Vermont Sustainable Jobs Fund

Accelerating the Development of Vermont's Green Economy

Cellulosic Ethanol in the Vermont Context

What is Cellulosic Ethanol?

Cellulosic ethanol is widely touted as the holy grail of renewable liquid fuels. While corn-based ethanol produced in the Midwest and Brazilian ethanol made from sugarcane are derived from plant starch or sugar, cellulosic ethanol is made from the abundant cellulose in plant walls. The beauty of cellulosic ethanol is that it can be produced from a wide variety of biomass feedstocks including "agricultural plant wastes (corn stover, cereal straws, sugarcane bagasse), plant wastes from industrial processes (sawdust, paper pulp) and energy crops grown specifically for fuel production, such as switchgrass" (Greer, 2005). Consequently, many sources believe that cellulosic ethanol can replace a significant portion of our current gasoline consumption (Greene and Mugica, 2005; Greer, 2005; Jenner, 2006; Oak Ridge National Laboratory, 2005; the 25 by '25 initiative).

Benefits of Cellulosic Ethanol

Cellulosic ethanol is reported to have many benefits over corn-based ethanol. A recent report from Lester Brown and the Earth Policy Institute looked at U.S. Department of Agriculture corn projections and determined that about 70 percent of the growth in world grain use will be for ethanol, not food consumption.

Brown writes "The 55 million tons of U.S. corn going into ethanol this year represent nearly one sixth of the country's grain harvest but will supply only 3 percent of its automotive fuel." The Earth Policy Institute website includes graphs showing that world grain stocks have dropped and world grain production per person has leveled off. The obvious implication is that corn for ethanol is competing with corn for food while not providing a significant energy benefit. On the other hand, as currently imagined, the feedstocks for cellulosic ethanol do not compete with food production. Additionally, Jenner reports that up to three times more biomass is possible from crops such as switchgrass compared to corn (2006: 17).

Much of the debate around corn-based ethanol has revolved around its net energy balance (Pimentel and Patzek, 2005; Farrell et al., 2006). For example, Pimentel and Patzek's widely distributed article claims that ethanol production using corn required 29 percent more fossil energy than the ethanol produced (2005: 65). On other hand, Farrell et al. find that corn ethanol

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reduces petroleum use by about 95% on an energetic basis but only reduces GHG emissions by about 13% (2006: 506).

An Argonne National Laboratory study and a British study (Elsayed and Mortimer, 2003) found that cellulosic ethanol required the least fossil energy of any other source considered (because of the plant lignin burned for electricity and heat). Cellulosic ethanol also had the lowest greenhouse gas emissions of any transportation fuel considered (-61 percent compared to gasoline).

The Argonne National Laboratory well-to-wheel study compared internal combustion engines (19.6 miles per gallon of gasoline equivalent) to high efficiency vehicles (27.9 miles per gallon of gasoline equivalent) when using cellulosic E85 (Table 1). Reductions in high efficiency vehicle emissions and internal combustion engine emissions are not more pronounced due to blending with gasoline and the use of fossil fuels to grow feedstocks and make E85.

Table 1. Well-to-Wheel Emissions of Cellulosic E85

	Internal Combustion Engine	High Efficiency Vehicle
Fossil Fuels	-65%	-65%
Petroleum	-67%	-68%
Greenhouse Gases	-61%	-60%
VOC	7%	6%
Carbon monoxide	0%	0%
NO_x	36%	33%
PM_{10}	-20%	-16%
SO_x	-42%	-42%

Source: Argonne National Laboratory. 2001

The sources of NO_x increases include nitrogen fertilizer production, N-fertilizer application for switchgrass, biomass transportation, fuel production, and fuel transportation. The authors suggest that the increase is smaller than they expected.

The substantial greenhouse gas reductions achieved by using cellulosic ethanol would go a long way toward meeting the objectives of Act 168, signed into law by Governor Douglas in 2006. Act 168 stipulates that Vermont will reduce its emissions of greenhouse gases from the 1990 baseline by 25 percent by January 1, 2012, by 50 percent by 2028, and, if practicable using reasonable efforts, by 75 percent by January 1, 2050.

Vermont's Market for Cellulosic Ethanol

Vermont's market for cellulosic ethanol is comparatively huge, encompassing over 600,000 gasoline powered vehicles, or 95 percent of all vehicles in Vermont (Table 2).

Table 2. Transportation Market for Cellulosic Ethanol in Vermont

	Cars	Trucks	Ag.	Cycle	Moped	ATV	Muni.	State	Total
Gas	417,964	135,666	1,939	24,540	591	15,645	2,755	1,112	600,212
% of Total	98.79	86.30	54.27	99.97	100	99.55	37.14	52.18	94.63

Source: Vehicle information supplied by Vermont Department of Motor Vehicles, June 20, 2006.

