and it has been shown in other research to be economically attractive, particularly when competitiveness concerns are addressed through the creative recycling of revenues, sectoral exemptions and border tax adjustments.[82] However, an emissions price applied to the industrial sector was considered by most to be politically unviable despite its very limited effect on output: the macroeconomic assessment of the impact of the case study's \$30/tonne CO_2e price signal (with no mitigation policies) concluded that only the industrial minerals and the iron and steel sectors would experience changes in output prices high enough to reduce output.

For these reasons, participants considered market-oriented regulation (similar to the LFE domestic emissions trading system) to be the most environmentally effective, economically efficient and politically acceptable means of encouraging market uptake of energy-efficient technologies and processes in the manufacturing and mining industries.

Not all energy efficiency technologies are mature technologies. Others are at the demonstration stage or have been applied in a relatively narrow niche (e.g., direct reduction in iron and steel). Still others have not been technically realized and are the subject of active research and development programs. Technological innovation may be incremental (small and gradual innovation in existing technologies) or radical (the development and introduction into the marketplace of new technologies or processes that dramatically improve energy efficiency performance). It is not always possible to predict which type will be more effective in reducing energy over longer periods.

Radical innovation is where the step changes in energy efficiency are to be found. At the same time, much greater capital stock replacement is required for these radical, process-based innovations than for incremental innovations that may only involve some technological components. The need for greater capital stock replacement presents an additional hurdle to the adoption of radically innovative technologies, since the energy efficiency marketplace, especially in the industrial sector, is bound by the timetables of capital stock turnover. It is thus difficult to predict how such innovation will contribute to decarbonizing the energy system. The impact of not including future radical innovation may make the analysis conservative.

Recommendation

To support long-term carbon emission reductions through the adoption of industrial energy efficiency, the federal government should:

a) Integrate a carbon efficiency focus in activities to promote energy efficiency, so that these activities do not perversely increase carbon emissions.

b) Implement a broad-based price signal for carbon emission reductions.

c) If (b) is not possible, augment targeted tax measures (best suited to generic and auxiliary technologies) with broader, market-oriented regulation (either emissions- or technology-based) to capture system-wide opportunities.

d) Provide R&D support for the development of new energy efficiency technologies, particularly those that offer radical energy efficiency benefits (e.g., through new production processes). Support, in the form of targeted tax measures, should continue through to commercialization of the technology.

10. SPECIFIC FINDINGS: EMERGING RENEWABLE POWER TECHNOLOGIES

Emerging renewable power was delineated in this study as EcoLogo-certifiable, electricity-generating, grid-connected technologies. The scope of technologies covered includes wind turbines (onshore and offshore), small hydro, grid-connected photovoltaics (PV), landfill gas (for electricity generation), biomass (for electricity generation), ocean energy (including wave and tidal power conversion technologies) and geothermal. Thermal technologies, such as ground-source heat pumps, solar hot water heaters and stand-alone systems, were excluded because of modelling constraints, and large hydroelectricity was not included because it was considered a mature technology. Participants highlighted these exclusions, cautioning that these renewable sources are significant and also need to be considered when designing policy.

Emerging renewable power technologies face many barriers to development: market acceptance and demand, permitting and community acceptance, intermittency of the resource, proximity of resources to transmission grids, insufficient transmission capacity, dearth of resource mapping, lack of engineering standards and national technical rule making, shortages in trained technical labour, and a wide variety of policies and regulations that, inadvertently perhaps, give preference to other technologies.[83]

Added to this long list are economic barriers. These include generally higher prices than for conventional electricity sources, although steep cost reductions from economies of scale and continued research and development are forecast. Renewable energy facilities are normally capital-intensive but have no ongoing fuel costs (with the exception of biomass); this makes their economic viability sensitive to the cost of capital and the ability to reduce capital costs. Generally, access into the market is favoured by retail competition in deregulated electricity markets. Investors tend to see emerging renewable energy technologies as high risk, and immature public policy and changing fiscal incentives in the field contribute to a lack of certainty.[84]

These barriers combine to create a large gap between the technical resource potential for emerging renewable power and actual installed capacity. Technical resource potential was estimated in the case study at 68,500 to 336,600 MW capacity and 244,700 to 1,210,400 GWh/yr supply, compared with an actual installed base today of only 2,300 MW capacity and 12,100 GWh/yr supply.[85]

This case study, like the others, encountered challenges in data reliability. The study identified *technical potential* for emerging renewables (the long-term "upper limit" of installed capacity for a given technology) and *practical potential* (a largely subjective estimate of the generating capacity of a given technology that could reasonably be installed within a given time period). The discussion of the data revealed that different studies and individuals interpret these potentials differently. For example, the assessment of practical potential relies on an appraisal of whether the resource is accessible and/or whether it is possible to access with transmission upgrades. How should transmission constraints be assessed? What level of investment is needed to enhance transmission? Who should ultimately pay for these connections?

Some participants in the EFR and Energy Program felt that current analysis may also overemphasize central power generation; this would diminish the impact of the small-scale, distributed power generation that is evolving in many jurisdictions. There was also discussion of whether there would eventually need to be limits to renewable power generation to preserve grid stability. It was noted that some renewables (e.g., wind and hydro) complement one another in such a way as to increase grid stability.

10.1 STATUS OF THE EMERGING RENEWABLE POWER SECTOR

In 2003, the installed base of emerging renewable power technologies (using the boundaries described above) in Canada was approximately 2,300 MW. It generated an estimated 12,100 GWh of electricity and accounted for about 2 percent of Canada's installed electricity generation capacity. Of this, hydro represents 1,800 MW and 9,460 GWh/yr; if the large hydro screened out by the EcoLogo criteria were included, the total installed capacity for hydro would be 68,100 MW, generating 346,000 GWh, or 59 percent of Canada's total annual electricity generation of 589,500 GWh.

Looking beyond Canada, in 2001 renewable energy sources provided 5.7 percent of total primary energy supply for the OECD countries, of which 54 percent was supplied by combustible renewables and waste,[86] 35 percent by hydro power and 12 percent by geothermal, solar, wind and tide energy. Worldwide, renewables represented 15 percent of electrical energy production worldwide, but only 2.1 percent if one excludes large hydro.

10.2 STATUS OF THE EMERGING RENEWABLE POWER SECTOR TO 2030 ASSUMING BUSINESS AS USUAL

The business-as-usual scenario for emerging renewable power technologies in 2030 identified the technical potential and the practical resource potential of each technology. The technical potential is the long-term "upper limit" of installed capacity for a given technology.[87] The practical potential is a subset of technical potential; it refers to the generating capacity of a given technology that could "practically" be installed within a specific time period.[88]

The research results unearthed a very wide range of estimates, and therefore the data for both technical and practical potential are estimates. For total (not additional) technical resource potential, a low capacity of 68,550 MW and a high capacity of 336,600 MW were estimated. These translated to a supply of 244,700 GWh/yr at the low end and 1,210,400 GWh/yr at the high end. The estimated practical potential of emerging renewable power in Canada is identified in Table 4, using ranges to reflect the inherent uncertainty.[89]

Emerging Renewable Power

To achieve a 12 percent reduction in emissions would require:

- an emissions price of \$10/tonne CO_2; or
- a 24 percent renewable portfolio standard; or
- a \$0.006/kWh renewable generation subsidy; or
- a combination of a 24.21 percent renewable portfolio standard plus a \$0.002/kWh renewable generation subsidy; or
- a 61 percent increase in renewable energy R&D.

For comparison, the United States aims to nearly double energy production from renewable sources (excluding hydro) between 2000 and 2025, while the European Union has adopted a target for 2010 of 22.1 percent of electricity from renewable energy and 12 percent of renewables in gross national energy consumption.

Table 4: Estimated Practical Resource Potential of Grid-Power Renewable Energy Technologies (RET) in Canada, 2010 and 2020

Grid-Power RET (EcoLogo certifiable)	Capacity (MW) 2010 Low	Capacity (MW) 2010 High	Capacity (MW) 2020 Low	Capacity (MW) 2020 High	Supply (GWh/yr) 2010 Low	Supply (GWh/yr) 2010 High	Supply (GWh/yr) 2020 Low	Supply (GWh/yr) 2020 High
Total estimated practical resource potential	12,434	22,185+	26,829+	51,295+	57,412	98,260+	112,512+	174,700+

"+" indicates that lack of data has led to an underestimation of practical resource potential. Full details on underlying data can be found in Appendix B.

10.3 STATUS OF THE EMERGING RENEWABLE POWER SECTOR TO 2030 WITH GOVERNMENT INTERVENTION

The model used for the emerging renewable power case study sets one emission reduction target (in this case a 12 percent reduction in carbon emissions from the base case) and then assesses a variety of policy options for achieving this target. The model has two stages: 2010–2015 and 2015–2030; electricity generation, consumption and emissions occur in both, while investment in knowledge takes place in the first stage, followed by technological change and innovation that lowers the cost of renewable power generation in the second. Fossil fuel is assumed to be the marginal technology that would be displaced by renewable generation and that sets the overall market price.

The carbon intensity of the electricity market hinges on three drivers:

- *Renewable power penetration:* How much of total Canadian electricity generation is supplied by renewable power. This driver is affected by the cost of renewable compared with fossil fuel generation.
- *Carbon intensity of fossil fuel generation:* How much carbon a unit of electricity generated by fossil fuels contains. This driver is affected by the cost of carbon emissions.
- *Total electricity demand:* Determined by consumer energy efficiency and conservation. This driver is affected by the price of electricity.

The economic efficiency and environmental effectiveness of these instruments is linked to their ability to influence the entire electricity market and the three decarbonizing drivers in particular. As a general rule, the economic instrument will be more efficient and effective if it signals to multiple agents in the electricity market that carbon is more expensive: fossil energy producers will reduce their emission intensity; renewable energy producers will supply more output when the price difference between renewable and fossil generation decreases; and consumers will take measures to conserve electricity, reduce demand and displace fossil output. This finding holds up under multiple input variable assumptions and explains why an emissions price is preferable to a renewable portfolio standard or renewable generating subsidy. The R&D instrument scenario offers a good example of the increased risk in using a single instrument: here the emission reduction depends entirely on the ability of R&D investments to reduce the costs of renewables through innovation. While cost reductions can be expected to result from R&D spending, the scope and scale of the cost reductions are questionable, increasing the overall uncertainty in the instrument.

The model used in the case study showed that the target of a 12 percent reduction in emissions (compared with the business-as-usual case) could be achieved through any of the following instruments:

- a carbon emissions permit price of $10/tonne CO_2;
- a 24 percent renewable portfolio standard, which requires green certificates, or the equivalent, to be purchased by utilities so that renewable generation increases relative to fossil fuel generation;
- a $0.006/kWh renewable generation subsidy, modelled as a direct subsidy from government to emerging renewable power producers;
- a combination of a 24.21 percent renewable portfolio standard and $0.002 renewable generation subsidy, modelled in tandem; and
- a 61 percent increase in renewable research subsidies to reduce the cost of future renewable energy generation.

The modelling results for each of these instruments are listed in Table 5. A summary of the distributional results of the instruments is provided in Table 6. Further detail on the case study findings is provided in Appendix B.

Table 5: Summary of Modelling Results for Fiscal Instruments (2000 $)

	Base case	Emissions price	Renewable portfolio standard	Renewable generation subsidy	Combination RPS and RGS	Renewable research subsidy
1. Policy level for 12% emission reduction		$10/t CO_2	24% of generation in case*	$0.006	RPS=24.21% RGS=$0.002	61%
2. Electricity price (in $/kWh)						
1st stage	$0.092	$0.097	$0.095	$0.092	$0.095	$0.092
2nd stage	$0.092	$0.097	$0.093	$0.092	$0.092	$0.092
3. Carbon emissions (Mt)						
1st stage	106	98.10	91.00	98.97	91.08	104.00
2nd stage	101	84.40	91.90	83.50	91.95	77.40
4. Renewable output (MWh 10^11)						
1st stage	0.29	0.40	0.54	0.42	0.55	0.31
2nd stage	0.38	0.66	0.55	0.72	0.55	0.83
5. Fossil output (MWh 10^11)						
1st stage	2.00	1.85	1.71	1.87	1.72	1.98
2nd stage	1.91	1.59	1.73	1.57	1.73	1.46
6. Total electricity output (MWh 10^11)						
1st stage	2.29	2.25	2.26	2.29	2.27	2.29
2nd stage	2.29	2.25	2.28	2.29	2.29	2.29
7. Renewable R&D ($M)	$129	$450	$320	$533	$325	$1,576
8. Additional renewable cost reduction	0%	15%	13%	16%	13%	26%
9. △Consumer surplus ($M)	$0	($11,690)	($4,521)	$0	($3,533)	$0
10.△Producer surplus ($M)	$0	$2, 215	$3,480	$2,846	$3,547	$1,590
11.△Transfers ($M)	$0	$8,896	$0	($3,557)	($1,072)	($3,890)
12.△Welfare—no benefits measured ($M) (9+10+11=12)	**$0**	**($579)**	**($1,041)**	**($711)**	**($1,058)**	**($2,300)**
13.△Welfare relative to emissions price	—	1.00	1.80	1.23	1.83	3.97

Figures may not sum due to rounding.

** This is 9% of all annual Canadian generation.*

Source: Marbek Resource Consultants and Resources for the Future.

Table 6: Summary of Distributional Results

	I. Base case	II. Emissions price	III. Renewable portfolio standard	IV. Renewable generation subsidy	V. Combination RPS and RGS	VI. Renewable research subsidy
To achieve a **12% carbon emission reduction** target from 2010 to 2030, you would see…	(No attempt to reach target)	Emitters pay $10 for each tonne of CO_2	Renewables have a **24%** share of case study generation—9% of annual total Canadian generation	Government subsidy of **$0.006** for each kWh generated by renewables	An RPS at **24.21%** and an RGS at **$0.002**	The public and private sectors increase their R&D spending by **61%**
Impacts on electricity generation	Renewables gain some market share; carbon is reduced by 5%	Renewables penetrate slightly more quickly than in I; electricity producers work hardest on reducing carbon emissions	A greater penetration of renewables than in II; costly for electricity producers at first but costs fall over time	A greater penetration of renewables than in II; not a driver of lower emissions intensity (= higher efficiency)	Slightly more renewables in the mix; fossil fuel–generated output remains unchanged	High penetration of renewables near end of time frame only
Impacts on consumers	Status quo	Electricity prices rise the most; conservation emphasized; negative impacts on some sectors	Overall electricity prices are lower than in II, but rise and then fall; conservation not emphasized	Electricity prices remain the same; conservation not emphasized	Electricity prices slightly lower than in IV; conservation not emphasized	Electricity prices remain unchanged; conservation not emphasized
Impacts on government	Status quo	Government revenues raised (as government collects on emissions price); redistribution to affected sectors is possible	No government revenues raised, lost or transferred	Government makes significant disbursements to fund the subsidy	Government makes disbursements ($1 billion) to fund the subsidy	Government makes significant disbursements to fund R&D in renewables
Impacts on the renewable sector	Status quo; some continued penetration	Output up; production cost down; some profit; R&D levels high	Output up more than in II; slightly more profit than in II; but less R&D is done	Greater profits as more production lowers costs; high investment in R&D	Output slightly higher; R&D also higher	Highest potential penetration near end of time frame with high R&D

Table 6 continued on next page

Table 6: Summary of Distributional Results (cont'd)						
	I. Base case	**II. Emissions price**	**III. Renewable portfolio standard**	**IV. Renewable generation subsidy**	**V. Combination RPS and RGS**	**VI. Renewable research subsidy**
Impacts on Canadian societal welfare*	Status quo	Overall lowest welfare costs of the five options	Greater welfare costs than in II and lower than in IV	Second highest welfare costs	Welfare costs slightly lower than in IV	Highest welfare costs
Level of uncertainty in reaching target	Target is not achieved	Low; all long-term carbon emission reduction drivers are acted on to work toward target	Medium; only two long-term carbon emission reduction drivers affected	Medium–high; only one long-term carbon emission reduction driver affected	Medium; only two long-term carbon emission reduction drivers affected	High due to reliance on one long-term carbon emission reduction driver (penetration not assured)

** = adding together (1) costs to consumers and (2) losses/profits of electricity producers (both renewable and fossil fuel) and (3) net government revenues, but* excluding *environmental costs/benefits (e.g., the costs of adapting to climate change are not included here).*

10.4 MACROECONOMIC IMPACT: EMERGING RENEWABLES CASE STUDY

This case study considers a variety of potential instruments for meeting a predefined emission reduction target of 12 percent in the electricity sector. These instruments differ in overall costs, distributional impacts, risks and effects on technological change.

The macroeconomic impacts of the instruments proposed in the renewables case study can be summarized as follows:

- *Aggregate macroeconomic impact:* Insignificant from a national perspective.
- *Distributional and competitiveness impact:* Varies greatly depending upon the instrument employed.

In the case of subsidies, costs are borne by taxpayers and widely distributed throughout the economy. Consumers do not see any increases in electricity prices. In the case of emissions pricing and renewable portfolio standards, costs are borne primarily by consumers. Increases in electricity prices will disproportionately affect low-income households.

Emissions prices, renewable portfolio standards and renewable energy subsidies can all lead to windfall profits for some producers of emerging renewables that are already cost-competitive with conventional fossil fuel plants.

The regional and sectoral impact is more difficult to estimate. The case study was conducted from a national perspective. At the national level, average electricity prices increase from zero under subsidies to 5 percent under emissions pricing. These increases are relatively small from a national perspective, particularly in light of a 20-year phase-in and the possibility of revenue recycling to offset price impact. However, the national averages could mask important differences in price impact across regions and end users. These differences, in turn, could affect some sectors more than others. The impact will also depend on the instrument used and its design.

In the case of emissions pricing, costs will be highest in jurisdictions with higher fossil fuel–based electricity generation (e.g., Alberta, Saskatchewan and New Brunswick), with a higher percentage change for industry and a lower percentage change for house holds. In the case of an RPS, regional price impact will depend on the existing percentage of renewable power generation in each province and the costs of renewable energy supply. If credit trading is permitted among provinces, regional cost differences might be small under an RPS because provinces with higher-cost supplies could access lower-cost sources in other provinces. Provinces with low-cost supplies would in turn pay higher prices as a result of national trading.[90]

Assuming minimum regional variation in price increases and using national average changes, sector-specific impact can be assessed using national electricity intensities by sector. Costs for most sectors would increase by no more than 0.1 percent. Cost increases are highest for metal mining and smelting (1.6 percent in 2010) and for pulp and paper (0.8 percent in 2010), both electricity-intensive sectors. Metal mining, and pulp and paper are also highly export-intensive sectors, raising concerns about the broader impact on competitiveness and trade.[91] Even though larger, the relative change in prices is still small, and the impact on exports could be mitigated through policy design.

