Ecological Fiscal Reform and Energy Program
Case Study on Energy Efficiency
Executive Summary and Lessons Learned

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Executive Summary

Introduction

The National Round Table on the Environment and the Economy (NRTEE) has launched a program to examine ecological fiscal reform (EFR) in Canada. The EFR program is examining the potential of fiscal policy to be aligned with other policy tools to achieve economic and environmental objectives. This study is one of three parallel case studies on how fiscal policy can promote the development of renewable energy, hydrogen technologies, and energy efficiency in Canada's industrial sector. This study explores the role of fiscal policy in achieving long-term reductions in energy-based carbon emissions through energy efficiency.

Background

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

Energy efficiency refers to the relationship between the output (service) of a device or system and the energy put into it. Improving energy efficiency entails doing more with equal or less energy input. Energy efficiency analysis can be applied to industrial activities at many different points; it can be applied to energy-using equipment, major industrial processes, energy supply, delivery networks, and even urban form and infrastructure. *Energy intensity* is a common indicator in energy analysis, since energy efficiency cannot be measured directly at an aggregate level. Energy intensity is defined in units of energy per unit of output. It can be measured in physical units or in monetary units, in terms of (Gross Domestic Product (GDP).

There are various ways to reduce the *carbon intensity of energy* (tonnes of carbon per gigajoule of energy). Improvements in energy efficiency will only result in lower carbon emissions if the carbon intensity of the energy consumed does not increase significantly — which may well be the case.

In designing policies and assessing their impact and costs, it is useful to clearly distinguish between *actions* and *policy*. An action is a change in acquisition of equipment/technology, rate of equipment use, lifestyle or resource management practices that result in changes net greenhouse gas (GHG) emissions. This study focuses on actions that represent changes in acquisition of technology, but also considers these actions in relation to other actions to decarbonize **.**

In describing carbon-based emissions for the industrial sector, it is useful to use the concepts of *direct* and *indirect emissions*. The term direct emissions is used to describe emissions that are produced by a source controlled by the sector, while the term indirect emissions describes emissions that result 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 like co-generation.

Industry Sector Characteristics

The industrial sector is the largest GHG-producing sector in Canada. It produced 237 Mt of carbon dioxide emissions (CO_2e) in 2000, the majority of which were a result of energy consumption. Energy consumption reflects levels of activity, industry structure and the energy efficiency of energy used, while GHG emissions also reflect the intensity of energy used and process-related emissions. Energy use is particularly heavy in primary industries, such as iron and steel, pulp and paper, metal smelting, petroleum refining, chemical manufacturing and industrial minerals, which produce primary goods for final consumption, within or outside Canada. These industries account for more than 80 percent of total industrial energy consumption. The remaining industries are numerous and diverse (food processing, transportation equipment manufacturing, etc.), but use relatively little energy — 15 percent of the total industrial energy consumption, although they are responsible for 60 percent of industrial economic output.

In 2002, energy intensity (relative to GDP) in Canadian industry had generally decreased to a level 27 percent below 1990 levels. This decline in energy intensity is due 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 volume of production. Between 1995 and 2001, the share of economic activity of the less-energy-intensive industries increased, while the share represented by the more-energy-intensive (primary) industries decreased, resulting in a decline in total energy use of 11.5 percent relative to 1995 levels.

However, trends based on economic output cannot provide an accurate picture of energy intensity because monetary units are affected by so many other factors, such as costs of labour or selling price. Energy intensity trends measured in terms of physical units suggest a smaller decline in energy intensity than trends measured in terms of GDP.

Industry managers are considered to be more motivated to minimize costs of energy consumption than are residential and commercial consumers. As such, many establishments may have already pursued several cost-effective actions to reduce energy consumption, particularly when energy costs make up a high percentage of total production costs. Some sectors are more limited in their ability to reduce energy use, in particular, fossil fuel use, due to their location. Nevertheless, the potential for improvements in energy efficiency can still be significant, particularly for some industry sectors.

Current Policy

Current policies related 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. In Canada, early programs targeted at industry include Natural Resources Canada's (NRCan's) Canadian Industry Program for Energy Conservation (CIPEC) and the Industrial Energy Innovators Initiative. Since then, industrial energy efficiency has become closely related to climate change policy initiatives. It has figured strongly in voluntary efforts by industry to curtail their GHG emissions as part of the Voluntary Challenge and Registry (VCR), 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 its *Climate Change Plan*, in which it established an approach to address GHG emissions from large industrial emitters.

