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

Executive Summary

National Round Table on the Environment and the Economy
Table ronde nationale sur l'environnement et l'économie

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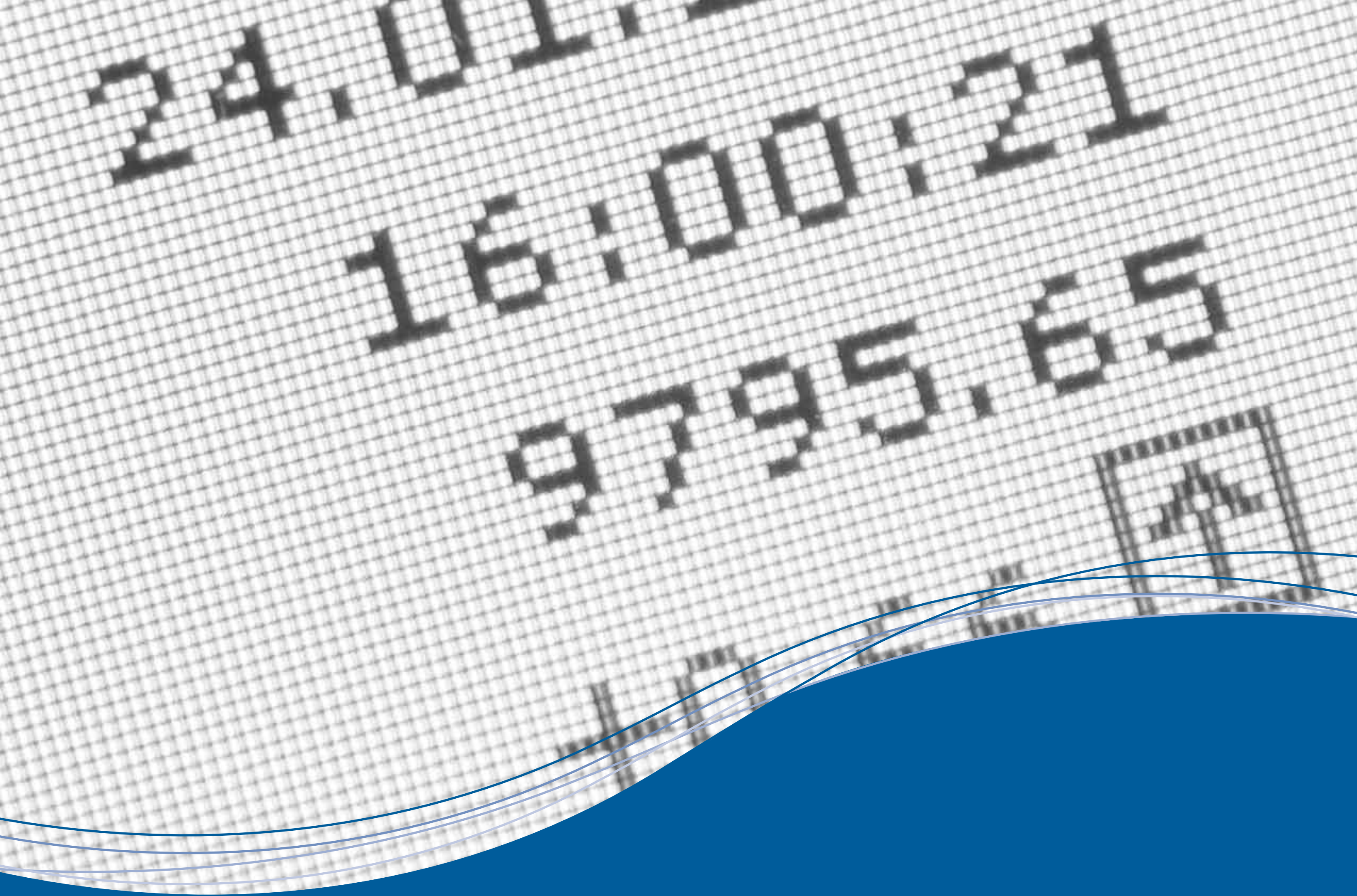

Economic Instruments for Long-term Reductions in Energy-based Carbon Emissions

Executive Summary

1. BACKGROUND

A coherent energy strategy will be driven by multiple factors, including climate change. However, while climate change is an important consideration, there is debate about how much weight should be given to climate change issues in energy policy and about the appropriate tools for incorporating them. To aid further understanding of this critical issue, the National Round Table on the Environment and the Economy (NRTEE) launched the Ecological Fiscal Reform (EFR) and Energy Program. The Program has explored a scenario in which economic instruments are used as a key tool to promote long-term reductions in carbon emissions. Our operating assumption is that a long-term reduction in energy-based carbon emissions is among the priorities shaping energy strategy.

