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The Potential of Short Rotation Forestry on Marginal Farmland in BC and Alberta to Provide a Feedstock for Energy Generation and to Reduce Greenhouse Gas Emissions

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The Potential of Short Rotation Forestry on Marginal Farmland in BC and Alberta to Provide a Feedstock for Energy Generation and to Reduce Greenhouse Gas Emissions

by

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EXECUTIVE SUMMARY

Objective 1: To assess the potential of short-rotation forest plantations on marginal farmlands for production of wood as a feedstock for energy production.

The physical availability of marginal farmland suitable for short-rotation forestry can be estimated using government data and statistics on land and agriculture. However, it is the cost of land that restricts the potential scale of afforestation, not its physical availability. A survey of western Canadian farmers found that those willing to have trees planted on their land required at least $40/acre ($98.84/ha). The condition or quality of the land available is highly variable within the identified land classification and is reflected in the shadow price of agricultural production, which is included in the rental cost.

The productivity of afforested land, in terms of how much wood-biomass can be produced, depends on site productivity, species planted, and the management regime used. The potential total aboveground yield from a hybrid poplar plantation on a 12-year rotation is estimated at about 500m^3/ha. For the purposes of the case study, the cost of plantation establishment and maintenance are estimated at $1575.50/ha and include site preparation, planting, herbicide application and overhead. Harvesting cost can vary considerably depending on the system used and the yield. An average value of $12.00/m^3 was used in the case study. Given a yield of 500m^3/ha, the ethanol yield is estimated at 44 kL/ha, based on a conversion efficiency of 242 litres per oven-dry tonne of biomass.

In order to assess the impact of the wood-ethanol production on greenhouse gas emissions, changes in the following carbon sinks and sources were accounted for: soil organic carbon; belowground carbon; aboveground carbon; emissions from plantation operations; and the emissions avoided through the use of ethanol in gasoline. In the case of a smaller-scale facility (122 ML/yr), approximately 350,000 tonnes of CO_2 are sequestered and avoided each year. This would amount to about 2% of Canada's required reductions under the Kyoto Protocol, based on business-as-usual scenarios.

It is anticipated that the demand for biomass from afforestation will increase over time, as industrial wood waste supplies become scarce due to increasing efficiency of mills as well as increased competition from other users. The value of carbon based on emerging carbon markets has not been included in the analyses, but if a value can be applied to sequestered or avoided carbon emissions then the potential for afforestation increases.

Afforestation and wood-ethanol production are excellent opportunities for Canada to reduce its greenhouse gas emissions and help meet its Kyoto commitment while boosting the economy and contributing to rural employment. What is required now is investment to develop the wood-ethanol industry and to address the technology gaps present in wood-ethanol processes.

Objective 2: To assess the potential of ethanol and wood-derived electricity produced from the above feedstocks for reducing greenhouse gas emissions as compared to gasoline and other fossil fuels. The GHG emissions will be evaluated by the Delucchi model using the information gathered in Objective 1.

Delucchi's full fuel cycle greenhouse gas (GHG) model was used to calculate the amount of GHG emissions from production and combustion of wood-derived ethanol under the following three land-use scenarios: 1) short rotation forestry on a land previously covered by pasture (70%), agricultural fields (15%) and forest (15%); 2) short rotation forestry on a previously forested land (100%), and 3) using sawmill wood residues with no energy-dedicated wood plantation. The modelling results indicated that in comparison with pure gasoline, utilisation of a gasoline blend containing 10% wood-derived ethanol under the three land-use scenarios could reduce GHG emissions by 7.9%, 1.0% and 6.3%, respectively. The difference in the level of emission reduction is primarily due to the changes in the amount of above-ground biomass and soil organic carbon under each land-use scenario.