Included in the federal budget in 2003, which followed up on the *Climate Change Plan*, were budget allocations to provide long-term support for research and development (R&D) of emerging energy-efficient technologies ($250 million), and to subsidize industrial energy efficiency actions and carbon offsets ($303 million). R&D of advanced end-use efficiency technologies is one of the five priority areas in the area of science and technology. Besides 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.

Fiscal policies may provide an uneven 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-percent 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 to encourage energy efficiency as part of the personal or corporate income tax system.

Most programs by government and utilities to promote energy efficiency by industry are part of broader policies that include elements of information provision. For instance, the *Climate Change Plan* seeks to develop a tradable permit system to provide an incentive for decarbonization by large industrial emitters. The government is currently considering how design of such a system would best develop this market. However, a pilot 'voluntary' emissions trading system, the Pilot Emission Removals, Reductions and Learning Initiative (PERRL), is currently operating.

As noted above, the *Climate Change Plan* provides for direct funding for R&D into energy-efficient technologies. The Office of Energy Research and Development (OERD) coordinates federal energy efficiency R&D activities and directs the Program of Energy Research and Development (PERD), which includes a strategy for energy efficiency in industry. NRCan's CANMET Energy Technology Centre (CETC) and Innovative Research Initiative (IRI) for GHG mitigation also fund research programs that include energy efficiency projects. Overall, Canada has favoured fiscal incentives over direct funding to support energy efficiency R&D, and provides one of the most generous systems among all Organisation for Economic Co-operation and Development (OECD) countries.

Energy Efficiency Opportunities

Energy use in industry can be understood in terms of g*eneric or auxiliary energy 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 co-generators); lighting; heating, ventilating and air-conditioning (HVAC) systems; and electric motor systems (pumps, fans, compressors and conveyors). Significant reductions in energy use can occur through improvements to the energy efficiency of 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 improvements in energy efficiency can also occur by using co-generators rather than simple steam boilers. Although some potential exists to improve the efficiency of electric motors, there is greater potential to improve the efficiency of equipment driven by them — pumping, air displacement, compression, conveyance and other types of machine-driven equipment — as well as the demands for these later energy services.

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, industries that produce materials such as iron, steel and other primary metals, or building materials, are characterized by heavy use of direct heat in processing. Other industries are very dependent on electricity to drive large motors, or to generate or purify chemicals or metals in electrolytic cells. Energy-intense industries typically have fewer options for energy (or CO_2) reduction, because the processes are straightforward and energy-intense, compared to industries that may employ many tens or hundreds of smaller processes, each requiring only a small amount of energy to transform semi-finished products into manufactured products.

Many energy-efficient technologies are currently available; they may have been commercially available for some time, but could still make considerable inroads. 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 aluminium 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 results in changing the way people think about the product or process. Incremental innovation occurs as small and gradual innovation in existing technologies.

Challenges to Adoption

During the past 30 years, research has shown that consumers and establishments routinely forego readily apparent cost-effective investments in energy efficiency. They appear to dismiss future savings from energy-efficiency investments at rates well in excess of market rates for borrowing or saving. This has often been referred to as the ‘energy efficiency gap,’ and is a critical challenge this case study addressed in evaluating the economic cost and potential for EFR policy to influence the adoption of energy-efficient technologies.

Understanding the potential for industrial establishments to make improvements in energy efficiency is a complex task. To begin with, new technologies carry with them a greater potential for failure than tried-and-true methods. The presence of uncertainty can be a significant barrier to investing in new, energy-efficient technologies. Furthermore, acquisition, installation and operating costs will vary according to location, and some equipment will be more appropriate in some situations than in others.

The impact of adopting energy efficiency opportunities on aggregate energy consumption and on decarbonization is also a complicated matter to understand. First, while improved energy efficiency can result in decarbonization, one must keep in mind that primary fuels differ substantially in terms of their carbon emissions. Significant ‘second-order’ feedbacks would also 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. Where energy-efficient technologies achieve substantial market penetration, the resulting lower cost of energy services elicits a *rebound effect* of increased demand for energy services and thus greater energy consumption.

