C.D. Howe Institute

Benefactors Lecture, 2007

Designing Canada's Low-Carb Diet:
Options for Effective Climate Policy

Mark Jaccard
Professor, Simon Fraser University

Toronto, November 28, 2007

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Foreword

The debate in Canada over global warming and measures to reduce the greenhouse gas emissions reported to cause it has been discouraging for advocates of reasoned and evidence-based policymaking. The combination of extreme positions on the threat and reluctance to design, let alone implement, practical measures is reflected in Canada's conflicted position, as a long-time advocate of major international efforts to curb emissions on one hand, and a large and relentlessly increasing emitter on the other. Bringing the potential costs of continued rapid growth in greenhouse gas emissions into a framework that allows reasonable comparisons with the costs of reducing those emissions is essential. It can serve as a guide for Canadians to make wise decisions about how to balance their desire for environmental protection with their needs for energy.

Professor Mark Jaccard, a Research Fellow at the C.D. Howe Institute, and a professor in the School of Resource and Environmental Management at Simon Fraser University (SFU) since 1986, has long sought to further Canadians' understanding of the elements that will allow a sensible balancing of potential costs and benefits through public lectures and more than 90 publications. They include his new book, *Hot Air,* co-authored with Jeffrey Simpson and Nic Rivers; *Burning Our Money to Warm the Planet — Canada's Ineffective Efforts to Reduce Greenhouse Gas Emissions*, a C.D. Howe Institute Commentary; and the Donner Prize winning *Sustainable Fossil Fuels.* Professor Jaccard has contrasted more and less sensible ways for Canadians to manage the risk that their uses of energy are contributing to global warming. He and his colleagues at SFU's Energy and Materials Research Group have undertaken modeling of energy use and economic activity that has become a standard reference for students and policymakers interested in responding to environmental imperatives over reasonable timeframes and at manageable cost.

In this year's Benefactor's Lecture, Professor Jaccard presents a valuable framework for future Canadian action in this contentious area. He argues that the threat of anthropogenic climate change is worth insuring against, presents a number of criteria for evaluating potential "premiums" Canadians might pay for an insurance policy, canvasses some less promising options (subsidies and offsets) and some more promising ones (emissions taxation), and closes with a novel suggestion for a carbon-management standard that would apply to all producers and importers of fossil fuels for domestic use.

Professor Jaccard's recommendations will not satisfy those who wish to force sudden reductions in Canadians' energy production and use, and will sit badly with those who maintain that changes in the energy economy are costless. If Canada is to respond to the pressure to reduce greenhouse gas emissions, however, his careful analysis of the incentive-compatible policies that offer larger gains at lower costs gives important guidance to policy-makers and businesspeople alike.

The production of this lecture, of course, requires more than an insightful and articulate author such as Mark Jaccard. It also requires financial support, and we gratefully acknowledge Bennett Jones LLP for sponsoring this year's Benefactors Lecture. My colleagues and I thank the many reviewers who commented on drafts of the lecture. The editing skills of Barry Norris and James Fleming, and the desktopping flair of Wendy Longsworth and Diane King, were also critical to the production of this document.

The C.D. Howe Institute's aim in the Benefactors Lecture series is to raise the level of public debate on issues of national interest. In doing so, the Institute hopes to give Canadians information and analysis that they will find valuable in considering public policy challenges. As with all C.D. Howe Institute publications, the opinions expressed here are those of the author, and do not necessarily represent the views of the Institute's members or Board of Directors.

William B.P. Robson
President and Chief Executive Officer
C.D. Howe Institute

Concerns about climate change and human-produced greenhouse gases (GHGs) have intensified in recent years, but there is still uncertainty and confusion over the appropriate policy response. My goal in this lecture is to clarify the policy issues for a Canadian audience. To begin, I present the factors to consider when deciding whether or not policy intervention to reduce GHG emissions is warranted. I conclude that intervention is indeed warranted, which leads me to survey the design options for GHG emissions reduction policy in Canada and to present my own views on these options.

I view this issue primarily through an economics lens, particularly with respect to addressing the decisionmaking challenge facing public policymakers. The economics discipline can address both the policy rationale question and the policy design question. In terms of policy rationale, economists can apply tools such as cost-benefit analysis to help policymakers determine if the benefits of intervention exceed the costs for different levels of intervention. Thus, the policy rationale question is: should we act, and to what extent? In this regard, however, the climate change risk poses particular challenges for the application of benefit-cost analysis to public choices.

If policymakers agree that GHG emissions reduction is justified, economics can then help with the policy design question: how should we act? In particular, using models that simulate how the economy might respond to different public policies, economic analysis can show the likely effect of alternative policies.

The Rationale for Reducing GHGs

At first blush, the benefit-cost analysis of reducing GHG emissions seems straightforward. The benefit is the reduced risk to humans and to the environment they value — risk, in this case, being the probability of damage multiplied by the magnitude of the damage. The cost is the estimated cost of reducing GHG emissions. Analysis suggests that society should reduce emissions up to the point where there is no longer net benefit from further emissions reduction. Analytically, the problem appears simple.

Unfortunately, in the case of the climate change risk and our response to it, substantial uncertainties exist in the research findings of both natural and social scientists. On the natural science side, there is now a broad consensus among climate experts that humanity's release of GHGs is affecting

I wish to acknowledge advice and suggestions from Chris Bataille, John Nyboer, Finn Poschmann, Nic Rivers, Bill Robson and many others, including anonymous readers, who provided helpful comments.

the climate, with effects on the environment and on humans, yet researchers acknowledge that the probabilities associated with different levels of effects are still highly uncertain, whether in the fields of climatology, meteorology, oceanography, glaciology, hydrology, biology, ecology, or even epidemiology.

These uncertainties are to some extent inevitable, given the intrinsic complexities of the interrelated systems that scientists are trying to comprehend. This is especially so because the conventional methods of scientific inquiry are designed to err on the side of understatement — that is, not to infer a causal relationship unless theory supports it and real-world data verify it with a likelihood of 19 out of 20 cases.[1] This method means that scientists should reach a consensus that human-produced GHGs are changing the climate only if their quantitative techniques consistently revealed such an outcome — and, indeed, this is what has occurred. It also means, however, that the precise empirical outcomes of the demonstrated causal relationship — say, the amount of temperature change, the rate of glacial melting, the number and intensity of storm events, the extent of ecological changes, and so on — will remain highly uncertain. Thus, at a certain atmospheric GHG concentration, climatologists might be willing to say that there is a greater than 70 percent chance that average temperatures will rise by two degrees or more, but not that there is a greater than 95 percent chance, as demanded by conventional scientific methods.

On the social science side, economists still debate the methods for estimating the value of common property resources that might be harmed by climate change but whose full value to society cannot be derived from conventional market activities. The challenge of estimating a monetary value for the decline or extinction of polar bears is an example. A survey of research shows that estimates for nonmarket values such as these can vary a hundredfold depending on the method for eliciting them.[2]

1 Surveys of the research literature on natural systems — see, for example, Parkhurst (1990); Peterman (1990); M'Gonigle et al. (1994); and Wade (2000) — explain that empirical studies of these complex systems almost inevitably have low statistical power, meaning that they are strongly biased toward making a Type II error: failing to reject the null hypothesis of no effect when they should have. In other words, they have a high chance of failing to detect causal relations that actually exist. In environmental systems, low power often results from large natural variability, large measurement error, or both, and is exacerbated by small sample size.

2 The key issue is that the value for a nontraded good is essentially subjective. It is difficult to anchor this value to conventional monetary measures of income because the total income of humanity includes not just monetary income but also the unvalued benefits of the earth's environmental services: clean air to breath, clean water to drink, cultivable soil, biodiversity that sustains other ecosystem services, and a climate that supports life (Knetsch 2007).

Economists also debate the methods for comparing future, long-term, climate-related damage with near-term GHG abatement costs. Small changes in the discount rate used to translate future values into current-day equivalents can lead to very different conclusions about the appropriate response, if any, to the climate change risk. Recent debates about the discount rate that Stern (2006) uses in his widely publicized report for the UK government illustrate this controversy. To reflect concern for the possibility of extremely high damage (to key life-support functions of the earth's biogeophysical cycles) many decades from now, Stern uses an extremely low discount rate (about 1.4 percent) to present this future damage in current-value terms. While many economists argue that Stern's discount rate is too low (and is estimated using an inappropriate methodology), some of the leading economists in the field are nonetheless willing to entertain very low discount rates once the potential but uncertain extreme damage is factored into the decisionmaking algorithm. Weitzman (2007), for example, argues that "a fair recognition of the truth that we are genuinely uncertain about what interest rate should be used to discount costs and benefits of climate changes a century from now brings discounting rates down from conventional values $r \approx 6\text{-}7\%$ to much lower values of perhaps $r \approx 2\text{-}4\%$."

Indeed, nervousness about the ability of cumulative human-produced capital to compensate effectively for future major losses of "natural capital" (harm to ecosystems, changes in ocean levels) has led several key economists to suggest the imposition of firm ecological constraints on the human economy. Nordhaus notes that, if we are using low discount rates to justify preventing dangerous interference with the climate system, "why not impose the limit directly?….[W]hy not simply adopt policies that will directly keep climate change below the dangerous threshold? Limiting climate change directly is more efficient as well as more transparent" (2006, 19). This is consistent with the oft-heard argument of so-called ecological economists that human-produced capital should not be considered a perfect substitute for natural capital (see Neumayer 1999; Ayres 2007). When considering the climate change risk, this concern is shared even by more conventional economists such as Weitzman, who states:

> If the definition of consumption is broadened (as it should be) to include non-market enjoyment of the natural environment — like habitats, ecosystems, and species — then it is difficult to imagine what the compensating investments are for which we should now be saving more as an alternative that might substitute for holding down temperature change directly. (2007, 18.)

