IEA Bioenergy Task 39, Liquid Biofuels Final Report 2001-2003:

Biofuels for Transportation: An Examination of Policy and Technical Issues.

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ABSTRACT

The International Energy Agency Bioenergy Agreement (IEA Bioenergy) provides a mechanism for participating countries to exchange information and conduct collaborative RD&D activities on bioenergy-related topics. IEA Bioenergy includes Tasks covering a range of biomass production, conversion, and utilization topics. As part of this effort, IEA Bioenergy established "Task 39, Liquid Biofuels" in 2001 to examine both the policy and technical issues that influence the use of biofuels.

The use of biofuels is rapidly expanding in many countries around the world. Approximately 30 billion (30×10^9) liters of biofuels were used in North and South America and Europe in 2003. This represents a more-than 3-fold increase in the volume of biofuels in the last decade. Liquid biofuels, including ethanol and biodiesel, account for nearly all current biofuels use. Ethanol or ethanol-derived ETBE are used in the gasoline market while biodiesel is used to replace petroleum diesel. Ethanol is used in the greatest volumes, but biodiesel is experiencing the most rapid rate of growth. Biogas is also available commercially in limited markets, particularly in Europe.

The increasing use of biofuels has been spurred in substantial part by policy decisions over the past few years that help biofuels compete in the market. The policy decisions recognize the value of biofuels to the nations and regions that use them. Biofuels help countries meet their goals of reducing carbon dioxide emissions, meet their goals of reducing imports of petroleum, and meet their goals of local and regional economic development.

As the demand for biofuels continues to increase in the future, new production technologies will be required to utilize a greater range of feedstocks than are commercially feasible at present. The future production of ethanol, for example, is expected to include both the use of traditional grain/sugar crops and lignocellulosic biomass feedstocks such as wood, corn stover or wheat straw. As a result of R&D activities in this area over two decades, the advanced technologies for utilizing the lignocellulosic feedstocks are now being tested at large-scale proof-of-concept facilities operated by industry.

The IEA Bioenergy Task 39 on Liquid Biofuels was established in 2001 to assist the participants with the implementation of liquid biofuels. The Task was formed by integrating previous IEA Bioenergy Tasks 26 and 27. Task 26 dealt with the technical issues of producing ethanol from lignocellulosic feedstocks, and Task 27 dealt with the policy and regulatory issues influencing the implementation of biofuels. The goal of Task 39 has been to encourage cooperation across the broad range of topics relating to biofuels.

This report outlines the major projects conducted by Task 39 in the period from 2001 through early 2004. Task 39 is a continuing collaboration, and work from 2004 and beyond will be reported separately. Overviews of the major projects are provided and summaries of primary findings are outlined. In addition, detailed reports prepared during this effort are attached as appendices.

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1.0 INTRODUCTION

1.1 The Importance of Biofuels

In the past decade, the use of biofuels has increased dramatically to a total volume of approximately 30 billion (30×10^9) liters in 2003. The increase in the use of biodiesel has been particularly rapid, growing from essentially zero in 1995 to more than 1.5 billion liters in 2003. The use of ethanol and ethanol-derived ETBE (ethyl tertiary butyl ether) has also grown steadily, experiencing a nearly 3-fold increase in a decade.

The increase in biofuels utilization has also been accompanied over the past 3-4 years with policy decisions that encourage future growth of these fuels. In North America, policies which help grain-based ethanol compete in the market were extended, and additional policies to increase biodiesel utilization are being discussed. In Europe, guidelines to ensure motor fuels contain certain levels of alternate fuels have been established, and biofuels are expected to be the primary way these goals are met. In South America, Brazil also continued policies that mandate at least 22% ethanol on motor fuels and encourage the use of vehicles that use hydrous ethanol to replace gasoline.

The basic driving forces behind the growth of biofuels are similar throughout the world. First, biofuels help countries meet their goals of reducing emissions of carbon dioxide to the atmosphere. Biofuels are produced from plant-derived materials which "recycle" carbon dioxide from the atmosphere, thus reducing the overall emissions of CO_2 as compared to petroleum fuels. Current analyses consistently show that biofuels produced in modern facilities result in lower carbon dioxide emissions than the use of petroleum fuels. Second, biofuels reduce the dependence of countries on imported petroleum. The domestic production of biomass resources provides a secure source of raw materials relatively unaffected by international disruptions. In addition, the use of biofuels allows countries to coordinate their agricultural and energy policies while creating local and regional economic development opportunities. While the relative importance of each of these priorities may vary by region, countries using biofuels attain benefits in all three of these areas.

Ethanol continues to be the most widely-used biofuel. Produced primarily from grain and sugar crops, ethanol is widely blended with petroleum gasoline. Low concentration blends ($\leq$ 10% by volume) are common in North America and in some locations in Europe. Higher concentration blends (~22%) are used in Brazil. ETBE (ethyl tertiary-butyl ether) produced from ethanol is also used in low-concentration blends in France and some other European locations. Blends containing 85% ethanol (E-85) are available in some North American and European cities for use in "flexible fuel" vehicles, which are capable of operation on gasoline or blends up to E-85. Hydrous ethanol (the azeotrope containing 96% ethanol and 4% water) is used in Brazil in vehicle manufactured for this purpose. In the future, ethanol will likely be produced not only from grain and sugar crops but also from lignocellulosic

biomass. These feedstocks greatly expand the amount of resource available for ethanol production. Ethanol from these feedstocks has been the subject of R&D over three decades, and this technology is now in the near-commercial stage of demonstration and process verification.

Biodiesel, produced from the esterification of vegetable oils or waste fats, is rapidly growing in importance. Biodiesel growth has been most rapid in Europe where a greater percentage of vehicles have diesel engines, but significant growth has also occurred in North America. Biodiesel is typically used in both North America and Europe as 5-20% blends (B5 – B20) with conventional diesel fuel, and B100 is used in considerable quantities in Europe.

Biogas from the anaerobic digestion of biomass and wastes is also used as a biofuel in a few locations. The gas, primarily methane, is compressed and used in vehicles equipped for using natural gas. Biogas is available at fueling stations in a limited number of locations including some major cities in Europe. The total contribution of biogas is less than 1% of the total biofuels used for transport.

Because of the importance of biofuels in meeting environmental, energy security, and economic development targets, many countries have increased their interest in these fuels. To help the implementation of biofuels, countries are making policy decisions that allow biofuels to compete in the marketplace. The policy decisions include taxation-based incentives, fuel mandates and other policies that create markets for biofuels. Many countries are also conducting R&D efforts to resolve remaining technical issues relating to biofuels. The research efforts are aimed at finding ways to more efficiently convert a wider range of biomass feedstocks to ethanol and biodiesel, and to create additional non-fuel products that enhance the overall financial performance of the biorefinery. Research is also being conducted to examine other potential "second-generation" products that would serve as biofuels such a DME (dimethylether).

1.2 IEA Bioenergy Task 39, Liquid Biofuels

To better understand the both the policy and technical influence the implementation of liquid biofuels, IEA Bioenergy established Task 39 on Liquid Biofuels. The overall goal of this work was to provide an information exchange network that would provide technical and policy information to participating countries to assist them with the implementation of biofuels.

Task 39 is part of the IEA Bioenergy Agreement. The International Energy Agency (IEA) is an international agreement that provides a mechanism for participating countries to exchange information and conduct collaborative RD&D activities on energy-related topics. More information about International Energy Agency is available at www.iea.org.

As part of this effort, the IEA Bioenergy Agreement was established in the late 1970's to deal with the area of bioenergy. IEA Bioenergy has established several Tasks dealing with high-priority aspects of biomass production, conversion and utilization. More information about IEA Bioenergy including lists of country contacts is available at www.ieabioenergy.com.

