Cellulosic Ethanol

The potential for biofuel production in Vermont

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EXECUTIVE SUMMARY

Cellulosic ethanol is a renewable liquid biofuel that has emerged as a prospective alternative transportation fuel source with significant environmental implications. Sources of cellulosic biomass from which ethanol can be made include, but are not limited to: agricultural wastes such as corn stover, cereal straws, and sugarcane bagasse; grasses; woods; and plant wastes from industrial processes, such as sawdust and paper pulp.

Ethanol can be blended with gasoline to power cars. The two most common blends are E10 (10 percent ethanol, 90 percent gasoline) and E85 (85 percent ethanol, 15 percent gasoline). Increased use of cellulosic ethanol has the potential to reduce the state's dependence on foreign oil and reduce overall greenhouse gas emissions.

No cellulosic ethanol is currently being produced in the United States, but ethanol is being made from corn. The production of cellulosic ethanol releases less greenhouse gases than does the production of corn-based ethanol. It also does not put a strain on the nation's food supply. Ethanol from cellulose is not yet cost competitive with corn-based ethanol, and it will likely be three to ten years before the industry could be economically viable in Vermont.

There is little to no cellulosic ethanol research and development in the state of Vermont. Both the state and the federal government have programs that could help fund a cellulosic ethanol plant, but none are currently being utilized. If cellulosic ethanol becomes economically viable in Vermont, there is the potential to produce approximately 140 million gallons annually.

In Georgia, Range Fuels, Inc. will build the country's first commercial cellulosic ethanol plant. Woodchips will be used as the feedstock. The company is receiving significant sales tax breaks from the state. In Tennessee, the government has given $51 million to support the University of Tennessee's Biofuels Initiative. The university conducts research into switchgrass production and has partnered with the Mascoma Corporation to build a pilot plant that utilizes switchgrass.

Six policy options to encourage cellulosic ethanol production in Vermont are:

1. Increase funding for cellulosic ethanol research and development. This may include partnering with a company to build a pilot plant.
2. Increase tax incentives for the industry, including a state gas tax exemption for all gasoline blended with a specified quantity of ethanol.
3. Increase funding for feasibility studies to better determine the potential for cellulosic ethanol in the state when the industry becomes cost competitive.
4. Mandate that fuel sold is at least E10.
5. Increase demand for ethanol through tax incentives for flex fuel vehicles and E85 pumps.
6. Better utilize current state incentives.

1. ETHANOL AS AN ALTERNATIVE TRANSPORTATION FUEL

1.1 Ethanol: An Introduction

Ethanol is used as an alternative transportation fuel that is blended with gasoline, most frequently as E10, or "gasohol" – a blend of 10 percent ethanol and 90 percent gasoline that can be used by most modern cars with an internal combustion engine. Higher concentrations of ethanol, such as E85 (85 percent ethanol, 15 percent gasoline), are also available. These higher concentrations, however, require flexible-fuel engines, which are available only in a limited number of individually-owned automobiles and employed most commonly in government-owned vehicles.

In all cases of production, ethanol is manufactured by fermenting sugars. The sugars needed to make ethanol can be found in a variety of sources, including corn, sugar cane, or cellulosic mass from plants. Currently, corn based ethanol represents the overwhelming majority of ethanol being produced in the United States, with national production exceeding 4.9 billion gallons in 2006.[1]

Ethanol supporters claim that increased demand for and production of both cellulosic and corn-derived ethanol stand to significantly boost the United States' agricultural farming industry. Moreover, supporters argue that such a practice may genuinely work to lessen U.S. dependence on foreign oil and energy sources – a consequence with resounding foreign policy implications. However, some scientists counter that only the use of massive quantities of ethanol (quantities that far outstrip current production levels and may be infeasible to produce in the near future) could make a significant dent in American importation of foreign oil.[2]

The Renewable Fuel Standard (RFS) set by the Energy Independence and Security Act of 2007 (EISA) demonstrates that both Congress and President Bush support the continued growth of ethanol production. The RFS sets minimal quantities of biofuels to be mixed into the US gasoline supply. The total amount of required biofuels is increased annually, reaching 36 billion gallons by 2022. Of that 36 billion gallons, 15 billion gallons must be ethanol produced from corn, while 16 billion gallons must be biofuels produced from cellulosic materials. In addition, 4 billion gallons of "other advanced biofuels" must be produced, and this quantity may include cellulosic ethanol.[3] Because research and development on cellulosic biofuels overwhelmingly focuses on the production of ethanol, the EISA legislation is essentially a mandate for the annual production of 20 billion gallons of cellulosic ethanol and related fuels by 2022. EISA therefore decreases some uncertainty associated with the nascent cellulosic ethanol industry by providing a guaranteed market for the product.

