The Macroeconomic Impacts of Fiscal Policy Promoting Long-term Decarbonisation in Canada

FINAL REPORT

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Executive Summary

In April 2003, the National Roundtable on the Environment and the Economy (NRTEE) launched Phase II of its Ecological Fiscal Reform (EFR) program. The objective of Phase II 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". This report provides a qualitative analysis the possible macroeconomic impacts of fiscal policies arising out of three case studies prepared for the NRTEE seeking to promote long-term "decarbonisation" through increased use of hydrogen, energy efficiency and renewable power. The findings of this study will be incorporated into the NRTEE's final State of the Debate report.

What are macroeconomic impacts?

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

One of the most comprehensive and common measures of macroeconomic impacts of policy is the percentage change in Real Gross Domestic Product (GDP) relative to a Reference Case or Business as Usual (BAU) Case without the policy. However, there are shortcomings with using GDP as an indicator of long-term effects and overall societal well-being. For example, this measure does not include changes in non-marketed goods and services such as the quality of goods, environmental amenities, and leisure. Changes in real GDP can also mask distributional effects – i.e., differences in incidence of costs and benefits among different sectors, regions, firms, and individuals. Finally, long-term impacts on GDP are difficult to predict and they are sensitive to many different and controversial assumptions such as the rate of technological change with and without the policy. For these reasons, many impact studies report effects on both short- and long-term growth of GDP, together with distributional consequences and effects on specific determinants of long-term growth or structural change such as the rate of technological change (innovation) and competitiveness. Some studies also consider other non-market costs and benefits such as effects of energy or carbon policies on local air quality.

How do economists evaluate macroeconomic impacts?

The macroeconomic impacts of energy and GHG policies are very uncertain. Impact studies conducted after the implementation of policies are complicated by the difficulty of unraveling the effects of a specific policy or instrument from the changes in a multitude of other factors that may be affecting the overall economy. Estimating macroeconomic impacts prior to the implementation of a policy requires complex models and numerous assumptions.

There are numerous competing models for assessing macroeconomic impacts and different models yield different results depending upon model structure and input assumptions. Even using the same model, the magnitude and duration of macroeconomic impacts associated with the same mix of policies can also vary across economies and over time as a result of differences in initial resource endowments, economic structure, or labour and capital markets, among other factors.

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

What do we know about the general impacts of fiscal instruments?

In describing and comparing the possible macroeconomic impacts of fiscal instruments, it is useful to group instruments into three broad categories, reflecting their combined effect on government finances and industry costs:

1) *Revenue-raising instruments* such as taxes and auctioned permits that provide revenues to the government, and that increase the relative cost of emission- and/or energy-intensive technologies and products;

2) *Budget-neutral instruments* such as freely allocated permits or renewable portfolio standards that increase the relative cost of

emission- and/or energy-intensive technologies and products, but that do not raise revenues for government; and

3) *Expenditure instruments* such as subsidies and other incentives that reduce the relative cost of technologies and products with lower emission- and/or energy intensity, and that require governments to increase other taxes or reduce other expenditures.

The type and magnitude of impacts to achieve the same environmental outcome will vary across these different types of instruments. At the same time, there are many opportunities to mitigate impacts and to improve effectiveness in the detailed design of specific instruments. Often there will be some trade-off between minimizing aggregate costs and other objectives such as minimizing distributional impacts.

Regardless of the instrument, 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 would normally replace existing equipment or when they are considering new equipment purchases are less costly than instruments that require them to accelerate capital replacement.

Revenue-generating instruments such as taxes, as well as many budget-neutral instruments such as the renewable portfolio standard, can increase prices for producers and consumers. These policies will typically have larger effects on energy-intensive sectors or regions, and they will tend to have disproportionate effects on low-income households. These impacts can in part be offset through instrument design and revenue recycling policies.

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

At the same time, the cost and distributional impacts of revenue-generating instruments such as taxes can be greatly reduced through revenue recycling policies. For example, costs can be reduced by lowering or eliminating other taxes that dampen economic activity. Alternatively, more focused recycling policies can be used to mitigate impacts on specific income groups, sectors or regions of the economy. Recycling mechanisms must be designed carefully to balance multiple objectives – e.g., protecting historical investments, providing incentives for new investment, and encouraging desirable long-term technological changes. Recycling mechanisms for industry must also be designed carefully to minimize any possible windfalls as a result of the policy.

The cost of subsidies can be spread out over the entire economy, reducing, although not eliminating, negative distributional impacts. However, the total cost of subsidies often exceed the direct costs to government since governments must raise funds from other taxes and these have dampening effects on economic activity. The cost of subsidies required to achieve a given environmental effect can also be higher due to the presence of free riders – i.e., firms and individuals that would have undertaken the desired change in the absence of the subsidy. The costs of free riders can be large but is often underestimated. Subsidies also tend to focus on specific technologies or solutions rather than environmental outcomes (e.g., emissions). As a result, there is a greater risk that subsidies support more costly options for achieving the desired environmental outcomes. In all cases, the performance of subsidies can be improved through better policy design.

The impact of fiscal instruments on innovation (particularly technological change) is ambiguous. Dysfunctional government policies can clearly impede innovation. Whether governments can actually stimulate innovation is less clear. Much of the existing literature suggests that governments can have the most influence on innovation through general taxation policies, legal systems for intellectual property, and public spending on basic research and higher education. There is evidence that targeted fiscal policies could also influence the rate of technological change in specific sectors. The likelihood and magnitude of innovation may be improved by designing policies that are gradual, continuous, and predictable; that encourage real innovation rather than political rent-seeking; and that are linked as close as possible to desired environmental outcomes rather than specific technologies.

What do recent studies suggest about the macroeconomic impacts of carbon fiscal policies?

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

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

Acting alone, the AMG study found that the marginal cost of all measures to meet the Kyoto target would range from $40 to 120/tonne in 2010. If passed through to energy prices, these costs would raise gasoline prices 13 – 35 per cent, natural gas prices (for residential use) 30 to 75 per cent, and coal prices 300 to 800 per cent. Electricity price impacts vary greatly across regions depending upon the dominant sources of supply and pricing regime. Assuming average cost pricing, price increases range from a low of 2% in Quebec to almost 84% in Alberta.

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

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

What are the possible macroeconomic impacts of instruments proposed in the NRTEE case studies?

THE NRTEE conducted case studies of targeted fiscal instruments to promote three classes of low-carbon technologies:

- *Hydrogen energy* in transportation and stationary power production in residential/commercial buildings (Pembina Institute and the Canadian Energy Research Institute 2004).
- *Renewable* electricity production for the integrated electricity grid (Marbek Resource Consultants 2004).
- *Energy efficiency* in mining and manufacturing (MK Jaccard & Associates 2004).

In general, the aggregate macroeconomic costs of the various instruments proposed in the case studies prepared for the NRTEE are likely much small in comparison to the estimates produced for the NCCP for the following reasons:

- For the most part, the marginal cost of emission reductions in the case studies are lower than those assumed under the NCCP to meet the Kyoto targets.

- The total emission reductions by 2010, even without adjusting for possible double-counting among the case studies (e.g., both the renewables and energy efficiency case studies include reductions in the electricity sector), are three to ten times lower in the case studies than those assumed in the NCCP.

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

The specific distributional effects and effects on competitiveness or innovation are uncertain and ambiguous. They will depend in large part on the type of instrument applied and the detailed design of each instrument. At the same time, there are also numerous opportunities to reduce aggregate costs, mitigate distributional impacts and enhance effects on technological change through the detailed design of instruments.

For example, the dampening effects of other taxes to fund subsidies may be partly offset by raising government funds through more targeted approaches that correct for other distortions. For example, a subsidy for hydrogen vehicles may be funded through a levy on gasoline that reflects its external costs. Free riders may be reduced through more discriminating methods for distributing subsidies. For example, grants could be tied to specific performance criteria rather than general tax credits for a class of technologies. Concerns about supporting higher-cost technologies can be addressed in part by targeting subsidies more at specific outcomes rather than specific technologies. For example, a carbon trust could be established purchase reductions (through competitive bidding) from a wide variety of sources, rather than a single technology. The benefits of these various design options must also be weighed against other considerations such as higher administration costs.

Revenue-generating instruments provide direct and continuous incentives for reducing impacts and developing new technologies. However, they also have the greatest impact on market prices and they can often affect some sectors and regions more than others. These impacts can in part be offset through the design of instruments and through revenue recycling policies. For example, impacts on low-income households can be mitigated through revenue recycling strategies targeted specifically at this demographic – e.g., increases in personal deduction limits, reductions in other consumption taxes, or weatherization and other efficiency programs targeted at low-income households. Differences in regional costs can be mitigated through revenue recycling strategies targeted at specific regions – e.g., tax credits for households in northern communities (which use more energy) or increases in general transfers to specific provinces. Impacts on electricity-intensive, export-oriented industries (e.g., mining and pulp and paper) can in part be mitigated through the allocation of a certain number of free permits to these industries and by recycling revenues to industry through specific tax credits or rebates for exporters, or via general reductions in payroll and capital taxes. Recycling policies must be designed carefully to minimize impacts on efficiency and possible windfalls for consumers or producers.

The only budget-neutral instrument specifically identified in the case studies is the Renewable Portfolio Standard. Design of this instrument can greatly affect performance. For example, if implemented through a quota system for retailers, the instrument will not affect international trade of electricity. Similarly, under a quota system for retailers, it is possible to apply the RPS to residential and commercial customers only in order to reduce possible impacts on industry. Setting targets for new supply may reduce the chances of windfall profits for existing renewable producers. Different regional targets may be developed to reflect regional differences in supplies and costs. Costs could be further reduced through a national credit trading system. A phased implementation with clear targets and timelines may also offer more opportunity for technological changes that lower the ultimate costs of the instrument. Finally, the use of a system of penalties can provide a cap on the costs of the instrument, which are uncertain. Any revenues raised from penalties can be reinvested in R&D or development of new renewables.

In developing packages of instruments, it is very important to consider the interactions among policies. For example, providing a subsidy to renewables in the context of an RPS will most likely re-allocate the costs of meeting the RPS from electricity consumers to taxpayers without greatly increasing the supply of renewables relative to an RPS alone.

A key consideration in designing policy packages is staging. In general, gradual implementation of fiscal instruments can reduce costs by allowing adaptations to follow the natural rate of turnover in long-lived capital stocks. Establishing gradual, continuous and expected incentives or disincentives can also stimulate greater innovation (e.g., R&D) that could lower the eventual costs of the instruments. The staging of different fiscal instruments can also be important. For example, in the very early stages of implementation, where the cost difference between existing and new technologies is quite large, R&D subsidies may be the most effective instrument to consider (such as in the case of hydrogen technologies). Instruments that encourage or force market adoption of these technologies may be very costly and may actually have a negative impact on future uptake because they reinforce impressions that these technologies are expensive and because their performance is often poor in such early stages of development. Once the cost differential is reduced and performance is improved, instruments that encourage some market adoption would be most useful to encourage learning by doing and economies of scale in manufacture. Often, set-asides (such as portfolio standards) and/or subsidies will be most effective and acceptable at this stage. Once the cost differential is lower, policy makers may wish to consider broader-based revenue instruments such as permits or taxes that reinforce the position of these new technologies and stimulate competition from other new technologies.

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1.0 Introduction

In April 2003, the National Roundtable on the Environment and the Economy (NRTEE) launched Phase II of its Ecological Fiscal Reform (EFR) program. The objective of Phase II 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". Key outputs from Phase II include (a) three case studies examining specific sectors and issues; (b) a broader examination – in the form of a State of the Debate report - of the role of fiscal policy in climate change and energy policy; (c) a summary of lessons and findings that relate generally to the issue of EFR in Canada; and (d) a series of targeted outreach products and consultative processes that support and promote the program's objectives.

In July 2004, the NRTEE engaged Compass Resource Management Ltd., in association with MK Jaccard and Associates, to conduct a qualitative analysis the possible macroeconomic impacts of fiscal policies arising out of three case studies prepared for the NRTEE seeking to promote long-term "decarbonisation" through increased use of hydrogen, energy efficiency and renewable power. The findings of this study will be incorporated into the NRTEE's final State of the Debate report.

This report is organized as follows. Section 2 reviews what economists mean by macroeconomic impacts. Section 3 summarizes the various methods used by economists to evaluate macroeconomic impacts. Section 4 presents some results and key insights from recent attempts to quantify the macroeconomic impacts of climate change and energy policies, with emphasis on fiscal policy and research touching on the Canadian context, particularly research arising out of the work of the Analysis and Modelling Group (AMG) that supported the Issues Tables established as part of Canada's Climate Change National Implementation Strategy in the period from 1998 to 2003. Section 5 provides a qualitative assessment of the potential macroeconomic impacts of fiscal policies proposed in the three case studies of fiscal instruments prepared for the NRTEE. Given the small magnitude of aggregate impacts that are likely with the proposed instruments, we focus here on a discussion of regional and sectoral effects, together with the effects on technology development. In particular, we discuss design considerations for increasing mitigating distributional impacts, if any, and for increasing the net benefits of the proposed instruments. Finally, Section 6 provides a brief summary of overall findings and conclusions.

Our emphasis throughout this paper is on practical considerations for policy makers. To that end, we avoid some of the more theoretical and esoteric debates in macroeconomic impact evaluation.

2.0 What are macroeconomic impacts?

Macroeconomic impacts are the economy-wide effects of a policy – i.e., the direct and indirect changes in prices and output throughout the economy as a result of backward and forward linkages among sectors and markets, both domestically and internationally. Many policy analyses start with the direct compliance and administrative costs of an instrument in the target sector, taking prices and output in other sectors and the economy as a whole as given. This is referred to as a *partial equilibrium* analysis. A macroeconomic analysis considers so-called "second order effects" by allowing prices and output in all sectors of the economy, including international trade, to adjust in response to the direct costs of a policy. This is referred to as *general equilibrium* analysis.

For example, if the government imposes a carbon price on fossil fuels, the price of primary energy will increase. Prices of secondary energy forms such as electricity will also rise. Higher fuel and electricity costs will, in turn, increase operating costs for transportation, agriculture and other energy-intensive industries. Households will also see higher utility costs, higher transportation costs, and, depending upon the ability of producers to pass increased costs onto consumers, higher prices for many other consumer products. The ability of producers to pass increased costs onto consumers depends upon the strength of demand for their products, the degree of international competition, and the extent to which trading partners implement similar policies.

Changes in prices will, in turn, be accompanied by changes in the demands for products and services. Producers may alter their mix of inputs to reduce costs. Consumers may lower their demand for energy and for energy-intensive products. Domestic producers may lose market share to producers in other countries. Reduced demand and/or productivity could lower employment and wages in industry, affecting per capita incomes and savings rates, leading to further declines in demand.

