Appendix C

Status and Growth Potential of U.S. Ethanol Production and Markets

Ethyl alcohol, or ethanol, has existed since the beginning of recorded history. The ancient Egyptians produced alcohol through natural fermentation of vegetative materials while the Chinese discovered the art of distillation to increase the concentration of alcohol in fermented solutions.

Centuries later in 1907, ethanol was made available to the American motoring public by Henry Ford. He not only produced his first vehicle to run on ethanol, he built ethanol plants to supply the fuel. Ethanol also established itself in other markets such as the production of gunpowder for the war effort and in the developing chemical industry. As these markets expanded, the fossil fuel-based industry gained momentum in the fuel and chemical industries.

In the 1970s, the ethanol industry began to reemerge as international oil demands and Middle East oil-producing regions collided, resulting in a rise of world oil prices. When the Organization of Petroleum Exporting Countries imposed an oil boycott on the United States, the resulting gasoline shortages and price hikes caused a shock to the nation's economy. This prompted a demand for alternatives such as ethanol. In order to encourage the use of alternative fuels, Congress enacted the Federal Gasoline Excise Tax Exemption for ethanol. It was designed to spur use, not only by gasoline marketers, but by consumers as well.

EPA's lead phase-out program added additional demand for ethanol in the fuels market. The industry began marketing ethanol as a replacement for lead in gasoline. Ethanol's high octane value of 113 points made it an ideal anti-knocking agent. A 10-percent blend adds about 2.5 octane points to standard gasoline. The use of 10-percent blends in their automobiles is covered by the warranties of every major auto manufacturer.

In the late 1980s, ethanol began a different role in the transportation fuel market by providing cleaner burning gasoline for cities, including Denver and Phoenix, where air quality was very poor. Ethanol's high oxygen content increases the efficiency of combustion in the engine, resulting in lower levels of carbon monoxide and hydrocarbon tailpipe emissions. In 1990, oxygenated fuels became part of the Clean Air Act Amendments to mitigate air pollution in our nation's dirtiest cities.

Today, the United States has the capacity to produce over 1.8 billion gallons of ethanol per year to meet these demands. Due to increasing demand, another 145 million gallons per year (gpy) of ethanol production capacity is under construction. Many more millions of gallons of production are in the planning stages. However, the importation of petroleum is still on the rise. The U.S. now imports 61 percent of its oil supply.

While capacity is at 1.8 billion gpy, plants are currently operating at about 85 percent of capacity. Ethanol facilities therefore have the capability of producing about 250 to 270 million more gallons of ethanol per year if favorable market conditions exist. Spare capacity is generally concentrated among major ethanol producers, particularly in wet-milling operations, where starch can be diverted to other sugar products.

Over the past 10 years, advancements in ethanol production technology have enabled more ethanol to be extracted from a bushel of corn. Ethanol yields have improved from 2.5 gallons per bushel to as much as 2.75 gallons per bushel, a 10-percent increase. Enzymes have become more effective in breaking down the sugar for advanced yeast strains to ferment the sugars into more ethanol. Molecular sieves reduce the time and energy required to separate the alcohol from water in the distillation process.

U.S. Ethanol Production

Currently there are 55 producing ethanol production facilities in the United States (see **Map 2** and **Table 10**) with several under construction (**Table 11**). Grain crops including corn, milo, barley and wheat make up 95 percent of the ethanol produced today. The majority of grain ethanol plants are located in the Midwest near their feedstock source. Illinois is the largest producer of ethanol. Minnesota and Iowa follow closely behind.

Two processes – dry and wet milling – are used to convert grain feedstocks to ethanol and other co-products. An estimated one-third of ethanol produced comes from corn dry-milling plants and two-thirds from corn wet milling. In a wet mill, only the starch is fermented, unlike dry milling where the entire corn mash is fermented. The objective of wet milling is to obtain as many fractions of the corn kernel as possible while using only the most readily fermentable fraction (starch) for ethanol production.

In dry milling, the corn is ground in dry form before it is cooked in water. Enzymes are added to hydrolyze the starch to glucose, which is then fermented by yeast to ethanol. The ethanol is stripped of any remaining water through various processes. Dry milling typically results in product yields of 2.7 gallons of ethanol, 17.5 pounds of distiller's dried grains and 17 pounds of carbon dioxide per bushel of corn.