1.2 Ethanol and Gasoline Compared

Petroleum is a nonrenewable resource. Due to its finite supply, it is expected that prices will increase as availability decreases over time. In contrast, ethanol derived from plant matter is a renewable resource. As such, it should not suffer from these limitations.[4]

At corn prices of about $2 per bushel, corn-based ethanol can be produced for $1.00 to $1.06 per gallon (2005 dollars; excludes start-up costs). Ethanol can also be produced from soybeans at a cost of $1.80 to $2.40 per gallon. Additionally, a $0.51 per gallon tax credit currently makes ethanol cost competitive with unleaded motor gasoline (see Fig. 1). The recent steep rise in the price of oil has further increased cost competitiveness of ethanol relative to gasoline. However, the rising demand for ethanol has also increased the cost of corn, causing the price of ethanol to fluctuate significantly.[5]

On the retail side, the average price of a gallon of E85 fuel in 2007 was $2.40, compared to $2.76 for gasoline. However, one gallon of ethanol produces less energy than one gallon of gasoline. As a result, E85 is more expensive than gasoline on an energy equivalent basis ($3.39 vs. $2.76 per gallon).[6]

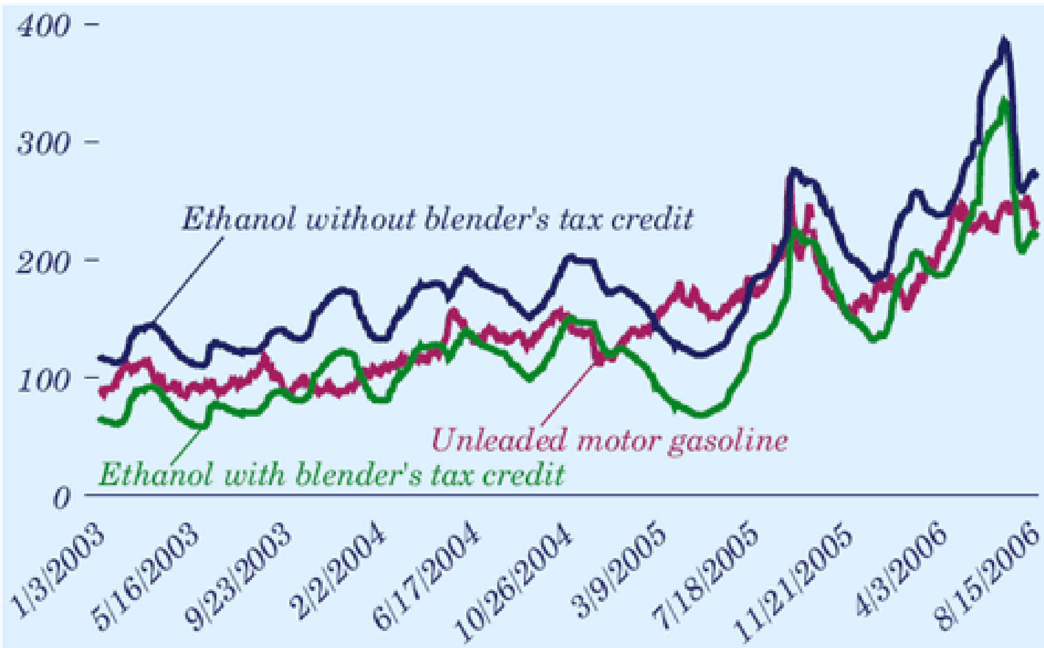

Figure 1. Average US price for ethanol and gasoline, 2003-2006 (nominal cents per gallon)[7]

Ethanol seems to compare favorably to gasoline fuel in terms of greenhouse gas (GHG) emissions. Because ethanol is the product of agricultural products rather than fossil fuels, the carbon dioxide released when the fuel is burned is equivalent to the quantity removed from the atmosphere during the lifecycle of the plants. In terms of relative contribution to climate change, researchers at the Argonne Center for Transportation Research found that replacing gasoline fuel with cellulosic ethanol can result in up to a 64 percent decrease in greenhouse gas emissions on a per mile basis in an E85 mixture. With respect to climate change, it should also be noted that deforestation to create new cropland may decrease the benefits of ethanol as an alternative fuel.

The use of ethanol in gasoline does have several negative effects compared to gasoline. For E85, the major drawback is an increase in the emissions of certain air pollutants relative to E0 (i.e., conventional gasoline) and E10 fuels.[8] These pollutants have negative implications for human and ecosystem health and include:

- Acetaldehyde (an irritant and possible carcinogen)[9]
- NO_x (one component of smog)
- Ethanol
- Methanol
- Ethylene

However, compared to gasoline, ethanol blends do achieve reductions in tailpipe emissions of carbon monoxide – a toxin that negatively affects delivery of oxygen in the blood stream – by as much as 40 percent compared to conventional fuels. [10]

It is also important to note that once production is complete, another obstacle – fuel transportation – stands in the way of true viability for both cellulosic and corn-based ethanol. The water solubility of ethanol distinguishes it from petroleum. Transporting ethanol through pipelines is problematic because pipelines are prone to water accumulation. If ethanol absorbs even a moderate quantity of water, it will be "unusable as a transportation fuel."[11] Furthermore, high concentrations of ethanol can lead to corrosion in conventional gasoline pipelines. Thus, tanker trucks and rail tank cars are currently the only valid option for transporting ethanol to fuel pumps.[12]

2. CELLULOSIC ETHANOL AS A TRANSPORTATION FUEL

The ethanol introduced into mainstream markets over the past two decades has been produced almost entirely from corn. Due to concerns about the viability of corn based ethanol as a long term solution to America's energy needs, the production of cellulosic ethanol has begun to generate notable interest in certain areas of the country. States like Georgia and Tennessee have recently created an infrastructure for the eventual production of ethanol from cellulose.

