Task 39 Liquid Biofuels from Biomass
IEA Bioenergy
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Ethanol from Lignocellulosics:

Policy options to support bioethanol production

A REPORT TO IEA BIOENERGY TASK 39

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Executive Summary

The technology for 2nd-generation biofuels enables the use of lignocellulosic biomass, derived from sustainable, renewable crops and trees, as a feedstock in the production of renewable transportation fuels. In North America, 2nd-generation biofuels join 1st-generation fuels, including starch-based ethanol and vegetable or waste oil-based biodiesel, as a potential substitute for fossil reserves. Of particular interest is bioethanol, which is advocated by many as a potential substitute for gasoline.

The use of bioethanol is generally associated with lower greenhouse gas emissions, which makes it an attractive option for combating climate change and meeting national or international targets of environmental performance. Bioethanol is particularly important to North America because of the established 1st-generation capacity that exists here, the investment in technical and human resources to service the industry, and the ability of ethanol to be used within the existing transportation fuel distribution network and conventional engines. These attributes make the bioethanol industry attractive to policymakers in both the United States and Canada.

A 2nd-generation bioethanol industry will be use lignocellulosic biomass as a feedstock, unlike the current generation of starch-based fuels which use corn or wheat grain. Development of the 2nd-generation industry will lead to a diversified rural economy and increased employment, which can support domestic development goals. The abundance of lignocellulosic feedstocks will extend the ability of bioethanol to contribute to domestic fuel requirements. Developing capacity for 2nd-generation bioethanol may follow a similar pattern to successful programs for 1st-generation bioethanol. Increases in 1st-generation bioethanol production, particularly in the United States, can be related to federal and state government policies.

This report provides an analysis of two common tools used to establish biofuel capacity, and examines their utility in creating a viable bioethanol industry. The report includes a summary of material generated by the Forest Products Biotechnology group at the University of British Columbia, as well as by the International Energy Agency's Bioenergy Task 39 'Liquid Biofuels'. In the document, tax exemptions and funding designed to promote biofuel production are examined in Canada, the United States, and Europe. In part, the dramatic difference in bioethanol production between Canada and the United States may be related to the individual policies of each jurisdiction. There are a variety of incentives that can be offered for ethanol production and/or consumption. Some of these incentives can be applied on a per-unit basis, while others can be assigned to the construction of a facility. Some incentives can be cash or cash rebates, while others can be in the form of tax exemptions. Discerning a winning strategy from these incentives can be very difficult.

The US, with its wide variety of incentives and fast-growing production capacity, was chosen as a focus for comparing different incentives. It is found that the success of four major bioethanol producing states (Iowa, Nebraska, South Dakota, and Minnesota) is closely related to the presence of funding designed to support the industry in its start-up phase, while tax exemptions on bioethanol use do not influence the development of production capacity. The study concludes that successful policy interventions can take many forms, but that success is equally dependent upon external factors which include biomass availability, an active industry, and competitive energy prices. Thus, the biorefinery strategy is presented as a path for ethanol producers to follow.

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1. Introduction

1.1. Report Overview

The simplest way to generate bioethanol is to ferment the 'native' sugars found in crops such as sugarcane or sugar beet using yeast. In Brazil, the sugar-based industry currently has the capacity to produce almost half of the world's bioethanol supply, or about 15.4 billion litres per annum (F.O. Licht 2004). Another source of the sugars required for fermentation is starch, produced in corn, wheat, and other cereal crops. Both sugar and starch-based processes are employed in Europe, with France (830 million litres) and Spain (420 million litres) currently leading production (F.O. Licht 2004). In North America, corn is the preferred biomass source due to the high proportion of starch found in its kernels, and its high yield per hectare in comparison to other cereal crops. Bioethanol generated from sugar or starch is referred to as '1st-generation bioethanol' for the purpose of this paper.

The large discrepancy in levels of bioethanol production between the EU, Canada and the US may be in part explained by the differences in corn availability. Levels of bioethanol production may also influenced by the presence or absence of bioconversion technologies, the participation of industry, and government interest in the products of bioconversion.

In the United States, most bioethanol production capacity is concentrated in the Midwest, where state and federal government incentives have combined to make an attractive environment for investment in the infrastructure required for bioethanol production. Over half of US production capacity is found in just four states, all of which have supplied significant capital resources to the bioethanol industry. The US states with the highest bioethanol capacities include Illinois (annual bioethanol production capacity, 4.8 billion litres), Minnesota (1.5 billion litres), Nebraska (1.2 billion litres) and South Dakota (1.1 billion litres) (Renewable Fuels Association 2005).

In this report, two types of policies that act as incentives for bioethanol production are considered. The first type of incentive is exemptions on fuel excise taxes; the second is funding designed to support projects, infrastructure, or capacity development for bioethanol production. The latter category is nebulous as many policies are written to be applicable to a variety of renewable technologies, including projects that are wind-, solar-, geothermal-, and biomass-related. The bioethanol industry is then evaluated on its ability to successfully promote broad policy goals of employment, environmental performance, and fuel security. A number of recommendations for the formulation of future policies are proposed.

The report is to be submitted to the Task 39 of IEA Bioenergy. Initial findings were presented at the Task 39 workshop in Kyoto, December 2004. It will be reviewed by policymakers in Europe, Canada and the United States, and will hopefully provide valuable information to the industry at a crucial time in its development. Parts of this report are being prepared for peer-reviewed publication.

