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ECONOMIC GROWTH AND INNOVATION

Going Green for Less:

Cost-Effective Alternative Energy Sources

Roger A. Samson
Stephanie Bailey Stamler

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In this issue...

Canadian governments have many renewable energy programs in place to reduce greenhouse gas emissions. But which ones are the most cost-effective use of taxpayers' money? The authors conduct an audit to find out.

The Authors of This Issue

Roger A. Samson is Executive Director and Stephanie Bailey Stamler is a Project Manager at Resource Efficient Agricultural Production Canada (REAP-Canada), an independent, non-profit organization working on research, development and policy issues concerning sustainable bioenergy systems in Canada and abroad.

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The Study in Brief

The federal and provincial governments have numerous renewable energy programs in place to reduce Canadian greenhouse gas (GHG) emissions. We have analyzed the cost effectiveness of these incentive programs and, in doing so, have identified the most and least cost-effective uses of taxpayers' money for subsidies and incentives to mitigate GHGs.

The lowest-cost government incentive programs identified are for renewable heat and power technologies such as wind power, solar air and hot water heating, and biomass pellet heating, as well as energy retrofitting strategies. For these programs, mitigation could be realized at $10-to-$60 of government subsidy per tonne of carbon dioxide equivalent (CO_2e) offset.

In contrast, the most expensive government incentives were found to be liquid biofuels, which ranged from $295-to-$430/tonne of CO_2e for ethanol and $122-to-$175/tonne of CO_2e for biodiesel. The federal government's $4.5 billion ecoENERGY program has dedicated over half of the total budget towards liquid biofuels.

A redirection of federal funds towards more fiscally cost-effective carbon mitigation approaches would create greater parity in the way incentives are currently used to encourage renewable energy deployment. One such approach is an incentive that could be applied equitably across all renewable energy technologies and reward those that are most cost-efficient.

Overall, governments in Canada are presently over-investing taxpayers' money in high-cost mitigation technologies and under-investing in low-cost mitigation technologies.

About the Institute

The current federal government has committed to reducing greenhouse gas (GHG) emissions to 20 percent below 2006 levels by 2020 (Canada 2008a), and all provinces have set GHG emission reduction targets as well (Bollinger and Roberts 2008).

To meet these goals, governments have provided subsidies and incentives for developing and implementing renewable energy technologies, focusing predominantly on liquid biofuels and renewable electrical power. Typical strategies used to encourage the development of these energy sources include renewable fuel standard mandates, tax incentives, producer incentives, and capital cost write-downs. Renewable energy policies also provide other policy benefits to Canadians, such as enhancing energy security and rural development, but these policy drivers appear of secondary importance. The main message on the federal government's ecoENERGY website is that abating GHGs is the principal goal of renewable energy incentives programs. How cost effectively do these programs meet that goal?

Criticism of incentive programs ranges from arguments that they will be generally unsuccessful at reducing GHG emissions (Jaccard and Rivers 2007) to examinations of the high cost of specific subsidies, such as those for corn and wheat ethanol (Auld 2008). Yet, despite empirical evidence of the ineffectiveness of subsidies to reduce GHGs, these tools remain popular among policymakers. Since governments that aim to be fiscally responsible need to understand how the cost effectiveness of incentives could be improved,[1] we review the efficacy of the entire portfolio of federal and provincial renewable energy incentive programs – with respect to major liquid biofuels, renewable power, and renewable heat options – to determine their cost effectiveness at reducing GHGs.[2] Government subsidies, however, are only part of the overall economic costs of these renewable technologies. In this study, we do not examine the costs of equipment, the labour required to build and operate machinery, and the material used as a power source. A more detailed analysis that includes these costs and the proportion of overall costs that subsidies and other incentives represent still needs to be undertaken.

In Canada, energy is used in three broad ways: for transportation, for electrical generation, and for thermal energy in space and process heat applications. In 2006, out of a total of 721 megatonnes (MT) of carbon dioxide equivalent (CO_2e) emissions, transportation was responsible for 159 MT, electricity production for 113 MT, and fossil fuel combustion from the manufacturing/industrial, services, and residential sectors to provide thermal energy for space and process heat accounted for 217 MT. In addition, the fossil fuel industries and agriculture sectors accounted for 158 MT and 69 MT of emissions, respectively.

Currently, $3.5 billion in federal government incentive programs to mitigate emissions of GHGs is focused primarily on biofuel development for passenger vehicles and, to a lesser extent, on power generation. However, these areas represent only 13.4 percent and 16.3 percent of total Canadian GHGs, respectively (Environment Canada 2008), and only $36 million in planned spending on renewable energy is targeted toward thermal energy incentives – an energy use that is responsible for at least 30 percent of Canadian emissions.

Understanding the GHG emissions associated with fossil fuel and renewable fuel use can provide a sound basis for creating effective policy strategies for GHG mitigation. When analysing government

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In the interest of full disclosure, REAP-Canada's primary activities in Canada have been in the research and development of bioenergy feedstocks for cellulosic ethanol and heat-related applications. It is currently involved in the development of grass pellets for thermal energy applications.

1 See Auditor General's December 2008 report.

2 Some provincial incentive programs developed or modified since September 2008 might not be included here.

incentives to offset GHG emissions, one should consider two main factors: first, the potential of the incentive to reduce emissions – by which we mean the net percentage of the reduction of emissions gained by replacing a fossil fuel with a renewable option; and, second, its cost effectiveness – by which we mean the dollar amount of subsidy for each unit of energy produced that is required to offset emissions by 1 tonne of CO_2e.

Our Methodology

Renewable energy alternatives almost always have lower GHG emissions than traditional fuel sources, which creates a savings, or offset, when they replace fossil fuels. To determine the potential savings gained by replacing fossil fuels, we use a complete life-cycle analysis of the emissions created in the production of both fossil fuels and renewable energy alternatives from "cradle to grave" – that is, taking into account both the emissions created by the end user and those created during the manufacture, maintenance, and raw materials phases of production and disposal. One can take a number of different approaches to determine which key elements or activities should be included in the analysis, but for our purposes, we base our analysis on the federal government's GHGenius 3.14 program (Natural Resources Canada 2008a).

A considerable scientific debate is under way about how much and whether to include in life-cycle analyses the effects of both (i) GHGs released due to land conversion to biofuel production (see Searchinger et al. 2008) and (ii) quantification of nitrogen oxide, a greenhouse gas 300 times more potent than CO_2 that originates from the application of nitrogen fertilizers for crop production (see Crutzen et al. 2007).

Including these other emissions sources often puts estimates of the GHG intensity of ethanol above that of gasoline. Here, however, we use more modest assumptions about other GHG emissions produced from ethanol that are more favourable to ethanol than are those in many studies.

Moreover, the large range of scientifically defensible estimates of emissions related to liquid biofuels makes comparisons difficult. For the production of corn ethanol, we acknowledge the wide range of estimates by using an average of the GHGenius 3.14 model and the US Department of Energy's Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) model, in which natural gas, rather than coal, is assumed to provide process energy for ethanol production (see Wang, Wu, and Huo 2007). This compromise produces an average offset estimate of 35 percent for Canadian corn ethanol, considerably higher than the average GHG offset value of 18 percent for US corn ethanol (Farrell et al. 2006). In our analysis of overall Canadian GHG emissions, we ignore the effects of imported US corn ethanol and wheat-based ethanol production. Currently 75 percent of Canadian ethanol production comes from the use of corn in eastern Canadian plants, while western plants operate on both corn and wheat, depending on grain commodity prices.[3] In the case of biodiesel, we use an average of the GHGenius 3.14 model, the US GREET model, and a European model to derive carbon offset values for soybean and canola biodiesel of 66 percent and 77 percent, respectively.[4] Finally, for all fuels, we use the "lower heating value," which is a measure of energy that excludes the energy released by water vapour (as opposed to the "higher heating value," which includes the energy capture from water vapour).[5] We obtain life-cycle GHG emissions for wind, solar, and biomass power, as well as biomass pellets for thermal energy, from the sources noted in Appendix Table A-1.

