# Ecological Fiscal Reform and Energy
## *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. EFR is the systematic alignment of fiscal policy with other policy tools for the achievement of simultaneous economic and environmental objectives. This study explores the role of fiscal policy in promoting the energy efficiency of Canada's industrial sector in a way that leads to long-term reductions in energy-based carbon emissions. This study is one of three parallel case studies, which seek to deliver pragmatic, policy-relevant, recommendations on how fiscal policy can promote the development of renewables, hydrogen, and industrial energy efficiency.

**Deleted:** energy

## Background

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

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

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

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

In describing carbon-based emissions for the industry sector it is useful to use the concepts of direct and indirect emissions. 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 cogeneration.

## Industry Sector Characteristics

The industrial sector, which includes all mining and manufacturing activities, is the largest GHG-producing sector in Canada. It produced 237 Mt $CO_2e$ of direct GHG emissions in 2000, the majority of which are energy consumption based. Energy consumption reflects activity levels, industry structure and the energy efficiency of energy use, while GHG emissions also reflects the GHG intensity of energy used and process-related emissions. Energy is particularly critical in the production of basic industrial products, which are used to produce goods for final consumption, either within or outside of Canada. These primary product industries account for more than 80% of total industrial energy consumption. They include industries such as iron and steel, pulp and paper, metal smelting, petroleum refining, chemical manufacturing and industrial minerals. The remaining industries, which are numerous and diverse (food processing, transportation equipment manufacturing, etc.) use relatively little energy, 15% of the total, but are responsible for 60% of industrial economic output.

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

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

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

## Current Policy

Current policies relating to industrial energy efficiency have their roots in the 1970s. The oil price shock of 1973 made energy security a high-priority concern and led to, among other responses, the development of numerous energy efficiency programmes internationally, and within Canada, such as *The 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*, which was initially launched by government to encourage private and public sector organizations to voluntarily limit their net GHGs. Just prior to ratifying the Kyoto Protocol in December 2002, the Government of Canada released the Climate Change

Plan for Canada in which it established an approach to address 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 of emerging energy efficient technologies ($250 million), and to subsidize industrial energy efficiency actions and carbon offsets ($303 million). Research and development of advanced end-use efficiency technologies is one of the five priority areas in science and technology. Outside of federal policy and initiatives, provincial governments and crown utility corporations have also been active in promoting energy efficiency in industry and in climate change policy in general.

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

Outside of the tax system, a few programs by government and utilities provide incentives to promote energy efficiency by industry. Most programs are part of broader policies that include elements of information provision. The *Climate Change Plan for Canada* seeks to develop a tradable permit system to provide an incentive for decarbonisation by large industrial emitters. The government is currently considering how design of its permit 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 research and development (R&D) into energy efficiency technologies. The Office Of Energy Research and Development (OERD) coordinates federal energy research and development activities and directs the Program of Energy Research and Development (PERD) which includes a strategy for energy efficiency in industry. The Canmet Energy Technology Centre (CETC) and the Innovative Research Initiative (IRI) for Greenhouse Gas Mitigation also fund research programs that include energy efficiency projects. Overall, Canada has favoured fiscal incentives over direct funding to support research and development (R&D), and provides one of the most generous systems among all OECD countries.

### Energy Efficiency Opportunities

Energy use in industry can be understood in terms of generic or auxiliary services and unique processes. Generic or auxiliary energy services are those that are not specific to a particular industry. They fall into four general categories: steam generation systems (boilers and co-generators), lighting, HVAC systems, and electric motor systems (pumps, fans, compressors or conveyors). Significant reductions can occur through energy efficiency improvements to steam generation systems and to electric motors and their attached auxiliary devices. The efficiency of steam generation varies greatly depending on boiler design, age, and fuel used. Substantial energy efficiency improvements can also 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 efficiencies of equipment driven by them - pumping, air displacement, compression, conveyance and other types of machine drive, 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 materials production industries, such as iron, steel, and other primary metals and building materials production, are characterized by heavy use of direct process heat. Other industries are very dependent on electricity to drive large motors or to generate or purify chemicals or metals in electrolytic cells. Energy intense industries have typically fewer options for energy (or $CO_2$) reduction because the processes are straightforward and energy-intense compared to industries where many tens or hundreds of processes, each requiring only a small amount of energy, transform semi-finished products into their final form.