1.2. Task 39 Liquid Biofuels

The International Energy Agency was founded in 1974 as an autonomous body within the OECD to implement an international energy programme in response to the oil shocks. Membership consists of 25 of the 29 OECD member countries. Activities are directed towards the IEA member countries' collective energy policy objectives of energy security, economic and social development, and environmental protection. One important activity undertaken in pursuit of these goals is a programme to facilitate co-operation to develop new and improved energy technologies. A key commitment is to affordable, renewable energy (IEA 2002).

IEA Bioenergy was created in 1978 by the parent organization with the aim of improving cooperation and information exchange between countries that have national programmes in bioenergy research, development and deployment. Activities operating under IEA Bioenergy are

set up under Implementing Agreements. These are independent bodies operating in a framework provided by the IEA. There are 40 currently active Implementing Agreements, one of which is IEA Bioenergy.

IEA Bioenergy Task 39, "Liquid Biofuels," is currently composed of 9 countries/regional associations (Austria, Canada, Denmark, European Union, Finland, The Netherlands, Sweden, USA and UK) interested in working together to successfully introduce biofuels for transportation into the marketplace. This Task reviews technical and policy/regulatory issues and provides participants with comprehensive information that will assist them with the development and deployment of biofuels for motor fuel use.

Biofuels are presently the only renewable source of liquid transportation fuels and offer many potential environmental and economic benefits. The production of the raw biomass material and its subsequent conversion to fuels creates local jobs, provides regional economic development, and can increase farm and forestry incomes. Biofuels also offer many environmental benefits including reduction of carbon dioxide emissions associated with global climate change and improved waste utilization. The chemical composition of many biofuels also leads to improved engine performance and reduces unwanted pollutants such as carbon monoxide and unburned hydrocarbons. Billions of litres of ethanol are used annually for transportation fuels, and biodiesel is gaining in popularity in some regions.

Because the costs of biofuels are relatively high, these fuels presently have significant impact only in those locations where biomass is abundant, and where governments provide policies and incentives that encourage their use. Ethanol from starch and grain crops is used extensively in Brazil, Canada, United States, and to a lesser extent in Sweden. Biodiesel has attracted increasing interest throughout Europe, and to a limited extent in North America. In the short term, governmental policies and incentives allow the infrastructure for biofuels to be established, and they start the transition from a petroleum-only economy. At the same time, governments are also sponsoring research and development efforts to reduce the cost of biofuels so they can compete more effectively in the marketplace. The long-term viability of biofuels will require both that the infrastructure for biofuels exists and that economically competitive processes are available. To achieve this goal, it will be necessary to deal with both the technical and the non-technical issues (i.e., policy, regulatory, legislative) relating to biofuels in a comprehensive manner.

2. Excise Tax Exemptions

Excise taxes, one of the most common instruments of policy as related to transportation fuels, are designed to fill the gap between property and income taxes. These types of taxes can be imposed on the sale or use of certain articles, including fuels, and on certain transactions and occupations. In many cases, these taxes are not itemized in sales receipts and cannot be easily detected, and thus result in a hidden cost to the consumer (US Department of Energy 2001). The excise tax rates for the countries under consideration range considerably, as shown in Table 1.

Table 1: Excise tax rates and exemptions (2005)

Country	Leaded Gas[1] (US ¢/L)	Unleaded Gas[1] (US ¢/L)	E10[2] (US ¢/L)	Diesel[1] (US ¢/L)	Biodiesel[2] (US ¢/L)
Canada*	8.0	7.3	**6.6**	3.1	n/a
Mexico***	n/a	66.6%	78.9%	43.5%	n/a
United States**	4.9	4.9	**3.5**	6.4	n/a
Austria	49.2	41.8	41.8	29.0	**26.2**
Belgium	56.6	50.6	50.6	29.8	29.8
Czech Republic	30.3	30.3	30.3	22.8	22.8
Denmark	53.7	44.9	44.9	30.9	30.9
Finland	65.3	57.5	57.5	33.4	33.4
France	n/a	60.1	**54.1**	39.9	39.9
Germany	66.1	60.8	**60.0**	42.0	42.0
Greece	35.5	30.5	30.5	25.8	30.5
Hungary	39.8	36.8	36.8	29.8	29.8
Ireland	47.1	38.4	38.4	22.8	22.8
Italy	57.1	57.1	57.1	30.9	30.9
Luxembourg	43.5	38.2	38.2	33.4	33.4
Netherlands	66.4	59.5	**59.0**	29.8	29.8
Norway	76.0	78.6	78.6	52.7	78.6
Poland	38.4	34.5	34.5		34.5
Portugal	56.3	34.3	34.3	25.2	25.2
Russia(3)***	30.0%	30.0%	25.0%	30.0%	25.0%
Spain	41.5	38.1	**34.3**	27.2	27.2
Sweden	61.3	53.4	53.4	34.9	34.9
Switzerland	n/a	46.7	46.7	48.5	**46.7**
United Kingdom	86.6	77.3	77.3	77.3	77.3

Sources: [1]OECD 2005, [2]CEC 2002, [3]IEA 2003a. Conversion factors: $1.000 USD = $1.366 CDN = € 0.920 EUR

*Canadian Federal excise tax rate is shown. Provincial rates are variable, ranging from 4.5 US ¢/L (Yukon Territory) to 12.1 US ¢/L (Newfoundland and Labrador). Provincial excise tax exemptions range from 0.7 US ¢/L (Alberta) to 1.8 US ¢/L (Manitoba).