- *Effects on technological change:* This case study included an explicit analysis of the effects of instruments on technological change. Depending on the fiscal instrument, the case study estimates a 58 to 80 percent increase in production from renewables over the study period. Annual R&D spending on renewables increases by $22 to $172 million compared with the base case. Increased R&D, together with increased penetration of technologies, produces cost reductions of 13 to 26 percent. These cost reductions, however, are uncertain and depend in part on the success of R&D spending in earlier periods. The effects on technological change could vary greatly among instruments and could be enhanced through the design of individual instruments.

Further detail on the macroeconomic impacts of the proposed instruments can be found in a background paper prepared for the EFR and Energy Program.[92]

10.5 POLICY IMPLICATIONS: EMERGING RENEWABLE POWER TECHNOLOGIES

Canada has similar or better renewable energy resources than the nations that are leaders in renewable energy supply. These resources include substantial wind potential and viable sites across the country, a rich solar resource (Toronto has more sunshine than Berlin, and Regina more than Tokyo), several thousand potential sites for small hydroelectric plants and unused biomass potential. The large and expanding electricity market also offers attractive opportunities for the deployment of grid-connected renewables.

The rapidly evolving energy policy landscape in Canada (described in more detail in Part 1, Section 3) provides an excellent opportunity and indeed an exigency for aggressive policy innovation on emerging renewable power technologies. Such innovation could help solve growing supply, security and environmental challenges in the short, medium and long term. Aggressive action on renewables would also be a necessary (but not sufficient) component of a carbon-efficient hydrogen strategy, as discussed elsewhere in this report.

Emerging renewable power technologies face many barriers to development, as described at the top of this section. These need to be overcome to enable maximum uptake of economic instrument–driven opportunities. Some emerging renewable power technologies are intermittent, and developing them will require complementary sources that can compensate for this. Large-scale hydro does this well, as will hydrogen.

This case study did not cover non-grid-connected emerging renewable power technologies, such as geothermal, passive solar and photovoltaics; however, these are considered to have strong potential and deserve their own set of targeted measures.

The study reveals a strong case for the effectiveness and efficiency of economic instruments.[93] This conclusion appears to be linked to three factors:

1. Market failures of two types work against emerging technologies. First, present fiscal and regulatory regimes have been tailored to support the needs of incumbent generation technologies, such as large-scale hydro, nuclear, coal and fossil fuel. Second, market prices do not fully incorporate environmental externalities, so the environmental advantages of emerging renewables are not recognized in their price.

2. Certain classes of emerging renewable energy technologies (most notably wind but also others for niche applications) are near-competitive with incumbent technologies. This puts them in an excellent position to respond to the additional stimulus of fiscal instrument support.

3. Most of these technologies are still produced in low volumes; therefore, their production costs are comparatively higher than those of incumbent technologies. Economic instruments are able to support the cost-reduction and upscaling stages of their evolution.[94]

Economic instruments that target the price gap between emerging renewable energy technologies and incumbent technologies can therefore promote market penetration. However, unlike fossil fuel generation, emerging renewable power technologies are characterized by high capital costs but lower and less volatile operating costs; thus policy certainty and durability over the long term are essential for investor confidence. Non-fiscal policies are important elements of this enabling context to remove some of the non-market barriers.

The three drivers determining the carbon intensity of the electricity market (renewable power penetration, carbon intensity of fossil fuel generation and total electricity demand) are each affected differently by the different economic instruments. As in both other case studies, the choice of preferred economic instrument will depend on the priority policy objective:

- If the exclusive priority is economically efficient, long-term carbon emission reductions, an emissions price is the preferred option.
- However, a scenario with multiple policy objectives is more likely. In this case a renewable portfolio standard or a renewable generation subsidy are the preferred options for maximizing renewable output because they target production as opposed to consumption. Here, producer-targeted fiscal instruments such as accelerated capital cost allowance or government procurement programs can help mitigate the large upfront capital costs of a renewable power generating project. For consumers, the fact that the end product of renewable power—electricity—is not segregated according to its source means that consumption incentives are relatively "invisible" and therefore not as effective. Combining the RPS with an RGS alleviates some of the distributional consequences of an RPS on its own and also leads to the fastest penetration of emerging renewables.
- An emphasis on R&D investment, on its own, could lead to major increases in renewable output but only in the 2015–2030 period—and with significant government disbursement and very high levels of uncertainty.

Participants in the EFR and Energy Program cautioned against economic instruments that exclusively encourage current least-cost choices. These will consistently select more mature technologies, rewarding wind or biomass production, for example, and precluding solar from benefiting from the learning by doing and economies of scale that will help make it more competitive. Production incentives should be broadened to enable a wide choice of emerging technologies, with different levels of subsidy set for each technology according to the cost difference that must be overcome. Policy-makers should be aware, however, that such targeting of less mature technologies will be more costly and may not always lead to Canadian R&D benefits, because Canada imports many renewable technologies.

Recommendation

To support long-term carbon emission reductions through the development of emerging renewable power technologies, the federal government should ensure that its policies are fully supportive of, and consistent with, provincial policies in this area. Specifically, the federal government should:

a) Implement a broad-based price signal for carbon emission reductions. This is the only tool of the ones considered in our study that will also influence consumer demand and the carbon emission intensity of the full power system. Or, alternatively:

b) Supplement provincial renewable portfolio standards—which are being developed across the country—with a national system for trading of renewable energy certificates (REC),[95] and combine this with a federally funded renewable generation subsidy covering a range of emerging technologies. The development of a national REC market and its relationship with a generation subsidy should be carefully thought through and informed by experience in other jurisdictions.

c) Facilitate the implementation of feed-in tariffs—where a minimum price for electricity generated from emerging renewables is combined with clear grid access rules—by working with provinces to develop clear standards for grid access and power purchase agreements. Feed-in tariffs are more effective than other policy measures in promoting distributed renewable generation, which provides benefits in energy security and grid stability.

d) Develop targeted measures for non-grid-connected emerging renewables such as geothermal and passive solar.

e) Expand its program to purchase electricity generated from emerging renewable power technologies.[96]

There is also concern that the existing renewable generation subsidy, the Wind Power Production Incentive (WPPI), favours centralized production. Renewable power has tremendous potential for distributed production, which will increase the resilience of the power system. Generation subsidies that are more supportive of distributed generation should also be introduced—feed-in tariffs, which guarantee price and grid access, have been successful in stimulating distributed generation in Denmark, France, Germany and Spain. Adopting feed-in tariffs, however, would also require supporting policies (net metering and regulations) and infrastructure (distributed power networks).

Discussion within the EFR and Energy Program also addressed the impact of Canadian R&D investment in emerging renewables. Total expenditure on R&D in renewables in Canada was $91 million in 2001 and is forecast to increase to $129 million in 2010. Renewable Energy Working Group members agreed that innovation in emerging renewable technologies would primarily come from international sources and that Canada would stand to benefit. However, Canadian R&D alone will not be able to shift the supply curve and reduce costs. Moreover, an emphasis on Canadian R&D alone would mean doing without all the current opportunities for carbon reductions from market-ready renewable technologies.

11. SPECIFIC FINDINGS: HYDROGEN ENERGY

Hydrogen energy is defined in this study as any energy system where the primary fuel, at some point within the process, is hydrogen. Fuel cells, because they use hydrogen as their primary fuel, are a major component of this sector.[97] This study focused exclusively on carbon dioxide equivalent[98] reductions; however, another main benefit of hydrogen is reduced urban air emissions and human health benefits.

Hydrogen technologies are generally still in the fundamental research, prototype development or product demonstration stages, although there are niche applications in which they are near-competitive with incumbent technologies. Hydrogen technologies face technical, economic and infrastructure barriers to market penetration, as summarized in Table 7.

For further detail and explanation, see Appendix C.

The case study focused on three end uses and pathways:

1. On-road transportation applications using hydrogen production from decentralized steam methane reformers (SMRs).
2. On-road transportation applications using hydrogen production from decentralized electrolyzers.
3. Fuel cells in the residential and commercial sectors, using natural gas from pipelines.

Hydrogen is an energy carrier, not an energy source. This means that the life-cycle environmental impact of hydrogen is closely related to the environmental profile of its feedstock or primary energy source. For hydrogen conversion technologies that use electricity as a feedstock, the carbon intensity will depend on the technology and fuel type of marginal electricity generation. This accounts for some counterintuitive findings, showing that some hydrogen pathways have the potential to lead to increases in carbon emissions.

The carbon intensity of hydrogen feedstocks could potentially be reduced through carbon capture and sequestration. This technique was not included in the assessments of greenhouse gas emission impact. However, it was noted that the inclusion of carbon sequestration in fossil fuel generation processes significantly alters the energy balance of generation, as generated energy is directed away from consumers and into carbon dioxide capture. The cost of these systems would also be very different with carbon capture and sequestration.

11.1 STATUS OF THE HYDROGEN ENERGY SECTOR

Canada is a leader in hydrogen technology development, along with the United States, the United Kingdom, Japan and Germany. Hydrogen development spans from early research stages to pre-commercialization and commercialization.

Table 7: Barriers Limiting Hydrogen Development in Canada

SECTOR	ECONOMIC	TECHNICAL
Hydrogen fuel infrastructure	Cost of hydrogen production Cost of hydrogen distribution	Storage, compressors and distribution network Fuel reformers and processors
Fuel cell technologies	Cost of materials and components Cost of production Current market design for electricity	Durability, perfecting manufacturing processes and improving performance Maintenance support
Hydrogen fuel infrastructure and fuel cell technologies	Need for capital investment and financing Limited scale of operation	Need for codes and standards integration with other systems

Developments in hydrogen energy technologies are primarily focused on three end-use sectors: transportation, stationary electricity and heat generation (both for primary and backup power), and portable power applications. New technologies and products are being discovered, advanced and introduced to the marketplace every year. Only the most commercially advanced of these technologies were considered, because the focus of this study is on the impact of hydrogen technologies between now and 2030.

11.2 STATUS OF THE HYDROGEN ENERGY SECTOR TO 2030 ASSUMING BUSINESS AS USUAL

The hydrogen technologies considered in this analysis realize relatively little market penetration in the business-as-usual (reference) cases. In both the steam methane reformer and the electrolyzer transportation reference cases:

- Energy demand from hydrogen internal combustion engine (ICE) light duty vehicles (LDV) and fuel cell LDVs almost triples between 2010 and 2030. Demand associated with fuel cell buses remains fairly constant or slightly declines over the study period. This is because the price difference between diesel and hydrogen creates less incentive for diesel vehicles to switch to hydrogen. In contrast, energy demand from conventional LDVs and from conventional transit buses increases by about 25 percent each over the same study period.

The growth in numbers of hydrogen vehicles and buses, and in conventional vehicles/buses, follows roughly the same trends.

- The share of energy demand attributable to hydrogen vehicles increases from 1.31 percent of transportation energy demand in Canada in 2010 to 3.1 percent in 2030 in the SMR case, and from 1.28 percent in 2010 to 2.8 per cent in 2030 in the electrolyzer case. The share of demand associated with fuel cell buses actually declines.
- There is a slight shift in demand from personal light duty vehicles to fuel cell vehicles and hydrogen ICE vehicles.
- Greenhouse gas emissions from the transportation sector increase from 202.42 Mt/yr in 2010 to 266.41 Mt/yr in 2030 in the SMR reference case, and from 204.13 Mt/yr in 2010 to 269.11 Mt/yr in the electrolyzer reference case.

In the business-as-usual forecast for stationary fuel cells, there is also only a small degree of penetration within the study period:

- Total energy consumption associated with these technologies increased from 2.38 PJ in 2015 to 3.02 PJ in 2030. The share of total energy demand remains modest, growing from 0.07 percent in 2012 to 0.16 percent in 2030 of total residential demand, and 0.01 per cent in 2012 to 0.03 percent in 2030 of total commercial sector demand.
- Ontario realizes the greatest penetration of stationary fuel cells, because of relatively high regional prices for electricity compared with natural gas. Penetration in eastern and northern regions is constrained by limited access to natural gas.
- Greenhouse gas emissions from the residential and commercial sectors grow from 239.93 Mt/yr in 2010 to 274.05 Mt/yr in 2030.

11.3 STATUS OF THE HYDROGEN ENERGY SECTOR TO 2030 ASSUMING GOVERNMENT INTERVENTION

The case study considers the impact of two categories of fiscal instruments: consumer incentives and producer incentives (primarily tax credits and grants). These were chosen for their ability to narrow the price gap between hydrogen and competing technologies and increase the competitiveness of hydrogen: producer incentives reduce the cost of hydrogen production, and consumer incentives reduce the cost of end-use hydrogen technologies. Consumer and producer incentives from the following list were combined:

- investment tax credits;
- producer tax credits;
- accelerated capital cost allowances;
- research and development grants;
- consumer tax credits; and
- pilot projects.

These instruments were set at levels to reduce the costs of producing hydrogen and the upfront cost of end-use hydrogen technologies by between 10 percent (low case) and 25 percent (high case).[99] The following analysis focuses on the combined impact of producer and consumer incentives under the high-subsidy case (i.e., a 25 percent reduction in costs for each).

Life-cycle emissions associated with transportation would decrease by 0.24 Mt/yr, or 0.465 percent with SMR technology, but increase by 0.23 Mt/yr, or 0.085 percent, with hydrogen production using electrolysis. This increase is due to the fact that new electricity to power the electrolyzers is generally assumed to be coming from combined-cycle natural gas units in the Energy 2020 model.[100] (This outcome will depend on the regional mix of electricity generation; nonetheless, the increase in emissions in the case of hydrogen from electrolyzers is consistent with U.S. research.[101])

These emission reductions are achieved at high costs: for Alberta in 2010, the cost would be $927/tonne for reductions from fuel cell buses and $5,090/tonne for fuel cell cars in the SMR case, and $1,033/tonne for fuel cell buses in the electrolyzer case (all prices in 2000 dollars). For Ontario in the same year, the cost would be lower: $774/tonne for reductions from fuel cell buses and $3,768/tonne for fuel cell cars in the SMR case, and $868/tonne for fuel cell buses in the electrolyzer case. These costs increase by 2030. The high costs are due to the combined impact of the high costs associated with producing hydrogen and purchasing hydrogen technologies, and the limited emission reductions achieved with limited penetration of hydrogen technologies in absolute terms. No reductions were achieved from the hydrogen internal combustion engine and the fuel cell car in the electrolyzer case (i.e., subsidies led to additional emissions).

In the residential sectors, the increased penetration of stationary fuel cells raises emissions by 0.19 percent by 2030 (57.42 Mt/yr to 57.54 Mt/yr), but this is offset by reduced emissions in the electric utilities sector, as fuel cells are used to generate power in houses and less energy is demanded from the electrical grid. A 0.3 percent decrease in emissions from the commercial sector between 2010 and 2030 (64.24 Mt/yr to 64.22 Mt/yr) arises from the movement away from oil and liquefied petroleum gas as the use of stationary fuel cells increases. Electric utility emissions drop in the same time period by 0.53 percent (152.38 Mt/yr to

Hydrogen Energy

Reducing the combined costs of producing and consuming hydrogen fuels and technologies by 25 percent leads to an increase by 2030 of:

- 47,312 fuel cell vehicles, 33,371 hydrogen internal combustion engines and 218 fuel cell buses; and
- 15,770 stationary fuel cells in the residential sector and 90 in the commercial sector.

It also reduces greenhouse gas emissions by:

- 1,240 kt from transportation applications using SMR hydrogen production, or 2,650 kt if the hydrogen source is zero-emission; and
- 710 kt from stationary fuel cells in the residential and commercial sectors.

However,

- greenhouse gas emissions increase from electrolyzer transportation applications, if the marginal electricity source is combined-cycle natural gas.

The transportation emission reductions are achieved at high costs (all prices in 2000 dollars):

- For Alberta in 2010, $927/tonne for reductions from fuel cell buses and $5,090/tonne for fuel cell cars in the SMR case, and $1,033/ tonne for fuel cell buses in the electrolyzer case.
- For Ontario in 2010, $774/tonne for reductions from fuel cell buses and $3,768/tonne for fuel cell cars in the SMR case, and $868/tonne for fuel cell buses in the electrolyzer case.

151.58 Mt/yr). The total emission reduction between 2010 and 2030 from the fiscal measures to promote stationary fuel cells is 0.71 Mt/yr, or 0.26 percent. These reductions come at a lower cost than those from transportation but nonetheless remain very pricey compared with other mitigation options: the Canadian average is $293/tonne in 2010, escalating to $944/tonne in 2030. There were wide regional and temporal variations in costs (from $12.50/tonne in British Columbia in 2010 to $1,670/tonne in Saskatchewan in 2030). (All prices are in 2000 dollars.)

These findings are conservative because of the assumptions made for technology development, which were based on current knowledge and projected performance. While it is prudent and necessary, from a public policy point of view, to rely on these conservative assumptions, they are probably not reflective of the real pace of technology development in the sector. This observation points to a central constraint on public policy in this area, which is particularly acute in the case of hydrogen (but also relevant in the other two cases) because of the still-speculative nature of the technology.

Further detail and discussion of the case study findings is provided in Appendix C.

11.4 MACROECONOMIC IMPACT: HYDROGEN CASE STUDY

The case study does not account for any other significant government policies associated with greenhouse gas reduction targets, other than those in place when *Canada's Emission Outlook: An Update* was developed for the National Climate Change Process. Other greenhouse gas policies could affect the relative price of different fuels and, in turn, the uptake of hydrogen with or without subsidies. In addition, the analysis does not account for general breakthroughs or possible developments in hydrogen technologies as a result of policies in other countries.

The macroeconomic impacts of the proposed instruments in the hydrogen case study can be summarized as follows:

- *Aggregate macroeconomic impact:* Insignificant from a national perspective.
- *Distributional and competitiveness impacts:* The costs of the fiscal instrument vary widely across end use, pathway and region. However, since reductions are achieved entirely through subsidies, these costs are spread out over the entire economy. Uptake will be by actors willing to pay a premium for non-financial reasons and, therefore, will likely be limited to consumers with higher incomes. The greatest penetration of stationary fuel cell technologies occurs in Alberta and Ontario based on relative energy prices, and these jurisdictions would see the largest share of any co-benefits arising from policy (e.g., reductions in local emissions of air pollutants). Penetration in the transportation sector is much more evenly distributed across the country. The subsidies could benefit developers of hydrogen technologies, which tend to be clustered in British Columbia and Ontario. However, the magnitude of additional demand is unlikely to be sufficient to stimulate domestic production of these technologies.
- *Effects on technological change:* With the proposed fiscal instruments (higher level of subsidy), there is a 50 percent increase in hydrogen demand for transportation and a 43 to 67 percent increase in hydrogen-related vehicles by 2030. There is a 472 percent increase in hydrogen demand for stationary fuel cells, with a 230 percent increase in number of installed fuel cells. Although significant in relative terms, the increases in hydrogen production and penetration of hydrogen end-use technologies are small in absolute terms. Moreover, it is unlikely the policy will have significant effects on technological evolution. Advances in the technology are more likely to come from changes in global demand and policies in much larger countries.