ACKNOWLEDGEMENT

Objective 1 contributors:

Contributor	**Affiliation**	**Area of Contribution**
Peter J. Graham	Forest Economics and Policy Analysis Research Unit, University of British Columbia	Conducted research under Objective 1, completed a Master's thesis, presented findings at Temperate Agroforestry conference (August, 2001) and submitted journal article (currently in peer review) for the 24th Symposium on Biotechnology for Fuels and Chemicals.
Dr. G. Case van Kooten	Professor and Chair, Department of Applied Economics and Statistics, University of Nevada, Reno Associate of the Forest Economics and Policy Analysis Research Unit, University of British Columbia	Supervised graduate work of Peter Graham and conducted research in the economics of afforestation
Dr. Emina Krcmar-Nozic	Research Associate, Forest Economics and Policy Analysis Research Unit, University of British Columbia	Supervised graduate work of Peter Graham and served as graduate committee member
Dr. Gary Bull	Professor, Department of Forest Resources Management, University of British Columbia	Served as graduate committee member for Peter Graham
Dr. Ali Esteghlalian	Research Associate Department of Wood Science University of British Columbia	Conducted research under Objective #2 and

Pavel Suchanek	Faculty of Agricultural Sciences University of British Columbia	Graduate student of Dr. G. Case van Kooten. Conducted research, including survey of farmland owners, into economics of afforestation and climate change mitigation.
Dr. Bryan Bogdanski	Industry, Economics and Programs Branch, Canadian Forest Service	Served as external examiner on Peter Graham's graduate committee. Provided input on economics of afforestation and policy issues.
Diane Park		

Objective 2 contributors:

Contributor	**Affiliation**	**Area of Contribution**
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INTRODUCTION

In compliance with its commitment to the Kyoto protocol, Canada has to take serious actions for reducing its greenhouse gas emissions. The forest sector plays an important role in achieving such reductions because:

1. The forest industry is Canada's leading manufacturing sector and the largest industrial energy consumer. This sector also uses a great deal of transportation services that generate large amounts of greenhouse gases.
2. As recognised in the Kyoto Protocol, forests act as both sources and sinks of carbon, therefore, forestry activities, i.e., deforestation, afforestation and reforestation, can have significant impacts on the way each country's (including Canada's) GHG reductions are calculated.

In this regard, wood presents an attractive option for generating energy for the industrial and transportation sectors as it replaces the inherently carbon-intensive fossil fuels and also promotes forestry and biomass production. While pyrolysis, gasification and combustion technologies are currently under intensive investigation to actualise their potential for deriving energy from wood, ethanologenic bioconversion (i.e., fermentation of wood-derived sugars to ethanol) has become a promising technology. Wood-to-ethanol bioconversion can specifically produce a clean fuel for the transportation sector, the largest contributor to greenhouse gas emissions in Canada (National Energy Board, 1999). Wood used in the bioconversion process can be supplied by residues from woodlands and processing facilities, and by producing short-rotation woody crops on lands currently used for other purposes (e.g., grassland, agricultural fields, idle, etc.) Land use mitigation strategies can slow down the rate of greenhouse gas production. Eventually, however, fossil fuels will need to be replaced "as the prime energy sources in order to secure a continuing economic and social development in the world" (Marland and Schlamandinger, 1999). Diminishing the role of fossil fuels in the current global economy will require extensive capital investments and take many years (Suchanek, 2000).

One viable option for production of wood within the boreal region of Northern BC and Alberta is to establish short-rotation forest plantations on marginal farmlands. These plantations will increase the terrestrial carbon stock, provide an alternative source of income for the landowners, and may have additional environmental benefits such as improving biodiversity and preventing soil erosion. Such plantations increase the terrestrial carbon sink by sequestering atmospheric carbon in the form of wood biomass both above and below ground. While calculation of the above ground carbon sink is relatively straight forward the effect of site preparation, plantation establishment and harvesting operations on the soil organic carbon storage has to be determined. It is generally accepted that land use conversion from agriculture to forestry increases the soil carbon content (Marland and Schlamandinger, 1999; Lal and Bruce, 1999; Paustian et al, 1997). Determinations of the increase in carbon content vary due to differences in soil type, agricultural systems, tree species, climate, and experimental method. The Kyoto Protocol does not currently include soil carbon in its measurements, even though, in land use issues, the influence of soil carbon can be significant (certainly in countries with large areas of marginal agricultural land). The amount of greenhouse gas emissions associated with site preparation and harvesting operations, as well as the production and application of fertilisers and pesticides, also need to be taken into account.