2.1 Cellulosic Biomass Sources

Cellulosic ethanol is made from plant matter, which consists of three major components: cellulose, hemicellulose, and lignin. Cellulose is a polymer of glucose, a six-carbon sugar. The polymer constitutes nearly two thirds of the carbohydrate makeup for "woody plants" and almost one half of the carbohydrate content for herbaceous plants.[13]

While a vast array of cellulosic biomass and waste products could potentially be transformed into alternative fuels, cellulosic ethanol proponents focus on two primary biomass sources: wood/lumber and grasses. Forestry wastes, like "underutilized wood and logging residues," can serve as fodder for ethanol production.[14] Nevertheless, widespread ethanol production using wood or lumber would involve a greater supply than forestry wastes alone could provide. Therefore, a potential difficulty with employing wood or lumber to produce ethanol is the negative impact it would have on the needs of the lumber industry's current (non-ethanol) client-base.

Herbaceous sources are also considered possible long-term feedstocks for ethanol production.[15] Example sources include certain agricultural wastes and "energy crops" like switchgrass, hybrid poplar, and hybrid willow. As with forestry wastes, the supply of agricultural wastes, although continuous, is less massive than the potential volume of energy crops that could be grown and developed solely for the purpose of providing an alternative fuel source. Switchgrass is produced on a ten-year crop rotation but can reach harvest age after year one in some regions, while hybrid willows have a 22-year rotation with a four-year maturity span. Hybrid poplars reach harvest maturity in six-to-eight years.[16] Thus, within a decade from the start of cultivation, three major sources of cellulosic biomass could be in full reproduction mode.

Of the three plant types, switchgrass is viewed by many as the most promising energy crop, if harvested "progressively and consistently." This is primarily due to its diverse growth platform and potential for exponential yield increases.[17]

2.2 Cellulosic Ethanol vs. Corn-Derived Ethanol

The attractiveness of cellulosic ethanol can largely be depicted through a comparative lens with its corn-derived counterpart. The potential advantages of cellulosic ethanol take form in the utter abundance of low-cost biomass sources versus that of corn. Furthermore, it is thought that increasing use of cellulosic ethanol can produce greater reductions in the amount of atmospheric carbon dioxide generated by the transportation sector compared to corn-derived ethanol.

Although the argument over differences in greenhouse gas (GHG) emissions between corn-derived and cellulosic ethanol has not reached a conclusion, it seems clear that the processes entailed in producing cellulosic ethanol offer significantly reduced GHG emissions compared with corn-based ethanol products. Some estimate that use of corn-derived ethanol in E85 reduces GHG emissions between 20 and 30 percent from the level caused by gasoline use. Ethanol from cellulose, on the other hand, is estimated to reduce GHG emissions by up to 85 percent.[18] The difference arises from greater fossil fuel inputs used in the cultivation and production of ethanol from corn. However, it should be noted that scientists are not in full agreement over the amount of fossil fuels needed to convert cellulosic and corn feedstocks to ethanol. At one extreme, some have argued that "about 1.5 gallons of oil equivalents are required to produce 1 gallon of cellulosic ethanol."[19] Conversely, others claim that as the production of ethanol from cellulosic sources becomes more commercially widespread, "energy balances will improve dramatically."[20]

Additionally, increased production of corn derived ethanol may greatly affect the world food trade and food supply. As the corn based ethanol initiative grows on a national – and even global – scale, some insist that upwards of 70 percent of the world's grain production will be utilized for ethanol rather than foodstuffs.[21] Many have expressed concern that allocating high levels of the grain supply for ethanol production would cause an increase in food prices for products containing grain, thereby adversely affecting the food supplies of developing countries around the world.[22]

Critics are skeptical that the United States could even produce enough corn to provide for a significant increase in ethanol production. In 2006, 55 million tons of U.S. corn were used to produce ethanol. This represented nearly 20 percent of the nation's grain yield and provided merely three percent of the U.S.'s automotive fuel.[23] In addition, the increased allocation of corn to ethanol production has contributed to volatile and rising corn prices (illustrated in Figure 2).