Further detail on the macroeconomic impacts of the proposed instruments can be found in a background paper prepared for the EFR and Energy Program.[102]

11.5 POLICY IMPLICATIONS: HYDROGEN ENERGY

The hydrogen economy holds considerable economic promise for Canada, although large-scale penetration of hydrogen technologies (e.g., fuel cell vehicles) is decades away. Canada is a global leader in the development of hydrogen technologies and applications, and support from the federal government has been important—in August 2003 alone, the sector received $130 million in additional federal support.

Continued success, however, will depend on properly positioning Canadian efforts, particularly with respect to the development of a North American hydrogen transportation industry. Our current leadership position is threatened by rapid progress in the United States and European Union, which have multibillion-dollar investment strategies, and inherent weaknesses in Canada's ability to deliver new technologies at the commercial stage.

Canada's investments in maintaining capacity and stimulating innovation in this field reflect our ambition to be a player in the emerging hydrogen economy. The level of investment is driven primarily by industrial objectives. A long-term carbon emission reduction objective alone, or even a broader environmental objective, would be unlikely to secure this level of investment, although reductions in transportation tail-pipe air pollutants are a significant co-benefit of hydrogen technologies.

Whether the production of hydrogen yields environmental benefits will depend on its pathways—the choices of primary energy, intermediate energy carriers, distribution systems and final use. To be carbon-effective, a hydrogen system must contribute, on a life-cycle basis, relatively lower levels of carbon emissions than the incumbent technology. This case study confirmed that the choice of primary fuel source and hydrogen production technology has major implications for carbon emissions and, therefore, on the cost per tonne of carbon reduction:

- The choice of primary energy source (whether fossil fuel–based or a source such as wind, nuclear or hydro that produces almost no greenhouse gas emissions) can affect greenhouse gas emission reductions by as much as 175 percent (1,940 kt vs. 3,360 kt for hydrogen produced by SMR).
- On a life-cycle basis, the choice of hydrogen production technologies can reduce greenhouse gas emissions (in the case of SMR) or increase them (in the case of hydrogen production using electrolysis, where combined-cycle natural gas is the marginal energy source). This is because the new electricity to power the electrolyzers is assumed to be coming from combined-cycle natural gas units, the dominant technology for generation at the margin. However, this assumption does not hold true in every region of the country nor for every hydrogen pathway.

These findings echo the results from other studies of the greenhouse gas profiles of various hydrogen pathways. For example, a study of several dozen transportation hydrogen pathways conducted for Fuel Cells Canada in 2003 concluded that:

> *GHG emissions for the hydrogen pathways range from 1.3% to 395% of the gasoline baseline vehicle. With such a wide range in the GHG emission and energy use results it is clear that an unmanaged "Hydrogen Economy" is not a panacea for solving the GHG emissions problem or for resolving the energy security issues for energy importing nations. There are hydrogen pathways that can produce very significant GHG emission reductions and energy savings but there are also pathways that would result in increased GHG emissions and increased energy use. One of the challenges of managing a transition to a hydrogen economy will therefore be ensuring that society receive the maximum possible benefits.*[103]

Public investment in hydrogen technologies should therefore focus on lower-carbon (on a life-cycle basis) hydrogen pathways, particularly those from zero-emission primary energy sources.

Adding further complexity to decisions on policy priorities, the same study concluded that the most carbon-efficient pathways do not align with the most energy-efficient pathways: "the coal to hydrogen pathways have some of the best energy efficiency results but the highest GHG results."[104]

While Canada has clearly decided to compete in the hydrogen economy, we have not, to date, made any decisions about the carbon intensity of the hydrogen path we want to pursue. The government's present approach (i.e., pursuit of a wide diversity of hydrogen sources) risks maintaining the momentum toward carbon-intensive source options. Given the fiscal constraints and the onset of an increasingly carbon-constrained economy—and assuming limited public funds to invest in hydrogen, climate change mitigation and other air quality improvements—the time may be right for a second Canadian public policy decision. Should Canada's hydrogen strategy be exclusively technology-driven or also consider long-term carbon emission reductions?

There could be three different, but compatible, Canadian policy objectives for hydrogen:

1 *Maintain our flexibility and ability to engage in the hydrogen economy:* Canadian capacity and potential in this field is sharply different from that in the other two case studies—we are already a leading innovator, not merely a technology taker. There are strong industrial strategy reasons for adopting this objective at a minimum. The long-term future of two vital sectors of the Canadian economy, the energy and automobile sectors, will be shaped by developments in the hydrogen economy.

2 *Make the transition to the hydrogen economy*: There are many additional reasons to want Canada to be an early adopter of hydrogen technologies. These include environmental benefits (potential greenhouse gas and urban smog reductions), employment benefits particularly in remote communities, and increased energy security from diversification of primary energy sources and increased distribution of energy systems.

If making the transition to the hydrogen economy is the chosen objective, then policy-makers need to consider how policies in other energy sectors will influence the viability of this transition. A key insight from our modelling work is that the uptake of hydrogen technologies is very sensitive to the prices of other energy sources (both primary fuels for hydrogen production and competitor fuels). Therefore, the transition to a hydrogen economy will be affected by policies in other energy sectors, such as electricity and natural gas. These include greenhouse gas policies that would affect the relative price of different fuels and in turn the uptake of hydrogen.

3 *Use hydrogen as the backbone for a long-term carbon emission reduction strategy:* In this case, there would need to be a deliberate focus on carbon-efficient hydrogen supply options. Ecological fiscal reforms implemented in support of this latter objective would not be carbon-neutral but would differentiate on the basis of the life-cycle carbon content of hydrogen.

Pursuit of this objective would require action on two fronts: enhancing low-carbon[105] primary energy supplies in the country, and developing carbon capture and sequestration technologies to mitigate emissions from fossil fuel combustion.

Even under aggressive scenarios for developing emerging renewable technologies, these sources will not be sufficient to support the full potential demand for hydrogen energy. The most aggressive targets that have been proposed for emerging renewables remain in the range of 15 to 16 percent of Canadian electricity supply in 2020.[106] From a carbon-efficiency perspective, it would be better to use energy from renewables to displace coal generation than to power hydrogen conversion. This conclusion further suggests that other forms of low-carbon electricity, such as large-scale hydro or nuclear, would need to be tapped and even expanded to support a low-carbon hydrogen strategy.

The forecast shortfall in the supply of natural gas is another reason for emphasizing renewables as a primary source for hydrogen energy. For example, an October 2003 report by the U.S. National Petroleum Council indicates that conventional gas sources will satisfy only 75 percent of continental demand over the next 15 years.[107] Oil sands production is one significant new source of this demand. The Canadian Energy Research Institute forecasts that "even with … expected additional sources, gas supply in Canada is expected to flatten by 2009 and begin declining by 2016."[108] As demand pressure generates higher natural gas prices, this will also benefit the price competitiveness of hydrogen energy from renewable sources.

Carbon capture and sequestration (another long-term energy-based carbon emission reduction technology) may offer a companion technology for reducing the carbon intensity of other hydrogen pathways. However, the introduction of this mitigation technology would come at a significant cost to the energy balance of hydrogen fuels, making hydrogen systems more expensive.

The marginal costs of the emission reductions identified in the hydrogen case study greatly exceed those identified under the National Climate Change Process, ranging from $300 (stationary fuel cells) to $2,000/tonne depending on end use and hydrogen pathway. These costs reflect only the cost of government subsidies and exclude any costs borne by program participants, which although voluntary could still be substantial. In comparison, the NCCP estimated marginal costs of $0 to $10/tonne for the residential and commercial sectors, $50/tonne for the transportation sector under a sector-specific approach and as high as $120/tonne for both sectors under a national target. Despite these high unit costs, total emission reductions are very small: less than 1 Mt. These small gains would require a subsidy of about $1 billion in 2015, rising to about $1.6 billion per year by 2030.[109] Assuming government expenditures grow at roughly the same rate as GDP, this subsidy would increase government expenditures by about 0.4 percent in 2030.[110]

These results led to significant debate regarding hydrogen's potential to contribute to emission reductions, as well as substantial additional input from the hydrogen industry. This process led to two conclusions:

1. The policy instrument modelled (producer and consumer incentives to cut costs by 10 to 25 percent) will not increase the market penetration of hydrogen technologies, which are still largely in the research, development and demonstration stages. This conclusion is based on the prohibitive cost per tonne emission reduction.

2. Greater technology uptake might have been achieved if the case study had been based, not on on-road hydrogen fuel cell vehicles, but on other near-commercial transportation applications with fewer infrastructure challenges. Many of these technologies are competitive in niche applications such as off-road utility vehicles (e.g., forklifts). These applications are particularly well suited to settings where diesel is now used but zero emissions are desired. The on-road vehicles modelled are particularly challenging since they require replacing an entire energy infrastructure—to produce, transport, store and convert the fuel to useful forms and distribute it to end users—as well as changes in the end-use technology. However, these niche applications would not result in very large emission reductions at the national scale.

Recommendation

To support long-term carbon emission reductions through the use of hydrogen fuel, the federal government should:

a) Drive public investments toward lower carbon pathways, including carbon-free hydrogen production and elimination of carbon at its source through sequestration.

b) Fund and stimulate increased research and development to reduce the capital costs of fuel cell technologies and to improve the energy balance and costs of hydrogen production.

c) Continue to focus on transportation applications with long-term carbon emission reduction potential, in recognition of Canada's industrial interests in the fuel cell, hydrogen and auto sectors.

These conclusions point to the need for an integrated hydrogen strategy that considers the best sequence of fiscal tools in relation to the development cycles of hydrogen technologies and business models. An integrated strategy would also need to address informational and regulatory policies that would complement the fiscal tools.

12. MACROECONOMIC IMPACTS OF THE PROPOSED MEASURES

As stated earlier, the NRTEE commissioned a qualitative assessment of the likely macroeconomic costs of the various instruments proposed in the case studies. It then compared these estimates with similar estimates produced in 2000 for the National Climate Change Process. The NRTEE found that, in general, the aggregate macroeconomic costs of the various instruments proposed in the NRTEE case studies are likely much smaller than those proposed for the NCCP. There are several reasons:

- For the most part, the marginal costs of emission reductions in the case studies are lower than those assumed under the NCCP to meet the Kyoto targets.
- The total emission reductions by 2010, even without adjusting for possible double-counting among the case studies (e.g., both the renewables and energy efficiency case studies include reductions in the electricity sector), are 3 to 10 times lower in the case studies than those assumed in the NCCP study.
- Some proposed instruments such as subsidies have no direct impact on prices. Even for instruments such as emission prices, the estimated impacts on energy and other product prices are smaller than those estimated for the NCCP, suggesting more limited demand feedbacks.

It must be stressed, however, that in all cases the macroeconomic impacts of economic instruments related to greenhouse gases and energy are still very uncertain and controversial.

13. A SUPPORTING SUITE OF COORDINATED ECONOMIC INSTRUMENTS

The coordinated transition strategy described above demands a coordinated and synergistic set of supporting economic instruments. Adopted as a suite, these would support each technology through its present stage of development and prepare the subsequent additional technology for commercialization and uptake.

A Coordinated Suite of Economic Instruments

TECHNOLOGY	RECOMMENDED INSTRUMENTS		
	Broad-based	*Targeted*	*Long-term support*
Mature: Already in market at competitive price	1. Emissions charge or tradable permit (supported by targeted relief)	1. Performance-based instruments 2. Technology-based instruments (e.g., CCA)	R&D subsidies and investment incentives
Emerging: In the product commercialization/market development or market-ready stages, but face cost differential with incumbent technologies and need for learning by doing		1. Market-based regulations (e.g., portfolio standards) and/or 2. Subsidies (e.g., production incentives)	
Longer-term new: In the fundamental research/prototype stage; large technical challenges remain and there is a large cost differential with incumbents		R&D subsidies and investment incentives	

Recommendation

The recommendations made above in relation to the three case studies should be adopted as a coordinated suite, from the short term to the long term, to enable the maximum benefit to be derived from the technologies at the most appropriate point in their projected development, and to mitigate any discontinuity in the implementation of the economic instruments.

14. SUMMARY OF RECOMMENDATIONS, PART II

a) Implement a broad-based price signal for carbon emission reductions. This is the only tool of the ones considered in our study that will also influence consumer demand and the carbon emission intensity of the full power system. Or, alternatively:

b) Supplement provincial renewable portfolio standards—which are being developed across the country—with a national system for trading of renewable energy certificates (REC), and combine this with a federally funded renewable generation subsidy covering a range of emerging technologies. The development of a national REC market and its relationship with a generation subsidy should be carefully thought through and informed by experience in other jurisdictions.

c) Facilitate the implementation of feed-in tariffs—where a minimum price for electricity generated from emerging renewables is combined with clear grid access rules—by working with provinces to develop clear standards for grid access and power purchase agreements. Feed-in tariffs are more effective than other policy measures in promoting distributed renewable generation, which provides benefits in energy security and grid stability.

d) Develop targeted measures for non-grid-connected emerging renewables such as geothermal and passive solar.

e) Expand its program to purchase electricity generated from emerging renewable power technologies.

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HYDROGEN CASE STUDY

- **To support long-term carbon emission reductions through the use of hydrogen fuel, the federal government should:**

a) Drive public investments toward lower-carbon pathways, including carbon-free hydrogen production and elimination of carbon at its source through sequestration.

b) Fund and stimulate increased research and development to reduce the capital costs of fuel cell technologies and to improve the energy balance and costs of hydrogen production.

c) Continue to focus on transportation applications with long-term carbon emission reduction potential, in recognition of Canada's industrial interests in the fuel cell, hydrogen and auto sectors.

A SUPPORTING SUITE OF COORDINATED ECONOMIC INSTRUMENTS

- **The recommendations made above in relation to the three case studies should be adopted as a coordinated suite, from the short term to the long term, to enable the maximum benefit to be derived from the technologies at the most appropriate point in their projected development, and to mitigate any discontinuity in the implementation of the economic instruments.**

Appendices

A. EXECUTIVE SUMMARY: CASE STUDY ON ENERGY EFFICIENCY

By M.K. Jaccard & Associates

1 INTRODUCTION

Ecological fiscal reform (EFR) is the systematic alignment of fiscal policy with other policy tools for the achievement of simultaneous economic and environmental objectives. This case study explores how fiscal policy can promote the energy efficiency of Canada's industrial sector in a way that leads to long-term reductions in energy-based carbon emissions.

For the purposes of this case study, *industry* is defined as establishments engaged in manufacturing and mining activities. It does not include establishments involved in electrical generation, agriculture or providing services.

Energy efficiency refers to the relationship between the output (service) of a device or a system and the energy put into it. Improved energy efficiency is doing more with equal or less energy input. Energy efficiency analysis can be applied to different aspects of the energy system, including energy-using equipment, major industrial processes, supply technologies, delivery networks, and even urban form and infrastructure. Energy intensity is a common indicator in energy analysis, given that energy efficiency cannot be measured directly at an aggregate level. *Energy intensity* is defined as unit energy per unit output, where output is measured in physical units (gross output) or monetary units (gross domestic product or GDP).

There are various ways of reducing the carbon intensity of energy. Improving energy efficiency will result in lower carbon emissions if, as is often the case, the carbon intensity of energy (tonnes of carbon per gigajoule energy) does not increase significantly.

In designing policies and assessing their impact and costs, it is useful to clearly distinguish between action and policy. An *action* is a change in equipment acquisition, equipment use rate, lifestyle or resource management practice that changes net greenhouse gas (GHG) emissions from what they otherwise would be. This study focuses on energy efficiency actions based on changes in technology acquisition, but it also considers these actions in relation to other actions to decarbonate.

In describing carbon-based emissions for the industry sector, it is useful to use the concepts of direct and indirect emissions. *Direct emissions* are emissions that are produced by a source controlled by the sector, while *indirect emissions* are those resulting from that sector's activity but are produced by an external source. When considering the impact of actions, we consider the combined impact on both indirect and direct emissions, since considering only direct emissions would actually show an increase in emissions for an action such as cogeneration.

2 INDUSTRY SECTOR CHARACTERISTICS

The industrial sector, which includes all mining and manufacturing activities, is the largest GHG-producing sector in Canada. In 2000, it produced direct GHG emissions of 237 Mt carbon dioxide equivalent (CO_2e), the majority of which were energy consumption–based. Energy consumption reflects activity levels, industry structure and the energy efficiency of energy use, while GHG emissions also reflect the GHG intensity of energy use and process-related emissions.

Energy is particularly critical in the production of basic industrial products, which are used to produce goods for final consumption, either within or outside Canada. These primary product industries account for more than 80% of total industrial energy consumption. They include industries such as iron and steel, pulp and paper, metal smelting, petroleum refining, chemical manufacturing and industrial minerals. The remaining industries, which are many and diverse (food processing, transportation equipment manufacturing, etc.), account for only 15% of industrial energy consumption but are responsible for 60% of industrial economic output.

Energy intensity (based on GDP) in Canadian industry generally decreased after 1990 to a level 27% below 1990 levels in 2002. The decline in energy intensity is due both to improved efficiency among energy users as well as to structural change in industry. The term *structural change* in this context refers to a change in product or industry mix that determines total industrial production volume. Between 1995 and 2001, the activity share of less energy-intensive industries has increased while the share represented by more energy-intensive industries has decreased, leading to a decline in total energy use of 11.5% relative to 1995.

Trends based on economic output cannot provide an accurate picture of energy intensity because monetary units are affected by many factors not associated with energy, such as costs of labour or selling price of the final product. Indicators computed for aggregate physical energy intensity suggest a smaller decline in energy intensity relative to the measure based on GDP.

Managers in industry are considered more directly motivated to minimize costs than are residential and commercial consumers. Thus firms may have already pursued many cost-effective options to reduce energy consumption, particularly when energy costs make up a high percentage of total production costs. Some sectors are more physically limited in their ability to reduce energy use, particularly fossil fuel use. Nevertheless, the potential for energy efficiency improvements can still be significant, depending on the industry sector.