These vehicles, and tourists passing through the State, consumed 353,094,000 gallons of gasoline in 2004 (about a 3 percent increase over 2002 consumption). This is equal to 3,453,965 tons of carbon dioxide (353,094,000 x 19.564 pounds CO_2 per unit volume = 6,907,931,016 pounds, or 3,453,965 tons). If all of Vermont's gasoline powered vehicles miraculously used cellulosic E85, then 2004 greenhouse gas emissions would have dropped 2,106,919 tons (.61 * 3,453,965). This is equal to a 39 percent reduction of 1990 greenhouse gas emissions levels.

Obstacles

Although cellulosic ethanol holds tremendous promise, the fact is that there are no commercially operating cellulosic ethanol facilities in the United States. Unlike the growth of local biodiesel production in Vermont, the difficulty with cellulosic ethanol is that there are currently no decentralized models or home brewing options for production. For example, the process created by Iogen Corporation (www.iogen.ca) uses proprietary enzymes to separate glucose from the cellulose. The glucose is then fermented into ethanol. Lignin, which also comes from plant cell walls, is separated from the cellulose and burned to generate electricity and heat.

A feasibility study conducted in Oregon estimated that the capital cost of building a cellulosic ethanol facility is over $100 million for a 20 to 25 million gallons per year plant (Graf and Koehler, 2000). Since the development of cellulosic ethanol production facilities promises to be expensive, the Department of Energy is spending $160 million on a competition to build the nation's first three plants (Fialka and Kilman, 2006). Although over 30 businesses have entered the competition, a few very large players—ADM, Abengoa Bioenergy, DuPont—are making huge investments in cellulosic ethanol. Iogen has also received a substantial investment from Goldman Sachs ($30 million), and is looking at building a facility in Idaho.

As Table 3 demonstrates, cellulosic ethanol is not a commercially ready production process. Nearly every existing and planned ethanol facility in the United States continues to use the starch in corn as a feedstock, rather than cellulose. The majority of ethanol plants in the United States are located in the Midwest, for obvious reasons. There are no ethanol facilities located in the Northeast/New England. It is worth noting that if all the existing or under construction plants in the United States were operating at full capacity (7,040,400,000 gallons a year); it would equal 5 percent of total gasoline use in the United States in 2002.

Table 3. Ethanol Production Facilities in the United States

Company	Location	Feedstock	Current Capacity (mmgy)	Under Construction/ Expansions (mmgy)
Abengoa Bioenergy Corp.	York, NE	Corn/milo	55	
	Colwich, KS		25	
	Portales, NM		30	
	Ravenna, NE			88
ACE Ethanol, LLC	Stanley, WI	Corn	39	
Adkins Energy, LLC	Lena, IL	Corn	40	
Advanced Bioenergy	Fairmont, NE	Corn		100
AGP	Hastings, NE	Corn	52	
Agra Resources Coop. d.b.a. EXOL	Albert Lea, MN	Corn	40	8
Agri-Energy, LLC	Luverne, MN	Corn	21	
Alchem Ltd. LLLP	Grafton, ND	Corn	10.5	
Al-Corn Clean Fuel	Claremont, MN	Corn	35	
Amaizing Energy, LLC	Denison, IA	Corn	40	
Archer Daniels Midland	Decatur, IL	Corn	1,070	
	Cedar Rapids, IA			
	Clinton, IA			
	Columbus, NE			
	Marshall, MN			
	Peoria, IL			
	Wallhalla, ND	Corn/barley		
ASAlliances Biofuels, LLC	Albion, NE	Corn		100
	Linden, IN			100
	Bloomingburg, OH			100
Aventine Renewable Energy, LLC	Pekin, IL	Corn	100	57
	Aurora, NE		50	
Badger State Ethanol, LLC	Monroe, WI	Corn	48	
Big River Resources, LLC	W. Burlington, IA	Corn	40	
Blue Flint Ethanol	Underwood, ND	Corn		50
Broin Enterprises, Inc	Scotland, SD	Corn	9	