Over time, firms and consumers may replace existing equipment with more efficient versions to reduce their production costs. The level and allocation of domestic and foreign direct investment could change across sectors in response to changes in returns and growth rates (structural change). Over the very long-term, the costs of more efficient technologies may decline and new technologies may be developed through research and development, as well as cumulative learning and economies of scale with the higher penetration of more efficient technologies. Accompanying changes in economic activity would be some improvement in environmental quality as a result of the instrument.

Allowing for these various economy-wide and/or dynamic effects can increase or decrease the costs of a policy. They can also increase or decrease the aggregate environmental benefits of the policy - e.g., by reinforcing or offsetting changes in energy use and total GHG emission in linked sectors. The magnitude of impacts depends in part upon the type and magnitude of fiscal intervention and economic conditions at the time instruments are introduced.

In assessing macroeconomic effects, it is important to distinguish between short-term and long-term dynamics – i.e., immediate effects and effects after adaptations such as changes in capital stocks and improvements in technology. In the short-term, industry has a fixed capital stock and household savings and preferences are assumed fixed (a static analysis). This can produce high cost estimates. In the medium-term, these assumptions can be relaxed, reducing costs over time. In the long-term, policies may even induce technological change, further reducing the long-term costs of a policy. By incorporating these dynamic effects, short-term costs may even turn into long-term net benefits.

One of the most comprehensive and common measures of macroeconomic impacts of policy is the change in real Gross Domestic Product (GDP) relative to a Reference Case or Business as Usual (BAU) Case.[1] "Real" GDP is used to control for general increases in price levels. This measure reflects real changes in all marketed outputs of a country. It is a standardized measure of economic output that can also be used for cross-country comparisons. Changes in real GDP can be expressed in one of three ways: a) absolute terms; b) as a percentage change; or c) as differences in growth rates. The most common metric is the percentage change in GDP. Unlike the absolute change, this metric conveys the scale of change relative to total economic output. It also avoids the need for

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[1] Per capita GDP is a more direct indicator of living standards. However, since population growth is often assumed to be the same in scenarios with and without policies, any change in absolute GDP is synonymous with a change in per capita GDP.

discounting future changes in GDP and allows easier comparisons across years or countries.

Despite its common use, there are shortcomings with employing GDP as an indicator of overall well-being or what economists refer to as "social welfare." For example, this measure does not include changes in non-marketed goods and services such as the quality of goods, environmental amenities, and leisure. These are also important components of social welfare that may not be reflected in market activity. To address this concern, so-called ancillary benefits or co-benefits are sometimes added to changes in real GDP to provide a more complete indicator of the impacts of a policy on social welfare (e.g., reductions in local air pollution and associated health effects from reduced use of fossil fuels, together with effects on congestion, land quality, and fuel security). However, estimation of these co-benefits is often difficult and controversial.

Changes in real GDP can also mask important distributional effects. Distributional effects refer to the incidence of costs and benefits among different sectors, regions, firms, and individuals. For example, two policies may have similar impacts on GDP but costs (and co-benefits) could be distributed unevenly across sectors or regions. The distribution of impacts is important for social equity, but it can also sometimes affect overall societal costs. For example, policies may increase unemployment among individuals with poor prospects of alternative employment, leading to social problems and higher government costs to support these individuals.

Finally, reliance on a single indicator of social welfare such as GDP may mask huge differences in the certainty associated with macroeconomic impacts. For example, long-term impacts on GDP are notoriously difficult to model and they are very sensitive to assumptions about the rates of technological change and other factors. In these cases, policy makers may want a more direct assessment of the potential impacts of policies on long-term technological changes, as opposed to highly uncertain estimates of GDP many years in the future.

Given these various shortcomings, many impact studies rely on several indicators of macroeconomic impacts. Different indicators may be used to distinguish between short-term and long-term impacts; between aggregate impacts and impacts on specific sectors, regions or individuals; and effects on market output and non-market impacts such as health or environmental quality. Policy-makers can then attach different weights to different criteria in ranking alternative policies or packages of policies. Some indicators typically considered include effects on productivity (i.e., the cost of inputs relative to the value of outputs), innovation (i.e., the rate of technological change), competitiveness (i.e., the cost of domestic producers relative to foreign producers), government budget balances, exchange rates (i.e., terms of trade or the amount of imported goods a country can purchase from a given level of exports), trade flows (i.e., imports and exports), and international capital flows (e.g., government reliance on foreign debt and foreign direct investment). These effects are inter-related and will ultimately translate into changes in GDP. Analysis of these variables, however, is complex and impacts are often presented in both quantitative and qualitative terms.

3.0 How do economists assess macroeconomic impacts?

Given the size and complexity of linkages within an economy, the macroeconomic impacts of any policy are very uncertain. Impact studies conducted after the implementation of a policy are complicated by the difficulty of unraveling the effects of a specific policy or instrument from simultaneous changes in a multitude of other factors that may also have affected performance of the overall economy. Estimating macroeconomic impacts prior to the implementation of a policy requires complex models and numerous assumptions.

The most comprehensive tools for estimating macroeconomic impacts are Input-Output (IO) models, Macroeconomic (Keynsian or Effective Demand) Models, and Computable General Equilibrium (CGE) models. All of these models can be characterized as "top-down" in that they do not explicitly portray technological detail. To varying degrees, these models take into account all production and consumption in the economy; the demand and supply for capital, labour and energy; investment, taxes and government spending; international trade; prices; and interest and exchange rates, among other factors. They vary in terms of their level of aggregation of economic activity, their treatment of factors such as market structure, and in their treatment of dynamic effects such as turnover of capital equipment, international capital flows, and changes in technology over time.

Top-down models tend to be most useful for examining broad price- or quantity-driven policy environmental instruments (e.g., carbon taxes or tradable permits). In the past, these models were often criticized for not capturing the potential effect of policies on the rate of technological change. The rate of technological change has proven to be an important determinant of the long-term costs of environmental policies. In recent years, however, considerable attention has been paid to improving the capability of these models to reflect technological changes that may be induced by policies (see for example, Carraro et al. 2003 and Löschel 2002).

So-called bottom-up models are more technologically rich and therefore tend to be more useful for assessing technology policies. However, many bottom-up models do not capture macroeconomic feedbacks and other welfare costs associated with policies. As a result, researchers and policy makers are often forced to integrate information from many sources, each providing insights on different aspects of impacts. Many estimates of macroeconomic impacts are generated using a combination of one or more bottom-up and top-down models to estimate macroeconomic impacts.[2] There are also a growing number of hybrid models being developed that incorporate features from both bottom-up models (e.g., detailed information on technologies and capital stocks) and top-down models (e.g., substitution effects with other sectors and other welfare costs) (see for example Jaccard et al. 2003, Löschel 2002, and Carraro et al. 2003).

There are numerous competing models for assessing environmental and energy policy. Different models yield different results. In its Third Assessment Report (IPCC 2001), the IPCC assessed the literature and found that the macroeconomic costs of GHG management produced by different models depend upon a range of factors including:

- the structure of the model (e.g., level and form of disaggregation; treatment of substitution and technology dynamics; representation of people's behaviour as adaptive or forward-looking);

- assumptions about parameter values (e.g., substitution elasticities; rates of autonomous technological change; availability and price of backstop technologies);

- assumptions about policy design (e.g., what policy instruments are used for mitigation, what happens to any price or emission permit revenues, whether permits are traded, which GHGs are included);

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[2] For example, this approach was used in the macroeconomic analysis conducted by the Analysis and Modelling Group for Canada's Climate Change National Implementation Strategy.

- whether the environmental benefits of mitigation are included (e.g., averted costs of climate change and/or other ancillary benefits such as local air quality improvements, if any);

- assumptions about the GHG policies of major trading partners; and

- the selected baselines / reduction targets (i.e., magnitude and timeframe of reductions).

Even using the same model, the magnitude and duration of macro-economic impacts associated with the same policy mix or reduction target will also vary across economies as a result of differences in initial resource endowments, economic structure, and labour and capital markets, among other factors.

Differences in the estimated costs of GHG mitigation highlight the difficulty and uncertainty of modeling economies and policies, and in projecting the future. Regardless of the model or modeling approach, precise quantitative assessments of macroeconomic impacts are often resource- and time-intensive. Furthermore, many models of macroeconomic impacts are too aggregated to capture the impacts of smaller, more targeted policies (i.e., policy instruments directed at specific sectors and technologies), and do not necessarily provide an adequate "story" of the macroeconomic impacts or long-term dynamics for decision makers. The design and analysis of targeted policies could benefit greatly from the use of more qualitative approaches such as simple screening techniques and rules of thumb for predicting possible macroeconomic impacts.

4.0 Lessons from recent studies of the macroeconomic impacts of fiscal instruments

4.1 Introduction

There are literally hundreds of estimates of the costs and benefits of environmental protection in the literature. In recent years, considerable analysis has been directed towards the costs (and in some cases benefits) of meeting emission reduction targets under the Kyoto Protocol. Many of these analyses consider price or quantity instruments (i.e., taxes or tradable permits) applied on an economy-wide basis to encourage the least-cost mix of achieving the desired target. A few examine more targeted sector- or technology-specific instruments.

Studies vary greatly in terms of modeling approach, level of disaggregation of the economy, and types of costs (and in some cases benefits) included. Most studies focus on a limited set of impacts / issues. There are very few integrated assessments of all issues (e.g., studies that simultaneously examine impacts on trade, final demand, employment, the price system, environmental quality, and technological development).

In this section we review the results and key insights from recent attempts to quantify the macroeconomic impacts of climate change and energy policies, with emphasis on insights related to targeted policies. Our review is limited mostly to studies in developed countries and in particular studies related to the Canadian context such as studies conducted by Analysis and Modelling Group (AMG) to support Canada's National Climate Change Process (NCCP) in the period from 1998 to 2003.

We begin with a brief introduction to the main types of fiscal instruments. We then review key insights regarding the interactions of each category of fiscal instrument with the overall tax system. Next we discuss the distributional effects of different instruments, followed by an overview of possible impacts of each type of instrument on competitiveness and technological change. In the final portion of this section we summarize some recent quantitative estimates of the national and international impacts of GHG-focused policies.

4.2 Categories of Fiscal Instruments

In describing and comparing possible macroeconomic impacts, it is useful to group fiscal instruments broadly into three categories, reflecting their combined effect on government finances and industry costs:

4) *Revenue-raising instruments* such as taxes and auctioned permits that provide revenues to the government, and that increase the

relative cost of emission- and/or energy-intensive technologies and products;[3]

5) *Budget-neutral instruments* such as freely allocated permits or renewable portfolio standards that increase the relative cost of emission- and/or energy-intensive technologies and products, but that do not raise revenues for government;[4] and

6) *Expenditure instruments* such as subsidies and other incentives that reduce the relative cost of technologies and products with lower emission- and/or energy intensity, and that require governments to increase other taxes or reduce other expenditures.[5]

These three broad categories differ in terms of their potential costs, distributional effects, competitiveness impacts, and effects on technological change. For example, taxes or other requirements will increase industry costs, producing immediate effects on domestic or international competitiveness. However, these costs provide a direct and continuous incentive for process and technological innovations. Subsidies will not affect the costs of industry but could affect the magnitude of incentives required to achieve the same environmental outcome (e.g., due to free riders) and could encourage rent-seeking behaviour rather than stimulate real innovation. The costs of taxes will be more concentrated compared with the benefits from revenue recycling in general taxes, unless recycling schemes are highly targeted. In comparison, the benefits of subsidies will tend to be more concentrated while their costs will be distributed more broadly from increases in taxes throughout the economy.

Within each category of fiscal instruments there can also be important variations in impacts depending upon specific policy decision considerations. For example, the distributional effects of revenue-

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[3] This category would also include instruments that reduce existing subsidies as this would raise the costs of goods and services while increasing government funds available to be used elsewhere or to lower other taxes.

[4] Budget neutral instruments can still have indirect impacts on government revenues and expenditures. For example, if they change the level of economic output or mix of inputs they will affect revenues from existing labour, capital, income, and product taxes,

[5] We include here only expenditures intended to influence the behaviour of firms of individuals. We exclude direct government expenditures to reduce GHG emissions (e.g., to decrease emissions from government operations).

raising instruments can be offset in part by the specific design of revenue recycling mechanisms (e.g., re-allocating revenues to specific sectors or regions).

4.3 Interactions with the Tax System

The literature demonstrates theoretically and empirically that the costs of fiscal instruments can be higher or lower than otherwise anticipated because of interactions with the existing tax system and choices about how to recycle any new revenues associated with some types of fiscal instruments.

In the case of subsidies or direct government actions to reduced GHG emissions, other taxes must be increased to fund the additional government expenditures. A dollar of new government expenditure, however, may cost the economy more than just one dollar because its collection can exacerbate the dampening effect of taxes on the economy (see for example Ruggeri 1999). This is because taxes on things such as labour and investment income change the economic returns to labour and capital. In some cases, this may distort the efficient use of these resources and give rise to what economists refer to as “dead-weight” losses. Each source of public finance will typically have its own marginal cost. For example, Devarajan *et al*. (1999) estimates that the “marginal cost of public funds” varies between US$1.08 and US$1.56 for the USA – i.e., each dollar of additional government expenditure actually costs the economy between $1.08 and $1.56 when efficiency losses from taxes are included. The European Commission uses a value of US$1.28 for a marginal cost of public funds (IPCC 2001).

New expenditures may also be funded through higher deficits, but deficits also have negative macroeconomic effects (e.g., government borrowing can crowd out more productive private investment). Similarly, they could be financed through reductions in other forms of government spending (rather than new taxes or borrowing). However, cutting these programs can also reduce social welfare and these impacts should be taken into account in assessing the costs of the subsidy.

Even regulations or freely allocated permits, which do not involve significant new direct expenditures or revenues for government, can still have indirect effects on government revenues and hence tax collection. By reducing demand and returns on capital or labour, new regulations may reduce overall government revenues, requiring an increase in tax rates, further exacerbating prior distortions in labour or capital markets.

In contrast to subsidies, instruments such as carbon taxes or auctioned permits raise additional revenues for government. These revenues can be "recycled" by reducing other distortionary taxes in the economy.[6] Revenue recycling can reduce the gross costs of the instrument. In some cases, it can even produce what is referred to as a double dividend – i.e., environmental improvements and a more efficient price system.