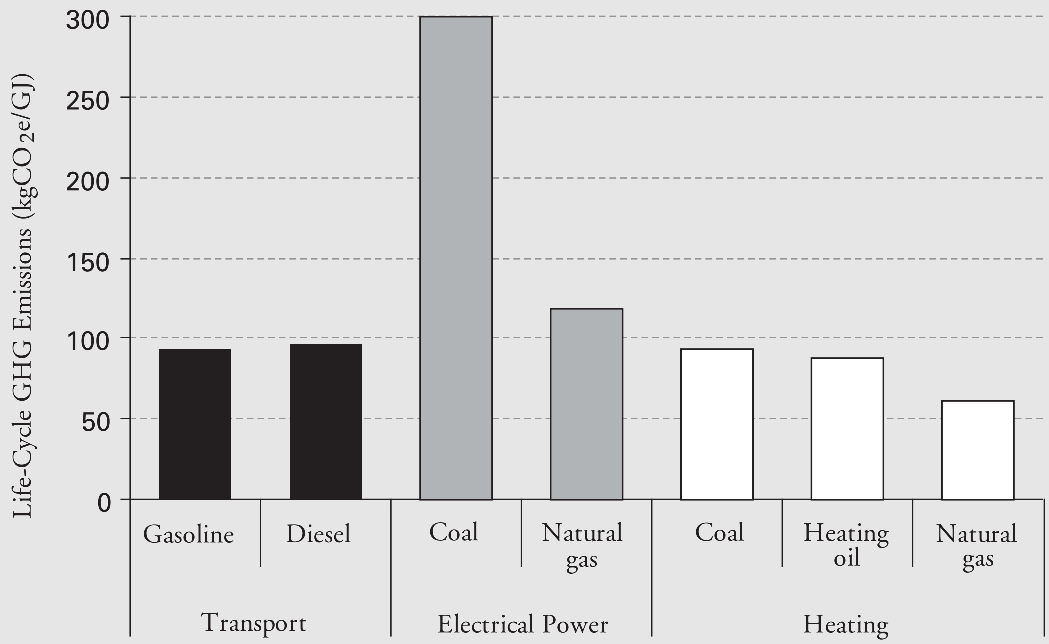
GHG emissions from current nonrenewable power, transportation fuels and thermal energy vary by the type of energy (see Figure 1). Electrical power

3 Corn feedstock is often used in wheat-based ethanol facilities in Western Canada (Vannahme 2008). However, as of January 2009, wheat is the primary feedstock in ethanol plants in Western Canada.

4 There is considerable inconsistency in the estimations of GHG balances among studies. The only recent peer-reviewed Canadian study of which we are aware estimates a range in the ratio of energy output to input of 2.1 to 2.4 for both soybean and canola biodiesel production (Smith, Janzen, and Newlands 2007). Unfortunately, however, the authors present no associated GHG offsets.

5 The exception is natural gas, for which we use an average of the lower heating value and the higher heating value, as the fuel is widely used in condensing boilers, which recover some of the additional heat dissipated in water vapour.

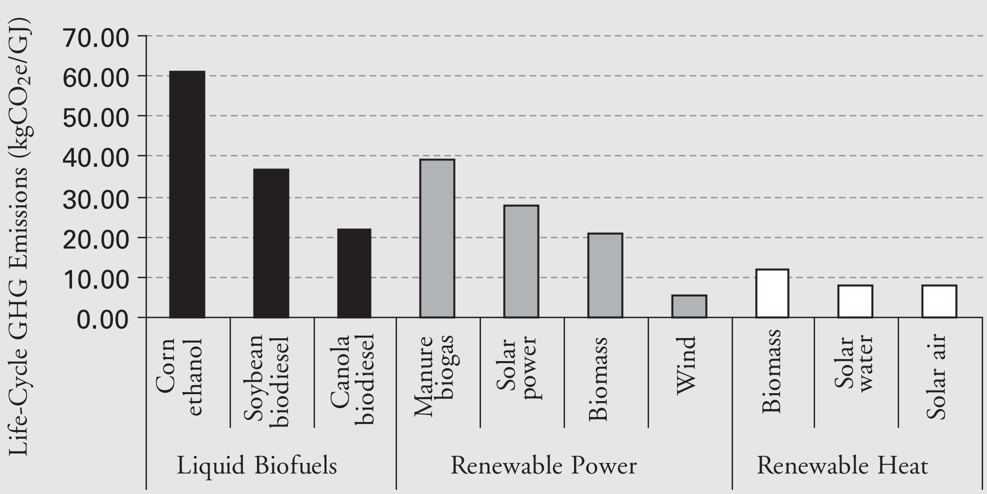
Figure 1: Life-Cycle GHG Emissions of Fossil Fuels by Sector, Canada



Note: We assume 48 percent domestic production and 52 percent international sources for heating oil.

Source: See Appendix Table A-1.

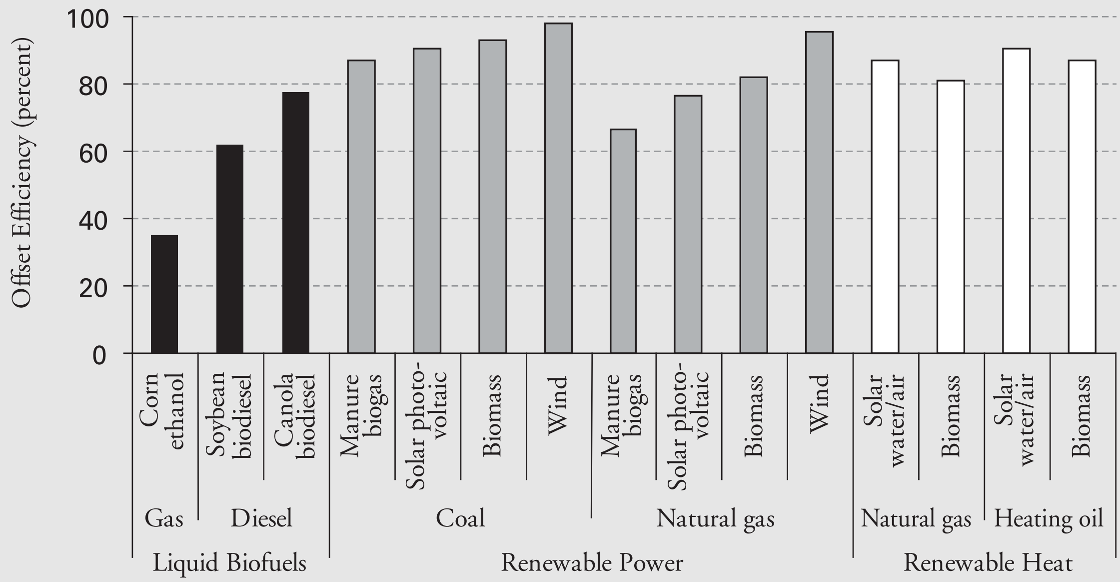
Figure 2: Life-Cycle GHG Emissions from Alternative Renewable Energy Sources



Note: Biomass life-cycle GHG emissions are an average of emissions from wood and grass pellets.

Source: See Appendix Table A-1.

Figure 3: Offset Efficiency of Alternative Renewable Energy Options



Note: Manure biogas does not include landscape emission reductions; biomass is an average of wood and straw pellets.

Source: Authors' calculations from Appendix Table A-1.

generation has the highest GHG profile if the power comes exclusively from coal (300.0 kg of CO_2e per gigajoule, GJ) or from natural gas (118.1 kg of CO_2e per GJ). Gasoline and diesel emit 93.4 and 96.6 kg of CO_2e per GJ of energy produced, respectively. This takes into account all stages of the fuel-production process. Home and industrial heating emit fewer tonnes of CO_2e per GJ of heating energy than transportation fuels or fossil fuel electricity. Natural gas is the lowest emitting fossil energy source that can be used for thermal energy applications, releasing 61.6 kg of CO_2e per GJ of energy consumed.

Among biofuels, liquid biofuel technologies produce the highest GHG emission profiles, ranging from 60.9 kg of CO_2e per GJ in the case of corn-based ethanol to 22.0 kg of CO_2e per GJ for canola biodiesel.[6] Biogas produced from manure, when used in electricity generation, emits 39.44 kg of CO_2e per GJ of energy. Other renewable energy sources, such as solar or wind power, that produce no emissions during the electricity production phase still produce emissions during the manufacture of the equipment, estimated at 27.78 kg of CO_2e per GJ for solar power and 5.56 kg of CO_2e per GJ for wind power (Gagnon, Bélanger, and Yohji 2002; Banerjee et al. 2006). As Figure 2 shows, renewable heating applications, along with wind power, produce the lowest GHG emission profiles.