The EFR and Energy Program's objective is "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 GDP, without increasing other pollutants." The rationale for this focus is twofold:

- Fiscal policy is one of the most powerful means at the government's disposal for influencing 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.
- 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—forms 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 and to promote the expanded use of ethanol as a transportation fuel, these efforts have been piecemeal.

The Program has looked at how economic instruments can be used to support technologies with the potential to reduce energy-based carbon emissions on both the demand and supply sides of the energy equation, and at three different stages of development: mature technologies, emerging technologies and longer-term, new technologies. This analysis was carried out through case studies commissioned by the NRTEE on industrial energy efficiency, emerging renewable power technology and hydrogen energy technology.

It should be noted that, in presenting the findings and recommendations of the Program, we are drawing not only from the specific analysis carried out in the case studies (and their general lessons for the use of economic instruments) but also from 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?

The 25-year perspective arose from the NRTEE's conviction that a sole focus on the Kyoto timetable, while necessary to meet our international obligations, would not allow sufficient time for the optimum,

Ecological Fiscal Reform (EFR)

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*. The focus on economic instruments does not imply the exclusion of other policy instruments but enables drilling down on one set of the policy reforms.

1 *This deficiency has been noted most recently in the Organisation for Economic Co-operation and Development's* Environmental Performance Review of Canada, 2004 *(Paris: OECD, 2004)*.

orderly development and implementation of mitigation and adjustment strategies. Investment decisions are being made now about capital stock that may last for several decades. Without clear long-term direction with respect to climate change policy, long-lived, carbon-inefficient new stock will continue to be installed, complicating future mitigation efforts. The NRTEE's longer-term horizon allows for fundamental shifts in the energy system. It reflects the advice of bodies such as Natural Resources Canada (NRCan)'s 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."[2]

[2] *NRCan Advisory Board on Energy Science and Technology,* Innovation in Canada: Submission *[on-line]. Accessed March 2005, at:* <***www.innovation.gc.ca***>.

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

Addressing the many opportunities and challenges reflected in Canada's evolving energy marketplace will mean taking into account many factors, such as energy security, economic and industrial development, employment, international competitiveness, environmental protection and sustainability. Mitigating climate change will also 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 (1) that responds to the ecological urgency implied in the current understanding of climate change impacts and the challenge of mitigation, and (2) that does so in a way that limits impacts on other societal priorities. Canada confronts 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 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, coal, uranium 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—for example, 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, as well as for cold and moderate weather conditions. In other words, we have all the resources necessary to adapt to the coming energy revolution—if we advance strategically and with clear vision.

In contrast to these unparalleled opportunities on the energy resources front, there are real constraints on the policy front. 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. And these 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 during 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 amounts in research, capital and infrastructure to bring each of these new energy sources to market.

Drivers of 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 of energy technology change in the past. And they will not be in the future, unless greater priority is given to long-term carbon emission reductions in energy policy.

There is broad agreement that long-term carbon emission reductions need to be a greater priority in energy policy; however, many fear that single-minded pursuit of this goal, in isolation from other public priorities, focuses too heavily on one aspect of energy production and consumption.

Other priorities, such as quality jobs, regional and community development, productivity and energy security are also important concerns for Canadians. If the benefits and opportunities arising from long-term reductions in energy-based carbon emissions can be shown to align comfortably with these priorities, there will be broader interest in and greater gains from the agenda.

Participants in the EFR and Energy Program, for their part, deemed that public investments in a long-term carbon emission reduction strategy would yield many benefits in addition to climate change mitigation. In light of the Program's emphasis on economic instruments and on its review of selected technologies, they saw these benefits to include:

- *Energy security:* By 2020, 42,000 MW of new electrical generation capacity will be required to replace capacity lost as older plants are decommissioned and to meet new demand in Canada; this amount is equal to 40 percent of current stock. Aggressive conservation measures and growth in generation, including through the use of renewable sources, are key to bridging supply–demand imbalances across the country. More diverse energy sources, a more responsive supply mix and greater energy efficiency would also contribute to security of supply, which has been a concern in the last few years. Distributed generation would increase the resilience of the power system and reduce the costs of transmission and distribution. It would also reduce the cost of power in remote communities. In addition, reduced demand and increased penetration of renewables could help to stabilize energy pricing, a priority given record high crude oil prices and price volatility in the natural gas and deregulated electricity markets.
- *Cleaner 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 health impacts such as respiratory problems and impaired lung function. Smog alerts have become an all-too-familiar summer experience 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 would all reduce emissions of smog precursors in Canadian urban centres and improve the quality of life.