Researchers sometimes distinguish between a weak and strong double dividend. The latter refers to a situation where the efficiency improvements as a result of reducing other taxes more than outweigh the direct costs of the instrument. While the weak form of double dividend enjoys broad support from theoretical and numerical studies, the strong double dividend hypothesis is more controversial. There is little empirical support for a strong double dividend in developed countries. It would imply that the original tax structure is seriously inefficient (e.g., that capital is highly overtaxed relative to labour). If true, this would provide sufficient reason for tax reform independent of the introduction of new fiscal instruments, suggesting the benefits of these reforms should not be ascribed to those new fiscal instruments, even if they are introduced at the same time.

Not all of the revenue from price instruments or auctioned permits is necessarily available for recycling. Revenue-raising instruments can also reduce other tax revenues, raise other forms of government social spending (e.g., employment insurance), and increase the government's operating costs (e.g., energy costs for heating buildings). Some of the revenues of the fiscal instrument would need to cover reductions in other revenues and costs and would not therefore be available for recycling. However, in general revenue gains would still exceed losses elsewhere, providing some net revenues for redistribution.

Price interaction effects and the potential for a double dividend arising from GHG mitigation policies have been extensively studied during the 1990s. The magnitude of these effects depends upon a) the size of the expenditure or revenues collected; b) the marginal form of revenue collection or recycling (e.g., lump-sum transfers or reductions in the margin rate of income taxes, capital taxes, payroll taxes, or

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[6] These taxes can also interact with existing taxes to increase current distortions but the magnitude of such "tax interaction" effects is still uncertain and controversial.

sales taxes); and c) the magnitude of pre-existing distortions caused by the price system. A high marginal cost of public funds suggests more scope for a double dividend than a small marginal cost of public funds. The best revenue recycling policies, however, will vary from country to country.

Empirical studies try to gauge the impact of these many determinants and to understand why the effects of a given recycling strategy (reducing payroll, personal income, corporate income, investment income, or expenditure taxes) differ from one country to another. For example, numerous studies suggest that the shift between carbon and payroll taxes will reduce the net burden of climate policies in the USA but does not avoid net welfare losses. However, the same shift can produce a strong double dividend in Europe. These differences can be explained by the differences both in taxation systems and in the rigidities of the labour markets. In contrast, recycling via capital taxes tend to reduce net costs more in the USA compared with Europe (see IPCC 2001 for a more detailed discussion of this literature).

In selecting among re-distribution options, governments often face trade-offs among competing objectives. For example, using revenues to offset specific distributional effects (e.g., through direct payments to producers or consumers) may raise the aggregate costs of a policy compared with a strategy to reduce marginal tax rates across the entire economy.

In summary, interactions with the broader tax system may increase the cost of subsidies and other government expenditures above their direct costs. Revenues from taxes and other revenue-raising instruments may be used to reduce other distortionary taxes or to compensate sectors and individuals affected by the instruments, reducing aggregate or distributional impacts of these instruments. All instruments, including budget-neutral instruments, may interact indirectly with existing taxes to increase the efficiency losses of taxes in the economy and to alter government revenues and expenditures.

4.4 Distributional Effects

Policies with similar effects on aggregate output can have very different distributional consequences. Distributional consequences refer to the incidence of costs and benefits across firms, sectors, regions, social groups (e.g., low-income households), and individuals. The distributional effects of policies can also vary over time in response to other feedbacks, long-term growth and other factors.

The costs of subsidies tend to be more widely distributed throughout the economy compared with the costs of other instruments. Nonetheless, subsidies and direct expenditures can still affect some income groups or sectors more than others. For example, low-income households may bear a higher share of costs (as a percentage of household income) if funds are raised via consumption taxes rather than income taxes.

The relative costs of both revenue-raising instruments and many revenue-neutral instruments tend to be higher for some income groups, industry sectors, and/or regions. For example, many fiscal instruments related to energy and GHG emissions tend to increase the relative prices of energy. For households this can mean higher costs for energy services such as heating, lighting, and transport. Measured as a percentage of current household income, the relative impact of these policies tends to be greatest among low-income households and people living in cold or low-density areas. This is particularly important for seniors and other households with fixed incomes. However, for other households the impact may be fairly small when measured relative to lifetime income[7] (see for example, Poterba 1991; Bull et al. 1994; Schillo et al. 1996; and Metcalf 1998).

The incidence of costs can also vary across industry sectors. In the short-term, policies to reduce energy or GHG intensity can raise the costs and/or prices of goods with high energy- or GHG- intensity. In the long-term, changes in relative prices and returns on capital can shift demand and investment away from these goods and towards ones with lower energy- or GHG- intensity. This is referred to as structural change. Two policies with similar aggregate costs could have different structural effects.

Individual regions typically vary in terms of household and industrial composition. Thus, differences in the incidence of costs across income groups and across sectors can also translate into differences in the regional incidence of costs. These differences may be reflected in relative impact on local government revenues, public services, or regional growth prospects.

The incidence of benefits may also vary across the economy. For example, policies may have differential effects on the location of environmental benefits such as improvements in local air quality. These locational differences may also translate into differences

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[7] Younger households can typically expect to move among income classes over time and can borrow against future earnings.

across households. For example, poor households tend to be located in the most polluted areas and may benefit most from improvements to local air quality if this is a by-product of a GHG policy. Similarly, some industries could also benefit from a particular policy – e.g., renewable energy developers may benefit from policies that increase the cost of fossil fuels.

Distributional effects can often be mitigated in part through policy design. In particular, with revenue raising instruments, distributional effects can be reduced through revenue recycling policies. For example, any undesirable effects on low-income households may be reduced by lowering personal income tax rates at the bottom end of the income scale or through direct transfers. Direct transfers could even be designed to reinforce environmental benefits – e.g., weatherization programs for low-income households. Similarly, effects on certain industrial sectors can be reduced through changes in other taxes or direct transfers.

Policy design often requires trade-offs between distributional considerations and other policy objectives. For example, using revenues from environmental taxes to offset specific distributional effects (e.g., through direct payments to producers or consumers) may raise the aggregate costs of the policy compared with recycling strategies that reduce marginal tax rates across the entire economy. Similarly, re-distribution policies may affect incentives for technological innovation and other behavioural changes. In some cases, these trade-offs may be small or they may be mitigated through better policy design. For example, investments in existing plants could be protected by providing free permits or tax exemptions to cover their existing output. The instruments would then discourage increased output or new investment in the sector, or marginal improvements in efficiency.

In designing mechanisms to mitigate distributional impacts, it is also very important to consider the possibility of windfalls. For example, some environmental and energy policies have the potential to generate large rents. In these cases, governments can protect firms' profits and equity values by enabling firms to retain only a fraction of these rents through tax exemptions or freely allocated permits. For example, a recent study of re-distribution policies in the U.S. found that only 15% and 4.3% of carbon permits in the oil & gas and the coal industries, respectively, need to be grandfathered in order to maintain current equity values of firms (Boveberg and Goulder 2000). Indeed, this study suggests that allowing a dollar-for-dollar offset between environmental taxes and other taxes could substantially overcompensate firms if producers can capture additional rents by shifting the costs of a carbon tax onto consumers.

4.5 Impacts on Competitiveness

Impacts on industry often come down to a discussion of international competitiveness. Competitiveness can be viewed at three levels:

- Firm competitiveness;
- Industry or sector competitiveness; and
- National competitiveness.

At the firm level, competitiveness refers to the ability of an individual firm to capture and grow market share relative to its competitors. Competitive success is a function of the firm's costs and product differentiation. The standard indicator of firm competitiveness is sustained profitability.

At an industry or sector level, competitiveness refers to the competitiveness of an entire industry relative to foreign rivals. This depends upon industry-wide costs and product attributes. Indicators of sector competitiveness include import intensity (competitiveness in domestic markets) and world market share (competitiveness in export markets).[8]

National competitiveness is a more nebulous and controversial concept. In an open economy, some sectors will be better at exporting goods than other sectors. These exports, in turn, can be used to purchase imported goods that are too costly or difficult to produce locally. The value of exports can determine the value of imports. The net result of such trade is an increase in aggregate economic output and overall well-being. National competitiveness refers to the ability of a nation as a whole to generate export revenues for financing imports of other desirable goods and services. Indicators of national competitiveness may include unit labour costs, total factor productivity and productivity growth rates, or total employment, but the ultimate indicator is GDP growth.

[8] One problem in assessing competitiveness impacts is the high level of aggregation. Most firms produce a wide variety of products and services and regulations will not affect each product or service equally.

Obviously, sectoral competitiveness implies competitiveness of at least some firms in the sector. However, overall sectoral competitiveness can also be low or declining while the prospects for a few firms with unique advantages are still increasing. Similarly, national competitiveness implies that at least some sectors are competitive. However, it is also possible that efforts to preserve the competitiveness of one sector may divert resources from sectors that could contribute even more to national competitiveness. This is often the case where governments intervene in sectors that are in decline in order to avoid transitional problems such as high regional unemployment. These policies, however, can increase aggregate costs to economic growth and prosperity over the long-term.

Complicating analyses of competitiveness is the fact that it depends upon so many interacting factors including wage rates, price rates, input costs, capital costs, transportation costs, factor productivity, technology, culture, etc. Indeed, it is instructive to look at how changes in other factors can and have affected trade patterns. A very useful example is the recent appreciation of the Canadian dollar. The Canadian dollar has appreciated 20 percent relative to the U.S. dollar since the first quarter of 2002 (the most comparable appreciation in recent years took three years between 1987 and 1990). This represents a large and rapid increase in the relative cost of Canadian exports to the U.S. However, impacts on trade have been much lower than expected. This is not to suggest there will be no long-term impacts. It merely highlights the competitive "slack" that may exist at any point in time and the fact that firms are always dealing with changing input costs.

Critical elements in assessing the impacts of policy instruments on trade include:

- The magnitude of costs imposed by the instrument on each sector, which in the case of energy and climate change policies is a function of the energy and/or GHG intensity of the sector;
- How substitutable imports are with domestic products and the price elasticity of export demand;
- The extent to which trading partners implement similar policies;
- The magnitude of pre-existing competitive advantage in the sector (e.g., based on other factors such as wage rates, factor productivity, product quality, other price rates, etc.); and

- Further in time, how mobile is capital in these sectors.

The literature provides little empirical support for the proposition that environmental regulation affects trade. However, this result is due in part to:

- The difficulties of measuring and comparing the magnitude of environmental costs across jurisdictions;

- The relatively small costs of complying with most existing regulations;

- The relatively small differences between regulations in developed countries; and

- Despite beliefs to the contrary, multi-nationals adopting home-country standards for most new plants no mater there they are located. This can be explained by a belief that future regulations will likely be more stringent and the costs of retrofitting plants later will be more expensive; and public relations pressures from major disasters.

The effects of GHG policy may be more significant given the potential magnitude of its costs compared to other existing environmental regulations. In addition, those costs could be highly concentrated in energy-intensive industries. At the same time, policies may benefit other sectors (e.g., developers and exporters of environmental technologies).

As with distributional effects, competitiveness impacts may in part be offset through policy design (e.g., tax exemptions or freely allocated permits for energy-intensive and export-intensive industries). In designing these mitigation policies, however, it is important to consider the extent to which the industry is likely to be affected, the magnitude of any offsetting rents a policy may create (e.g., through increases in domestic prices), and the impact on overall competitiveness of the industry. Governments also need to decide the extent to which they want policies to encourage long-term structural adjustments at the margin. For example, policies could protect existing investment and output while discouraging expanded output or investment in the sector.

4.6 Impacts on Innovation

Many competitiveness studies focus on static effects – i.e., changes in competitiveness based on current costs, capital assets, etc. Equally important are dynamic effects – i.e., effects on innovation. Innovation encompasses the ability of firms and countries to create and maintain competitive advantage by continuously developing new technologies or processes that reduce costs, and by continuously developing new or more desirable products and services. Firms that are more innovative tend to be more profitable. Countries that show more signs of innovation are wealthier and grow faster.

The effect of government policy on innovation, particularly long-term technological change, is still controversial. Dysfunctional government policies can clearly impede innovation. Whether governments can actually stimulate innovation is less clear. Much of the existing literature suggests that governments can have the greatest influence on innovation through general taxation policies, legal systems for intellectual property, and public spending on basic research and higher education (Morck and Yeung 2001). The so-called "Porter" or "innovation" hypothesis suggests that "smart" regulation can also improve long-term competitiveness by stimulating industrial innovation (Porter 1995). However, empirical support for this proposition is still ambiguous. Nonetheless, there is historical evidence that relative energy prices have influenced the direction and pace of R&D. The energy price shocks of the 1970s clearly stimulated investment in R&D into more efficient equipment, exploration and development technologies, and alternative energy sources (e.g., Newell, Jaffe and Stavins 1998; Jaffe, Newell and Stavins 2000; Popp 2001).

Many economists believe that instruments that extract a payment from producers or consumers stimulate more innovation than other instruments such as subsidies. They believe that producers have even less incentive to innovate under command-and-control regulations. However, the impacts of different instruments vary greatly depending upon the sector and local context.

Some studies suggest that using grants or tax credits are considerably more effective than changes in energy prices in encouraging firms and consumers to purchase new equipment. This is because users focus more on upfront costs rather than long-term operating costs (e.g., Jaffe, Newell, and Stavins 2000). However, such tax credits and other subsidies also have drawbacks. First, they often do not focus specifically on emission reductions, but rather installation of specific technologies, and so they may not stimulate development of new emission-reduction technologies. Second, a considerable portion of subsidies also often go to so-called free riders – people or firms that would have purchased the equipment even in the absence of the tax credits. These free riders can increase the costs of achieving a given level of emission reductions. Third, subsidies encourage political rent-seeking behaviour among firms. That is, in the face of potential subsidies, firm may allocate more resources to influencing governments than pursuing real innovative activity. Murphy *et al*. (1991) suggest the relative number of engineers and lawyers who graduate from a country's universities as a measure of the value of a career in innovation relative to one in political rent-seeking. They find a clear, statistically significant correlation: countries with more law graduates grow more slowly, countries with more engineering graduates grow faster.

Subsidies to support R&D run the risk of funding R&D that would have occurred anyway (free riders) and of supporting inappropriate or unsuccessful technologies. The returns for R&D subsidies depend greatly on how well governments are at selecting technological winners. There is little evidence that governments are good at this. In a recent study of Japan's Ministry of International Trade and Industry (MITI), Beason and Weinstein (1996) find that MITI mainly subsidized losers, and that firms that received MITI subsidies tended to perform worse afterwards.

