Generation 1.5 Ethanol: The Bridge to Cellulosic Biofuels

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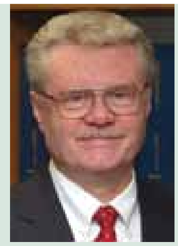

Phil Madson has served as President of KATZEN International, Inc. since 1993. He has held a number of technical and executive positions since joining the firm in 1980, including process engineering, project management, startup services and marketing. KATZEN's focus throughout this period has been the research and development, design and execution of advanced technology for the fuel, industrial and potable ethanol industries worldwide. Phil has concentrated his efforts in the field of value-added agricultural processing as it integrates with ethanol production. His technical specialty is advanced distillation systems development and design. Phil has taught courses on distillation and dehydration around the world for the past quarter-century. He has authored chapters published in the Alcohol Textbook editions 2, 3, 4, and 5. Phil received B.S. and M.S. degrees in Chemical Engineering from Iowa State University and is a registered Professional Engineer. He was the recipient of the "2009 Award of Excellence" for technical and development achievements as recognized by the International Fuel Ethanol Workshop & Expo.

The shortfall of cellulosic biofuel production in the U.S. is threatening the existence of the Renewable Fuel Standard. Utilizing conventional processing technology to convert new sugar and starch sources to ethanol is the next evolutionary step in the development of *Advanced Biofuels* in what we view as Gen 1.5.

In 2007, Congress passed an Energy Independence and Security Act (EISA) which expanded the Renewable Fuel Standard (RFS) program. The revised standard, known as RFS2, established new categories of renewable fuels based on the percent reduction of so-called greenhouse gas (GHG) emissions compared to the petroleum fuels being displaced.

RFS2 Category	GHG Reduction Threshold
Conventional Biofuels	20%
Advanced Biofuels	50%
Cellulosic Biofuels	60%
Biomass-Based Diesel	50%

In their zeal to limit the use of corn, due to unfounded concerns regarding food vs. fuel, Congress capped the amount of ethanol that can be made from corn in the conventional manner, otherwise known as first-generation (Gen 1) ethanol. Congress also gave the Environmental Protection Agency (EPA) authority to regulate the implementation of RFS2. The regulations for RFS2 were finalized in 2010—prescribing an aggressive schedule to increase the total volume of renewable fuels consumed in the U.S. from 9 billion gallons in 2008 to 36 billion gallons in 2022. RFS2 has potential to benefit the U.S. economy in many ways—such as decreased dependence on foreign oil, job creation, and lower pollution, to name just a few—if it could really succeed.

RFS2 mandates annual increases to the amount of *Advanced Biofuels* that must be blended into the domestic fuel supply, with a specific requirement for biofuels made from cellulosic feedstocks. The emphasis on this cellulosic subset of *Advanced Biofuels*—Generation 2 (Gen 2) biofuels—was intended to minimize GHG emissions compared to gasoline. Despite the intent, the environmental objectives of RFS2, as regulated by the EPA, seem to trump all other considerations—including at times, common sense.

We believe that it is unrealistic to "jump" straight to Gen 2 biofuels, and that a more rational course will follow the proven model that has yielded a continuous stream of commercial innovations since the introduction of Gen 1 ethanol. The growth of the biofuels industry will be facilitated by modifying RFS2 to shift away from the singular focus on cellulosic biofuels by implementing policies to promote the development of a wider range of *Advanced Biofuels*. The biofuels industry will then be following a proven strategy, not unlike the development of today's biofuels: building upon existing technologies to develop the *Advanced Biofuels* of tomorrow. Thus, the logical step on the path to Gen 2 biofuels is actually an evolutionary step between corn-based ethanol and Gen 2 biofuels. This can be described as Generation 1.5 (Gen 1.5) ethanol. Gen 1.5 ethanol is the natural bridge to support the deliberate steps necessary to grow the biofuels industry toward the fulfillment of the real RFS2 objectives.