- *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 charge on the health care system: $600 million in 2000 in Ontario alone, according to research by the Ontario Medical Association.[3] These costs would be lower if smog were reduced.

- *Enhanced industrial capacity in new environmental technologies:* The benefits to the domestic economy of large investments in long-term carbon emission reductions would be amplified if the needed technology and expertise were available in Canada. This is not the case at present, however, and many of the energy technologies required for carbon mitigation would need to be imported. More aggressive Canadian commitments to specific technologies, for example, a renewable portfolio standard, would prompt European companies to locate manufacturing plants in Canada and, possibly, to use this country as their entry point into the North American market. This benefit would occur both in sectors where we are considered "technology takers" (such as wind turbines) and sectors where we are "technology makers" (such as proton exchange membrane fuel cells).

- *Greater presence in growing export markets:* Nearly 70 percent of the increase in world primary energy demand between 2001 and 2030 will be in developing and transition economies; half of total global energy investments during this period—US$7.9 trillion—will be directed to developing countries. 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 per 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.

- *Increased commercialization and leveraging of 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. However, with the recent establishment of the Sustainable Development Technology Fund, government funding is now also available at the demonstration and pre-commercialization stages. Such funding could increase the rate of uptake of currently available carbon mitigation technologies. Economic instruments explored in the EFR and Energy Program would complement government investments in carbon mitigation technologies by stimulating uptake of market-ready technologies and thus the market-pull stage of the innovation chain.

- *New jobs and regional development:* Other countries are achieving worthwhile employment benefits from the development, manufacturing and servicing of technologies that reduce carbon emissions: for example, 45,000 jobs have been created in the German wind industry and 20,000 in the U.K. offshore wind industry. Analysis in Canada indicates that 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."[4] Renewable energy sources offer employment potential in rural and remote locations, including First Nation communities, while jobs related to energy efficiency are distributed across all regions of the country.

- *Development of value-added and intellectual property–intensive secondary industries:* Canadian leadership in new knowledge-based industries, such as hydrogen fuel cells or carbon sequestration, can supplement commodity-based energy sector exports.

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[3] *Ontario Medical Association,* The Illness Costs of Air Pollution in Ontario: A Summary of Findings *(June 2000) [on-line]. Accessed October 27, 2004, at:* **<www.oma.org/phealth/icap.htm>**.

[4] *Matt Horne, "Canadian Renewable Electricity Development: Employment Impacts," Prepared for the Pembina Institute for Appropriate Development, 2004.*

- *Better ability to compete in international markets:* 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: (1) to ensure the continued acceptance of conventional Canadian commodities—whether heavy crude from oil sands, electrical power or minerals—in international markets, and (2) to position ourselves to participate in new growth sectors, such as the production of hydrogen-fuelled vehicles. Improved energy efficiency in the industrial sector would also enhance the productivity of Canadian firms.

In other words, a long-term carbon emission reduction strategy could yield many positive and relevant outcomes. Success will depend on the development of policy responses—particularly the use of economic instruments and fiscal policy—within a framework that embraces each of these objectives alongside a focus on long-term carbon emission reductions.

Other participants saw the relationship between long-term carbon emission reductions and other objectives as complementary to a certain point, but felt that eventually it would involve 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 of 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 and that any environmental objective should be considered secondary.

Regardless of their views on the ranking of long-term carbon emission reductions in energy strategy, participants in the EFR and Energy Program clearly believed that carbon emission reductions must not become an implied secondary effect of other policies. Moreover, it was clear from our research that the pursuit of other objectives of a sustainable energy strategy, without a specific long-term carbon emission reduction objective, might lead to perverse emission impacts. This finding, which was particularly striking in the case of hydrogen fuels, is a significant one, since the present policy debate often tends to assume an inherent substitutability between sustainable energy initiatives (such as energy efficiency, renewable energy deployment or development of hydrogen technologies) and carbon mitigation.

FINDINGS

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

1 **Economic instruments can make a significant contribution to achieving long-term reductions in 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 emissions**. 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.
- 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.

4. A COORDINATED TECHNOLOGY STRATEGY FOR LONG-TERM CARBON EMISSION REDUCTIONS

Energy is a basic good in society, essential for the functioning of our modern civilization. Energy is also 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 energy technology strategy will be an orderly transition and greater certainty for all actors.