Many energy efficient technologies are available currently, and may have been commercialized for some time, but still could make considerable inroads. Others are poised to emerge and are currently at demonstration stages or have been applied in a relatively narrow niche (i.e. direct reduction in iron and steel). Still others have not been technically realized and are the subject of active research and development programs (i.e., inert anodes/wetted cathodes in aluminium electrolysis). Technological innovation may be either radical (disruptive) or incremental. Radical technology 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

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

Understanding the potential for firms to make energy efficiency improvements is complex. New technologies carry a greater potential for failure. When making irreversible investments that can be delayed, the presence of this uncertainty can lead to a significant investment hurdle rate. Also, different consumers in different locations will face varying acquisition, installation and operating costs, and equipment will be more appropriate in some situations than others.

Understanding the impact of adopting energy efficiency opportunities on aggregate energy consumption and on decarbonisation is complicated by several factors. First, pursuing energy efficiency can result in decarbonisation, but one must keep in mind that primary fuels differ substantially in terms of their carbon emissions. There are also significant ‘second order’ feedbacks that would 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 impact the demand for electricity, with potential price impacts that would affect energy-related decisions throughout the economy. In cases where energy efficient technologies achieve substantial market penetration, the resulting lower cost of energy services elicits a *rebound effect* of increased energy service demand and thus greater energy consumption.

## Modelling Methodology

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

### *Model overview*

A CIMS simulation involves six basic steps.

1. *Assessment of Demand*: Technologies are represented in the model in terms of the quantity of service and/or product they provide (ie. tonnes of paper produced). A forecast of service growth drives the model simulation in five year increments.
2. *Retirement*: In each future period, a portion of the initial-year's technology stock is retired based on age. The residual technology stocks in each period are subtracted from the forecast energy service demand.
3. *New Technology Competition/ Retrofit Competition*: Prospective technologies compete for the new investment required to meet service demand based on the minimization of annualized life cycle costs that include identified differences in non-financial technology preferences and failure risks. The model allocates market shares among technologies probabilistically to reflect varying acquisition, installation and operating costs and equipment. In each time period, a similar competition occurs prior to new stock purchases to simulate retrofitting of residual stock.
4. *Equilibrium of Energy Supply and Demand*: In each future time period, a cycle occurs between technology choice in the energy demand models and technology choice and energy prices supply models, until prices and demand have stabilised at an equilibrium.
5. *Equilibrium of Energy Service Demand*: Once the energy supply and demand cycle has stablized, this step adjusts demand for energy services based on price elasticities. If this adjustment is significant, the whole system is rerun from step 1 with the new demands.

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

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

**The Baseline Scenario**

The baseline scenario is developed using the CIMS model according to the simulation steps 1 - 3, and 6 described in the preceding section (Step 5 is not used in the case study). The baseline forecast period covers between 2000 (CIMS base year) and 2030. For this study, assumptions regarding economic growth (more specifically region-specific growth rates for GDP for 2000 to 2020) and future energy prices are adopted from Canada's Emissions Outlook: An Update (CEOU). For the simulation past 2020, annual price and growth trends of the 2015-2020 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), which was formulated since the release of the CEOU.

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

**Table 1 Baseline Forecast of GHG Emissions and Energy Consumption for Canada.**

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

**Alternative scenarios**

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

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

Simulating a carbon emission shadow price in the industrial sector sub-models indicates the emission reduction potential from energy efficiency actions. This type of simulation reveals the potential for emission reductions that could occur from energy efficiency actions up to a specified marginal abatement cost for carbon. This methodology is built on the principle that the goal (decarbonisation) would drive the formulation of an alternative GHG scenario (as simulated by a shadow price for GHG), which would indicate what role energy efficiency investments could play in decarbonisation 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 result in GHG reductions of 46 Mt $CO_2$e and 58 Mt $CO_2$e by 2030. Direct emissions make up most of these emission reductions, though the response of indirect emissions to the imposition of a shadow price is stronger than the response of direct emissions (indirect emissions decline by 53-62% in 2030, while direct emissions only decline by 5-7%). Actions behind this strong indirect response include the greater adoption of cogeneration systems and actions that improve the overall efficiency of auxiliary motor systems. The metal smelting and refining sector, petroleum refining, and iron and steel sub-sectors contribute the most emission reductions due to improved energy efficiency.