Understanding the Renewable Fuel Standard

RFS is a hybrid program of energy, agriculture, national security, economic, and environmental objectives. The goal appears to be the reduction of so-called greenhouse gas (GHG) emissions—a noble goal. Unfortunately, RFS has been implemented in a manner that has led the biofuels industry to its current no-growth predicament. The original RFS mandated the blending of 7.5 billion gallons of renewable fuel into gasoline by 2012. This led to an extraordinary number of ethanol plants being built almost overnight. Most of these plants proceeded along a similar pattern: major equity participation; burdensome bank debt; natural gas for energy; and corn feedstock. Unfortunately, many of these plants could not survive commodity market fluctuations, and were forced to declare bankruptcy or find new owners. This, in turn, resulted in loss of equity and banks closing their doors to new investments in ethanol plants. The no-growth repercussions of the mandate are being felt to this day.

Of the end-point 36 billion gallons annually required by RFS2, 16 billion must be derived from cellulose, and meet the 60% GHG reduction threshold (Figure 1). This prescription ignores (or even denies) the benefits that could be realized from "non-cellulosic" *Advanced Biofuels*. This broader category is defined in the Federal Register[1] to include any biofuel not made by fermenting corn starch that meets the EPA criteria for 50% reduction in lifecycle

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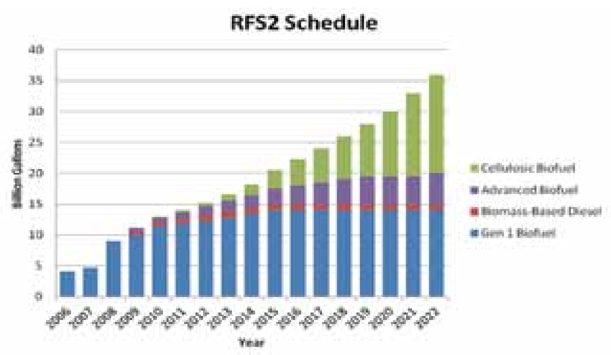
GHG emissions. By mandating the growth to principally cellulosic biofuels, the RFS2 effectively handcuffs the biofuels industry and forces it to put its limited resources into the development of Gen 2 biofuels, which simply cannot be commercially deployed on the prescribed schedule.

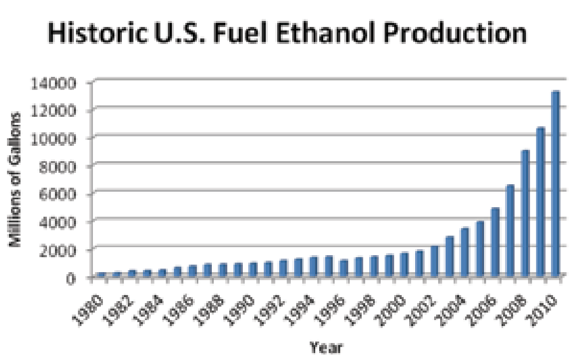
Figure 1 – Original RFS2 Mandate



Lack of Production of Gen 2 Biofuels Is Threatening the Ultimate Goal

Despite the emphasis on the development of Gen 2 biofuels, the reality is that the volume of cellulosic biofuels required by the RFS2 schedule has not been and will not be available (Figure 2). In fact, the sales transactions tracked through Renewable Identification Numbers (RINS) show that the first cellulosic biofuel wasn't produced in the U.S. until April 2012, and the amount produced was only 20,069 gallons.[2] The path from science to commercial success is tortuous, and few developments outside of laboratories and pilot plants have demonstrated economic viability.

Figure 2 – Cellulosic Requirements vs. Reality



The lack of cellulosic biofuels production has not gone unnoticed. The American Petroleum Institute (API) has filed a lawsuit against the EPA to reduce the 2012 RFS2 volume requirements.[3] The growing backlash against the RFS2 schedule by API and others could ultimately unravel the RFS2. That would severely diminish the role of renewable fuels in the U.S., thus undermining the significant investments to produce Gen 1 fuels and to develop *Advanced Biofuels*. (Because of inability to deliver cellulosic biofuels, there is a growing discussion about allowing natural gas to be used as a feedstock for Gen 2 ethanol production.)