Unfortunately, some individuals and interest groups have used this high level of uncertainty about climate change and its cost-benefit implications to take extreme positions on the appropriate response to the climate change risk, which has hindered the development of good policy (see Schelling 2007). On one side are those who argue that we should wait until the uncertainty is resolved completely before doing anything — a position associated with climate change skeptics, some members of the business community, and those who distrust the benefits of government intervention for environmental ends. On the other side are those who say we should act as if the threat is certain and continue to do so until we are completely sure there is no further danger whatsoever — a position frequently associated with the extreme precautionary approach of some environmentalists.

Neither of these positions corresponds with how we usually approach the many other risks we face as individuals or collectivities. For one thing, it is disingenuous to pretend we are certain about any threat when we are not; such an approach undermines the credibility of those who argue for an appropriate policy response. But waiting for certainty that severe damage will occur is also inappropriate. As Schelling points out:

> It is interesting that this idea that costly actions are unwarranted if the dangers are uncertain is almost unique to climate. In other areas of policy, such as terrorism, nuclear proliferation, inflation, or disease, some "insurance" principle seems to prevail: if there is sufficient likelihood of sufficient damage we take some measured anticipatory action. (2007, 4.)

As Weitzman suggests above, however, acquiring insurance — in the conventional sense of having recourse to financial compensation for damage — might not be sufficient when it comes to the climate change risk if we believe that greater future human wealth will not compensate fully for future environmental damage; there is, after all, no second planet to provide us with insurance against the risk of destroying this one. This leaves us with risk-reduction efforts as the appropriate response, just as we make expenditures today to prevent terrorist acts, impede nuclear weapons proliferation, reduce the chance of oil and gas pipeline explosions, and vaccinate people against disease.

Moreover, given that some of the potential harm of climate change is extreme — for example, the accelerated melting of polar ice could lead eventually to a significant rise in sea levels; the accelerated release of methane from the arctic tundra could increase global temperatures more rapidly — at least some immediate effort to slow the rise of human-produced GHG emissions appears justified. Implicit in such a conclusion, however, is again the notion that human-produced capital cannot compensate fully for major losses of natural capital.

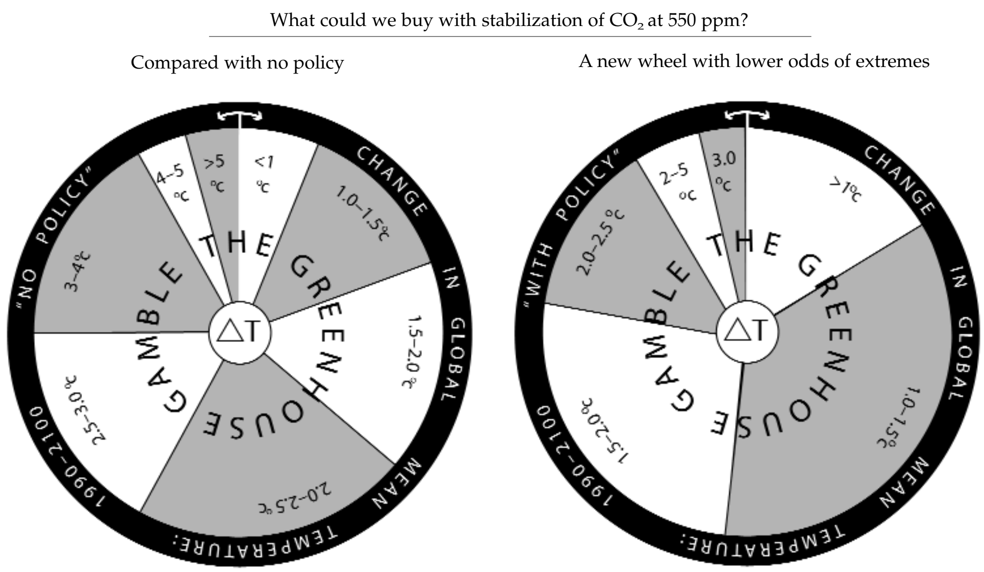
From this discussion, it might appear that I am relying very little on the tools of economics to conclude that humanity should be reducing GHG emissions. But the assessment of potential damage inevitably relies on some notion of the implicit costs of climate change to humanity and to the environment, even if not all of the costs are monetized explicitly and even if they are highly uncertain. And it includes a notion of relative benefits and costs. Where we think future costs could be very large and for which human-produced wealth is likely to provide inadequate compensation, it is justifiable to initiate risk-reduction efforts in the form of reducing GHG emissions today, if only to improve our understanding over the coming decades of what the full costs will be of disconnecting economic growth from GHG emissions. If, in contrast, it appears that future benefits from action would be very small and that the costs of reducing GHG emissions would be exorbitant, then there is much less justification for making a significant effort. At this point, the cost-benefit evidence suggests that actions to reduce emissions are indeed warranted.

Most research in the area of mitigating GHGs has focused on estimating the cost of reducing carbon dioxide (CO_2) emissions from the combustion of fossil fuels to provide energy, which account for almost 80 percent of human-produced GHG emissions. This research suggests that, although reducing these GHGs will not be cheap (despite the claims of some environmentalists), the cost of reducing global emissions by 50 to 70 percent over the next 50 to 100 years is unlikely to have a dramatic negative effect on economic growth (despite the claims of some who oppose any effort whatsoever). As noted, however, the pace and magnitude of emissions reduction is still highly uncertain.

How Much and How Fast for Humanity?

The scientists assembled by the United Nations Intergovernmental Panel on Climate Change have produced estimates of the average global temperature increase associated with different atmospheric concentrations of GHGs. Prinn (2006) depicts this uncertain relationship as a "gamble the greenhouse game." As Figure 1 shows, the wheel on the left reflects the odds of global temperature outcomes later this century if we keep emitting greenhouse gases until their atmospheric concentration is double, then triple the current level of 370 parts per million (ppm). This results in a more than 50 percent chance that the global average temperature will rise by more than 2 degrees,

Figure 1: *Gamble-the-Greenhouse Game*



Source: Prinn 2006.

a 25 percent chance it will rise by 3 degrees or more, and a not insignificant chance it will rise by 4 degrees or more. These outcomes are uncertain, but they are the best estimates on which most scientists in this field can agree. If, instead, we reduce GHGs over the coming decades so that atmospheric concentrations stabilize at 550 ppm, the wheel on the right depicts scientists' best estimate of the new odds we would face: about an 80 percent chance that the temperature will not rise by more than 2 degrees and only a small chance of its rising by more than 3 degrees. The outcomes are still uncertain, but the odds have improved.

It is likely that our understanding of the earth's climate system, and our influence on it, will continue to be encumbered with considerable uncertainty. But, as the game suggests, in an uncertain world, we can still act in ways to reduce the risk of damage from climate change. Moreover, given the long time lag between emissions and temperature changes, and then between temperature changes and changes in ecosystems, ice caps, and the ocean level, we need to act now to ward off these effects.

The stock of GHGs in the atmosphere is the result of a complex interplay of human and natural emissions, offset in part by absorption of CO_2 by oceans and growing plants. What would it take to stabilize GHGs at 550 ppm? Leading experts in the field generally agree that current or soon-to-be-available technologies could allow us to reduce human GHG emissions substantially — that is, 40 to 50 percent below current levels — by mid-century at the cost of about one or two years of economic growth, or a reduction in global gross domestic product of 3 to 5 percent from its business-as-usual level. We could reduce emissions from fossil fuels by powering personal vehicles to a significant extent with biofuels or electricity (including battery-only cars and plug-in hybrids) or even hydrogen fuel cells. We could become more energy efficient and switch to the greater use of nuclear and renewable energy sources like wind, hydro, and solar power. We could reduce CO_2, methane, and other GHG emissions from agriculture and forestry by changing land management practices (with respect to soil tillage, for example) and animal husbandry practices (such as treating manure to reduce methane emissions). We could also change some production technologies to reduce process-related industrial emissions (such as in aluminum, cement, and steel production).

Finally, humans could capture and store — that is, sequester — carbon. Growing plants extract carbon from the atmosphere, so increases in vegetative cover (desert to grassland, grassland to forests) would increase the carbon sequestered on and just below the earth's surface — although, of course, planting a tree today would not guarantee that a tree will remain in the same location throughout the next century and beyond. A more secure form of carbon sequestration would be to capture CO_2 and store it permanently in geological strata at least 1,000 metres below the earth's surface. Although technologies exist to capture CO_2 directly from the flue gases of a coal-burning electricity plant, a promising alternative is to convert coal, oil, or natural gas into electricity or hydrogen (both zero-emission energy forms) while streaming off all carbon in the form of CO_2 for storage (see Jaccard 2006). The technologies required for the "zero-emission" use of fossil fuels are, surprisingly, already in commercial use today, albeit for other purposes — such as fertilizer production, synthetic gasoline production, and enhanced oil recovery — since industry has not been required to prevent CO_2 emissions.

We could also prevent the carbon in CO_2 from reaching the atmosphere by various means, including pumping CO_2 to the ocean floor or converting it back into solid form for surface storage. But the most promising option at this point involves injecting CO_2 deep in sedimentary basins. Although the original intention was not to store CO_2, this option has already been commercially tested by the oil and gas industry through the decades-old practice of injecting CO_2 to increase the extraction rate in aging oil wells, a process called enhanced oil recovery. More recently, the natural gas industry in some locations has turned to acid gas injection — the underground disposal of hydrogen sulphide and CO_2 removed from sour gas — to deal with public and regulatory opposition to flaring and with the low economic incentive for sulphur recovery. Thus, underground storage of CO_2 is already a technological, economic, and regulatory reality, in some cases motivated by the wish to increase the recovery of oil, in others by the need to dispose of unwanted acid gas by-products. And for almost a decade now, a major project called Sleipner, off the coast of Norway, has injected CO_2 into a saline aquifer 1,000 metres below the ocean floor to avoid paying the carbon emission taxes initiated in 1991 by the Norwegian government.

