MINNESOTA DEPARTMENT OF AGRICULTURE

Biobased Diesel Alternatives

Report to the Legislature

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January 15, 2011

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Executive Summary

Minnesota is home to four biodiesel plants capable of producing 65 million gallons of biodiesel annually from a variety of feedstocks. The state's mandate for 5 percent biodiesel blends helps Minnesota meet its goals for replacing fossil fuel use with homegrown renewable alternatives. Minnesota's efforts also contribute to federal renewable fuel standards for biomass-based diesel and other renewable fuels.

In addition to biodiesel, companies in Minnesota and throughout the United States are working to develop more alternatives to diesel fuel. These alternatives include a variety of products, technologies and processes for producing biobased-diesel alternatives such as iso-butanol (a possible jet fuel), renewable diesel fuel (a hydrocarbon made from fat) diesel fuel from biomass through gasification, pyrolysis, or fermentation and biodiesel made from new feedstocks like algae oil. Projects are located throughout the country and are at various stages of development; however, only one project is of commercial scale at this time.

The U.S. Environmental Protection Agency (EPA) uses a classification system to regulate compliance with the federal Renewable Fuel Standard (RFS2). D-codes are assigned to each type of renewable fuel based on feedstocks, processes and greenhouse gas reduction profiles; biomass-based diesel is generally categorized as a D-code 4. Renewable Identification Numbers (RINs) are assigned to each gallon of renewable fuel based on the D-code; biodiesel earns 1.5 RINs per gallon because it is considered an advanced biofuel under the RFS2. Together, D-codes and RINs are submitted to the EPA to document compliance with RFS2 based on the type and quantity of renewable fuels utilized.

ASTM International is an industry association that designates quality specifications for a wide variety of industrial products, including fuels. ASTM has set standard specifications for diesel, pure biodiesel and biodiesel blends—but not for other biobased diesel alternatives.

Although numerous biobased diesel alternatives are under development, it is difficult to recommend specific products for use in Minnesota at this time based on the requirements for such recommendations outlined in statute. First, the only commercial-scale renewable diesel facility is in the start-up phase, and thus the economic and operational characteristics of the product have not been assessed. Similarly, environmental and local economic development benefits cannot be estimated for products that are not yet commercially available. Moreover, no standards have been developed for the various alternative products discussed in this report. Should certain developments come to pass, it is feasible that Minnesota could engage in the use of products such as biogas from anaerobic digestion or biofuels from feedstocks like cellulosic biomass and/or algae in the future.

Introduction

This report is submitted pursuant to MN Laws 2008, Ch. 297, Sec. 69.:

Biobased Diesel Alternatives.
By January 15, 2011, the commissioners of agriculture, commerce, and pollution control shall consult with a broad range of stakeholders with technical expertise to develop and present recommendations to the NextGen Energy Board and to the chairs and ranking minority members of the Environment, Agriculture, Transportation, and Energy Policy and Finance Committees for the use of biobased diesel alternatives in the state, after reviewing the technology, economics, and operational characteristics associated with their use. For the purposes of this section, "biobased diesel alternatives" means alternatives to petroleum diesel fuel that are warrantied for use in a standard diesel engine without modification and derived from a biological resource. The commissioners may not recommend the use of a biobased diesel alternative for which an ASTM specification has not been developed, and which does not provide at least the equivalent environmental emissions benefits and local economic development potential as biodiesel produced using feedstocks grown or raised in the United States and Canada.

Background

Minnesota is actively engaged in policies and programs for reducing fossil fuel use in the state, including efforts to replace diesel fuel with biobased alternatives. The state's four biodiesel plants are capable of producing approximately 65 million gallons per year. Minnesota's biodiesel mandate requires the blending of 5 percent biodiesel into the state's diesel supply—assuming an 800 million gallon diesel fuel market, this equates to about 40 million gallons of biodiesel annually.[1] Thus, Minnesota is more than able to meet in-state demand.[2]

Three of Minnesota's biodiesel plants have used soybean oil as their primary or sole feedstock; FUMPA Bio-fuels in Redwood Falls is designed to use yellow grease or animal fats as well. Soy Mor in Albert Lea shut down in 2009 to convert to operations that would use a variety of feed stocks and has not yet reopened. EverCat Fuels in Isanti utilizes a unique esterification process that allows it to produce biodiesel from plant and animal fat, spent cooking oil, or even fatty acid materials from various industrial sources.