In wet milling, the corn kernel is first soaked in a solution of water and sulfur dioxide for 24 to 48 hours to loosen the germ and hull fiber. The germ is then removed from the kernel and corn oil, a valuable co-product, is extracted from the germ. The starch is removed from the endosperm and converted to ethanol or other sugar co-products such as high fructose corn syrup. Typically, one bushel of corn will yield 2.5 gallons of ethanol, 13.5 gallons of corn gluten feed, 3 pounds of corn gluten meal and 1.55 pounds of corn oil.

In addition to grain, several plants use innovative feedstocks such as wastes from food and beverage manufacturing. Parallel Products in California collects, separates and processes liquid waste sugars from discarded or dated bottled soda, juices and beer. Kraft Corporation in Minnesota and Golden Cheese in California are producing ethanol from cheese whey and other dairy processing waste. Coors Brewery in Colorado uses waste beer to produce ethanol. J.R. Simplot uses potato waste slurries at its processing plants in Idaho. Georgia Pacific uses pulp mill liquor, a waste product from its paper plant in Washington.

Map 2: Map of U.S. Ethanol Plants

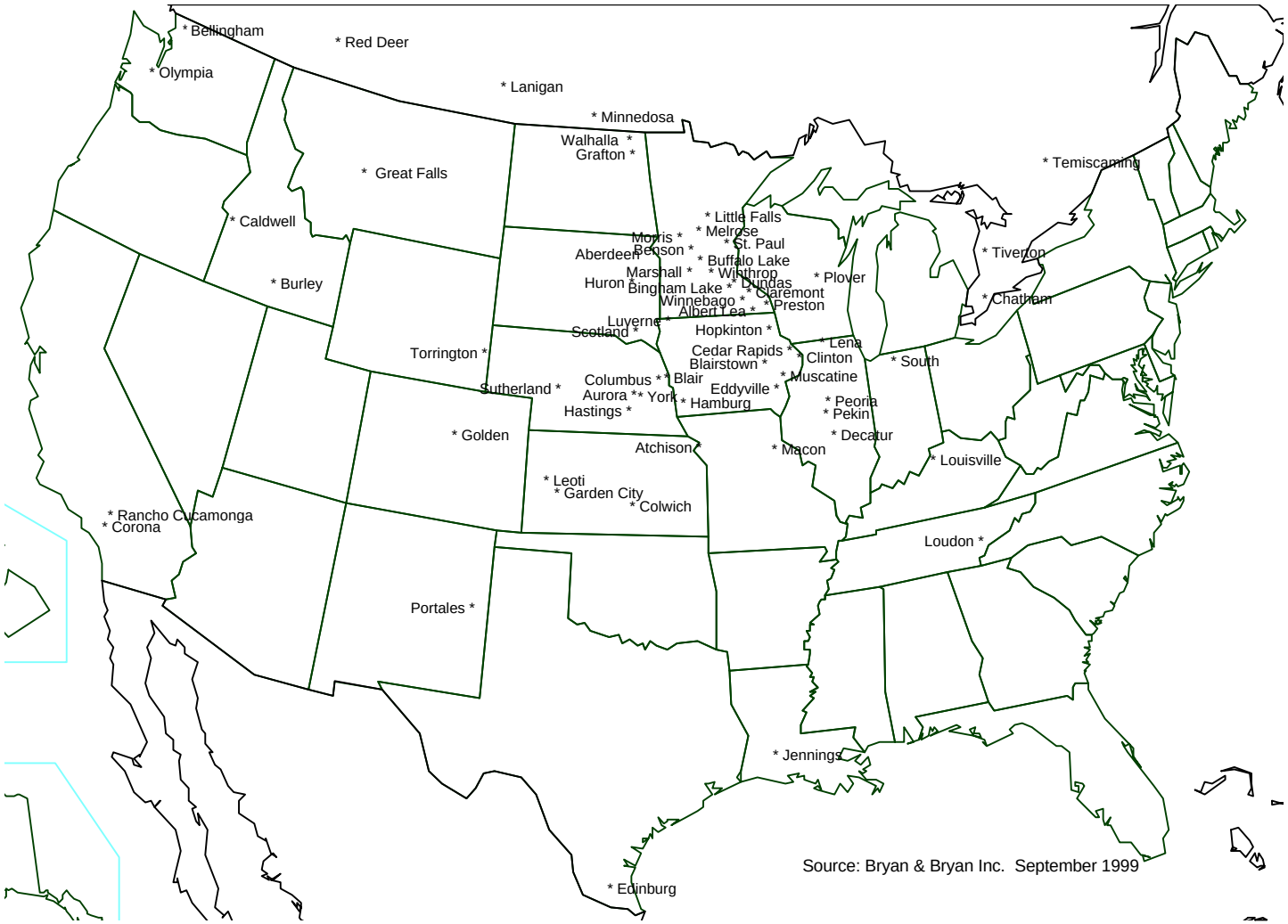


Table 10: U.S. Ethanol Production Capacity

COMPANY	LOCATION		FEEDSTOCK	MMGY
A.E. Staley	Loudon	TN	Corn	45
AGP	Hastings	NE	Corn	52
Agri-Energy	Luverne	MN	Corn	17
Alchem	Grafton	ND	Corn	10.5
Al-Corn	Claremont	MN	Corn	17
Archer Daniels Midland (total capacity)	Decatur	IL	Corn	750
	Peoria	IL	Corn	
	Cedar Rapids	IA	Corn	
	Clinton	IA	Corn	
ADM Corn	Walhalla	ND	Corn/barley	28
Broin Enterprises	Scotland	SD	Corn	7
Cargill (total capacity)	Blair	NE	Corn	100
	Eddyville	IA	Corn	
Central Minnesota	Little Falls	MN	Corn	17
Chief Ethanol	Hastings	NE	Corn	62
Chippewa Valley Ethanol	Benson	MN	Corn	19
Corn Plus	Winnebago	MN	Corn	18
DENCO, LLC.	Morris	MN	Corn	15
ESE Alcohol	Leoti	KS	Seed corn	1.1
Ethanol2000	Bingham Lake	MN	Corn	15
Exol, Inc.	Albert Lea	MN	Corn	15
Georgia-Pacific	Bellingham	WA	Paper waste	7
Golden Cheese	Corona	CA	Whey	2.8