**US Federal excise tax rate is shown. State rates are variable, ranging from 2.0 US ¢/L (Georgia) to 7.7 US ¢/L (Rhode Island). State excise tax exemptions range from 0.1 US ¢/L (Florida) to 0.7 US ¢/L (Idaho).

***Mexican and Russian rates are *ad valorem* and vary on a monthly basis, depending on world petroleum prices

Excise tax exemptions could be a source of important cost savings to the emerging ethanol industry, particularly in facilities based in European countries. This is due to the high level of excise tax that is currently levied on petroleum and diesel in these countries. When compared to North American countries, European excise taxes are very high. Thus, a reduction of even a few percent can mean cents per litre, which translates into significant cost savings. For instance, in Austria, a ten percent reduction in excise taxes on biodiesel reduces the cost by 2.8 US ¢/L (OECD 2005). This sum is almost equivalent to the federal excise taxes paid for diesel fuel in

Canada. A similar percentage reduction in the US federal excise tax for diesel would result in a selling price of 5.8 ¢/L and a savings of only 0.6 ¢/L (OECD 2005, CEC 2002).

Despite their potential to support the ethanol industry, European governments have not always utilized excise tax exemptions to the same extent as their Canadian and US counterparts. This may be because national control over excise tax rates is somewhat complicated by the rules of the European Union. One of the precepts of the EU and its predecessor, the European Economic Community, is that trade between borders should be facilitated, and unfair advantages should not be provided by one member of the union over another. To this end, a directive was issued by the EEC on October 16, 1992 which was intended to harmonize the structures of excise duties among all member nations (OJL 1992, OJL 1994). When France decided to create an aid scheme for biofuels that would exempt these fuels from national excise taxes, objections were raised and an appeal to the Commission of the European Communities was made by BP Chemicals Ltd (OJC 2001). Ultimately, however, the Commission decided to validate the French decision, allowing an exemption amounting to 6 US ¢/L to be extended through December 31, 2003 (OJL 2003, European Biodiesel Board 2003). This move has created the precedent within the EU to allow excise tax exemptions for biofuels, freeing a powerful policy tool for decision-makers within the nations of the Union. It may be expected that other countries will make the decision to grant excise tax exemptions as ethanol production becomes more widespread within Europe.

In North America, excise taxes have been used as a tool to support renewable biofuels for some time. The federal governments of both Canada and the US offer an exemption on ethanol which results in a slightly reduced tax rate for E10 blends. In addition, some state and provincial governments also offer exemptions. The largest North American exemption on excise taxes is currently offered in Manitoba, although that status is primarily dependent upon the strength of the Canadian dollar.

In Figure 1, the excise tax exemptions are shown for North America and Europe, and related to ethanol production capacity. The federal and state exemptions are illustrated by the shading on the map, with darker blue indicating lower exemptions, and darker red indicating higher exemptions respectively. Overlaid on these data is the ethanol production capacity, as indicated by the size of the yellow circles. In the United States, Idaho offers the largest combined exemption on E10 fuels at 2.1 US ¢/L. Total ethanol production capacity in Idaho is about 22 million litres per year, which is significant, but low when compared with that of other states, particularly Illinois, Minnesota, Nebraska and South Dakota. Of the four largest ethanol-producing states, South Dakota is alone in offering an exemption on state excise taxes. It may be inferred that excise tax exemptions provide a benefit for producers, but are not the deciding factor in determining where to install capacity for production.

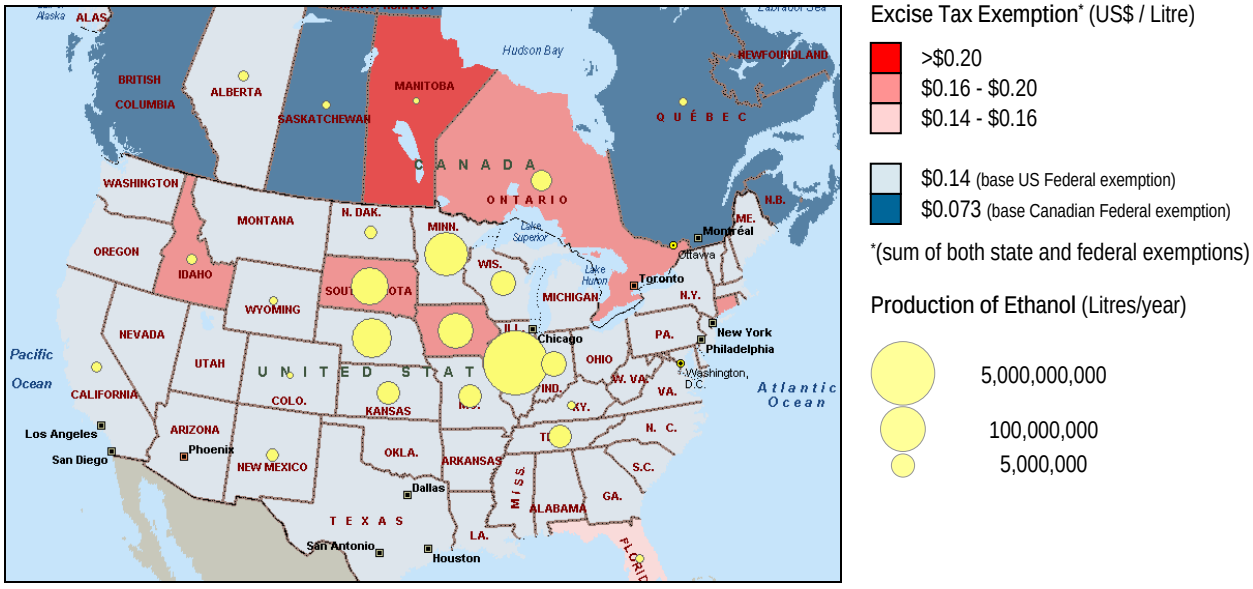

Figure 1: Map of excise tax exemptions and ethanol production capacity

Sources: Canadian Renewable Fuels Association 2005, Department of Finance Canada 2003, DSIRE 2003, Federal Highway Administration 2002, National Biodiesel Board 2003, NRCan 2003, Renewable Fuel Association 2003, Statistics Canada 2002, Statistics Canada 2003a, US Department of Energy 2003a, US Census Bureau 2003