Minnesota's public and private sector is also exploring the efficient production of biobased diesel alternatives from new feedstocks such as algae oils and cellulosic biomass, and advanced processes like hydro-treating, gasification and pyrolysis. These developments promise renewable diesel products from a variety of triglycerides and even fatty acids.[3]

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[1] In January 2010, the Minnesota Department of Commerce (MDOC) temporarily waived the requirement that #1 diesel fuel be blended with 5 percent biodiesel (B5) from October through March 2010. The 2010 Minnesota Legislature implemented legislation allowing MDOC to extend this waiver for the winter months through March of 2012. The B5 mandate still applies to #2 diesel fuel year-round.

[2] For more information about Minnesota's biodiesel industry, see the Minnesota Department of Agriculture's annual report to the legislature on biodiesel on the Department's website: http://www.mda.state.mn.us/en/renewable/biodiesel.aspx.

[3] The U.S. Department of Energy defines renewable diesel as diesel derived from hydrotreated and isomerized fat or from biomass using a thermal depolymerization process. Biodiesel is the mono alkyl esters of long-carbon-chain fatty acids derived from renewable lipid feedstocks through the transesterification of triglycerides (fats and oils) contained in oil-rich biomass and animal fats.

The federal Renewable Fuel Standard (RFS2), expanded by the federal Energy Independence and Security Act (EISA) of 2007, requires the blending of 36 billion gallons of biofuels into the national fuel supply by 2022—including 21 billion gallons of "advanced biofuels," of which 1 billion gallons must be biomass-based diesel.[4],[5] EISA outlined annual requirements for each type of renewable fuel, but also gave the U.S. Environmental Protection Agency (EPA) authority to set incremental percentage standards for fulfilling RFS2 requirements based on production capacity each year.

EPA set the 2011 requirement for biomass based-diesel at 800 million gallons and 1.35 billion gallons of advanced biofuels. Based on the RIN value of biomass-based diesel (1.5 RINs/1 gallon), the advanced biofuels requirement could be met with 900 million gallons of biomass-based diesel. EPA also published rules in 2010 certifying that biodiesel from canola oil meets EISA requirements and therefore qualifies as an advanced biofuel and biomass-based diesel under the RFS2. Biomass-based diesel has been the only commercially available fuel that meets the EISA definition of non-cellulosic advanced biofuel. Biodiesel production is estimated to reach 350 to 385 million gallons nationally in 2010.

In October 2010, the Minnesota Department of Agriculture (MDA) convened a meeting with staff from the Minnesota Department of Commerce and the Minnesota Pollution Control Agency to discuss biobased diesel alternatives in the state. MDA also engaged the technical expertise of various stakeholders to identify promising biobased processes, products and technologies that could replace diesel consumption. MDA developed the report that follows based on these discussions.

Options for Biobased Diesel Alternatives

Various products, technologies and processes for producing biobased-diesel alternatives are under development—some at the national level and others in Minnesota. However, none in Minnesota have demonstrated consistent commercial scale production capacity. No alternative fuels—other than starch based ethanol and biodiesel from oilseed, animal and recycled fats and fatty acids—have been produced commercially in Minnesota. It is not clear how much renewable diesel has been imported into the Minnesota or U.S. markets, although certain companies are reportedly introducing some products into the marketplace as discussed below.

Some examples of products and processes currently under production or development by various companies are detailed in Table 1.

[4] EISA is Public Law 110-140.
[5] The U.S. Environmental Protection Agency may increase the amount of biomass-based diesel required under the RFS2 in 2012 and later years.