But whether we consider energy efficiency, fuel switching, changes in forestry and agriculture, or carbon sequestration, none of these actions to reduce emissions is free. Advocates of energy efficiency, for example, argue that savings on energy bills would offset the higher cost of more efficient buildings and equipment, but they overlook the extra financial risks — and, hence, the real costs — associated with new and untried technologies that also require a long period to pay back the extra investment (Jaffe, Newell, and Stavins 1999). They also overlook the expanding demand for energy services — such as lighting, heating, and transportation — that would accompany improvements in the productivity of energy-using technologies (Fouquet and Pearson 2006).

The cost of a particular level of emissions reduction, of course, would depend on the speed and intensity of actions to achieve it. Uncertainty, however, is an issue here, too, with economists producing wide-ranging estimates of the welfare losses of everything from switching to efficient light bulbs to forgoing one's personal vehicle in favour of public transit, although the degree of uncertainty is less than on the environmental damages side of the ledger.

Yet we do not need a formal cost-benefit analysis to set emissions goals for the next 50 or 100 years. We can simply decide how much we are willing to pay to reduce the risks, using the gamble-the-greenhouse game as a guide. Thus, if we are willing to pay the economic cost of stabilizing GHGs in the atmosphere at 550 ppm, then one can assume that we value the resulting risk reduction by at least this much. We might even wish to stabilize GHGs at 450 ppm, but the cost of doing so would be considerably higher. The relationship of cost to stabilization targets is not linear: a more stringent stabilization target would require the faster transformation of buildings and equipment such that investments to reduce GHGs would no longer be in sync with the normal rate of investment in new capital stock. This relationship illustrates what economists call "rising marginal costs": in this case, the rising incremental costs of GHG abatement.

What about Canada-Specific Targets?

The risk of climate change is truly a global challenge. But this is too broad a focus for setting targets and taking action to reduce GHG emissions. After all, it is individuals and businesses that will take action, through their investment decisions and their choices of the equipment they use and the buildings they design or transform. Moreover, these actions will be influenced by the policies that national and even subnational levels of government put in place.

Some argue that, if humanity is to reduce its emissions by 50 percent by mid-century, then this should also be Canada's target. Such an approach has the benefit of simplicity, but there are others that depend on the relative weight of moral, economic, and strategic arguments. Perhaps Canada should do more because it is a rich country and could better bear the cost. Perhaps it should do less because it is saddled with additional emissions for exporting its abundant fossil fuel products to other countries. Perhaps it should do more because its emissions are among the highest per capita in the world. Perhaps it should do less because the marginal cost of its emissions reduction is higher than that of many countries. Perhaps it should do more because Canadians see global leadership as one of our virtues — as we often tell ourselves and others.[3]

All these factors were debated during the setting of Canada's previous targets for GHG emissions, and they will probably play a role in future negotiations about national roles. But if we are to measure actions rather than words, Canada's desire to be a global leader certainly has not played a part thus far. Since 1990, Canada's GHG emissions have risen almost 30 percent, despite our bravado commitment in the 1997 Kyoto Protocol that, by now, our emissions would be about 6 percent below 1990 levels. And Canada's emissions are still on a trajectory to nearly double current levels by 2050.

3 These diverse considerations explain why it has been so difficult to reach global agreement on each country's contribution to the reduction of GHGs. I avoid this critical issue in this lecture, but as an aside I believe that it is only through the threat of trade sanctions that rich countries (including the United States) eventually will convince all developing countries to participate in a comprehensive, global GHG reduction effort. Their participation might well be via globally applicable technology-specific regulations or GHG emissions taxes rather than through difficult-to-negotiate national GHG emission allocations. I should also point out that, because the post-Kyoto conditions have yet to be negotiated, it is difficult to talk about Canada's "doing more" in the second phase of Kyoto to compensate for not having achieved its commitments under the Kyoto Protocol, as some environmentalists and politicians argue. Other countries know that, as Australia did in Kyoto, Canada will approach negotiations armed with numerous reasons why its past and future emission trajectories are unique and deserving of special dispensation.

Yet, recent cost estimates suggest that Canada could indeed afford to reduce its emissions levels by 2050 to half those of 2006 if we were to implement effective policies immediately. Canada's National Roundtable on the Environment and the Economy (2007), for example, estimates that the cost of "effective and efficient policies" to achieve such a target would be the loss of one or two years of economic growth distributed over the next 40 years, assuming that our major trading partners were making similar efforts. Given polls that suggest Canadians are increasingly concerned about the negative effects of climate change and increasingly aware that GHG abatement would come at some cost to their standard of living, such a reduction would be consistent with a century-long progression toward a near-zero GHG emission energy system.

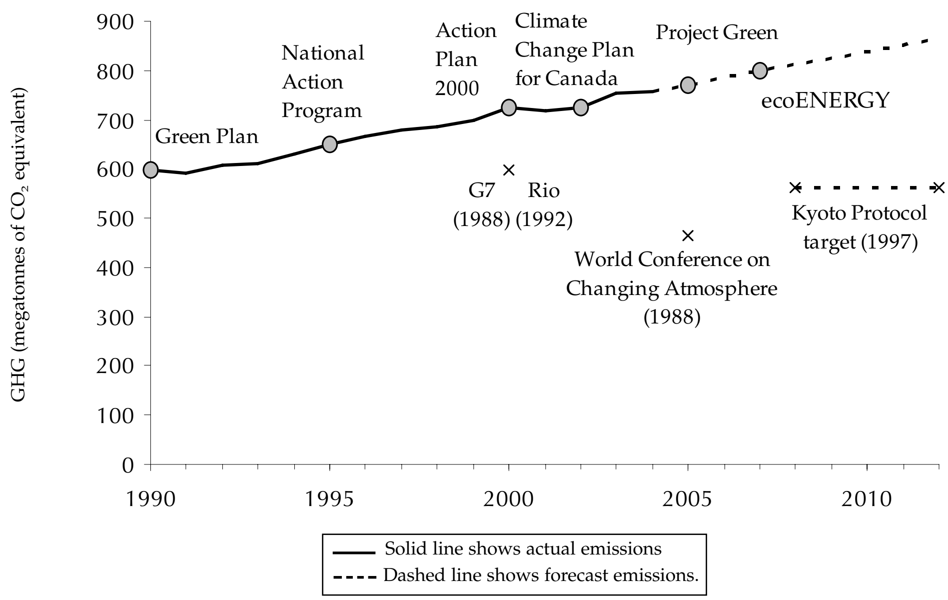
Setting a national target for mid-century emissions might be desirable for mobilizing political support for GHG reduction policies, but it is a somewhat misleading exercise in view of the major uncertainties about the risks of climate change and the costs of abatement. For this reason, leading economists have been arguing since the early 1990s that the appropriate policy response would be to start early with modest efforts to reduce emissions, but to signal clearly that the intensity of this effort would gradually increase, with the precise target left uncertain for the time being, given the large uncertainties on both the benefit and cost sides of the ledger. As Nordhaus argues,

> efficient or "optimal" economic policies to slow climate change involve modest rates of emissions reductions in the near term, followed by sharp reductions in the medium and long term. We might call this the "climate-policy ramp," in which policies to slow global warming increasingly tighten or ramp up over time. (2006, 3.)

In Canada, however, discourse on climate change policy thus far has focused mainly on the selection of targets and less on evaluating the effectiveness of alternative policy designs. This focus is especially remarkable considering our lack of success in enacting policies to reduce GHG emissions. Figure 2 shows that, over the past 18 years, Canadian governments have generated three distinct targets for future GHG emissions and six major policy initiatives to achieve these targets. Yet Canada's emissions have risen faster over that period than during the previous 10 years, relentlessly climbing as the country misses one target after another.

This unfortunate history provides a compelling argument for focusing climate policy discussions on policy effectiveness. Instead, however, politicians and environmentalists remain preoccupied with debating targets: Can Canada achieve its 2010 Kyoto target? What should the target be for 2020?

Figure 2: *Canadian Greenhouse Gas Targets, Policies, and Emissions Since 1990 (as specified by the documents or protocols shown)*



Note: x indicates target set by past initiative(s).

Source: Author and Canada (2005).

For 2050? Clearly, we need to devote more time to designing, evaluating, and publicly debating policies to slow the growth of, then eventually reduce, GHG emissions without incurring unnecessary economic costs in a world in which comprehensive international agreements still lie in the future.

Criteria for Evaluating Climate Policy Options

The GHG problem is what economists refer to as a "negative externality market failure": the unfettered market causes the overproduction of GHG emissions because the costs of their damage do not show up in the prices of the goods and services that caused them. In the absence of policy, the atmosphere is a free waste receptacle for GHGs, even though these emissions might cause substantial uncompensated costs for someone, perhaps for everyone.

Early in the twentieth century, Pigou (1920) suggested that a tax on emissions would be the most economically efficient response to this type of market failure. The tax presumably would stimulate the level of reduction of

GHG emissions that would be optimal from society's perspective — that is, the point at which the marginal costs and benefits of emitting GHGs would be equal. In the 1960s, economists showed that, if a government was confident it knew society's "optimal" level of emissions, it could regulate an emissions cap and then allocate tradable emissions permits (also called allowances) that equalled the cap in total (see Dales 1968). The trading price of the emissions permits should turn out to be roughly equal to the level of tax that would achieve the same aggregate level of emissions. Economists have since debated the relative merits of these two approaches to negative externality — pricing emissions versus setting their quantity and allocating tradable permits — in what is known as the "prices versus quantity debate." One approach or the other might be preferable in a particular circumstance, depending, for example, on the relative importance of the risk of not attaining the emissions target and the risk of higher-than-anticipated costs of GHG abatement (see, for example, Weitzman 1974). A tax would give greater cost certainty, but an emissions cap would give greater emissions certainty — although, as I discuss later, it is possible, perhaps even desirable, to design hybrids of taxes and caps.

