INL/CON-07-13406
PREPRINT

The Role of Cellulosic Ethanol in Transportation

Practical Paths: Climate Change and Beyond

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October 2007

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Summary of presentation at Practical Paths: Climate Change and Beyond
October 30-31, 2007
Boise, ID

Petroleum supplies 40% of total U.S. energy consumption (99.96 Quadrillion Btu in 2006). The transportation sector used 28% of total U.S. energy consumption in 2006. Petroleum provides essentially all of the energy used in the transportation sector. In Idaho during 2005, the cost of motor transportation fuel purchases exceeded $2 billion. In our state, gasoline provides almost 70% of the motor transportation fuel with the balance coming from distillate fuel (diesel). U.S. oil production peaked in 1970 at 3.5 billion barrels with current production at less than 1.9 billion barrels per year (2006). This has resulted in an increase in net imports of crude oil and petroleum products to over 4.5 billion barrels per year (2006). Imports account for 60% of domestic oil and petroleum product consumption. Issues associated with our dependence on foreign sources for so much of our transportation energy include, but are not limited to, security of our energy supplies and import cost transfer.

Ethanol has a long history as a motor fuel and was used to power early model T and other automobiles. However, with the advent of Prohibition in 1920, the use of ethanol use as a motor fuel essentially ended. In recent years, oil embargos and high oil prices has resulted in renewed interest in ethanol. Corn grain is almost exclusively used to produce ethanol fuel in the United States. There are currently 131 fuel ethanol plants in the U.S. with a capacity of 6.9 billion gallons per year and an additional 83 new plants and expansions, with a capacity of 6.6 billion gallons per year, planned or under construction (October 2007). In 2006, 4.86 billion gallons of ethanol were produced in the United States, which used 17% of domestic corn production.

While there is some dispute, the Energy Returned on Energy Invested (EROEI) to produce corn ethanol is generally considered to be 1.34, providing a net energy balance of 34%. This is much lower than the EROEI for gasoline production. Ethanol has lower energy content than gasoline. On a volume basis, ethanol has 68% of the energy content of gasoline. Ethanol fuel blends also have lower energy content than gasoline. E10 (gasoline with 10% ethanol) has 97% of the energy content of gasoline on a volume basis. Similarly, E85 (gasoline with 85% ethanol) has 72% of the energy content of gasoline on a volume basis. As such, gasoline-ethanol blends will provide lower mileage that gasoline alone when used in a conventional internal combustion engine. However, ethanol has an octane rating of 113 compared to 87 for regular unleaded gasoline. As a result, gasoline-ethanol fuels can be used at higher engine compression ratios than with gasoline, which provides improved engine efficiency and can help compensate for the lower energy content of ethanol in engines designed for its use.

With 17% of the domestic corn crop being used to produce 5 billion gallons of ethanol in 2006, alternatives to corn (grain) are needed to avoid excessive competition with corn for its food, feed, and fiber uses. Cellulosic ethanol has the potential for greatly expanded ethanol production using cellulosic residues from agriculture and forestry and from the production of dedicated non-food energy crops. However, it must be done in a sustainable fashion to maintain soil fertility, minimize soil erosion and compaction, minimize water pollution, and conserve water supplies.

In addition, cellulosic ethanol provides environmental advantages in CO_2 emissions, which are of concern relative to climate change. Life cycle analyses indicate that the CO_2 emissions from using corn ethanol for transportation are 14 to 39% lower than gasoline (with the range largely depending upon the source of process heat at the biorefinery). Cellulosic ethanol is essentially CO_2 neutral when lignin (a by-product of the cellulosic ethanol production process) is used for process heat.