For all programs analyzed in this study, we determine the cost of the GHG offset by dividing the incentive provided (cents per litre, dollars per kilowatt hour, and so on) by the actual savings of CO_2e when a renewable fuel is substituted for a nonrenewable option (such as a fossil fuel), and we include life-cycle emissions produced during the renewable fuel's production. Obviously, the higher the GHG emissions required to produce a renewable fuel, the lower its potential offset. Canola and soybean biodiesel are estimated to reduce emissions by 77 percent and 62 percent, respectively, when

6 These estimates differ slightly from those in GHGenius 3.14, which reports that corn ethanol emits 54.5 kg of CO_2e per GJ and soybean biodiesel 19 kg of CO_2e per GJ. Again, we use a basket of estimates to take account of the wide range of estimates of the energy balance and GHG intensity of biodiesel reported in the most recent studies. See Appendix Table A-1 for details.

Table 1: Federal Renewable Energy and Environmental Programs and Funding

Program	Description	Total Program Cost
ecoAGRICULTURE Biofuels Capital Initiative	Liquid biofuels production incentive.	$200 million in loans
ecoENERGY for Biofuels	Liquid biofuels production incentive.	$1.5 billion
NextGen Biofuels Fund	Liquid biofuels technology grant.	$500 million
Agricultural Bioproducts Innovation Program	Liquid biofuels and forms of bioenergy technology grant.	$145 million
ecoENERGY for Renewable Power	Wind, hydro, biomass energy, solar production incentive.	$1.48 billion
ecoENERGY for Renewable Heat	Solar air heating consumer incentive Solar water heating consumer incentive.	$36 million
ecoENERGY Technology Initiative	Carbon capture and storage technology grant.	$125 million
	Reduce impacts of oil sands technology grant.	$15 million
ecoENERGY Retrofit	Building energy saving consumer incentive.	$520 million

Source: Canada 2008a.

replacing regular diesel fuel. Corn ethanol is estimated to reduce emissions by as much as 35 percent when it replaces gasoline (see Figure 3). Renewable electrical power reduces emissions by as much as 98 percent when wind power replaces coal power plants, while renewable heat strategies using biomass pellets and solar water- or air-heating applications reduce GHGs by 86 percent and 91 percent, respectively, relative to natural gas and heating oil.

Wind, biomass, solar power, and solar renewable heat are among the most technologically efficient technologies for reducing GHG emissions – on average, when substituted for fossil fuels, they offset more than 80 percent of the GHG emissions (Figure 3).

Federal Energy Programs

Canada's federal renewable fuel strategy has four components: increasing the retail availability of renewable fuels through regulation, supporting the expansion of Canadian production, assisting farmers to produce renewable feedstock, and accelerating the commercialization of new technologies. The principal policy behind these strategies is the use of incentive programs that apply to various stages of renewable energy production and consumption. Currently, these incentives take four main forms: legislative mandates, research and development contributions, producer incentives, and consumer incentives. Producer and consumer incentives make up most of the $4.5 billion in incentives the federal government announced in its ecoACTION program in 2006 (Table 1). The program has five main areas of focus: liquid biofuels, renewable power, renewable heat, energy retrofit, and energy technology initiatives. Greenhouse gas mitigation is clearly the primary focus of these incentive programs, but other factors, such as domestic energy security, reduction of other pollutants, and rural development have been cited as ancillary justifications for these subsidies. We focus on the primary objective of these subsidies, but we acknowledge these other, unquantifiable benefits.

Liquid Biofuels

Legislation enabling the federal government to mandate up to 5 percent renewable gasoline fuel content by 2010 and 2 percent renewable diesel content in transportation fuel and heating oil by 2012 was passed on July 15, 2008. These regulations are still under development, but are expected to require the use of approximately 2 billion litres of ethanol and 500 million litres of biodiesel by 2012. The federal government, through its ecoENERGY for Biofuels program, will provide $1 billion worth of production subsidies to the ethanol industry and $500 million to the biodiesel industry over nine years beginning in April 2008. The funds are targeted at producers of liquid biofuels for transportation to encourage domestic producers to meet the mandated demand. In addition to the producer incentives, capital assistance for ethanol production facilities is administered through the ecoAGRICULTURE Biofuels Capital Initiative (ecoABC), which provides $200 million in support, with individual loans of up to $25 million to ethanol facilities with at least 5 percent equity from farmers. Ottawa has slotted another $500 million for nonfood-based cellulosic ethanol production research. Liquid biofuels will also receive part of $145 million worth of research grants over seven years. In all, federal incentive programs directed at liquid biofuels are worth around $2.3 billion, or more than half of all renewable energy program funds.

The ecoENERGY for Biofuels program provides for producer incentive rates of up to 10 cents per litre for gasoline alternatives and 20 cents per litre for diesel alternatives during the first three years of the program, declining thereafter to 4 cents per litre for ethanol and 6 cents per litre for biodiesel by 2016. Given current market conditions, with highly visible bankruptcies in the US ethanol sector, we assume Canadian producers will receive the upper limit in producer incentives (Parker 2009).[7] Capital incentive rates under the ecoABC program for ethanol and biodiesel were estimated at 0.9 cent per litre based on the analysis by Fox and Shwedel (2007), which calculates the opportunity cost of the foregone interest on generously termed loans. The producer and capital incentives combine for a total incentive of up to 10.9 cents per litre for ethanol and 20.9 cents per litre for biodiesel.[8]

Renewable Electrical Power

About one-quarter of all the energy Canadians use is in the form of electricity. The federal government is encouraging the production of 14.3 terawatt hours of new, clean electricity, or 2.5 percent of Canada's total power use in 2006 (Statistics Canada 2008). Ottawa has committed $1.4 billion to the ecoENERGY for Renewable Power policy program to fund renewable power projects in areas such as wind, biomass, low-impact hydro, geothermal, solar photovoltaic, and ocean energy that are constructed in the next four years and that produce more than 1 megawatt of electricity. These projects are eligible for an incentive of 1 cent per kilowatt hour (kWh) for up to 10 years. Most farm-based manure biogas projects are too small to be eligible for the incentive.

Renewable Residential and Industrial Heating

Federal programs to support renewable heat are currently limited even though heat-related energy applications – such as residential and commercial space and hot water heating and thermal energy for industrial processes – account for the largest proportion of demand for fossil fuel energy in Canada, as in other industrialized countries, and, therefore, represent a very large opportunity for the mitigation of GHG emissions. So far, only $36 million in

7 The federal incentive rate is a function of estimated ethanol industry profitability, which, in turn, is largely a function of ethanol and gasoline market prices. For July through September 2008, a period of high gasoline and ethanol prices, the credit was 7.8 cents per litre; between July 2008 and January 2009, ethanol prices on the Chicago Mercantile Exchange fell by nearly half (see Natural Resources Canada 2008b).

8 These estimates do not include programs such as the NextGen Biofuels Fund, the Agricultural Bioproducts Innovation Program, or the Biofuels Opportunities for Producers Initiative, which has been discontinued.

federal funding is designated for capital cost incentives for renewable heat in the industrial, commercial, and institutional sectors through the ecoENERGY for Renewable Heat program.[9]

This support is directed toward the installation of solar space and water heating and to help establish geothermal technologies in the marketplace. Typical applications for solar air heating include farms, recreational complexes, schools, and warehouses, as well as water heating technologies often used by dairy farms, hotels and motels, laundromats, and outdoor pools. For the purposes of the ecoENERGY for Renewable Heat program, solar heating technologies are broken down into glazed (glass or plastic cover) and unglazed (no cover). Capital costs for glazed technologies are significantly more expensive than those for unglazed and are reflected by the 25 percent capital cost incentive for the former versus 15 percent for the latter. Based on current capital costs for solar air heating, the average federal subsidy is 1 cent per kWh for unglazed and 7 cents per kWh for glazed systems. For solar water heating, the subsidy is 3 cents per kWh and 6 cents per kWh for unglazed and glazed systems, respectively. The solar heating incentives are provided as a capital cost offset – that is, a one-time payment. In order to reflect the actual cost-competitiveness of the grant in terms of dollars per tonne of CO_2e offset, the value of the capital grant has been estimated on an annual basis over 20 years using an interest rate of 6 percent.

Energy Retrofit and Technology Initiatives

The ecoENERGY Retrofit program provides $520 million in grants to homeowners as well as financial incentives to small and medium-sized businesses, industry, and public institutions to help them invest in energy- and pollution-saving upgrades.[10] Commercial and institutional entities can receive up to $10.00 per GJ of estimated energy savings, 25 percent of eligible project costs, or $50,000 per project, while corporations are entitled to a maximum of $250,000. The allocation of monies through this program is highly variable, as there is a wide array of retrofitting applications, from the purchase and installation of compact fluorescent lighting to the installation of geothermal ground pumps.