In summary, general economic policies appear to have the greatest impact on overall innovation. There is some evidence that well-designed sector-specific policies can influence the rate of technological change, but the magnitude of this effect is controversial. In general, the cost and success of fiscal policies to promote technological innovation in specific sectors could be improved by designing policies that provide gradual, continuous, and predictable incentives; minimize incentives for political rent-seeking (e.g., by delegating the allocation of subsidies to arms-length agencies with clear criteria for allocating funds); minimize opportunities for free riders (e.g., using price-based instruments or very selective subsidy programs); and provide incentives that are closely linked to desired environmental improvements (e.g., policies that avoid selecting specific technological solutions but instead encourage competition among a variety of possible solutions).

4.7 National and International Estimates of GHG-Focused Fiscal Policies

In 2000, a macroeconomic analysis of national and provincial effects of GHG reduction options was conducted by the Analysis and Modelling Group (AMG) for Canada's National Climate Change

Process (NCCP) (AMG 2000; Inofmetrica 2000). The analysis was based on input from sector tables on specific reduction measures, microeconomic analysis of abatement costs and energy sector adjustments, and macroeconomic analysis of second-order effects based on the costs from the microeconomic models. Two microeconomic models were used to estimate the direct cost of abatement.

The MARKAL model included only anticipated financial costs for producers and consumers. The CIMS model included these anticipated financial costs plus additional losses reflected in consumer product preferences, attitudes to risk, and time preferences. While only financial costs from CIMS were included in the macroeconomic analysis, these were still higher than MARKAL because they reflected the higher expected costs of policies required to induce the desired changes in consumer and producer behaviour given non-financial factors such as the risk of technological failure and long payback periods. Except for adjustments in the energy supply industries, the two microeconomic models excluded second-order effects such as changes in relative demand and overall output. These effects were evaluated separately using several macroeconomic models.

The AMG analysis found that, depending upon assumptions about microeconomic costs and international actions, meeting the Kyoto targets could reduce real GDP by 0 to 3 percent in 2010, if all necessary policies had been implemented by 2000. This is equivalent to up to one year's growth in GDP. The GDP impact varies over time. There is a small increase in activity in the short-term as a result of increased capital spending to reduce emissions. However, GDP declines after a few years as a result of the higher production costs, lower productivity, trade effects, and reduced income.

The analysis indicated possible spikes in inflation in early years, which could affect adjustment costs. Impacts on employment vary over time and reduction path, as well as by sector, in most cases, impacts on employment are modest. Disposable household incomes are reduced by consumption is little changed or higher due to reduced saving. The magnitude of foreign borrowing is increased. Because the investments to reduce emissions of GHG do not produce a market-based return, total factor productivity, measured as labour and capital costs per unit of output, also declines. By 2018, total factor productivity declines by 2.3% compared to the base case.

Provincial impacts are generally within 1.5% of the national average. However, the relative impacts on each province vary depending upon the reduction path. If Canada acts alone, Ontario and Saskatchewan are the most negatively affected. With international action, Saskatchewan, Alberta and New Brunswick are the most negatively affected.

The industrial sector, in particular the oil and gas industry, together with the transportation sector would have the most difficulty reducing emissions. However, the study found substantial variation in impacts across industries and there was no consistency in the types of industries affected across models or reduction paths. The study confirmed potential trade effects from both changes in relative costs, and in the case with simultaneous international implementation of GHG policies, reductions in the GDP of major trading partners.

The AMG found that the greatest emission reduction possibilities exist in the electricity sector, which accounts for 40 to 60% of the total reductions depending upon the model and reduction Path. Most of these reductions come from two actions – increased hydroelectric production and trade among provinces and capture and storage of CO2 in aquifers in Alberta and Saskatchewan. Consumption of all other energy sources also decline.

Acting alone, the marginal cost of all measures to meet the Kyoto target would range from $40 to 120/tonne in 2010. If passed through to energy prices, these costs would raise gasoline prices 13 – 35 per cent, natural gas prices (for residential use) 30 to 75 per cent, and coal prices 300 to 800 per cent. Electricity price impacts vary greatly across regions depending upon the dominant sources of supply and pricing regime. Assuming average cost pricing, price increases range from a low of 2% in Quebec to almost 84% in Alberta.

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

Studies in other countries have produced results with similar ranges of impacts (Table 1). An interesting observation from Table 1 is that there is no strict correlation between the necessary carbon price to reach a certain emission target and the GDP loss faced by a country. For example, higher carbon taxes are required in Japan compared to the USA, but GDP impacts are lower in Japan than in the USA. This is explained in part by pre-existing differences in energy supply, economic structure, and the tax system. For example, if a country relies more on renewable energy and is specialized in low energy-intensive industry, a higher carbon price may be required to achieve a given target but the aggregate impact on output will be lower. However, in these cases, the burden of emission reductions likely falls only on only a few sectors.

Table 2 illustrates that impacts can sometimes be positive for individual countries (in an international implementation framework) and that impacts are often non-linear; that is, the impact on GDP may increase more or less rapidly than the increase in carbon price or permit values.

Some general conclusions from the global and Canadian studies include the following:

- Costs are lower when policies are expected, gradual and well-designed.
- All things being equal, broad instruments that provide more flexibility with respect to the form of mitigation and possibly trading of reduction requirements are generally less costly than more targeted and prescriptive instruments for achieving the same reductions.[9]
- Instruments that encourage firms and households to invest in more efficient equipment and processes when they would normally replace existing equipment or when they are considering new equipment purchases are less costly than instruments that require them to accelerate capital replacement.
- Without mitigation measures, the relative impacts of climate change and energy policies will be largest on energy-intensive and trade-intensive industries. Impacts on trade, however, will depend upon many factors including other sources of competitive advantage.
- Fiscal instruments can interact with existing taxes to increase the costs of a policy. At the same time, revenues from

[9] Here flexibility refers to the ability for regulated sectors to pursue alternative compliance options including alternative forms of direct reductions as well as options for purchasing permits or paying taxes in lieu of direct compliance. It does not refer to regulatory discretion to alter targets. Regulatory discretion (e.g., providing firms with exemptions or lowering targets) with may also reduce costs but can reduce achievement of environmental objectives and can encourage rent-seeking behaviour over investment in innovation.

instruments such as taxes and auctioned permits can be used to reduce other distortionary taxes, producing a potential double dividend.

Table 1: Energy Modelling Forum Results: carbon price and GDP losses in 2010 with lump-sum recycling (in 1990 US$)

	Carbon price in 2010				GDP losses in 2010 (%)			
Model	**USA**	**OECD-E**	**Japan**	**CANZ**	**USA**	**OECD-E**	**Japan**	**CANZ**
ABARE-GTEM	322	665	645	425	1.96	0.94	0.72	1.96
AIM	153	198	234	147	0.45	0.31	0.25	0.59
CETA	168				1.93			
G-Cubed	76	227	97	157	0.42	1.50	0.57	1.83
GRAPE		204	304			0.81	0.19	
MERGE3	264	218	500	250	1.06	0.99	0.80	2.02
MIT-EPPA	193	276	501	247				
MS-MRT	236	179	402	213	1.88	0.63	1.20	1.83
Oxford	410	966	1074		1.78	2.08	1.88	
RICE	132	159	251	145	0.94	0.55	0.78	0.96
SGM	188	407	357	201				
WorldScan	85	20	122	46				

Source: Weyant (1999). The carbon price required (either explicitly or implicitly) and the resultant GDP losses are calculated to comply with the prescribed limits under the Kyoto Protocol for four regions under a no trading case: the USA, OECD Europe (OECD-E), Japan, and Canada, Australia, and New Zealand (CANZ).

Table 2: Impacts of Kyoto Protocol on World Economies in 2010 for Various International Carbon Prices

	Impacts on Gross Domestic Product at Different Carbon Price (Percent Change from Business-as-Usual 2010 GDP Levels)		
Country/Region	Range of International Carbon Price Estimates		Ratio of impacts at $50/tonne relative to $10/tonne
	$C50/Tonne of CO2	$C 10/Tonne of CO2	
Japan	-0.203	-0.023	8.8
S. Korea-Taiwan	0.174	0.084	2.1
Southeast Asia (1)	-0.008	-0.022	0.4
China	0.17	0.087	2.0
Hong Kong	0.233	0.1	2.3
Rest of Asia (2)	0.092	0.063	1.5
European Union	-0.144	-0.028	5.1
OEC (3)	-0.534	-0.348	1.5
USA	0.04	0.019	2.1
Mexico	0.027	0.002	13.5

Based on MS-MRT Model, multiple runs analysis, February 2002, Analysis and Modelling Group.
(1) The countries included in the Southeast Asia region are Indonesia, Malaysia, the Philippines and Singapore.
(2) The 'Rest of Asia' region includes India, Pakistan, Thailand, Vietnam, Sri Lanka.
(3) 'Oil Exporting Countries' region includes oil producers of the Middle East and Venezuela.

5.0 Analysis of NRTEE Case Studies

5.1 Overview

THE NRTEE conducted case studies of targeted fiscal instruments to promote three classes of low-carbon technologies:

- *Hydrogen energy* in transportation and stationary power production in residential/commercial buildings (Pembina Institute and the Canadian Energy Research Institute 2004).
- *Renewable* electricity production for the integrated electricity grid (Marbek Resource Consultants 2004).
- *Energy efficiency* in mining and manufacturing (MK Jaccard & Associates 2004).

The three case studies shared a similar analytical framework:

- Define a business-as-usual (BAU) evolution assuming no government intervention;
- Identify elements that offer an opportunity to alter development either in time or intensity;
- Identify barriers that prevent opportunities from being achieved;
- Define instruments that could overcome the barriers; and
- Assess the economic and environmental efficiency and effectiveness of the potential instruments.

The hydrogen and renewable energy case studies model the period from 2010 to 2030. The energy efficiency case study models a slightly longer period from 2005 to 2030.

The work of the Analysis and Modeling Group from the National Climate Change Process was used as a common baseline for calibrating assumptions in order to ensure consistency and comparability of results.[10] The BAU scenarios used in these studies do not include any of the measures committed to under Canada's Action Plan.

Each case study uses different types of models to evaluate the possible impacts of fiscal instruments on GHG emissions in the target sectors. The case studies also differ in terms of definitions of costs, levels of regional and sectoral detail, and the scope of feedbacks included in the analysis. For example, the energy efficiency case study considers non-price factors affecting the adoption of energy efficiency technologies in evaluating the impact of different fiscal instruments. In contrast, the renewables case study assumes the penetration of renewable energy is related primarily to relative prices only (except in the case of the renewable portfolio standard which mandates a minimum level of renewable production). Similarly, the energy efficiency case includes limited assumptions about induced technological change (primarily in the form of a decline in technology costs with increasing market shares). In contrast, the renewables case study includes effects of policies on R&D decisions, and, in turn, the effects of both R&D investments and cumulative experience on future renewable costs.

None of the case studies includes feedbacks from changes in aggregate demand, including trade impacts, or structural changes in the national economy. However, as we show below, these impacts are likely small for the type and level of fiscal instruments considered in the case studies, and for the length of time associated with their implementation. Nonetheless, there may still be some important distributional impacts to consider in their implementation. These effects, however, can also be mitigated through changes in policy design. Policy design can also affect the likelihood and magnitude of technological changes induced by the various instruments. There are also potential interactions with other taxes that should be considered in design and evaluation of the various instruments.

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[10] There have been some important updates to these assumptions since 2000. Prices for most energy commodities have been higher than assumed in Canada's Emissions Outlook, An Update (CEOU) used in the National Climate Change Process. In addition, estimates of BAU emissions in 2010 have increased from 770 MT to 809 MT due to higher economic growth from 1997 to 2000 than original projected, substantially more oil sands development, higher natural gas production, and changes in the electricity generation mix. In addition, the price of natural gas used in the 2000 study is now outdated. Modelling results from the case studies are very sensitive to the price of natural gas. The Analysis and Modelling Group has recently conducted some new studies based on updated input assumptions (Analysis and Modelling Group 2002).

Table 3 provides a summary of key assumptions and outputs for each case study. We focus here on issues that are most relevant to a macroeconomic evaluation. Because each study team reported inputs and outputs in very different ways (e.g., present values vs. annual averages; aggregate impacts vs. sectoral or regional impacts), direct comparison was not easy. This table represents our best interpretation of the results of each case study.

The macroeconomic impacts of sector-specific fiscal instruments are uncertain. Impacts also vary depending upon the general type of instrument used as well as the specific design of the instrument. Most of the case studies consider several alternative instruments for achieving the desired changes. For the most part, however, the case studies do not delve into detailed design of these instruments.

In general, the magnitude of total costs and emissions reductions associated with the fiscal instruments proposed in these case studies is small in relation to the total economy, and in relation to Canada's overall reduction targets examined in the NCCP. For example, ignoring possible macroeconomic feedbacks and overlaps in reductions assumed by each case study, the combined magnitude of direct and indirect reductions from the proposed instruments from all three case studies is 23 to 42 MT by 2010 and 53 to 77 MT by 2030.[11] In comparison, the AMG assumed a total reduction of 199 MT by 2010 under the Kyoto Protocol, and recent emission forecasts have increased the gap to 238 MT, five to ten times larger than the reductions estimated for the instruments considered here.

In the following sections we provide a brief description of each case study, together with a qualitative analysis of potential macroeconomic impacts of the fiscal instruments considered. Where appropriate, we discuss some opportunities to reduce impacts and enhance benefits associated with proposed instruments. The macroeconomic impacts of fiscal policies are very uncertainty. Given the magnitude of proposed instruments, any impacts are likely small. However, we provide some examples of specific opportunities to reduce impacts and enhance benefits in the design of specific instruments.

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[11] The energy efficiency case study also includes emission reductions associated with industrial electricity use. These reductions may overlap with reductions assumed in the renewables case study.

It is important to note that there are possible interactions among instruments proposed in each case study. For example, changes in electricity prices as a result of the fiscal instruments proposed in the renewables case study could affect the costs and magnitude of impacts of fiscal instruments to promote energy efficiency and hydrogen technologies. However, it is difficult to determine the direction or magnitude of such effects and they are in any event likely small given the magnitude of the instruments considered in these case studies. We therefore examine the macroeconomic impacts of each case study separately.