The 25-year time frame envisioned by the EFR and Energy Program enables the exploration of a coordinated transition: phased deployment of proven mature technologies, 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 three case studies to examine the use of economic 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.

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

It should be noted that the choice of specific technologies for these case studies does not imply primacy for any of the 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; 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 response to long-term carbon emission reductions. It should also be noted that the specific recommendations stemming from 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.

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.

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

4.1 STAGING AND CONSIDERATIONS FOR A COORDINATED TECHNOLOGY TRANSITION STRATEGY

A key consideration for Canada as it develops 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 to be given to how to create synergies between current and future technologies, so these technologies can reinforce one another where possible. The emphasis in the present report is on fiscal measures that can advance these objectives without compromising other measures, fiscal or other, that later work may identify.

Mature technologies. Many carbon emission reduction options are already 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" from a cost–benefit perspective for emission mitigation. This should be the priority before any investment in new supply. Mature 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 document. 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. It is also 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.

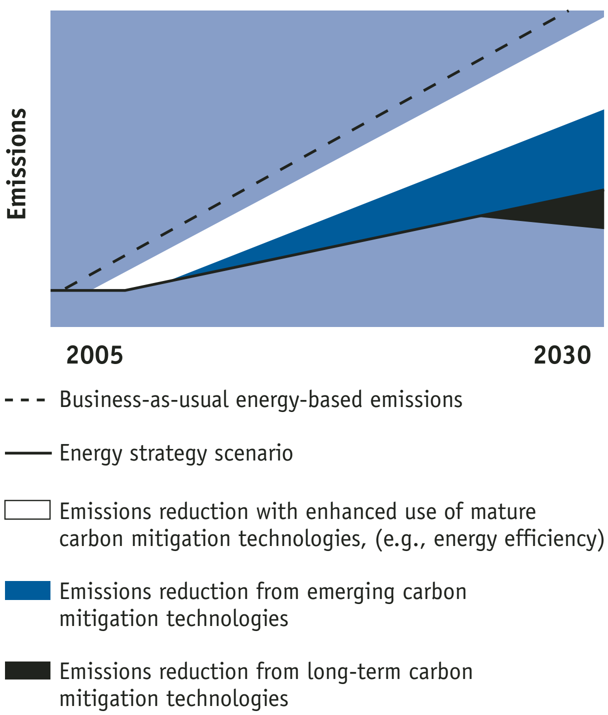
Emerging technologies. Some of these technologies (e.g., hybrid cars, wind and solar) are commercially viable or near-viable in certain applications and ready for immediate expanded use. Other technologies (e.g., wave power) require further development and would only be commercially viable in the mid- 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.

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 through research and development subsidies and incentives. Where the technology is more mature, demonstration and pre-commercialization assistance is important.

- Of the economic instruments 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 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 R&D 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.

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



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 based on 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 was found to affect 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 throughout the life cycle to produce a given unit of energy.

5. 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.[5]

There is also an important place for other tools such as regulations, disclosure requirements and educational programs, but these were outside the boundaries of this 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 sectors; these approaches include building construction codes, appliance standards and auto efficiency standards. Economic instruments often also need to be complemented by other policy measures to be effective. For instance, access to transmission grids is essential for renewable energy deployment.

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 are replacing existing equipment or 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. (A carbon charge, for example, would need to be accompanied by targeted revenue recycling or transition measures to avoid transferring wealth from fossil fuel–intensive regions to those with hydroelectric resources.)

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 enabling 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.

5.1 APPLICATION OF BROAD MEASURES

Participants in the EFR and Energy Program acknowledged that, in theory, broad-based price signals (e.g., emission charges such as taxes and tradable permits) supplemented by targeted relief offer the best combination of effectiveness and efficiency in reducing long-term carbon emissions and are a necessary element in a long-term carbon emission reduction strategy. 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. The precise response to a price signal cannot be predicted; hence, price signals do not ensure the achievement of a specific emission reduction target. However, the level of the price signal can be increased or decreased over time, depending on the impact it is having. Broad-based measures will stimulate the most immediate response from mature technologies, but when applied in a predictable and continuous fashion, they will also stimulate the gradual uptake of emerging technologies and investment in the development of new ones. These measures were considered to offer a better approach than the alternative array of complex and possibly arbitrary individual regulations and standards.