Company	Location	Feedstock	Current Capacity (mmgy)	Under Construction/ Expansions (mmgy)
Bushmills Ethanol, Inc	Atwater, MN	Corn	40	
Cargill, Inc	Blair, NE	Corn	85	
	Eddyville, IA		35	
Central Indiana Ethanol, LLC	Marion, IN	Corn		40
Central MN Ethanol Coop	Little Falls, MN	Corn	21.5	
Central Wisconsin Alcohol	Plover, WI	Seed corn	4	
Chief Ethanol	Hastings, NE	Corn	62	
Chippewa Valley Ethanol Co	Benson, MN	Corn	45	
Commonwealth Agri-Energy, LLC	Hopkinsville, KY	Corn	33	
Conestoga Energy Partners	Garden City, KS	Corn/milo		55
Corn, LP	Goldfield, IA	Corn	50	
Cornhusker Energy Lexington, LLC	Lexington, NE	Corn		40
Corn Plus, LLP	Winnebago, MN	Corn	44	
Dakota Ethanol, LLC	Wentworth, SD	Corn	50	
DENCO, LLC	Morris, MN	Corn	21.5	
E3 Biofuels	Mead, NE	Corn		24
East Kansas Agri-Energy, LLC	Garnett, KS	Corn	35	
ESE Alcohol Inc.	Leoti, KS	Seed corn	1.5	
Ethanol2000, LLP	Bingham Lake, MN	Corn	32	
Frontier Ethanol, LLC	Gowrie, IA	Corn	60	
Front Range Energy, LLC	Windsor, CO	Corn	40	
Glacial Lakes Energy, LLC	Watertown, SD	Corn	50	
Global Ethanol/ Midwest Grain Processors	Lakota, IA	Corn	95	
	Riga, MI	Corn		57

Company	Location	Feedstock	Current Capacity (mmgy)	Under Construction/ Expansions (mmgy)
Golden Cheese Company of California	Corona, CA	Cheese whey	5	
Golden Grain Energy, LLC	Mason City, IA	Corn	60	50
Golden Triangle Energy, LLC	Craig, MO	Corn	20	
Grain Processing Corp.	Muscatine, IA	Corn	20	
Granite Falls Energy, LLC	Granite Falls, MN	Corn	45	
Great Plains Ethanol, LLC	Chancellor, SD	Corn	50	
Green Plains Renewable Energy	Shenandoah, IA	Corn		50
Hawkeye Renewables, LLC	Iowa Falls, IA	Corn	100	
	Fairbank, IA		100	
Heartland Corn Products	Winthrop, MN	Corn	36	
Heartland Grain Fuels, LP	Aberdeen, SD	Corn	9	
	Huron, SD		12	18
Heron Lake BioEnergy, LLC	Heron Lake, MN	Corn		50
Horizon Ethanol, LLC	Jewell, IA	Corn	60	
Husker Ag, LLC	Plainview, NE	Corn	26.5	
Illinois River Energy, LLC	Rochelle, IL	Corn		50
Iowa Ethanol, LLC	Hanlontown, IA	Corn	50	
Iroquois Bio-Energy Company, LLC	Rensselaer, IN	Corn		40
James Valley Ethanol, LLC	Groton, SD	Corn	50	
KAAPA Ethanol, LLC	Minden, NE	Corn	40	
Land O' Lakes	Melrose, MN	Cheese whey	2.6	

Company	Location	Feedstock	Current Capacity (mmgy)	Under Construction/ Expansions (mmgy)
Lincolnland Agri-Energy, LLC	Palestine, IL	Corn	48	
Lincolnway Energy, LLC	Nevada, IA	Corn	50	
Liquid Resources of Ohio	Medina, OH	Waste beverage	3	
Little Sioux Corn Processors, LP	Marcus, IA	Corn	52	
Merrick/Coors	Golden, CO	Waste beer	1.5	1.5
MGP Ingredients, Inc	Pekin, IL	Corn/wheat starch	78	
	Atchison, KS	Corn		
Michigan Ethanol, LLC	Caro, MI	Corn	50	
Mid America Agri Products/Wheatland	Madrid, NE	Corn		44
Mid-Missouri Energy, Inc	Malta Bend, MO	Corn	45	
Midwest Renewable Energy, LLC	Sutherland, NE	Corn	25	
Millennium Ethanol	Marion, SD	Corn		100
Minnesota Energy	Buffalo Lake, MN	Corn	18	
Missouri Ethanol	Laddonia, MO	Corn		45
New Energy Corp	South Bend, IN	Corn	102	
North Country Ethanol, LLC	Rosholt, SD	Corn	20	
Northeast Missouri Grain, LLC	Macon, MO	Corn	45	
Northern Lights Ethanol, LLC	Big Stone City, SD	Corn	50	
Northstar Ethanol, LLC	Lake Crystal, MN	Corn	52	
Otter Creek Ethanol, LLC	Ashton, IA	Corn	55	
Pacific Ethanol	Madera, CA	Corn		35
Panhandle Energies of Dumas, LP	Dumas, TX	Corn/ sorghum		30