Currently, there are a number of technologies available that can utilise the wood generated from such plantations to produce "renewable energy". The next section provides a summary of the wood-to-energy technologies currently available in Canada. This energy can be in form of electricity, heat or alternative fuels for road vehicles and/or industrial operations. Considering the significance of the boreal forests in the global carbon budget, a major criterion for selecting a wood-to-energy technology for Canada should be its potential in reducing GHG emissions. Such emissions are generated in various steps of the overall life cycle of a fuel from production to utilisation, all of which have to be taken into account when comparing different energy sources. Full-fuel cycle analysis is a cradle-to-grave approach that takes into account the emission of greenhouse gases throughout the production, processing and utilisation of a fuel. A cost-benefit analysis of the substitution of biofuels for fossil fuels requires full-cycle comparisons between fossil fuels and conversion alternatives. For example, in the case of wood-derived transportation fuels, the fuel cycle will encompass i) feedstock (wood) production, ii) the fuel production process, iii) fuel delivery, and finally, iv) fuel combustion in internal combustion engines. This analysis is closely tied in with the land use change issues, such as above ground biomass and soil organic carbon, which are two main components in calculating the GHG emissions from wood plantations.

The objectives of the proposed project are to assess the potential of short rotation forest plantations on marginal farmlands for production of wood as a feedstock for energy production and to evaluate various wood-to-energy conversion alternatives in terms of conversion efficiency, carbon emissions and economics.

ENERGY FROM WOOD

Viable technologies for deriving energy from wood include combustion, gasification, fermentation, and liquid fuel production. A decision regarding the choice of technology and feedstocks for a bioenergy production plant has to satisfy multiple objectives and criteria. For example, the ratio of the energy derived from wood or fuels produced from wood to the energy required to produce, process and utilise the fuel has to be maximised. The conversion technology of choice has to also minimise the amount of greenhouse gas emissions over its entire life cycle in comparison with current and other possible energy sources. Maintaining or improving the quality of various environmental components (e.g., soil, air and local and regional ecosystems) will be another major criterion in selecting a suitable technology for producing energy from woody feedstocks.

Conversion Technologies

Combustion: Wood can be used to generate electricity through direct combustion. It can also be incinerated in a co-generation facility to produce electricity and heat for district heating or for wood processing plants. Combustion is perhaps the easiest technology to implement, as it is the most developed conversion technique.

Gasification: This technique converts wood into hydrogen and carbon monoxide (Syngas) which can be used for electricity generation or for synthesis of various chemicals. This technology is still in the development stage, but holds substantial promise as an efficient conversion technology.

Fermentation: Anaerobic bacteria can break down the chemical components of the wood to produce a mixture of methane and carbon dioxide, known as biogas, which can in turn be used for electricity generation or consumer use. This technique is relatively mature and is used in industries that produce 'wet' waste streams, such as food processing or wastewater treatment operations.

Liquid fuel production: The major technologies in this category are thermic conversion (pyrolysis) and ethanologenic bioconversion. Pyrolysis is based on the decomposition of wood organic materials in the absence of oxygen at elevated temperatures. The resulting product is a mixture of gaseous and fluid fuels. The liquid stream, known as bio-oil, can be used as an industrial or heavy-vehicle transportation fuel and the gaseous phase could be burned to provide energy for the bioenergy plant.

The ethanologenic fermentation technology -transformation of wood-derived biomass to fuel-grade ethanol- is becoming a global reality with major production plants being established in the United States, Canada and Sweden. Production and use of ethanol as an alternative transportation fuel or as an octane booster helps reduce greenhouse gas emissions from road vehicles, and can promote sustainable development/management of forests and forest industries through waste minimisation. This presents a twofold environmental advantage as it is has been realised that stabilisation of atmospheric greenhouse gas concentrations requires both reduction of fossil fuel consumption and preservation and enhancement of carbon sinks and reservoirs, such as forests (Lashof and Hare, 1999).