[5] *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." Department of Finance,* The Budget Plan 2005 *(Ottawa: Department of Finance, 2005) [on-line]. Available at: <**www.fin.gc.ca**>, p. 184.*

During discussion of broad-based measures, participants noted that fluctuating market prices for energy will likely overwhelm most signals sent by policy and be a stronger influence on the choice of fuel and technologies—an example is the hikes in the price of oil in 2004. However, since the fuel switching provoked by fluctuating prices could result in the use of more carbon-intensive fuels (such as coal or heavy fuel oil), such a market price signal should not be considered a substitute for policy action in achieving long-term carbon emission reductions.

The primary appeal of broad-based measures is that they are technology-neutral, leaving the choice of response to the subject parties. Because these instruments are by nature performance-based, they avoid the risks inherent in "picking winners" and instead enable winners to emerge through continuous improvement and innovation. This will occur because it will always be in a party's interest to lower the marginal cost of abatement.

However, broad-based price signals have received virtually no thoughtful discussion, let alone application in Canada. Among the reasons:

- 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.
- 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 that 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, some findings from the industrial energy efficiency case study suggest that the concern is overplayed. Modelling carried out as part of the study examined the effects of a price signal of $30/tonne of carbon dioxide equivalent (CO_2e) with no mitigation policies. The results showed 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 that base. For this reason, a low charge on energy or carbon, 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 its simplicity and targeted revenue recycling. This 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.[6]

[6] *Her Majesty's Customs and Excise (U.K.),* A general guide to climate change levy *(March 2002) [on-line]. Available at: <**www.hmce.gov.uk**>; and* Climate Change Agreements *[on-line]. Available at: <**www.defra.gov.uk/environment/ccl/intro.htm**>. Both sites accessed October 30, 2004.*

Recommendation 1

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.[7]

5.2 APPLICATION OF TARGETED MEASURES

While opinions differ over the viability of broad-based measures for long-term carbon emission reductions, there is no doubt as to their effectiveness. The charge for policy-makers using other approaches, therefore, is how to capture the performance-based benefits of broad-based measures.

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

- Through subsidies (expenditure instruments such as tax incentives and credits, loan programs and grants) that reduce the relative cost of technologies and products with lower emission intensities, making them as or more attractive than incumbent technologies. Subsidies may target current decisions by reducing upfront capital costs, or they may target long-term cost competitiveness through funding for research, development and commercialization of new technologies.
- Through so-called market-based regulation, such as renewable portfolio standards or the planned large final emitters' domestic emissions trading system.[8] Market-based regulation requires designated firms to meet certain targets but allows them to trade with other parties in meeting this commitment.

Market-based regulation imposes the costs of emission reductions on consumers and shareholders. Subsidies transfer this cost to taxpayers, a less economically efficient approach but one that may be politically more feasible. Subsidies can also play an important role in complementing other economic instruments, when used to alleviate transition-stage distributional impacts.

Subsidies have three main weaknesses:

High cost per unit of effect. Subsidies tend to require relatively large public expenditures per unit of effect, due to the presence of firms and individuals that would have undertaken the desired change even without the subsidy. This number can be large (as high as 40 to 85 percent in evaluations of energy efficiency programs) but is often underestimated. The total cost of subsidies also often exceeds the direct costs to government, since governments must raise funds from other taxes, and these have dampening effects on economic activity.

Uncertain results. The precise response to subsidies, like the response to emissions charges, cannot be accurately predicted. Hence, neither of these instruments is able to assure a specific emission reduction target.

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[7] *Ibid.*

[8] *More information on the large final emitters emissions trading system is available on-line at:* ***<www.nrcan-rncan.gc.ca/lfeg-ggef/English/industry_en.htm>***.

Tendency to be technology-prescriptive. Subsidies targeting current decisions, such as accelerated capital cost allowances or consumer rebates, usually aim to reduce the upfront capital costs of investments in specific technologies. This raises three issues: (1) there is a greater risk that subsidies support more costly options for achieving the desired environmental outcomes; (2) the administrative need to designate specific technologies dampens innovation and new market entrants; and (3) the reduction of upfront capital costs favours technology-specific responses rather than systems innovation and substitution.

Market-based regulation in the form of a tradable permit market avoids all of these weaknesses. 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. The possible limitation in applying market-based regulation in Canada is the need for the market covered by the regulation to have adequate supply and demand to ensure liquidity. In addition, these instruments require the same complexity of infrastructure (program design, reporting, monitoring and enforcement) as any other regulation.

Recommendation 2

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.[9]

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.

5.3 TRANSITION MEASURES

The EFR and Energy Program case studies did not examine transition issues. However, EFR literature highlights transition measures as a key aspect in achieving acceptance, particularly of new charges. Among the transition mechanisms identified are use of pilot projects, predictability and continuity, modest pace of implementation and targeted subsidies or credits to support transition costs.