In 2001, IEA Bioenergy initiated Task 39 to provide participants with a comprehensive approach for dealing with the complex technical and infrastructure issues relating to biofuels. The Task was a combination of two previous IEA Bioenergy Tasks, Task 26 which dealt with the technical issues related to lignocellulosic ethanol, and Task 27 which dealt with policy and regulatory issues.

The Task had ten participants including Austria, Canada, Denmark, Finland, Ireland, Netherlands, Sweden, United Kingdom, United States, and European Union. United States served as the Operating Agent, or project leader, for this work. Participants exchanged information and conducted analysis activities to provide governments, policy makers, and stakeholders with improved information on non-technical issues related to biofuels. This three-year effort was completed in early 2004, and this report summarized the progress during that period.

At the beginning of 2004, continuation of Task 39 was authorized for a second three-year period, and the effort is continuing with Canada serving as Operating Agent. Information about the ongoing effort is located at www.forestry.ubc.ca/task39.

1.3 The Task 39 Work Programme

The overall objective of Task 39 was to establish an information exchange network that would provide technical and policy information to participating countries to help them with the implementation of biofuels. The work programme had four main elements including

1. Providing information and analyses on policy, regulatory and market issues to help participants encourage the establishment of the infrastructure for biofuels as a replacement for fossil-based biofuels.

2. Catalyzing cooperative research and development projects to help participants develop improved, cost-effective processes for converting lignocellulosic biomass to ethanol.

3. Providing information and analyses on specialized topics relating to the production and implementation of biodiesel technologies.

4. Providing for information dissemination, outreach to stakeholders, and coordination with other related groups.

The projects in these areas are summarized below, and more detailed discussions of results are provided in the following sections of this report.

1.3.1 Providing Information and Analyses on Policy, Regulatory, and Market Issues

The Task completed three major reports in this area. These reports primarily address implementation issues but also address technical issues.

Two of the reports addressed the issues relating to ethanol as a liquid biofuel. Ethanol continues to be the most prevalent biofuel, particularly in North America. One report analyzes North American ethanol production to provide updated information on this biofuel. This report focuses primarily on the existing commercial industry but also provides an overview of the status of advanced conversion technologies for producing ethanol. The second report provides an analysis of the issues that will have to be addressed to bring ethanol from advanced conversion technologies into successful production.

- Analysis of North American Ethanol Production

  This report examined the status of the fuel ethanol industry in North American and its recent evolution. The report provides an update of growth over the past five years and discusses critical success factors relating to this growth. The report provides a summary of economic and market impacts relating to fuel ethanol and the impact of co-products on ethanol fuels. The report also provides a summary of prospects for next-generation biological and thermal conversion technologies for producing ethanol. A summary of the findings of this report are provided in Section 2 of this report, and the full report is attached as an appendix.

- Analysis of Implementation of Ethanol from Lignocellulosics

  This report examines the needs and possible strategies to assist the implementation of ethanol from lignocellulosic biomass. The initial facilities producing lignocellulosic ethanol will have higher risk and likely higher production costs than established grain-based facilities. This report discusses the implementation issues associated with getting lignocellulosic ethanol into a very competitive marketplace and provides possible strategies that could be employed to achieve this goal. The report is summarized in Section 2 of this report and is attached as an appendix.

The Task produced a third report on implementation of biodiesel in North America. Implementation of biodiesel in this region has bee slower than in Europe. The report examines the current state of the industry in this region and provides analysis of the implementation issues.

- Analysis of Biodiesel Implementation Issues in North America

  This report examined the issues relating to implementation of biodiesel in North America. The report provides a market overview and summary of 5-year growth, and it discusses feedstock supply and cost issues. The report also analyzes biodiesel cost and market price issues in North America and the opportunities for co-products to help process economics. The findings of the report are summarized in Section 3 of this report and the complete report is attached as an appendix.

1.3.2 Catalyzing cooperation to help participants develop improved, cost-effective processes for converting lignocellulosic biomass to ethanol

The primary effort in this area was the continuation and expansion of the information exchange network started in previous Tasks. The Task organized two types of workshops including:

- Specialists Workshops

  The Task organized two specialists' workshops to provide participants with detailed information on the technology and business developments in the area of lignocellulosic biomass. A Workshop held in York, England, in November 2002 focused on the status of technology developments for lignocellulosic biomass. A follow-up workshop, held in Denmark in November 2003, continued the examination of lignocellulosic ethanol and its advancement toward commercial practice. In each case, industry leaders, government representatives, and lab/university researchers were brought together to discuss the latest advancements in ethanol production. Proceedings of each of these workshops are attached as appendices to this report.

- IEA Sessions at Major Technical Meetings

  The Task organized technical sessions at the Symposium series "Biotechnology for Fuels and Chemicals" held annually in North America. These sessions were organized to provide an international perspective on the RD&D developments in lignocellulosic biomass conversion. Sessions were organized in the meetings held in Breckenridge, Colorado in 2001 and 2003, and in Gatlinburg, Tennessee in 2002. Summaries of these meeting sessions are provided in the Newsletters published by the Task. Proceedings of two of these meetings were prepared and are attached as appendices.

1.3.3 Providing information and analyses on specialized topics relating to the production and implementation of biodiesel

Task 39 produced four additiona reports focused on the rapid growth of biodiesel, particularly in Europe, but in other locations as well. The two reports include:

- World-Wide Review on Biodiesel Production

  This report summarizes the production of biodiesel on a world-wide basis and provides detailed information on a country-by-country basis. The report addresses the growth of biodiesel over the past few years and describes driving forces behind this growth. The report is summarized in Section 3 of this report, and the complete text is attached as an appendix.

- World-Wide Review of Biodiesel Standardization

  This report provides a detailed overview of biodiesel standardization on a world-wide basis. The report provides details about the standards that are in place, the background on those standards, and the details about each. This report is summarized in section 3 of this report, and the complete report is attached as an appendix.

- Best Case Studies on Biodiesel Production Plants in Europe

  This report provides information about the specific biodiesel producers in Europe. It includes information about the processes used and other information from facilities that are in operation. The report is summarized in Section 3, and the complete text is attached as an appendix.

- Rapeseed Oil for Farm Tractors

  This report addresses the use of unmodified vegetable oils as fuels for farm machinery. The report examines the need for quality standards for the vegetable oils and provides additional information related to on-farm use of these fuels. The report is summarized in Section 3, and the complete report is attached as an appendix.

1.3.4 Providing for information dissemination, outreach to stakeholders, and coordination with other related groups

The Task conducted several activities in this area as summarized below:

- Development of a Web Site

  The Task developed a web site located at www.forestry.ubc.ca/task39. This site will remain active through at least 2007 and will incorporate new information as Task 39 continues.

- Overview Brochure on Liquid Biofuels

  Task 39 prepared brochure that provides a summary overview of the status of biofuels. A copy of that brochure is attached as Appendix 1 to this report. The report was distributed as part of the IEA Bioenergy Annual Report for 2003 and as a stand-alone publication.

- Newsletters

  The Task published seven newsletters during the Task period. These are available at the Task 39 web site listed above.

- Interactions with Others

  The Task had interactions with numerous other groups and stakeholders. A summary of these interactions included:

  - *Involvement in other international meetings and seminars.*
    Task 39 actively participated in international workshops on biofuels beyond those initiated by the Task itself. Task 39 helped organized and made presentations at the 4th European Motor Biofuels Forum in Berlin, Germany in

November 2003. The Task also helped organize a session on biofuels Windsor Workshop Transportation Technology and Fuels Forum in Windsor, Canada. The meeting, originally scheduled for 2003, was postponed to June 2004 in response to public health concerns relating to a viral outbreak.

- *Interactions with other IEA groups*
  The Task interacted with other IEA groups in several ways. Task 39 provided input and a detailed review for a book on Liquid Biofuels being produced by IEA Headquarters. The book was published in 2004. The Task also provided assistance in planning discussions with other IEA Implementing Agreements on a joint effort related to hydrogen production and utilization. Task 39 also interacted with other IEA Bioenergy Tasks in a variety of ways.