Similarly, exemptions on excise taxes cannot be simply related to ethanol production in Canada or Europe. In Canada, Manitoba offers combined exemptions that are higher than any offered in the United States. Combined federal and provincial excise tax exemptions on E10 reach as high as 2.56 US ¢/L in Manitoba, as compared to 1.81 US ¢/L in Ontario. At the current time, however, Ontario continues to lead Canada in the amount of ethanol produced, while Manitoba lags behind jurisdictions such as Saskatchewan (which has individual incentives) and Quebec (where exemptions are limited to the federal level). In Europe, high excise taxes mean that exemptions for ethanol (and other biofuels) are very significant and orders of magnitude larger than those found in North America. France offers the largest incentive in the form of tax exemptions, but produces less ethanol than Spain, which offers a significantly lower excise exemption.

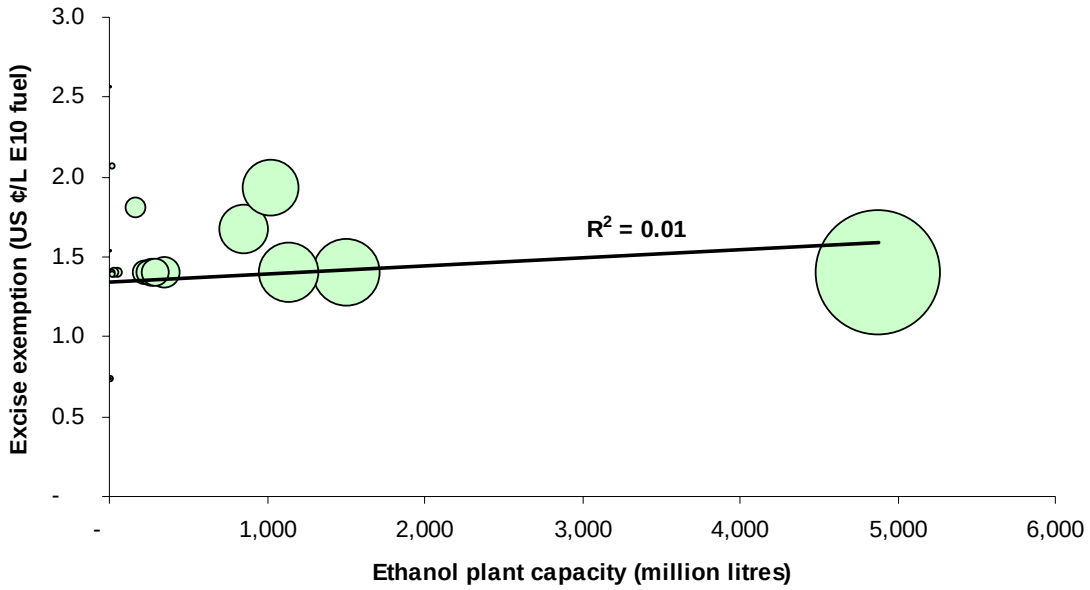

Figure 2: Excise tax exemptions and ethanol production capacity

Sources: Canadian Renewable Fuels Association 2005, Department of Finance Canada 2005, DSIRE 2005, Federal Highway Administration 2002, National Biodiesel Board 2003, NRCan 2003, Renewable Fuel Association 2003, Statistics Canada 2002, Statistics Canada 2003a, US Department of Energy 2003a, US Census Bureau 2003

In Figure 1, the level of excise tax exemptions are plotted against bioethanol production capacity and the correlation between the two is examined. No relation (r^2=0.01) may be discerned between excise tax exemptions for biofuels and bioethanol production. The data presented in this figure makes it clear that, while excise tax exemptions may play a role in the continued economic performance of the industry, there is no clear cause-and-effect relationship between the level of these exemptions and the establishment of the industry within individual jurisdictions. Evidently, while the benefits that can be accrued due to excise tax exemptions are significant, particularly in Europe, they are not sufficient to lead to the creation of capacity. In likelihood, this type of incentive will play a more important role in maintaining the profitability of bioethanol production after it has been established, by encouraging greater consumption of this product.

3. Direct and indirect funding for fuel ethanol

Another common policy instrument used to support the bioethanol industry is government program funding, in the form of direct or indirect subsidies, loans, or grants. For the purpose of this study, direct funds are considered to be funds earmarked for ethanol production, while indirect funds are those intended to support the operation of biofuel production facilities, or biomass production, for general energy purposes. When different funding sources were considered, the only real criteria applied to warrant their inclusion in this study were (1) that the funds be applicable to the construction or modification of production facilities, and (2) that bioethanol is accounted as an eligible product. Indirect sources of funding were included because ethanol can often be created as a co-product of material or bioenergy generation.