Further discussion of economic instruments to support the development of the specific technologies examined in the case studies is found in Section 6, below.

[9] *More information on the Enhanced Capital Allowance is available on-line at:* ***<www.inlandrevenue.gov.uk/capital_allowances/cars.htm>***.

6. THE CASE STUDIES

The three case studies shared a similar analytical framework. They began by defining a business-as-usual (BAU) evolution that assumes no government intervention. They then went on to 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; and assess the economic and environmental efficiency and effectiveness of the potential instruments. Finally, policy and technical experts reviewed these modelling results, and validated and shaped recommendations for economic instruments specific to each technology.

It must be emphasized that the 25-year time horizon introduced sizable uncertainties into the technology development pathways and commodity prices, influencing the reliability of the results. Also, the case studies used three different modelling programs; the definition of cost was therefore different in each case study, precluding comparisons of cost per tonne emission reductions.

6.1 INDUSTRIAL ENERGY EFFICIENCY

Energy efficiency refers to the relationship between the output (service) of a device or system and the energy put into it. The study focused on Canadian manufacturing and mining industries.[10] Energy efficiency opportunities were sought within energy-using equipment, major industrial processes, supply technologies and delivery networks. Fuel switching was considered in conjunction with efficiency options. The opportunities thus covered system-based, transformative technologies and processes as well as more incremental ones.

The industrial sector, which includes mining and manufacturing activities, is a significant producer of greenhouse gases (GHG) in Canada, and most of these emissions come from energy consumption. The BAU scenario forecast a 50 percent increase in GHG emissions from these industry sectors over the 2000–2030 period, an average annual emissions growth rate of 1.53 percent, and an annual energy consumption growth rate of 1.48 percent. The economic instrument scenario explored "achievable" potential, using a technology competition that represents a firm's purchasing decisions based on minimization of annualized life-cycle costs, performance preferences, cost heterogeneity, option value and failure risk.

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. In Low Carbon I, GHG emissions were reduced by 46 Mt CO_2e; in Low Carbon II, GHG emissions were reduced by 58 Mt CO_2e. Forecast financial costs for the Low Carbon I scenario were \$17.64 billion and for the Low Carbon II scenario, \$24.87 billion. In other words, the value of energy savings was greater than any associated increase in upfront capital costs for all industry subsectors. 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—that is, the "energy efficiency gap." The total monetary incentive needed to overcome this gap 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 potentially significant group.

The underlying conclusion from the case study is that energy efficiency in the industrial sector is essentially an issue of project financing. One reason for this is that energy efficiency projects must compete for capital within a firm, and they 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.

For the mature industrial energy efficiency technologies, policy intervention should encourage market uptake of existing technologies and processes. The choice of EFR tools will depend on the nature of industrial energy efficiency opportunities. Energy use in industry can be categorized into generic or auxiliary services (steam generation; lighting; heating, ventilation and air conditioning or HVAC; and

[10] *Chemical products, coal mining, industrial minerals, iron and steel, mining, natural gas extraction, other manufacturing, petroleum crude extraction, petroleum refining, pulp and paper, smelting and refining.*

electric motors) and processes unique to each specific sector and even each facility. 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 well 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- or process-specific technology opportunities that are radical in nature—such as process substitution based on membrane techniques or biotechnology rather than 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 tradable permits.

These findings underscore the role that energy prices and market forces play in stimulating energy efficiency actions; they also highlight the need for a price signal given that current prices appear too low to stimulate major efficiency improvements. Although a 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, an emissions price applied to this sector was considered by most to be a political non-starter.

For these reasons, market-oriented regulation (similar to the large final emitters' domestic emissions trading system) was considered 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.

The case study also showed that energy efficiency and GHG mitigation are not always identical and, depending on which is the priority, different actions will be needed. An emphasis on energy efficiency alone could, in some cases, result in increased carbon intensity. Take, for example, the installation of an efficient coal-fired boiler. Although the boiler might be more efficient than wood-fired or certain natural gas–fired boilers, it would be much more carbon-intensive. An emphasis on greenhouse gas mitigation alone would open the door to non-efficient means of reducing emissions, such as fuel switching, reducing fugitive emissions, reducing process emissions, and the capture and storage of carbon dioxide. This study brought to light the importance of pursuing a dual objective—an approach that will support a broader set of public policy objectives, including narrowing the supply gap.

Recommendation 3

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

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

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

3 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.

4 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.