Table 3: Summary of Case Study Assumptions and Results

	Hydrogen energy	Renewable energy	Energy efficiency
Fiscal instruments considered	Only subsidies are considered. Two alternative fiscal packages are examined with different levels of subsidy in each: - Producer tax credits or grants to lower the cost of hydrogen production by 10% or 25% - Producer incentives as above together with consumer incentives to reduce price of hydrogen vehicles and stationary fuel cells by 10% or 25%	Five alternatives packages to achieve a 12% reduction in renewables: - Renewable portfolio standard (24%) - Emission pricing ($10/tonne) - Renewables subsidy (.6 cents / kW.h) - R&D subsidy (61% of forecast base case R&D) - Combined renewable and R&D subsidies	Three alternative instruments with two levels of shadow cost ($15 and 30/tonne): - GHG tax - Tradable permits (auctioned) - Subsidies (grants, loans and tax incentives)
Estimated emission impacts (excluding macroeconomic feedbacks)	From an increase of 0.3 to a decrease of 1.2 MT/year by 2030 (Note 1)	Decrease of 9 to 24 MT/year by 2030	Decrease of 46 – 58 MT/ year by 2030
Marginal cost of emission reductions in 2030	~$800 – >2,000/tonne (depending upon sub-sector)	~$10 – 40 /tonne (Note 3)	~$15 - $30/tonne
Total direct costs of instrument (excluding other feedbacks)	No estimate of total costs is provided but assuming average reduction costs of $1,400 / tonne we estimate ~$1.6 billion in government subsidies per year will be required by 2030.	Case study estimates net levelized welfare costs of $68 to 270 million per year calculated as changes in consumer costs + changes in producer profits + changes in net government revenues. In case of a emission pricing, government revenues would equal ~$1 billion per year. In the case of subsidies, government expenditures would be $125 – 460 per year.	In the case of emission taxes, government would raise $5 – 10 billion per year (after changes in GHG intensity). In the case of subsidies, government would spend $0.2 to 0.5 billion per year. This estimate assumes no free riders, which could increase costs as much as 85%. In both cases, these costs represent the cost of inducing changes in industry based on price and non-price considerations. In terms of real financial costs, Industry will also save $1.9 to 2.7 billion per year in energy costs (net of capital investment).
Price impacts of instruments	Use of subsidies results in no price increases for non-participants (Note 2)	No price increases with subsidies. Under emission pricing and RPS, national average electricity prices (delivered) increase 4 - 5.4% in 2015. Impact of RPS declines to 1% beyond 2015 as a result of R&D investments. (Note 4)	In case of subsidies, combined effects of subsidies and energy savings could actually lower prices in some sectors (by 0.1 to 9% depending upon the reduction scenario and sector). In the case of carbon taxes, prices could decline in

			some sectors (energy savings exceed cost of price) and increase in other sectors. Largest price impacts occur in industrial minerals where additional costs exceed 5% of total value of output. These impacts could be mitigated in part through revenue recycling mechanisms.
Consideration of non-price factors in the analysis	Modelling framework considers non-price factors in estimating impact of subsidies on producer and consumer decisions	Modelling framework assumes all technologies / options are perfect substitutes with decisions based entirely on relative prices	Modelling framework considers non-price factors in estimating impact of instruments on producer decisions
Effects included	Hydrogen production costs Equipment purchases by producers and consumers Hydrogen demand	Uptake of renewables In the case of emission pricing, fuel switching (coal to natural gas) is included Demand feedbacks based on electricity price increases (aggregate elasticities) R&D investment and subsequent reduction in technology costs Reduction in technology costs associated with increased experience	Investments in energy efficiency equipment in target sectors as well as reductions in upstream electricity emissions (via co-generation) Some reduction in technology costs incorporated with increased market shares
Effects excluded	Incremental effects of policies on R&D activity Effect of incremental R&D and/or penetration on rate of technology change Indirect costs of government funds for subsidies Possible changes in prices of fossil fuel generation (through technological change and changes in fossil fuel prices)	Electricity trade Downstream impacts on output for individual sectors Aggregate demand feedbacks Indirect costs of government funds for subsides and indirect benefits from revenue recycling of taxes	Effects of policies on R&D activity Effect of cumulative experience on technology costs Sectoral demand feedbacks Aggregate demand feedbacks Indirect costs of government funds for subsides and indirect benefits from revenue recycling of taxes
Sectors directly affected	Transportation, residential and commercial	Electricity	Mining and manufacturing (indirect impacts on electricity sector via fuel substitution and co-generation)
Regional impacts	Impacts modeled by region Uptake is largest in Alberta, Ontario, BC and Saskatchewan	Impacts modeled using aggregate national parameters	Impacts modeled by region but sub-regional impacts not reported separately

Technology impacts	50% increase in transportation hydrogen demand for transportation (43-67% increase in hydrogen-related vehicles) by 2030 472% increase in hydrogen demand for stationary fuel cells (230% increase in number of installed fuel cells)	58 to 80% increase in renewables production $22 – 172 million increase in annual R&D spending 13 – 26% reduction in renewables costs	Encompasses a wide variety of technologies and processes. Impacts are very diffuse.

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

5.2 Hydrogen Case Study

For the purposes of this case study, hydrogen energy is defined as any energy system where the primary fuel, at some point, within the process, is hydrogen. The study focuses on specific three end-uses and production pathways: a) transportation applications using hydrogen production from decentralized steam methane reformers (SMR); b) transportation applications using hydrogen production from decentralized electrolyzers; and c) fuel cells in residential and commercial sectors, using natural gas from pipelines, decentralized SMR, or decentralized electrolyzers. Hydrogen used in oil refining, manufacturing or medical applications are excluded from the analysis.

The case study considers the impact of two categories of fiscal instruments: consumer incentives and producer incentives (primarily tax credits and grants). These instruments are set at levels to reduce the costs of producing hydrogen and the upfront cost of end-use hydrogen technologies by between 10% (low case) and 25% (high case).[12] For the purposes of this analysis, we focus on the combined impact of producer and consumer incentives under the high subsidy case (i.e., a 25% reduction in costs).

The impacts of these instruments are modeled using Energy 2020. Energy 2020 is an integrated multi-region, multi-sector model that simulates the supply, price and demand for all fuels. The model simulates the behaviour of both energy consumers and suppliers in relation to all fuels and end-uses. The model reflects both price and non-price factors in energy use and technology selection decisions. Model parameters such as price response of demand, price response of supply, and non-price factors in technology selection are based on historical data.

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

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

countries. Given the reliance on historical databases, it also does not appear to include any significant feedbacks of fiscal policies on technology development or consumer preferences in Canada. However, it is unlikely that the pace of technology change or consumer preferences in Canada will be significantly affected with the magnitude of fiscal instruments proposed in this case study.

Aggregate Macroeconomic Impacts

The aggregate macroeconomic impacts of the proposed instruments are insignificant from a national perspective. We base this conclusion on the following observations.

- The marginal cost of emission reductions assumed in this study exceed by a significant margin the marginal cost of emission reductions under the National Climate Change Process (NCCP). The case study estimates marginal costs of $800 to more than $2,000 per tonne depending upon end use and hydrogen pathway. These costs only reflect the cost of government subsidies and exclude any costs borne by program participants, which although voluntary, could still be substantial. In comparison, the NCCP estimates marginal costs of $0-10/tonne for the residential and commercial sectors and $50/tonne for the transportation sector under a sector-specific approach. Under a national target, the marginal costs of reductions in both sectors could be as high as $120/tonne.

- Although the costs are relatively large per unit of emission reduction, total emission reductions are very small - less than 1 MT – suggesting small overall impacts. In the NCCP analysis, emission reductions in the transportation, residential and commercial sectors are between 63 and 66 MT.

- Only subsidies are considered in this case study. With subsidies, costs are spread over the entire economy (via general taxation) rather than individual sectors. Of course, increases in taxes can have additional costs in the form of dampening effects on the economy. However, the magnitude of proposed subsidies is ~$1.6 billion per year by 2030.[13]

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[13] This estimate is based on an average cost of emission reductions of $1,400 per tonne. The case study does not provide an estimate of aggregate costs. Rather, it

Assuming government expenditures grow at roughly the same rate as GDP, this subsidy would increase government expenditures by ~0.4% in 2030.[14]

Distributional and Competitiveness Impacts

Costs of the fiscal instrument vary widely across end use, pathway and region. However, since reductions are achieved entirely via subsidies, these costs are spread out over the entire economy.

Given that the subsidies do not remove the gap between hydrogen energy and conventional energy sources, uptake is contingent upon participants who are willing to pay a premium for non-financial reasons. In general, uptake will be limited to consumers with higher incomes.

The greatest penetration of technologies occurs in Alberta and Ontario based on relative energy prices. These jurisdictions would therefore see the largest share of any co-benefits arising from policy (e.g., reductions in local air emissions).

The subsidies could benefit developers of hydrogen technologies, which tend to be clustered in B.C. and Ontario. However, Canada currently has little production capacity for these technologies so the equipment is likely to be imported. The magnitude of additional demand is unlikely to be sufficient to stimulate domestic production of these technologies.

Effects on Technological Change

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provides an estimate of "representative" costs by end use and pathway. An average cost of $1,400 was based on qualitative review of the range of costs presented in the analysis.

[14] It is not entirely clear from the analysis whether the estimate of subsidies includes administrative costs and potential free riders. Free riders can greatly increase the costs of achieving a given level of emission reduction, particularly in the case of broad instruments such as tax credits, which do not discriminate between consumers and firms that would have made investments in the absence of the credit.

With the proposed fiscal instruments (higher level of subsidy), there is a 50% increase in transportation hydrogen demand for transportation and a 43-67% increase in hydrogen-related vehicles by 2030. There is a 472% increase in hydrogen demand for stationary fuel cells, with a 230% increase in number of installed fuel cells. Although these represent large relative gains, the additional installations are small in absolute terms. These gains also occur over a period of 20 years.

The case study does not explicitly incorporate any induced technological change as a result of the proposed instruments. That is, there is no assumption about an increase in R&D effort in response to subsidies or incremental cost reductions from higher penetration of technologies beyond what is assumed in the base case. Although significant in relative terms, the increases in hydrogen production and penetration of hydrogen end use technologies are very small in absolute terms. It is unlikely the policy will have significant effects on technological evolution. Advances in the technology are more likely to come from changes in global demand and policies in much larger countries.

5.3 Renewables Case Study

The renewables case study focuses on grid-based renewable electricity production that is EcoLogo certifiable. The technologies covered include wind, low-impact hydro, grid-connected photovoltaics, landfill gas, biomass, ocean, and geothermal. Solar thermal and large hydro are excluded as options. Under certain instruments (e.g., emission taxes), some emission reductions can also come from switching production among existing plants (e.g., displacing coal production with power produced in natural gas plants). However, the study does not consider emission reductions possible from new co-generation of electricity. Co-generation is one of the least-cost methods of reducing emissions from the electricity sector at the margin and it constitutes a significant portion of the emission reductions obtained in the energy efficiency case study.

The case study compares several alternative instruments and packages as means of achieving a 12% reduction in carbon emissions from the electricity sector relative to the base case. These four instruments are:

i. an emissions price of \$10/tonne CO_2 (either via a tax or tradable permits);

ii. a renewable portfolio standard (RPS) requiring 24% electricity generation (excluding large hydro and nuclear generation) to come from renewable sources (through quota obligations for retailers, or green certificates for fossil generators);

iii. a renewable generation subsidy of $0.006/kW.h using tax credits or direct subsidies to encourage the expansion of carbon-free generation;

iv. a combination of a 24.2% RPS and generation subsidy of $0.006/KW.h; and

v. a renewable research subsidy of 61% above forecast 2010 R&D levels, to reduce costs of future renewables production.

These instruments are modeled using a framework developed by Resources for the Future. The model has two stages: 2010-2015, and 2015-2030. Electricity generation, consumption, and emissions occur in both stages, but investment in knowledge takes place in the first stage and through technological change and innovation lowers the cost of renewable generation in the second. Fossil fuel is assumed to be the marginal technology that would be displaced by renewables generation, and that sets the overall market price. For the purposes of this case study, renewables are assumed to be perfect substitutes for fossil fuel-based electricity. This assumption ignores non-price considerations that could affect the selection of technologies.[15]

The analysis is conducted from the perspective of Canada as a whole, using aggregated national parameters (e.g., a single national average electricity price). Although national parameters are developed from disaggregated regional and sectoral values, it is not so easy to translate aggregate impacts into regional and sectoral impacts given

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[15] Non-price considerations are not relevant in the can of an RPS, where there is a minimum market share mandated for renewables. However, non-price factors (e.g., risk perceptions) could reduce the uptake of renewables in the face of a particular emission price or subsidy, compared to a situation where these factors are ignored. Interestingly, the renewables case study assumes much larger penetration of renewables under a $10/tonne CO2 price compared with results from the energy efficiency case study, which considered cost-effective reductions in upstream electricity emissions in addition to reductions in energy intensity. At a shadow price of $15 / tonne, virtually all of the emission reductions associated with industrial electricity use are in the form of co-generation. The National Climate Change process also assumed much lower penetration of renewables at $10 / tonne.

the wide variations in costs and prices across different sectors and regions.

Aggregate Macroeconomic Impacts

The aggregate macroeconomic impacts of the proposed instruments are insignificant from a national perspective. We base this conclusion on the following observations.

- Under an emission price, the marginal cost of emission reductions in the case study is approximately $10 / tonne. In the NCCP, the marginal cost of emission reductions in the electricity sector ranged from $30 – 120 per tonne.

- Under a renewables subsidy, the case study assumes a credit of 0.6 cents per kW.h. The NCCP included a production credit for renewables of 2.5 cents per kW.h.[16]

- In addition to lower unit costs, the case study assumes lower aggregate emission reductions – 7 to 15 MT by 2010. In the NCCP, electricity sector emissions decline by 37 to 78 MT by 2010, the largest single source of emission reductions in the analysis. These reductions are two to ten times higher than the reductions estimated in the renewable energy case study.

- Electricity prices in the NCCP increased by as little as 2% in Quebec to nearly 84% in Alberta (under a shadow price of $120/tonne). In the renewables case study, the shadow price of carbon is considerably lower and national average electricity prices increase by zero to 5% depending upon the instrument, which is towards the low end of the regional electricity price increases in the NCCP.

There are some uncertainties, however, regarding costs and impacts. The NCCP posits a smaller uptake of renewables than suggested in this case study, even at higher marginal costs. In the NCCP, most of the electric sector emission reductions come from additional hydroelectric production and trade among provinces, capture and

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[16] Interestingly, the NCCP analysis also estimated lower penetration of renewables under a higher production subsidy.

storage of CO_2 in aquifers in Alberta and Saskatchewan, and increased co-generation. A more recent assessment of emission reductions measures for Canada suggests only 2.4MT of emission reductions from switching to non-hydro renewables in electricity at a cost of $10/tonne (Bataille 2004). This suggests that the emission reductions from the proposed emission price could be overestimated while the costs of the proposed RPS could be underestimated. In either case, we do not believe these uncertainties would alter out general conclusions regarding aggregate impacts of the instruments.