Table 1. Examples of Biobased-Diesel Alternative Developments

Company	Plant/Company Location	Process/Technology/Product	Notes
Dynamic Fuels (Tyson/ Syntroleum joint venture)	• 75 MMG plant in Geisman, LA (start-up)	• Hydrotreated triglycerides to make hydrocarbon (HC) diesel fuel (similar to petroleum diesel). • Not co-processed with petroleum.	• Qualifies as D-code 4 (biomass-based diesel), or D-code 5 (advanced biofuel).[6] • Low cloud point (-26 degrees F) and high cetane (as high as 88).[7] • Making jet fuel for testing by the U.S. Air Force Research Laboratory. • Ongoing production and marketing (see discussion below). • Largest U.S. producer of renewable diesel.
Various refiners	• Not consistently in production	Co-processed HC diesel fuel	
Neste Oil	• Three plants in Finland and Singapore with combined capacity of 370 million gallons/year.	• Hydrotreated fat; not co-processed. • "NExBTL" is a hydrocarbon product similar to diesel or jet fuel.	• Qualifies as D-code 4 or 5. • Used in Finland's diesel fuel. • Germany's Lufthanza airline plans to test product in commercial flights later in 2011. • World's largest producer of renewable diesel.
Solazyme	California	• Biodiesel from algal oil. • Very small production to date; algal oil not readily available in large quantities.	• Has produced biodiesel from their algal oil using a new process. • Not commercial scale production.
Amyris		C15 hydrocarbon suitable as diesel fuel.	• Yeast ferments sugar to isoprene. • Trimerization and hydrogenation of isoprene creates a C15 molecule with good cold flow characteristics. • Similar to #1 diesel or jet fuel. • Currently very small production (lab scale).
LS9	• Pilot plant operating; demonstration plant will be in Okeechbee, FL. • Office in California.	• Fermentation-derived esters and hydrocarbons. • Diesel or gasoline	• Fermentation of sugars. • Initial feedstock will be cane sugar.
Gevo	• Purchased ethanol plant in Luverne, MN. • Home office in Colorado.	• Iso-butanol • Variations can be used as gasoline or jet fuel.	• Use in gas or jet engines or as heating fuel, but not diesel. • Plans to convert corn ethanol plant to iso-butanol production from corn (qualifies as D-code 6, renewable fuel); later from biomass (qualifies as D-code 7, cellulosic biofuel).
Jet-E	Minnesota	Renewable Diesel or jet fuel	• Hydrotreated and isomerized fat • Would qualify as D-code 5 (advanced biofuel), or 4 (biomass-based diesel). • Has technology for hydro-treating fats

[6] See discussion of D-codes in next section.

[7] Cloud point, the most common measure of cold weather properties, refers to the temperature at which fuel begins to have a cloudy appearance. This indicates the presence of solidified waxes that can thicken the oil and clog fuel filters and injectors in engines. Cetane, a major measure of diesel fuel quality, refers to the combustion property of a diesel fuel product.

			and oils into biomass based diesel using their own hydrogen generators running on natural gas. • If they can find a buyer for their technology they say they are prepared to start construction immediately.
Various companies	No commercial scale plants	Fischer Tropsch diesel fuel from biomass.	• Gasification of biomass to create "syn gas" (CO & H2) • Catalysis of syn gas can make a hydrocarbon diesel fuel. • This process has been done large scale with coal but not with biomass.
Various companies	No commercial scale plants	Pyrolosis and other processes to make diesel , jet or heat fuel.	• Make biocrude and then upgrade in a petroleum refinery to make hydrocarbon diesel fuel. • Still in developmental stages with biomass.

As seen in Table 1, there is currently one commercial scale biobased diesel alternative manufacturer in the United States— Dynamic Fuels, a joint venture between Tyson and Syntroleum, with a 75 million gallon renewable diesel facility in Geisman, Louisiana. Their technology includes hydro-treating, which is a common practice in petroleum refineries. The plant is located near large hydrogen gas suppliers and has access to large quantities of biomass fat. A ready supply of hydrogen is one of the main hurdles to hydro-treating operations in many areas. In addition, the plant is located near the Colonial Pipeline, which serves the southeastern United States and up to Washington, D.C. On January 1, 2011, Colonial posted a price for a 5 percent renewable diesel blend at their terminals and is reportedly marketing product at this time. This indicates a high level of confidence that Dynamic Fuel's product will perform well in the marketplace.

The Dynamic Fuels plant is still in start-up mode, however, and therefore there is no reasonable way to evaluate the economics or operational characteristics of such a plant. In addition, the unique proximity and relationship to crucial resources necessary for a large plant may not be replicable in Minnesota nor in traditional local economic impact areas, as is the case with biodiesel. Performance of the renewable diesel product in commercial use has apparently been demonstrated in Europe and should be more evident as the product circulates in Canada and the U.S.