6.2 EMERGING RENEWABLE POWER TECHNOLOGIES

Emerging renewable power technologies were delineated in this study as those that are EcoLogo-certifiable, electricity generating and grid-connected. Thermal technologies, such as ground-source heat pumps, solar hot water heaters and stand-alone systems, were excluded due to modelling constraints, and large hydro 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.

The technologies covered by the case study currently represent about 2 percent of Canada's installed electricity generation capacity (2,300 MW capacity and 12,100 GWh/yr supply). The "technical" resource potential is estimated at 30 to 146 times this capacity and 20 to 100 times this supply. The generating capacity that is considered could be installed by 2020, and the "practical" resource potential is estimated in the BAU scenario at 11 to 22 times present capacity and 9 to 14 times present supply.

Emerging renewable power sources are generally more expensive than conventional electricity sources. 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. Investors tend to see emerging renewable technologies as high risk, while immature public policy and changing fiscal incentives in the field contribute to lack of certainty. These and other barriers (see below) combine to create a large gap between the technical resource potential and actual installed capacity.

The economic instrument scenario used a model that set a target of a 12 percent reduction in carbon emissions (from the base case) and then assessed a variety of policy options for achieving this. The model revealed that the target could be achieved through:

- a carbon permit price of \$10/tonne CO_2;
- a 24 percent renewable portfolio standard (RPS), which requires that tradable green certificates, or the equivalent, be purchased by utilities so that renewable generation increases relative to fossil fuel generation;
- a 0.6 cents/kWh renewable generation subsidy (RGS), modelled as a direct subsidy from government to emerging renewable power producers;
- a combination of a 24.21 percent RPS and 0.2 cents/kWh RGS, in tandem; or
- a 61 percent increase in renewable research subsidies to reduce the cost of future renewable generation.

The economic efficiency and environmental effectiveness of each instrument is linked to its ability to influence the entire electricity market and three drivers of the carbon intensity of the electricity market in particular: *renewables penetration*, affected by the cost of renewable generation compared with other types of generation; *carbon intensity of generation*, affected by the cost of carbon emissions; and *total electricity demand*, affected by the price of electricity. The study concluded that if the exclusive priority were economically efficient long-term carbon emission reductions, an emissions price is the preferred option; but a scenario with multiple policy objectives was considered more likely. In this case, then the RPS and/or the RGS would be the preferred option. The combination RPS and RGS led to the fastest penetration and alleviated some of the distribution consequences of the RPS alone. 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.

These findings were broadly supported by program participants, with some additional insights:

- 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. These barriers need to be overcome.
- Some emerging renewable power technologies are intermittent in nature. Developing these technologies will therefore require complementary sources that are able to compensate for this intermittency. Large-scale hydro does this well, as will hydrogen.

- 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.
- Non-grid-connected emerging renewable technologies, such as geothermal, passive solar and photovoltaics, have strong potential and also deserve targeted measures.
- Economic instruments that encourage least-cost choices will consistently select more mature technologies. For example, they consistently reward wind or biomass production, while 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 gap that must be overcome.
- For biomass sources, energy use and emission benefits should be evaluated on a life-cycle basis. The differentiation between agricultural biomass—an agricultural policy issue—and waste biomass should be kept clear.

The rapid evolution of provincial energy policies and the emerging supply challenge across the country provide opportunity, and indeed exigency, for enhancing the penetration of renewable sources of supply.

Recommendation 4

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:

1. 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:

2. Supplement provincial renewable portfolio standards—which are being developed across the country—with a national system for trading of renewable energy certificates (REC),[11] 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.

3. 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.

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

5. Expand its program to purchase electricity generated from emerging renewable power technologies.[12]

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[11] *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.*

[12] *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."*

6.3 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.[13] Hydrogen technologies are, generally speaking, still in the fundamental research, prototype development or product demonstration stages; they face technical, economic and infrastructure barriers to market penetration. The case study focused on (1) on-road transportation applications using hydrogen production from decentralized steam methane reformers (SMRs) or decentralized electrolyzers and (2) fuel cells in the residential and commercial sectors using natural gas from pipelines. The fiscal instrument scenario considered the impact of producer and consumer incentives (various tax credits and grants) whose combined effect would be to reduce both the cost of producing hydrogen and the upfront cost of end-use hydrogen technologies by 25 percent.