In response to the intensified environmental concerns of the 1960s, governments implemented a plethora of command-and-control regulations that often stipulated identical technology or emission requirements for all businesses and consumers. Such policies are still widely used and in many cases might be the most appropriate tool. But economists have gradually been able to convince politicians, business leaders, and even some leading environmental groups that the use of market-oriented policies such as the tax or cap-and-trade policies would make it possible to achieve the same environmental objective at lower cost. These kinds of policies are flexible in that they allow businesses and consumers to decide on their own level of emissions depending on their specific costs and preferences. It matters little if some people choose to drive a Hummer and others wish to fuel their vehicles with gasoline if the total emissions from private vehicles fall to the desired levels because of the net effect of everyone's responses to a market-oriented policy. With this understanding, taxes and cap-and-trade policies have made inroads in addressing some types of negative environmental externalities.

The 1980s and 1990s, however, witnessed a wave of initiatives to reduce government intervention in the economy as a way of fostering economic growth. In terms of environmental protection, this period was associated with efforts to foster voluntary actions by firms and even households to reduce environmental impacts of various kinds, including the reduction of GHG emissions. This voluntarism would result, ostensibly, from governments assisting organizations and individuals with voluntary actions by providing information about the environmental and possible economic benefits of low-emission technologies and by helping out with modest subsidies (see Khanna 2001; OECD 2003).

Consistent with this policy approach, early Canadian initiatives to reduce GHGs were almost entirely about the provision of information and subsidies. As the emissions history in Figure 2 shows, emissions did not decline as government policymakers predicted they would. However, while the failure of this approach appears to have vindicated the arguments of some people for taxes and/or cap-and-trade regulations, others still argue that the problem was simply one of inadequate provision of information and subsidies, and that more public spending is the answer. Certainly, politicians would be happier providing subsidies than invoking regulations and levying taxes.

This is where the debate stands in Canada today. In increasing numbers, politicians, business leaders, and even environmentalists are stating publicly that we need to heed the decades-old prescriptions of economists such as Pigou and Dales if we are to make serious headway in reducing Canada's GHG emissions. Some still hope that subsidies are the answer, whether from government to private entity or from private entity to private entity. The discussion is shifting, however, toward the design of alternative tax and regulatory schemes, thanks to the growing realization that, in a market economy with plentiful fossil fuels, continuing to allow the free dumping of CO_2 into the atmosphere will result in more of the same.

Thus far, I have focused on the "effectiveness" of policies as an evaluation criterion, but other criteria are, of course, also important. Economists repeatedly point, for example, to the importance of "economic efficiency": society should achieve its environmental goals at the lowest possible cost. In following the path-breaking work of Pigou and Dales, economists note that the policies with the greatest chance of promoting economic efficiency are those that provide the same cost signals throughout the economy. In this regard, economists refer to the "equi-marginal principle": society's costs of achieving a certain level of emissions would be minimized if every emitter reduced emissions to the point where the cost of additional reductions were the same for everyone. This outcome would be most likely if every emitter faced the same cost penalty for the next unit of emission — the same GHG emissions tax, the same GHG emissions permit price, and so on. If every agent in the economy faced the same GHG emissions tax, then presumably each would pursue only those emission reductions that cost less than the alternative, which would be to pay the tax. As each agent reduced emissions up to that point and no farther, the total societal cost of emissions reductions would be minimized.

In contrast, policies would be unlikely to satisfy the equi-marginal principle if they imposed identical technological requirements or emission levels, even though the costs of meeting these requirements differed from one firm or individual to another. Thus, a requirement that every plant in a given industry adopt the same technology would likely transgress the equi-marginal principle, leading to different marginal costs of emissions reductions for different plants. Also, policies that focused closely on the environmental objective would be more likely to satisfy the equi-marginal principle of cost minimization than policies that were indirect. Thus, a requirement for lower average vehicle gasoline *consumption*, by focusing on energy efficiency rather than emissions reduction, would seek only indirectly to reduce emissions. A policy that instead called for lower average vehicle *emissions* would give manufacturers and consumers extra, cost-reducing options: they could pursue energy efficiency to reduce emissions, but they could also pursue fuel switching to electricity, biofuels, and hydrogen. The emissions requirement could be met with greater fuel economy, but also with other emissions-focused technologies and fuels, whereas the fuel economy requirement would provide much less flexibility for achieving the ultimate goal of reducing emissions at the lowest possible cost.

Another policy design criterion is “administrative feasibility.” For 10 years, Canadian governments have toyed with the idea of applying to large industrial emitters — about 700 plants that together account for half of Canadian GHG emissions — some form of emissions cap combined with the ability to trade permits. The equi-marginal principle suggests that the permit price resulting from a cap-and-trade system should be the price signal that would apply equally to the other half of emissions. Such a system is difficult to envision, however, given the complexities of setting allowances and designing workable trading mechanisms for the millions of small emitters across the country. For this other half, then, an alternative policy — perhaps an emissions tax — might be required. The United Kingdom, for example, has a carbon tax that affects the prices of fuels small consumers use, while large industry is subject to the European Union’s emissions cap-and-trade system, which went into force in 2005.

Still another policy design criterion is “political acceptability,” which some analysts are unwilling to consider. They argue that politicians should simply have the courage to implement the right policy, even if it dashed any hope of re-election. In the real world of democratic governance, however, it is obviously unhelpful and pointless for policy analysts to design policies that politicians will not implement. In referring to the need to consider this criterion when designing policies for the United States, Stavins notes that “[p]olicy instruments that appear impeccable from the vantage point of

Cambridge, Massachusetts, but consistently prove infeasible in Washington, D.C, can hardly be considered 'optimal'" (1998, 83). Thus, although economists tend to favour Pigouvian taxes, which are likely to be the most economically efficient way to achieve the equi-marginal principle and thus economic efficiency, they must take into consideration when arguing for such a policy the real challenges politicians face. This is why the GHG taxes various European countries have applied over the past decade have been implemented in concert with compensatory reductions in other taxes, to ensure that net government tax revenues do not increase. It also explains why even the terminology is sometimes vague — for example, the UK's carbon tax is called a "carbon levy."

Another policy design criterion to consider is "coordination with the natural rate of turnover of capital stock" — that is, the rate of investment in new equipment, buildings, and infrastructure. The goal of cost effectiveness obliges governments to ensure that their market-oriented policies do not change costs so rapidly that businesses and consumers are forced to replace much of their capital stock before they need to for reasons of physical obsolescence. Indeed, this obligation is another justification for Nordhaus's "climate policy ramp." A cost-minimizing path to GHG reduction likely would start with a GHG tax (or cap), initially at a modest level but followed by a widely advertised increase (or tightening of the cap) that would influence investments in new capital without causing the earlier retirement of too much of the existing capital stock.

The global nature of the climate change challenge and the consequent international response creates yet another policy design criterion: "international coordination." To the extent that Canada hopes to minimize the costs of its GHG reductions, it will want to coordinate its policy efforts with those of other countries where possible. Canada has talked a lot about policy leadership over the past two decades, but some countries have actually taken a leadership role. Norway, for example, with its 16 years of carbon taxes, has already demonstrated that leadership does not automatically imply economic hardship.[4] The EU has implemented a cap-and-trade system for large industries that has had implications for the cost of production. Some regions of the United States are pursuing a similar system, and some Canadian

4 Norway, like Canada an oil and gas exporter, imposed a GHG tax in 1991 that averages C$30 per tonne of CO_2 (and as high as C$75 for some sectors), yet it has since seen economic growth of 40.3 percent per capita compared with 23.9 percent in Canada. Norway's GHG emissions have decreased by 0.2 percent per capita since then, while Canada's have grown by 6.0 percent per capita. Norway's GHG tax undoubtedly is not the only factor in the difference between the two countries over this period, but a detailed look at certain developments, such as investments in carbon capture and storage in Norway, suggests that the tax has played a not insignificant role.

provinces have indicated they would join these initiatives. Canada thus appears to be in the position of "policytaker," but this need not be the case. A closer look at both the EU and the United States shows that there is a wide range of policies in various guises and combinations, including taxes, caps, technology regulations, and fuel standards. Canada still has many options for designing its own policies, but coordination with other countries must be a key consideration.

It is also frequently said that, in Canada, GHG policy is especially difficult to implement because the provinces have jurisdiction over natural resources, notably energy. This concern cannot be ignored, but we must be careful not to confuse the issue of the provision of clean energy on a global scale with provincial jurisdiction over natural resources — the issue is emissions, not energy. Emissions occur more at the point of consumption than at the point of production. When the federal government designs policies to reduce emissions, these will affect every Canadian who drives a car and heats a home, no matter what province they live in. Moreover, the pressure to reduce emissions by the fossil fuel production industry — which is concentrated in Alberta and a few other provinces — will come from provincial and even foreign governments, not just the federal government. Indeed, Alberta's fossil-fuel-producing and -using industries already face the strictest GHG emissions regulations in Canada. Emerging regulations in US states such as California will favour imports of clean fuels, which will force Alberta and other fossil-fuel-producing regions to shift gradually toward electricity and hydrogen rather than continuing to produce petroleum products such as gasoline and diesel.

Policy Effectiveness: The Special Problem of Subsidies and Offsets

All the criteria I have just reviewed are important for the design of GHG abatement policies. I want to focus on the criterion of policy effectiveness, however, for the obvious reason that our past policies have been so ineffective. In particular, I want to look at the effectiveness of subsidies, which have dominated Canada's failed policy efforts. Economists and other social scientists have made a considerable effort to assess and explain the failure of these subsidy policies, but very little of their work seems to have made an impression on the interested public, politicians, or even their policy advisors.[5] Nonetheless, it is useful to recap briefly the lessons from this literature, since

5 Among these attempts are several of my own; see Jaccard, Nyboer, and Sadownik (2002); Jaccard (2006); Jaccard et al. (2006); and Jaccard and Rivers (2007b).

governments have not given up their love of subsidies — indeed, individual citizens and corporations have now joined in with their own subsidy programs, commonly known as "offsets."