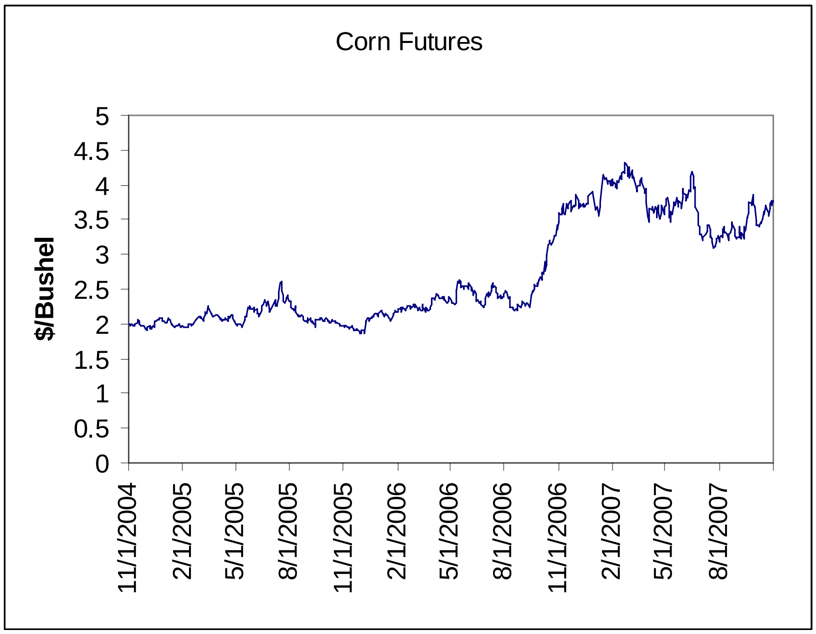

Figure 2. Corn Futures Contract Prices from 11/2004 – 9/2007

Figure 3 illustrates the use of corn for ethanol production projected by the U.S. Department of Agriculture through 2017.[24] Successfully utilizing a more stable source of production could go a long way toward decreasing price levels and avoiding a "corn famine."[25]

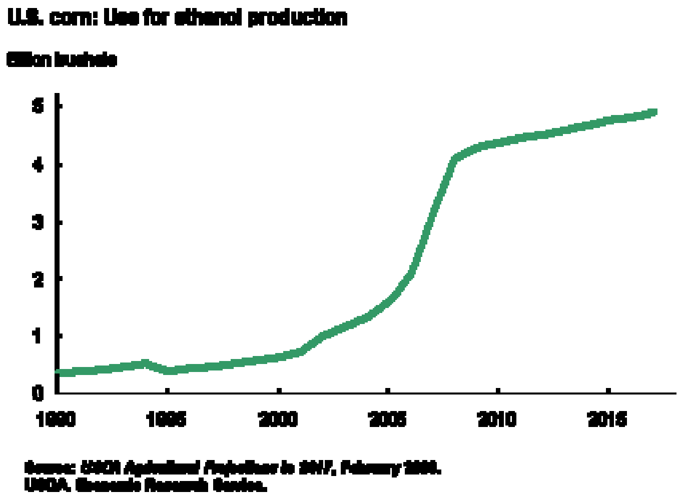

Figure 3. Projected use of corn for ethanol production

2.3 Environmental Concerns Surrounding Cellulosic Ethanol

Major environmental concerns do exist concerning the question of converting land to grow products containing the biomass that can be used to produce cellulosic ethanol. Converting land use to energy crop production could potentially result in:

- Loss of biodiversity due to monoculture of biomass feedstocks
- Displacing natural land cover (that has higher carbon sequestration potential) with crops such as corn.
- Loss of food producing agricultural area
- Increased use of fertilizers that are harmful to overall ecosystem health

In addition, there is active scientific debate over the extent to which these land use changes will counteract the benefits of fixing atmospheric carbon into organic carbon. As an example, one recent study (that does not reflect a universally accepted scientific understanding of the topic) suggests that greenhouse gas emissions from the transportation sector could nearly double over the next 30 years as the use of corn-based ethanol increases. The same study states that increasing cultivation of switchgrass (for cellulosic ethanol) on corn lands could increase greenhouse gas emissions by 50 percent beyond expected increases.[26]

Irrespective of the accuracy of these findings, an important consideration is that *many of the problems associated with land use change could be avoided by relying on feedstocks composed of waste biomass or sustainably harvested forest products.* The conversion of "waste materials" is less environmentally worrisome than that of "dedicated feedstocks," since no additional land is needed for the production of already existing waste.

2.4 Economic Concerns Surrounding Cellulosic Ethanol

The price of production remains the central concern when examining the economic foundation for cellulosic ethanol. The robust start-up costs for widespread cellulosic ethanol plants have a direct impact on the price of the alternative fuel, and these costs have thus far prevented viability. The exact per gallon cost of cellulosic ethanol is much debated, as claims range from $1.15 to over $3.00. In fact, this cost ambiguity is representative of the long-term uncertainty about potential markets and cost-effective production techniques that currently affect the feasibility of cellulosic ethanol as an alternative fuel. The price and production cost insecurity leads many to conclude that cellulosic ethanol will not be able to replace corn-based ethanol for years to come.[27]

According to Lee R. Lynd, professor at Dartmouth's Thayer School of Engineering and leading cellulosic ethanol expert, the quickest route to viability would be to circumvent expensive start-up costs by converting existing facilities that could most easily accommodate cellulosic ethanol production (such as wood-burning plants and paper mills).[28]

There are examples, however, of positive economic side-effects from the process of production. For instance, lignin (one of the three base elements of cellulosic biomass) cannot be chemically converted into ethanol and generally survives unaltered from production processes. Lignin constitutes approximately 40 percent of the energy in the feedstock sources (as well as roughly 25 percent of the dry weight), and there is a "very large volume demand for lignin-rich residues." This is a potential additional source of revenue for cellulosic ethanol producers.[29]

2.5 Ultimate Viability of Cellulosic Ethanol

The potential economic and technological viability of cellulosic ethanol remains the ultimate impediment to acceptance. The debate over the feasibility continues, with predictions of a timeframe for viability ranging from three years to over a decade. Research seems to point in two possible directions: If provided with ample government and private subsidies and investments, cellulosic ethanol production could reach a viable state within a five year window. However, if general skepticism increases about the role of ethanol as an alternative fuel and its potential to replace gasoline, the decade-plus forecast for viability may prove more accurate.