Feedstock Production

Wood-based bioenergy plants can obtain their feedstock from different origins and in a variety of shapes and conditions. This wide range includes whitewood from both regular forests and short rotation plantations, residues from woodlands as well as wastes and process rejects from pulp mills and sawmills. Woodland residues associated with harvesting activities include thinnings, branches, ends, low-value trees, etc. The availability of woodland residues will likely be limited to roadside accumulations because of economic and ecological constraints. Wood processing residues, mainly pulp mill and sawmill residues, and other dryland debris include bark, primary sludge, sawdust, small chips, decayed and stained lumber. British Columbia's sawmill sector produces approximately 5 million tonnes of wood residues per year. A small number of co-generation facilities have begun operating since the phase-out of bee-hive burners with the main alternative method of disposal being landfills. In addition to co-generation plants, demand for sawmill residues also comes from MDF/OSB and pellet fuel manufacturers. As demand for industrial wood waste increases beyond supply, the value of wood fibre from fast growing energy plantations will increase.

Afforestation of marginal farmland with fast growing trees, such as hybrid poplar, may offer a relatively inexpensive source of wood-biomass for energy conversion. Research in this area is fairly scarce, especially that which takes carbon into account. Work by G.C. van Kooten et al. 1999, 2000a, 2000b) includes investigations into the potential for and costs of carbon sequestration in Northeast BC and Alberta (the boreal regions). In this area the total amount of marginal agricultural land considered suitable for planting trees was estimated at 7.25 million hectares based on Statistics Canada data (Lashof and Hare, 1999). A survey of landowners' preferences regarding afforestation will provide more accurate information about the availability of land and its current use and forest cover. The scale of afforestation will depend on landowners' willingness to accept compensation for planting trees and society's (or governments') willingness to pay for this compensation. If demand for biofuels increases, and with trade in carbon credits, then the marginal value of afforestation would likely increase and, in turn, so would the supply of biomass.

SUMMARY OF DATA ANALYSIS

Land use factors important for carbon accounting and cost-benefit analysis

Accounting for carbon emissions and sequestration was carried out through the collection and analysis of pertinent data in order to calculate the following:

- the area and condition of available land suitable for afforestation (in Alberta and B.C.)
- the carbon initially sequestered in plantations over the first rotation (in the roots, bole and branches);
- the carbon sequestered in the soil;
- the carbon emissions from the management and harvesting of the afforested land;
- the carbon emissions from transporting the biomass to the conversion facility;
- the emissions offset through substitution of fossil fuels (including emissions from extraction and production processes related to the various types of fossil fuels); and
- the residue (or ash) from the biomass-energy conversion process.

An economic cost/benefit analysis was carried out accounting for the following:

- cost of afforestation (including the opportunity cost of land in the alternative activity, agriculture), harvesting and transport;
- capital cost and operational cost of various sizes and types of conversion facilities; and
- the selling price of the electricity or liquid fuel produced through the conversion process.

The shadow price of alternative waste wood disposal methods (e.g. shipping to landfill, incineration) was assumed to be zero in the accounting. Non-market values (such as biodiversity and aesthetics) of afforestation, and related shadow prices of fossil fuel extraction or hydroelectric projects were examined but not explicitly analysed.

Full Fuel Cycle Analysis

The full-fuel cycle analysis methodology was used to assess and compare greenhouse gas emissions from the use of wood either as a primary fuel or as the feedstock for production of other alternative fuels (e.g., ethanol, syngas, etc.). Full-fuel cycle analysis is a cradle-to-grave approach that takes into account the emission of greenhouse gases throughout production, processing and utilisation of a fuel. If wood is used as a primary fuel for generating electricity, the cycle will include wood production (site preparation, growth, fertilisation, irrigation and harvesting), transportation of wood to the power plant, combustion of wood and finally the disposal of ash and other waste materials. The emissions generated from this cycle will be compared with those resulting from a similar power plant that uses other types of fuels. In the case of wood-derived transportation fuels, such as ethanol, the fuel cycle will encompass i) feedstock (wood) production, ii) fuel production process, iii) fuel delivery, and finally, iv) fuel utilisation in internal combustion engines. Fig. 1 is a simple representation of various components that are responsible for release or uptake of atmospheric carbon over the entire life cycle of wood-derived ethanol. The fuel utilisation component also includes GHG emissions from vehicle materials and assembly, as these emissions are closely dependent upon the type of fuel and vehicle technology.