The ecoENERGY Technology Initiative provides $125 million to advance carbon capture and storage technologies to aid in reducing GHG emissions from the oil sands and from coal-fired electricity plants, as well as a $15 million fund to further the development of applications to reduce the environmental effects of oil sands production.

Assessing the Federal Programs

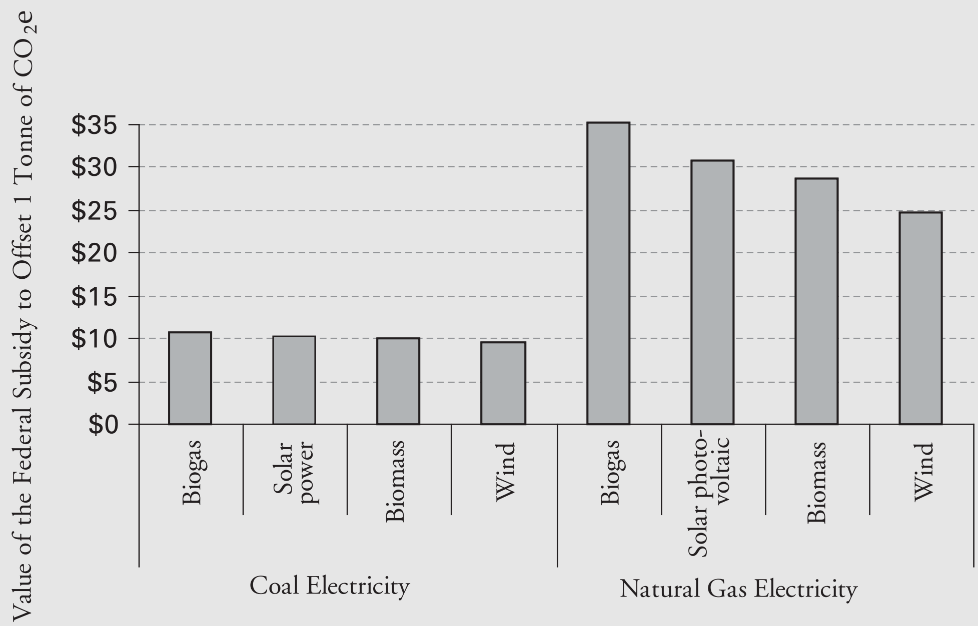
The federal incentives applied to liquid biofuels – including producer and capital incentives for plant construction costs – equate to a GHG emission mitigation cost of $160/tonne for corn ethanol, $98/tonne for soybean biodiesel, and $79/tonne for canola biodiesel. Ethanol reflects a higher mitigation cost due to its lower GHG offset efficiency (35 percent) and lower energy content per litre (21.2 megajoules, MJ, per litre) compared with biodiesel (about 70 percent and 35.4 MJ per litre, respectively) – see Appendix Table A-2.

Electrical power generation mixes and GHG intensity vary regionally across the country. Hydroelectric power dominates in Quebec, British Columbia, Manitoba and Newfoundland and Labrador, while coal and natural gas are predominant in Alberta and Saskatchewan. In Ontario and Atlantic Canada, generation sources are fairly diverse, with nuclear power providing the greatest percentage of supply in Ontario. In this analysis, we compare the cost effectiveness of renewable electrical power alternatives primarily to coal, which is the main fossil fuel targeted for replacement for power generation. Although renewable sources might be used to offset electricity produced by low-GHG sources, they receive the highest market price and are the most effective at reducing GHGs when they are used to provide electricity during peak-load periods, and when the power sources they offset are most likely to be coal or natural gas, even in provinces with a large amount of nuclear or hydroelectric power.

9 The basis of incentive payments we use in this analysis has changed since September 2008, but this change is unlikely to affect our general conclusions about the cost effectiveness of renewable heat programs.

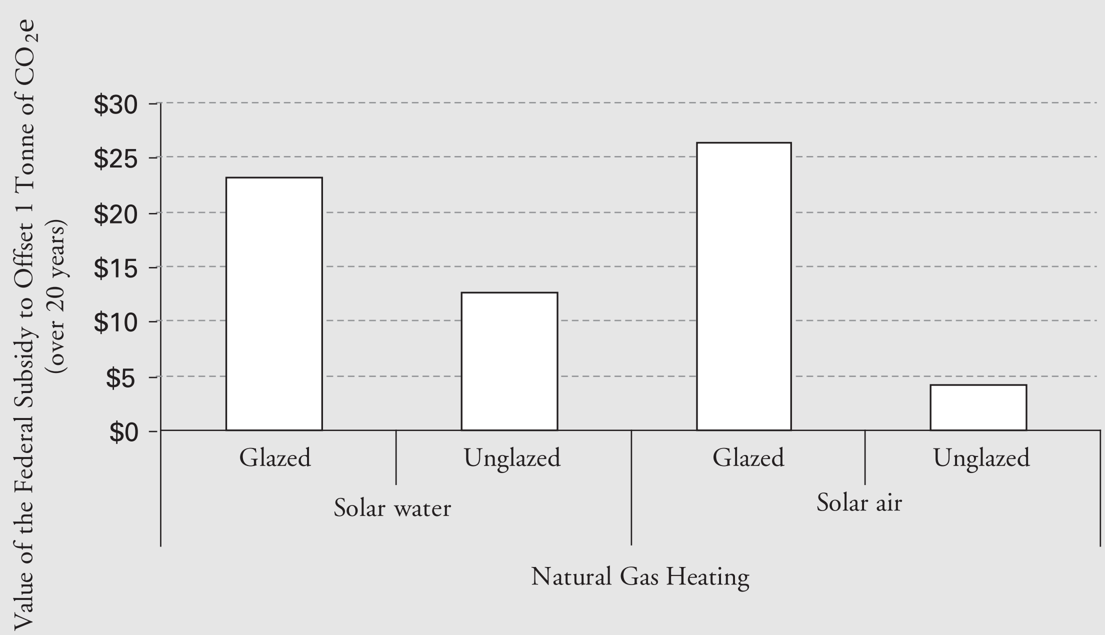
10 An additional $300 million was awarded in the 2009 federal budget on top of the original $220 million.

Figure 4: Value of the Federal Subsidy to Offset 1 Tonne of CO_2e with Renewable Electrical Power Alternatives



Source: See Appendix Table A-1.

Figure 5: Value of the Federal Subsidy to Offset 1 Tonne of CO_2e with Solar Water and Air Renewable Heating Alternatives over 20 Years



Source: See Appendix Table A-1.

As Figure 4 shows, federal incentives related to the ecoENERGY for Renewable Power program cost taxpayers about $10 per tonne of CO_2e abated when biomass, solar, and wind technologies are used to replace coal, and about $30 per tonne when used to replace natural-gas-fired power plants. Wind and biomass technologies are slightly more cost effective than solar or biogas due to their high offset efficiency of more than 90 percent.

Solar water and air heating are most typically used to replace natural gas heating. Incentives for unglazed solar air- and hot-water-heating applications provide the most inexpensive offsets, which we estimate to be between $4.08 and $12.55 per tonne of CO_2e, while glazed solar air- and hot-water-heating options provide between $23.15 and $26.38 per tonne of CO2e (see Figure 5 and Appendix Table A-2).

Finally, we estimate the cost to taxpayers of the incentive given to industrial and commercial users to install energy- and pollution-saving upgrades to be $173.70 per tonne of CO_2e if the main energy saved in retrofitting is natural gas used for space heating.[11] Assuming this investment is financed over 20 years, the CO_2 mitigation cost is $14.84 per tonne of CO_2e. A general energy efficiency grant will have a wide range of effectiveness in reducing GHGs given the wide variety of energy types eligible for these grants.

Thus, energy efficiency grants, though capital intensive, appear to be a cost-effective means to mitigate GHG emissions. A potential negative aspect of energy retrofitting is that grants might go to firms that were going to retrofit anyway, to take advantage of the substantial energy cost savings from reducing long-term energy consumption. In such cases, taxpayer subsidies would have little marginal impact on overall emissions. Another potential drawback is that increases in energy efficiency are often met with an increase in energy use, which negates much of the savings from grants (Jaccard and Rivers 2007).

Even with these potential drawbacks, however, energy retrofits appear to be a leading low-cost way to offer incentives to save energy and cut GHG emissions. Indeed, among current federal renewable energy incentives, renewable power, heat and energy retrofits are the least expensive programs to reduce GHG emissions, ranging between roughly $4 and $30 per tonne of CO_2e abated. In contrast, the most expensive program is that for ethanol, which costs Canadian taxpayers $160 per tonne of CO_2e abated. A litre of ethanol contains one-third less energy than a litre of gasoline, yet federal and provincial fuel taxes are applied on a litre basis, leaving consumers to pay more fuel taxes per unit of energy. This reduces the net fiscal balance of renewable fuel mandates to the government but taxpayers still bear the costs of the incentive program.