The modelling outcomes showed that hydrogen technologies realized relatively little market penetration in the business-as-usual cases, and barely more penetration in the fiscal instrument scenario, despite government subsidies of about $1.6 billion per year by 2030 (resulting, in 2015, in per tonne CO_2e emission reduction costs ranging from $126 for stationary fuel cells in Saskatchewan to as much as $6,130 for SMR fuel cell cars in Alberta). And, depending on the choice of primary fuel source and hydrogen production technology, the use of hydrogen fuels could actually lead to increases in life-cycle greenhouse gas emissions. This latter finding echoes the results from other studies of the greenhouse gas profiles of various hydrogen pathways.

These results led to significant debate, skepticism among many as to hydrogen's potential to contribute to emission reductions, and substantial additional input from the hydrogen industry. Our conclusions were as follows:

- The policy instrument modelled (producer and consumer incentives to cut costs by 10 to 25 percent) was not appropriate for increasing the market penetration of hydrogen technologies, which are still largely in a research, development and demonstration stage. This fact is reflected in the prohibitive cost per tonne emission reduction.
- Market penetration of the on-road hydrogen fuel cell vehicles modelled is particularly challenging, since it requires replacing an entire energy infrastructure (to produce the fuel, transport it, store it, convert it to useful forms and distribute it to end users), as well as changes in the end-use technology. Other near-commercial hydrogen transportation applications have fewer infrastructure challenges and are competitive in niche applications. These include industrial fleets of off-road utility vehicles (e.g., forklifts), particularly in settings where diesel is now used but zero emissions are desirable.
- The environmental benefits of hydrogen will depend on the pathway—the choice of primary energy, intermediate energy carriers, distribution systems and final use. The case study revealed that some hydrogen pathways will actually increase carbon emissions on a life-cycle basis (hydrogen production using electrolysis where combined-cycle natural gas is the marginal energy source). Other pathways not considered in the case study (e.g., where hydrogen is produced using waste biomass, hydroelectricity or nuclear power as the marginal energy source) would have a different carbon signature. Public investment in hydrogen technologies should therefore be directed toward lower life-cycle, carbon-efficient hydrogen pathways, particularly those from zero-emission primary energy sources.

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

Recommendation 5

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

1. Drive public investments toward lower-carbon pathways, including carbon-free hydrogen production and elimination of carbon at its source through sequestration.
2. 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.
3. 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.

6.4 A COORDINATED SUITE OF 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	

**capital cost allowance*

Recommendation 6

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.

MACROECONOMIC IMPACTS OF THE PROPOSED MEASURES

The NRTEE commissioned a qualitative assessment of the likely macroeconomic costs of the various instruments proposed in the case studies, then compared these with the estimates produced for Canada's National Climate Change Process (NCCP) in 2000.[14] This assessment found that, in general, the aggregate macroeconomic costs of the various instruments proposed in the NRTEE case studies are likely much smaller than those estimated 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 in the NCCP study to meet the Kyoto targets.

[14] *More information on the modelling used in the NCCP study is available on-line at:* <***http://climatechange.gc.ca/english/publications/canadascontribution/appendix1.html***>.

- 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 produce no direct impact on prices. Even in the case of instruments such as emission charges, the estimated impacts on energy and other product prices are smaller than those in the NCCP study, suggesting more limited demand feedbacks.

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

7. LESSONS: THE EXPERIENCE WITH ASSESSING FISCAL INSTRUMENTS

One objective of this NRTEE program on EFR and Energy was to test approaches, processes and methodologies that link fiscal policy with the issues of energy, climate change and technology development in order to generate findings that can inform policy development in the fiscal area.

Our efforts to assess fiscal instruments for application in the energy sector revealed several challenges. The ability to assess anticipated effectiveness, and hence to make sound policy, is severely constrained by the absence of reliable, timely and comprehensive data. The case studies proved highly sensitive to the price of fossil fuels and, in particular, the price of natural gas. But there were no up-to-date forecasts of commodity prices to use as a common baseline for calibrating the case study models. The path for long-term reductions in carbon emissions from energy use is inherently uncertain, because it will involve both proven and still-emerging technologies. Some of these technologies could be adopted on a gradual and incremental basis, other shifts may take place in a stepwise fashion, and still other technologies are likely to be fundamentally disruptive and unpredictable. Other uncertainties in developing the mid- to long-term scenarios include the likely depletion of non-renewable energy stocks, as well as non-price factors that will also influence the rollout of new technologies and fuels. Sub-national and international market settings will influence both the effectiveness and the unintended impacts of national fiscal measures to promote a lower-carbon energy future.

Recommendation 7

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.

Recommendation 8

To support a better ability to assess economic instruments for long-term carbon emission reductions:

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 of both energy supply and use systems and on its performance characteristics.

Notes:

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