The financial commitment that the US has made to biofuels dwarfs the contribution that Canada or the European Union has put forward. In 2002, total cumulative US funding through national or state programs applicable to bioethanol topped US $422 million. The largest amount of funds was offered by the federal government. Total (cumulative) program spending by all government agencies, primarily the US Department of Agriculture and the US Department of Energy, exceeded US $253 million in 1998 and have risen since to more than US $300 million (Chum 2001, Renewable Fuel Association 2005). This has resulted in improving the technology that is utilized by the industry, and has broadened the potential number of coproducts that can be generated from the ethanol production process. The remainder of federal funds went to support a number of incentive programs, including the Alcohol Fuel Credit (a corporate tax credit designated for industry producing ethanol), deductions for both clean-fuel vehicles and refuelling properties, and the Renewable Energy Systems and Energy Efficiency Improvements Program. The latter program is designed to aid in the construction of new facilities, and will cover up to 25% of construction costs. Maximum grants for a single project under this program are US $500,000, and the fund generally pays out between US $3-5 million in any given year (DSIRE 2005).

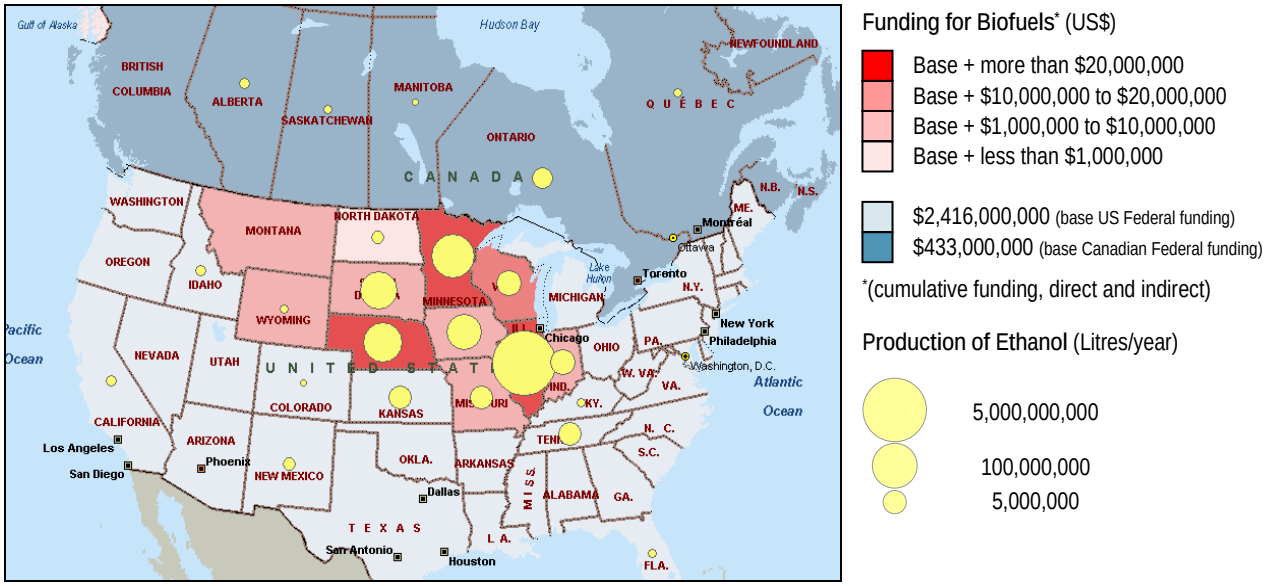

Figure 3: Map of direct and indirect funding for ethanol and ethanol production capacity

Sources: Canadian Renewable Fuels Association 2005, Department of Finance Canada 2003, DSIRE 2003, Federal Highway Administration 2002, National Biodiesel Board 2003, NRCan 2003, Renewable Fuel Association 2003, Statistics Canada 2002, Statistics Canada 2003a, US Department of Energy 2003a, US Census Bureau 2003

In Figure 3, federal funds available in each nation are by the shading on the map, from dark and light blue (base levels of funding provided by federal governments) to light or dark red (additional provincial/state funding, depending upon the total amount of funds available). These funding opportunities are compared to existing bioethanol production capacity, which is indicated by the yellow circles sized according to availability. It should be noted that, because the figure includes funding targeted at renewable projects including biomass-based initiatives, certain jurisdictions, including California, are indicated as having funding available with no corresponding ethanol production.

The figure clearly shows that the financial commitment that the US has made to biofuels dwarfs the contribution that Canada has put forward. In 2002, total cumulative US funding through national or state programs applicable to bioethanol topped US $422 million. The largest amount of funds was offered by the federal government. Total (cumulative) program spending by all government agencies, primarily the US Department of Agriculture and the US Department of Energy, exceeded US $253 million in 1998 and have risen since to more than US $300 million (Chum 2001, Renewable Fuel Association 2003). This has resulted in improving the technology that is utilized by the industry, and has broadened the potential number of coproducts that can be generated from the ethanol production process. The remainder of federal funds went to support a number of incentive programs, including the Alcohol Fuel Credit (a corporate tax credit designated for industry producing ethanol), deductions for both clean-fuel vehicles and refuelling properties, and the Renewable Energy Systems and Energy Efficiency Improvements Program. The latter program is designed to aid in the construction of new facilities, and will cover up to 25% of construction costs. Maximum grants for a single project under this program are US $500,000, and the fund generally pays out between US $3-5 million in any given year (DSIRE 2003).