Provincial Energy Programs

Liquid Biofuels

Incentive programs to support liquid biofuel development have also been introduced at the provincial level of government, primarily in the main field-crop-producing provinces (see Table 2). Producer incentive credits range between 8 cents and 20 cents per litre in Ontario, Alberta, and Manitoba, while Saskatchewan and British Columbia provide tax exemptions of 15 and 14.5 cents per litre for ethanol, respectively.[12] These incentives are based on the production capacity of the plant. In Ontario, the incentive is a grant; in Saskatchewan, it is a repayable loan requiring payback beginning three years after the plant goes into operation and based on the plant's profitability. Ontario ethanol producers receive a capital incentive estimated to be 1.3 cents per litre of production, while those in Saskatchewan receive a capital incentive of approximately 0.9 cents per litre.[13] Quebec's only ethanol plant receives a producer incentive of up to 19 cents per litre, applicable when the price of oil drops below $65 per barrel.

11 Here, we base our calculation on the retrofit grant that is the lowest of (i) $10.00 per GJ of estimated energy savings, (ii) 25 percent of eligible project costs, or (iii) $50,000 per project. We do not analyze the residential retrofit program.

12 The Ontario grant varies with the market prices of ethanol, crude oil, and corn.

13 Ontario's capital incentive of 1.3 cents per litre is derived from the assumed economic value of the Ontario ethanol growth fund capital assistance program of 10 cents per litre for plant construction annually over 10 years at an interest rate of 6 per cent. Saskatchewan's 0.9 cents per litre is based on Fox and Shwedel 2007.

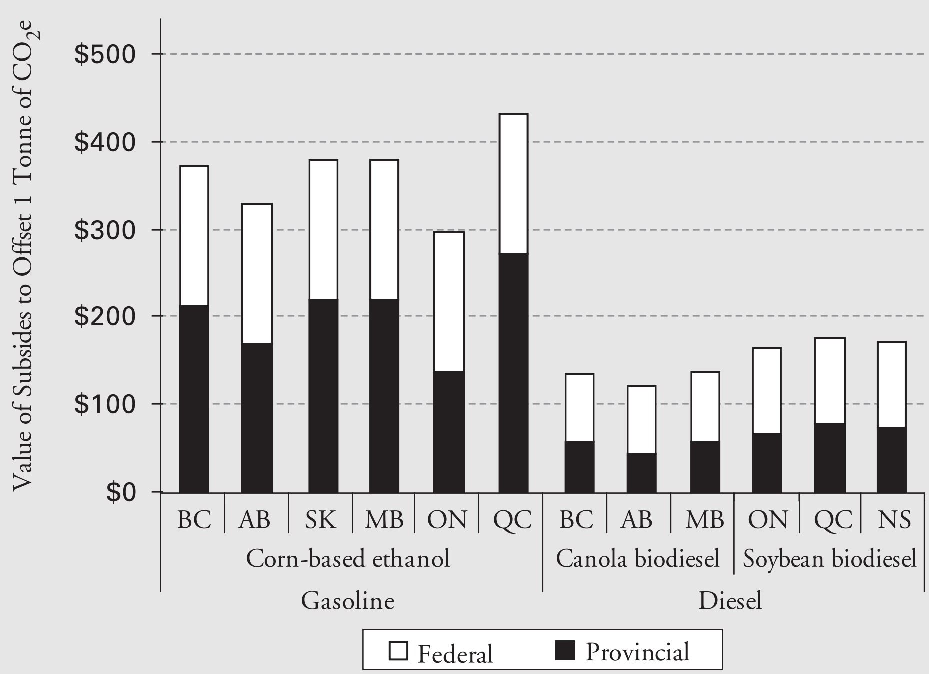
Table 2: Ethanol and Biodiesel Incentives, by Province

Province	Producer Incentive Ethanol	Producer Incentive Biodiesel	Capital Incentive Ethanol	Capital Incentive Biodiesel	Tax Exemption Ethanol	Tax Exemption Biodiesel	Total Incentive Ethanol	Total Incentive Biodiesel
	(cents per litre)							
British Columbia					14.5	15	14.5	15
Alberta	9-14	9-14					9-14	9-14
Saskatchewan			0.9	0.9	15		16	1
Manitoba	10-20					16	10-20	16
Ontario	about 8		1.3			14.3	about 9	14.3
Quebec					19	16	19	16
Nova Scotia						15		15

Notes: Incentive rates as of September 2008; Saskatchewan capital incentive is considered a repayable loan.

Sources: Various provincial biofuel program documents; Samson et al. 2008a.

Figure 6: Value of Federal and Provincial Subsidies to Offset 1 Tonne of CO_2e with Ethanol and Biodiesel, 2008



Source: See Appendix Tables A-1 and A-4.

In the case of biodiesel, overall subsidies by the provinces per unit of energy produced are generally lower than for ethanol, although Alberta applies the same liquid biofuel incentive, ranging between 9 cents and 14 cents per litre, to both. British Columbia, Manitoba, Quebec, and Nova Scotia offer biodiesel fuel tax exemptions ranging between 14 cents and 16 cents per litre.

The prairie provinces offer subsidies for ethanol that cost between $131 and $292 per tonne of CO_2e mitigated; when combined with federal subsidies, taxpayers in those provinces are paying between $328 and $380 to mitigate one tonne of CO_2e using ethanol. In Ontario, corn ethanol incentives cost $136 per tonne of CO_2e abated (Figure 6), while in Quebec they cost $271; adding federal subsidies, taxpayers pay $295 per tonne of CO_2e abated in Ontario and $430 in Quebec (see Auld 2008 for further details on ethanol).

Provincial biodiesel incentives mitigate GHG at a lower cost than ethanol, with western provinces providing subsidies that range between $34 and $58 to mitigate one tonne of CO_2e using canola biodiesel. Ontario and some other provinces do not provide producer incentives for biodiesel, instead providing tax exemptions. In those provinces that offer biodiesel subsidies, combined federal and provincial subsidies range between $122 and $175 of taxpayers' money to offset one tonne of GHG emissions.

Renewable Electrical Power

The provinces have developed renewable energy power mandates using two main approaches: energy conservation and increasing renewable power capacity (see Table 3). Saskatchewan and Manitoba have aimed to conserve energy by decreasing electricity load, while New Brunswick, Prince Edward Island, Nova Scotia, Alberta, and Ontario have mandated increases in renewable power capacity. Both Newfoundland and Labrador and British Columbia have committed to meeting almost all of their electricity needs through renewable sources. To meet these goals, the provinces offer a range of production subsidies for renewable energy that are substantially higher than federal subsidies per tonne of CO_2 offset. For small energy producers, British Columbia, Saskatchewan, Ontario, New Brunswick, and Prince Edward Island offer net metering – a method of crediting customers for electricity they generate on site in excess of their own consumption (Table 3). We are unable to estimate how much these subsidies cost, however, as they are a function of variable electricity costs.

Ontario and British Columbia offer subsidies under "standard offer programs" to help meet their renewable energy supply targets. The net amount of any subsidy is the amount given to producers of renewable energy minus the market price at which the power is sold. Ontario provides 11 cents per kWh for renewable biomass, biogas, water power, and wind technologies, and 42 cents per kWh for solar photovoltaic projects. The net subsidy of the standard offer programs is the subsidy given to renewable producers minus the market price at which the power is sold. For Ontario, conventional fuel producers receive market prices of approximately 6.5 cents per kWh, resulting in a 4.5 cent per kWh incentive for renewable biomass, biogas, water and wind technologies, and a 35.5 cent per kWh incentive for solar photovoltaic projects.

British Columbia's program pricing is based regionally, and offers rates of between 7 cents and 8 cents per kWh for small hydro, biomass, and biogas producers, which represents a premium over conventional electricity rates. Both provinces offer an additional premium rate if the power is generated at peak-load times, and British Columbia also supplies 11 cents per kWh to technologies that are EcoLogo certified. Ontario provides a capital cost incentive for biogas producers of up to 40 percent of the capital cost, to a maximum of $400,000 (see Appendix for an explanation of how biogas incentives are calculated).