Modelling Methodology

A variety of energy/economics models can be used to develop a baseline for GHG emissions in the industrial sector, and to estimate how changes in energy efficiency, fuel type or emissions-control technologies could lead to different levels of GHG emissions. The Canadian Integrated Modelling System (CIMS) model, developed by the Energy and Materials Research Group (EMRG) at Simon Fraser University, is used in this analysis. In the CIMS model, unique technologies, processes and technological interactions in the Canadian industrial sector are represented in detail; it is therefore possible to explicitly explore the relationship between the underlying process and technology structure of the sector relative to aggregate energy use and GHG emissions. The CIMS model also portrays decisions about acquisition of technology based on a combination of financial costs and behavioural parameters projected from empirical studies of consumer and business decision making. This approach is preferred to one that uses a single, *ex ante* (anticipated) estimate of financial cost as the basis for choosing between competing technologies, which does not address the complexities of decision making, as 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.

Model Overview

A CIMS simulation model 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 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 new investment, based, not only on the minimization of annualized life-cycle costs, but on costs associated with risks of failure, as well as on consumers’ (non-financial) preferences. The model allocates market shares among technologies probabilistically to reflect varying acquisition, installation and operating costs and equipment. Competition occurs in each time period 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 choice of technologies in the energy demand models and prices in the energy supply models, until prices (supply) and demand have stabilized at an equilibrium.
5. *Equilibrium of Energy Service Demand*: Once the energy supply-and-demand cycle has stabilized, this step adjusts demand for energy services based on price elasticities. If this adjustment is significant, the whole system is re-run from Step 1 with the new demands.

6. *Output*: Total energy, emissions and cost information can be derived from the final model results, since each technology has net energy use, net energy-related 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 energy efficiency, fuel type or emissions-control technologies can lead to different levels of GHG emissions in the industrial sector.

The Baseline Scenario

The baseline scenario is developed using Steps 1 to 3 and Step 6 described above (Step 5 is not used in the case study). The baseline forecast period covers the period between 2000 (CIMS base year) and 2030. For this study, assumptions regarding economic growth (more specifically, region-specific growth rates for GDP from 2000 to 2020) and future energy prices are adopted from *Canada's Emissions Outlook: An Update* (CEOU), by Natural Resources Canada (NRCan). For the simulation past 2020, annual price and growth trends for the period from 2015 to 2020 are assumed to continue between 2020 and 2030. The emissions forecast generated by CIMS is calibrated to the official GHG forecast (as of December 2003), formulated since release of CEOU.

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

Table 1: Baseline Forecast of GHG Emissions and Energy Consumption for Canada (Industrial Sector)

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

Alternative Scenarios

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

Emerging technologies have a greater ability to gain market acceptance in a 25-year time frame. 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 to reflect a more targeted R&D and commercialization effort.

Simulating a carbon emission shadow price in the industry sector sub-models indicates the potential for emissions reduction from energy efficiency actions. This type of simulation reveals the potential for reductions in emissions 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 formulation of an alternative GHG scenario (as simulated by a shadow price for GHG), which would indicate what role investments in energy efficiency could play in decarbonization, amongst other options. The choice of carbon prices reflects a relatively modest ‘achievable potential’ that could be influenced by EFR policy.

The Low Carbon I and II scenarios shown in Table 2 below result in reductions of 46 Mt CO_2e and 58 Mt CO_2e, respectively, by 2030. Direct emissions make up most of these reductions, although the response of indirect emissions to the imposition of a shadow price is stronger than the response of direct emissions (indirect emissions decline by 53–62% in 2030, while direct emissions only decline by 5–7%). Actions behind this strong indirect response include the greater adoption of co-generation 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 reductions in emissions due to improved energy efficiency.

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

	Year			
	2000	**2010**	**2020**	**2030**
Total GHG Emissions (Mt CO_2e)				
Business As Usual (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 (petajoules) (PJ)				
BAU	4239	5030	5783	6579
Low Carbon I	4239	4822	5537	6298

Low Carbon II	4239	4818	5497	6232

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. The alternative scenarios do not elicit the same effect.

Economic and Policy Analysis

The alternative scenario simulations revealed that up to 58 Mt CO2e could be reduced by 2030, brought about in part by actions that lead to greater energy efficiency by industry. We calculate *ex ante* financial costs of the scenarios (as shown in Table 3), representing the difference in the net present value of capital, energy and operating and maintenance costs between the baseline and each alternative scenario, in 2004 (Cdn $ 2000) discounted at a social discount rate**,** for the period from 2005 to 2030. All industry sub-sectors show negative costs, because the value of energy savings is greater than any increase in up-front capital costs of 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$_2$e.

Table 3: ***Ex ante*** **(Anticipated) Financial Costs for the Period 2005 to 2030 ($ billions)**

	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: These figure are reported in Cdn $ 2000.