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

| | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| **Total GHG Emissions (Mt $CO_2$e)** | | | | |
| **BAU** | 288 | 343 | 396 | 453 |
| **Low Carbon I** | 288 | 322 | 365 | 407 |
| **Low Carbon II** | 288 | 316 | 355 | 395 |
| **Direct GHG Emissions (Mt $CO_2$e)** | | | | |
| **BAU** | 237 | 307 | 358 | 407 |
| **Low Carbon I** | 237 | 292 | 339 | 386 |
| **Low Carbon II** | 237 | 293 | 335 | 378 |
| **Indirect GHG Emissions (Mt $CO_2$e)** | | | | |
| **BAU** | 50 | 36 | 38 | 46 |
| **Low Carbon I** | 50 | 29 | 26 | 22 |
| **Low Carbon II** | 50 | 23 | 20 | 17 |
| **Energy (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 incorporate this 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* (expected) financial costs of the scenarios (shown in Table 3), which represent the difference in the net present value of capital, energy and operating and maintenance costs in 2004 (Cdn $ 2000) discounted at a social discount rate, for the period 2005-2030 between the baseline and each alternative scenario. All sub-sectors show negative costs because the value of energy savings are greater than any increase in upfront capital costs in 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 Financial Costs for 2005 – 2030 ($2000 billion)**

| | Low Carbon I | Low Carbon II |
|---|---|---|
| **Chemical Products** | -4.98 | -4.04 |
| **Coal Mining** | -0.99 | -2.19 |
| **Industrial Minerals** | -1.16 | -2.08 |
| **Iron and Steel** | -1.84 | -1.93 |
| **Metal Smelting and Refining** | -1.42 | -1.76 |
| **Mining** | -0.26 | -0.59 |
| **Other Manufacturing** | -1.92 | -2.75 |
| **Petroleum Crude Extraction** | -0.04 | -0.03 |
| **Petroleum Refining** | -0.19 | -0.38 |
| **Pulp and Paper** | -3.39 | -4.80 |
| **Natural Gas Industry** | -1.45 | -4.32 |
| **Total** | **-17.64** | **-24.87** |

Note: These figure are reported in $2000.

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

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

### *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 emission emitted when it is burned.[1] However, because the carbon price was applied to all GHG emissions represented 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 industry sector promotes each sub-sector to increase or decrease their emission reduction efforts until each is facing the identical incremental cost for the next unit of reduction.

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

### *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 manner of participation is at the discretion of the firm or household (whether to reduce emissions or acquire the designated technology, or pay others to do so).

The model results suggest an emissions cap and tradable permit (ECTP) system applied to all industry with auctioned permits, with a cap equivalent to the emission levels reported in the alternative scenarios – 407 Mt $CO_2e$ in 2030 in low carbon I, and 395 Mt $CO_2e$ in low carbon II (Table 3-2). The tradable permit prices correspond with the shadow prices applied in those simulations (\$15 / tonne $CO_2e$ and \$30 / tonne $CO_2e$ respectively).

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

### *Subsidies*

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

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[1] A *$CO_2$ tax* is specified per ton of $CO_2$ emitted instead of carbon. It can be easily translated into a carbon tax – 1 tonne of carbon corresponds to 3.67 tonnes of $CO_2$. A GHG tax covers other GHGs, and is measured in tonnes of $CO_2e$.

The alternative scenarios could suggest the impact of a subsidy program *that is perfectly designed to target cost-effective actions*. The size of the incentive required to target the actions inherent in the model simulation is estimated by calculating the perceived private costs of the alternative scenarios (shown in Table 3). The estimates are made by calculating the area under a curve which plots cumulative emission reductions against rising $CO_2e$ shadow prices. The area under the resulting marginal cost curve, up to the shadow price of the alternative scenario, represents the compensation required to have firms undertake actions that they would not have undertaken otherwise (their perceived private cost).