Biomass and wind power generation offer GHG emission mitigation at slightly more than $50 per tonne of CO_2e for offsetting electricity generation from coal (Figure 7). In Ontario, solar power incentives are approximately $363 per tonne. British Columbia, which currently imports electricity produced from coal-fired power plants in Alberta, provides up to $71 per tonne of CO_2e for biogas and $87 per tonne for biomass electrical power that offsets electricity production from coal, depending on the premium over conventional electricity rates.

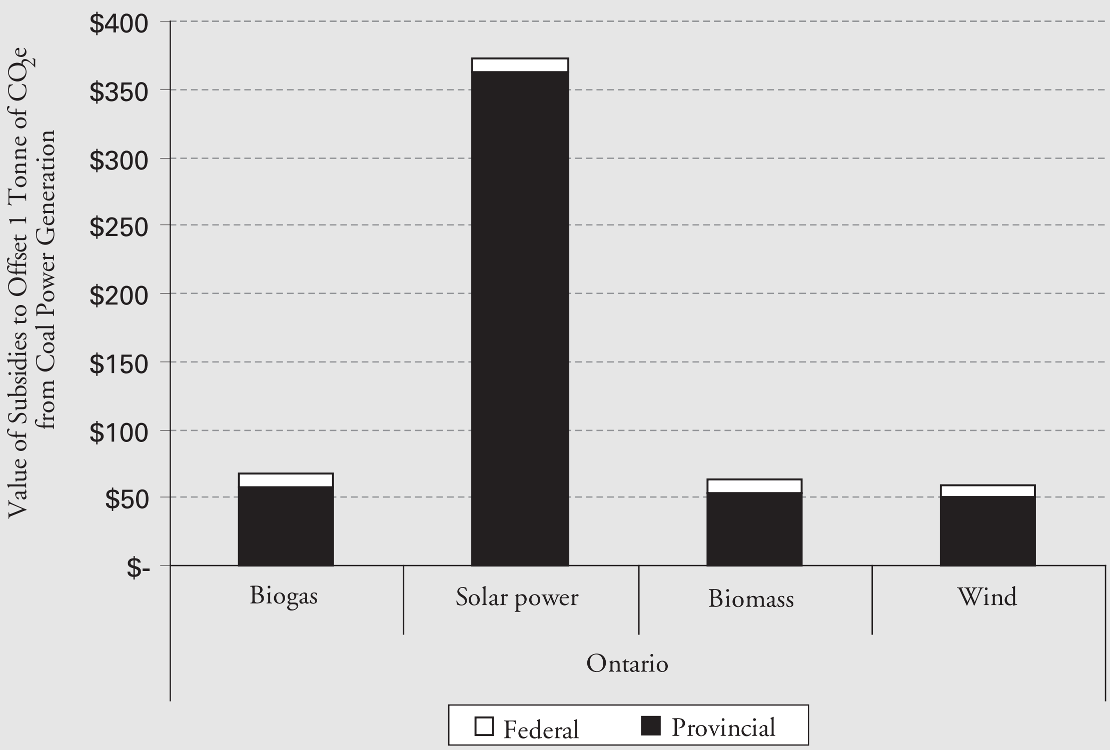
Table 3: Renewable Energy Mandates and Subsidies, by Province and Territory, 2008

Province/Territory	Renewable Energy Electricity Mandates	Renewable Energy Equipment Rebates	Renewable Electricity Initiatives	Renewable Heat Rebates
British Columbia	– 90% of new generation renewable. – 100% net zero GHG emissions by 2016.	– 7% PST exemption, including solar.	– net metering for small producers up to 50 kW. – 7-8¢/kWh for small renewables.	
Alberta	– 3.5% of total generation will be renewable by 2008. – 20% from renewable or alternate sources by 2020.		– electrical power from by-products of bio-refining or biomass processes receive 2¢/kWh for 3+ MW, 6¢/kWh for <3 MW.	
Saskatchewan	– decrease electricity load by 300 MW annually by 2017. – 100% new generation net zero GHG emissions.	– 5% PST exemption.	– net metering for small producers up to 100 kW. – one-time maximum payment of 25% or $100,000 for eligible costs.	– maximum of 50% combined with federal programs for solar water or air heating.
Manitoba	– save 842 MW by 2017. – 1,000 MW of wind power by 2014.	– 10% refundable credit on new equipment purchases.		– maximum $3,000 for geothermal in new homes. – low-interest loan up to $20,000 for installation of geothermal heat pump (hydro).
Ontario	– produce 15,700 MW from renewable sources by 2015. – 50% increase in renewable capacity by 2025.	– 8% PST exemption on solar, wind, micro-hydro, and geothermal.	– 11¢/kWh for renewable biomass, waterpower, wind. – 42¢/kWh for solar photo-voltaic. – net metering for small producers up to 500 kW.	– up to 25% of eligible project costs, to maximum $80,000 for solar thermal in com-mercial/ industrial buildings (hydro).
Quebec	– wind as 10% of installed capacity by 2015 (4,000 MW). – 10% equivalent to all new hydroelectric power developed.	– 35% refundable credit for corporations that do not develop mineral resources or gas and oil wells; 30% for other corporations.		– maximum $2,800 for geothermal in new homes, $2,000 for conversion.
New Brunswick	– 10% renewable by 2016.		– net metering for small energy producers up to 100 kW.	
Nova Scotia	– 5% renewable generation by 2010; 18.5% by 2013.		– $5,500/MW based on total capacity.	– 15% rebate on installed solar water, or $500; 15% rebate on solar air equipment, up to $20,000.
Prince Edward Island	– 15% of electricity from renewable sources by 2010; possibly 100% by 2015, depending on wind capability.	– 10% PST exemption.	– net metering for small energy producers up to 100 kW.	– $1,000–$5,000 low-interest loan for wood, solar, geothermal, drain water heat recovery.
Newfoundland	– 98% of electricity to be derived from renewable sources by 2015, 50 MW of wind power.			
Northwest Territories	– up to 50% or maximum.		– rebate up to $1,000.	
Yukon		– $5,000, or $50,000 per project for residential or commercial buildings.		– rebate up to $500.

Note: Mandates and subsidies as of September 2008, not including liquid biofuels.

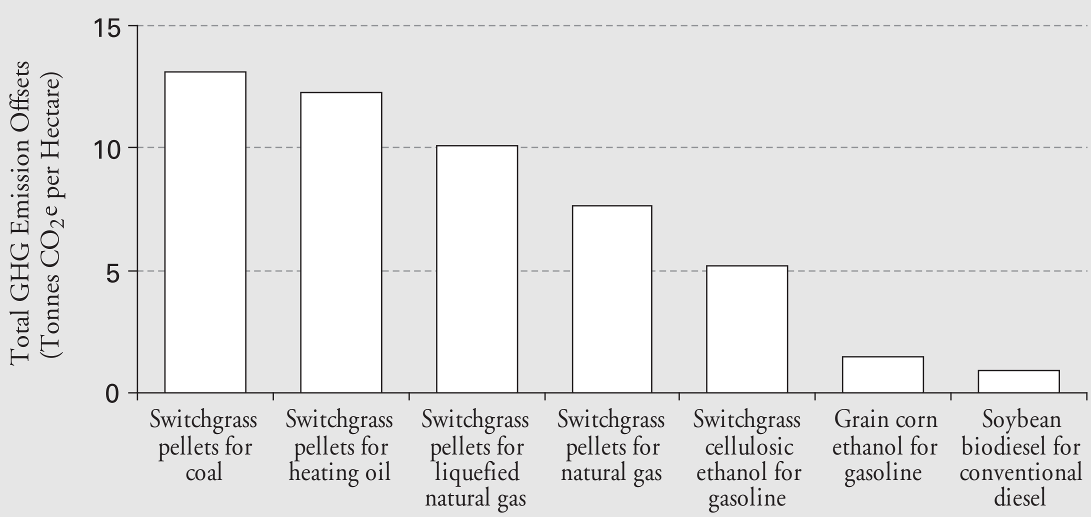
Sources: Various provincial and territorial documents; Bollinger and Roberts 2008; Pembina Institute 2008.

Figure 7: Value of Federal and Provincial Subsidies to Offset 1 Tonne of CO_2e with Renewable Power, Ontario



Source: See Appendix Tables A-1 and A-4.

Figure 8: Evaluation of Different Methods of Producing GHG Offsets from Ontario Farmland Using Biofuels



Source : Samson et al. 2008b.