As I noted earlier, energy-related GHG emissions will fall if businesses and consumers make investments that use comparatively less fossil fuels or that capture the emissions from doing so. Energy efficiency and fuel switching will result in lower fossil fuel use, everything else being equal. But everything is not equal: at any given time — certainly in every decade since World War II — some new equipment and buildings are more energy efficient than their predecessors and some investments in energy favour fossil fuel substitutes such as hydro power, nuclear power, and biomass. Yet, these investments have not led to falling energy use or GHG emissions in the past because they have been more than offset by the increasing use of energy associated with economic growth and the continued advantages of fossil fuel combustion. Indeed, much of the increase in energy use has come from improvements in energy productivity (that is, the output of the economy per unit of energy input), just as improvements in labour productivity lead to job creation. Moreover, fossil fuels, which currently account for 85 percent of the world's energy production, are likely to remain a significant part of the energy mix because they are often the cheapest way to produce energy. (Conventional oil might rise in price, but this would favour unconventional oil, unconventional gas, and ubiquitous coal as much as it would promote the use of substitutes for fossil fuels.)

Thus, even in the absence of policy to reduce GHG emissions, localized investment in energy efficiency and alternatives to fossil fuels — "business as usual" — will continue. Herein is the problem. How can governments, or anyone, provide subsidies that ensure investment in "additional" efficiency and fuel switching? Could governments convince people to decline subsidies voluntarily if they intended to make the investment anyway? Would governments need to create bureaucracies to administer lie detector tests, and would people who changed their minds about buying a more energy-efficient fridge in three years' time be considered to have lied when applying for a subsidy to do so? It is possible to make aggregate forecasts of human behaviour, albeit with great uncertainty, but not forecasts of what specific individuals will do. Yet this is precisely what subsidy programs require. To be effective, they must ensure that subsidies go almost entirely to people and firms who otherwise would not have made the investment.

Some researchers have tried to estimate the true incremental effect of subsidies to foster energy efficiency and fuel switching. For data, we have a 25-year history of such policies by electric utilities in North America. While some of the results from this research inevitably are in dispute (we cannot run history twice in a controlled experiment), several of the top economists in the field conclude that subsidy programs are significantly ineffective and that improved policy design cannot rectify this. Many studies suggest that half and more of all subsidies (depending on the program) have gone to people who would have made the investment anyway.[6]

Moreover, to the extent that subsidies cause some incremental improvement in the productivity of energy use, they likely trigger increasing use of existing energy-using technologies and a more rapid dissemination of technologies that provide new, related energy services. More efficient fridge technologies improve the prospects for the development and sale of desktop fridges, water coolers, wine coolers, beer coolers, and picnic coolers, to name just a few new cooling technologies and services. Again, the precise effect is difficult to forecast, but we know from history that, in the absence of offsetting and substantial cost increases for energy services, dramatic improvements in energy productivity lead to dramatic expansion of these and new energy services.[7]

A critical assumption about relying on energy efficiency subsidies alone is that it is possible to reduce the use of energy significantly without increasing its price. A similar approach has been applied to reducing GHG emissions, both domestically and internationally. At the international level, the Kyoto Protocol's Clean Development Mechanism is based on the assumption that GHG emissions will fall by the same amount whether the reductions occur from investments in wealthy countries that face internationally binding GHG constraints or from subsidies by these countries to foster energy efficiency and alternative fuels (as well as tree planting and reduction of other GHGs) in poorer countries that face no GHG constraints. For this approach to be effective, investments in unconstrained countries would have to be in addition to those that otherwise would have been made. Again, however, we run into the inability to determine whether an investment was truly an incremental change or simply something that would have happened a few years later.

Although the Clean Development Mechanism provides international sanction and facilitation for subsidies between countries — usually between firms in rich and poor countries — some countries, environmental organiza-

6 See, for example, Train (1988); Joskow and Marron (1992); Jaffe, Newell, and Stavins (1999); and Loughran and Kulick (2004).

7 See Fouquet and Pearson (2006). In the United Kingdom, for example, the cost of lighting service had fallen by 2000 to one-three-thousandth of its value in 1800, but per capita demand for lighting service was 6,000 times greater.

tions, and even green-looking entrepreneurs have established similar mechanisms in which individuals and businesses can participate voluntarily. Individuals in rich countries, frustrated with the inaction and ineffectiveness of their own governments' policies, justify their air travel by the use of "offsets" subsidizing energy efficiency, energy forms such as biomass and wind that do not emit GHGs, and planting trees for just a few dollars per tonne of CO_2. In other words, one "offsets" the CO_2 emissions from burning jet fuel by capturing carbon in a growing tree in Guatemala or investing in a wind generator in India.

Whether we are talking about offsets or subsidies, however, the problem remains: was the planted tree in Guatemala truly an additional investment in reducing GHGs or would another tree have sprouted eventually in that spot anyway? Does the planted tree represent a permanent increase in biosphere sequestration of carbon or will it be cut down in 10 years' time as the land is converted from forestry to agriculture? Has the Indian wind generator actually helped prevent or delay the construction of a coal-fired power station or was it simply a wealth transfer to one region in India while the expansion of coal stations has continued at the same pace? We cannot know, because future individual actions are unknowable. All we can know with some confidence is that, in the absence of charges for emitting GHGs, economies will continue to evolve in the direction of greater GHG emissions. Offsets and subsidies can have little effect on this trend, and a significant share of them is likely to be completely ineffective.

Yet, despite the lack of evidence of their effectiveness, offsets are politically attractive, as governments in rich countries have discovered. What better way to address the climate change problem than to facilitate subsidies between private entities, with governments safely on the sidelines? So-called green entrepreneurs are finding them rather attractive, too. Earning a commission on offset payments is an attractive value proposition, one that is enhanced if no one has an interest in rigorous verification tests. Even many environmentalists support offsets. Desperate for government support for reducing GHGs and wishfully assuming that reductions will not require substantial increases in the cost of emitting fuels, they tend to view offsets in a favourable and uncritical light.

The Canadian experience helps explain the growing popularity of this approach among politicians. In spring 2007, caught by surprise by rising public concern about the effects of climate change, the federal Conservative government launched apparently tough requirements for emissions intensity reductions by Canada's 700 large industrial emitters over the next several years. At the same time, however, it offered these industries the option of meeting virtually all of their requirements by purchasing offsets from the sources of emissions not covered by the regulation (Canada 2007, 13). Industries would pay some consumers, institutions, small businesses, and farmers to make investments in energy efficiency, switch to alternative fuels, or change their farming and forestry practices. The federal government also committed to throw in additional subsidies from its budgetary surpluses.

Whether these subsidies or offsets come from government or from the large final emitters, however, the problem does not change: many of these businesses and individuals will be paid for what they would have done anyway, resulting in far fewer real reductions in emissions than claimed. Moreover, the role of offsets potentially could be large, depending on the relative costs of the subsidies versus in-house emissions reductions by industry — the policy places no limit on the use of this provision. There will also be rebound effects in the form of increased equipment use and new energy-using and GHG-emitting technologies and services resulting from the increased productivity of energy, especially because GHG emissions will still be free for these individuals. As with all the other failed climate policies since 1988, however, years will pass before analysis can demonstrate that this offset policy has had little or no effect on aggregate emissions.

Economists agree that more information and subsidies are insufficient to induce a shift to low-GHG technologies. Several are prepared to countenance the use of taxpayers' funds to subsidize research and development (R&D) and demonstration programs, however, arguing that, although patents provide some protection, the market discourages innovative low-GHG technologies because innovators find it difficult to prevent copycats also benefiting from their discoveries or insights (see, for example, Goulder (2004); Jaffe, Newell, and Stavins (2005)). This rationale is problematic, however, as a general principle for initiating public policy, since it suggests that, if the information market failure did not exist, low-GHG technologies would be more plentiful. In fact, the opposite could be the case: presumably the market also discourages high-GHG-emitting technologies that would increase business profits and consumer satisfaction. Equally, providing more energy-related R&D funding might augment the invention and dissemination of new devices, such as outdoor patio heaters, that increase GHG emissions.

My point is that we must be careful not to conflate these two market failures. It is true that markets underprovide R&D. But if we want R&D to focus on reducing GHGs and if we want more such R&D than is currently occurring, we can address this objective by focusing on the GHG externality market failure alone. Increasing the cost of emitting GHGs, especially if such costs were widely advertised well in advance, would stimulate R&D by private entities in GHG-reducing technologies without subsidies from government. Some government subsidies could be included in the mix, but we should not delude ourselves that such support is essential for correcting an R&D market failure. Moreover, evidence suggests that public expenditures on R&D are not as effective as private expenditures (OECD 2003).

Canada's Policy Options

The importance I place on Canada's ongoing failure to implement policies that impose a cost on GHG emissions should now be obvious. For climate policy advisors, therefore, the task is to help Canada's policymakers design politically acceptable ways to reduce emissions.

One can view the policy design options in many different ways. Should we regulate GHG prices (via a carbon tax) or GHG quantities (via emissions caps and tradable permits)? Should we apply the policy upstream (on fossil fuel producers, according to the carbon content in fuels) or downstream (on the final sources of CO_2 emissions)? Instead of, or in concert with, GHG prices and quantities, should we regulate fuels (by imposing carbon content standards) and technologies (via vehicle emissions standards)? Should we also regulate energy use (via energy efficiency standards) and fuel choices (via renewable portfolio standards)? Should we start from scratch or modify existing policies?

As an economist who hopes for policies that achieve Canada's environmental objectives at the lowest possible cost, my responses to these questions are predictable.