- *Interactions with other Groups*
  The Task interacted with other groups and stakeholders. The Task participated in a project funded by the European Commission to gather information on biomass-based processes. Titled the Clear Views on Clean Fuels, or "VIEWLS", the project is collecting data and providing a database for bioenergy and biofuels. Task 39 provided information primarily related to North America to the project on an "in-kind" basis.

1.4 Organization of this Report

As described above, Task 39 produced numerous reports and meeting proceedings. Reports and Proceedings relating to ethanol production and utilization are discussed in Section 2 of this report. Reports relating to biodiesel production and utilization are discussed in Section 3 of this report. The complete reports and Proceedings in each area are attached as appendices. Section 4 of this report provides a summary of the overall findings of this work.

The work of IEA Bioenergy also includes separate stand-alone reports attached as appendices:

Appendix 1: Biofuels for Transport.

Appendix 2: North American Fuel Ethanol Industry. Review of Industry Growth 1999-2003.

Appendix 3: Ethanol from Lignocellulosics: Views to Implementation.

Appendix 4: Current State of Fuel Ethanol Commercialization. Proceedings of the Specialists Workshop, York, UK, December 11-12, 2002.

Appendix 5: Current State of Fuel Ethanol Commercialization. Proceedings of the Specialists Workshop, Copenhagen, Denmark, November 19-22, 2003.

Appendix 6: Current State Of Lignocellulosic Fuel Ethanol Commercialization. Proceedings of the Special Topics Session B. Breckenridge, CO, May 3-7, 2003.

Appendix 7: World-Wide Review on Biodiesel Production 2003.

Appendix 8: Review on Biodiesel Standardization World-Wide.

Appendix 9: Best Case Studies on Biodiesel. Production Plants in Europe.

Appendix 10: Biodiesel in North America: Implementation Issues.

Appendix 11: Rapeseed Oil as Fuel for Farm Tractors

2.0 TASK 39 STUDIES RELATED TO THE USE OF ETHANOL AS A BIOFUEL

2.1 Introduction

Ethanol remains the most-used biofuel in the world at present, with wide-spread implementation in North and South America and increasing implementation in Europe. Task 39 performed extensive work related to the production of ethanol. Reports on the production of ethanol included:

- A report updating the status of ethanol production and implementation issues in North America
- A report addressing the special implementation issues related to the introduction of ethanol from lignocellulosic biomass feedstocks.

In addition, Task 39 continued and expanded an information exchange network related to the technical progress of technologies for using advanced processing technologies to produce ethanol form lignocellulosic biomass. The information exchange network organized several specialists' workshops and technical sessions at major meetings. As a result of these meetings, the Task published:

- Proceedings of Specialists Workshops
- Proceeding of technical sessions at major Conferences

The reports and proceedings relating to ethanol production are summarized in this Section, and the complete reports and proceedings are attached as appendices.

2.2 Analysis of North American Ethanol Production

2.2.1 Project Overview

Task 39 conducted a study to update previous work on ethanol implementation in North America and to examine selected technical and market issues. The work was conducted by Don O'Connor at S&T Squared Consultants in Delta, British Columbia, Canada.

The report updated information developed by the previous IEA Biofuels Task and addressed the following issues:

- Growth of the industry over the past 5 years
- Discussion of critical growth factors resulting in rapid growth
- Summary of economics and market impacts including examination of correlations between demand and product cost
- Impacts of co-products on ethanol implementation including effects of distillers dried grains (DDG)
- Update of the status and prospects for next-generation ethanol technologies including advanced biological and thermal processes

2.2.2 Summary of Results

The following summary of results is from the Executive Summary of this Report. The complete report is attached as Appendix 2.

EXECUTIVE SUMMARY

The fuel ethanol industry has grown rapidly in the United States over the past five years. Production has doubled from 5.3 billion liters to 10.7 billion liters between 1998 and 2003. About 40% of the increase has been from the expansion of existing plants and 60% from new plants being constructed. New plants that are expected to come on-line in 2004 will add an additional 2.1 billion liters of production capacity.

There has been no increase in the production capacity in Canada over this time period although imports of ethanol from the United States have increased which indicates that the market for ethanol blended gasoline in Canada has been increasing.

The primary demand for fuel ethanol in Canada and the United States has been as a blending agent with gasoline. Ethanol gasoline blends were sold in 38 states in 2002 according to US FHWA statistics and at least two of the remaining states did sell ethanol blended gasoline but are not included in the official data for some reason.

Large increases in ethanol used in both conventional and reformulated gasoline have been experienced in the US. The growth in the RFG market has been driven primarily by problems with MTBE blended gasoline contaminating groundwater. Seventeen states have passed legislation banning the use of MTBE in gasoline. The most significant states have been California, New York, and Connecticut.

Ethanol is also being used in growing quantities in E85 blends. Millions of flexible fuel vehicles have been sold in the United States over the past five years but less than 5% of them are estimated to be using the fuel on a regular basis. Demand for this application of ethanol is over 40 million liters per year.

The United States is also a significant exporter of fuel ethanol. Brazil has been a customer in the past but was not a customer in 2002. Canada, Mexico and Taiwan are the most significant customers although Mexico may be an importer of industrial ethanol rather than fuel ethanol. Canadian imports of US ethanol reached 105 million liters in 2003. The United States also imports some ethanol. Most of the fuel ethanol (200 million liters) is imported duty free under the Caribbean Basin Initiative. The US imports about 35 million liters per year from Canada. The ethanol trade between Canada and the US is split on a geographic basis, with Canada exporting in the west and importing in the east.

The price of ethanol has moved between $1.00 and $1.50 per gallon for most of the past 15 years. There are some regional price differences that are caused by local supply and demand factors and transportation costs. Of perhaps more interest than the absolute price of ethanol is the understanding of how ethanol is priced relative to gasoline. In the past ten years, ethanol has sold at both a premium of about $0.40 per gallon to gasoline and at other times a discount of $0.40 per gallon to gasoline. Ethanol's price relative to gasoline was found to correlate with the ethanol inventory position.

If there are more than 35 days of ethanol supply in the system then ethanol will sell at a discount to gasoline and if there are less than 35 days on hand then ethanol sells at a premium to gasoline. This relationship is a function of the two types of gasoline markets that is sold in, the regulated RFG and Winter Oxyfuel markets and the more price sensitive conventional gasoline market.

The production of DDG has more than doubled in the past five years as dry mill plants become a larger proportion of the production mix. DDG is still a small source of the vegetable protein meal supply in the United States with the combined production of soybean meal, corn gluten meal and corn gluten feed production being an order of magnitude higher than DDG production. The increased DDG production appears to have been easily absorbed by the market. DDG exports have been relatively stable since the mid 19990's. Exports of soybean meal have also been relatively stable but corn gluten meal exports of been declining. Overall, there has been a significant increase in the domestic consumption of vegetable proteins.

Canada is a small net exporter of DDG to the United States. There are imports of DDG into western Canada and exports to the United States in eastern Canada.

While increased DDG production has been absorbed by the market, there is a long term decline in the DDG price relative to soybean meal and corn gluten meal evident. This decline in price is also apparent in the pricing of corn gluten feed. DDG prices have been increasing slightly relative to corn gluten feed prices. The price of DDG is relatively well described by the following equation:

DDG=$51.78 + 0.256*SBM + 18.6*Corn -1.75*(Year-1981)

Where SBM is the price of soybean meal in $/ton, and Corn is the price of corn in $/bushel. There is an additional factor, which reduces the price by $1.75 per ton per year beyond 1981. With 56 pounds in a bushel of corn the corn term could also be expressed as 1.04*corn price in $/ton. DDG prices are generally lowest in the Midwest, the centre of production, and increase with freight costs to remote markets. Prices are highest on the east and west coasts of North America.