This case study also considers a variety of potential instruments for meeting a pre-defined emission reduction target of 12% in the electricity sector. These instruments differ in terms of overall costs, distributional impacts, risks, and effects on technological change. These differences are summarized briefly in Table 4. It is important to note that some of the differences reflect the specific design of instruments rather than reflecting generic features of each instrument type. For example, the welfare costs of the RPS are higher than emission pricing. However, this is due in part to the fixed target established for both stages considered in the analysis. A phased target could reduce costs by allowing more opportunities for R&D in stage 1 to reduce the (anticipated) costs of stage 2.

Table 4: Summary Comparison of Proposed Instruments

	Emission price	RPS	Renewable Subsidy	R&D Subsidy
Present Value Costs ($2002 millions)	$579	$1,041	$711	$2,300
Distributional impacts (w/o mitigation measures)	Higher consumer and industrial electricity prices (5% on average) Minimal regional costs differences expected at low price levels	Higher consumer and industrial electricity prices (1-3% on average) Minimal regional cost differences expected with tradable renewable certificates	No change in consumer and industrial prices	No change in consumer and industrial prices
Estimated reduction in cost of renewables	15%	13%	16%	26%
General incentives for technological improvement	Increases potential returns on renewables R&D but also creates competition from other sources of emission reductions such as conservation, fossil fuel switching, and co-gen.	Encourages competition among individual technologies but dampens incremental returns to renewables R&D as a whole. Greatest impact comes from learning by doing effects.	Renewable subsidy increases returns to renewables R&D but may encourage more lobbying rather than investments in real innovation	Direct increase in R&D funding but danger that funds not allocated to best technologies. Does not guarantee uptake and limited impact on learning by doing.
Key Risks / Uncertainties	Impacts on electricity trade and industrial demand Regional distribution of costs Magnitude of emission reductions Cost reduction in renewables	Costs of emission reductions Cost reduction in renewables	Number of free riders Magnitude of emission reductions Cost reduction in renewables	Number of free riders Effectiveness of R&D on reducing costs Magnitude of emission reductions

Distributional and Competitiveness Impacts

The distributional impacts of the case study vary greatly depending upon the instrument employed.

In the case of subsidies, costs are borne by taxpayers and widely distributed throughout the economy. Consumers do not see any increases in electricity prices. As noted above, the full costs of a subsidy can exceed the amount of the subsidy due to the dampening effects of taxation on economic activity. However, these costs could be offset somewhat through more targeted revenue collection instruments that address other distortions (e.g., externalities) to fund subsidies for renewables, such as taxes on air emissions.

In the case of emission pricing and renewable portfolio standards, costs are borne primarily by consumers. Increases in electricity prices will disproportionately affect low-income households in terms of existing household budgets. In the case of emission pricing, these effects can in part be offset by using revenues to reduce other taxes or increase direct transfers to low-income households.

Emission prices, renewable portfolio standards and renewable energy subsidies can all lead to windfall profits for some renewables producers who are already cost-competitive with conventional fossil fuel plants. As noted below, these windfall gains, however, can in part be reduced through better policy design.

Regional and sectoral impacts are more difficult to estimate. The case study was conducted from a national perspective. At a national level, average electricity prices increase from 0% under subsidies to 5% under emission pricing. While relatively small from a national perspective, particularly in light of a 20-year phase-in and the possibility of revenue recycling to offset price impacts, these national averages could mask important differences in price impacts across regions and end users. These differences, in turn, could affect some sectors more than others. The analysis does not provide sufficient detail for a formal analysis of regional and sectoral impacts, but we can make some inferences of impacts based on other recent studies and some simple screening.

In the case of emission pricing, costs will be highest in jurisdictions with higher fossil fuel-based electricity generation (e.g., Alberta, Saskatchewan, and New Brunswick). The percentage change, however, will also depend upon the base case price, which varies across jurisdictions. Under an emission price of $120/tonne, prices increase as much as 84% in Alberta (Jaccard et al. 2003). Average changes can mask differences across individual sectors. For example, industrial electricity prices tend to be lower than residential and commercial prices, reflecting historical rate policies and differences in delivery costs. Thus, given change in production costs may translate into a higher percentage change for industry and a lower percentage change for households. For example, in the energy efficiency case study, which contains more regional detail, a shadow price of $15/tonne increases industrial electricity prices by 1-2% in provinces such as B.C. and Quebec, and as much as 25% in provinces such as Alberta and Saskatchewan. The use of a single national price in the renewables case study complicates comparisons. In general, we expect regional differences in price impacts will be much smaller at lower emission prices such as those assumed in this case study, particularly since other reduction options may be pursued such as switching production among plants (and increasing co-generation, which is not considered in the renewables case study).

In the case of an RPS, regional price impacts will depend upon the existing percentage of renewables in each province and the costs of renewable energy. The type, magnitude and cost of existing and new renewable supplies vary greatly among provinces. If credit trading is permitted among provinces, regional cost differences may be small under an RPS as provinces with higher cost supplies can access lower cost sources in other provinces. Provinces with low cost supplies would in turn pay higher prices as a result of national trading.[17]

Assuming minimum regional variation in price increases, and using national average changes, we can evaluate sector-specific impacts using national electricity intensities by sector. Table 5 summarizes the projected output and net electricity intensity per unit output (net of self-generation) of different sectors. These are derived from the energy efficiency case study. Table 6 shows electricity costs as a percentage of the total value of output, together with the percentage change in total costs as a result of a 5% increase in electricity price. We use the national average delivered costs of electricity used for the rewewables case study ($25.6 per GJ). In fact, industrial prices are likely lower than the national average. For example, in the energy efficiency case, industrial electricity prices range from ~$12/GJ in B.C. and Manitoba, to almost $20/GJ in the Atlantic provinces. Lower starting prices could imply a higher percentage change in electricity prices for industry, but would also lower electricity costs as a percentage of total output. For the purposes of this qualitative

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[17] Under a renewable credit trading system, investment will likely be allocated to jurisdictions with a higher share of low cost non-hydro renewable resources such as B.C.

analysis, we use the average electricity prices and price changes from the renewables case study.

As illustrated in Table 6, under the above assumptions, costs for most sectors would increase by no more than 0.1%. Cost increases are highest for metal mining and smelting (1.6% in 2010) and for pulp and paper (0.8% in 2010), both electricity-intensive sectors. Metal mining and pulp and paper are also highly export-intensive sectors, raising concerns about broader impacts on competitiveness and trade.[18]

Even though larger, the relative change in prices is still small. In addition, possible impacts on exports can be mitigated through policy design, as discussed in more detail below.

Table 5: Electricity Intensity of Industry

	Output (2000$ millions)			Net Electricity Intensity (GJ / C$2000 million) (Business as usual case)		
	2010	2020	2030	2010	2020	2030
Chemical Products	55,723	72,724	91,089	746	725	749
Coal Mining	2,266	2,753	3,363	1,866	1,413	1,084
Industrial Minerals	1,728	2,135	2,751	4,800	4,428	4,250
Iron and Steel	16,007	17,537	19,804	2,190	2,159	2,118
Metal Smelting and Refining	20,508	24,808	28,589	11,831	9,917	8,866
Mining	65,441	69,551	73,476	589	581	575
Other Manufacturing	168,772	208,665	226,934	984	838	838
Oil and Gas Extraction	64,237	73,981	81,804	1,310	1,496	1,842
Petroleum Refining*	22,823	25,970	28,533	369	- 71	- 249
Pulp and Paper	32,956	39,138	45,329	5,485	4,948	4,797

* A negative net electricity intensity indicates the sector is a net exporter of electricity (e.g., co-generation production exceeds own requirements).

Source of output and electricity intensity information: MK Jaccard and Associates

[18] Armington elasticities produced by Bataille (2004) are -1.3 to -1.5 for mining and pulp and paper production, respectively, indicating a high responsiveness of domestic and export demand to price changes. However, metal smelting is much less sensitive (-0.59).

Table 6: Impact of Electricity Price Changes in Industry

	Electricity Costs as % of Output Value			Increase in Costs with a 5% Increase in Electricity Price (No Change in Intensity)		
	2010	2020	2030	2010	2020	2030
Chemical Products	1.9%	1.9%	1.9%	0.1%	0.1%	0.1%
Coal Mining	4.8%	3.6%	2.8%	0.3%	0.2%	0.2%
Industrial Minerals	12.3%	11.3%	10.9%	0.7%	0.6%	0.6%
Iron and Steel	5.6%	5.5%	5.4%	0.3%	0.3%	0.3%
Metal Smelting and Refining	30.2%	25.3%	22.7%	1.6%	1.4%	1.2%
Mining	1.5%	1.5%	1.5%	0.1%	0.1%	0.1%
Other Manufacturing	2.5%	2.1%	2.1%	0.1%	0.1%	0.1%
Oil and Gas Extraction	3.3%	3.8%	4.7%	0.2%	0.2%	0.3%
Petroleum Refining	0.9%	-0.2%	-0.6%	0.1%	0.0%	0.0%
Pulp and Paper	14.0%	12.6%	12.3%	0.8%	0.7%	0.7%

Effects on Technological Change

This case study includes an explicit analysis of the effects of instruments on technological changes. There are two primary pathways for effects on technological change. The first pathway is increased R&D spending in stage 1 in response to the instrument, which can in turn reduce the cost of technologies in stage 2. The second pathway is via learning by doing–i.e., the reduction in costs that accompanies the cumulative installations of a technology.

Depending upon the fiscal instrument, the case study estimates a 58 to 80% increase in renewables production over the study period. Annual R&D spending on renewables development increases by $22 – 172 million compared to the base case. Increased R&D, together with increased penetration of technologies, produce cost reductions of 13 – 26%. These cost reductions, however, are uncertain, depending in part on the success of R&D spending in earlier periods.

As discussed below, we believe that effects on technological change could vary greatly among instruments. We also believe there may be ways to enhance these effects through the actual design of individual instruments.

5.4 Energy Efficiency Case Study

The energy efficiency case study covers the following sectors: 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. The study considers fuel switching; reductions in fugitive emissions; and more efficient energy conversion technologies (e.g., co-generation), end-use equipment, and production processes. The study considers both direct and indirect emissions (primarily emissions associated with electricity inputs). As a result, there is some potential overlap in the carbon reductions included in this study and those assumed in the renewables case study.[19]

The case study considers the impact of imposing two alternative shadow prices for carbon. The *Low Carbon I Scenario* assumes a shadow price *of* \$15/tonne CO_2e. The *Low Carbon II* scenario assumes a shadow price of \$30/tonne CO_2e. Both scenarios are simulated over a 25-year period (2005-2030). These results could be achieved through carbon taxes, tradable permits, or subsidies. About 41% of the estimated reductions in both scenarios are from actual increases in efficiency while the remaining 59% is due to fuel switching, process and fugitive emission reductions.

Aggregate Macroeconomic Impacts

The aggregate macroeconomic impacts of the proposed instruments are insignificant from a national perspective. We base this conclusion on the following observations.

- The marginal cost of emission reductions in the efficiency case study are \$15 – 30/tonne, compared with costs for the industrial sector of \$120 – 300/tonne in the NCCP.

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[19] In the energy efficiency case study, at \$15 and \$30 per tonne the majority of emission reductions in the electricity sector come from fossil fuel switching and co-generation opportunities. The renewables case study does not explicitly consider co-generation opportunities.

- Total emission reductions are also smaller, ranging from 21 – 27 MT in 2010, compared with 30 – 37 MT in the NCCP.
- If achieved through subsidies, the reductions would increase government expenditures $220 – 540 million/year.[20] This is less than 0.1% of current federal expenditures, and this percentage declines with growth in the economy.
- Subsidies would result in modest increases in producer profits and/or decreases in output prices. If achieved via carbon taxes, the instrument would raise $5 – 9.5 billion per year. This revenue would be available to reduce other distortionary taxes in the economy or to mitigate impacts on industry. Furthermore, these additional costs would in part be offset by energy savings in industry of $2 – 3 billion per year. Net costs to industry represent between 0.6 and 1.5% of the value of total output in 2010.

Distributional and Competitiveness Impacts

Possible distributional impacts vary with the specific type of instrument employed. The main concern is possible impacts on competitiveness of specific sectors. If significant, these impacts can also be mitigated in part through appropriate policy design, as discussed further below.

As noted above, subsidies produce no price increases and, in the case of energy efficiency investments, they could even lower output prices. Lower prices could lead to higher demand, reducing some of the emission reductions produced from increased efficiency (referred to as the rebound effect).

Emission pricing (via taxes or tradable permits) will increase costs for industry. In general, costs will be highest in the most carbon-intensive sectors. However, these costs will in part be offset by savings from energy efficiency and fuel switching, including co-generation. Many industries experience cost increases of less than 1% of the value of output. Under a shadow price of $15/tonne, price impacts vary from

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[20] This assumes no free riders. Estimates of free riders in efficiency programs are as high as 85%. This implies that subsidies may need to be as mush as 85% higher to achieve the target level of emission reductions assumed with no free riders.

reductions of 0.4% in the chemical products and pulp and paper sectors, to an increase of more than 5% in the industrial minerals sector (Table 7). There are fewer cases of cost decreases at $30/tonne, and costs (as a percentage of the value of output) increase more than 12% in the industrial minerals sector.

Table 7: Potential Change in Output Prices with a Carbon Tax (Before Demand Adjustments)*

	Low Carbon I			Low Carbon II		
	2010	2020	2030	2010	2020	2030
Chemical Products	-0.4%	-0.2%	-0.1%	0.3%	0.4%	0.5%
Industrial Minerals	5.3%	5.7%	6.6%	12.3 %	10.6%	11.5%
Iron and Steel	0.5%	0.5%	0.7%	2.1%	2.1%	2.3%
Metal Smelting & Refining	0.6%	0.6%	0.6%	1.8%	1.6%	1.6%
Mining	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
Other Manufacturing	0.2%	0.2%	0.2%	0.4%	0.4%	0.4%
Oil and Gas Extraction	3.7%	3.8%	3.8%	7.0%	7.2%	7.3%
Petroleum Refining	1.3%	1.3%	1.4%	2.7%	2.7%	2.8%
Pulp and Paper	-0.4%	-0.3%	-0.2%	-0.3%	-0.2%	0.0%
Total	0.6%	0.7%	0.7%	1.5%	1.5%	1.5%

*Price changes estimated by dividing costs of taxes (less net energy savings) by value of total output. This calculation assumes no change in output associated with the instrument. Coal mining is excluded since changes in output are endogenous to the model used in this case study.