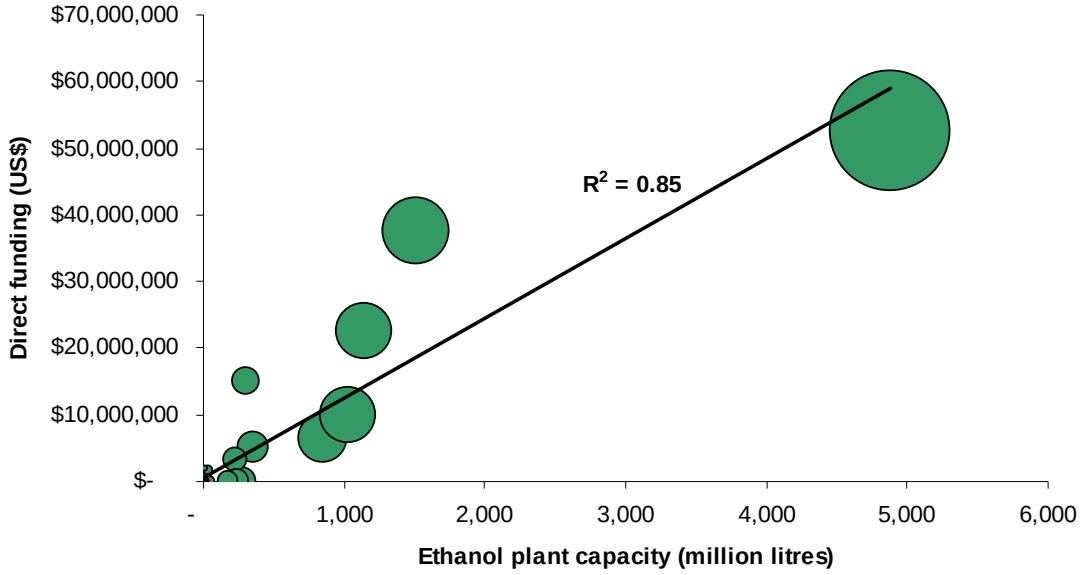

Figure 4: Direct and indirect funding for ethanol production capacity

Sources: Canadian Renewable Fuels Association 2005, Department of Finance Canada 2003, DSIRE 2003, Federal Highway Administration 2002, National Biodiesel Board 2003, NRCan 2003, Renewable Fuel Association 2003, Statistics Canada 2002, Statistics Canada 2003a, US Department of Energy 2003a, US Census Bureau 2003

There is a strong relation between bioethanol production and the amount of capital available for infrastructure development, biomass procurement, and plant operation. In Figure 2, the cumulative total direct and indirect funding is plotted against bioethanol production capacity. The strong correlation that is shown between the two (r^2=0.85) indicates that production capacity is likely to be found where significant resources have been committed to the industry.

The US model for the ethanol industry has evolved to see the federal government taking a leadership role in funding research and development, with the state governments putting the majority of their resources towards incentives for the creation of new production facilities. Each of the four major ethanol producing states, including Minnesota, Illinois, Nebraska and South Dakota, have followed a different approach in creating these incentives. Each approach represents a successful strategy for attracting the industry and expanding ethanol production capacity. In Minnesota, the chief incentive is the Ethanol Production Incentive. Originally, this incentive provided direct payments to producers at a rate of approximately 5.2 US ¢/L ethanol, although the passage of bill SF 905 (2003) has reduced this amount to 3.4 US ¢/L. In 2007, the original incentive will be restored and producers may be reimbursed for lost incentive if funds are available. The total fund available is US $37,000,000, although there is a cap of US $3,000,000 per producer. This essentially means that producers of more than 15 million litres per year are ineligible for extra incentive. The Ethanol Production Incentive expires in 2010 (DSIRE 2005).

In Illinois, the primary incentive offered to ethanol producers is the Illinois Renewable Fuels Development Program, which offers up to US $15 million a year in grants for the construction or retrofitting of renewable fuels plants. While the wording of program is broad, ethanol production facilities are currently the primary recipient of these funds (DSIRE 2005). In addition, the Renewable Energy Resources Program offers funding at various levels to promote the development and adoption of renewable energy within the state. Applicable funds within this program include US $150,000 for dedicated crops that may be used for biofuel production. With two new plants under construction in 2003, the total funding available to the ethanol industry is estimated at approximately US $30,150,000. Currently, Illinois has 5 operating facilities with a capacity of 4.9 billion litres per year, while 2 new facilities are under construction (Renewable Fuel Association 2005). In Nebraska, the main program is the Ethanol Production Incentive,

which offers a tax credit of 4.8 US ¢/L ethanol for up to 60 million litres of annual production per facility. This credit, which will expire in 2012, is limited to a total of US $22,500,000. As a tax credit, these funds can be considered to be defrayed costs in direct support of the industry (DSIRE 2005). Nebraska currently has a production capacity of 1.1 billion litres annually in 7 facilities, with 3 new installations currently under construction (Renewable Fuel Association 2005). In South Dakota, the Ethanol Production Incentive is designed as a direct payment of 5.2 US ¢/L, with a maximum of $1,000,000 annually or $10,000,000 in total to any single facility. Unlike the incentives described for Minnesota, Illinois or Nebraska, this particular program is targeted specifically at ethanol from cereal grains; the program is set to expire in 2006 (DSIRE 2005). While this level of support is lower than the other three states under consideration, it is important to recall that South Dakota also has an excise tax exemption on ethanol, which provides additional financial incentive for production. Currently, South Dakota has 8 operating facilities, 2 plants under construction, and a total production capacity of 1.0 billion litres per year (Renewable Fuel Association 2005).