The per unit capital costs of new ethanol plants have declined over the past five years as plants have tended to become larger in size and the industry continues to become more efficient at building plants. The non-plant portion of the project costs can range from 15 to 25% of the total project costs. This portion covers factors such as interest during construction, permitting, capital funding, working capital and other factors.

There has not been any new plant construction in Canada over the past five years but several projects appear to be ready to start in 2004. In most cases, these projects are projecting much higher capital costs than are found in the United States. There is little detail available on these projects so it is not apparent what the reason for this is.

The cash cost of production for a typical dry mill plant has been calculated on a monthly basis and compared to the ethanol selling prices for the past twenty years. Through most of 2000 and 2001, the industry experienced a period of very good margins with the two year average margin being $0.49 per gallon before the consideration of any USDA Bioenergy payments or any direct state incentives. This period is certainly one of the most profitable in the industry's history. Through 2002 and 2003, the margins were much lower at $0.21 per

gallon. At this lower level, the plants will be able to service their debt but returns on equity will be very modest.

The rapid growth in the industry would not have occurred without the state bans on the use of MTBE. Future growth of the industry is dependent on either the continued reduction in MTBE usage or the introduction of a Renewable Fuels Standard, as has been proposed in the various versions of the Energy Bill that the US Congress is trying to pass. The conventional gasoline market could be accessed by future ethanol production but the margins that this segment netbacks to the industry are not high enough, at current gasoline prices, to provide the financial returns that the industry needs for rapid growth.

The emergence of the farmer owned plants and new generation co-ops was a factor in the rapid development of the industry. This corporate structure transferred some of the commodity price risk from the lenders to the feedstock suppliers and facilitated the acquisition of bank debt for many projects. The continued acceptable financial performance for most of the ethanol plants also helps to increase the level of comfort that lenders have with the sector.

It would appear that it is likely that the US Congress will pass some sort of energy legislation that includes a Renewable Fuels Standard in the near future. This should enable the continued profitable growth of the industry. The moves to address some of the issues created by the existing ethanol tax incentive through the VEETC will be helpful to the industry as will be the extension of the incentive to 2010. The tax incentive is important for ethanol to be able to access the conventional gasoline market. This market requires ethanol to be priced at a discount to gasoline. If a RFS is put in place and the conventional gasoline market as it exists today was not required to absorb all of the ethanol production then the industry could survive and likely flourish with a smaller tax incentive than currently exists.

The market for DDG is not a barrier to industry growth. It represents a relatively small proportion of the vegetable protein market. The industry efforts to expand the use of DDG beyond dairy and cattle rations will increase demand for the product and facilitate the growth. The long term decline in the price of DDG should be an issue for the industry to address. While some decline might be expected, the rate of decline is higher than that of the corn feedstock and is resulting in an increase in net feedstock costs over time. Since not all vegetable protein meals are experiencing the same trend, it may be possible to overcome the issue with DDG.

There continues to be a significant level of effort expended on the production of ethanol from lignocellulosic feedstocks. The US DOE, through NREL and others, has made significant progress in reducing the cost of enzymes required for many of the processes but the costs must be reduced by a further factor of about five for the processes to become economically attractive. Much of the recent success in reducing enzyme costs has come through a systems approach to the challenge where improvements were obtained not only in the reactivity of the enzyme but also in how it is produced and used. This systems approach has been used by Iogen for many years and it is likely that their production economics are currently better than that for any other technology developer in this field.

The thermochemical approaches to producing ethanol from lignocellulosic feedstocks are interesting but it is not clear that the advantages of converting all of the feedstock to ethanol instead of just the cellulose and hemicellulose will be sufficient to overcome the operational

issues of biomass gasification and the chemical synthesis of the producer gas to ethanol. None of the process developers of the various thermochemical pathways has yet reached the stage where serious systems development work can be undertaken.

2.3 Ethanol from Lignocellulosics: Views To Implementation

2.3.1 Project Overview

While ethanol is currently produced from sugar and grain crops, it is expected that lignocellulosic biomass will be come and important feedstock for this biofuel in the future. Lignocellulosic crops greatly expand the potential availability of the available biomass resource, particularly in Europe and North America. Extensive RD&D activities over the past two decades have resulted in significant technical progress toward this goal, and technologies to convert the lignocellulosic feedstocks are now being demonstrated in near-commercial demonstration facilities. The conversion technologies, being different than those for grain or sugar crops, currently entail greater risk, both technical and financial, than traditional approaches. For countries that have invested in developing this technology, it is important that there is a path forward which over time will reduce the risk and allow the conversion technologies to compete in the established market.

Task 39 prepared an analysis of the factors that will influence the implementation of lignocellulosic ethanol. The report provides a detailed discussion of these issues and provides views of how the implementation can be accomplished. The report was prepared by Warren Mabee, David Gregg , and Jack Saddler at University of British Columbia in Vancouver, Canada.

2.3.2 Summary of Results

The Executive Summary of the report is provided below. The complete report is attached as Appendix 3.

Executive Summary:

Creating a viable, commercial-scale lignocellulosic-to-bioethanol industry is an endeavour that will require the coordination of technical expertise within certain political, economic and environmental realities. A view describing where the industry is going and the challenges that must be faced along the way may be a helpful contribution.

An economical technology for bioconversion of lignocellulosic biomass, such as forest and agricultural residues, will greatly extend the potential of the ethanol industry to become a substantial contributor to the fuel and energy requirements of North America and Europe. The successful development of this technology will require the continued efforts of a range of participants in the areas of research, government, and industry, and an extended degree of cooperation between these parties. A greater chance of success in commercialization may be realized by linking participants with complementary characteristics.

Industrial participants in the commercialization of fuel ethanol from lignocellulosics may be characterized according to a number of factors, including the size of the organization, their interest in the process, and the policies under which they must operate. Small, entrepreneurial companies are often leaders in developing the technology and processes required for bioconversion. Larger companies have access to the resources required to support long-term development goals, and are connected to the marketplace and able to introduce new products more effectively than an entrepreneurial venture. Some industrial participants may be organized according to their interest creating products related to the bioconversion process; others focus on creating the technology and improving the process. Government participants view ethanol technology as a tool to achieve priorities in the areas of economics, the environment, or security. Reflecting these priorities are the policies of the state, province or nation in which the organization is based; these policies are instrumental in creating an atmosphere in which the industry can survive and thrive. A significant difference in the levels of subsidy, incentive and mandated use exists between different nations according to their political priorities, and these political realities must be incorporated in a commercialization plan.

To illustrate the different challenges faced by various participants in the lignocellulosic-to-ethanol industry, the report provides two case studies. British Sugar is an established sugar-producing firm based in the United Kingdom. They are currently seeking ways in which they might use the agricultural residues associated with sugar beet production, and they have identified ethanol as a possible product from the process. Lignol is an entrepreneurial venture based in Canada. This organization is attempting to create a process capable of generating a stream of value-added, lignin-based products from sawmill or forestry residues. Ethanol is a by-product of this process. These two examples will be called upon to illustrate the various strategies and concepts that different roadmaps to commercialization might entail.

The participation of government in the commercialization process is essential to facilitate the growth of the industry. To a large extent, the future of the liquid fuel from lignocellulosics industry is dependent upon national and supra-national priorities in the realms of economics, the environment, and security. To meet priorities in these areas, governments will continue to develop policy, which in turn may support the ethanol industry. The industry's challenge is to clearly describe the potential benefits of lignocellulosic-to-ethanol technology within the context of national priorities, and to explore the opportunities that these priorities may provide the industry.