Gopher State Ethanol	St. Paul	MN	Corn	15
Grain Processing Corp.	Muscatine	IA	Corn	10
Heartland Corn Products	Winthrop	MN	Corn	17
Heartland Grain Fuel	Aberdeen	SD	Corn	8
	Huron	SD	Corn	14
High Plains Corporation (total capacity)	York	NE	Corn/milo	70
	Colwich	KS		
	Portales	NM		
J.R. Simplot (total capacity)	Caldwell	ID	Potato waste	6
	Burley	ID		
Jonton Alcohol	Edinburg	TX	Corn	1.2
Kraft, Inc.	Melrose	MN	Whey	3
Manildra Ethanol	Hamburg	IA	Corn/milo/wheat starch	7
Merrick/Coors	Golden	CO	Waste beer	1.5
Midwest Grain (total capacity)	Pekin	IL	Corn/wheat starch	108
	Atchison	KS		
Minnesota Clean Fuels	Dundas	MN	Waste sucrose	1.5
Minnesota Corn Processors (total capacity)	Columbus	NE	Corn	110
	Marshall	MN	Corn	
Minnesota Energy	Buffalo Lake	MN	Corn	12
New Energy Corp.	South Bend	IN	Corn	85
Northeast MO Grain Processors	Macon	MO	Corn	15
Pabst Brewing	Olympia	WA	Brewery waste	0.7

Parallel Products	Louisville	KY	Beverage waste	12
	Bartow	FL		
	R. Cucamonga	CA		
Permeate Refining	Hopkinton	IA	Sugars & Starches	1.5
Pro-Corn	Preston	MN	Corn	17
Reeve Agri-Energy	Garden City	KS	Corn/milo	10
Sunrise Energy	Blairstown	NE	Corn	7
Sutherland Associates	Sutherland	NE	Corn	15
Williams Energy Services	Pekin	IL	Corn	100
Nebraska Energy (Williams Energy)	Aurora	NE	Corn	30
Wyoming Ethanol	Torrington	WY	Corn	5
Total Capacity				**1,865.8**

Source: Bryan & Bryan Inc., May 2000

Table 11: U.S. Ethanol Plants Under Construction

COMPANY	LOCATION		FEEDSTOCK	MMGY
Golden Triangle*	St. Joseph	MO	Corn	25
Adkins Energy	Lena	IL	Corn	30
BC International	Jennings	LA	Bagasse/rice hulls	20
Lake Areas Corn Processors	Wentworth	SD	Corn	40
City Brewery	La Crosse	WI	Corn	20
Under Construction Capacity				**175**

Source: Bryan & Bryan Inc. (BBI) May 2000

U.S. Ethanol Markets

The demand for ethanol has grown to over 1.5 billion gallons annually in 2000 (see **Diagram 3**). Ethanol's primary purposes are to serve as an octane extender for gasoline and a clean air additive (oxygenate). In addition, the use of ethanol reduces America's dependence on imported oil, thereby improving the country's balance of trade.