The model developed by M. Delucchi takes a cradle-to-grave approach in estimating the amount of emissions over the entire life cycle (see Fig. 1) of a fuel (Delucchi, 1998). In 1998-1999, this model was expanded and modified to include Canada, and has been used for multiple studies funded by Natural Resources Canada and Agriculture & Agri-Food Canada. This version has been further developed and is considered to be the most rigorous life-cycle analysis of greenhouse (CO_2, CH_4 and N_2O) and non-greenhouse gases from alternative motor fuels. In this model, emissions are calculated as a weighted sum of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and are reported as *gram equivalent* CO_2.[1]

Using the Delucchi model, we have previously shown that land-use change has an appreciable impact on full-cycle emissions of wood-derived ethanol fuel (O'Connor et al, 2000). In our study, emissions from the following three scenarios were evaluated:

I. Wood from short rotation forestry on a land previously covered by pasture (70%), agricultural fields (15%) and forest (15%);

II. Wood from short rotation forestry on a forested land (100%), and

III. Wood residues from the saw-milling industry.

The results indicated that the first scenario (mixed land use converted into a short rotation plantation) has the greatest potential for reducing greenhouse gas emissions relative to the amounts generated throughout the life cycle of gasoline as a transportation fuel. This scenario produces about 8% less emissions than gasoline. This is primarily due to the increased levels of above ground biomass (AGB) in a plantation as compared to that of the mixed land use (mostly pasture). Also, replacing agricultural land to a plantation, which requires less annual tillage, harvest and fertilisation, can also reduce the release of soil organic carbon.

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[1] Gram CO_2 equivalent = (g CO_2) + (310 x g N_2O) + (21 x g CH_4); where 310 and 21 are the *100-year global warming potentials* of N_2O and CH_4, respectively.

The use of wood residues for ethanol production can result in a 6.3% emission reduction, primarily because no change in AGB or soil carbon is assumed to occur for the production of wood residues. Under the second scenario (conversion of forested land to a short rotation plantation), however, only a 1% reduction can be obtained. The reason for such marginal benefit is lower levels of AGB and higher amounts of soil carbon release due to more intensive tillage in a short rotation plantation (10-15 years) as compared to a regular forest that is usually harvested every 70 years or so. Therefore, it is essential to evaluate the effect of land-use change on the potential of emission reduction resulting from the use of wood-derived energy in lieu of fossil fuels.

RESEARCH OBJECTIVES

The objectives of the proposed research were as follows:

Objective 1:

To assess the potential of short-rotation forest plantations on marginal farmlands for production of wood as a feedstock for energy production. More specifically, the following questions will be answered:

i. How much marginal farmland suitable for short-rotation forestry is available?

ii. What are the current conditions (including the use) of the land?

iii. What is the potential biomass production yield (m^3 wood/m^2 plantation forest)?

iv. What are the costs associated with various productions operations (site preparation, chemical input, and harvest operations)?

v. What is the ethanol production equivalent (L ethanol/m^2 plantation) of the feedstock produced?

vi. What is the effect of afforestation and reduction of fossil fuel use on non-market values (e.g. biodiversity, water quality, wildlife habitat, etc.)?

vii. What would be the impact of an ‘afforestation-for-energy’ policy on Canada’s Kyoto commitment and total carbon stock?

viii. What is the potential for increased utilisation of forest residues (i.e. material that is unsuitable for pulp chips or sawlogs)?

ix. What degree of land use change are farmers/landowners willing to accept?

Objective 2:

To assess the potential of ethanol and wood-derived electricity produced from the above feedstocks for reducing greenhouse gas emissions as compared to gasoline and other fossil fuels. The GHG emissions will be evaluated by the Delucchi model using the information gathered in Objective I. The following questions will be answered:

i. How much gasoline will be ultimately replaced by the ethanol produced from the above biomass?

ii. How much reduction in GHG emissions can be achieved by using that wood for ethanol production?