The ability of ethanol to contribute positively to the environmental performance of a country makes the nascent industry a valuable tool for policymakers, and connects the potential performance of the industry to the influence of environmental policy. The issue of climate change has become a major concern for all people, but the sectors most closely linked to ethanol 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 many European nations and by Canada in North America. The Clean Skies Initiative in the U.S. is another example of these policies. Because the use of ethanol has the potential of reducing net greenhouse gas emissions

significantly over petroleum products, an expansion of ethanol production may become a significant part of national climate change strategies. Indeed, Canada has recently announced a commitment of $100 million over five years to boost ethanol production, and an additional $30 million to fund research into biofuels. These funds represent a significant portion of the overall Canadian budget for meeting Kyoto Protocol requirements, and hints that the Canadian political perspective on ethanol is indeed predominantly environmental.

Another point of view realizes that ethanol production can be a tool for economic development, which in turn may or may not be utilized to bring about social change. This perspective targets employment and economic diversification. Social diversification can be engineered, predominantly in rural areas. Local level governments are more likely to utilize ethanol production facilities in this manner. For example, the government of Minnesota has instituted incentives for the construction of ethanol production facilities that are smaller than 15 million tons per year. By instituting this cap on plant size, the government has spurred the creation of multiple mills where a single facility might otherwise have been built. Major political support has come from elected state and federal government officials, who have a mandate to support their electorate and thus have crafted incentives to develop the industry in agricultural regions. As a result, major centres of biofuel production have developed in the Midwest, with the majority of production centered in Illinois, Minnesota, Nebraska and South Dakota. Since 1976, over 70 new ethanol production facilities have been built in the U.S., with thirteen additional plants slated to open in the next two years. When one considers increased employment on the farm and the secondary jobs created to provide equipment and services for these operations, this can be translated into an estimated 200,000 new jobs and $500 million in annual tax receipts. This has led to the creation of both direct and indirect employment, and has had the added benefit of improving ethanol technology significantly. The U.S. perspective on ethanol would seem to be predominantly economic and social.

Finally, ethanol production can be viewed as a tool for increasing energy security. This outlook reflects the need to provide a renewable energy source to replace existing fuels, as the existing reserves of fossil oil are being consumed at an increasing rate, and the discovery of new reserves is in decline. It also recognizes that ethanol may be an important tool in reducing reliance upon foreign-owned oil supplies, which are subject to political uncertainty. Many pundits have argued that access to oil reserves played a role in the conflict and destruction currently seen the Middle East, particularly in countries such as Iraq. The European Union has overtly embraced the security doctrine by including it as a major point in their Directive on the promotion of the use of biofuels for transport.

With an idea of the national priorities that are shaping the industry in place, it is possible to identify some of the challenges that the ethanol industry will face in different political climes. It must be recognized that the industry can satisfy each of these three perspectives, but that some policies will be better suited to one or two particular goals. For instance, environmental policy to reduce greenhouse gas emissions will indirectly support ethanol production. This type of policy can be applied across the full range of the ethanol supply chain, and can be brought to influence biomass generation, biofuel use, or the bioconversion process itself. Policy designed from the environmental perspective will likely focus on maximizing the effectiveness of greenhouse gas reduction, within the most basic economic

constraints. The onus will be on the industry to prove the effectiveness of the bioconversion process at reducing greenhouse gas emissions, and to lobby their government for recognition of this service. Industrial participants working under an environmental perspective will be best suited to establishing partnerships along the supply chain, in order to maximize the potential benefits associated with the policy.

Some industrial requirements may be difficult to achieve under an environmental policy perspective; such a policy would not necessarily support the creation of pilot or demonstration plants, which is a necessary stage in the creation of a viable industry. On the other hand, economic policies designed to support the creation of a sector are much more likely to be directly applicable to technology development and demonstration. This is likely to be true even when social concerns, such as economic diversification and employment, are the highest priority. Under this type of scenario, it must be recognized that the most effective social strategy will be to focus on small to midsize plants that optimize employment at the local level, and that large plants where economies of scale can be brought into play may be precluded. In fact, the experience that Minnesota has had with smaller ethanol production facilities indicates that a series of smaller facilities may be the most effective way to evolve and improve the bioconversion process.

Policy designed with a strong security perspective may have the largest effect on bioconversion of lignocellulosics to ethanol in the future, although it is difficult to forecast the effectiveness of this approach. A component of this type of policy is the inclusion of rising mandates for biofuels within the fuel supply. These mandates are designed to reduce the requirement for foreign oil, and have the potential to be independent of the normal pricing structure applied to fuel, although it is unlikely that the political fallout of rising fuel prices could be offset by the security argument for an extended period. It should be noted that these types of policies are not likely to be applied in isolation of economic or environmental policies designed to support the industry. The only current example of this type of policy exists with the European Union's directive on biofuels, which is only now coming in to effect. Despite the evolution of the biorefinery concept, ethanol has yet to play a major role in the fuel supply of any nation outside of Brazil. It has not been demonstrated that a significant proportion of the fuel supply can be supplied by ethanol sustainably, in North America or Europe.

The cost of ethanol manufacture remains relatively high. Because of this, these fuels presently have significant potential only in those locations where governments provide policies and incentives that encourage their use. The positive social and environmental aspects of ethanol will always make this technology an attractive policy option, but the long-term success of the ethanol industry will require technological breakthroughs and refinements as well as political support. The outlook for commercialization is thus divided into two distinct phases. 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 must continue to sponsor research and development efforts to reduce the cost of biofuels so they can compete more effectively in the marketplace. In the long term, the viability of biofuels will be dependent upon the availability economically competitive processes for bioconversion

The first step in the road to commercializing ethanol from lignocellulosics should be to identify winning strategies that have been employed by the sugar- and starch-based portions of the industry. In this case, the two most dominant producers and consumers of ethanol fuel – the United States and Brazil – have each achieved success primarily through policy-based initiatives. In the short-term, policy is identified as the principle tool for successful commercialization.

As immediate political and technical concerns are surpassed, a pattern of growth for the lignocellulosic-to-ethanol industry may be discerned. A review of residue availability illustrates the obvious locations for future industrial facilities. In the medium-term, issues regarding biomass availability will be of paramount concern to the industry.

Even today, there are technological options for the lignocellulosic-to-ethanol process which affect the future development of the industry. While one option is to focus attention on process efficiency and capacity, the choice of product diversification or biorefining has many benefits for ethanol producers. The biorefinery concept allows for the production of bioproducts, biofuels and bioenergy within the same facility. As with petroleum refineries, some of the products of the process can be very high value, which means that the concept of biorefineries has great economic potential. In the long-term, the biorefinery concept will make the manufacture of ethanol economically and environmentally sustainable, and will make energy security through renewable fuel use an attainable goal. Thus, the biorefinery strategy is presented as a path for ethanol producers to follow.

2.4 Ethanol from Lignocellulosic Biomass: Information Exchange Workshops

2.4.1 Project Overview

A significant part of IEA Bioenergy was the continuation of an information exchange network on conversion of lignocellulosic biomass. As shown in previous IEA Bioenergy Liquid Fuels tasks, as well as by others, lignocellulosic biomass is an essential resource for the future production of ethanol biofuels. Current ethanol is produced from grain and sugar crops, and while these resources can be expanded, the availability of land to grow these crops is ultimately limited. The limitations are particularly significant in Europe but also important in North America. Lignocellulosic biomass provides the potential for a larger biomass resource and hence higher levels of ethanol production.

The IEA Bioenergy information exchange network on lignocellulosic ethanol began several years ago as part of previous Tasks. The network initially focused on the basic science and engineering research necessary to convert lignocellulosic biomass to ethanol. The basic nature of the information exchange reflected the state of development of the technology at that time.

As extensive progress has been made over the past decade or more, the IEA Bioenergy information exchange network has both continued its discussion of the basic biology and engineering issues that underpin technology, and has also expanded participation to

include representatives of the developing industry and government decision makers in the discussions.

IEA Bioenergy Task 39 organized conferences and specialists workshops as the primary means of continuing the information exchange. Two specialists' workshops were organized to discuss the "Current State of Fuel Ethanol Commercialization". These included a range of scientists, engineers as well as government and industry representatives. The two included an initial specialist's workshop hosted by British Sugar in York, UK, in November 2002 and a second meeting in Denmark in November 2003. In addition, the Task organized focused sessions at the "Symposium on Biotechnology for Fuels and Chemicals" series held annually in USA. The purpose of these sessions was to highlight recent international progress at this major meeting.