3 CURRENT POLICY

Current policies relating to industrial energy efficiency have their roots in the 1970s. The oil price shock of 1973 made energy security a high-priority concern and led to, among other responses, the development of numerous energy efficiency programs internationally and within Canada (e.g., the Canadian Industry Program for Energy Conservation, or CIPEC, and the Industrial Energy Innovators Initiative). Since then, industrial energy efficiency has become closely associated with climate change policy initiatives. It has figured strongly in voluntary efforts by industry to curtail its GHG emissions as part of the Voluntary Challenge and Registry, which was initially launched by government to encourage private and public sector organizations to voluntarily limit their net GHG emissions. Just prior to ratifying the Kyoto Protocol in December 2002, the Government of Canada released the Climate Change Plan for Canada, which established an approach for addressing emissions from large industrial emitters.

The federal budget of 2003 followed up on the Climate Change Plan with allocations to provide long-term support for research and development in emerging energy-efficient technologies ($250 million) and to subsidize industrial energy efficiency actions and carbon offsets ($303 million). Research and development in advanced end-use efficiency technologies is one of the five federal priority areas in science and technology. Outside federal policy and initiatives, provincial governments and Crown utility corporations have also been active in promoting energy efficiency in industry and in climate change policy in general.

The fiscal system may provide a non-level playing field for competing energy investments due to different tax treatments of investments. A special capital cost allowance (CCA) class for "Energy Conservation and Renewable Energy" equipment (Class 43.1) qualifies certain investments for an annual 30% depreciation rate. This class specifically targets combined heat and power systems, high-efficiency gas generation and heat recovery equipment as energy efficiency investments relevant to the industrial sector. Canada does not employ any other tax incentives as part of the personal or corporate income tax system.

Outside the tax system, a few programs operated by government and utilities provide incentives to promote energy efficiency by industry. Most programs are part of broader policies that include information provision. The Climate Change Plan for Canada seeks to develop a tradable permit system that will provide an incentive for decarbonization by large industrial emitters. The government is currently considering how its permit system could be designed to best develop this market. However, it is already operating a pilot "voluntary" emissions trading system, the Pilot Emission Removals, Reductions and Learnings Initiative.

As noted above, the Climate Change Plan provides for direct funding for R&D in energy efficiency technologies. The Office of Energy Research and Development coordinates federal energy research and development activities and directs the Program of Energy Research and Development (which includes a strategy for energy efficiency in industry). The Canmet Energy Technology Centre and the Innovative Research Initiative for Greenhouse Gas Mitigation also fund research programs that include energy efficiency projects. Overall, Canada has favoured fiscal incentives over direct funding to support research and development, and it provides one of the most generous systems among all Organisation for Economic Co-operation and Development countries.

4 ENERGY EFFICIENCY OPPORTUNITIES

Energy use in industry can be understood in terms of generic or auxiliary services and unique processes. Generic or auxiliary energy services are those that are not specific to a particular industry. They fall into four general categories: steam generation systems (boilers and cogenerators), lighting, HVAC (heating, ventilation and air conditioning) systems, and electric motor systems (pumps, fans, compressors or conveyors). Significant reductions can occur through energy efficiency improvements to steam generation systems and to electric motors and their attached auxiliary devices. The efficiency of steam generation varies greatly depending on boiler design, age and fuel used. Substantial energy efficiency improvements can also be achieved by using cogenerators rather than simple steam boilers. Although some potential exists to improve the efficiency of electric motors, there is greater potential to improve the efficiencies of equipment driven by them (pumping, air displacement, compression, conveyance and other types of machine drive).

The remaining energy efficiency opportunities are quite specific to the unique processes of each particular industry. Some industries use large amounts of heat to accomplish their activities. For instance, materials production industries (such as iron, steel, other primary metals and building materials) are characterized by heavy use of direct process heat. Other industries are very dependent on electricity to drive large motors or to generate or purify chemicals or metals in electrolytic cells. Such energy-intensive industries typically have fewer options for energy (or CO_2) reduction than industries that make use of many tens or hundreds of processes, each requiring only a small amount of energy, to transform semi-finished products into their final form.

Many energy-efficient technologies are on the market today. Some have been available for some time but could still see greater uptake. Others are poised to emerge and are currently at demonstration stages or have been applied in a relatively narrow niche (e.g., direct reduction in iron and steel). Still others have not been technically realized and are the subject of active R&D programs (e.g., inert anodes/wetted cathodes in aluminum electrolysis). Technological innovation may be either radical (disruptive) or incremental. Radical technological innovation represents a transition to a new technology or a new paradigm, which often changes the way people think about the product or process. Incremental innovation occurs as small and gradual innovation in existing technologies.

5 CHALLENGES TO ADOPTION

Research during the past 30 years has shown that consumers and firms forgo apparently cost-effective investments in energy efficiency. They appear to discount future savings of energy efficiency investments at rates well in excess of market rates for borrowing or saving. This phenomenon has often been referred to as the energy efficiency "gap" and is a critical issue for this case study in evaluating the economic cost and potential for fiscal policy to influence the uptake of energy-efficient technologies.

While there is clearly potential for firms to make energy efficiency improvements, determining the extent of that potential is not easy. New technologies carry a greater potential for failure, and this uncertainty can create a significant investment hurdle for firms considering irreversible investments that can be delayed. Also, different consumers in different locations will face varying acquisition, installation and operating costs, and energy efficiency equipment will be more appropriate in some situations than others.

Understanding the impact of energy efficiency improvements on aggregate energy consumption and on decarbonization is complicated by several factors. First, pursuing energy efficiency can result in decarbonization, but one must keep in mind that primary fuels differ substantially in their carbon emissions. There are also significant "second order" feedbacks that occur between the energy demand and supply sectors in the economy. For instance, the widespread adoption of high-efficiency electric motor and auxiliary systems would affect the demand for electricity, with potential price impacts that would affect energy-related decisions throughout the economy. In cases where energy-efficient technologies achieve substantial market penetration, the resulting lower cost of energy services elicits a rebound effect of increased energy service demand and thus greater energy consumption.

6 MODELLING METHODOLOGY

A variety of energy economy models can be used to develop a baseline of GHG emissions in the industry sector and to estimate how changes in the energy efficiency, fuel type or emission controls of technologies would lead to different levels of GHG emissions. The CIMS model, developed by the Energy and Materials Research Group at Simon Fraser University, is used in this analysis. Unique technologies, processes and technological interactions in the Canadian industry sector are represented in detail. It is therefore possible to explicitly explore the relationship between the underlying process and technology structure of the sector and its aggregate energy use and GHG emissions. CIMS also portrays technology acquisition decisions based on financial cost and behavioural parameters estimated from empirical studies of consumer and business decision making. The model thus differs from those that use a single, *ex ante* (expected) estimate of financial cost as the basis for technology selection and thus do not address the complexities of decision making evidenced by the energy efficiency gap. The CIMS model is also able to incorporate energy price feedbacks between energy demand and supply sectors, as well as energy service demand feedbacks.

6.1 Model Overview

A CIMS simulation involves six basic steps.

1 *Assessment of demand:* Technologies are represented in the model in terms of the quantity of service and/or product they provide (e.g., tonnes of paper produced). A forecast of service growth drives the model simulation in five-year increments.

2 *Retirement:* In each future period, a portion of the initial year's technology stock is retired based on age. The residual technology stocks in each period are subtracted from the forecast energy service demand.

3 *New technology competition/retrofit competition:* Prospective technologies compete for the new investment required to meet service demand based on the minimization of annualized lifecycle costs, which include identified differences in non-financial technology preferences and failure risks. The model allocates market shares among technologies probabilistically to reflect varying acquisition, installation and operating costs and equipment. In each time period, a similar competition occurs prior to new stock purchases to simulate retrofitting of residual stock.

4 *Equilibrium of energy supply and demand:* In each future time period, a cycle occurs between technology choice in the energy demand models and technology choice and energy prices in the supply models, until prices and demand have stabilized at an equilibrium.

5 *Equilibrium of energy service demand:* Once the energy supply and demand cycle has stablized, this step adjusts demand for energy services based on price elasticities. If this adjustment is significant, the whole system is rerun from step 1 with the new demands.

6 *Output:* Total energy, emission and cost information can be derived from the final model results since each technology has net energy use, net energy emissions and costs associated with it.

The CIMS model is used to construct the baseline scenario and to develop two alternative scenarios that estimate how changes in the energy efficiency, fuel type or emission controls of technologies can lead to different levels of GHG emissions in the industry sector.

7 BASELINE SCENARIO

The baseline scenario is developed using the CIMS model according to simulation steps 1, 2, 3 and 6 described in the preceding section (steps 4 and 5 are not used in the case study). The baseline forecast period runs from 2000 (CIMS base year) to 2030. For this study, assumptions regarding economic growth (more specifically, region-specific growth rates for GDP for 2000 to 2020) and future energy prices are adopted from *Canada's Emissions Outlook: An Update* (CEOU).[1] For the simulation past 2020, annual price and growth trends of the 2015–2020 period are assumed to continue to 2030. The emission forecast generated by CIMS is calibrated to the official GHG forecast (as of December 2003), which was formulated since the release of the CEOU.

[1] *Available on-line at:* ***www.nrcan.gc.ca/es/ceo/update.htm***

Table 1: Baseline Forecast of GHG Emissions and Energy Consumption, Canada

	2000	2010	2020	2030	Average Annual Growth
GHG emissions (Mt CO_2e)	288	343	396	453	1.53%
Direct	237	307	358	407	1.82%
Indirect	50	36	38	46	-0.30%
Energy (PJ)	4,239	5,030	5,783	6,579	1.48%

A summary of the baseline scenario for the industry sector in Canada is presented in Table 1. Overall, emissions in the industry sector (as defined for this case study) grow by 50% over the 30-year simulation period, with direct emissions increasing and indirect emissions decreasing. The share of electricity produced by cogeneration in the sector increases over the simulation period, particularly in oil sands operations. The oil and gas sector generates the largest increase in GHG emissions, which is driven by a strong growth in oil and gas exports to the United States.

8 ALTERNATIVE SCENARIOS

Two alternative forecasts are produced by simulating two different shadow prices over a 25-year simulation period (2005–2030). We model one price of \$15/tonne CO_2e and one of \$30/tonne CO_2e to influence a shift in investment patterns. In addition to applying this shadow price to the industry sector sub-models, we also apply the price to the electricity sector so that a carbon price can be reflected in the electricity price seen by the industry subsectors.

Emerging technologies have a greater ability to gain market acceptance in a 25-year time frame. In order to capture the long-term promotion of these technologies through R&D and commercialization support, we adjust the "intangible costs" of a selection of emerging technologies in the model to reflect a more targeted R&D and commercialization effort.

Simulating a carbon emission shadow price in the industrial sector sub-models indicates the emission reduction potential from energy efficiency actions. This type of simulation reveals the potential for emission reductions that could occur from energy efficiency actions up to a specified marginal abatement cost for carbon. This methodology is built on the principle that the goal (decarbonization) would drive the formulation of an alternative GHG scenario (as simulated by a shadow price for GHG), which would indicate what role energy efficiency investments could play in decarbonization compared with other options. The choice of carbon prices reflects a relatively modest "achievable potential" that could be influenced by fiscal policy.

The Low Carbon I and II scenarios result in GHG reductions of 46 Mt CO_2e and 58 Mt CO_2e by 2030 (see Table 2). Direct emissions make up most of these emission reductions, though the response of indirect emissions to the imposition of a shadow price is stronger than the response of direct emissions (indirect emissions decline by 53% to 62% in 2030, while direct emissions decline by 5% to 7%). Actions behind this strong indirect response include the greater adoption of cogeneration systems and improvements to the overall efficiency of auxiliary motor systems. The metal smelting and refining sector and the petroleum refining and iron and steel subsectors realize the most emission reductions from improved energy efficiency.

Where energy-efficient technologies achieve substantial market penetration, the resulting lower cost of energy services produces a rebound effect, driving up energy service demand and increasing energy consumption. The alternative scenarios do not incorporate this effect.

Table 2: GHG Emissions and Energy for Alternative Scenarios, Canada

	2000	2010	2020	2030
Total GHG emissions (Mt CO_2e)				
BAU	288	343	396	453
Low Carbon I	288	322	365	407
Low Carbon II	288	316	355	395
Direct GHG emissions (Mt CO_2e)				
BAU	237	307	358	407
Low Carbon I	237	292	339	386
Low Carbon II	237	293	335	378
Indirect GHG emissions (Mt CO_2e)				
BAU	50	36	38	46
Low Carbon I	50	29	26	22
Low Carbon II	50	23	20	17
Energy (PJ)				
BAU	4,239	5,030	5,783	6,579
Low Carbon I	4,239	4,822	5,537	6,298
Low Carbon II	4,239	4,818	5,497	6,232

BAU = business as usual

9 ECONOMIC AND POLICY ANALYSIS

The alternative scenario simulations reveal that reductions of up to 58 Mt CO_2e could be achieved by 2030 in part by actions leading to greater energy efficiency by industry. We calculate *ex ante* (expected) financial costs of the scenarios (shown in Table 3), which represent the difference in the net present value of capital, energy and operating and maintenance costs in 2004 (2000 $), discounted at a social discount rate for the period 2005–2030, between the baseline and each alternative scenario. All subsectors show negative costs because the value of energy savings is greater than any increase in upfront capital costs from adopting these measures. Welfare costs may be, and usually are, much higher and are embodied in the technology choices of firms and households.

Because the CIMS simulation did not incorporate final demand feedbacks (step 5 of the CIMS simulation), the results provide only a partial equilibrium portrayal of the response to the shadow price of CO_2e.

Table 3: Ex Ante *Financial Costs for 2005–2030 ($ billion)*

	Low Carbon I	Low Carbon II
Chemical products	-4.98	-4.04
Coal mining	-0.99	-2.19
Industrial minerals	-1.16	-2.08
Iron and steel	-1.84	-1.93
Metal smelting and refining	-1.42	-1.76
Mining	-0.26	-0.59
Other manufacturing	-1.92	-2.75
Petroleum crude extraction	-0.04	-0.03
Petroleum refining	-0.19	-0.38
Pulp and paper	-3.39	-4.80
Natural gas industry	-1.45	-4.32
Total	**-17.64**	**-24.87**

Note: Figures are reported in 2000 $.

Pursuing long-term carbon emission reductions by targeting industrial energy efficiency may be accompanied by benefits that go beyond reducing GHG emissions and the ecological harm associated with global warming. First, declining energy intensity will reduce the energy costs per unit of service output, and economic growth will be less constrained by future energy costs. Second, the innovation of more efficient technologies will be encouraged, which may serve as an opportunity to increase exports. Third, negative health effects associated with poor air quality may be reduced.

Ecological fiscal reform as defined in this study (see Introduction) is a broad approach, which can employ suites of instruments in a reinforcing package to support the shift to sustainable development. As described in the NRTEE's report *Toward a Canadian Agenda for Ecological Fiscal Reform: First Steps*, the common purpose of these instruments is to provide incentives for producers and consumers to alter their decisions and behaviour. These instruments either internalize environmental costs or reward more sustainable practices. We relate three key policy tools to the modelling analysis: the application of environmental taxes, tradable permits (as part of market-oriented regulation) and subsidies.

9.1 Environmental Taxes and Tax Shifting

The modelling results directly suggest the application of a GHG tax—a charge paid on each fossil fuel, proportional to the quantity of GHG emissions emitted when it is burned.[2] However, because the carbon price was applied to all GHG emissions represented in the industry subsectors (including process and fugitive emissions), non-fuel combustion emissions were also subjected to the carbon price. The Low Carbon I scenario describes a tax of \$15/tonne CO_2e, and the Low Carbon II scenario represents a tax of \$30/tonne CO_2e. A GHG tax applied across the industry sector causes each subsector to increase or decrease its emission reduction efforts until each is facing the identical incremental cost for the next unit of reduction.

Revenues from environmental taxes can be used for different purposes: they may be part of general revenues, earmarked for specific environmental projects, redistributed as rebates or used to reduce other taxes. Each option has different costs for different members and sectors of the economy. In practice, environmental tax designs have used varying degrees of refunds, differentials in the tax rates applied to industry and households, and exemptions to address equity and competitiveness concerns.

9.2 Tradable Permits (Market-oriented Regulation)

An important area of policy innovation has been the development of market-oriented regulation, which like a GHG tax allows individual flexibility in achieving a compulsory limit or requirement. Unlike traditional command-and-control regulation, the manner of participation is at the discretion of the firm or household (whether to reduce emissions or acquire the designated technology, or pay others to do so).

The modelling results suggest an emissions cap and tradable permit system applied to all industry sectors through auctioned permits, with a cap equivalent to the emission levels reported in the alternative scenarios: 407 Mt CO_2e in 2030 in Low Carbon I, and 395 Mt CO_2e in Low Carbon II (Table 2). The tradable permit prices correspond with the shadow prices applied in those simulations (\$15/tonne CO_2e and \$30/tonne CO_2e respectively).

Market-oriented regulation can also be applied in different contexts by, for instance, specifying the desirable market outcome rather than the environmental outcome. Considerable design options also exist with emissions cap and tradable permit systems.

9.3 Subsidies

EFR can support decarbonization through the removal or redirection of existing subsidies and through the provision of new subsidies. Financial support in the form of direct grants, guaranteed or low-interest rate loans, and tax incentives can be used to directly support the greater adoption of energy-efficient technologies and long-term research and development in new energy-efficient technologies.

The alternative scenarios suggest the impact of a subsidy program that is perfectly designed to target cost-effective actions. The size of the incentive required to target the actions inherent in the model simulation is estimated by calculating the perceived private costs of the alternative scenarios (shown in Table 4). The estimates are made by calculating the

[2] *A CO_2 tax is specified per tonne of CO_2 emitted, not carbon. It can be easily translated into a carbon tax: 1 tonne of carbon corresponds to 3.67 tonnes of CO_2. A GHG tax covers other GHGs and is measured in tonnes of CO_2e.*

Table 4: Costs of Incentive (Perceived Private Cost) for 2005–2030 ($ billions)		
	Low Carbon I	**Low Carbon II**
Chemical products	0.528	1.284
Coal mining	0.026	0.104
Industrial minerals	0.047	0.194
Iron and steel	0.070	0.158
Metal smelting and refining	0.124	0.309
Mining	0.015	0.036
Other manufacturing	0.189	0.436
Petroleum crude extraction	0.101	0.093
Petroleum refining	0.003	0.026
Pulp and paper	0.203	0.608
Natural gas extraction	0.707	1.636
Total	**2.012**	**4.885**

Note: Figures are reported in 2000 $.

area under a curve that plots cumulative emission reductions against rising CO_2e shadow prices. The area under the resulting marginal cost curve, up to the shadow price of the alternative scenario, represents the compensation required to have firms undertake actions that they would not have undertaken otherwise (their perceived private cost).