- Regulating the price of GHG emissions is likely to be superior to regulating the quantity of emissions. The reason: it is administratively easier to ensure that every emitter faces the same cost than to apply a cap on many small emitters.
- The emissions cost should be applied to all forms of GHG emissions, not just CO_2.
- Given the global nature of the problem, Canada's policies should be designed to coordinate or combine with those of other countries or with international trading mechanisms.
- The emissions cost should be applied as directly as possible to emissions where they occur — in industrial plants, buildings, and vehicles — to minimize the risk of unintended consequences, such as creating a disincentive to use energy or fossil fuels when the objective is to reduce the emissions from fossil fuel use.

- It will be costlier to regulate fuels and technologies than to price or regulate GHG emissions, but if we are determined to do so, such policies should be designed to approximate the pricing approach.
- The preferred approach would be to introduce an economy-wide CO_2 emissions tax. Given the political capital that has already been expended, however, the more politically feasible path might be to reform the current policy slate.

The last point guides my organization of this section. I start by explaining the benefits of a GHG emissions tax and showing how to make its design politically acceptable. I then provide two options for how Canada's current policy approach, which both Conservative and Liberal governments have pursued, could be modified to approximate more closely the GHG tax approach. Finally, if for some unfortunate reason Canada's politicians cannot resist additional regulations on energy use, fuel choices, and technologies, I suggest how such policies could be designed to minimize their negative economic effects.[8]

A Tax on GHG Emissions: The Best Policy for Economically Efficient Climate Protection

Economists like a tax on GHG emissions because it can reduce emissions at the lowest cost. By imposing the same cost on the emission of GHGs throughout the economy, a tax allows individuals and firms to choose to cut their emissions only where the cost of doing so is cheaper than paying the tax. As the level of the tax increases, cutting emissions becomes cost-effective for more and more activities. At each level of tax, however, some consumers and businesses will continue to emit GHGs from activities for which there is no lower-cost substitute or from which they derive high value. This is the feature that makes a carbon tax so economically attractive: it ensures that the lowest-cost emissions reductions throughout the economy are pursued first and allows other emissions to continue, provided that emitters pay their tax. In this way, a society achieves its GHG reduction targets without imposing heavy-handed regulations that determine how much each person or industry should be allowed to emit or what technologies to acquire.

A GHG emissions tax should be applied incrementally, on a policy ramp that reflects both our uncertainties about the risks of climate change

8 In the interests of space the discussion focuses on CO_2, although in some cases the policies discussed may apply to other GHGs.

and our desire to minimize the cost of reducing GHGs. The tax should also include a widely advertised schedule for regular increases to ensure that incremental investments and even R&D efforts reflect the future high cost of emitting GHGs. From my review of Canadian GHG abatement costs, I suggest a tax of about $30 per tonne of CO_2 in 2015, with scheduled increases to $60 by 2020 and to $100 by 2030.[9] Evidence suggests that this level would stimulate substantial GHG reductions without devastating the economy. As a way of dealing with uncertainty about other countries' policies and about climate change science, Ottawa might state up front that the tax levels in 2020 and 2030 would depend in part on what other countries do — edging up or down depending on whether Canada's major trading partners and competitors face comparable GHG emissions prices and whether the climate change risk intensifies or abates.

For a GHG emissions tax to garner political acceptance, it likely would need to be revenue neutral — meaning that it should be offset completely by visible tax decreases elsewhere. Several European countries have used their GHG taxes to decrease payroll taxes, unemployment insurance premiums, and even income taxes.[10] Canada, however, faces the added challenge that a tax applied at the federal level and then reimbursed by a general tax reduction would result in a significant transfer of revenue from Alberta to other provinces — a glance at Alberta's share of Canadian emissions and population suggests that it would pay over 30 percent of the tax and receive less than 15 percent of the recycled revenue. One solution would be for the federal government to reimburse each province the exact amount of GHG tax revenue that it generates. Another solution would be for Ottawa to convince each province to levy the tax itself and keep the revenue. Either approach would eliminate the argument that a GHG emissions tax would be unfair to a particular region.[11]

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9 See National Roundtable on the Environment and the Economy (2007) and Simpson, Jaccard, and Rivers (2007). To get a sense of the effect of a carbon tax on fuel prices, a tax of $50 per tonne of CO_2 would increase the cost of gasoline by 12 cents per litre, but it would not increase the cost of electricity or hydrogen from zero-emission sources and it would increase the cost of biofuels only to the extent that fossil fuels were still used in their production.

10 A large literature exists on the "double dividend" — the argument that using recycled GHG tax revenues to reduce taxes that are a drain on economic activity would provide environmental and economic benefits simultaneously. I avoid this discussion here, as it mixes the argument for tax reform with correcting environmental externality. Policy proposals in each area should stand on their own merits.

11 One could also show how to construct a cap-and-trade mechanism that would not involve a transfer between regions, despite recent claims to the contrary by both Alberta's premier and leader of the opposition.

Since reimbursing GHG tax revenues to provincial governments might also have trouble garnering political acceptance, Ottawa could reimburse them directly to businesses and individuals — in the latter case, via fixed payments on a per capita basis. For Albertans, this would be similar to the petroleum resource rent cheques the provincial government once provided. To take the example of gasoline, suppose $260 million in GHG emissions taxes (by carbon content) were collected from retail gasoline sales in Alberta in 2010, then the following year each of that province's 2.6 million adults would receive a cheque for $100, regardless of how much gasoline they purchased. Of course, those who purchased more gasoline in 2010 would make a larger contribution to the $260 million in revenue collected, which presumably would enhance the incentive to shift gradually to the use of more fuel-efficient vehicles, biofuel cars, battery electric cars, plug-in hybrid cars, fuel cell hydrogen cars, public transit, and other low-emission alternatives.

In the case of firms, the tax reimbursement should take into account differences in size. Each firm's share of the GHG tax reimbursement could be based on its fuel consumption (hence emissions) at an initial period prior to the introduction of the tax say, in 2000 or 2005. (New firms would be assessed a share based on an average of firms of comparable size.) At first blush, though, this approach might seem ineffective: why would any firm reduce its GHG emissions in response to a GHG tax it knew would be reimbursed? Key to the policy's success would be to tie a firm's share of the GHG tax reimbursement to its emissions in an initial year, prior to the start of the policy. While this proportion of the total tax revenue would stay constant — with revenue rising or falling depending on the rate at which the GHG tax increases and GHG emissions fall — each firm would have an opportunity to reduce its share of tax payments by taking actions to reduce its GHG emissions. Doing more than other firms, however, would not reduce a firm's share of the GHG tax reimbursement each year; rather, firms that reduced their GHG emissions more than others would do better on the tax payment/reimbursement ledger than other firms. Of course, the extent to which a firm reduced its GHG emissions ultimately would depend on the cost of GHG abatement. For some firms, the best strategy would still be to do no GHG abatement whatsoever.

Given the need to tailor the policy to firm size, data on fuel consumption in the initial year would be required. Fortunately, such information is available even for small firms from the billing records of electric and natural gas utilities and companies that supply refined petroleum products. Thus, tax revenue could be reimbursed using existing billing and payment methods, in the same way that utility and regular fuel customers are sometimes credited for overpayment of their natural gas, electric, and fuel bills. Administratively, the reimbursement of tax revenues would require no added bureaucracy.

Finally, a small amount of the GHG tax revenue (much less than 1 percent) could be used to pay for whatever administration and information services would be needed to inform Canadians as to how the tax revenues were being recycled and how the policy was performing in terms of reducing emissions of GHGs.

The Second-Best Option: Reforming Canada's Current Policy Path

A better-informed public and a more honest political discourse should be enough to move Canada to a tax on GHG emissions. If it turns out, however, that Canada's politicians lack the confidence to make such a policy switch, then we should at least reform current GHG policies so that they approximate the effect of a GHG emissions tax — namely, by ensuring that GHG emissions are no longer free and that Canada no longer applies ineffective subsidies.

In recent years, Liberal and Conservative federal governments have proposed an intensity-based cap-and-trade system for large emitters (with its option of unlimited use of offsets), major government subsidy programs for businesses and individuals, and emissions and energy efficiency regulations for vehicles, buildings, and equipment. Several provinces have followed suit with their own mix of fuel and vehicle regulations and, in the case of Alberta, an intensity-based cap-and-trade system for large industrial emitters that has strong similarities to proposed federal regulation (see Alberta 2006).

The design of these initiatives, however, is likely to lead only to large expenditures by governments and, perhaps, industry, with much less reduction of GHG emissions than anticipated (Jaccard and Rivers 2007b). The reason is that each additional federal or provincial technology- and fuel-focused regulation increases the likelihood of transgressing the equi-marginal principle, leading to the pursuit of high-cost emission reductions in some sectors or regions while low-cost reductions are neglected in others. More important, none of the government policy proposals includes even a modest price signal for nonindustrial emissions.[12]

12 For example, in 2007, the Quebec government implemented a tiny carbon tax, but, amazingly, it also warned fuel suppliers that it would not allow consumer prices of GHG-emitting fuels to increase because of the tax.

At first blush, intensity-based cap-and-trade policies for large final emitters would appear to be consistent with my call for compulsory policies that would result in an unavoidable cost for emitting GHGs. Both types of policy would set an intensity-based cap on GHG emissions and, as long as the intensity cap fell at a fast enough rate — the federal proposal is for a 6 percent reduction per year for three years — the absolute level of emissions should fall. Yet, both the federal proposal and Alberta's cap-and-trade policy contain "flexibility provisions" that allow firms to sidestep the original intent of a cap-and-trade system — which is to force firms that cannot meet their targets to pay other firms that are willing to exceed their targets by making extra efforts to reduce their emissions. Flexibility provisions allow firms to opt out of permit purchases and instead to contribute to a technology fund — at $15 per tonne of CO_2 emissions in excess of the intensity cap in Alberta, with a similar initial value that rises after 2010 in the proposed federal regulation — or to pay offset subsidies, presumably at less than $15 per tonne of CO_2 emissions, to consumers and smaller businesses that face neither a carbon tax nor an emissions cap. If many firms were to purchase these lower-priced offsets from small emitters, the nationwide reduction in GHG emissions would be significantly lower than anticipated (perhaps only half as much) given the ineffectiveness of subsidies. If, instead, many firms were to opt to pay into the technology fund, this would also slow down anticipated emissions reductions in the short term; moreover, there would be no guarantee that such payments would translate into equivalent reductions at some later date. And since cumulative emissions are key to determining atmospheric concentrations of GHGs, reductions starting at a later date would be of less value than those that begin now and endure into the future.