3. STATUS OF CELLULOSIC ETHANOL IN VERMONT

3.1 Level of Production and Use

Vermont produces no commercial ethanol. This is primarily because Vermont's short growing season makes it difficult to grow corn at a scale large enough for ethanol production. Without the adoption of cellulosic ethanol technology, it is unlikely that ethanol production will rise significantly.[30] Because of the lack of production, no ethanol is being blended into Vermont's gasoline. There are only 8,700 alternative fuel vehicles in the state and no E85 gas stations.[31]

3.2 Level of Research and Development

Vermont is not known as a leader in cellulosic ethanol research or development. Nationally, cellulosic ethanol production is still an infant industry and is not cost effective. The first six commercial cellulosic ethanol plants are under development in states such as California and Georgia, but none are being constructed in Vermont.[32] Little to no research on cellulosic ethanol technology is being conducted in the state, and there are no demonstration plants.[33]

Both the Vermont Department of Agriculture and the Division of Forestry are conducting research on how much of the state's agricultural and forest resources could be used to produce cellulosic ethanol. The Department of Agriculture gave the Rutland Development Corporation a grant of $25,000 to examine the potential for cellulosic ethanol production in the Rutland area.[34] The Department of Agriculture has also funded University of Vermont Professor Sid Bosworth's case study on the production of various grasses in the state, including switchgrass.[35]

3.3 State Incentives

The state does have programs that could be used to encourage the growth of cellulosic ethanol, but none are currently being utilized. A cellulosic ethanol company could receive funding through the Vermont Economic Progress Council's Vermont Employment Growth Incentive Program. The VEGI awards $10 million annually in job creation incentives to encourage companies to relocate or start up in Vermont if they otherwise would not have done so.[36] The VEPC provided some funding for the Biocardel Biodiesel Plant that was completed this year, and it is likely that they would also fund a future cellulosic ethanol plant.[37] In October 2007, the VEPC authorized a $1.6 million grant to Mascoma Corporation, a cellulosic ethanol company located in New Hampshire, to relocate its research facilities to Vermont.

The state also tries to promote the use of flex-fuel vehicles. The Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Research and Development Tax Credit offers tax breaks to companies that develop flex-fuel cars in the state.[38] In addition, the state requires government agencies to consider using flex-fuel vehicles when feasible.

3.4 Federal Incentives

In his 2007 State of the Union address, President Bush announced the government's "20 in 10 Initiative" which aims to reduce gasoline consumption by 20 percent in ten years, and make cellulosic ethanol cost-competitive with corn based ethanol by 2012.[39] Funding for the initiative comes primarily through the Department of Energy's Biomass Program, which in 2007 offered $141 million in grants and loan guarantees to businesses, industry, and universities to conduct biofuel research and development.[40] The money spent on cellulosic ethanol research is expected to increase as the "20 in 10 Initiative" progresses. However, industries and universities in Vermont currently receive little to none of these federal grants. In addition, the federal government also offers $0.51 per gallon tax credit to all ethanol producers.

3.5 Potential for Future Growth

The market for ethanol in Vermont is large. Approximately 600,000 vehicles in the state could run on E10 fuel. If all of these cars were to switch, it would create a demand of approximately 35,309,400 gallons of ethanol annually.[41]

There are two main feedstock sources for cellulosic ethanol: low grade wood and fast growing grasses. Annually, Vermont's forests produce about 1.4 million green tons of biomass that could be converted into ethanol. This could yield roughly 50-to-60 million gallons of ethanol a year.[42] The source of wood would include waste from Vermont's timber industry and plantations of fast growing trees, such as poplars.[43]

The state's two biomass power plants, which burn wood chips to produce electricity, are additional local resources.[44] Because ethanol production leaves most of the combustible wood untouched, these power plants could be modified into two-phase facilities that burn woodchips after their use in cellulosic ethanol production.[45]

The Vermont Department of Agriculture has estimated that one third of the 100,000 acres of farmland not currently being cropped could sustain feedstock for cellulosic ethanol production. This could potentially yield 90 million gallons of ethanol annually.[46] Possible crops include switchgrass, reed canary grass, and miscanthus. In addition agricultural waste and biomass waste in landfills could be potential feedstocks for a cellulosic ethanol plant.[47]

4. CASE STUDY: RANGE FUELS IN GEORGIA (WOOD FEEDSTOCKS)

4.1 Introduction

On November 6, 2007, Range Fuels, a Colorado-based biofuel company, officially broke ground in Soperton, GA on the site of the first commercial cellulosic ethanol plant in the United States.[48]

Important features of the Range Fuels' facility are that it will:

- rely primarily upon woodchips as the source for ethanol production.
- cost $225 million at the outset.
- be located in the center of the state's timber-producing region.[49]