As these examples demonstrate, significant production capacity can be achieved through a variety of political mechanisms. The tools of tax exemptions, direct payments, or grants are shown to be effective in attracting capacity to individual jurisdictions, and the tools are shown to be flexible in achieving different results. The Minnesota example, in particular, shows the potential impacts of small changes to policy. By limiting the capacity to which the incentive applied, the state government was able to spur the creation of many individual facilities, which will have a direct impact on jobs and the local economy. It is important to remember, however, that each of these strategies build upon the US federal governments strong commitment to research and development. Without that commitment, the rapidly improving technology that makes these facilities possible would not exist.

In other countries, the dual funding model which has worked well in the US does not exist. For instance, the total French commitment to biofuels is just under US $200 million, of which about $180 million is devoted to investment subsidies for biofuels, and a further US $11 million is put towards wood energy programs. This leaves only about US $9 million for research and development into renewables, a sum that will not be fully devoted to ethanol or biofuel research (CEC 2002). The American government commitment to research is part of the success story; although the incentives that the French government offer are dramatic, they may lack the cutting edge in technology. This may in part explain the relatively low level of bioethanol production in France, currently at about 115 million litres per year (Platts Global Energy 2003). In Spain, the total investment is much lower at approximately US $30 million per year, but over half of this amount (US $17 million) is available for research and development into various renewables, while the other half may be used for commercial facilities or demonstration plants (CEC 2002). The balance between research and production incentives that is present in both Spain and the United States, and the resultant human capital, may in part account for the success that these nations have had in nurturing the ethanol industry.

4. Policy goals and biofuel policy

The ability of ethanol to contribute positively to the environmental and economic performance of a country, and to improve energy security in the long term, makes the nascent industry a tool that policymakers can employ to meet national priorities in these areas. A review of the priorities that governments are pursuing when designing ethanol-related policy illustrates some issues that the emerging ethanol industry might consider. These issues may have particular relevance to the commercialization of the lignocellulosic-based component of the industry.

In the United States, the primary political drivers that support research and development into ethanol for fuel are related to the economy and to energy security. Two agencies have become the primary implementing bodies for US policies related to ethanol. The Department of Agriculture (USDA) has a mandate to increase rural employment, diversify agricultural economies and stimulate rural development by harnessing crops and crop residues and identifying new uses for this material. The Department of Energy (DOE) has a mandate to diversify the energy supply, expand the availability of renewable energy sources, and develop new technologies to exploit renewables in all forms.

From an economic perspective, ethanol policy in the US has been highly successful. While no new oil refineries have been built in the US since 1976, bioethanol production capacity has grown significantly. Today, there are 73 ethanol plants in the United States, producing about 11 billion litres per year, with an additional 13 plants and 2 billion litres of capacity under construction (Renewable Fuels Association 2005). Within ten US states, the ethanol industry alone can be credited with creating an estimated 200,000 new jobs, and generating $500 million in annual tax receipts (Evans 1997). These figures include direct employment within biorefineries, but also reflect increased employment on the farm and the creation of secondary jobs to provide equipment and services for these operations. In Minnesota, for instance, the use of a cooperative approach means that about 8,000 farmers have shares in ten ethanol plants (Morris 2000).

Urbanchuk (2000) reports that continuing to promote biorefineries through mandatory renewable fuel use, such as a Renewable Fuels Standard, would encourage growth of the US ethanol industry to approximately 19.0 billion gallons of production by 2012. This level of growth would require an estimated US $5.3 billion investment in new facilities and would increase demand for crops by 1.6 billion bushels per year. The author anticipates that the ethanol industry could reduce the US trade deficit by US $34 billion per year, create 214,000 new jobs within the USA., and generate US $51.7 billion in new US household income (Renewable Fuels Association 2005, Urbanchuk 2001).

From a security perspective, ethanol policy has been less successful. Demand for petroleum in the US continues to outpace domestic supply, resulting in growing petroleum imports. A rising trend in oil imports is anticipated to place American dependence on foreign oil supplies at nearly 70% by 2020 (Renewable Fuel Association 2005). The impact of the biomass on the nation's energy and fuel supplies has been very small; only about 3% of that nation's total energy needs supplied by biomass (IEA 2003), and only about 0.7% of American total transportation fuel consumption is derived from biofuels (Renewable Fuel Association 2005). From the perspective of energy security, the US could benefit from continued expansion of the bioethanol industry and increased utilization of the industry's potential.

What is considered a significant level of production may vary, but a common blend for ethanol in gasoline is 10% ethanol by volume, or E10 fuel. Five individual US states (South Dakota, Nebraska, Minnesota, Iowa, and Illinois) now produce enough ethanol to provide an E10 option to their entire local population. However, the majority of states and all of the Canadian provinces do not come close to this production capability. In Canada, gasoline sales are in the range of 38 billion litres per year (Statistics Canada 2002), while in the United States this figure is close to 480 billion litres per year (US Department of Energy 2002). Therefore, the production capacity required to provide E10 fuel blends to every consumer in North America would exceed 50 billion litres on an annual basis, which is about 4 times the current production levels. The United States

comes closest with the ability to substitute 2.2% of its national gasoline demand with ethanol, followed by Spain (1.8%), Sweden (1.4%) and Canada (1.1%).