The largest market for ethanol is as an octane enhancer (see **Table 12**). In 1978, to help American industry compete in the fuel market, Congress established an incentive in the form of a tax credit. The tax credit was designed to encourage the oil industry to blend ethanol. The tax credit continues today. Congress recently extended the tax credit to 2007.

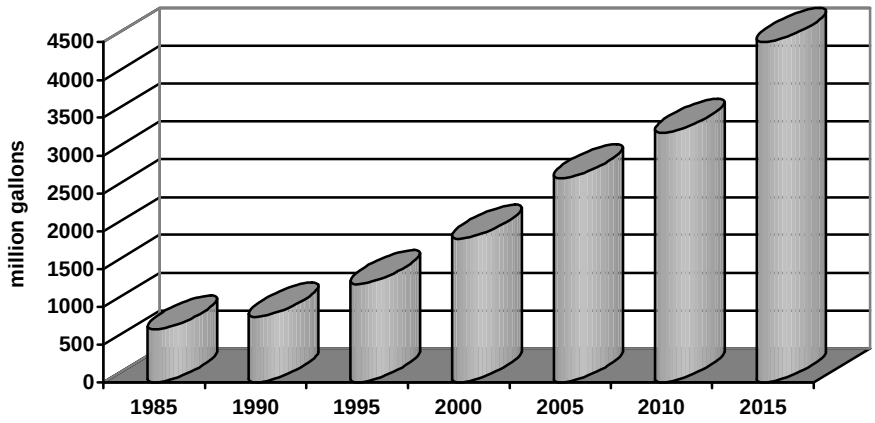
Federal programs such as the Clean Air Act Amendments of 1990 have had significant impacts on the U.S. ethanol industry by creating new markets and initiating new plant construction across the country. Over 30 new ethanol plants and expansion projects have evolved, doubling production capacity from 850 million gpy to over 1.8 billion gpy.

New restrictions on automobile emissions, reductions in carbon monoxide, smog mitigation programs in major cities and a general trend toward the reduction of greenhouse gas emissions continue to drive the demand for ethanol.

Recently, California has been the focus of a major ethanol campaign as methyl tertiary butyl ether (MTBE) is being phased out. MTBE has had the majority share of the oxygenate market in reformulated gasoline in the United States. Discoveries of ground water contamination from MTBE have spurred greater interest in ethanol, the primary competitor for the oxygenate market. Incidences of ground water contamination have occurred in

hundreds of wells in California and in the Northeast where MTBE is the predominant oxygenate. As a result, a nationwide effort to discontinue its use began, following a ban proclaimed in California by the Governor. Ethanol, a fully biodegradable product, is poised to fill the void left in California as well as other parts of the country where the use of MTBE may be banned. California alone represents a potential market equal to almost all of the industry's total current production.

Diagram 3: U.S. Ethanol Demand



Source: Energy Information Administration

Table 12: U.S. Ethanol Markets

Market	Million gpy
Oxygenated Fuels Program	200
Reformulated Gasoline Program	400
Octane Enhancer	650
Minnesota State-Wide Ethanol Program (10% blend used in all gasoline)	250
Total	**1,500**

Source: Renewable Fuels Association, 1999

While there is a great deal of focus on California, another emerging ethanol market in the Northeast is poised for opportunity. As in California, the primary drivers are the health and water concerns surrounding the use of MTBE. Oxy-Busters of New Jersey has been actively seeking the ban of MTBE use for over 5 years. It is likely that other states, including many in the Northeast, will follow suit. As this happens, there could be tremendous market potential for ethanol in these areas.

In 1990, Congress adopted programs that would increase the manufacture and use of alternatively fueled vehicles. The first phase was to incorporate these new low-emission vehicles into the federal and state fleets. Phase II will introduce such vehicles into public and private fleets. Ethanol has an opportunity to help meet those demands with E85 fuel (85% ethanol/15% gasoline). According to the National Ethanol Vehicle Coalition, Ford, Chrysler and General Motors have manufactured about 750,000 E85 flexible fuel vehicles.

E85 vehicles require almost no modification to the factory-produced automobile. In fact, there is so little modification required that the auto industry has not increased the price of an

E85 vehicle compared to a standard car. The challenge for the ethanol industry is to provide sufficient refueling sites to accommodate these cars.

Finally, there are a variety of new uses being developed for ethanol and the co-products associated with ethanol production. Ethanol is gaining interest as a road and power-line de-icer. In addition, ethanol use in a new generation of both stationary and mobile fuel cells is beginning to emerge.