Renewable Heat

Most provinces, as well as the Yukon and Northwest Territories, provide renewable heating incentives ranging from low-interest loans to capital cost incentives (see Table 3). Saskatchewan and Ontario are the only provinces to match federal solar water and air heating funds, to a maximum of 50 percent of capital costs. If those two provinces were to reduce their incentives to match the percentages provided by the federal government, they would pay approximately $23 to $26 per tonne of CO_2e mitigated by glazed solar heating technologies that offset natural gas, and $4 to $12 per tonne for unglazed technologies. Combined, federal and provincial incentives in these provinces top out at between $46.30 and $52.75 for glazed and between $8.16 and $25.10 for unglazed solar heating.

Currently, no provinces offer solid biofuel support programs for thermal energy applications other than power generation, but some provinces in eastern Canada (including Quebec) provide capital cost offsets for the installation of boilers. A recent report suggests that proposed incentives of $2 to $4 per GJ of biomass pellets would mitigate greenhouse gases associated with coal displacement in thermal applications at a cost of $25 to $50 per tonne (Samson et al. 2008a). These solid biofuels are derived from non-food crops that are predominantly grown on lower-quality farmland commonly not used to grow food crops. A major advantage of solid biofuels is that, on a per hectare basis, they are more efficient than liquid biofuels in mitigating GHG emissions (Figure 8).

Retrofitting and Technology Initiatives

British Columbia, Saskatchewan, Manitoba, Ontario, and Prince Edward Island provide retail tax exemptions on the purchase of renewable energy equipment. Saskatchewan and Ontario offer retrofitting grants to a maximum of $1,500 and $1,300, respectively, in combination with federal subsidies. New Brunswick offers a maximum of $50,000 for retrofitting commercial and industrial buildings. Saskatchewan supports energy efficiency through the provision of a maximum of $2,500 for the purchase or construction of energy-star-rated homes, while the Northwest Territories and New Brunswick offer rebates of up to $1,000 and $2,000, respectively, for the purchase of energy-efficient equipment.

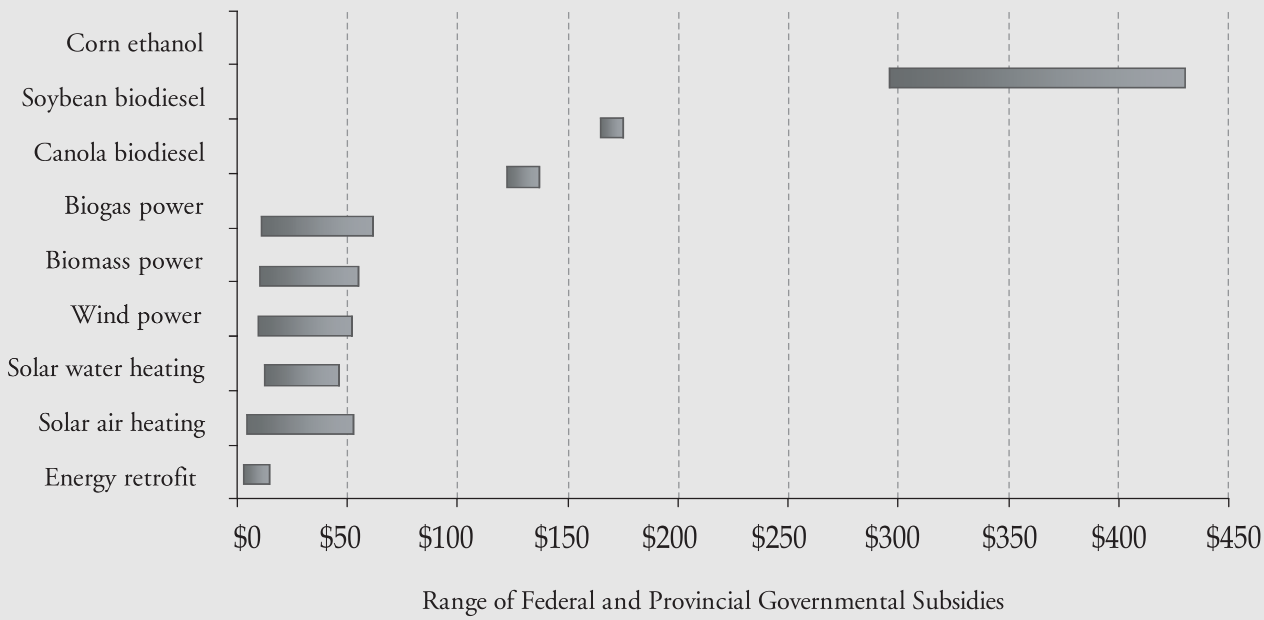
Summary and Recommendations

Canada needs an effective policy framework for technologies that aim to achieve its goal of mitigating GHG emissions. Thus far, however, Canadian governments have relied on a combination of subsidies and energy-use regulations that are poorly directed and will not meet targets for GHG reduction (Jaccard and Rivers 2007). Moreover, as Figure 9 shows, fiscal incentives are heavily slanted toward developing liquid biofuels made from grain and oilseed crops.

Accordingly, subsidies in the renewable energy sector need to be reformed. Taxpayers could shoulder incentives for emerging technologies, such as solar electric, that have significant potential for further cost reduction. But the spending of billions of dollars on incentives for specific renewable energy technologies that result in high-cost GHG abatement is incongruous with the federal government's use of results-based management to govern program spending. A more cost-effective approach would be to create policy instruments that lead to the adoption of renewable energy technologies that abate CO_2 emissions both effectively and at a low cost per tonne of CO_2 avoided. Instead, the least-efficient technologies are heavily subsidized, while the most cost-effective technologies receive limited support. Renewable electrical power and renewable heat are the lowest-cost GHG abatement strategies available for wide-scale implementation in Canada. As well, energy retrofits are highly cost-effective incentive programs for GHG mitigation, but might be offset by increased energy usage.

The best approach would be, in effect, to place a bounty on CO_2 and to pay between $30 and $50 per tonne of CO_2e mitigated for each renewable energy technology. A technology-neutral GHG bounty could encourage switching to the most cost-effective GHG-reducing energy technology. This would require that grant applicants demonstrate the GHG-reduction capability of their project (based on such criteria as their local source of electricity or emissions created

Figure 9: Value of Combined Provincial and Federal Incentives per Tonne of CO_2e Offset for Renewable Energy Technology Options, Canada



Source: See Appendix Tables A-1 and A-4.

during the production and use of a renewable fuel), with all projects receiving the same amount per tonne of GHG that can be verifiably reduced. Since this approach would be technology neutral, it would have an effect similar to that of a carbon price, although it would still be subject to many of the common problems of subsidization, and would be inferior to a uniform carbon price, where polluters must pay to emit. Indeed, as Jaccard and Rivers (2007) show, a uniform carbon price applied on all sources of emissions would have a much larger impact than subsidies and regulations alone on reducing overall emissions.

A carbon bounty for renewable fuels would be most effective if it were to apply to sectors of the economy that would be disproportionately harmed by CO_2 taxes or exempted from a hypothetical carbon price, such as a cap-and-trade system, which creates a private incentive to reduce emissions just as the carbon bounty does. If subsidies are a necessary component of the political acceptability of GHG mitigation in Canada, it is evident that new policy instruments need to be well thought through to ensure that they result in more cost-effective mitigation.

Overall, it is clear from this analysis that the approach of "picking winners" with taxpayers' money is not the right way for governments to encourage low-cost carbon offsets and to make progress in meeting Canada's carbon mitigation commitments. Instead, governments should reduce the incentives to ineffective GHG mitigation technologies, and direct more resources toward rewarding more cost-effective renewable energy technologies – particularly renewable heat and electricity.

Appendix 1

Table A1: GHG Emission Offset Calculations for Renewable Alternative Energy Fuels

Fossil Fuels		Renewable Alternative Fuels			
Energy Type	**GHG Emissions** *(kg of CO_2e per GJ)*	**Energy Type**	**GHG Emissions** *(kg of CO_2e per GJ)*	**Net Offset** *(kg of CO_2e per GJ)*	**Offset Efficiency** *(percent)*
		Liquid Biofuels			
Gasoline transport	93.4[1]	Corn ethanol	54.5;[1] 67.25[2]	32.53	35
Diesel transport	96.6[1]	Soybean biodiesel	19.0;[1] 33.74;[3] 56.66[4]	60.02	62
		Canola biodiesel	12.8;[1] 31.1[5]	74.65	77
		Renewable Electrical Power			
Coal	299.5[1]	Wind power	5.56[6]	293.94	98
		Solar power	27.78[7]	271.72	91
		Renewable biomass			
		Wood pellets	23.28[8]	276.22	92
		Straw pellets	18.89[9]	280.61	94
		Biogas	39.44[10]	260.06	87
Natural gas	118.1[1]	Wind power	5.56	112.54	95
		Solar power	27.78	90.32	76
		Renewable biomass			
		Wood pellets	23.28	94.82	80
		Straw pellets	18.89	99.21	84
		Biogas	39.44	78.66	67
		Renewable Residential/Industrial Heating			
Natural gas	67.76[1]	Solar heating	8.15[11]	53.45	87

Note: For natural gas, an average of the higher and lower heating value is used since some natural gas heating appliances recover waste heat (58.0 and 65.2 kgCO_2e/GJ), as well as a 90% combustion efficiency. Solar technologies were assumed to have a 100% combustion efficiency.