These estimates do not include expenditures required to subsidize firms that would have purchased energy-efficient technologies in the baseline scenario ("free riders"). If this effect is incorporated, the subsidy cost of the program is greater. Evaluations of energy efficiency incentive programs suggest that the proportion of free riders can be significant, often in the order of 85% of program recipients. Subsidy programs can therefore require relatively large public expenditures per unit of effect. The administrative costs of program delivery and the transaction costs of firm participation, which depend significantly on the design of the specific measure, have not been considered.

Potential avenues for new subsidies include direct financial transfers (as grants or preferential- or low-interest loans) and tax incentives (e.g., the expansion of CCA 43.1 to include more energy efficiency technologies). The use of revolving loan programs has gained popularity in the commercial and institutional sector in Canada and could be applied in an industry context.

The amount spent on a subsidy will have different effects depending on program design. Financial incentives can be directed to reduce the upfront or the operating costs of energy-efficient investments, and they can be based on prescriptive or custom (performance-based) criteria. Subsidies directed at upfront capital costs recognize that the higher capital cost of energy-efficient technologies can deter investment. Measures that target upfront costs are not based on the actual performance of the investment in meeting the desired policy objective. Performance-based subsidies can be more flexible in allowing firms to meet "demonstrated" improvements in energy efficiency or carbon emission reduction.

Another factor to consider in designing subsidies is differences in how firms respond to incentive tools. Small and medium-sized enterprises, which may not have the capital required to make use of tax incentives, may find more value in loans, loan guarantees and interest rate subsidies, as well as the support provided by private sector incentive mechanisms such as energy performance contracts, leases and venture capital.

10 POLICY DESIGN CONSIDERATIONS

The choice of fiscal policy tools and the ultimate design of a policy package involve many considerations. For instance, the policy package that realizes environmental benefits in the most cost-effective way may be difficult to administer or politically unfeasible. We offer a general assessment of how the fiscal policy tools discussed above stack up against common policy design criteria.

10.1 Effectiveness in Reaching Environmental Targets

An emissions cap and tradable permit is the most effective policy tool for realizing the environmental objective, because it specifies the emission reduction. A subsidy, on the other hand, may fail to achieve sufficient reductions if it is too low or not directed properly. In both cases, poor design can weaken the intended policy impacts. Broad-based economic instruments (taxes and permit systems) are more efficient than subsidies in preventing the rebound effect, encouraging a long-term carbon emission reduction in the energy system.

10.2 Economic Effectiveness

A uniform carbon tax or an emissions cap and tradable permit system is theoretically the most efficient way to achieve a decarbonization objective, because the least expensive reductions throughout the economy are undertaken first. A subsidy may go to firms with higher reduction costs (unless it is allocated via a bidding process), and it can require large public expenditures per unit of effect due to free riders. Also, a subsidy requires that revenue be raised somewhere else in the economy, which can also produce "dead weight" losses.

10.3 Administrative Feasibility

Fiscal policy design should consider the burden on firms in either complying with a tax or market-oriented regulation, or in applying for grants and submitting tax credit claims. This burden may be particularly onerous for smaller firms. Data must be available to ensure proper program monitoring and evaluation, which should focus on impacts (i.e., carbon emission reductions) rather than processes and outputs (e.g., number of applications, program recipients).

10.4 Political Acceptability

Concern about political acceptability has limited the use of policy tools such as GHG taxes to achieve decarbonization, even in countries where they are currently applied. The use of subsidies avoids imposing costs on firms by instead enhancing the ability of energy-efficient technologies to compete. However, the government must acquire the funds from somewhere else in the economy, which has led to criticism. Tax incentives are a less visible form of public subsidy.

Industry groups have generally lobbied for voluntary and tax incentive approaches in climate change policy, arguing that new measures must be situated within an overall framework that is consistent with the broad fiscal and economic direction of the country.

10.5 Distributional and Competitiveness Impacts

With a GHG tax or emissions cap and tradable permit, the manner of participation is at the discretion of the firm. Competitiveness impacts will arise if the policy imposes different levels of costs on competing firms; this may occur if policies and regulations differ at the country or sub-national levels or if firms have different specific carbon intensities, substitution possibilities and trade levels.

Policy design is critical in minimizing distributional and competitiveness impacts. For instance, sector-specific market-oriented regulation can minimize average price increases, because only a small percentage of the market is devoted to the newer, higher-cost technologies and manufacturers will average these costs with their lower-cost, conventional technologies in determining prices.

10.6 Technological Innovation

The level of technological innovation of environmentally related technologies will be below the theoretical socially optimal level in the presence of externalities such as environmental damage. This reality provides an argument for the use of environmental taxes and market-based instruments that internalize this externality and provide a "pull" to innovation and deployment. Other policies that support innovation directly by lowering the costs of R&D (e.g., by subsidizing R&D expenditures or encouraging joint ventures) may be most valuable at the earliest stage of deployment. However, subsidies run the risk of supporting private R&D that would have taken place anyway and supporting inappropriate technologies.

11 CONCLUSIONS

The potential for industrial energy efficiency actions to contribute to the decarbonization of the energy system is complex: it depends on the degree to which technical potential can be further developed through innovation; the degree to which energy efficiency technology and habits can be adopted; the degree to which this adoption translates into reduced aggregate energy use; and the carbon intensity of conserved energy. The adoption of energy efficiency as a way to lower energy-based carbon emissions in industry is further complicated by the fact that energy efficiency is only one among a number of options that industry can use to reduce carbon-based emissions.

In developing policy recommendations in this case study, it was important to evaluate the specific focus on promoting industrial energy efficiency in the context of a broader focus on the objective of decarbonization. The alternative scenario simulations demonstrate that improved energy efficiency in industry is closely interrelated with fuel switching and other means of reducing carbon emissions, suggesting that energy efficiency should be considered among other actions in moving toward a decarbonized energy system. However, focusing on energy efficiency alone as the means of achieving decarbonization in industry may run the risk of orienting incentives and efforts in a direction that is not cost-effective.

Our evaluation of specific policy tools indicates that no one policy tool is optimal in its performance against the criteria of environmental effectiveness, economic efficiency, administrative feasibility and political acceptability. Rather, it suggests that a portfolio of policy instruments can enable a government to combine the strengths, while compensating for the weaknesses, of individual policy instruments. Such a policy package should focus on measures that would be politically acceptable today while nonetheless influencing technological innovation. Considerable potential exists to use ecological fiscal reform to create conditions under which "winners" can emerge and attract sufficient investment in order to develop and be widely adopted.

With this in mind, we recommend an emphasis on tradable permits (as part of market-oriented regulation) to drive fundamental change, with a complementary role for subsidies in supporting energy-efficient technologies. Subsidies, and tax incentives in particular, score well on public acceptability and may be effective if designed carefully and with an understanding of relative costs in different sectors and activities in the economy. Nevertheless, the impact and cost (including free-rider costs) should be realistically assessed in the design of any program. Tax incentives and direct grants should also be designed to minimize government's role in picking technologies (by being more performance-based) and to minimize the transaction costs of program participation.

There is a history of policy support for promoting energy efficiency through information and awareness programs and through subsidies for research and development. Voluntary programs have laid the groundwork for EFR policies in stimulating awareness of decarbonization opportunities; they will also provide needed complements to any new fiscal policy initiatives that are developed. There may be a role, too, for EFR to connect with traditional command-and-control policy. While fiscal policy can drive technological gains, standards that phase out the sale of inefficient equipment can serve to consolidate change.

12 LESSONS LEARNED

- While energy efficiency can be considered a path toward long-term carbon emission reductions of the energy system that can be targeted immediately through the greater diffusion of technologies already in the market, it is also important to consider how energy-efficient technologies can fit into the long-term picture through continued innovation and commercialization.
- Energy efficiency is not necessarily the most cost-effective option available for reducing carbon emissions in the industry sector. Other means include fuel switching, reducing fugitive emissions, reducing process emissions, and the capture and storage of CO_2. While a significant share of the emission reductions occurs through increased energy efficiency in the modelling results, considerable reductions also occur through other means. Focusing on energy efficiency alone as the means of achieving decarbonization in industry may run the risk of orienting incentives and efforts in a direction that is not cost-effective.
- Promoting greater energy efficiency is not a new policy objective, but it has been actively pursued in many countries over the past 30 years. Considerable experience can be gained from understanding the successes and failures of these efforts. For example, research shows a gap between the level of investment in energy efficiency that appears cost-effective and the lower level of investment that is actually occurring. This "efficiency gap" is a critical issue for this case study, particularly in estimating an alternative carbon emission scenario, as well as evaluating the economic cost and potential of fiscal policy to influence the uptake of energy-efficient technologies. This is an emerging analytical area that has only recently been incorporated into technology simulation modelling.
- Technical energy efficiency gains do not translate directly into reduced carbon emissions. The potential for industrial energy efficiency actions to contribute to long-term carbon emission reductions in the energy system is complex and is based on the following four factors.

1 *The degree to which technical potential can be further developed:* Our energy system is far from its maximum technical potential for second law efficiency, but how and when will technologies and systems be developed?

2 *The degree to which this potential can be adopted:* Mature energy-efficient technologies that appear cost-effective are available but have not transformed the market. To what degree will energy-efficient technologies, systems and practices be adopted?

3 *The degree to which this adoption translates into reduced aggregate energy use:* Lower-cost energy services from energy efficiency investments elicit a rebound effect of increased energy service demand and thus greater energy consumption.

4 *The carbon intensity of conserved energy:* Reductions in carbon emissions will depend on the carbon intensity of energy. For instance, the impact of improved electrical end-use efficiency will be considerably different depending on whether that electricity was generated by hydropower or thermal generation.

- The modelling work in the case study sought to analyze the complex relationships noted in the preceding point. Models are inevitably wrong in that they cannot possibly incorporate all information and relationships of potential importance, nor accurately depict all uncertainties.[3] Still, one can look to the modelling results to suggest the ability to harness the energy efficiency potential of current and emerging technologies, the role energy efficiency can play among other options to decarbonize industry, and the relative long-term carbon emission reduction potentials of various subsectors.
- Modelling the long-term potential for policy to increase energy efficiency adoption suggests a dynamic analysis that could consider how technological innovation and perhaps even consumer and firm preferences may be influenced by policy. This analysis was beyond the capability of the case study, but it is an emerging research direction that should be noted.
- The results of the alternative scenarios reflect the magnitude of the carbon price that was modelled; that is, a $250 price for carbon would have revealed a different reduction potential. While higher carbon prices have greater long-term carbon emission reduction potential, they tend to show diminishing returns (less additional emission reduction for each additional dollar per tonne of carbon).
- The long-run potential for energy efficiency to contribute to a decarbonized energy system will be constrained by what it will cost to produce a clean energy supply. Energy price represents an upper-bound constraint on the contribution of energy efficiency.

[3] *Energy use in the industry sector is particularly complex given the large number of end uses and interactions between energy-using and -producing processes.*

B. EXECUTIVE SUMMARY: CASE STUDY ON RENEWABLE GRID–POWER ELECTRICITY

By Marbek Resource Consultants in association with Resources for the Future

1 INTRODUCTION

This case study analyzes the role that fiscal policy can play in promoting the long-term development of Canada's renewable energy sector. Ecological fiscal reform (EFR) is recognized as a lever for promoting and, where appropriate, accelerating the use of renewable energy technologies in order to make long-term reductions in energy-based carbon emissions. This case study addresses the renewable energy sector and explores the ability or "traction" of five fiscal instruments to improve the uptake or deployment of grid-power renewable energy technologies (RETs) in Canada.

2 THE RENEWABLE ENERGY CONTEXT

The focus of the current study is on renewable energy technologies. However, the term *renewable energy technologies* is commonly used interchangeably throughout the literature with terms such as *clean energy, green power, alternative energy* and *low-impact technologies*. While there is considerable overlap in the technologies included within each group, they are not identical. In practice, these definitional differences can become quite important when dealing with the RET policy and technology eligibility issues.

After some discussion of the scope of RETs to be used in this case study, it was concluded that the Environmental Choice Program (ECP)'s EcoLogo definition provided the best available match with the overall goals of this study. This conclusion was based on consideration of two factors:

- the goal of the NRTEE's EFR initiative clearly states that "long-term carbon emissions reduction" should not result in increased loading of other pollutants; and
- an implied goal of this initiative is the promotion of innovation.

In addition, to provide a focused output, the NRTEE directed the study team to examine only those RETs that generate electrical power (as opposed to thermal technologies such as solar hot water heaters). In a similar vein, the NRTEE directed the study team to look only at those RETs that are, or will be, tied into the national electricity grid (as opposed to stand-alone systems).

Consequently, the following technologies are considered in this case study:

- wind turbines (onshore and offshore);
- low-impact hydro;
- grid-connected photovoltaics (PV);
- landfill gas (for electricity generation);
- biomass (for electricity generation);
- ocean energy, including wave and tidal power conversion technologies; and
- geothermal.

For this case study, the term RET refers to renewable grid-power technologies or grid-power RETs.

3 RENEWABLE GRID POWER IN CANADA

The study addresses three key areas with respect to grid-power RETs:

- *Current status:* What is the current status of each technology in terms of installed Canadian grid electricity generating capacity, technical maturity and costs?
- *Future potential in Canada:* What is considered the long-term upper-limit capacity for each technology and how much of this upper limit is practically achievable by 2010 and 2020?
- *Renewable power technology costs and learning trends:* What are the current and projected future costs for the targeted technologies and what are the learning trends that impact these costs?

3.1 Current Status

Table 1 shows the current total installed electricity generation capacity in Canada as well as the total share of electricity generated by each source in 2003. As illustrated, if the estimate includes large hydro and all biomass installations, then Canada's total installed base of renewable electricity generation capacity is over 70,000 MW, or about 60% of the total; virtually all of this capacity is large hydro.

Table 1: Installed Electricity Capacity and Annual Electricity Generation in Canada in 2003

Source	Installed capacity		Generation	
	MW	Share	GWh	Share
Hydro	68,100	58%	346,000	59%
Nuclear	12,600	11%	81,700	14%
Coal	16,600	14%	109,400	19%
Oil	7,500	6%	14,200	2%
Natural gas	11,000	9%	29,100	5%
Wind and biomass	2,200	2%	9,100	2%
Total	118,000	100%	589,500	100%

Note: Figures may not sum due to rounding.
Source: National Energy Board <**www.neb.gc.ca/energy/SupplyDemand/2003/index_e.htm**>.

Table 2: Current Installed Base of ECP Grid-Power RETs in Canada in 2003

Grid-power RET (EcoLogo-certifiable)	Current installed base			
	Cap factor	Capacity (MW)	Supply (GWh/yr)	Share of total grid-power RET supply
Wind (onshore)	35%	316	970	8%
Hydro*	60%	1,800	9,460	78%
Solar PV	14%	0.092	0.1	0%
Landfill gas (LFG)	90%	85	670	6%
Biomass	80%	128	900	7%
Wave	35%	0	0	0%
Tidal	35%	0	0	0%
Geothermal (large)	95%	0	0	0%
Total		2,300	12,100	100%

Notes:
1. *Installed capacities are for grid-power electricity and potentially could be EcoLogo-certifiable.*
2. *Figures may not sum due to rounding.*

**Includes many existing small hydro sites that may not be EcoLogo-certifiable.*

If the more stringent low-impact environmental criteria defined by the Environmental Choice Program (ECP) are used, then large hydro and some of the biomass facilities are excluded. (A summary of the ECP criteria is presented at the end of this appendix.) A breakdown of the estimated current (2003) installed base of EcoLogo-certifiable grid-power RETs is shown in Table 2. In 2003, these renewable energy technologies generated an estimated 12,100 GWh of electricity or about 2% of Canada's total electricity generation.

3.2 Future Potential in Canada

Technical potential refers to the long-term upper limit of total installed capacity for a given technology. For example, if wind power has a technical potential of 100,000 MW, it means that this is the maximum total generating capacity that wind turbines could supply if they were installed in every technically feasible location across the country.

Table 3: Technical Resource Potential of Grid-Power RETs in Canada

Grid-power RET (EcoLogo-certifiable)	Cap factor	Technical resource potential (total, not additional)			
		Capacity (MW)		Supply (GWh/yr)	
		Low	High	Low	High
Wind (onshore)*	35%	28,000	100,000	85,800	306,600
Low-impact hydro	60%	11,000	14,000	57,800	73,600
Solar PV	14%	9,800	100,000	12,000	122,600
Landfill gas (LFG)	90%	350	700	2,700	5,500
Biomass	80%	6,800	79,300	47,700	555,600
Wave	35%	10,100	16,100	31,000	49,400
Tidal	35%	2,500	23,500	7,700	72,100
Geothermal (large)	95%	No data	3,000	No data	25,000

**Offshore not included due to lack of independent estimates.*

Table 4: Estimated Practical Resource Potential of Grid-Power RETs in Canada

Grid-power RET (EcoLogo-certifiable)	Cap factor	Practical resource potential (total, not additional)									
		Annual growth in deployment to fill practical potential*		Capacity (MW)				Supply (GWh/yr)			
				2010		2020		2010		2020	
		Min.	Max.	Low	High	Low	High	Low	High	Low	High
Wind (onshore)	35%	25%	64%	5,000	10,000	15,000	40,000	15,300	30,700	46,000	122,600
Low-impact hydro	60%	18%	27%	5,600	9,000	9,800	no data	29,400	47,300	51,500	no data
Solar PV	14%	152%	347%	60	265	225	3,295	100	300	300	4,000
Landfill gas (LFG)	90%	10%	17%	170	no data	250	no data	1,300	no data	2,000	no data
Biomass	80%	42%	73%	1,500	2,000	no data	6,000	10,500	14,000	no data	42,000
Wave	35%	0%	infinite	0	20	4	no data	0	60	12	no data
Tidal	35%	infinite	infinite	4	300	50	2,000	12	900	200	6,100
Geothermal (large)	95%	infinite	infinite	100	600	1,500	no data	800	5,000	12,500	no data

** Assuming logarithmic growth and based on practical resource potential numbers in 2010 and 2020. The growth rates are not forecasts of a base case of renewable supply, but rather the growth required on an annual basis to satisfy the practical potential. Refer to the full case study for details on the data presented (available at <**www.nrtee-trnee.ca**>).*

Table 5: IEA Cost Reduction and Estimates for Targeted Grid-Power RETs

Grid-power RET (EcoLogo-certifiable)	Cap factor	Cost reduction				Cost estimates					
		Cost reduction every 10 yrs*		Annual cost reduction*		Levelized cost estimates (2000 cents/kWh)					
						2003		2010		2020	
		Min.	Max.	Min.	Max.	Low	High	Low	High	Low	High
Wind (onshore)	35%	25%	25%	3%	3%	3.8	15.1	3.0	11.3	1.9	8.5
Low-impact hydro	60%	0%	13%	0%	1%	2.5	18.8	2.5	16.3	2.3	15.2
Solar PV	14%	30%	50%	4%	7%	22.6	100.3	12.5	50.2	7.5	30.1
Landfill gas (LFG)	90%	0%	20%	0%	2%	2.5	18.8	2.5	15.1	2.3	13.5
Biomass	80%	0%	20%	0%	2%	2.5	18.8	2.5	15.1	2.3	13.5
Wave	35%	no data	no data	no data	no data	4.4	7.6	no data	no data	no data	no data
Tidal	35%	no data	no data	no data	no data	4.7	9.6	no data	no data	no data	no data
Geothermal (large)	95%	10%	25%	1%	3%	2.5	15.1	2.5	12.5	2.1	10.3

Note: Cost estimates are for all OECD countries; the wide range of values reflects both the diversity of conditions experienced and the high levels of uncertainty.