The U.S. Department of Energy has set a goal ("30 x 30") to replace 30% of motor gasoline demand by 2030. This will require 60 billion gallons per year of ethanol. While corn ethanol plays a role, this goal cannot be achieved with corn ethanol alone. Cellulosic ethanol provides the promise of achieving this goal while reducing CO_2 emissions. As mentioned previously, the development and implementation of cellulosic ethanol is not without issues. It must be done properly to avoid soil and water issues and technology improvements are needed to enable cost effective production. To achieve the "30 x 30" goal, an estimated one billion tons of biomass per year is required. In a study conducted by Oak Ridge National Laboratory, an estimated 1.3 billion tons of biomass can be produced sustainably per year. This biomass comes from agricultural residues (dry herbaceous residues such as wheat straw and wet herbaceous residues such as corn stover), forest residues, and perennial energy crops (such as switchgrass). It is projected that the "30 x 30" goal is achieved with cellulosic ethanol beginning to come on-line about 2010 and providing over 75% of the fuel ethanol with corn (grain) derived ethanol providing the balance by 2030.

This ethanol can be produced through two general processes, fermentation or gasification. In the fermentation process, cellulosic residues are converted by enzymes into sugars, which are then fermented to ethanol. In the fermentation process, one is concerned with, among other things, the carbohydrate content of the feedstock and the difficulty of converting it to sugars. In the gasification process, the cellulosic feedstock is heated in a pressure vessel with steam to produce gases, which can be reformed using catalysts to produce ethanol and other value added products. In the gasification process, primary concerns are the Btu and moisture contents of the feedstock.

The ethanol must be produced at a cost that is competitive. The DOE program projects an ethanol production cost of $1.07 in 2002 dollars (about $1.30 in today's dollars). This is production cost and not selling price. Considering the fermentation process, estimates have been made as to what needs to be achieved regarding feedstock supply, enzymes, and conversion process costs to achieve this cost target. Significant gains have been made in recent years. For example, in 2001 the cost of the enzymes alone to produce a gallon of cellulosic ethanol was over $3.00. As a result of technology advancements in enzymes, the cost of the enzyme package today is approximately $0.25 per gallon of ethanol and is likely to decrease further in coming years. The current focus is on providing feedstock to the biorefinery at a cost target of $35 per dry ton. This includes the cost of harvesting, collection, transportation, storage, and preprocessing; it also includes a payment to the farmer for the agricultural residue. Feedstock assembly is the focus of research at the Idaho National Laboratory for the DOE-Office of the Biomass Program.

The Energy Policy Act of 2005 authorized grants for the initial "pioneer" biorefineries to demonstrate the feasibility of commercial cellulosic ethanol production. This past spring, six awards were announced. One of them was to the Canadian company Iogen for commercial demonstration of their process to produce ethanol from wheat and barley straw. Their preferred site in the United States is in Shelley, ID where they propose to ultimately build a 60 million gallon per year cellulosic ethanol plant, which will process approximately 800,000 tons of straw per year. This plant provides considerable benefits to Idaho. It will cost the order of $325 million and will take 24-30 months to construct. During construction, it will provide an estimated 1,000 construction jobs. When built, it will require 180 skilled personnel to run. It is also expected to include an R&D center providing about 150 professional jobs, a merging of Idaho's technology and resource based economies.

There are infrastructure issues associated with the distribution and use of ethanol for transportation fuel. All vehicles manufactured since 1990 can use E10. However, use of higher ethanol fuels like E85 requires engine and fuel system modifications. Most of these are simple modifications, involving, for example, proper selection of compatible elastomeric materials and can be accomplished at low cost to provide flex-fuel vehicles. Ethanol is not compatible with transport by existing pipelines due to its propensity to absorb water and because it dissolves deposits on the inside of petroleum pipelines. Currently ethanol is transported from its production point to the distribution center by tanker truck. Ethanol could be transported in pipelines designed for its use. Special pumps are required for dispensing E85 at fuel stations since it can only be used in flex fuel vehicles and because some elastomeric materials in existing gasoline pumps are not compatible with it.

Cellulosic ethanol can help to provide substantial substitution for gasoline and achieve the "30 x 30" goal. It is an important part of the solution to provide domestic transportation fuels. This will displace the need to import at least one billion barrels of petroleum per year with a current value of $85 billion. In doing so, it will keep money in this country, providing jobs and revenues for farmers and rural communities. At the same time, it will reduce life cycle CO_2 emissions that affect climate change. However, it must be implemented in a sustainable fashion, technology advancements are needed to reduce cost, and infrastructure needs must be addressed.