Neste Oil, the largest manufacturer of renewable diesel in the world, also produces a product they claim to be the same as or better than petroleum. Neste has commercialized the hydro-treating of biobased fat into a diesel fuel product called NExBTL. Two plants in Finland provide the supply of renewable diesel for NExBTL blends marketed in Finland and other locations across Europe and North America. Another large Neste plant has started production in Singapore. The combined production capacity of all three plants is 370 million gallons. Neste Oil is also involved in a joint venture in Finland to build a 60 million gallon capacity facility for wood to renewable diesel production.

NExBTL is currently being reviewed by ASTM for its potential use in jet aircraft. Upon ASTM adoption (possibly in Spring 2011), Germany's Lufthanza airlines will begin a test program with a 50/50 blend of NExBTL and jet fuel. This program should answer crucial questions about the performance of renewable jet fuel. Ongoing testing will also determine the "sustainability" of renewable jet fuel from palm oil, an important feedstock for world biofuel production. The determination of good sustainability ratings for jet fuel from palm oil is likely to ensure a strong market for airlines worldwide. The airline industry is anxious to use renewable fuels to comply with EU restrictions regarding the sustainability and carbon footprint of transportation fuels. The EU has also implemented an emissions trading scheme to be effective beginning in 2012. The International Air Transport Association established a goal of being carbon-free by 2020.

Jet fuel being a large and profitable market, success in this area could stimulate significant increases in the production of renewable diesel and possibly change the dynamics of the market for biofuels feedstock fats.

EPA Classification and Compliance for Biobased Diesel Alternatives

The EPA uses a classification system to ensure compliance with federal Renewable Fuel Standard (RFS2) requirements. This system uses “D-codes” and “RINs” to categorize and quantify the use of various types of renewable fuels in the United States, including biobased diesel alternatives.

Renewable Identification Numbers (RINs) allow refiners and importers to document to the agency that they are in compliance with applicable RFS2 requirements. D-codes are assigned to RINs on the basis of the feedstocks used, the process by which feeds tocks are converted into fuel, and the calculated greenhouse gas reduction that each bio-fuel represents compared to the baseline (petroleum) fuel. For instance:

- Ethanol and other fuels from corn or industrial corn starch qualify as a D-code 6 and are referred to as “renewable fuels”;
- Biodiesel (trans-esterified fat) and “renewable diesel” (hydro-treated fat) (triglycerides) not including refined corn oil can be either D-code 4 (biomass-based diesel) or D-code 5 (advanced biofuels); Most biodiesel is registered as D-code 4, (biomass-based diesel) but can be used as D-code 5 as well.
- Hydro-treated triglycerides that are co-processed along with petroleum are designated D-code 5;
- Cellulosic based ethanol from any process is code 3 (cellulosic biofuels);
- Cellulosic diesel and heating oil is code 7 (cellulosic biofuels or biomass based diesel).

A designated quantity of RINs are assigned to each gallon of biofuel depending on energy content and “renewability”. Ethanol from corn has been designated as the base fuel, and is therefore valued at 1 RIN per gallon. Biodiesel is valued at 1.5 RINs because of its higher energy content.

The RFS2 specifies that a given amount of “gasoline” or “diesel fuel” produced or imported each year must be derived from renewable sources. The RFS2 provides EPA with the authority to set renewable fuel requirements on an annual basis, based on supply and demand assessments. For 2011, the standards set by EPA in terms of biomass-based diesel and advanced biofuels require the following number of RINs and gallon equivalents:

Table 2. Biomass-Based Diesel and Advanced Fuel Requirements, 2011

RIN Classification	Equivalent Biodiesel Gallons	Equivalent Ethanol Gallons/RINs
Biomass-based diesel	0.8 billion	1.2 billion
Advanced biofuels	0.9 billion	1.35 billion

Table 2 shows that EPA requires 1.35 billion ethanol equivalent gallons—or RINs, since 1 gallon of ethanol is equal to one RIN—from biomass-based diesel or other advanced biofuels in 2011. These RINs could be acquired through the use 0.9 billion gallons of biodiesel or through the purchase of other qualifying fuels that are registered and meet the definition of biomass-based diesel or advanced biofuels.[8] In addition to biodiesel, a product called "renewable diesel" that is processed separately from petroleum using certain fats through hydro-treating also meets the definition of "biomass-based diesel". "Advanced biofuels" also include 1) "renewable diesel" when co-processed with petroleum, 2) ethanol made from sugarcane, 3) ethanol and renewable diesel from non-cellulosic food waste and 4) biogas from landfill, sewage, manure and waste treatment facilities.