The macroeconomic effects of these cost increases depend in part on demand responses. In general, much of the increased costs for goods and services that are not traded internationally will be passed onto consumers. In the case of goods and services that are traded internationally, producers may be unable to pass on cost increases, resulting ultimately in a decline in output and an increased share of domestic and international markets by producers from other countries. Armington elasticities can be used to approximate the responsiveness of a sector to price increases. Armington elasticities reflect the price responsiveness of both domestic and international demand for a sector's output (Table 8). A value greater than one indicates an elastic demand in which output declines more quickly than increases in price. Some sectors are extremely elastic – e.g., mining and segments of the industrial minerals and pulp and paper sectors. Table 9 illustrates possible demand feedbacks based on average Armington elasticities in each sector. In some cases, demand feedbacks are lower than anticipated price changes; in other cases they are higher. For the most part, demand feedbacks are less than 1%. The most significant impacts are on the industrial minerals sector.

Table 8: Representative Armington Elasticities

Sector	Armington Elasticity
Chemical Products	-0.44 to -.88
Industrial Minerals	-0.53 to –1.75
Iron and Steel	-0.6
Metal Smelting & Refining	-0.59
Mining	-1.38
Other Manufacturing	-.38 to –1
Pulp and Paper	-0.79 to -1.72

Source: Bataille (2004). Values are adapted from Wirjanto (1999)

Table 9: Estimated Demand Feedbacks Under Carbon Tax

	Low Carbon I			Low Carbon II		
	2010	2020	2030	2010	2020	2030
Chemical Products	0.2%	0.1%	0.0%	-0.1%	-0.2%	-0.2%
Industrial Minerals	-5.3%	-5.7%	-6.6%	-12.3%	-10.6%	-11.5%
Iron and Steel	-0.3%	-0.3%	-0.4%	-1.3%	-1.3%	-1.4%
Metal Smelting and Refining	-0.4%	-0.4%	-0.4%	-1.1%	-1.0%	-0.9%
Mining	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.2%
Other Manufacturing	-0.2%	-0.2%	-0.2%	-0.4%	-0.4%	-0.4%
Pulp and Paper	0.7%	0.5%	0.2%	0.4%	0.3%	0.1%

Note: Coal, oil and gas extraction and petroleum refining are excluded. Coal demand is estimated endogenously in CIMS based primary on changes in coal demand for electricity consumptions. Total output from oil and gas extraction and petroleum refining are assumed to be constant to consistency with the NCCP. However, this implies instruments are not applied to exports.

The above analysis excludes the coal sector. Coal output is modeled explicitly within the case study based on fuel substitution in other sectors (primarily the shift to co-generation). In the case study, coal sector output declines 9% and 22% by 2030 under the Low Carbon I and Low Carbon II scenarios, respectively.

The above impacts assume no mitigation policies are implemented (i.e., they represent the worst case impacts). For example, possible impacts on export demand may be mitigated through various exemptions and other recycling policies.

Effects on Technological Change

The case study does not evaluate in detail the possible impact of instruments on the rate of technological change, except indirectly through reductions in costs with higher market shares. The impacts on long-term technological change are very uncertain and will depend in part upon the type of instruments employed and the detailed design of those instruments. However, there is also empirical evidence that the energy price shocks of the 1970s clearly stimulated investment in R&D into more efficient equipment (e.g., Newell, Jaffe and Stavins 1998; Jaffe, Newell and Stavins 2000; Popp 2001).

5.5 Design Considerations for Proposed Fiscal Instruments

For the most part, the macroeconomic impacts of the proposed instruments are uncertain, although they are likely small. The nature and magnitude of possible impacts vary greatly depending upon the types of instruments employed and their detailed design. The case studies do not delve into detailed design options for the proposed fiscal instruments.

In this section we offer some examples of design considerations that could improve the performance of proposed instruments. We focus in particular on opportunities to reduce distributional impacts and increase incentives for technological change. Given the large number of instruments considered in the three case studies, we focus here on some select examples of design considerations within each broad category of instrument. Our goal is to highlight some general issues that warrant attention in the detailed design phase. Many of the case studies suggest using combinations of instruments. We therefore also discuss briefly some general issues related to developing policy packages, particularly some considerations for the staging of instruments.

Expenditure Instruments

All three case studies highlight opportunities for expenditure instruments such as production incentives, equipment subsidies, and R&D subsidies. The hydrogen case study considers only subsidy instruments. As noted in previous sections, subsidies tend to have fewer negative distributional impacts because costs can be spread across the entire economy. At the same time, subsidies will generally cost more to achieve the same environmental outcome. There are three reasons for this. First, there are often free riders (i.e., people or firms that would have implemented changes in the absence of subsidies). Second, the collection of revenues to fund subsidies tend to increase the dampening effects of other taxes on the overall economy. Finally, subsidies tend to target specific solutions (e.g., installation of a specific technology) and there are risks that those solutions are not the most cost-effective options for achieving the environmental improvement. Subsidies can encourage improvements in specific technologies but depending upon design some resources may be diverted from innovation activities to political rent-seeking (lobbying). Also, the innovation tends to be directed towards pre-defined solutions (e.g., a particular technology) rather than more broadly at minimizing a particular environmental impact.

The performance of subsidies can generally be improved through better design. Some examples of possible design considerations include the following:

- Dampening effects may be partly offset by raising government funds through more targeted approaches that correct for other distortions. For example, a subsidy for hydrogen vehicles may be funded through a levy on gasoline that reflects its external costs.

- Free riders may be reduced through more discriminating techniques for distributing subsidies. For example, subsidies could be distributed through grants tied to specific performance criteria rather than through general tax credits.

- Political rent-seeking may be reduced by administering subsidies through arms-length agencies (e.g., a carbon trust) with accountability for explicit performance criteria.

- The most cost-effective innovations may be encouraged by linking subsidies more closely to environmental outcomes rather than specific technologies. For example, a carbon trust could seek requests for proposals to purchase emission reductions from a wide range of mitigation options. Proposals could then be ranked on the basis of their cost-effectiveness.

There will be trade-offs across different objectives in designing instruments. For example, more targeted approaches for collecting revenues to fund subsidies and/or for distributing grants will likely incur higher administrative costs. Similarly, different options for distributing subsidies may favour different firms and/or income groups. For example, general tax credits tend to reduce pay-offs from lobbying and can be more accessible to smaller firms, which may not have the same resources to lobby or apply for grants. At the same time, however, small firms may lack the resources to finance investments, making grants a more attractive alternative for them.

Revenue-generating Instruments

Both the renewables and energy efficiency case studies consider revenue-generating instruments such as emission pricing (via taxes or tradable permits). Revenue-generating instruments provide direct and continuous incentives for reducing impacts and developing new technologies. However, they also have the greatest impact on market prices and they can often affect some sectors and regions more than others. These impacts can in part be offset through the design of instruments and through revenue recycling policies.

For example, the emission prices explored in the renewables case study results in the greatest rise in final electricity prices. Increased electricity prices can affect low-income households and the competitiveness of energy-intensive and export-intensive industries. If these impacts are significant, they can be mitigated in part through appropriate design of the instrument and in the selection of different mechanisms to recycle revenues collected by the instrument. Three examples are as follows:

- Impacts on low-income households can be mitigated through revenue recycling strategies targeted specifically at this demographic – e.g., increases in personal deduction limits, reductions in other consumption taxes, or weatherization and other efficiency programs targeted at low-income households.

- Differences in regional costs can be mitigated through revenue recycling strategies targeted at specific regions – e.g., tax credits for households in northern communities (which use more energy) or increases in general transfers to specific provinces.

- Impacts on electricity-intensive, export-oriented industries (e.g., mining and pulp and paper) can in part be mitigated through the allocation of a certain number of free permits to these industries and by recycling revenues to industry through specific tax credits or rebates for exporters, or via general reductions in payroll and capital taxes.

In selecting a recycling mechanism for industry it may be important to distinguish between protecting existing investments versus encouraging new investments. Failing to discourage new investment may simply delay desired long-term structural change. In addition, it is important to ensure that mechanisms to protect industry do not generate large windfall profits (see for example, Bovengerg et al. 2000).

Recycling policies can be designed to meet multiple objectives such as lowering aggregate costs to the economy, increasing environmental benefits (e.g., subsidies for R&D on low-carbon technologies), reducing impacts on export-oriented sectors, reducing impacts on specific regions, or reducing impacts on specific income groups. Often, however, trade-offs will be required among these different objectives in the overall design of policies.

In addition to recycling considerations, it is also important to consider the phase-in of instruments. In general, costs will be lower if instruments are phased in gradually over a longer period of time. In addition to allowing more time for adjustments in long-lived capital stocks, a phased approach can provide opportunities for firms to search for innovations that will reduce the ultimate costs of an instrument. However, in order to influence innovation, schedules, prices and/or targets must be clearly outlined and expected. Uncertainty over future regulations reduces incentives to invest in innovation. In addition, if industry perceives an opportunity to influence the phase-in, resources may be diverted from innovation to lobbying activities.

Budget-neutral Instruments

The only budget-neutral instrument specifically identified in the case studies is the Renewable Portfolio Standard in the renewables case study. The proposed design of this instrument is vague but there are several important considerations (for a more detailed discussion of these design considerations see Berry and Jaccard 2001).

First, the case study suggests that the general effects of a quota obligation for retailers or fossil generators are the same. However, these have different potential implications in terms of macroeconomic impacts. For example, a quota system for retailers will not affect international trade of electricity. Similarly, under a quota system for retailers, it is possible to apply the RPS to residential and commercial customers only in order to reduce possible impacts on industry.

Second, the RPS considered in the case study does not appear to distinguish between existing and new sources of supply. As a result, there is a greater chance of windfall profits for existing renewable producers. An RPS can be designed to focus on incremental electricity supply, thereby eliminating possible price increases for existing resources.

Third, there is no consideration of possible regional differences in targets. Targets could vary across regions to reflect regional differences in current supplies, resource availability, and costs.[21]

Fourth, there is no phase-in of the proposed RPS target. Producers and consumers therefore have fewer opportunities to reduce long-term costs through additional investments in R&D. As with emission pricing above, a phased approach with clear targets and timelines may offer more opportunity for technological changes that lower the ultimate costs of the instrument.

Finally, there is no explicit discussion in the case study of credit trading, credit banking, or penalties. These are important considerations that can greatly influence the costs and effectiveness of the instrument. For example, credit trading can lower the costs of meeting targets by allowing producers to access low-cost renewables regardless of their location. In addition, a system of penalties can act to reduce the risks of higher costs than anticipated by providing a ceiling on the cost of obligations. Any revenues raised from penalties can in turn be reinvested in R&D or development of new renewables.

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[21] It is important to note that the federal government currently has no obvious ability to create a national RPS in Canada. We assume the RPS would therefore be implemented through some sort of agreement among the provinces. This implies that targets could vary across provinces, depending upon the current mix of resources and the quantity and cost of new renewable supplies.

Policy Packages

Many case studies suggest the use of multiple instruments. In designing policy packages, it is important to also consider the interactions among instruments. For example, a subsidy for renewables coupled with an RPS, may not increase the penetration of renewables compared with an RPS alone, but simply re-distribute the costs of meeting the RPS from electricity ratepayers to taxpayers. This is a valid objectives but policy designers and policy makers must understand the incremental impacts of each instrument in order to weigh costs and benefits.

Often, many discussions of policy packages revolve around the simultaneous implementation of several instruments. Often, however, a staged approach to instruments may be more useful for stimulating technological change. For example, in the very early stages of implementation, where the cost difference between existing and new technologies is quite large, R&D subsidies may be the most effective instrument to consider (such as in the case of hydrogen technologies). Instruments that encourage or force market adoption of these technologies may be very costly and may actually have a negative impact on future uptake because they reinforce impressions that these technologies are expensive and because their performance is often poor in such early stages of development. Once the cost differential is reduced and performance is improved, instruments that encourage some market adoption would be most useful to encourage learning by doing and economies of scale in manufacture. Often, set-asides (such as portfolio standards) and/or subsidies will be most effective and acceptable at this stage. Once the cost differential is lower, policy makers may wish to consider broader-based revenue instruments such as permits or taxes that reinforce the position of these new technologies and stimulate competition from other new technologies.

6.0 Summary

General Lessons

The macroeconomic impacts of fiscal instruments related to GHG and energy are typically uncertain and controversial. However, some general lessons can be gleaned from the existing literature.

The type and magnitude of impacts to achieve the same environmental outcome will vary across the different instruments. At the same time, there are many opportunities to mitigate impacts and to improve effectiveness through the design of specific instruments. Often there will be trade-offs between minimizing aggregate costs and other objectives such as minimizing distributional impacts.

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 would normally replace existing equipment or when they are considering new equipment purchases are less costly than instruments that require them to accelerate capital replacement.

Revenue-generating instruments such as taxes, as well as many budget-neutral instruments such as the renewable portfolio standard, can increase prices for producers and consumers. These policies will typically have larger effects on energy-intensive sectors or regions, and they will tend to have disproportionate effects on low-income households. These impacts can in part be offset through instrument design and revenue recycling policies.

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

The impacts of revenue-generating instruments such as taxes can be greatly reduced through revenue recycling policies. For example, costs can be reduced by lowering or eliminating other taxes that dampen economic activity. Alternatively, more focused recycling policies can be used to mitigate impacts on specific income groups, sectors or regions of the economy. Recycling mechanisms must be designed carefully to balance multiple objectives – e.g., protecting historical investments, providing incentives for new investment, and encouraging desirable long-term technological changes. Recycling mechanisms for industry must also be designed carefully to minimize any possible windfalls as a result of the policy.

The cost of subsidies can be spread out over the entire economy, reducing, although not eliminating, negative distributional impacts. However, the total cost of subsidies often exceed the direct costs to government since governments must raise funds from other taxes and these have dampening effects on economic activity. The cost of subsidies required to achieve a given environmental effect can also be higher due to the presence of free riders – i.e., firms and individuals that would have undertaken the desired change in the absence of the subsidy. The costs of free riders can be large but is often underestimated. Subsidies also tend to focus on specific technologies or solutions rather than environmental outcomes (e.g., emissions). As a result, there is a greater risk that subsidies support more costly options for achieving the desired environmental outcomes. In all cases, the performance of subsidies can be improved through better policy design.

The impact of fiscal instruments on innovation (particularly technological change) is ambiguous. Dysfunctional government policies can clearly impede innovation. Whether governments can actually stimulate innovation is less clear. Much of the existing literature suggests that governments can have the most influence on innovation through general taxation policies, legal systems for intellectual property, and public spending on basic research and higher education. There is evidence that targeted fiscal policies could also influence the rate of technological change in specific sectors. The likelihood and magnitude of innovation may be improved by designing policies that are gradual, continuous, and predictable; that encourage real innovation rather than political rent-seeking; and that are linked as close as possible to desired environmental outcomes rather than specific technologies.