2.4.2 Summary of Results

Task 39 prepared Proceedings three meetings including:

Specialists Workshops:

The Task prepared Proceedings of both the York and the Denmark Workshops on the "Current State of Fuel Ethanol Commercialization". These include the presentations or abstracts of most presenters. The Proceedings of the Denmark workshop also includes a summary of the sessions. The Proceedings of the York meeting are attached as Appendix 4, and those of the Denmark meeting in Appendix 5.

Symposium Technical Sessions:

The Task prepared Proceedings of the session held May 5, 2003 in connection with the 25th Symposium on Biotechnology for Fuels and Chemicals, held in Breckenridge, Colorado. The Proceedings contains presentations of most of the presenters. The Proceedings are attached to this report as Appendix 6.

3.0 TASK 39 STUDIES RELATED TO THE USE OF BIODIESEL AS A BIOFUEL

3.1 Introduction

Biodiesel is the biofuel experiencing the most rapid growth at present. Task 39 completed five reports relating to the use of biodiesel as a fuel. These included the following:

- A report providing updated information on the world-wide use of biodiesel as motor fuel
- A report providing an update on the world-wide efforts on biofuels standardization
- A report analyzing the "best-case" studies of biodiesel implementation in Europe
- A report analyzing biodiesel implementation in North America
- A report analyzing the use of un-modified vegetable oils for on-farm uses

The reports and proceedings relating to biodiesel production are summarized in this Section, and the complete reports and proceedings are attached as appendices.

3.2 World-Wide Review On Biodiesel Production

3.2.1 Project Overview

Having completed the first IEA-report on the world-wide production of Biodiesel production in December 1997, the Task provided an update of that information. The method applied was approaching targeted active and potential actors with a short questionnaire in electronic and hard copy versions with approx. 280 detailed responses from all over the world. The report was prepared by W. Körbitz, St. Friedrich, E. Waginger, and M. Wörgetter.

3.2.2 Summary of Results

A summary of the findings from the study are provided below. The complete report is attached as Appendix 7.

Abstract:

Legislation: Legislative actions are a required basis for implementation, and several initiatives for pace setting legislation were established. The mechanisms include defining market share targets in the European Union (EU), by establishing subsidies to feedstock usage in the USA and by requiring renewable energy usage in Australia. Recognition of the need to reduce greenhouse gas emissions was the largest single motivating factor.

Feedstock: Rapeseed production on set-aside non-food acreage represented the most important feedstock source in the EU, with recycling oils growing quickly in importance, while soybean was the oilseed of choice in the USA and South America and palm oil is being in consideration in Malaysia.

Technology: Process technology and engineering companies were striving for continuously improving the required Biodiesel quality and for reducing production cost with an increasing number of such companies providing reliable quality at low investment cost.

Fuel Quality: Biodiesel fuel quality reached a level of high quality definition by establishing the European standard EN 14214, the US standard ASTM D-6751-02 and the Australian Biodiesel fuel standard, with an effective quality management system in Germany (AGQM).

Marketing Strategies: New marketing strategies, which vary by country, as one can observe the pure Biodiesel usage, the anonymised blend as well as a "blend & brand" strategy, and also strategies selling only on a low price, while others are promoting the differential advantages at a higher price.

Regional Production: In world-wide production Europe took the lead with more than 1.6 mill t Biodiesel produced in 2002 (at capacities of approx. 2,1 mill t), with Germany producing 580 000 t, France 400 000 t, Slovakia 120 000 t (in 2001) and the Czech Republic producing 70 000 t, while the USA were second to Europe with approx. 40 000 t production and Australia being in the phase of establishing 48 000 t production capacity. New initiatives in Brazil, Canada, Malaysia and the United Kingdom may change however this situation quickly.

3.3 World-Wide Review of Biodiesel Standardization

3.3.1 Project Overview

Standardization is an important issue for biodiesel. Since biodiesel is different chemically than petroleum diesel, it is important to have standards that clearly define the qualities of the product. Such standards are important in establishing commercial markets for biodiesel and ensuring that consumers have a product that is suitable for vehicle use.

Over the past few users, standardization efforts in Europe and North America have resulted in well-define standards for biodiesel. This report summarizes the efforts in Europe and North America, provides background information on those efforts, and provides details of the specifications.

The report was prepared by BLT Wieselburg in Austria with input from a variety of sources. The report is summarized below, and the complete report is attached as appendix 8.

3.3.2 Summary of Results

Standardization is one of the key issues in the development of new products and markets. For the producers and distributors of biodiesel, standards are a vital necessity. Legislators and authorities need approved standards for the evaluation of safety and environmental risks. The development of engines, vehicles and equipment is based on the properties of the fuel; the range of the fuel parameters must be limited. The development of a new standard is complex and long-lasting task even on the national level. International standardization is the result of the co-operation of national standardization organization and enables the development international markets.

In respect of this aspects BLT initiated this review on biodiesel standardization worldwide. The study describes general aspects of the standardization process, important regulations and recommendations as well as and the state of the standardization in Europe, North America, Australia and Brazil. Standardization of biofuels is "work in progress", and therefore the Liquid Biofuels Task will try to continue the monitoring of the development.

3.4 Best Case Studies On Biodiesel Plants In Europe

3.4.1 Project Overview

The lack of knowledge on the successful implementation of biodiesel on national and international markets is a limitation to further development. Task 39 completed a report to document biodiesel facilities in Europe. The report was initially aimed at "Biodiesel Best Cases" including aspects of planning and financing, as well as technology and operation. During the study it became evident that the competition between the different companies of the Biodiesel industry does not allow a deep insight into success factors. However, data on companies, feedstock supply, installed technology, capacity, quality management and financial issues could be collected. The project was led by W. Körbitz of the Austrian Biofuels Institute, with support provided by Mrs. Waginger of the University of Economy in Vienna and from Biodiesel production plant owners, managers and engineers.

3.4.2 Summary of Findings

The following summary of primary findings is extracted from the abstract of the report. The complete report is attached as Appendix 9.

Abstract:

The Liquid Biofuels Task of IEA Bioenergy commissioned the Austrian Biodiesel Institute (ABI) to complete a detailed study "Best Case Biodiesel Production Plants in Europe" with the objective to give a comprehensive overview on the European Biodiesel industry and to select typical case examples out of the many existing Biodiesel industries.

Following an accelerating growth of Biodiesel production plants in number and volume over the past years in Europe this study had the task to present the impressive development of the European Biodiesel industry in the past decade according to well defined criteria and make this available to the interested Biodiesel community.

The European Biodiesel industry was carefully screened in a first step in order to identify candidate Biodiesel plants to be contacted in a second step and to finally ask to fill in a questionnaire, which was carefully developed at the ABI together with the Institute for Technology, University of Economy, Vienna, according a well defined set of success criteria.

The questionnaire was completed in mostly very close communication between the Biodiesel plant managers in charge and the ABI team. Additionally 10 plants were visited for further detailed search on the spot.

Basic company data, feedstock supply and usage, installed process technology, capacity, actual production and yield figures, Biodiesel quality management, financial issues and

ownership structure were requested as well as a self-evaluation by the Biodiesel plant manager along a list of best/worst criteria.

As a result this study contains detailed reports of 16 selected Biodiesel production plants in the range of 12.000 to 250.000 t Biodiesel production capacity from 7 European countries: Austria, Czech Republic, France, Germany, Italy, Slovakia, and Spain.