The timber industry has been struggling nationwide over the past decade. In Georgia, more than 140,000 jobs have been lost and almost 100 mills have been closed.[50]

Cellulosic ethanol production provides benefits to timber companies by providing more markets within which to sell their products (or byproducts).[51]

4.2 Site Suitability: Materials and History

Georgia's suitability for hosting the first wood-fed cellulosic ethanol plant is based primarily on two factors:

- Forests and their refuse are abundant in the state
- Georgia has a history of a "renewable and sustainable" forest industry.[52] Over the last 50 years, two trees have been planted for every one cut down. [53]

Statewide, Georgia has recently witnessed a push for the implementation of locally developed biofuels from locally available products.[54] The state consciously chose to site the facility in one of the most economically distraught rural areas to stimulate job growth.[55] Important points regarding site suitability and benefits to the state from utilizing locally produced wood feedstocks include:

- The woodchips to be used for ethanol production are byproducts of the lumber mills.
- Georgia contains 24 million acres of pine forests.
- The statewide forest industry is valued at $18 billion.
- Wood discarded by loggers accounts for 25 percent of forest harvests and would normally be left to rot or be burned.[56]
- Range Fuels plans to use parts of trees, including treetops and limbs, which are unusable for the pulp and paper industry.[57] The facility plans to use 1,200 tons/day of Georgia's lumber waste, which currently amounts to 18 million tons of unused trees and logging leftovers.[58]
- Soperton's close proximity to the source of wood products will minimize potentially crippling transportation costs.[59]
- More than 70 new jobs are expected in the Soperton locale alone.

4.3 Policy Incentives

Range Fuels received grants and tax cuts from both the state and federal government to shoulder the large start-up costs for a high caliber facility. Georgia presented the company with tax breaks, cheap land, and sizeable grants.[60] Governor Sonny Perdue introduced an initiative to the legislature to provide state level tax breaks on materials purchased for use in the construction and production of alternative fuels. The tax break was subsequently passed by the state legislature in early 2007.[61] Also in the works are incentives passed by the Georgia legislature that attempt to encourage more gasoline stations to offer E85 fuel.[62]

Range Fuels was one of six operations chosen to receive federal funding from the Department of Energy in February 2007.[63] Through this grant, Range Fuels will receive up to $76 million toward the construction and production of its Soperton facility.[64]

4.4 Technology

The Range Fuels process entirely eliminates the use of traditional, expensive enzymes and yeasts. Instead, it uses a thermochemical process dubbed K2.[65] A major strength of the K2 process is its modular design, which makes the intended expansion of a facility less complicated and additional modules easy to transport and install.[66]

4.5 Goals

Once operational, the Soperton ethanol plant will produce 20 million gallons of ethanol per year.[67] The long-term goal of Range Fuels is to produce 100 million gallons of ethanol annually.[68] Additionally, the company wants to expand its operations in Georgia by building multiple cellulosic ethanol plants along Georgia's southern pine belt. Overall, Range Fuels aims to produce more than one billion gallons of ethanol per year from the pine belt as it adds more plants to the region.[69]

4.6 Economic Development

One of the most important benefits from cellulosic ethanol production is the possibility of increased economic development of rural communities outside of the Midwestern "corn belt."[70] It is hoped that the plant in Soperton will help Georgia move toward greater rural economic development and add more than 70 jobs to the local Soperton economy.[71]

5. CASE STUDY: MASCOMA CORP. IN TENNESSEE (SWITCHGRASS)

5.1 Introduction

Mascoma Corporation has partnered with the University of Tennessee to build the nation's first cellulosic ethanol plant that uses switchgrass as a feedstock. The plant is expected to be operational in January 2009.[72] It will be located in Vonore, Tennessee, just 35 miles south of Knoxville in an economically undeveloped region of the state.[73] Placing the facility in Vonore furthers the state's goal of using ethanol production to reinvigorate the economy in poor, rural communities.[74] The agricultural community of Tennessee has shown interest in the state's effort to advance the production and use of biofuels, and farmers are generally accepting of their roles in this project.[75]

5.2 Site Suitability: Materials and Location

As an agriculturally grown feedstock, switchgrass is better suited for ethanol production than corn. Switchgrass is not a food crop and therefore does not have an impact upon the food supply or market.[76]

Switchgrass presents many advantages for cellulosic ethanol production:

- It does not require high inputs of nitrogen and phosphorus fertilizers that damage ecosystems when introduced in high concentrations.
- It is a perennial grass which can adapt well to a variety of soil and climate variations.[77]
- It has a high cellulose content, which makes the ethanol production process more efficient.
- It may yield approximately 500 gallons of ethanol per acre in well-managed, commercial-scale systems.[78]

Furthermore, switchgrass can be successfully grown nearly anywhere in Tennessee, with experienced agriculturalists producing two crops per year.[79]

It is recommended that producers locate themselves within a 50 mile radius of the cellulosic ethanol plant to reduce the costs of excessive transportation.[80] Planners anticipate that these producers will have contractual agreements with the operators of the plant regarding how much switchgrass they will deliver annually.[81]