** Assuming logarithmic cost reductions*

Source: IEA figures cited by Martin Tampier in "Background Document for the Green Power Workshop Series, Workshop 4," Prepared for Pollution Probe and the Summerhill Group, February 2004, pp. 30–32.

Table 3 provides an indication of the estimated technical potential for each technology. In each case, a range is provided, which reflects the relatively high level of uncertainty that exists.

Practical potential is necessarily a subset of technical potential. It recognizes that the ability to capture the technical potential within any given period will be affected by factors such as grid access and capacity; zoning and permitting; technological advances; financing; market demand and acceptance; and design, manufacturing and installation capacity.[1]

Table 4 provides the estimated practical potential. The estimates were developed based on broad consideration of a number of factors, complemented by consultations with industry and government personnel. As with all figures, the estimates are given in ranges to reflect the high level of uncertainty.

3.3 Renewable Energy Technology Costs and Learning Trends

A summary of the expected levelized costs for each of the targeted grid-power RETs is presented in Table 5. To ensure consistency among the technologies, all cost data are derived from recent estimates provided by the International Energy Agency (IEA). And, to reflect the cost uncertainties involved, the data are expressed as a range. Table 5 also provides a summary of IEA estimates of forecast cost reductions for each technology over the study period. The forecast cost reductions are based on learning theory. This theory, which is well supported by empirical data, defines the link between the increase in installed capacity and the rate of cost decrease.

The practical potential and levelized costs are used in modelling the fiscal instruments. The results of the modelling are discussed below in Section 4.

[1] *It is widely recognized that issues related to grid access, grid capacity and the costs of grid extension will be particularly influential in determining the amount of grid-power RETs that can be practically developed. While these issues are beginning to be addressed in some regions, they are far from being resolved at this time. Further consideration of these issues is well beyond the scope of this case study.*

Table 6: Projected Share of Grid-Power RETs and Fossil Fuel Generation in 2010

Electricity-generating technology	Projected electricity generation in 2010 (GWh)	Share of total generation
Grid-power RETs (as *included* in this study)	31,000*	5%
Fossil fuels (coal, gas, oil as *included* in this study)	198,000**	32%
Other (nuclear and renewables *excluded* from this study)	394,000	63%
Total	623,000**	100%

2003. National Energy Board,* Canada's Energy Future: Scenarios for Supply and Demand to 2025 *(Techno-Vert Scenario)* *<www.neb-one.gc.ca/energy/SupplyDemand/2003/index_e.htm>***.

1999. Natural Resources Canada,* Canada's Emissions Outlook: An Update ***<www.nrcan.gc.ca/es/ceo/update.htm>.

Finally, the share of total electricity generation in Canada in 2010 covered under this case study is presented in Table 6. As can be seen, the case study is concerned only with 37% of electrical generation in Canada in 2010.

4 ECONOMIC AND POLICY ANALYSIS—APPLICATION TO CANADA

This section presents the modelling results for each of the fiscal instruments. The discussion is organized and presented as follows:

- Overview of the fiscal instruments that are assessed;
- Overview of the Resources for the Future (RFF) model used to assess the instruments;
- Summary of results (including a road map for understanding the results);
- Detailed discussion of the base case and each fiscal instrument; and
- Sensitivity analysis results.

4.1 Fiscal Instruments Assessed

In collaboration with the NRTEE, a base case and five fiscal instruments were selected and modelled. The five instruments are:

1 *An emissions price*, which is analogous to an emissions trading permit system or a carbon tax. Under this scenario, a shadow price is placed on carbon equivalent to \$10/tonne CO_2. This shadow price is equivalent to the cost of an emissions trading permit or the tax rate on carbon. The emissions price is applied uniformly across all fossil fuel generation in Canada in 2010.

2 *A renewable portfolio standard (RPS)*, which requires utilities to buy green certificates, or the equivalent, so that renewable generation increases relative to fossil fuel generation. The model compares renewable generation attributable to an RPS with generation from fossil fuels (i.e., not all electrical generation). Constraints are not placed on technologies or regional shares of the total RPS. Instead, the prevailing electricity price determines the type of technology used to generate electricity.

3 *A renewable generation subsidy (RGS)*, which is modelled as a direct subsidy from government to grid-power RET producers on a per-kWh basis. In practice, a subsidy could include any fiscal instrument that lowers the cost of production for producers, such as a direct production subsidy or a capital cost allowance.

4 *A combination of RPS and generation subsidy*, modelled in tandem. We let the RPS be the dominant policy, since the standard is meaningless if the subsidy encourages more renewable generation than required. A notable feature of this combination is that the price of the green certificates is offset in part by the subsidy, in contrast to the situation where the instruments are implemented in isolation. This outcome will therefore trigger some redistribution of costs.

5 *An R&D subsidy*, which is a program to reduce the future cost of renewable generation. As such, the instrument can be anticipated to have a greater impact in future periods. The model identifies the annual increase in renewable energy R&D required to achieve the emission reduction target.

In the model, the levels of the instruments, such as an RPS target (i.e., 10% of generation from renewables) or a subsidy level (i.e., $0.01 per kWh), are solved endogenously. Each instrument is required to achieve a common emission reduction (or policy target), and then the model indicates the policy level that would achieve the carbon target.

4.2 Overview of RFF Renewable Energy Uptake Model

The RFF unified analytical model was employed to assess the impacts of the fiscal instruments on reducing greenhouse gas emissions, as well as the development and diffusion of renewable energy. This model was developed and tested for the U.S. Environmental Protection Agency to assess the preferred fiscal instruments for promoting renewable energy technologies. The analytical model includes two sectors, one emitting and one non-emitting, and both are assumed to be perfectly competitive and supplying an identical product, electricity. Fossil fuel production is the marginal technology, setting the overall market price; thus, to the extent that renewable energy is competitive, it displaces fossil fuel generation in future policy periods.

The model has two stages: a short-term stage covering 2010 to 2015, and a longer-term stage covering 2015 to 2030. Electricity generation, consumption and emissions occur in both, while investment in knowledge takes place in the first stage, followed by technological change and innovation that lowers the cost of renewable generation in the second.

The carbon-emitting sector of the electrical generation industry relies on fossil fuels. These are a mature technology, and the productivity improvements available through new R&D are assumed to be negligible.[2] The marginal production costs of the sector are assumed to be constant with respect to output, increasing with reductions in emission intensity. The representative firm chooses an emission intensity to equate the additional costs of abatement to the price of emissions. The full marginal costs of generation then include both the marginal production costs, given the emission intensity choice, and any effective tax, such as the price of the emissions or carbon embodied in an extra unit of output, or the cost of green certificates under an RPS. As long as fossil fuel generation occurs, the competitive market price must equal the sum of these marginal costs.

Another sector of the industry generates without emissions by using renewable resources. Unlike the fossil supply curve, which is flat and set at the long-term marginal cost of electricity, the renewable supply curve slopes upward, reflecting marginal production costs that increase with output. Because renewables are a young technology, the costs of renewable power shift down over time as the knowledge stock increases. There are two ways to increase the knowledge stock: through investments in R&D and "learning by doing," which is a function of total output during the first stage in the model. The representative renewable energy firm chooses output in each stage as well as R&D investment to maximize profits. In the first stage, it produces until the marginal cost of production equals the value it receives from additional output, including the competitive market price, any production subsidy, and the contribution of such output to future cost reduction through learning by doing. The firm also invests in research until the discounted returns from R&D equal investment costs on the margin.

Since we target equivalent emission reductions for each of the fiscal instruments, we hold the environmental effects constant across the policy scenarios. While we calculate the costs of achieving emission targets in this case study, the benefits of the fiscal instruments are not estimated. The fiscal instruments through their displacement of fossil fuel can be expected to trigger a number of environmental and economic benefits, including:

- improved ambient air quality and reduced carbon in the atmosphere;
- avoided ambient air quality impacts on sensitive ecosystem and health receptors and the associated economic value of the avoided damages; and
- climate change mitigation benefits such as avoided ecosystem, health and economic damages stemming from extreme weather events, temperature changes and sea-level rise and the associated economic value of the avoided damages.

While they are important in assessing the desirability of the fiscal instruments from a social perspective, the benefits are in a sense fixed in the case study because of the stipulation of a common emission target that all instruments achieve.

[2] *While it is not strictly true that fossil fuel technologies will experience no further technological advance, incorporation of a positive but slower relative rate of advance in fossil fuels would complicate the analysis without adding substantial additional insights.*

4.3 Summary Results

When reviewing the summary results, it is useful to understand that the outcomes are a function of how each instrument influences the energy market. In the model, outcomes differ due to changes in three decarbonization drivers: renewable power penetration, the carbon intensity of fossil fuel generation and total electricity demand.

The outcomes listed in Table 7 can be traced back to an instrument's ability to affect one or all of the three decarbonization drivers in the electricity market. Generally speaking, an instrument will be more economically efficient if it targets all of these three drivers. For purposes of comparison, the base case indicators are provided to allow for comparison with the policy scenarios. In the no-policy base case, our model predicts that renewable energy generation will increase from 13% to 17% of included generation in the second stage, which corresponds to a 5% emission reduction. Subsequent policy scenarios will target a 12% reduction overall from the combined emissions in the two stages of the no-policy case.

The numbered items in the first column of Table 7 are defined as follows:

1 *Policy level for 12% emission reduction:* This row provides an estimate of the size of the fiscal instrument required to achieve the carbon reduction target:

- For the emissions price, a tax of $10/tonne CO_2 would achieve the 12% reduction in total carbon emissions from the base case.
- For the RPS, a portfolio standard of 24% would achieve the 12% carbon reduction. This 24% is the final share of renewable power generation in the generation covered by this case study—which consists of both renewable and fossil fuel generation but excludes major hydro and nuclear.
- For the RGS, a value of about $0.006/kWh achieves the policy objective of a 12% carbon reduction.
- When combined with a subsidy of $0.002, the RPS needs to be set at a slightly higher target of 24.2%.
- For the R&D subsidy, a program that increases R&D spending by 61% annually above the base-case R&D levels would achieve the target.

2 *Electricity price ($/kWh):* This row indicates the impact of the fiscal measure on the annual price of electricity in the first and second stages (2015 and 2030, respectively).

3 *Carbon emissions (Mt):* Carbon emissions are presented as annual estimates in megatonnes of CO_2 for the last years in the first and second stages. Carbon reductions are influenced by the three drivers in the following ways:

- Renewable power penetration displaces fossil generation when an instrument reduces renewable production costs relative to fossil generation costs.
- The carbon intensity of fossil fuel generation is reduced when carbon is priced in the fossil sector (i.e., abatement from natural gas generation that displaces coal).
- An increase in the electricity price reduces total electricity demand, which displaces output from fossil fuels.

For each scenario, carbon emissions are estimated by multiplying the "on margin" emission intensity of fossil fuel by the quantity of fossil fuel supplied.

4 *Renewable output (MWh 10^11):* This row indicates the output of renewable generation in the two stages. Renewable output is a function of production cost differentials between renewables and fossil fuels. Instruments affect the cost differential through subsidizing renewable generation, inducing renewable production cost decreases through innovation, and/or taxing fossil fuel production. Instruments that promote innovation reduce renewable costs and carbon emissions in the second stage.

5 *Fossil output (MWh 10^11):* As with renewable output, fossil fuel output is altered by the instruments through price changes in production costs. Fossil output is also altered by total demand reductions, which occur when an instrument increases the price of electricity.

6 *Total electricity output (MWh 10^11):* Total generation includes fossil and renewable output; changes indicate that the instrument influences final demand through electricity price increases.

7 *Renewable R&D ($M):* Expenditures are expressed in millions of dollars annually in total R&D spending by the public and private sectors.

8 *Additional renewable cost reduction:* This row indicates the percent reduction in the cost of the renewable supply below the base case.

9 △*Consumer surplus ($M):* This is the net consumer cost of the instrument measured as the change in the present value of the total cost to consumers for both stages. The consumer surplus is negative and is present when the instrument increases the price of electricity.

10 △ *Producer surplus ($M):* This is the change in the measure of total profit in the renewable sector for both stages. Renewable sector profits increase when the instrument raises the price received by renewable generation, either by a

Table 7: Summary of Modelling Results for Fiscal Instruments (2000 $)

	Base case	Emissions price	Renewable portfolio standard	Renewable generation subsidy	Combination RPS and RGS	Renewable research subsidy
1. Policy level for 12% emission reduction		$10/t CO_2	24% of generation in case*	$0.006	RPS=24.21% RGS=$0.002	61%
2. Electricity price (in $/kWh)						
1st stage	$0.092	$0.097	$0.095	$0.092	$0.095	$0.092
2nd stage	$0.092	$0.097	$0.093	$0.092	$0.092	$0.092
3. Carbon emissions (Mt)						
1st stage	106	98.10	91.00	98.97	91.08	104.00
2nd stage	101	84.40	91.90	83.50	91.95	77.40
4. Renewable output (MWh 10^11)						
1st stage	0.29	0.40	0.54	0.42	0.55	0.31
2nd stage	0.38	0.66	0.55	0.72	0.55	0.83
5. Fossil output (MWh 10^11)						
1st stage	2.00	1.85	1.71	1.87	1.72	1.98
2nd stage	1.91	1.59	1.73	1.57	1.73	1.46
6. Total electricity output (MWh 10^11)						
1st stage	2.29	2.25	2.26	2.29	2.27	2.29
2nd stage	2.29	2.25	2.28	2.29	2.29	2.29
7. Renewable R&D ($M)	$129	$450	$320	$533	$325	$1,576
8. Additional renewable cost reduction	0%	15%	13%	16%	13%	26%
9. △Consumer surplus ($M)	$0	($11,690)	($4,521)	$0	($3,533)	$0
10.△Producer surplus ($M)	$0	$2, 215	$3,480	$2,846	$3,547	$1,590
11.△Transfers ($M)	$0	$8,896	$0	($3,557)	($1,072)	($3,890)
12.△Welfare—no benefits measured ($M) (9+10+11=12)	**$0**	**($579)**	**($1,041)**	**($711)**	**($1,058)**	**($2,300)**
13.△Welfare relative to emissions price	—	1.00	1.80	1.23	1.83	3.97

Figures may not sum due to rounding.

** This is 9% of all annual Canadian generation.*

Source: Marbek Resource Consultants and Resources for the Future.

subsidy or a tax on fossil generation. When this occurs, profits can be made if some renewable production costs are below the instrument electricity price in the scenario.

11 △ *Transfers ($M):* This is the change in government revenues, where a positive number is revenue and a negative one is a disbursement. Again, the estimate is a total cost for both stages.

12 △ *Welfare (excluding environmental benefits) ($M):* This is the change in social welfare and is a proxy for the societal cost of the instrument. It is the sum of consumer and producer surpluses and transfers. It is an important metric, since all scenarios achieve the same carbon reduction target, yet have differing social costs.

13 △ *Welfare relative to emissions price:* This is simply a ratio that indicates the welfare costs of each scenario compared with the emissions price scenario. The emissions price is selected as the basis for comparison since it has the lowest welfare cost.

4.4 Detailed Results by Instrument

4.4.1 Base Case

The base case provides the reference from which the percentage changes are estimated in Table 7. Renewable power penetration is forecast based on the relative costs of fossil fuel and renewable production. The baseline penetration of renewables increases over time, reflecting decreasing renewable power production costs due to innovation.

Total electricity output remains fixed in both periods in the base case[3], and thus increased penetration of renewables decreases the carbon intensity of overall generation. This reduction is captured as a decrease in carbon emissions over time, from an annual level of 106 Mt in the first stage to 101 Mt in the second stage.

4.4.2 Emissions Price

An emissions price works to reduce emissions by reflecting their cost, either in environmental damage (as with an environmental levy) or opportunity cost elsewhere in the economy (as with an emissions cap-and-trade system). This price sends a signal to everyone in the energy market to conserve carbon.

Fossil energy producers can reduce costs by boosting efficiency or switching to lower-carbon fuels and processes. Since the price of fossil energy will then incorporate the cost of the carbon associated with that form of generation, the price of electricity will also rise, creating two effects. First, it signals *consumers* to conserve and take advantage of opportunities to reduce their demand by, for example, adopting more energy-efficient appliances. Second, it increases the price received by *renewable energy producers*, encouraging production and investment in non-emitting generation technologies. From a distributional perspective:

1 Consumers incur the highest electricity price increase and consumer surplus loss under the emissions price. Since consumers are also taxpayers, the use of the revenues (i.e., transfers) is important in assessing the net effect on households.

2 For renewable energy producers, the emissions price has a modest but significant impact on renewable output, production cost decreases and producer surplus. The impact is also relatively consistent across stages.

3 For fossil fuel electricity generators, the emissions price is the only policy with an incentive to reduce emission intensity. Although profits for the fossil sector are not modelled—rather, they are assumed to be driven to zero in the long run by the market—the potential costs to the fossil sector under an emissions price would depend on its ability to pass along the production cost increases due to carbon abatement (i.e., coal to gas) to consumers, as well as any windfall gains from permit allocation.

4 For government, significant transfers or revenue could be raised under the emissions price, either through a tax-based system that collects revenue or through the allocation or auctioning of carbon permits under an emissions trading system. This is the only modelled scenario where significant government revenue potential exists. It also represents the value of the emissions rents, which are available to be allocated to consumers, generators and their shareholders, funds for transition assistance, or taxpayers more generally.