MANAGEMENT APPLICATIONS

This research can be applied to policy development in the area of bioenergy and climate change mitigation, as well to private industry for the purpose of identifying the costs, benefits and risks of potential bioenergy business opportunities.

Greenhouse gas mitigation would be realised most effectively through the combination of sink-enhancement and source-oriented measures. A system of renewable energy production that would use biomass from afforested land as feedstock would displace the use of fossil fuels in energy production while increasing the terrestrial carbon sink. This certainly would assist Canada in reducing net greenhouse gas emissions and meeting its commitment under the United Nations Framework Convention on Climate Change.

With respect to the ethanol industry, the adoption of stronger incentive programs, particularly at the federal government level, would provide the industry with the initial push it requires to justify the high capital cost and risks associated with wood-ethanol production. The potential market growth for ethanol is likely to be maintained due to the general population's level of concern for the environment and due to efforts to reduce greenhouse gas emissions from the transportation sector. Whereas the potential damage resulting from climate change may be perceived by some as not critical enough to require immediate action, the effects of decreased air quality in rapidly-growing cities are pushing policy and law makers to demand cleaner sources of transportation fuel.

CONCLUSIONS

The use of wood-biomass from afforested lands and industrial wood waste as a fuel for energy production can be an economically viable tool to reduce greenhouse gas levels in the atmosphere. Afforestation as a supply of wood-biomass for energy production (such as ethanol) has the combined benefit of increasing the terrestrial carbon sink, and offsetting the production and combustion of fossil fuels, thereby reducing net greenhouse gas emissions.

As a forestry measure for mitigating carbon-dioxide (CO_2) emissions through a change in land-use, afforestation has a number of potential benefits. The primary benefit is an increase in the size of the terrestrial carbon sink. Other benefits include the potential increase in wildlife diversity and abundance, reduced soil erosion and improved water quality. Additional benefits, in terms of net greenhouse gas reductions, include the opportunity either to extend the storage life of the carbon by converting the mature trees into wood-products, or to use the wood-biomass as a source of renewable energy and thereby offset the use of fossil fuels. The former option has distinct advantages including established processing facilities and markets; however, a potential market effect of leakage may result in negligible benefits in terms of net greenhouse gas reductions. The use of afforested biomass for renewable energy has the advantage of being emissions-neutral under the Kyoto Protocol, and further reductions are realised through the displacement of fossil fuels.

Of the carbon pools associated with the forest carbon sink, soil organic carbon is thought to be the largest pool compared to aboveground and root biomass. Unfortunately, soil carbon is also the most difficult to measure efficiently. It is likely that the measuring system agreed upon for accounting purposes under the Kyoto Protocol will be a compromise between precision and the cost and time required to undertake the measurements.

There are currently many millions of tonnes of industrial wood waste being disposed of by incineration or in landfills. The conversion of this waste wood into energy products provides an opportunity to avoid these current CO_2-intensive waste management practices and offset emissions from the production and consumption of fossil fuels. The level of wood waste production is a function of the volume of timber harvested and the efficiencies of the primary processes. Projections of trends in future harvest levels are highly varied depending on province or region. There is generally a downward influence due to reductions in landbase but also an upward influence from favourable yield projections of managed second-growth timber. At the processing end it is reasonable to assume that efficiency will increase, thereby reducing the amount of waste. Also, competition for that waste is likely to increase from the engineered wood products industry, thereby increasing the price.

Future reductions in the availability of low-cost wood waste will increase the demand for wood-biomass from fast-growing plantations. The potential for afforestation to meet this demand is limited mainly by the cost and productivity of marginal farmland and its suitability for growing trees. Farmers do not only consider the opportunity cost of agricultural production when considering the option to plant trees. Other factors such as the current condition of their land and the visual appeal of the landscape influence their willingness to plant trees. The productivity of the land initially available for afforestation will be marginal in terms of its potential for agricultural crop production. Trees will grow on this land but their yield will be restricted by nutrient and moisture availability. Management tools such as fertilization and irrigation can increase yields but the value of that increase must be weighed against the extra costs. Increasing demand combined with reductions in the costs associated with plantation establishment and harvesting will result in increased productivity (due to better land and more intensive management) and therefore greater potential to compete with wood waste.