How could we prevent this outcome? One obvious way would be to eliminate flexibility provisions in any intensity-based cap-and-trade proposals that apply to large final emitters. If governments are serious about real reductions in GHG emissions by Canadian industry, these options should not exist. To address concerns about the initial costs to industry, governments could simply start with less aggressive intensity targets. They could also combine these lower targets with a safety valve — the price at which unlimited permits would be provided, so that industry would know that its costs per tonne of excess emissions would never exceed the safety valve price (see Jacoby and Ellerman 2004). In line with my proposal for a GHG emissions tax, the safety valve price could be set according to a schedule that climbed in step with a declining intensity (or absolute) cap from, say, $30 in 2015 to $60 in 2020 and to $100 in 2030. Government revenues from the safety valve could be reimbursed to industry in the same way that I propose for GHG tax revenues. Administratively, this would be much less costly and much less prone to abuse than the proposed method for the technology fund, which is to return the funds to individual firms as they demonstrated in a bureaucratic adjudication process that they were using the money for true incremental reductions in GHGs — the subsidy problem all over again. If governments were worried that the cost to Canadian industry of reducing GHG emissions was too high relative to that of its competitors, they could adjust the schedule upward for the falling intensity cap and downward for the rising safety valve. Using these simple levers, instead of flexibility provisions, governments could reduce the overall cost to the Canadian economy and increase the effectiveness of the effort to reduce GHG emissions. As long as wide-scale subsidy programs are integral to Canada's GHG reduction policies, they will be far less effective than expected, and our poor record of applying ineffective policies that fail to meet their targets will continue.

A second essential reform of Canada's current policy path would be to cover sources of GHG emissions other than the large final emitters — fully half the total. One way to accomplish this would be to extend the cap-and-trade system to the entire economy, although, given current information technologies, it would be an administrative challenge to include all smaller sources of GHG emissions. Another option would be to apply a tax on emissions to all sources other than those covered by the large emitter cap-and-trade system, as the United Kingdom does. Still another option, though one that is less economically efficient, would be to apply regulations that truly control emissions to individual sectors — vehicles, buildings, appliances, industrial equipment, and so on.

Canada as Policy Leader: Introducing a Carbon Management Standard

An emissions cap and tradable permits policy might best be described as a market-oriented regulation. It is like a regulation in that it would require businesses and firms to cover their excess emissions or acquire permits from other firms or from government (via the safety valve), and it would apply penalties for noncompliance. But such a policy also has the market-like flexibility of a tax in that individuals and businesses would be free to decide how much emissions reduction, if any, they wish to undertake. They could make extra reductions and earn revenue by selling excess permits or they could do less and pay others to reduce emissions by purchasing their excess permits. The trading value of emissions permits would provide a price signal for carbon emissions that is comparable to that of a GHG tax.

A major challenge for a cap-and-trade system, however, is determining the allocation of permits. A great deal of money hinges on this decision, which would create incentives for aggressive lobbying, gamesmanship, and even legal challenges. If permits were allocated by auction, those who currently emit the most would face the greatest costs, with perhaps serious effects on their costs of production. In fact, it is possible to design an auction system such that, as with a GHG tax, government auction revenues would be returned in proportion to shares of emissions in an initial year prior to the policy, thus reducing the effects on production costs. So far, however, interest groups have convinced governments that apply cap-and-trade policies to allocate permits by "grandfathering" — allocating permits in proportion to emissions in an initial year prior to the policy. While this approach might produce politically acceptable results in the short term, there is some evidence that it is problematic. The grandfathering of permits in the European Union's large emitter cap-and-trade system (launched in 2005) led to surplus permits and a permit price crash in 2007. Some economic research suggests that permit-trading markets can be manipulated to hinder the entry of new firms into an industry and that transactions costs — legal costs, lobbying, trading commissions, regulations, and so on — can be substantial.

Another important policy design issue is the initial cost of technologies for providing near-zero-emissions sources of electricity and hydrogen, on the energy supply side, and technologies for providing near-zero-emissions buildings, vehicles, and equipment, on the energy demand side. The first near-zero-emissions coal-to-electricity plants are likely to cost between 25 and 75 percent more than conventional low-emissions coal plants. Electricity generation from renewable energy sources, with energy storage, is in the same cost range, while near-zero-emissions plug-in hybrid, biofuel, and hydrogen vehicles are likely initially to cost between 25 and 50 percent more, in up-front investment, than conventional, high-efficiency gasoline vehicles.

The need for political acceptability makes it difficult to imagine a carbon tax high enough, at an initial level, to stimulate electricity generators or vehicle manufacturers (in my two examples) to invest in near-zero-emissions technologies. With the modest carbon tax I propose (or the cap-and-trade and other policies currently being pursued in Canada), it is more likely that the next coal-to-electricity plants in Canada would not include carbon capture and storage and that the penetration of plug-in hybrids, full biofuel and hydrogen fuel cell vehicles would occur exceedingly slowly, if at all. What is needed is a way to send the correct marginal price signal for the need to foster near-zero-emissions technologies without causing dramatic increases in prices and costs of production for those who are dependent on existing capital stocks — namely, all of us as householders and firms using capital that has been accumulated over the past decades of incremental investments. We could achieve the correct marginal price signal with a higher initial carbon tax, but it would require the tax reimbursement mechanisms I described earlier, and even then it would result in energy price increases that well-meaning politicians would find difficult to defend, even as they tried to explain that the GHG tax revenues would be returned to Canadian individuals and firms.

Because of the challenges associated with a GHG emissions tax and cap-and-trade policies, a third policy approach might be what I call a "carbon management standard." This is a market-oriented regulation that would require producers and importers of fossil fuels — namely, coal, natural gas, conventional and unconventional crude oil, and refined petroleum products — to ensure that a growing fraction of the carbon they extract from the earth did not reach the atmosphere (see Jaccard and Rivers 2007a). The obligation initially would be small — that, say, 2 percent of the carbon not reach the atmosphere — but it would rise over time according to a preset schedule — rising to, for example, 10 percent in 2025 and 50 percent by 2050.

A carbon management standard differs from a cap-and-trade system applied to fossil fuel producers in that it obliges a growing share of processed carbon to be captured and safely stored, whereas a conventional cap-and-trade system sets a cap on the overall amount of carbon-based fuels fossil fuel producers can sell. Under a carbon management standard, rather than allocating permits to emitters in accordance with the cap, governments would collect certificates from firms that match their aggregate obligation. At the end of each year, each producer and importer of fossil fuels would be required to remit certificates in accordance with its overall obligation to ensure that a percentage of the carbon it extracted from the earth was permanently stored, and it would face fines for any shortfall in certificates (although a banking system would allow for balancing over several years). Firms that participated in the system would be able to trade certificates among themselves in an established market. Firms (such as a coal-fired electricity plant) that remained outside the system but captured and stored carbon would be able to generate certificates and sell them to fossil fuel producers.

Although a carbon management standard would apply to domestic sales of Canadian fossil fuel producers and processors, exporters of fossil fuel products would receive partial exemption from the obligation in accordance with the regulatory policies facing their major competitors in the export market. Importers of fossil fuel products would be required to meet the standard by demonstrating sufficient carbon capture and storage in their overseas carbon extraction processes or by paying for additional carbon capture and storage by Canadian fossil fuel producers. (This would be similar to California's policy of requiring lower emissions in the full production process of electricity and fuel imports.)

Such an "obligation and certificate" approach would allow governments to avoid politically and distributionally complex negotiations over the initial allocation of permits. As well, unlike a carbon tax or auctioned permits, a carbon management standard would generate no government revenue, which would increase its political acceptability compared with the tax approach. Like the "upstream" cap-and-trade system, however, such a policy would cover virtually all carbon flows from fossil fuels, thus affecting final prices of GHG-intensive fuels for all consumers, not just large final emitters. Stipulated in percentage terms, the carbon management standard would function like an intensity target: rapid growth of the fossil fuel industry could offset somewhat the fact that a growing percentage of the carbon it processed would be captured and stored. For example, a coal-mining company could acquire the necessary carbon management certificates by capturing itself some or all of the carbon it produced as a solid or as CO_2 gas. More likely, it would purchase certificates from industrial activities for which the cost of capturing carbon in solid or gaseous form and permanently storing it would likely be lower — say, a coal-fired electricity plant, an industry that used coal for thermal purposes, or perhaps in future a coal-to-hydrogen gasification plant. It is estimated that carbon capture and storage would increase the cost of generating electricity from coal by 2 to 4 cents per kilowatt hour (International Energy Agency 2004).[13] Even with this production cost increase, however, electricity generated from coal plants with near-zero GHG emissions would likely be competitive with nuclear power and renewable energy sources once the essential investment in energy storage was included in the cost of these latter, intermittent sources.

If it turned out that the cost of capturing carbon was high relative to increasing energy efficiency and switching fuels to reduce GHGs, the coal-mining industry would gradually lose market share over the coming decades as it became obvious that shifting away from coal was cheaper than near-zero-emission applications of it. More likely, the outcome would vary depending on each particular region's resource endowments — meaning that fossil fuel production would continue to thrive in some areas, including Alberta. A carbon management standard, however, would drive incremental investments in carbon capture and storage without causing massive produc-

13 Estimated costs have recently increased in Alberta and Saskatchewan, in part because of a global jump in commodity costs and in part because of the rapid growth, and associated cost inflation, of the fossil fuel sectors in these two provinces.

tion cost increases for the coal-mining industry as a whole. In fact, the certificate approach could actually foster collaborative efforts involving firms in coal mining, electricity generation, and enhanced oil recovery.