**Table 4: Costs of Incentive (Perceived Private Cost) for 2005 – 2030 ($ billions)**

| | Low Carbon I | Low Carbon II |
|---|---|---|
| **Chemical Products** | 0.528 | 1.284 |
| **Coal Mining** | 0.026 | 0.104 |
| **Industrial Minerals** | 0.047 | 0.194 |
| **Iron and Steel** | 0.070 | 0.158 |
| **Metal Smelting and Refining** | 0.124 | 0.309 |
| **Mining** | 0.015 | 0.036 |
| **Other Manufacturing** | 0.189 | 0.436 |
| **Petroleum Crude Extraction** | 0.101 | 0.093 |
| **Petroleum Refining** | 0.003 | 0.026 |
| **Pulp and Paper** | 0.203 | 0.608 |
| **Natural Gas Extraction** | 0.707 | 1.636 |
| **Total** | **2.012** | **4.885** |

Note: These figures are reported in $2000.

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

Potential avenues for new subsidies may be as direct financial transfers (as grants or preferential/low interest loans) or through tax incentives, for instance the expansion of CCA 43.1 to include more energy efficiency technologies. The use of revolving loans programs have gained popularity in the commercial / institutional sector in Canada, and could be applied in an industry 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 upfront or the operating costs of energy efficient investments, and can be based on prescriptive or custom (performance-based) criteria. Subsidies directed at upfront capital costs recognises that the higher capital cost of energy efficient technologies can be a deterrent to investment. Measures that target upfront costs are not based on the actual performance 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 carbon emission reduction.

The design of subsidies also needs to consider the differences in how firms may respond to incentive tools. Small and medium-sized enterprises which may not have the same access to capital to make use of tax incentives may find loans, loan-guarantees, and interest rate subsidization programs valuable, as well as the support private-sector incentive mechanisms such as energy performance contracts, leases and venture capital.

### Policy Design Considerations

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

#### *Effectiveness at Reaching Environmental Targets*

Because an emissions cap and tradable permit specifies the emission 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 not directed properly. In both cases, poor design can weaken the intended policy impacts. Broad-based economic instruments (taxes and permit systems) are more efficient than subsidies in preventing the rebound effect, encouraging a long-term decarbonization of the energy system.

#### *Economic Effectiveness*

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

#### *Administrative Feasibility*

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

#### *Political Acceptability*

Concern about political acceptability has limited the use of policy tools such as GHG taxes to achieve decarbonisation ends, even in countries where they are currently applied. The use of subsidies avoids imposing costs on firms by instead enhancing the prospect for energy-efficient technologies to compete. However, the government must acquire the funds from somewhere else in the economy and as such they have 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, and that new measures must be situated within an overall framework that is consistent with the broad fiscal and economic direction for the country.

### *Distributional and Competitiveness Impacts*

With a GHG tax or emissions cap and tradable permit, the manner of participation is at the discretion of the firm. Competitiveness impacts will arise if the policy imposes different levels of costs on competing firms, either because countries have different policies, regulations are different among domestic firms, or simply because firms have different specific carbon intensities, substitution possibilities and trade levels.

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

### *Technological Innovation*

The level of technological innovation of environmentally-related technologies will be below the theoretically social optimal in the presence of externalities, such as environmental damages. This argues for the use environmental taxes and market-based instruments that internalize this externality and provide a 'pull' to innovation and deployment. Other policies that support innovation directly by raising the expected private returns by lowering the costs of doing R&D – for instance subsidizing R&D expenditures, encouraging joint ventures – may be most valuable at the earliest stage of deployment. However, subsidies run the risk of supporting of private R&D that would have happened anyway and supporting inappropriate technologies.

## Conclusions

The potential for industrial energy efficiency actions to contribute to the decarbonisation 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 efficiency technology and habits can be adopted; the degree to which this adoption translates into reduced aggregate energy use; and the carbon-intensity of conserved energy. The adoption of energy efficiency as a means to lower energy-based carbon emissions in industry is complicated by the fact that energy efficiency is only one among a number of options that industry can use to reduce carbon based emissions.

In 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, relative to a broader focus on the objective of decarbonisation. The alternative scenario simulations demonstrate that improved energy efficiency in industry is closely interrelated with fuel switching and other means of carbon emission reduction, suggesting that it should be considered amongst other actions to move towards a decarbonised energy system. Focusing on energy efficiency alone as the means to achieving decarbonisation in industry may run the risk of orienting incentives and efforts in 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 optimal in its performance against criteria of environmental effectiveness, economic efficiency, administrative feasibility and political acceptability. Using a portfolio of policy instruments can enable a government to combine the strengths, while compensating for the weaknesses, of individual policy instruments. Such a policy package should focus on measures that might be politically acceptable today while nonetheless influencing technological innovation. Considerable potential exists to use EFR to create conditions under which ‘winners’ can emerge and attract sufficient investment in order to develop and be widely adopted.