Considering the conversion of wood-biomass to energy products, ethanol stands out for three main reasons. First, its use as a transportation fuel derived from renewable wood-biomass reduces the net greenhouse gases emissions through the reduced consumption of gasoline, the increase in the terrestrial carbon sink from bio-energy plantations, and the emissions avoided from incineration and landfilling of wood waste. Second, ethanol has a number of health and environmental benefits, including improving air quality, in addition to mitigating greenhouse gas emissions. The third benefit of ethanol production is that, as it gains a share of the transportation fuel market, the consumer becomes less vulnerable to drastic changes in oil and gas prices (as experienced in the winter of 2000-2001).

There are technological obstacles to overcome before wood-ethanol production can begin to realise its market potential. An increase in federal incentives in the form of tax concessions on ethanol-blended fuel, combined with provincial incentives designed to help overcome the large capital costs and associated risks, will provide the industry with the necessary boost to get it up and running. Canada can gain from a successful ethanol industry not only reduced greenhouse gas emissions, but also an increase in economic activity, particularly in rural areas.

Through a quantitative, economic analysis of a hypothetical wood-ethanol production facility, it was found that positive net present value could be achieved from the point of view of the ethanol producer. The allocation of resources that optimized net present value led to the maximum utilization of available industrial wood residues in the study area due to the significantly lower acquisition costs compared to afforestation and harvesting. However, to take advantage of some economies of scale while satisfying even-flow requirements, some afforestation is economically viable.

Land rental and transportation costs are the most significant costs limiting afforestation potential. Due to the large amount of suitable land available, to satisfy their demand for feedstock the ethanol producer need only rent the most marginal agricultural land and therefore pay the minimum rental rate. A relatively small change in rental cost at the margin would result in a change in the area afforested. The cost of transportation affects where afforestation occurs; in the case study involving a moderately-sized ethanol facility, it is uneconomical to plant and harvest trees over 50 km from the facility.

It must be noted that the carbon accounting system to measure compliance with the Kyoto Protocol is not yet finalized and therefore some assumptions regarding changes in carbon stocks in terrestrial carbon pools may change prior to the first commitment period (2008-2010). In the reporting of national greenhouse gas emissions, the federal government will have to take care to avoid double counting of emissions credits associated with renewable energy projects. In other words, the avoided emissions due to renewable energy production cannot be counted in addition to the reduced consumption of fossil fuels.

As a “no-regrets” option, the production of ethanol from wood waste and afforested wood-biomass may be economically viable and contribute to the mitigation of greenhouse gas emissions. The development of markets for the trading of carbon credits increases the incentive for such a process, especially when credits for displacing fossil fuel use are attributed to the ethanol producer. The science of greenhouse gas behaviour and its relation to climate change and global warming is not proven; and an effective and internationally accepted accounting system for carbon credits and debits is still under negotiation. Consensus on which carbon pools and sinks would be included was reached at the end of the 6th Conference of the Parties (COP 6) to the United Nations Framework Convention on Climate Change and significant progress was made at COP 7 on the details of how these pools and sinks will be measured. Further work and negotiation on these issues is on going.

For the wood-ethanol industry, there remains considerable risk for investors in this new technology due to high capital costs, technological obstacles and market barriers. In order for the industry to develop, the Federal and Provincial governments will have to create incentives beyond those that currently exist. Government subsidies aimed at overcoming the risks associated with this new technology can be justified on the basis of carbon gains. The government can also help promote the industry through the development of carbon markets where ethanol producers would be allowed to sell carbon offset credits. In the United States, incentives such as tax benefits, loan guarantees, and regulations have led to the development of a strong ethanol industry. The market potential in the U.S. and Canada is very large and could contribute significantly to economic growth over the next few decades. To the consumer, the debates over the future availability of fossil fuels is not as much of an issue as the effects of sudden, large jumps in oil and gas prices. Buffering the demand for gasoline through the addition of ethanol in the transportation fuel market will reduce the sensitivity of prices at the pump.

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