Case Study Impacts

The macroeconomic analysis conducted by Analysis and Modelling Group (AMG) that supported Canada's National Climate Change Process (NCCP) found that, depending upon assumptions about microeconomic costs and international actions, meeting the Kyoto targets could reduce real GDP by 0 to 3 percent by 2010 (equivalent to a one-year recession), if all necessary policies had been implemented by 2000. Although there is a small increase in activity in the short-term as a result of increased capital spending, GDP declines after a few years as a result of the higher production costs, lower productivity, trade effects, and reduced disposable incomes.

In the AMG results, provincial impacts are generally within 1.5% of the national average. However, the relative impacts on each province vary depending upon the reduction path. If Canada acts alone, Ontario and Saskatchewan are the most negatively affected. With international action, Saskatchewan, Alberta and New Brunswick are the most negatively affected.

Acting alone, the marginal cost of all measures to meet the Kyoto target would range from $40 to 120/tonne in 2010. If passed through to energy prices, these costs would raise gasoline prices 13 – 35 per cent, natural gas prices (for residential use) 30 to 75 per cent, and coal prices 300 to 800 per cent. Electricity price impacts vary greatly across regions depending upon the dominant sources of supply and pricing regime. Assuming average cost pricing, price increases range from a low of 2% in Quebec to almost 84% in Alberta.

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

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

The aggregate macroeconomic costs of the various instruments proposed in the case studies prepared for the NRTEE are likely much small in comparison to the estimates produced for the NCCP for the following reasons:

- For the most part, the marginal cost of emission reductions in the case studies are lower than those assumed under the NCCP to meet the Kyoto targets.

- The total emission reductions by 2010, even without adjusting for possible double-counting among the case studies (e.g., both the renewables and energy efficiency case studies include reductions in the electricity sector), are three to ten times lower in the case studies than those assumed in the NCCP.

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

The impacts of instruments on competitiveness and innovation are uncertain and ambiguous. They will depend in large part on the type of instrument applied and the detailed design of each instrument. There are also numerous opportunities to reduce aggregate costs, mitigate distributional impacts and enhance effects on technological change in the detailed design of instruments.

For example, the dampening effects of other taxes to fund subsidies may be partly offset by raising government funds through more targeted approaches that correct for other distortions. For example, a subsidy for hydrogen vehicles may be funded through a levy on gasoline that reflects its external costs. Free riders may be reduced through more discriminating methods for distributing subsidies. For example, grants could be tied to specific performance criteria rather than general tax credits for a class of technologies. Concerns about supporting higher-cost technologies can be addressed in part by targeting subsidies more at specific outcomes rather than specific technologies. For example, a carbon trust could be established purchase reductions (through competitive bidding) from a wide variety of sources, rather than a single technology. The benefits of these various design options must also be weighed against other considerations such as higher administration costs.

Revenue-generating instruments provide direct and continuous incentives for reducing impacts and developing new technologies. However, they also have the greatest impact on market prices and they can often affect some sectors and regions more than others. These impacts can in part be offset through the design of instruments and through revenue recycling policies. For example, impacts on low-income households can be mitigated through revenue recycling strategies targeted specifically at this demographic – e.g., increases in personal deduction limits, reductions in other consumption taxes, or weatherization and other efficiency programs targeted at low-income households. Differences in regional costs can be mitigated through revenue recycling strategies targeted at specific regions – e.g., tax credits for households in northern communities (which use more energy) or increases in general transfers to specific provinces. Impacts on electricity-intensive, export-oriented industries (e.g., mining and pulp and paper) can in part be mitigated through the allocation of a certain number of free permits to these industries and by recycling revenues to industry through specific tax credits or rebates for exporters, or via general reductions in payroll and capital taxes. Recycling policies must be designed carefully to minimize impacts on efficiency and possible windfalls for consumers or producers.

The only budget-neutral instrument specifically identified in the case studies is the Renewable Portfolio Standard. Design of this instrument can greatly affect performance. For example, if implemented through a quota system for retailers, the instrument will not affect international trade of electricity. Similarly, under a quota system for retailers, it is possible to apply the RPS to residential and commercial customers only in order to reduce possible impacts on industry. Setting targets for new supply may reduce the chances of windfall profits for existing renewable producers. Different regional targets may be developed to reflect regional differences in supplies and costs. Costs could be further reduced through a national credit trading system. A phased implementation with clear targets and timelines may also offer more opportunity for technological changes that lower the ultimate costs of the instrument. Finally, the use of a system of penalties can provide a cap on the costs of the instrument, which are uncertain. Any revenues raised from penalties can be reinvested in R&D or development of new renewables.

In developing packages of instruments, it is very important to consider the interactions among policies. For example, providing a subsidy to renewables in the context of an RPS will most likely re-allocate the costs of meeting the RPS from electricity consumers to taxpayers without greatly increasing the supply of renewables relative to an RPS alone.

A key consideration in designing policy packages is staging. In general, gradual implementation of fiscal instruments can reduce costs by allowing adaptations to follow the natural rate of turnover in long-lived capital stocks. Establishing gradual, continuous and expected incentives or disincentives can also stimulate greater innovation (e.g., R&D) that could lower the eventual costs of the instruments. The staging of different fiscal instruments can also be important. For example, in the very early stages of implementation, where the cost difference between existing and new technologies is quite large, R&D subsidies may be the most effective instrument to consider (such as in the case of hydrogen technologies). Instruments that encourage or force market adoption of these technologies may be very costly and may actually have a negative impact on future uptake because they reinforce impressions that these technologies are expensive and because their performance is often poor in such early stages of development. Once the cost differential is reduced and performance is improved, instruments that encourage some market adoption would be most useful to encourage learning by doing and economies of scale in manufacture. Often, set-asides (such as portfolio standards) and/or subsidies will be most effective and acceptable at this stage. Once the cost differential is lower, policy makers may wish to consider broader-based revenue instruments such as permits or taxes that reinforce the position of these new technologies and stimulate competition from other new technologies.

7.0 Literature

Analysis and Modelling Group. 2000a. An Assessment of the Economic and Environmental Impacts for Canada of the Kyoto Protocol. November 2000.

Analysis and Modelling Group. 2000b. Improving Understanding of the Kyoto Protocol on the Competitiveness of Canadian Industry. April 2002.

Analysis and Modelling Group. 2002. A Guide to the Assumptions and Methodology Underlying the AMG Results. May 2002

Barker, T. and P. Ekins. 2004. The costs of Kyoto for the US economy. The Energy Journal 25(3): 53-71.

Barker, T., J. Koehler and M. Villena. 2002. The costs of greenhouse gas abatement: meta-analysis of post-SRES mitigation scenarios. Environmental Economics and Policy Studies 5: 135-166.

Bataille, C. 2004. Design and application of a technologically explicit hybrid energy-economy model with macroeconomic feedbacks. DRAFT Ph.D. Dissertation, School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, Canada.

Bataille, C., A. Laurin, M. Jaccard, R. Murphy, J. Nyboer, B. Sadownik, and M. Tisdale (2002)."Construction and analysis of sectoral, regional and national cost curves of GHG abatement in Canada." M.K.Jaccard and Associates.

Baumol, William J., and Wallace E. Oates. 1988. *The Theory of Environmental Policy*. 2nd ed. Cambridge, U.K.: Cambridge University Press

Berry, T., and M. Jaccard. 2001. The Renewable Portfolio Standard: Design Considerations and an Implementation Survey. *Energy Policy* 29(4): 263-77.

Bovenberg, A. and L. Goulder. 2000. *Neutralizing the Adverse Industry Impacts of CO2 Abatement Policies: What Does it Cost?* Discussion Paper 00-27. Washington, DC: Resources for the Future.

Bull, N., K. Hassett, and G. Metcalf. 1994. Who Pays Broad-Based Energy Taxes? Computing Lifetime and Regional Incidence. *The Energy Journal* 15: 145-164.

Carraro, C., R. Gerglah, and B. van der Zwaan. 2003. Endogenous technical change in environmental macroeconomics. *Resource and Energy Economics* 25: 1-10.

Copeland, B.R. and M.S. Taylor. 2000. Free trade and global warming: A Trade Theory View of the Kyoto Protocol. NBER Working Paper No. 7657.

Devarajan, S., K.E. Thierfelder, and S. Shutiwart-Narueput, 1999: The Marginal Cost of Public Funds in Developing Countries. World Bank Working Paper.

Edmonds, J.A., J. Roop, and M. Scott (2000). Technology and the economics of climate change policy. Prepared for the Pew Center on Climate Change by Battelle National Laboratory.

Fischer, Carolyn, Ian W.H. Parry, and William A. Pizer. 1998. *Instrument Choice for Environmental Protection When Technological Innovation Is Endogenous*. Discussion Paper no. 99-04. Washington, D.C.: Resources for the Future. October.

Goulder, L.H. 1995. Environmental taxation and the double dividend: A reader's guide. *International Tax and Public Finance* 2: 157-183.

Industry Canada. 2002. The Kyoto Protocol and Industry Growth Opportunities. Input to the AMG Working Group. Produced by the Environmental Affairs Branch of Industry Canada, April 25, 2002.

Informetrica (2000). Macro-economic impacts of GHG reduction options: National and provincial effects. Ottawa: Informetrica.

Iorwerth, A., P. Bagnoli, Y. Dissou, T. Peluso, and J. Rudin (2000). A computable general equilibrium analysis of greenhouse-gas reduction paths and scenarios. Economic Studies and Policy Analysis Division, Finance Canada: Ottawa.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate Change 2001: Working Group III: Mitigation. Port Chester, NY: Cambridge University Press.

Jaccard, M., J. Nyboer, and B. Sadownik (2002). The Costs of Climate Policy. Vancouver: UBC Press.

Jaccard, M., J. Nyboer, C. Bataille, and B. Sadownik (2003a). Modelling the Cost of Climate Policy: Distinguishing between alternative cost definitions and long-run cost dynamics. Energy Journal 24(1): 49-73.

Jaffe, A. B., R.G. Newell, and R. N. Stavins (2000). *Technological Change and the Environment*. Discussion Paper 00-47. Washington, D.C.: Resources for the Future. October.

Jaffe, A., R. Newell, and R. Stavins (2002). Environmental Policy and Technological Change. Environmental and Resource Economics 22: 41-69.

Löschel, A. 2002. Technological change in economic models of environmental policy: a survey. *Ecological Economics* 43: 105-126

M.K. Jaccard & Associates. 2004. Case Study on Energy Efficiency Baseline Study. The National Round Table on the Environment and the Economy: Ottawa.

Marbek Resource Consultants. 2004. *Ecological Fiscal Reform and Energy Case Study on Renewable Grid Power Electricity. T*he National Round Table on the Environment and the Economy: Ottawa.

Markandya, A. and K. Halsnaes (Lead Authours). 2001. *Climate Change 2001: Mitigation.* Report of Working Group III to the Intergovernmental Panel on Climate Change.

McKitrick, R. (1997). Double dividend environmental taxation and Canadian carbon emissions control. Canadian Public Policy XXIII(4): 417-31.

Metcalf, G. 1998. A Distributional Analysis of an Environmental Tax Shift. NBER Working Paper No. w6546. Issued in May 1998

Morck, R. and B. Yeung. 2001. The Economic Determinants Of Innovation. Occasional Paper Number 25. Industry Canada Research Publication Program: Ottawa.

Newell, R.G., A.B. Jaffe, and R.N. Stavins. 1998. *The Induced Innovation Hypothesis and Energy-Saving Technological Change*. Discussion Paper 98-12 (revised). Washington, D.C.: Resources for the Future. October.

Palsev, S. V. 2001. The Kyoto Protocol: Regional and Sectoral Contribution to the Carbon Leakage. The Energy Journal 22(4): 53-79.

Parry, Ian W.H. 2002. *Adjusting Carbon Cost Analyses to Account for Prior Tax Distortions*. Discussion Paper 02-47. Washington, D.C.: Resources for the Future. August.

Pembina Institute and the Canadian Energy Research Institute. 2004. Case Study on the Role of Ecological Fiscal Reform in Hydrogen Development. The National Round Table on the Environment and the Economy: Ottawa.

Popp, David. 2001. *Induced Innovation and Energy Prices*. Working Paper no. 8284. Cambridge, Mass.: National Bureau of Economic Research. May.

Poterba, J. 1991. Tax Policy to Combat Global Warming : On Designing a Carbon Tax. In *Global Warming : Economic Policy Responses*. R. Dornbush, J.M. Poterba (eds.). Cambridge, MA: MIT Press.

Porter, M. and C. van der Linde. 1995. Toward a new conception of the environment-competitiveness relationship. Journal of Economic Perspectives 9: 97-118.

Ruggeri, G., 1999: The Marginal Cost of Public Funds in Closed and Open Economies. Fiscal Studies, 20, 1-60.

Shackleton, R. 2003. *The Economics of Climate Change: A Primer.* Congressional Budget Office: Washington, DC.

Schillo, B., L. Giannarelli, D. Kelly, S. Swanson, and P. Wilcoxen. 1996. The Distributional Impacts of a Carbon Tax. In *Reducing Global Carbon Dioxide Emissions: Costs and Policy Options,* D. Gaskins and J. Weyant (eds.) Energy Modeling Forum, Stanford University, Stanford, Calif.

Sinner, J. 2002. Addressing the Competitiveness Impacts of Climate Change Policies. Report to the New Zealand Ministry of Economic Development.

Stavins, Robert N., Jaffe, Adam B. and Newell, Richard G., "Environmental Policy and Technological Change" (April 2002). FEEM Working Paper No. 26.2002. http://ssrn.com/abstract=311023

Sutherland, R.J. 2000. ‘No cost’ efforts to reduce carbon emissions in the U.S.: an economic perspective. The Energy Journal 21(3): 89-112.

Watson, R.T. (ed) 2001. *Climate Change 2001: Synthesis Report.* Contribution of Working Groups I, II and III to the Third Assessment Report of the IPCC, Cambridge University Press.

Weyant, J., H. Jacoby, J. Edmonds, and R. Richels (1999). "The Costs of the Kyoto Protocol - A Multi-Model Evaluation." Energy Journal Special Issue.

Weyant, J.P. 2000. An introduction to the economics of climate change policy. Prepared for the Pew Center on Global Climate Change.

Weyant, J.P. and J.N. Hill. 1999. Introduction and overview. *The Costs of the Kyoto Protocol: A Multi-model Evaluation.* Special Issue of *The Energy Journal*, John Weyant (ed.).