Sources: 1. Natural Resources Canada 2008a; 2. Wang, Wu, and Huo 2007; 3. MacLean 2008; 4. Hill et al. 2006; 5. Edwards et al. 2008; 6. Gagnon, Bélanger, and Yohji 2002; 7. Banerjee et al. 2006; 8. Jungmeier et al. 2000; 9. Nielsen 1996; 10. Ghafoori, Flynn, and Checkel 2006; 11. Masruroh, Li, and Klemeš 2006.

Table A-2: Federal Incentive Calculations for Renewable Alternative Fuels

Fossil Fuels	Renewable Alternative Fuels	Net Offset	Federal Incentive Cost		Cost to Offset 1 Tonne of GHG Emissions
		(kg of CO_2e per GJ)	*(cents per unit)*	*($ per GJ)*	*($ per tonne of CO_2e)*
		Liquid Biofuels			
Gasoline transport	Corn ethanol	32.53	10.9 per litre	5.19	159.58
Diesel transport	Soybean biodiesel	60.02	20.9 per litre	5.90	98.22
	Canola biodiesel	74.65			78.98
		Renewable Electrical Power			
Coal	Wind power	293.94	1 per kWh	2.78	9.45
	Solar power	271.72	1 per kWh	2.78	10.22
	Renewable biomass				
	Wood pellets	276.22	1 per kWh	2.78	10.06
	Straw pellets	280.61	1 per kWh	2.78	9.90
	Biogas	260.06	1 per kWh	2.78	10.68
Natural gas	Wind power	112.54	1 per kWh	2.78	24.68
	Solar power	90.32	1 per kWh	2.78	29.57
	Renewable biomass				
	Wood pellets	94.82	1 per kWh	2.78	29.30
	Straw pellets	99.21	1 per kWh	2.78	28.00
	Biogas	78.66	1 per kWh	2.78	35.32
		Renewable Residential/Industrial Heating			
Natural gas	Solar water heating				
	Glazed	59.61	5.8 per kWh	16.15	23.15
	Unglazed	59.61	3.2 per kWh	8.75	12.55
	Solar air heating				
	Glazed	59.61	6.6 per kWh	18.40	26.38
	Unglazed	59.61	1 per kWh	2.85	4.08

Note: For solar heating costs, in order to reflect the actual cost-competitiveness of the grant in terms of dollars per tonne of CO_2 offset, the value of the capital grant is estimated on an annual basis over 20 years using an interest rate of 6 percent. It is also assumed that 1 GJ of solar heat replaces the equivalent of 1.1GJ of natural gas due to combustion efficiency losses in producing delivered heat to the consumer. Calculations are for programs as of September 2008.

Source: Canada 2008a.

Table A-3: Biogas Emission Reduction Calculations for a 250 kWh Digester, Ontario

Manure Energy Content	Efficiency of Digestion	Energy	Electrical Power Conversion	Manure Required for One Year	Energy Production	
(GJ per tonne)	*(percent)*	*(GJ per tonne)*	*(kWh per tonne)*	*(tonnes)*	*(kWh per year)*	*(GJ per year)*
0.86	40	0.345	95.79	20,670	1,980,000	7,128

Source: Ho Lem et al. Forthcoming.

Table A-4: Provincial Incentive Calculations for Renewable Alternative Fuels

Province	Fossil Fuels	Renewable Alternative Fuels	Net Offset	Provincial Incentive Cost		Cost to Offset 1 Tonne of GHG Emissions
			(kg of CO_2e per GJ)	*(cents per unit)*	*($ per GJ)*	*($ per tonne of CO_2e)*
			Liquid Biofuels			
British Columbia	Gasoline transport	Corn ethanol	32.53	14.5 per litre	6.90	212.28
Alberta				9-14 per litre	4.29 - 6.67	131.76 - 204.96
Saskatchewan				15 per litre	7.57	232.78
Manitoba				10-20 per litre	4.76 - 9.52	146.40 - 292.81
Ontario				About 9 per litre	4.43	136.15
Quebec				19 per litre	8.81	270.99
British Columbia	Diesel transport	Canola biodiesel	60.02	15 per litre	4.20	56.29
Alberta				9-14 per litre	2.52 - 3.92	33.77 - 52.53
Manitoba				16 per litre	4.34	58.16
Ontario		Soybean biodiesel	74.65	14.3 per litre	4.01	66.74
Quebec				16 per litre	4.60	76.68
Nova Scotia				15 per litre	4.40	73.31
			Renewable Electrical Power			
Ontario	Coal	Wind power	293.94	4.5 per kWh	12.50	42.53
		Solar power	271.72	35.5 per kWh	98.61	362.91
		Renewable biomass				44.90
		Wood pellets	276.22	4.5 per kWh	12.50	45.25
		Straw pellets	280.61	4.5 per kWh	12.50	44.55
		Biogas	260.06	4.5 per kWh	50.66	50.66
			Renewable Residential/Industrial Heating			
Ontario and Alberta	Natural gas	Solar water heating				
		Glazed	59.61	5.8 per kWh	16.15	23.15
		Unglazed	59.61	3.2 per kWh	8.75	12.55
		Solar air heating				
		Glazed	59.61	6.6 per kWh	18.40	26.38
		Unglazed	59.61	1 per kWh	2.85	4.08

Note: For renewable electrical power the incentive rate for wind, biomass and biogas is 11 cents per kWh and 42 cents per kWh in Ontario minus the market price of electricity of 6.5 cents per kWh. Biogas in Ontario has an additional capital cost subsidy of $40,000 annually see (Table A-3). Calculations are for programs as of September 2008.

Source: Various provincial documents, and OPA 2008.

Methodology: Biogas Emission Reduction Calculation

In determining biogas emissions savings at the provincial level (Table A-3), we assumed a test case of a 250 kWh digester, which produces, on average, 1.98 million kWh per year of energy. Ontario offers a producer incentive of 4.5 cents per kWh (11 cents per kWh minus 6.5 cents per kWh, the current buy rate) or $89,100 per year for a 250 kWh digester (1,980,000 kWh per year times 5.3 cents per kWh). Ontario also subsidizes up to 40 percent of the capital cost of the biogas unit to a maximum of $400,000. The average cost of a 250 kWh digester is in the range of $1.3 million, and the grant is assumed to replace the framer's investment of $400,000 borrowed over 15 years at 6 percent interest, generating payments of $40,000 per year. The total annual subsidy for the biogas unit is assumed to be $129, 100.

From Table A-1, we know that offsetting electrical power from coal with biogas provides savings of 260.06 kg of CO_2e per GJ. Since a 250 kWh digester produces 7,128 GJ per yr, this equates to savings of 1,853.7 tonnes of CO_2e per year. Offsetting electrical power from natural gas with biogas, in contrast, provides savings of 78.66 kg of CO_2e per GJ, or 560.7 tonnes of CO_2e per year.

Storage of liquid manure leads to spontaneous emissions of methane and ammonia, which can be reduced when manure digestion and the collection of the resulting biogas replace conventional storage. Börjesson and Berglund (2007) estimate savings of 1.6 kg of methane per tonne from manure pig slurry when used for biogas versus conventional storage. This equates to 33.6 kg of CO_2e per tonne of pig slurry, or about 695 tonnes of CO_2e saved in landscape emissions each year with a 250 kWh biogas digester.

Taking into account both the avoided landscape emissions (695 tonnes) and the emissions associated with offsetting coal (1,853.7 tonnes) results in savings of 2,548.7 tonnes of CO_2e a year. The replacement of electrical power from natural gas with biogas produces net savings of 1,255.7 tonnes of CO_2e per year (695 + 560.7). The total cost to offset electrical power produced from coal with biogas is $50.65 per tonne of CO_2e ($129,100 divided by 2,548.7). Offsetting natural gas electrical power generation in Ontario costs an estimated $102.81 per tonne of CO_2e ($129,100 divided by 1,255.7).

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