With this in mind, we recommend that tradable permits as part of market-oriented regulation should be emphasized in driving fundamental change and that a complementary role can be provided for by subsidies to 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 relative costs in different sectors and activities in the economy. Nevertheless, the impact and cost (including free-rider costs) should be realistically assessed in the design of any program. Tax incentives and direct grants should also be designed to minimize government’s role in picking technologies by being more performance-based, and to minimize transaction costs of program participation.

There is a history of policy support in promoting energy efficiency through information and awareness programs, and in subsidies for research and development. Voluntary programs not only have laid the groundwork for ERF policies in stimulating awareness of decarbonisation opportunities, but also provide needed complements to any EFR new 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 drives technological gains, standards that phase out the sale of inefficient equipment can serve to consolidate change.

## Lessons Learned

- While energy efficiency can be considered as a path towards decarbonization of the energy system that can be targeted immediately through the greater diffusion of technologies already in the market, it is also important to consider how energy efficient technologies can fit into the long-term picture though continued innovation and commercialization.
- Energy efficiency is not necessarily the most cost-effective option available to reduce carbon emissions in the industry sector. Other means include fuel switching, reducing fugitive emissions, reducing process emissions, and in the capture and storage of $CO_2$. While a significant share of the emission reductions occur through increased energy efficiency in the modelling results, considerable reductions also occur through other means. Focusing on energy efficiency alone as the means to achieving decarbonisation in industry may run the risk of orienting incentives and efforts in a direction that is not cost-effective.
- Promoting greater energy efficiency is not a new policy objective, but has been actively pursued across many countries over the past 30 years. Considerable experience can be gained from understanding the success and failures of these efforts. Of significant note is research that shows a 'gap' between levels of investment in energy efficiency that appears cost-effective and the lower levels of investment that is actually occurring. This 'efficiency gap' is a critical issue for this case study, particularly in estimating an alternative carbon emissions scenario, as well as evaluating the economic cost and potential for EFR policy to influence the uptake of energy efficient technologies. This is an emerging analytical area, that has only recently been incorporated into technology simulation modelling.
- Technical energy efficiency gains do not translate directly into reduced carbon emissions. The potential for industrial energy efficiency actions to contribute to the decarbonization of the energy system is complex, and is based on the following four factors.
    1. *The degree to which technical potential can be further developed* – Our energy system is far from its maximum technical potential for second law efficiency, but how and when will technologies and systems be developed?
    2. *The degree to which this potential can be adopted* – Mature energy efficient technologies that appear cost-effective are available but have not transformed the market. To what degree will energy efficient technologies, systems and practices be adopted?
    3. *The degree to which this adoption translates into reduced aggregate energy use* – Lower cost of energy services from energy efficiency investments elicits a *rebound effect* of increased energy service demand and thus greater energy consumption.
    4. *The carbon-intensity of conserved energy* – Reduction in carbon emission will depend on the carbon-intensity of energy. For instance, the impact of improved electrical end-use efficiency will be considerably different based on whether that electricity was generated by hydropower or thermal generation.

- The modelling work in the case study sought to analyze complex relationships noted in the preceding point. Models are inevitably wrong in that they cannot possibly incorporate all information and relationships of potential importance, nor accurately depict all uncertainties.[2] Still, one can look to the modelling results to suggest the ability to harness the energy-efficiency potential of current and emerging technologies, the role energy-efficiency can play among other options to decarbonate in industry, and the relative decarbonization potentials between sub-sectors.
- Modelling a long-term potential for policy to increase energy efficiency adoption suggests a dynamic analysis that can consider how technological innovation and perhaps even consumer and firm preferences may be influenced by policy. This was beyond the analytical capability in the case study, but is an emerging research direction that should be noted.
- The results of the alternative scenarios reflect the magnitude of carbon price that was modelled – i.e. a $250 price for carbon would have revealed a different reduction potential. While the decarbonization potential would be greater, higher carbon prices tend to show diminishing decarbonization returns (less additional emission reductions for each additional $/t carbon).
- The long-run potential for energy efficiency to contribute to a decarbonized energy system will be constrained by what it will cost to produce clean energy supply. Energy price represents an upper bound constraint on the contribution of energy efficiency.

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