The issue of climate change has become a major, global concern, but the sectors most closely linked to bioethanol production – including energy producers, farmers, and foresters – will feel the impact of this issue more closely. Climate change is the driver behind many new policies that influence the actions taken by these sectors. Perhaps the best-known of these is the Kyoto Protocol, which has been ratified by Russia, by the members of the European Union, and by Canada in North America. The Clean Skies Initiative in the US is another example of these policies. Because the use of ethanol has the potential to significantly reduce net greenhouse gas emissions compared to petroleum products, an expansion of ethanol production may become a significant part of national climate change strategies. It must be noted, however, that significant amounts of ethanol must be substituted for petroleum products in order for these reductions to make a significant impact on total greenhouse gas emissions.

In advising governments on the creation of ethanol-friendly policy, the US experience offers some valuable lessons to consider. The US goals behind policies supporting the ethanol industry are dominated by (1) economic and social issues, and (2) security-based concerns. Of these priorities, the ethanol industry has been more successful in meeting social criteria such as rural employment. The starch-based segment of the bioethanol industry has enjoyed particular success in the United States, particularly in Minnesota, Illinois, and Iowa. In the past, these jurisdictions have utilized a number of schemes, including direct payments, grants, corporate tax breaks and excise tax exemptions, as incentives to lure the industry and build ethanol capacity. Direct funding, regardless of the form, was found to be effective in building large amounts of local capacity. The success observed would likely have been lessened were it not for the significant commitment made by the US federal government to researching and developing new ethanol technology. This commitment ensured that cutting edge process technology, as well as human capital in the form of skilled personnel, was available to the emerging industry. The implication is that social or economic programs have great potential for success within the short-term, and thus recommendations to local governments should emphasize the suitability of this policy approach.

The ability of the industry to increase energy security in the United States, on the other hand, has been limited by the relatively small capacity of their production facilities at the current time. This should serve as a cautionary measure for governments in both Canada and the European Union, which have invested ethanol-related policy with more emphasis on the environment and on energy security than they have upon social or economic concerns. Improved energy security through ethanol production can only be achieved when enough capacity is brought on-line. Thus, security-related policy geared to the short-term cannot succeed to any great extent. Policymakers must realize that, in the immediate future, the goals of most successful policies will be related to the economy, and to the environment. The implication for the case studies is that security-related policy, such as mandated renewable fuel use, is likely to take the form of long-term programs that have very little immediate reward.

5. Actions for the future: Biorefining

Lignocellulosics in the form of forest and agricultural residues are a logical feedstock for the ethanol industry as it grows to the point where starch- and sugar-based sources of material are insufficient to supply production. Despite significant research commitments within the United States, Sweden, and Canada, there are no full-scale lignocellulosic-to-ethanol plants in North America. The primary short-term challenge for the ethanol industry as a whole is to expand production to a significant level in a number of countries, and to develop markets and ensure that consumption of product rises accordingly (Yancey 2003). To meet these challenges, continued government support is required.

To date, excise tax exemptions have not played a major role in the establishment of the ethanol industry, or in the creation of industrial facilities. Direct and indirect funding was found to play a much more positive role in the creation of production capacity. In many cases, it was difficult to isolate funding that was meant specifically for the ethanol industry, as the description of activities eligible for funding indicated a far broader scope that included a range of renewable or sustainable activities. It was noted that strong funding for establishment of facilities and for research was present in each of the states where significant ethanol production was present. However, it was also noted that similar levels of funding exists in other states where the industry has not successfully established itself. This indicates that other factors, including biomass supply, the presence or absence of interested industrial players, and the political will of the region in question, all play a significant role in the establishment of the industry.

A balance between research funding and funding for the creation of facilities might be more conducive to supporting the industry. It was noted that the United States has devoted a significant amount of funds to research as well as to supporting facility creation. A commitment to advancing the technology and improving efficiencies may serve to increase the industry's comfort level in committing resources to this sector.

In crafting policies that provide funding either for research or for the establishment of facilities, decision-makers have focused on three broad political goals, including improved rural economic performance and employment, improved environmental performance, and increased energy security. The ethanol industry has really only been successful in meeting the political goal of creating employment. Because of the relatively small size of the industry to date, its ability to contribute strongly to either improving energy security or to reducing environmental loads has not been realized. This offers a lesson in crafting policies to support the industry.

The experiences gained in commercializing sugar- and starch-based ethanol production facilities contain many lessons for the lignocellulosic-based industry, and offer suggestions as to the best political strategies for moving the industry forward. Bioethanol from all sources can be seen as a potential fuel that can be used to respond to a variety of domestic issues, including the need to diversify local economies, increased concerns over environmental damage associated with fossil fuel use, and a growing security rationale for a shift to domestic fuel sources. The emerging industry, including the lignocellulosic-based sector, may in turn find opportunities for strategic linkages and partnerships that capitalize upon these political issues.

Key actions:

1. Direct funding for infrastructure is by far the most successful policy for increasing biofuel capacity. There is very little relation between excise tax exemptions and biofuel capacity.
2. Policy intervention can take many forms, but success is equally dependent upon external factors which include biomass availability, an active industry, and competitive energy prices. Policies for 2nd-generation biofuels must recognize the importance of these external factors.
3. In other jurisdictions, even large-scale expansion of the ethanol industry has met with limited success in terms of broad policy goals of security, energy independence, and climate change. The ability of biofuels to contribute strongly to rural employment, however, is a success story that should be utilized in crafting policy to support 2nd-generation biofuels.
4. Funding strategies should seek to achieve a balance between research funding and funding for the creation of facilities, in order to optimize benefits for the near and long term. In the US, this strategy has been the most successful. Finding mechanisms for joint funding between members of the EU, Canada and the United States would also allow the industry to build on existing synergies.

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