Biofuel producers are the source of RINs and may sell fuels together with RINs or they may sell the fuel but retain the RINs temporarily to be sold later. RINs can be acquired by purchasing biofuels or by buying RINs from another buyer or RIN marketer. RIN values are posted daily by commercial price reporting companies. Blenders and marketers may also buy or sell biofuels with or without RINs or simply buy or sell RINs outright. There are also RIN traders who buy and sell RINs without taking possession of the fuel. Petroleum refiners and importers ("obligated parties") are required to provide documentation to the EPA demonstrating that they possess the number of RINs required under the RFS2, based on the volume produced or imported.

The value of a RIN at any point in time is determined by supply and demand conditions created by the transactions of the above mentioned players in the RIN market. At any given time, the value of various RINs may increase or decrease depending on the perceived present or future value of RINs as refiners and importers prepare to document compliance. Since July of 2010, the value of advanced biofuel and biomass-based diesel RINs has fluctuated from 47 to 90 cents each. Since a gallon of biodiesel is equivalent to one and one half RINs, the RIN value of one gallon of biodiesel has fluctuated from 70 cents to $1.35 in the past 6 months. As of January 11, 2011 the RIN value of one gallon of biodiesel was $1.15.

ASTM Standards for Biodiesel, Diesel Fuel and Heating Fuel Oil.

ASTM International (American Society for Testing and Materials) is an open forum for the development of high-quality, market-relevant international standards used around the globe. It utilizes technical expert individuals and employees from a wide range of public and private stakeholder entities in a consensus based process to designate standards for a wide range of products, materials and testing methods.

ASTM standards for biodiesel and diesel fuels currently include:

- D975 and D396—diesel fuel and heating fuel oil respectively. These standards include a blend of up to 5% biodiesel with diesel and heating oil.
- D6751—B100 (pure) biodiesel.
- D7464— B6-B20, mid-level biodiesel blends of 6 percent to 20 percent biodiesel in diesel or heating fuel.

Many other ASTM test methods are included within these standards to provide field and referee test procedures to help commercial and regulatory personnel verify that products bought and sold in the marketplace meet applicable specifications.

[8] This figure is arrived at by dividing 1.35 billion ethanol equivalent gallons by 1.5, the RIN value of one gallon of biodiesel. Therefore, 0.9 billion gallons is the number of biodiesel gallons that would be needed to fulfill the entire advanced biofuels requirement for 2011.

Recommendations

The guiding legislation for this report indicates that the commissioners may not recommend a biobased diesel alternative "*which does not provide at least the equivalent environmental emissions benefits and local economic development potential as biodiesel produced using feedstocks grown or raised in the United States and Canada."* At present, no significant commercial operations are producing biobased diesel in Minnesota other than the four biodiesel plants cited earlier in this document. Moreover, although significant strides have been made in many areas, there is only one commercial scale plant in the United States producing renewable diesel (Dynamic Fuels, which has only recently begun production). In the absence of an ongoing, fully operational U.S. commercial plant with significant production history, no emissions or economic impact data are currently available for evaluating and recommending specific biobased diesel alternatives for production and use in Minnesota.

In addition, Minnesota law cited in the introduction states that, *"biobased diesel alternatives means alternatives to petroleum diesel fuel that are warrantied for use in a standard diesel engine without modification."* Engine manufacturers do not generally warrant their products to operate on any specific fuel per-se. They instead posture their warranties such that any fuel meeting established performance specifications, such as ASTM D975, is considered suitable. If, however, a fuel is determined to damage an engine or to be the cause of a problem, the engine manufacturer is not obliged to provide a remedy for that problem under the manufacturer's warranty provisions.