5.3 Policy Incentives

Unlike Range Fuels, Mascoma did not receive any grant money from the Department of Energy. However, the 2007 federal farm bill, which has not passed Congress as of March 2008, contains $3 billion to promote biofuel energy programs much like the one in Tennessee.[82] Mascoma's work is complemented by research at the Oak Ridge National Laboratory, which received a grant of $125 million from the U.S. Department of Energy in June 2007.[83]

The state of Tennessee is committed to subsidizing development of cellulosic fuels, as is demonstrated by the $72.6 million of state funds dedicated to the Tennessee Biofuels Initiative in the 2007-2008 fiscal year budget.[84] The University of Tennessee proposed the Tennessee Biofuels Initiative, and state support for it is itemized as higher education funding. The Initiative is a model for biofuel research and business that attempts to position the state as a leader in biofuel production and implementation.[85] The partnership with the privately owned Mascoma Corp. is an essential component of the initiative.

The 2007-2008 Tennessee state budget allocates:

- $40.7 million to the construction of the plant in Vonore.[86]
- $27 million for research and development of cellulosic ethanol.[87]
- $8.25 million in farmer incentives that include seed purchase and technical support from University of Tennessee extension agents.[88]

In June 2007 Tennessee governor Phil Bredesen awarded 10 "Green Island Corridor" awards. These awards seek to expand the presence of biodiesel and E85 refueling stations in the state. The program subsidizes up to 80 percent of a project's cost, provided that the project's budget falls within $45,000.[89]

In order to create the large base of farmers that will produce the switchgrass needed for ethanol production, the Governor has dedicated $8 million to encourage local production of switchgrass until the market is stable.[90] This incentive program will be carried out through direct payments to farmers and will provide them with both high quality switchgrass seed and technical support throughout the growing process.[91]

5.4 Technology

Mascoma is developing a technique known as Consolidated Bioprocessing, which seeks to condense various biologically mediated phases associated with ethanol production into a single step.[92] The process requires more research and development in order to be competitive with Range Fuels' method.

5.5 Goals

Unlike Range Fuels' facility in Georgia, the Mascoma pilot plant in Tennessee will only be one-tenth of the size of a commercial production plant, thus allowing for a fine tuning of the conversion process.[93] Mascoma aims to produce five million gallons annually, which will require 170 tons of switchgrass per day.[94]

With the installation of several more cellulosic ethanol plants, Tennessee has the capacity to produce over one billion gallons of cellulosic ethanol annually. Models that set the wholesale price at $1.20 per gallon show that this increase could potentially offset one third of petroleum usage in the state.[95,96] However, the exact ethanol/gasoline mixture that would be utilized to achieve this level of consumption is not discussed in the UT Biofuels Initiative.

5.6 Economic Development

The implementation of the Tennessee Biofuels Initiative could lead to $100 million annually in new farm revenue as well as the creation of 4,000 new jobs in rural communities.[97] This could have a dramatic impact upon Tennessee's economy and the quality of life of its population.

6. POLICY OPTIONS

6.1 Help Fund a Cellulosic Ethanol Plant

Vermont might follow Tennessee's lead and partner with a corporation such as Mascoma to build a cellulosic ethanol demonstration plant. The state could run the plant through a new "Biofuels Innovation Center" in the University of Vermont which would also conduct research on cellulosic ethanol. These new funds could be itemized as higher education funding or delivered through a new "Vermont Biofuels Fund." Such a large infusion of funding into cellulosic ethanol research and development should encourage cellulosic ethanol companies to start up in the state and speed the development process of cellulosic ethanol.

There are at least three positive aspects to such a plan:

1. An ethanol plant would help revive rural economies since it would supply both the agricultural and timber industries with more revenue.
2. The new plant would attract many high-paying high tech jobs to the state.
3. The plant would reduce the states greenhouse gas emissions.

There are at least four negative aspects to adopting such a policy at present:

1. Because of its shorter growing season, lack of pulp mills, and small government, Vermont is at a competitive disadvantage in terms of potential for a cellulosic ethanol plant. The state's incentive package would have to be large to overcome that disadvantage.
2. There is still no consensus on the most efficient method of producing cellulosic ethanol. If the state were to invest too early in a plant, it might find itself funding a technologically inferior plant.
3. Any new cellulosic ethanol plants will have high costs
4. A very large amount of private and government money is already going into the industry, and it is likely that cellulosic ethanol will become commercially viable regardless of any action by Vermont. By waiting, the state would still be able to benefit from cellulosic ethanol research and development without having to pay for it.

6.2 Increase Funding for Feasibility Studies

Another option would be to expand funding into cellulosic ethanol feasibility research that would prepare the state for the day when the technology becomes commercially viable. Currently, both the Division of Forestry and the Division of Agricultural Development are conducting such research. Possible options include:

- Increase research into switchgrass, particularly with respect to finding the strain of the plant that could be best utilized in Vermont
- Fund a study looking into incorporating cellulosic ethanol plants into public biomass power plants
- Fund a study to predict the number of ethanol blending plants needed to supply Vermont with E10 gasoline

This plan has the advantage of costing little and not adding additional bureaucracy. The downside is that such research would do little to establish the state of Vermont as a leader in cellulosic ethanol research and development. There would be few jobs created, and Vermont's timber and agricultural industry would not benefit in the near term.