Company	Location	Feedstock	Current Capacity (mmgy)	Under Construction/ Expansions (mmgy)
Parallel Products	Louisville, KY	Corn	5.4	
	Rancho Cucamonga, CA	Corn		
Permeate Refining	Hopkinton, IA	Sugars/starch	1.5	
Phoenix Biofuels	Goshen, CA	Corn	25	
Pinal Energy, LLC	Maricopa, AZ	Corn		55
Pine Lake Corn Processors, LLC	Steamboat Rock, IA	Corn	20	
Pinnacle Ethanol, LLC	Corning, IA	Corn		60
Platte Valley Fuel Ethanol, LLC	Central City, NE	Corn	40	
Prairie Ethanol, LLC	Loomis, SD	Corn		60
Prairie Horizon Agri-Energy, LLC	Phillipsburg, KS	Corn		40
Pro-Corn, LLC	Preston, MN	Corn	42	
Quad-County Corn Processors	Galva, IA	Corn	27	
Red Trail Energy, LLC	Richardton, ND	Corn		50
Redfield Energy, LLC	Redfield, SD	Corn		50
Reeve Agri-Energy	Garden City, KS	Corn/milo	12	
Siouxland Energy & Livestock Coop	Sioux Center, IA	Corn	25	10
Siouxland Ethanol, LLC	Jackson, NE	Corn		50
Sioux River Ethanol, LLC	Hudson, SD	Corn	55	
Sterling Ethanol, LLC	Sterling, CO	Corn	42	
Tall Corn Ethanol, LLC	Coon Rapids, IA	Corn	49	
Tate & Lyle	Loudon, TN	Corn	67	
The Andersons Albion Ethanol LLC	Albion, MI	Corn		55
The Andersons Clymers Ethanol, LLC	Clymers, IN	Corn		110

Company	Location	Feedstock	Current Capacity (mmgy)	Under Construction/ Expansions (mmgy)
Trenton Agri Products, LLC	Trenton, NE	Corn	35	10
United WI Grain Producers, LLC	Friesland, WI	Corn	49	
US BioEnergy Corp.	Albert City, IA	Corn		100
	Lake Odessa, MI	Corn		45
U.S. Energy Partners, LLC	Russell, KS	Milo/ wheat starch	48	
Utica Energy, LLC	Oshkosh, WI	Corn	48	
Val-E Ethanol, LLC	Ord, NE	Corn		45
VeraSun Energy Corporation	Aurora, SD	Corn	230	110
	Ft. Dodge, IA	Corn		
	Charles City, IA	Corn		
Voyager Ethanol, LLC	Emmetsburg, IA	Corn	52	
Western Plains Energy, LLC	Campus, KS	Corn	45	
Western Wisconsin Renewable Energy, LLC	Boyceville, WI	Corn	40	40
Wind Gap Farms	Baconton, GA	Brewery waste	0.4	
Wyoming Ethanol	Torrington, WY	Corn	5	
Xethanol BioFuels, LLC	Blairstown, IA	Corn	5	
		Total	4817.9	2222.5

Source: Renewable Fuels Association, http://www.ethanolrfa.org/industry/locations/

Opportunities

Although the challenges of building a cellulosic ethanol production facility are substantial, the Vermont Alternative Energy Corporation (VAEC) has calculated that a ten million gallon a year facility (equal to about 3 percent of 2004 gasoline consumption) is possible based on Vermont's feedstocks, at a cost of $44 million. Burning lignin at the facility would also generate 2100 kilowatts of electricity.

Greenwaste, waste paper, wood and lumber, forest residues, agricultural residues, and a variety of grasses are usually described as feedstocks for cellulosic ethanol. The Oregon cellulosic ethanol feasibility study lists a range of yields per feedstock that was provided to them by the National Renewable Energy Laboratory:

- Greenwaste: 46.6 gallons/bone dry ton (bdt)
- Mixed waste paper: 54 gallons/bdt
- Wood and lumber: 45.6 gallons/bdt
- Paper mill sludge: 66.6 gallons/bdt
- Grass straw: 60.6 gallons/bdt
- Wheat straw: 60 gallons/bdt
- Forest residues: 66 gallons/bdt
- Agriculture residues: 50 gallons/bdt (2000: 18).

VAEC's cellulosic ethanol feasibility study concludes that wood, lumber, forest residue, and grass straw would make up the most likely ethanol feedstocks in Vermont. VAEC believes that 10 million gallons of cellulosic ethanol can be produced with about 60,000 acres of land devoted to hay. This is equal to 17 percent of the land currently devoted to forage in Vermont (and 4.8 percent of all agriculture land in Vermont). According to the Vermont Division of Forestry, there are over 140 million tons of wood in Vermont's forests. The McNeil Generating Station in Burlington uses 180,000 tons of wood per year (less than one percent of the total). Statistics for 2003 show that less than one percent (1,096,382 tons) of Vermont's total amount of wood was harvested. With a yield of 45.6 gallons of ethanol per bone dry ton of wood or lumber, 219,298 tons of wood (less than one pecent of the total) would be required to produce 10 million gallons. With a yield of 66 gallons of ethanol per bone dry ton of forest residues, 151,515 tons of residue (less than one percent of the total) would be required to produce 10 million gallons.

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