They vary significantly by e.g. type of feedstock used (refined or semi-refined oils, rapeseed or other vegetable oils, recycling oils, animal fats, trap grease, a.o.), feedstock supply (integrated oil mill, flexible oil purchasing), installed process technology (batch or continuous process, different catalysts, a.o.), size of production capacity, synergistic alliances (e.g. integrated fuel distributor as shareholder, joint glycerine refinery), transport cost (sea or river harbour site), they vary however not at all when it comes to quality assurance.

As one of the conclusion it becomes evident that a typical single best case solution does not exist, but that it takes careful consideration of all the potential positive and negative factors in order to exploit synergistic opportunities and to avoid risks.

3.5 Biodiesel in North America: Implementation Issues

3.5.1 Project Overview

Task 39 conducted a study to update and significantly expand previous work on the analysis of biodiesel implementation in North America. Implementation of biodiesel has been slower in North America than Europe, and the detailed analysis explores issues related to the differences. The report was prepared by Don O'Connor at S&T Squared Consultants in Delta, British Columbia, Canada.

The report provided information on the biodiesel in North America and compared that with production in other parts of the world. The report addressed the following issues:

- Market overviews including technology description and alternatives
- Summary of 5-year growth and discussion of growth factors
- Discussion of feedstock supplies and cost issues
- Summary of biodiesel production costs and market prices
- Discussion of co-products and opportunities/limitations including glycerol
- Discussion of other technical and non-technical implementation issues

3.5.2 Summary of Results

The following summary of results is from the Executive Summary of this Report. The complete report is attached as Appendix 10.

EXECUTIVE SUMMARY

The market drivers for biodiesel in Canada and the United States are slightly different. In

Canada, biodiesel's ability to reduce greenhouse gas emissions is the primary driver with the fuel's ability to reduce the emissions of criteria air contaminants a secondary driver. In the United States, biodiesel's impact on exhaust emissions has been an important factor in the success that the fuel has received. The agricultural support that biodiesel has received in the United States from governments and from agricultural producers has positively influenced the development of the fuel.

Energy security and diversity is a driving force in the United States but it is not an issue in Canada as Canada is a net exported of all forms of energy.

Biodiesel sales in the US are expected to reach almost 100 million liters in 2003. This product is being produced in 18 plants operated by 17 companies. There are no reliable estimates of biodiesel production or consumption in Canada for 2003. Development of the industry is behind the United States.

Canada and the United States both have significant resources that could be used as feedstocks for biodiesel production. Both countries are exporters of animal fats and exporters of processed vegetable oils and raw oilseeds. Some or all of these resources could be diverted from the export markets to produce biodiesel. The resources are summarized in the following table.

Biodiesel Feedstock Resources

	Canada	United States
Diesel Fuel Sales, 1,000 cubic meters	22,543,000	138,000,000
Biodiesel from exported Animal Fats, 1,000 cubic meters	280,000	1,450,000
% biodiesel of diesel sales	1.2	1.05
Biodiesel from exported Vegetable Oils, 1,000 cubic meters	2,300,000	8,200,000
% biodiesel of diesel sales	10.3	5.94
Total Biodiesel, 1,000 cubic meters	2,580,000	9,650,000
% biodiesel of diesel sales	11.4	7.0

There are a number of commercially developed technologies available for the production of biodiesel. Most of these involve variations of the traditional transesterification process. Some of the operating plants have imported their technology from Europe but there are a number of North American companies that have been developing their own production processes.

There are new biodiesel technologies being developed that utilize different processes such as the super critical processing being developed in Japan with produces a methyl ester from oils and fats. Processes that produce a slightly different product are also being developed. These include the NRCan Super Cetane process that converts fats and oils to pure hydrocarbons and the processes being developed to convert lignocellulosic feedstocks to FT Distillate fuels. These last two processes have the advantage of producing a product that contains no oxygen and is completely fungible with existing diesel fuels.

The characteristics of biodiesel fuels are becoming very well understood. There has been a

significant amount of work undertaken in North America to understand the impacts of different feedstocks on the properties of biodiesel.

The required biodiesel quality has been established in the US with the development of an ASTM standard for 100% biodiesel. Work is well underway for a similar standard in Canada. In both countries, it is expected that B5 blends can be made that meet the existing diesel specifications and the new biodiesel standard. Work is underway in both countries to develop specific standards for blends from B6 to B20.

As the biodiesel market develops it will be important to ensure that all biodiesel production meets required specifications. This may be a challenge for small plants not so much from a technical perspective but from a financial one.

The performance of biodiesel blends has been demonstrated many times in North America over the past ten years. There should not be any questions remaining of the performance of the fuel. Demonstrations are still useful not from a technical perspective, but as part of the diffusion process that must be undertaken to build confidence in the fuel among the broader market. The one performance issue that care must be exercised with is the impact that biodiesel addition has one the cold weather properties of diesel fuel. The negative influence of biodiesel on properties such as CFPP, pour point and cloud point are similar to the impact of using FT distillates as diesel blending components and a number of international oil companies are promoting that technology.

Very small levels of biodiesel in diesel fuel can dramatically improve the lubricity of diesel fuel. Diesel fuel lubricity is expected to becoming a larger issue over the next few years, as diesel fuel sulphur levels will be reduced to less than 15 ppm.

Biodiesel blends reduce the emissions of all exhaust emissions except NOx and the emission reductions are independent of the biodiesel feedstock. On a lifecycle basis the GHG emissions are also reduced but the reduction is dependent on the feedstock resource. The exhaust emissions impact for B20 is summarized in the following table.

Emission Impacts of 20 vol % Biodiesel Blend

	Percent Change in Emissions
NOx	+2.0
PM	-10.1
HC	-21.1
CO	-11.0

The GHG emissions reduction for a B20 fuel varies from 12 to 18% in Canada and from 12 to 16% in the United States. Larger reductions are found with the use of animal fats than with vegetable oils as the feedstock. There is some uncertainty regarding the production N20 emissions from plants that fix nitrogen from the air (such as soybeans) and this uncertainty does have an influence of the lifecycle GHG emissions. More work is required in this area.

Glycerin is produced as a co-product of the biodiesel production process. Both Canada and the United States import some glycerin to satisfy their markets. Large scale biodiesel production has the potential to reverse that situation and both countries would become exporters. Glycerin marketing will become an issue, for both countries once biodiesel

production reaches only about 10% of its production potential. There is some potential for the expansion of glycerin markets through the displacement of sorbitol in some applications. New glycerin markets will have to be developed before the full production potential of biodiesel is achieved.

Biodiesel production costs are dominated by the cost of feedstock. While some reduction in the total cost of production might be possible in the future through the experience gained building and operating biodiesel plants the impact of these improvements will be small. Biodiesel will need significant financial incentives to be cost competitive with diesel fuel.

Perhaps a larger issue in the longer term will be the commodity price risk that is inherent in biodiesel production and sale. Fixed value financial incentives will often not be enough for sustainable production or be too high for governments to tolerate. This situation will have a negative influence of the stability of the industry, as it is not likely that the petroleum industry will make a large commitment to biodiesel unless it is cost competitive with diesel fuel.

3.6 Rapeseed Oil for Farm Tractors

3.6.1 Project Overview

Task 39 prepared a report on the issues related to the use of un-esterified vegetable oil for on-farm applications. Vegetable oils are inexpensive and can potentially be used for on-farm uses close to where the crop is grown. The use of un-esterified vegetable oils in engines, however, involves more technical risk because the oils have different chemical properties than esterified biodiesel. The variability of un-esterified oils can also increase technical risk. Task 39 prepared a report to examine the use of rape seed oil for farm tractor uses. The report addresses the qualities of the product, its use in diesel engines, and the need for fuel standards. The report was prepared by BLT Wieselburg and is summarized below. The complete report is attached as Appendix 11.

3.6.2 Abstract

In the development of vegetable oil fuels the adaptation of the fuel to conventional engines has been preferred in the last decade. Programmes for the alteration of the engines have only been supported to a low extent. Obvious advantages of changes in engine technology (low expense of oil production, decentralised solutions) are above all stressed by proponents in the agricultural and environmental sector.