Pursuing decarbonization by targeting industrial energy efficiency may yield other benefits aside from reducing GHG emissions and the ecological harm associated with global warming. First, declining energy intensity will reduce energy costs per unit of service output, so that economic growth will be less constrained by future energy costs. Second, innovation and more energy-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.

EFR, as defined by NRTEE, is a broad approach that can employ suites of instruments to support the shift to sustainable development, as described in the report, *Toward a Canadian*

Agenda for Ecological Fiscal Reform: First Steps. The common purpose of these instruments is to provide disincentives – by incorporating environmental costs into the tax structure — or by providing incentives to reward more sustainable practices by producers and consumers who alter their decisions and behaviour. 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.

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 when it is burned.[1] However, because the carbon price was applied to all GHG emissions in the industry sub-sectors, 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 industrial sector encourages each sub-sector to increase or decrease its emissions-reduction efforts until each is facing an identical incremental cost for the next unit of reduction in emissions.

Revenues from environmental taxes can be used for many purposes; for instance, they may be used as part of general revenues, ear-marked to specific environmental projects, made available as rebates, or used to reduce other taxes. Each option represents different costs for different members and sectors of the economy. In practice, environmental tax design has addressed concerns about equity and competitiveness by using a combination of refunds, differentials in the tax rates applied to industry and households, and tax exemptions, in various degrees.

Tradable Permits (Market-Oriented Regulation)

An important area of policy innovation has been in the development of market-oriented regulation, which, like a GHG tax, allows individual flexibility in terms of achieving a compulsory limit or requirement. Unlike traditional command-and-control regulation, the choice to participate (whether in reducing emissions, acquiring the designated technology or paying others to do so) is at the discretion of individual establishments or households.

The model results suggest an Emissions Cap and Tradable Permit (ECTP) system could be applied to all industry, with auctioned permits and caps equivalent to the emissions levels reported in the alternative scenarios (i.e., 407 Mt CO_2e in 2030 in the Low Carbon I scenario, and 395 Mt CO_2e in the Low Carbon II scenario (Table 2). The tradable permit prices correspond with the shadow prices applied in those scenarios ($15 / tonne CO_2e and $30 / tonne CO_2e, respectively).

Market-oriented regulation can also be applied in different contexts — for instance, by specifying the desired market outcome, rather than the environmental outcome. A considerable range of design options is also possible with ECTP systems.

Subsidies

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[1] A *CO_2 tax* is specified per tonne of CO_2 instead of carbon emitted. 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.

EFR can support decarbonization through removal or redirection of existing subsidies, and through 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 greater adoption of energy-efficient technologies and long-term R&D for new energy-efficient technologies.

The alternative scenarios suggest a subsidy program could be *perfectly designed to target cost-effective actions*. The size of the incentive required to target such actions is estimated by calculating the *perceived private costs* of the alternative scenarios (shown in Table 3). The estimates are made by calculating the area under a curve that plots cumulative reductions in emissions 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 costs of the required subsidies program to have firms undertake actions they would not otherwise undertake (their perceived private costs).

Table 4: Costs of Incentives (Perceived Private Costs) 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: These figures are reported in Cdn $ 2000.

These estimates do not include expenditures required to subsidize firms that would have undertaken to purchase energy-efficient technologies in the baseline scenario (‘free-riders’). If this effect is incorporated, the cost of the subsidy program would be greater than that shown in Table 4. Evaluations of energy efficiency incentive programs suggest that the share of free-riders can be significant, often in the order of 85 percent of program recipients. Subsidy programs can therefore require relatively large public expenditures per unit of effect. Furthermore, the administrative costs of program delivery and the transaction costs of establishments’ participation, which depend significantly on specific measure design, have not been considered in the figures shown in Table 4.

Potential avenues for new subsidies may include direct financial transfers (as grants or preferential / low-interest loans) or tax incentives, such as the expansion of the special CCA (Class 43.1) to include more energy-efficient technologies. The use of revolving loans programs has also gained popularity in the commercial / institutional sector in Canada and could be applied in the industrial context.

The same monetary value of a subsidy will have a different effect depending on program design. Financial incentives can be directed to reduce the up-front or the operating costs of energy-efficient investments, and can be based on prescriptive or custom (performance-based) criteria. Subsidies directed at up-front capital costs recognize that the higher capital cost of energy-efficient technologies can be a deterrent to investment. Measures that target up-front costs are not based on the actual ability of the investment to meet the desired policy objective. Performance-based subsidies can be more flexible in allowing firms to meet ‘demonstrated’ improvements in energy efficiency or reductions in carbon emissions.