A carbon management standard's avoidance of permit allocation issues could prove to be particularly important when it came to setting international targets and policies for reducing GHG emissions. Allocation of permits inevitably is a contentious issue at the national level, and it is just as problematic at the international level. Nevertheless, countries might more easily agree on the parameters of a carbon management standard that applied to the use of fossil fuels (the largest source of GHG emissions) no matter where it was located. In essence, a carbon management standard would be an explicit and transparent expression of what actually must happen if global GHG emissions are to fall: emissions from the fossil fuel industry must fall substantially, whether because of the massive expansion of carbon capture and storage or because the additional costs of carbon capture and storage lead to substitution away from fossil fuels. In this sense, a carbon management standard would focus directly on the externality, thus improving its chances for a more economically efficient outcome.

Ancillary Policies: Command-and-Control and Niche Market Regulations

Although a tax on GHG emissions would be the optimal policy from an economic efficiency perspective, a carbon management standard could closely approximate a GHG tax while avoiding the challenges of reforming government taxation or allocating tradable emission permits. As I have argued and, I hope, demonstrated, both policies would be significantly superior to Canada's current path. Yet, because of Canadian governments' unwillingness so far to abandon that path, I have also suggested some reforms of current policies — notably, removing flexibility provisions in intensity-based cap-and-trade schemes for large emitters and extending price signals for GHG emissions to the rest of the economy. In addition to these approaches, there are a number of ways to improve the regulatory components of recent government policy initiatives.

As I noted earlier, policies are less likely to satisfy the equi-marginal principle when they impose unique technological outcomes in individual sectors of the economy. Command-and-control regulations that require specific technologies (to increase energy efficiency) or forms of energy (such as renewables) limit the options for firms in a specific sector to reduce GHG emissions and thus make it more costly for society to achieve a given level of emissions reduction. Despite these concerns, however, some economists are willing to countenance the limited application of technology-specific regulations in concert with broader, economy-wide policies that attach a price to GHG emissions. This is motivated in part by concerns about the so-called R&D market failure and in part by recognition that regulations are relatively easy for politicians to implement (Jaffe, Newell, and Stavins 2005). Certainly, as the Canadian GHG environmental policy experience suggests, the political process seems biased in this direction.

Without condoning the use of regulations, economists could offer some guidance to minimize their negative effects. In my suggestions for improving regulatory policy, I distinguish traditional command-and-control regulations from what I refer to as newly emerging "artificial niche market regulations."

All countries that are members of the Organisation for Economic Co-operation and Development apply command-and-control regulations to energy efficiency. In Canada, through the *Energy Efficiency Act*, the federal government sets standards for the minimum efficiency of most large household appliances, while some provinces use building codes to impose efficiency standards on home insulation and furnaces. To minimize their negative economic effects, however, such policies should be used only to consolidate, rather than to force, the use of a particular technology. By this I mean that efficiency regulations should be used to eliminate a relatively small subset of the available technologies — presumably, those that are the least energy efficient, subject to periodical technology reviews — rather than to impose a new, high-efficiency technology on all market participants. Eliminating too much choice would likely have unwarranted welfare costs; it would also impose real financial risks, since new technologies often have higher failure rates. To minimize costs, firms and households should be able to make their own decisions about the adoption of new technologies as their incentives change with the rising cost of GHG emissions, not bureaucrats trying to make a risky, one-size-fits-all technology determination for everyone.

Since command-and-control regulations are likely to be least costly if they focus directly on the objective, GHG emissions regulations are preferable to energy efficiency regulations. Policy should not preclude the possibility that, through individual and collective choices about technologies and lifestyles, society will decide it can use a lot more energy in future even as it aggressively reduces GHG emissions. Moreover, with sector-specific command-and-control regulations, it is important to have some means of comparing the incremental costs of emissions reductions between sectors to minimize transgressing the equi-marginal principle. This could be realized in part by continuous monitoring of the costs of different regulatory policies, and occasional adjustment of command-and-control requirements to bring closer together the costs of different policies in different sectors.

Finally, we should consider a wider application of an alternative regulatory approach: what I call "artificial niche market regulations." These regulations are similar to a carbon management standard in that they would function as an "obligation and certificate trading" system. The idea would be to regulate a sector by requiring a growing market share (a niche market) for a particular technology or form of energy. Notable examples of such systems include "renewable portfolio standards" for electricity generators and California's vehicle emissions standard, which was implemented initially to address a local air pollution problem but is now applied to GHG emissions in several US states. The niche market would be "artificial" in that it would be created by regulation; otherwise, however, it would act like any other "natural" niche market in that it would provide an early commercial demand for a new technology, which could then start to benefit from economies of learning and of scale with greater production. This would bring costs down and enable manufacturers to gauge the market potential once rising GHG taxes and/or falling GHG emissions caps improve the economic prospects for these technologies — in effect, converting the artificial niche market into a natural niche market.

Renewable portfolio standards, which half of all US states have implemented, are an "obligation" on electricity generators to demonstrate that they have acquired a specified portion of their power from renewable sources, a proportion that is scheduled to grow over time. Electricity generators choose whether to produce the required renewable power themselves or purchase "certificates" from renewable generators. Like the permit trading market, this type of flexibility should ensure that firms pursue the lowest-cost renewable resources first, thus lowering the overall cost of achieving the policy goal.

The vehicle emissions standard that California implemented in 1990 placed an "obligation" on vehicle manufacturers to sell a minimum quantity of zero-emission and low-emission vehicles by a given date, with a penalty of $5,000 per vehicle for missing the target. Again, such a policy allows manufacturers the flexibility to trade vehicle credits (essentially certificates) among themselves.

Thus, renewable portfolio standards create an artificial niche market for renewable energy in electricity generation while vehicle emissions standards create an artificial niche market for low-emission vehicles. The concept of artificial niche markets has important implications for economic efficiency. The niche obligation would reduce the risks to industry because it would be required to retool only a small part of its production process, enabling society to discover the cost of shifting toward these emerging energy sources and technologies. Yet the niche should be designed to be large enough to achieve-production levels that would trigger significant cost decreases from learning and large-scale production.

The artificial niche market regulation approach could be applied to several sectors. One example is the development of zero- and low-emission buildings. This obligation would require the building industry in different sectors (residential, institutional, retail, commercial) to create minimum market shares for these types of buildings in new construction. Anyone building such a structure would earn certificates that could be sold to mass-market builders that need to meet their obligation.

As these practical applications demonstrate, the niche market regulations approach is politically attractive. It enables policymakers to force much-needed technological change by imposing obligations on manufacturers that, unlike a tax on GHG emissions, would not involve highly visible cost increases to consumers, that would stimulate R&D investment — since manufacturers would be forced to undertake such investment and to pay for it from all vehicle sales — and that would not require the sudden restriction of technology choices by consumers and firms. Of course, such policies would have a better chance of not harming economic output if they were applied as broadly as possible. And this, indeed, is the motivation for my proposed carbon management standard, which would oblige the fossil fuel industry to take responsibility for the GHG emissions from its activities. The effects of such a policy would be economy-wide and the outcome would simply be what must happen in any case if we are to reduce GHG emissions: most CO_2 from using fossil fuels must not reach the atmosphere.

Conclusion

Economics, with its traditional expertise in cost-benefit analysis and cost-effective policy design, can contribute much to the challenge of climate policymaking. Yet the profession must recognize that the real world of policymaking often lies far from the theoretical principles in economic textbooks. Economists, therefore, can contribute by pointing out policies that are preferable from the perspective of economic efficiency while providing guidance on how to improve the policies that society is unwilling to abandon, however flawed they may be. To that end, I come to the following conclusions.

First, the magnitude of the potential damage from climate change and our potential inability to compensate for it suggest that we should make an effort now to begin reducing GHG emissions. At least in the early stages, it is safe to assume that well-designed policies would influence technological change toward low- and zero-emission options without causing undue economic costs, as the experience of countries such as Norway has shown.

Second, in the coming decades, Canada's increasingly intensive efforts to reduce GHGs — and thus the higher costs of doing so — should be coordinated to some extent with the efforts of our major competing economies.

Third, putting a price on the atmosphere is critical; the abatement of GHG emissions will not occur without it.

Fourth, energy efficiency is more expensive to achieve than its advocates suggest, but an understanding of this fact is critical if GHG abatement policies are to be well designed.

Fifth, subsidies and information programs are largely ineffective by themselves.

Sixth, a carbon tax would be the most economically efficient and administratively simple way to price the atmosphere.

Finally, in the absence of the political will to implement a carbon tax, policies should be modified to ensure that they approximate the effectiveness and economic efficiency of such a tax. Flexibility provisions in cap-and-trade systems that allow subsidies to flow from regulated to unregulated parts of the economy will not be effective. Cap-and-trade schemes that apply to only part of the economy will be only partially effective.

For the past two decades, Canadian policies have failed to reduce or even slow the growth of our greenhouse gas emissions. To economists, and increasingly to everyone, the reasons are obvious. In many cases, fossil fuels remain the cheapest source of energy, and this will continue. If there is no charge or regulatory constraint on choosing and using technologies that combust fossil fuels, and thus emit greenhouse gases, these will continue to dominate the economy. If we are to reduce these emissions, we must apply such charges or constraints as necessary. These will not be costless. But evidence suggests that well-designed policies could keep costs over the coming decades to a level that most Canadians would be willing to accept as a necessary burden for reducing the climate change risk — provided this was part of a global effort with a good probability of success. Even now, however, as the political focus finally shifts to the design and implementation of various forms of emissions charges and regulations, there is a substantial risk of policy failure — of ineffectiveness, of unnecessarily high costs, of political backlash. I hope that many of our best minds now turn their attention to this challenge.

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