6.3 Tax Incentives

Vermont could also encourage cellulosic ethanol production by increasing the tax incentives it offers for biofuels:

- To increase demand for cellulosic ethanol, the state could exempt all gasoline that contains a certain amount of ethanol (e.g., E85) from the gas tax. Currently no state offers such an exemption, although the governor Massachusetts has proposed legislation to do so.[98]
- Vermont could follow the lead of Georgia and exempt all materials used in the construction and production of cellulosic ethanol from the sales tax.
- The state could offer property tax relief to cellulosic ethanol plants.
- Ethanol plants could receive a tax credit for every gallon of ethanol they produce.

The primary benefit to these policies is they would, at very little cost, encourage cellulosic ethanol companies to relocate their facilities to Vermont. A major downside is that once the cellulosic ethanol industry matures and expands, these incentives could become a serious loss of revenue for the state unless a sunset provision was passed.

6.4 Increase the Demand for Cellulosic Ethanol

The state could increase the demand for cellulosic ethanol by:

- Mandating that all state cars and buses be flex-fuel vehicles
- Creating tax credits for individuals or companies who buy flex-fuel cars
- Providing low interest loans and tax breaks to gas stations that install E85 pumps

This option is both cheap and market oriented. The primary problem is that the current impediment to cellulosic ethanol production is not low demand but the high cost of production. There is already a large unfulfilled demand in Vermont for E10 fuel (because virtually all gasoline-powered vehicles can run on it), and it is doubtful increasing the demand for E85 fuel will be a large enough incentive for companies to build a plant in Vermont.

6.5 Mandate Use of Ethanol

Vermont could follow in the footsteps of states such as Hawaii and Minnesota and mandate that all gasoline sold be blended with at least a 10 percent ethanol – a blend on which all cars can run. This option would be cheap, but is unlikely to be economically feasible. Without a breakthrough in cellulosic ethanol technology, Vermont simply does not have the climate to produce ethanol in a scale large enough to satisfy the demand generated by such a policy. Vermont could get the ethanol from elsewhere, but high transportation costs would drive up prices. Additionally, the state would not experience the major secondary benefits (e.g., jobs).

6.6 Better Utilize Current Incentives

Vermont could fund more marketing and outreach programs to encourage ethanol companies to relocate into the state and take advantage of current incentives. The state could also offer technical assistance to local entrepreneurs aiming to start an alternative fuel company. The advantages to such a plan are that it is relatively inexpensive and aims to improve the effectiveness of current programs rather than to create new ones. On the other hand, similar action is already being taken through programs such as the VEPC.

7. CONCLUSION

Ethanol continues to receive a great deal of attention as a transportation fuel alternative to gasoline. Currently, most research supports the conclusion that the environmental benefits from the use of cellulosic ethanol outweigh those associated with corn-derived ethanol. In Vermont, the production of ethanol from corn is not highly feasible. However, cellulosic ethanol production may provide opportunities in the agricultural, research and development, and industrial sectors. In addition, the approximately 600,000 gas-powered vehicles in the state constitute a pre-existing market for ethanol in the form of E10.

The cases of Range Fuels in Georgia and Mascoma Corporation in Tennessee provide examples of how state governments can encourage the development of a local cellulosic ethanol industry. In particular, tax incentives, funding commitments, and/or the establishment of a formal program (e.g., the Tennessee Biofuels Initiative) for cellulosic ethanol plants can be used to attract private investment. Other policy options for Vermont include: increasing the funding and mandates for feasibility studies currently underway in the state; increasing the statewide demand for ethanol through tax credits, loans, or fuel mandates; and working to better promote incentives currently in place. Each of these possibilities has certain strengths and weaknesses in terms of effectiveness and potential impacts. Additionally, each would play a different role in any effort to build a new cellulosic ethanol industry in the state, if the policymakers and citizens of Vermont decided to pursue that opportunity.

APPENDIX I: CASE STUDIES FACT SHEET

	Range Fuels in Georgia	Mascoma Corp. in Tennessee
Feedstock	Wood	Switchgrass
Capacity	• 20 million gallons/yr (start date) • 100 million gallons/yr (optimum production)	• 5 million gallons/yr using 170 tons of switchgrass per day • Plant only intended to be one-tenth the size of a commercial plant
Production Start Date	Information unavailable	January 2009
Initial Costs	$225 million	Information unavailable
Flex-Fuel(E85)Vehicles in Use Statewide[99]	165,608	93,698
Government Subsidies	• Grants and tax cuts from both state and federal government, including $76 million grant from Department of Energy • State legislation working to encourage more gas stations to offer E85	• Tennessee's 2007-2008 fiscal year pledges $40 million to the construction of the plant and $27 million to research and development of cellulosic ethanol • Oak Ridge National Laboratory awarded $125 million by Department of Energy; its research supports the facility • $8 million incentive program for growing switchgrass locally
Job Creation	More than 70 new jobs expected in the Soperton locale alone	Tennessee Biofuels Initiative hopes to stimulate the creation of 4,000 new jobs

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