The design of subsidies must also take into consideration differences in how establishments may respond to incentives. Small and medium-sized enterprises may not have the same access to capital as large enterprises to make use of tax incentives; they may find loans, loan guarantees, and interest-rate subsidization programs, along with private sector support mechanisms such as energy performance contracts, leases and venture capital, more valuable than a tax instrument.

Policy Design Considerations

The choice of EFR policy tools and the ultimate design of a policy package involve many considerations. For instance, what may appear to be most economically efficient or effective in realizing environmental benefits may be difficult to achieve from the standpoint of administrative feasibility or political acceptability. The following section offers a general discussion of how EFR policy tools relate to common policy design criteria.

Effectiveness at Reaching Environmental Targets

Because an ECTP system specifies the level of emissions reduction, this type of policy tool would be most effective in realizing the environmental objective. In the case of a subsidy, sufficient reductions may not be realized if the subsidy is too low, or is 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 and encouraging long-term decarbonization of the energy system.

Economic Effectiveness

The imposition of a uniform carbon tax or an ECTP system is theoretically the most efficient way of achieving the decarbonization objective because they encourage the least expensive reductions to be undertaken first, throughout the economy. Subsidies may be captured by firms with higher costs of emissions reduction (unless tradeable permits are allocated via a bidding process), which could require large public expenditures per unit of effect, due to 'free-riders.' Subsidies also require revenues be raised elsewhere in the economy, which can produce dead-weight losses.

Administrative Feasibility

EFR policy design should consider the burden on firms, either in complying with a tax (or market-oriented regulation) or in applying for grants and submitting tax-credit claims. This work may be particularly burdensome for smaller firms. Availability of data is also necessary for proper monitoring and program evaluation, and data collection should focus on actual impacts on carbon emissions, rather than on indicators like the number of applications and recipients of funding, etc.

Political Acceptability

Concern about political acceptability has limited the use of such policy tools as a GHG tax to achieve decarbonization, even in countries where such a tax is currently applied. The use of subsidies avoids imposing costs on establishments; instead, it enhances the prospect for energy-efficient technologies to compete. However, since the government must acquire the funds from elsewhere in the economy, the subsidy option has not escaped criticism. (Tax incentives are a less visible form of public subsidy.)

Industry groups have generally argued for voluntary and tax-incentive approaches in climate change policy, asserting that measures to reduce GHG emissions must be consistent with the broad fiscal and economic direction for the country.

Distributional and Competitiveness Impacts

With a GHG tax or ECTP, participation is at the discretion of individual establishments. Competitiveness impacts will arise if the policy imposes different levels of costs on competing establishments, because different countries have different policies, because regulations are different among domestic establishments, or simply because different establishments use energy of different carbon intensities, have different possibilities for substitution or operate on different scales.

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

Technological Innovation

The level of innovation of environmental technologies will be below the theoretical social optimum due to the presence of externalities such as environmental damage. This policy tool attempts to use disincentives such as environmental taxes and market-based instruments to internalize this externality and provide a 'pull' to innovation and deployment. Other policies that support innovation directly by lowering the costs of R&D — for instance, by subsidizing R&D expenditures or by 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 happened anyway and of supporting inappropriate technologies.

Conclusions

The potential for industrial energy efficiency actions to contribute to the decarbonization of the energy system is complex and depends on the degree to which technical potential can be further developed through innovation; the degree to which energy-efficient technologies and habits are 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 means to lower carbon emissions from industrial activities is complicated by the fact that energy efficiency is only one among a number of options that industry can use to reduce carbon emissions.

In forwarding policy recommendations in this case study, it is important to consider the degree to which EFR policy should specifically focus on the promotion of industrial energy efficiency in itself, as opposed to a broader focus on the objective of decarbonization. The simulations in the model scenarios demonstrate that improved energy efficiency in industry is closely interrelated with fuel switching and other means of reducing carbon emissions, suggesting that, to move towards a decarbonized energy system, energy efficiency should be considered among other actions. Focusing on energy efficiency in industry alone as the means to achieve decarbonization may run the risk of orienting incentives towards a direction that is not cost-effective.