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[3] *It is recognized that electrical production is increasing over time, but total electricity output in the model is fixed in both stages so that the demand and supply responses of the policies can be better understood.*

5 For society as a whole, welfare costs are lowest with the emissions price, making it the preferred option. One negative consequence of this scenario, not incorporated into this single-sector analysis, is that the increase in electricity prices could lead to economy-wide competitiveness. Reserving some permits for allocation to trade-exposed sectors that are electricity-intensive could mitigate these impacts.

6 An advantage of a cap-and-trade system is certainty in reaching the carbon target; however, uncertainty will then manifest itself in the price. All the other policies face challenges in setting a policy level that would achieve the emissions target with certainty.

4.4.3 Renewable Portfolio Standard

The renewable portfolio standard requires total electricity generation to be based on a minimum share of renewable sources. Although such a market share requirement can be implemented in several ways—quota obligations for retailers, green certificates for fossil generators—the general effect is the same. As long as the market would not meet the requirement on its own, renewable energy producers receive a price premium (the value of the green certificates they generate), while fossil energy producers receive a negative one (the cost of the green certificates they must buy in proportion to their generation). Moreover, the total subsidy to renewable energy producers is equal to the total effective tax paid by fossil energy generators, so no net revenues are raised or lost by the government.

Since the RPS does not distinguish among fossil generation technologies, there is no incentive to reduce emission intensity in that sector. Consumer prices rise due to the effective tax on fossil energy to fund the renewable subsidy (i.e., buy green certificates), but not as much as with the emissions price instrument. Although under the RPS more renewable energy is generated than under the emissions price, the timing of that generation is changed. Normally, when prices are fixed, as costs fall over time renewable generation expands. However, the RPS fixes the share of renewables in both periods, and over time this becomes easier to meet; hence, the effective tax and subsidy fall (i.e., the price of green certificates falls), while total electricity generation increases with the reduced price (the market price is equal to the price of electricity plus the price of green certificates, which fall due to innovation over time; therefore, electricity prices fall and final demand increases).

Renewables then get a bigger boost in the first period and less in the second. The larger current subsidy may enable more learning by doing; however, recognizing that the support will fall in the future, investment in cost-reducing R&D may be smaller (this result is borne out in our scenarios). From a distributional perspective:

1 Consumers experience some electricity price increase and consumer surplus loss under the RPS. This effect is about 80% as large as with the emissions price in the first stage, and nearly negligible in the second. The electricity price rise is due to the purchase of renewable power in the form of green certificates (or the equivalent) by the fossil sector. Since renewables become cheaper with technical innovation, the cost of green certificates (and thereby consumer prices) is higher in the first stage but lower in the second as the cost of renewable supply decreases.

2 For renewable energy producers, the RPS induces a high uniform penetration through both periods, which is not surprising since the RPS fixes the share of renewables in both periods. Producer profits are also high, indicating the potential for the sector to benefit under an RPS. While there is certainty in terms of market share for the renewable sector, there is less stability in prices and less flexibility in the timing of renewable energy generation. Furthermore, the fact that the implicit subsidy falls over time with cost decreases means that incentives for innovation may be muted—indeed, our model predicts less R&D spending than under the emissions price. Although more renewable generation is needed overall, so much is done in the first stage that the return on lowering costs in the second stage is reduced, both because of the lower second-stage output (relative to the other policy scenarios) and also possibly because of greater learning by doing in the first stage, which can substitute for R&D.

3 For fossil fuel generators, output shares remain steady in the two periods, with lower output in the first stage and higher output in the second compared with other scenarios. In other words, cost reductions in renewables allow for fossil sector expansion. Still, short-term transitional costs could be expected to be greater under the RPS than in other scenarios. Actual potential costs to the fossil sector under an RPS will be higher if it is not fully able to pass along the costs of green certificates to consumers.

4 For government, the RPS has a neutral impact, with no revenue and no program disbursements.

5 For society as a whole, the welfare costs are greater than with the emissions price and generation subsidy, but lower than with the combination and R&D subsidy. This ranking does not necessarily hold in all circumstances but rather depends on the particular trade-off between the extra costs of encouraging more effort upfront and the inefficiencies of not giving consumers incentives to conserve. Indeed, if one coped with the former problem by optimally designing the RPS requirement to increase over time, the RPS could be made to dominate the subsidy always, due to the presence of the modest conservation incentive.

6 Looking beyond the electricity sector, the increase in electricity prices risks causing some economy-wide competitiveness impacts such as decreased productivity or reduced exports, but these effects will be less severe than with the emissions price, particularly in the second stage.

4.4.4 Renewable Generation Subsidy

This fiscal instrument includes a range of possible policies that subsidize renewable energy generation (e.g., tax credits or direct subsidies) to encourage the expansion of carbon-free generation; however, they do nothing to encourage conservation or reduce the emission intensity of fossil generators. As well, there is no impact on the price of electricity, and thus consumers are not encouraged to reduce demand and therefore carbon emissions. Hence, much more effort must be expended on higher-priced renewables to displace fossil generation and meet the carbon reduction target. From a distributional perspective:

1 Consumer prices are not affected in the subsidy scenario, since all of the reductions are supplied through lower renewable energy costs, which do not affect the fossil fuel sector directly. Consumers would be indirectly affected since it is their tax revenue that funds some portion of the subsidy transferred to the renewable sector.

2 For renewable energy producers, the generation subsidy has the largest impact on profits, since they must be encouraged to displace more fossil output than in the preceding scenarios. Ongoing innovation is stimulated by the greater scope for reducing production costs at the higher output levels induced by the price premium.

3 For fossil fuel generators, the impact of the generation subsidy on fossil output is similar to that of the emissions price, since the additional renewable energy generation is partly offset by additional demand. The decline in output is slightly larger in the second stage, due to the more dramatic increase in the competitiveness of renewables from innovation. It might seem surprising that fossil output may be lower with the subsidy than with the emissions price, since the electricity price increase is absent. However, since the fossil sector lacks an opportunity to adjust its own emissions, the full burden of reductions falls on renewables to displace fossil output.

4 For government, the subsidy required to achieve the emission reduction target is a significant disbursement.

5 For society as a whole, welfare costs are greater than with the emissions price. With respect to reaching the emissions target, the renewable subsidy is likely to suffer from greater uncertainty than the preceding policies. Although not modelled, the reasoning is twofold:

- First, the uncertainty over the scope and speed of cost reductions in renewables is likely to be greater than uncertainty surrounding the costs of abatement in the fossil sector or the extent of conservation by consumers.
- Second, even if all cost uncertainties were similar, the reliance on only one method of emission reductions raises overall uncertainty. In a broader scenario, if innovation does not lower renewable energy production costs significantly, one could engage in relatively more emission abatement or conservation, whichever turns out to have the lower costs.

The renewable subsidy alone has more uncertainty regarding how much emissions will be reduced. It also has more uncertainty regarding the revenue requirement. If costs fall more than expected, a high subsidy would induce an oversupply relative to the carbon target, reflecting additional efficiency loss, as well as lost public funds. If costs do not fall as expected, either the emissions targets will not be met (and some public funds will be saved) or the subsidy must be increased even more to meet them, requiring greater-than-expected outlays.

4.4.5 A Combination of RPS and RGS

Renewable energy is often addressed by a combination of policies. Reasons include the overlapping jurisdictions of the federal, provincial and local governments and, perhaps, a desire for diversification. We have estimated the effects of placing a portfolio standard and a renewable production subsidy in place simultaneously. The key result is that the subsidy weakens the effect of the portfolio standard and raises costs slightly.

With both policies, the fossil fuel producer must still purchase green certificates for every unit of electricity generated. For the renewable energy producer, there are now two subsidies—the value of a green certificate and the direct subsidy. Since the direct subsidy boosts renewable supply, the equilibrium price of a green certificate does not need to be as high to reach the portfolio standard (compared with the RPS implemented in isolation). Consequently, when the policy target is a portfolio share, a direct subsidy to renewables primarily offsets the burden to fossil producers and consumers instead.

Since we assume the RPS is the driving policy instrument in our combination scenario, the distributional effects are quite similar to those of the RPS alone. The slight differences are as follows:

1. Consumer prices are slightly lower. Despite the additional electricity demand, emissions are also lower in the first stage—this is because the standard must be raised to offset the loss of conservation incentive, leading to even more reduction in the first stage and less in the second.

2. Renewable energy production is 0.5% higher and R&D spending is 1.5% higher.

3. For fossil fuel generators, output is nearly unchanged relative to the portfolio standard alone. This is because, even though the fossil fuel producer has to buy more certificates, the cost of these certificates is lower because the subsidy has generated a greater supply of them.

4. Perhaps the most telling effect is that the government in this combination scenario spends just over $1 billion on a subsidy that has little or no effect on behaviour, given the presence of the RPS.

5. From society's perspective, to the extent the subsidy does affect behaviour, it tends to lower prices and raise overall welfare costs. The weaker conservation incentive and the additional frontloading of emission reduction efforts (through increases in the RPS) lead to an increase in welfare costs, from 1.80 to 1.83 times that of the emissions price.

4.4.6 Renewable Research Subsidy

The renewable research subsidy uses current investments in reducing costs to increase future renewable energy production. Since it does not change any price incentives for demand or production, or change current costs, all the burden of emission reductions is placed on future displacement of fossil by renewable energy generation. Furthermore, given the lack of future production incentives, the required cost reductions are large and the required investments even larger. The ability of an R&D subsidy alone to deliver all of this is clearly an area of uncertainty. From a distributional perspective:

1. Consumers do not experience electricity price increases and consumer surplus losses under the R&D subsidy. As with the generation subsidy, they indirectly contribute to the renewable sector through tax contributions to fund the R&D subsidy.

2. For renewable energy producers, the R&D subsidy induces the highest penetration in the second stage. This penetration is driven exclusively by innovation and cost decreases from renewable production. An important caveat is the degree to which Canadian learning by doing and R&D can drive cost decreases in renewables. While such production cost decreases are observed in Canada and internationally, it is not certain that Canadian R&D alone can reduce costs sufficiently to achieve the high levels of renewable power penetration predicted in this scenario. As a general observation, innovation in renewable production occurs internationally and is imported into Canada. This uncertainty regarding the ability of domestic R&D subsidies to achieve the penetration predicted in the model only reinforces the conclusion that this policy is a much more costly method for achieving emission reductions.

3 For fossil fuel generators, the R&D subsidy does not affect electricity price, but it does significantly reduce fossil output in the second stage. Although not modelled, costs associated with stranded assets or variable costs due to lower capacity utilization could arise. But transaction costs associated with decreased fossil demand are likely lower in this scenario, since a majority of reductions occur in the second stage. Thus, the transition period for the fossil sector to adjust to decreased demand is long and there is potential for costs to be minimized.

4 For government, the R&D subsidy requires the largest disbursement of the instruments. That said, promoting innovation is a government policy, and therefore R&D programs are generally part of a desirable policy approach to long-term carbon emission reductions. However, given the longer-term nature of the reductions associated with R&D, a government faced with a carbon reduction target would likely not achieve significant reductions in the short term under an R&D program.

5 From society's perspective, welfare costs are greatest under the R&D subsidy. Another negative consequence of this scenario is uncertainty. As with the renewable generation subsidy, the uncertainty of renewable cost reductions makes this a relatively risky policy for promoting carbon reductions—all the more so, since in the absence of cost reductions, there is no incentive for additional uptake of renewables in either stage. Given the uncertainty over innovation success in general and the impact of domestic efforts in particular, it is highly uncertain that a domestic R&D program alone could achieve a significant carbon reduction target through renewable generation. Instead, an R&D subsidy can be seen as a complementary instrument that could be used to achieve longer-term societal goals such as promoting innovation.

4.5 Sensitivity Analysis

To further test the robustness of the results presented in the preceding discussion, a sensitivity analysis was conducted for the following factors:

1 *An increase in the baseline price of electricity:* The sensitivity analysis shows that the differential between the renewables price and the electricity price is an important determinant of the size of the welfare cost. As well, this differential affects the desirability of an RPS compared with a renewable generation subsidy. These results can also be expected when the price of renewables changes; that is, a decrease in the price of renewables would produce results that are directionally similar to an increase in the electricity price.

2 *An increase in the baseline price of natural gas:* The sensitivity results indicate that increasing natural gas prices have a minimal impact on the outcomes with respect to the reference case. As discussed in the previous scenario, however, increasing gas prices could increase the price of electricity, and the response would be similar to an electricity price increase.

The sensitivity testing concludes that the results are robust to changing key variable assumptions. Indeed, our core observation holds: the economic efficiency and environmental effectiveness of the EFR instruments are linked to their ability to influence the entire electricity market and the three decarbonizing drivers in particular. As a general rule, an EFR instrument will be more efficient and effective if it signals to multiple agents in the electricity market that carbon is more expensive: fossil producers will reduce their emission intensity; renewable power producers will supply more output when the price differential between renewable and fossil generation decreases; and consumers will take measures to conserve electricity, reduce demand and displace fossil output. This finding holds under multiple input assumptions and explains why an emissions price is preferable to either an RPS or RGS. A good example of the increased risk in using a single instrument is highlighted by the R&D instrument scenario, where the emission reduction is entirely dependent on the ability of R&D investments to reduce renewable energy costs through innovation. While cost reductions can be expected from R&D spending, the scope and scale of the cost reductions are questionable, thus increasing the overall uncertainty in the instrument.

5 LESSONS LEARNED

Unquestionably, EFR instruments have traction with respect to decarbonizing electricity and increasing the uptake of renewables. Our results indicate that a wide range of EFR instruments can be used to decarbonize the economy and increase the installed capacity of renewable technologies. Important lessons learned include the following:

1 *Instruments are most economically efficient and environmentally effective if they are comprehensively applied and target all actors in a market:* Each EFR instrument outlined in the case study has different impacts on the three principal elements of an electricity market:

- renewable power penetration, which is how much of total Canadian electricity generation is supplied by renewable power;
- the carbon intensity of fossil fuel generation, which is how much carbon a unit of electricity generated by fossil fuels contains. Carbon intensity can be reduced by using natural gas instead of coal, for example; and
- total electricity demand, where consumers can reduce their electricity demand by practising energy conservation.

The success of one or more EFR instruments will rest on their ability to continue to influence the entire electricity market and these three decarbonization drivers in particular. Of the EFR options presented:

- the emissions price is the most effective at influencing the market and its drivers. It provides the means for attenuating negative effects;
- the renewable portfolio standard ensures a high penetration rate for renewables in the short and longer terms but only marginally influences consumer behaviour;
- the renewable generation subsidy ensures an even higher penetration rate for renewables, but it does not influence consumer behaviour or encourage electricity producers to work toward lower, permanent carbon emission intensities;
- a mix of RPS and RGS produces a slightly better result than the RPS or the RGS alone—however, the welfare cost is very high due to significant government disbursements to achieve the result; and
- the renewable research subsidy has considerable positive impact on the renewable sector, but it does nothing to influence the other drivers or assure market penetration in the long run.

2 *A small portion of renewable energy technologies are competitive with fossil fuel generation now:* Given that some renewables are competitive now, EFR instruments can be expected to increase the installed capacity of renewables in Canada to some degree. However, ambitious carbon reductions will require binding EFR instruments that close the price gap between fossil generation and renewable technologies.

3 *Innovation reduces renewable energy costs:* Innovation in renewable technologies will primarily come from international sources and ultimately reduce renewable supply costs in Canada. Thus the installed capacity of renewables in Canada can be expected to grow over time in the absence of EFR polices.

4 *Renewables are an immature technology with uncertain costs and practical potential:* Any modelling effort that targets renewables is faced with significant uncertainty in forecasting price and practical potential. This uncertainty is unavoidable, and the modelling should address uncertainty.

5 *Renewables are at different stages of technological development:* This implies that some instruments, such as an RPS, can be effective in deploying renewable technologies that are commercially viable in the short term, whereas R&D subsidies are better suited to targeting technologies still in the developmental stage.

6 *The temporal impacts of the EFR instruments differ:* The path of emission reductions and renewable power penetration can vary significantly between instruments. Instruments that require reductions from renewables in the short term will necessarily be more costly than instruments that target longer-term reductions. This effect occurs when the price of renewable supply drops over time.

7 *The distributional consequences of the EFR instruments differ significantly:* Comparing overall instrument costs can mask the distributional consequences of an EFR instrument. Table 8 provides an overview of the distributional consequences of the instruments included in this case study.

Table 8: Summary of Distributional Results						
	I. Base case	**II. Emissions price**	**III. Renewable portfolio standard**	**IV. Renewable generation subsidy**	**V. Combination RPS and RGS**	**VI. Renewable research subsidy**
To achieve a **12% carbon emission reduction** target from 2010 to 2030, you would see...	(No attempt to reach target)	Emitters pay $10 for each tonne of CO_2	Renewables have a **24%** share of case study generation—9% of annual total Canadian generation	Government subsidy of **$0.006** for each kWh generated by renewables	An RPS at **24.21%** and an RGS at **$0.002**	The public and private sectors increase their R&D spending by **61%**
Impacts on electricity generation	Renewables gain some market share; carbon is reduced by 5%	Renewables penetrate slightly more quickly than in I; electricity producers work hardest on reducing carbon emissions	A greater penetration of renewables than in II; costly for electricity producers at first but costs fall over time	A greater penetration of renewables than in II; not a driver of lower emissions intensity (= higher efficiency)	Slightly more renewables in the mix; fossil fuel–generated output remains unchanged	High penetration of renewables near end of time frame only
Impacts on consumers	Status quo	Electricity prices rise the most; conservation emphasized; negative impacts on some sectors	Overall electricity prices are lower than in II, but rise and then fall; conservation not emphasized	Electricity prices remain the same; conservation not emphasized	Electricity prices slightly lower than in IV; conservation not emphasized	Electricity prices remain unchanged; conservation not emphasized
Impacts on government	Status quo	Government revenues raised (as government collects on emissions price); redistribution to affected sectors is possible	No government revenues raised, lost or transferred	Government makes significant disbursements to fund the subsidy	Government makes disbursements ($1 billion) to fund the subsidy	Government makes significant disbursements to fund R&D in renewables
Impacts on the renewable sector	Status quo; some continued penetration	Output up; production cost down; some profit; R&D levels high	Output up more than in II; slightly more profit than in II; but less R&D is done	Greater profits as more production lowers costs; high investment in R&D	Output slightly higher; R&D also higher	Highest potential penetration near end of time frame with high R&D

Table 8 continued on next page

Table 8: Summary of Distributional Results (cont'd)

	I. Base case	II. Emissions price	III. Renewable portfolio standard	IV. Renewable generation subsidy	V. Combination RPS and RGS	VI. Renewable research subsidy
Impacts on Canadian societal welfare*	Status quo	Overall lowest welfare costs of the five options	Greater welfare costs than in II and lower than in IV	Second highest welfare costs	Welfare costs slightly lower than in IV	Highest welfare costs
Level of uncertainty in reaching target	Target is not achieved	Low; all long-term carbon emission reduction drivers are acted on to work toward target	Medium; only two long-term carbon emission reduction drivers affected	Medium–high; only one long-term carbon emission reduction driver affected	Medium; only two long-term carbon emission reduction drivers affected	High due to reliance on one long-term carbon emission reduction driver (penetration not assured)

** = adding together (1) costs to consumers and (2) losses/profits of electricity producers (both renewable and fossil fuel) and (3) net government revenues, but* excluding *environmental costs/benefits (e.g., the costs of adapting to climate change are not included here).*

8 *Program design and detail matter, but they are not captured in the analysis:* We assessed the EFR instruments at a high level but observe that enabling conditions significantly affect outcomes. Enabling conditions such as local permitting, regulations, transmission distance and access to the grid all affect the technical and economic feasibility of the renewable supply and ultimately the predicted results of the EFR instruments. Simply assuming that the EFR instruments will achieve cost-effective carbon reductions without a clear understanding of the enabling conditions for and barriers to the uptake of renewables is highly risky policy.