The absence of specific standards for certain biobased diesel alternatives also presents challenges in that the law states, "*The commissioners may not recommend the use of a biobased diesel alternative for which an ASTM specification has not been developed."* Currently, there is no separate ASTM specification that applies to any specific biobased diesel alternative beyond ASTM D6751, "Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels." Biodiesel meeting ASTM D6751 is specifically named in D975 (the ASTM specification for diesel fuel) and biodiesel blends up to 5 percent are described as meeting the requirements of that specification. Thus, no other biobased diesel alternative technically has its own separate ASTM specification or is specifically named in existing specifications.

Despite these issues, a number of products could be feasible in Minnesota should additional developments occur, including:

> **Biogas:** Several facilities in Minnesota are operating methane digestion facilities either at livestock (mostly dairy) enterprises or municipal solid waste (MSW) facilities. The dairy operations use the methane from their manure digesters to operate diesel engines and/or fuel cells to generate electricity at the facility while also selling power on the grid. Use of methane in diesel transportation applications is not common, but propane gas has been used by some firms including Schwan's Food Company delivery trucks.
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> **Cellulosic Biomass:** If other technologies such as the production of diesel fuels through gasification and pyrolysis of biomass are commercialized, Minnesota has a wide range of biomass options to consider. Research is being conducted on the production of many existing biomass feed stocks including crop residues, timber waste, municipal solid waste and livestock waste, as well as potential energy crops including perennial grass, legume and woody plants.

Algae: It is not clear that algae growth could be competitive in this climate or whether it would profitably provide suitable diesel fuel unless fatty acid components are significantly separated so that higher value products can be pulled and the remainder used for biodiesel. Again, there is no existing commercial scale algae oil production plant operating in the U.S. that is of sufficient size to allow a general evaluation of the potential economic or product performance characteristics. It has been reported that the military may have interest in evaluating algae production and fuel processing "on the battle field." Investments by military research grants have been valuable in the research and development of technologies that might otherwise have languished. Remediation of waters with high mineral or biological material content could also provide the impetus for cultivation and commercialization of algae that would yield lipids, parts of which could also be considered for fuel or other products.

Conclusions

Should certain developments occur, it might be possible to make recommendations about the adoption of alternative biodiesel products and technologies in Minnesota. As it stands, the profitability of local production and processing, the performance characteristics of the fuel in the marketplace, the status of ASTM specifications, and EPA certification of the various alternative fuels have not all been specifically determined.

The next few years are likely to answer many questions about the performance, feasibility and profitability of renewable diesel fuels from the hydrogenation of plant and animal fat. Even so, the profitability of hydro-treated fats (renewable diesel) depends greatly on a large source of fats and hydrogen gas. Both Neste and Dynamic are closely associated with refineries and large sources of hydrogen. The prospect for producing low cost hydrogen or acquiring large quantities of hydrogen in Minnesota may not be favorable. For these reasons, the prospect for renewable diesel making a significant contribution to local and especially rural economic development is unclear.

If hydro-treating is not feasible in Minnesota, gasification or pyrolysis may offer some hope for locally based non-biodiesel renewable diesel. However, none seems to be as well developed as Neste or Dynamic. The gasification and pyrolysis processes for renewable diesel production require solutions to many complex issues related to biomass production, economy of scale, process emissions and the conversion of biomass to marketable diesel or jet fuel products. Again the prospect for local rural economic development benefits remains to be seen.

Another pathway to renewable diesel includes specially engineered microbes that can turn plant-based materials or waste into fuels and chemicals. Various companies such as Amyris and LS9 claim to have microorganisms that can do this. However, most processes are in the development or pre-commercialization stage and business plans and pro-forma are not available to the public. This makes it difficult to determine the efficacy and profitability of the process or the performance of the product.

Some renewable diesel technology developers indicate that diesel fuel is a relatively low value market compared to other chemical products. Their business plans may require a higher value product to support the production of renewable diesel. Many times the higher value chemicals are positioned in relatively small niche markets that can easily be saturated by a large new source of product. If a business plan depends on a high value product to make the pro-forma work, the size of the plant or the industry that follows may overwhelm the high value niche market, convert it to a lower value market and change the profit structure of the operation or the entire industry.

Although there are apparently no current examples of commercialized alternative diesel technology that look promising for development in Minnesota, projects in the pilot and demonstration stage should be monitored. The state should continue to support the existing renewable fuels industry, monitor new developments and be prepared to provide an attractive venue for new technology development when a good match appears.