While we have described specific policy tools in the context of the modelling results and have noted a number of design considerations for each tool, no one policy tool is superior in its performance against the criteria of environmental effectiveness, economic efficiency, administrative feasibility and political acceptability. Using a portfolio of policy instruments can enable government to combine the strengths, while compensating for the weaknesses, of individual policy instruments. Such a policy package should focus on measures that are politically acceptable today, while nonetheless encouraging technological innovation. Considerable potential exists to use EFR to create conditions under which ‘winners’ can emerge, attract sufficient investment, develop and be widely adopted.

With that potential in mind, we recommend that tradable permits should be emphasized as part of market-oriented regulation in driving fundamental change, and that a complementary role be provided by subsidies that support 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 the relative costs for different sectors and activities in the economy. Nevertheless, the design of any program should realistically assess the impacts and costs (including ‘free-rider’ costs) of incentives. Tax incentives and direct grants should also be designed to minimize government’s role in the selection of energy-efficient technologies by being performance-based; they should also minimize transaction costs of participation.

Canada has a history of policy support in promoting energy efficiency through information and awareness programs, and of subsidies for R&D. Voluntary programs not only have laid the groundwork for ERF policies in stimulating awareness of decarbonization opportunities, but also provide needed complements to any new EFR policy initiatives that are developed. There may be a role, too, for EFR to connect with traditional command-and-control policy. While EFR policy can drive technological gains, standards that phase out the sale of inefficient equipment can serve to consolidate change.

Lessons Learned

- While the greater diffusion of technologies already in the market targets decarbonization of the energy system immediately, it is also important to consider continued innovation and commercialization of energy-efficient technologies in the long term.
- Energy efficiency is not necessarily the most cost-effective option to reduce carbon emissions in the industry sector. Other means include: fuel switching; reducing fugitive emissions; reducing process emissions; and capture and storage of CO_2. In the modelling results, while a significant share of reductions in emissions occurred through increased energy efficiency, considerable reductions also occurred through other means. Focusing on energy efficiency alone risks orienting efforts to achieve decarbonization in industry towards an option that is not the most cost-effective.
- Promoting greater energy efficiency is not a new policy objective; 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. Of significant note is research that shows an ‘energy-efficiency gap’ between the levels of investment in energy efficiency needed for cost-effectiveness and the lower levels of investment that are actually being made. This gap is a chief focus of this case study, which attempts to estimate alternative carbon emissions scenarios, as well as to evaluate the related economic costs and potential for EFR policy to influence the adoption of energy-efficient technologies. This is an emerging analytical area that has only recently been incorporated into technology simulation modelling.
- Technical gains in energy efficiency do not translate directly into reduced carbon emissions. The potential for industrial energy efficiency actions to contribute to the decarbonization of the energy system is a complex matter, based on the following factors:
    1. *The degree to which technical potential can be further developed* – Our energy system is far from being at its maximum technical potential for second-law efficiency, but how and when will new technologies and systems be developed?
    2. *The degree to which this potential is adopted* – Mature energy-efficient technologies that appear to be cost-effective are available, but have not penetrated 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* – The lower cost of energy services from investments in energy efficiency elicits a *rebound effect* of increased demand for energy services and thus creates greater energy consumption.
    4. *The carbon intensity of conserved energy* – Reductions in carbon emissions depend on the carbon intensity of energy; for instance, the impact of improved energy-efficient end-use will be considerably different depending on whether that electricity was generated by hydroelectric power or thermal generation.

- The modelling work in the case study sought to analyse complex relationships involved in the carbon intensity of conserved energy. Forecasting trends based on models is inevitably an uncertain endeavour, since models cannot possibly incorporate all information and relationships of potential importance, or accurately project all factors.[2] Still, the modelling results can suggest the potential of current and emerging technologies to harness energy efficiency; the role of energy efficiency in industry among other options to decarbonize; and the relative potential for decarbonization among industry sub-sectors.
- Modelling the long-term potential for fiscal policies that will increase adoption of energy efficiency suggests the need for a dynamic analysis that is capable of considering how technological innovation and perhaps even consumers' and establishments' preferences may be influenced by these policies. That kind of analysis was beyond the capability of this case study, but is emerging as a new direction for research.
- The results of the alternative scenarios reflect certain assumptions about carbon prices — different prices for carbon would have revealed different potentials for reductions. While the potential for decarbonization would appear to be greater, the model tended to show diminishing returns in decarbonization (lower additional reductions in emissions for each additional $ / tonne of carbon).
- The long-term potential for energy efficiency to contribute to a decarbonized energy system is also constrained by what it will cost to produce a clean energy supply. The price of energy represents an upper limit on the potential of energy efficiency to contribute to reductions in carbon emissions.

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