9 *Policy certainty and durability over the longer term are important:* Policy certainty or the durability of the EFR instrument over the longer term is an important driver of renewable uptake. This is particularly the case for renewables where startup capital costs are high and investment returns must be established prior to project implementation.

ENVIRONMENTAL CHOICE CRITERIA FOR RENEWABLE LOW-IMPACT ELECTRICITY

Summary only; for full technical criteria, see "Electricity Generation" at <***www.environmentalchoice.com***>.

Renewable Low-Impact Electricity

From a consumer perspective, electricity is clean, cheap and has no visible environmental consequences. If we look beyond the outlets in our walls, however, environmental costs become apparent. In Canada, the major methods of generating electricity include burning fossil fuels, harnessing the power of water and using nuclear power. Each power source has consequences for the environment, from creating acid rain to flooding lands to disposing of radioactive waste. The Environmental Choice Program has made a commitment to promoting electrical energy sources that have greatly reduced environmental impacts. The ECP recognizes electricity that has been generated from naturally occurring energy sources (such as the wind and the sun) and from power sources that, with the proper controls, add little in the way of environmental burdens (such as less intrusive hydro and certain biomass combustion).

Certification Criteria

All Sources

- The facility must be operating, reliable, non-temporary and practical.
- During project planning and development, appropriate consultation with communities and stakeholders must have occurred, and prior or conflicting land use, biodiversity losses and scenic, recreational and cultural values must have been addressed.
- No adverse impacts can be created for any species recognized as endangered or threatened.
- Supplementary non-renewable fuels must not be used in more than 2% of the fuel heat input required for generation.
- Sales levels of ECP-certified electricity must not exceed production/supply levels.

Specific Sources (additional criteria to those listed above)

- Solar (cadmium-containing wastes must be properly disposed of or recycled)
- Wind (protection of concentrations of birds including endangered bird species)
- Water (compliance with regulatory licences; protection of indigenous species and habitat; requirements for head pond water levels, water flows, water quality and water temperature; measures to minimize fish mortality and to ensure fish migration patterns)
- Biomass (use only wood wastes, agricultural wastes and/or dedicated energy crops; requirements for rates of harvest and environmental management systems/practices; maximum levels for emissions of air pollutants)
- Biogas (maximum levels for emissions of air pollutants; leachate management)
- Other technologies that use media such as hydrogen or compressed air to control, store and/or convert renewable energy
- Geothermal technologies

C. EXECUTIVE SUMMARY: CASE STUDY ON HYDROGEN TECHNOLOGIES

By the Pembina Institute and the Canadian Energy Research Institute

1 OVERVIEW

The Pembina Institute and the Canadian Energy Research Institute (CERI) were commissioned to complete a study on the role of fiscal policy in promoting development of hydrogen technologies and reducing greenhouse gas emissions in Canada. This exercise produced two studies, a baseline report and an economic analysis report.

The *baseline* report describes the state of development of hydrogen technologies in Canada and the existing policy framework, and it provides an initial evaluation of a range of fiscal policy options for promoting the development of hydrogen technologies. The report identifies six fiscal policies capable of providing direct incentives for the development of hydrogen technologies while explicitly addressing a major barrier limiting the technology's market penetration. The six fiscal policies are investment tax credits, producer tax credits, accelerated capital cost allowances, research and development grants, consumer tax credits and pilot projects. The initial evaluation focuses on producer incentives, designed to reduce the production cost of hydrogen technologies, and consumer incentives, designed to reduce the end-use cost of hydrogen technologies. More specifically, the fiscal policies considered in this analysis reduced the cost of hydrogen production, stationary fuel cells, fuel-cell vehicles and buses, and hydrogen internal combustion engine (ICE) vehicles.

The *economic analysis* report presents the results of the modelling exercise undertaken to test the impact of these fiscal policies on particular hydrogen technologies.

A national macroeconomic model—CERI's Energy 2020 model—was used to test the effect of the producer and consumer incentives on the market penetration of hydrogen technologies and associated GHG emissions. The model simulated two methods of hydrogen production: steam methane reformers (SMRs) and electrolysis. The modelling began with a reference case (or business-as-usual model), to which producer and consumer incentives were added (the fiscal scenario model). The results presented below and in the economic analysis report reflect the impact of a combination of producer and consumer incentives equivalent to a 25% decrease in production costs. For the transportation sector, the two different methods of hydrogen production were simulated and the fiscal results presented for both.

In all relevant sectors, the fiscal policies increase the demand for energy associated with hydrogen technologies. In the transportation sector, while the absolute energy demand associated with hydrogen technologies is not significant—constituting between 0.03 and 34.87 petajoules (PJ) of demand in 2030, depending on the particular region—the increase in hydrogen-related energy demand is significant. Nationally, energy demand associated with hydrogen-related vehicles increases from 64.36 PJ in 2030 in the SMR reference case and 62.24 PJ in 2030 in the electrolysis reference case, to 96.26 PJ in 2030 in the SMR fiscal scenario model and 93.25 PJ in 2030 in the electrolysis fiscal scenario model. This is an increase of almost 50%. In terms of the number of vehicles, the SMR fiscal scenario model leads to an increase of 47,312 fuel-cell vehicles, 33,371 hydrogen ICE vehicles and 218 fuel-cell buses. Similar results are realized for hydrogen production using electrolysis. On a regional basis, the fiscal scenario model results in an increase of over 45% in hydrogen-related energy demand for most provinces and territories.

Like the transportation sector, the residential building sector and the commercial sector realize an increase in energy demand associated with stationary fuel cells following the application of fiscal policies. In the residential building sector, energy demand from stationary fuel cells increases from 2.61 PJ in 2030 in the reference case to 14.45 PJ in 2030 in the fiscal scenario model, for an increase of 454%. Similarly, in the commercial sector, energy demand from stationary fuel cells increases from 0.41 PJ in 2030 in the reference case to 2.81 PJ in 2030 in the fiscal scenario model, for an increase of 592%. In terms of numbers of stationary fuel cells, the fiscal scenario model leads to an increase of 15,770 stationary fuel cells in the residential sector by 2030, with an increase of 90 in the commercial sector.

In the fiscal scenario model, GHG emissions associated with the transportation, residential and commercial sectors decline as the market penetration of hydrogen technologies increases. In the transportation sector, reductions in emissions equal 1,240 kt in 2030 for hydrogen produced from SMRs. If the hydrogen is produced from a source with almost no GHG emissions (i.e., wind or nuclear power), the reductions in emissions increase to 2,650 kt in 2030. The penetration of stationary fuel cells into the residential and commercial sectors leads to a decline in GHG emissions of 710 kt from these sectors in 2030. Taking into account the impact of mobile and stationary fuel cells, total GHG emissions in Canada decline by 1,940 kt for hydrogen produced from SMRs. These figures include GHG emissions associated with hydrogen production. Taking into account only those emissions associated with hydrogen consumption (i.e., assuming that the hydrogen is produced from zero-GHG emission sources, or that any GHG emissions are captured), emissions decline by 3,360 kt for hydrogen produced by SMRs and 3,370 kt for hydrogen produced by electrolysis.

The modelling analysis reveals that the reduction in GHG emissions as a result of the market penetration of hydrogen technologies comes at a fairly high cost per tonne. This high cost is due to the combined effect of the limited reductions in GHG emissions that are actually realized and the existing cost barriers associated with the development of hydrogen technologies. The producer and consumer incentives reduce capital and operating costs by 25% each; however, given the high costs associated with hydrogen technologies (initially 50% more than the capital costs associated with conventional technologies in the transportation sector), the investment required to achieve these reduced costs is significant.

This analysis reveals that fiscal policy could facilitate an increase in the market penetration of hydrogen technologies in the transportation, residential and commercial sectors. For all sectors, and in all regions in Canada, the introduction of fiscal policies leads to increased demand for energy associated with hydrogen technologies. This result holds true on an absolute basis and also as a percentage of total energy, with hydrogen technologies capturing a greater share of total energy when fiscal policies are in place.

Despite these results, the market penetration of hydrogen technologies is still relatively minor and the reduction in GHG emissions that is achieved is also relatively small, even with the fiscal policies.

2 LESSONS LEARNED

The time horizon for the hydrogen technologies included in this modelling exercise is longer than that for the technologies considered in the two other EFR case studies (i.e., energy-efficient and renewable energy technologies). Even over a 30-year period, relatively little market penetration of hydrogen technologies occurs. Reduced costs and technological improvements would increase the competitiveness of hydrogen technologies.

1. Given the long time frame associated with hydrogen technologies, any reductions in GHG emissions that result will also take place over a long time period.

2. The successful market penetration of hydrogen technologies does not guarantee significant reductions in GHG emissions. Consideration of source fuel and energy pathway is key if hydrogen is to be part of a plan to reduce GHG emissions. If the intention is to increase penetration of hydrogen technologies and reduce GHG emissions at the same time, then a focus on low-emission hydrogen sources is necessary (e.g., renewable energy, natural gas reformers and systems that capture carbon emissions).

3. Cost and technology barriers are still significant for some technologies and are expected to remain so for the next 10 to 20 years.[1]

4. Given the current cost barriers associated with hydrogen technologies, any reductions in GHG emissions that are achieved come at a very high cost. If the main objective of fiscal policy is to reduce GHG emissions in the near future, focusing on other methods to reduce GHG emissions is likely more cost-effective than focusing on hydrogen technologies.

[1] *According to the U.S. Department of Energy's* Hydrogen Posture Plan *(2004), the introduction into the transportation market of personal vehicles that use hydrogen is not expected to occur until after 2020. Hydrogen use in commercial fleets and distributed combined heat and power (CHP) are on the same timeline.*

5 It may be most effective to focus fiscal policies aimed at increasing the market penetration of hydrogen technologies on technological improvements (research and development, demonstration projects) and cost reductions. As indicated in item 2 above, the application of fiscal policies to hydrogen technologies will not necessarily ensure reductions in GHG emissions unless the source fuel and energy pathway is taken into account in policy design.

6 In the transportation sector, increasing the market penetration of hydrogen technologies will require a focus not only on cost reductions and improvements in efficiency but also on the supply and availability of hydrogen fuel and hydrogen-related vehicles. There may be a role for fiscal policies targeted at manufacturers and retailers in this regard, although that is outside the scope of this analysis.

7 The development of hydrogen technologies in Canada is and will be largely influenced by trends in other countries, such as the United States, Japan and Germany. While such trends were not taken into account in this analysis, it is useful to keep this factor in mind in interpreting the results.

8 From a methodological point of view, the calibration of the Energy 2020 model to Canada's *Emissions Outlook: An Update* (CEOU)[2] introduces an inherent level of uncertainty into the modelling results. We already know that the fuel prices contained in the CEOU are incorrect. The effect of this error on the model results is uncertain.

9 There are gaps in data when it comes to the technology parameters and predictions of market availability for hydrogen technologies. For any technologies that are not yet commercially available or even in real-world operation, assumptions made regarding both costs and performance are often based on best predictions by technology researchers and developers. Thus there is high uncertainty with these parameters. The modelling results are also highly dependent on assumptions about when particular technologies will be available in the marketplace and access to supporting services such as refuelling infrastructure. There is a wide range of predictions and speculation on when these new technologies will become available.

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E. PROGRAM PARTICIPANTS

Note: This program was carried out over a number of years, and some participants' titles/organizations may have changed during that time.

Hydrogen Scoping Group Meetings – May 28, 2003, January 13, 2004, April 7, 2004

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F. ENDNOTES

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76 *Developed by the Energy and Materials Research Group at Simon Fraser University.*

77 *Trent Berry, "Macroeconomic Impacts of Fiscal Policy Promoting Long-term Decarbonization in Canada," Working paper prepared for the National Round Table on the Environment and the Economy, August 2004.*

78 *Discounted to 2004 dollars at a 10 percent social discount rate.*

79 *Interlaboratory Working Group,* Scenarios for a Clean Energy Future *(Oak Ridge, Tenn.: Oak Ridge National Laboratory, and Berkeley, Calif.: Lawrence Berkeley National Laboratory, 2000), Section 5.21.*

80 *Industry Table,* Industrial Table Overview Report *(Ottawa: National Climate Change Process, 2000), p. 20.*

81 *Depending on the design of the fiscal instrument, energy efficiency gains may not be the mitigation option chosen to respond to the policy.*

82 *Organisation for Economic Co-operation and Development,* Environmental Taxes and Competitiveness: An Overview of Issues, Policy Options, and Research Needs *(Paris: OECD, 2003).*

83 *Martin Tampier, "Background Document for the Green Power Workshop Series, Workshop 5," Prepared for Pollution Probe and the Summerhill Group, April 2004, Chapter 4.*

84 *Ibid.*

85 *For a description of sources and assumptions behind these figures, see Appendix B or consult Marbek Resource Consultants and Resources for the Future,* Ecological Fiscal Reform and Energy Case Study on Renewable Grid-Power Electricity *(Ottawa: NRTEE, 2004).*

86 *Including biomass but excluding trash and non-renewable waste.*

87 *For example, if wind power has a "technical" potential of 100,000 MW, it means that this is the maximum total generating capacity that wind turbines could supply if they were installed in every technically feasible location across the country.*

88 *"Practical" potential integrates considerations such as grid access and capacity; technological advances; financing; market demand and acceptance; and design, manufacturing and installation capacity. This case study also included technology, site and industry supply criteria.*

89 *The technologies included for both technical and practical potentials were wind (onshore), low-impact hydro, solar photovoltaic, landfill gas, biomass, wave, tidal and large geothermal.*

90 *Under a renewable credit trading system, investment will likely be allocated to jurisdictions with a higher share of low-cost non-hydro renewable resources such as British Columbia.*

91 *Armington elasticities produced by Bataille are -1.3 to -1.5 for mining and pulp and paper production, respectively, indicating a high responsiveness of domestic and export demand to price changes. However, metal smelting is much less sensitive (-0.59). C. Bataille, "Design and application of a technologically explicit hybrid energy–economy model with macroeconomic feedbacks," Draft doctoral dissertation, School of Resource and Environmental Management, Simon Fraser University, Burnaby, B.C.*

92 *Trent Berry, "Macroeconomic Impacts of Fiscal Policy Promoting Long-term Decarbonization in Canada," Working paper prepared for the National Round Table on the Environment and the Economy, August 2004.*

93 *Although it should be noted that the modelling methodology used for the renewable power case study may have been biased toward a more favourable result. That methodology starts with the policy objective and then measures the effectiveness of a given instrument in achieving the objective; the other two methodologies start with the instruments themselves and then evaluate what contribution they can make to a set of more loosely defined policy objectives.*

94 *For example, the cost of wind turbines is forecast to drop by 15 percent every time cumulative installed capacity doubles, or every three years. See G. Estill and D. Duimering,* Manufacturing Commercial Scale Wind Turbines in Canada *(Ottawa: Canadian Wind Energy Association, April 2003).*

95 *Renewable energy certificates (or "green tags") are tradable commodities awarded to renewable power producers, consumers or financial backers. Demand for the certificates—which are meant to act as a proxy for the environmental attributes of the renewable power—typically comes from power producers, which are bound by regulation to deliver a certain percentage of renewable power but which do not have sufficient generating assets to do so.*

96 *The 2002* Climate Change Plan for Canada *currently commits the government to "green power purchases for 20 percent of the Government of Canada's electricity needs."*

97 *This definition purposely excludes hydrogen used in an oil refinery to produce gasoline and other fuel products, and hydrogen used for medical or manufacturing purposes.*

98 *Carbon dioxide equivalent (CO_2e) is the universal unit of measurement used to indicate the global warming potential (GWP) of each of the seven greenhouse gases. It is used to evaluate the impacts of releasing (or avoiding the release of) different greenhouse gases.*

99 *Two levels of incentives are considered. For the remainder of this discussion, we assume the higher level of incentives, which reduce the costs of production and the costs of end-use technologies by 25 percent.*

100 *Used by the Canadian Energy Research Institute.*

101 *See, for example, Matthew Wald, "Questions about a Hydrogen Economy,"* Scientific American *(May 2004).*

102 *Trent Berry, "Macroeconomic Impacts of Fiscal Policy Promoting Long-term Decarbonization in Canada," Working paper prepared for the National Round Table on the Environment and the Economy, August 2004.*

103 *(S&T)² Consultants Inc.,* Hydrogen Pathways, Greenhouse Gas Emissions and Energy Use, *Prepared for Fuel Cells Canada, December 2003, p. ii.*

104 *Ibid., p. iv.*

105 *To be consistent, these would all need to be assessed on a life-cycle basis.*

106 *See Martin Tampier, "Background Document for the Green Power Workshop Series, Workshop 5," Prepared for Pollution Probe and the Summerhill Group, April 2004, p. 24.*

107 *National Petroleum Council,* Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy *(Washington, D.C.: NPC, October 2003).*

108 *Canadian Energy Research Institute, "Continental Energy Sector Issues," Prepared for the National Round Table on the Environment and the Economy, March 2004, p. 18.*

109 *This estimate is based on an average cost of emission reductions of $1,400/tonne. The case study does not provide an estimate of aggregate costs. Rather, it provides an estimate of "representative" costs by end use and pathway. The average cost of $1,400 is based on a qualitative review of the range of costs presented in the analysis; but it would be much higher for certain applications ($4,450 for SMR fuel cell vehicles in 2030 in Ontario) and much lower for others ($856 for SMR buses in 2030 also in Ontario).*

110 *The estimate of subsidies does not include administrative costs.*

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