If pure rapeseed oil is used as a fuel for tractors technical changes are required. For a market introduction technical and non-technical barriers have to be overcome.

The agricultural centre Weihenstephan has developed a rapeseed oil quality standard which could support the development of rapeseed oil as a fuel. A demonstration project ("100-tractors-project") supported by the German Federal Government is to provide results on the current state of technology of modification devices. First results show some problems, however, the difficulties seem to be fewer than expected.

In Austria a vegetable oil tractors project is also planned on the basis of the results of the German demonstration project. In this project which could already start in 2003, 35 modified tractors are to be operated with accompanying scientific reasearch.

4.0 SUMMARY OF OVERALL FINDINGS

The use of biofuels increased remarkably during the three year period in which this Task was active. Presently about 30 billion liters of biofuels are used annually, and this figure is expected to continue growing rapidly over the next several years.

Task 39 produced extensive data related to the implementation of biofuels in Europe and North America. This information is summarized in this report and documented in individual reports totaling several hundred pages in length. The authors urge readers to examine these reports, attached as appendices, to obtain additional information related to biofuels.

From the work of the IEA Bioenergy Task 39, several general conclusions can be reached. These conclusions are outlined in bullet format below. It is important to remember that these conclusions capture only a small part of the results of the work.

- Ethanol continues to be the most prevalent biofuel and is used widely in North America and Brazil. Lesser amounts are also used in parts of Europe, where ethanol is also converted to ETBE. Essentially all ethanol is produced from grain and sugar crops at present using conventional fermentation technologies.

- The technology for producing ethanol from lignocellulosic biomass is advancing, and demonstration facilities are in operation. The Canadian corporation Iogen, for example, operates a demonstration facility and provides small quantities of ethanol to the commercial market. Other demonstration facilities for lignocellulosic ethanol are nearing completion in the IEA countries.

- Ethanol from lignocellulosic biomass continues to be a subject of significant RD&D interest in many countries. The IEA Bioenergy Task provides a mechanism for information exchange to allow government policy makers, industry participants, and researchers to collaborate and share information.

- Successful implementation of ethanol from lignocellulosic biomass may require different policy mechanisms than those in place at present. The technologies for lignocellulosic biomass have greater technical and hence greater financial risk than conventional fermentation systems. Countries or regions wanting to use lignocellulosic resources may want to consider implementing policies that will help reduce the risk of generating ethanol in the first few lignocellulosic facilities. While these policies or incentives would likely be short-term in nature, they may be needed to move the advanced technologies into the fully commercial marketplace.

- Biodiesel use has grown at an even more dramatic rate than ethanol over the past three years, particularly in Europe where a substantial portion of the motor vehicles operate on diesel fuels. Numerous commercial biodiesel facilities have been established throughout Europe and the product is readily available as blends of 2 – 20% with

petroleum diesel, or as B-100 in many locations. The use of biodiesel is also expected to continue to grow substantially in the next few years.

- The biodiesel industry has become solidly established over the past 3-5 years, growing from near zero production in the mid-1990's. Analysis shows that the factors contributing to the success of individual facilities are complex and can be achieved in different ways in different locations.

- Biodiesel standards have been successfully established in both Europe and North America. The establishment of such standards is complex, but the resulting standards are exceptionally helpful to the implementation of biodiesel. The quality standards allow biodiesel to be a commodity product in the marketplace and provide confidence to consumers that the product will be appropriate for their vehicles.

- There is continuing interest in the use of un-esterified vegetable oils for vehicle use, particularly for on-farm applications. The chemical properties of the un-esterified oils are different than those for esterified biodiesel, and those differences may lead to poorer performance in un-modified diesel engines. Work on the establishment of standards for using the un-esterified oils and the modification of engine systems is ongoing.

- Both ethanol and biodiesel continue to require policy mechanisms to be competitive in the marketplace in most locations. As compared to previous periods where such policies were simply debated, the past three years has resulted in wide-spread recognition of the need for policy decisions in this regard. As a result, established policies have been renewed, and new policies have been established in regions where they did not exist previously. In Europe, for example, the European Union established guidelines for achieving defined percentages of alternative fuels. Taxation policies have also been established to lower motor fuel taxes on biodiesel. In North and South America, policies based on either taxation or fuel mandates have helped create conditions which allow longer-term business decisions on biofuels to be made. Commercial acceptance of biofuels by policy makers, consumers, and petroleum companies is substantially greater now as compared to only five years ago.

- In the period from 2001 through mid-2003, the commercial spot prices of petroleum gasoline and diesel fuels (without taxes) remained below those of the ethanol and biodiesel equivalents on either a volumetric or an energy-content basis in North America and Europe. During that time the legislative policies were crucial in allowing biofuels to compete in the marketplace. However, with fuel prices increasing since mid-2003, the spot prices for petroleum gasoline have been similar to or in some instances higher than ethanol on a volumetric, or occasionally an energy-content basis. Ethanol prices were also less than gasoline in Brazil for much of this period. The price of biodiesel typically exceeded that of petroleum diesel during the past three years, but that margin has decreased significantly as petroleum prices rose. While biofuels prices tend to increase somewhat as the cost of petroleum fuels increases, it is clear that there are situations were the biofuels can actually cost less than petroleum equivalents in the short term. It is not clear if this pricing relationship can be maintained in the longer term, or what effect there might be on legislative policies.

- The increases in production of ethanol and biodiesel have been achieved without overwhelming the markets for secondary products, at least to date. Distillers dried grains (DDG) resulting from North American ethanol production and glycerin resulting from European biodiesel, continue to have reasonable markets even with significant growth in the biofuels industry. Further expansion of biofuels, however, will continue to put pressure on these markets. Work done by this Task suggests glycerin production could exceed market demands at the time biodiesel reaches about 10% of its potential. New uses for glycerin as well as more efficient utilization of spent grain are needed for the longer-term continuation of present biofuels growth.

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Biofuels for Transport.
IEA Bioenergy Task 39. IEA Bioenergy: T39:2004:01

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North American Fuel Ethanol Industry. Review of Industry Growth 1999-2003.
D. O'Connor, (S&T)^2 Consultants Inc., Canada

Appendix 3:

Ethanol from Lignocellulosics: Views to Implementation.
W. Mabee, D. Gregg, and J. Saddler, U. British Columbia, Vancouver, Canada.

Appendix 4:

Current State of Fuel Ethanol Commercialization. Proceedings of the Specialists Workshop, York, UK, December 11-12, 2002.
D. Gregg, ed. University of British Columbia, Vancouver, Canada

Appendix 5:

Current State of Fuel Ethanol Commercialization. Proceedings of the Specialists Workshop, Copenhagen, Denmark, November 19-22, 2003.
J. Saddler, ed. University of British Columbia, Vancouver, Canada

Appendix 6:

Current State Of Lignocellulosic Fuel Ethanol Commercialization. Proceedings of the Special Topics Session B.
J. Saddler, ed. University of British Columbish, Vancouver, Canada. Session organized in association with the 25th Symposium of Biotechnology for Fuels and Chemicals, Breckenridge, Colorado, May 3-7. 2003.

Appendix 7:

World-Wide Review on Biodiesel Production 2003.
W. Körbitz, St. Friedrich, Biofuels Institute, Vienna, Austria; E. Waginger, Institute of Technology, University of Economy, Vienna; and M. Wörgetter, Federal Institute for Agricultural Engineering, Wieselburg, Austria.

Appendix 8:

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H. Prankl, W. Körbitz, M. Mittelbach, and M. Wörgetter. Federal Institute for Agricultural Engineering, Wieselburg, Austria

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Biodiesel in North America: Implementation Issues.
D. O'Connor, (S&T)^2 Consultants Inc., Canada

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A. Ammerer, J. Rathbauer, and M. Wörgetter, Federal Institute of Agricultural Engineering, Wieselburg, Austria.