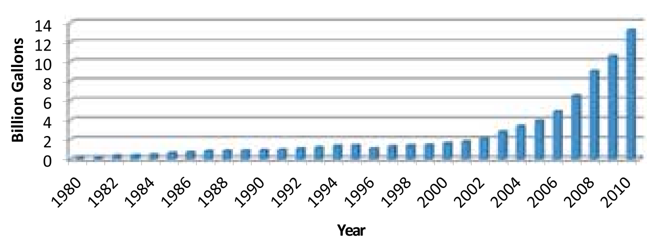
Keeping RFS2 in place, as is, will have serious negative consequences. Because of the lack of available cellulosic biofuels, U.S. refiners can make a strong argument that they are being forced to buy something that does not exist; and, therefore, the requirement should be eliminated. It is simply wrong to mandate implementation of RFS2 via the use of unknown or unproven technology.

Understanding the History of Ethanol

It is clear that the current regulation is limiting the development of non-cellulosic *Advanced Biofuels*; and is contributing to stunted growth. Proper changes will allow the industry to follow a more rational development progression. The pattern for rational commercial development can best be seen through the lens of history, examining the pattern that the industry followed for the development of Gen 1 ethanol during the past three decades.

Although the basic technology for Gen 1 ethanol has been developing for centuries, until about 1980 most ethanol operations were small scale. At that time, typical fermenter limits were 8 vol% ethanol, and technologies widely in use today (such as SSF and Molecular Sieves) were just being introduced. The investment cost to build an ethanol plant in 1981 was approximately $2 per annual gal. Commercially produced enzymes cost as much as $0.20 per gallon of ethanol. Energy consumption was typically in excess of 60,000 BTU's per gallon.

Figure 3 – Historic U.S. Fuel Ethanol Production



Because of continual technology developments that were implemented in deliberate risk-managing steps, the snapshot of the U.S. ethanol industry 20 years later showed a much brighter picture. By 2001, the total annual U.S. ethanol production had grown to 1770 million gallons per year (MM GPY) (Figure 3). A significant portion of the new capacity came from larger-scale plants. The construction investment, over the 20-year period, remained relatively constant at $2 per annual gallon—a dramatic decrease in investment, when adjusted for inflation. By 2001, advances in fermentation technology had increased fermenter performance to >14 vol% with SSF fermentations finishing 33% faster. The operating costs for plants also continued to decrease. For example, enzymes were available at $0.04 per gal of ethanol, and the operations workforce was reduced by 40% due to advances in automation. In a like manner, due to steady technological advances, energy consumption in the newest plants was reduced to half of the 1980's levels.

Developing Gen 2 Ethanol

By comparison, large-scale Gen 2 (cellulosic) processes are in their infancy. Today, despite advances in technology and development of specialized enzymes, processes to convert ligno-cellulose feedstocks to ethanol remain commercially unproven and uneconomic at the scale contemplated by RFS2. This is due, in large part, to the substantial additional complexities and costs of producing ethanol from cellulosic feedstocks.

Considering the development path of Gen 1 to better understand the current state of Gen 2 ethanol, several factors require further breakthrough developments and/or inventions for cellulosic ethanol to become commercially viable at the massive scale contemplated by RFS2:

- Lower feedstock cost
- Improved pretreatment technologies
- Improved bio-processing technologies (including C5 sugar conversion)
- Dramatically lower capital investment requirements
- Lower operating costs.

These developments will not happen overnight. The continued progression of manageable, deliberate steps, as observed in the development of Gen 1 ethanol, is the necessary and appropriate model for the development of Gen 2. While this development path is ongoing, the solution to achieving the RFS2 objectives is to develop Gen 1.5 based on proven commercial technologies.

Advancing Biofuels Growth (Gen 1.5)

For a Gen 1.5 ethanol process to be recognized as meeting the requirements for an *Advanced Biofuel* under the present RFS2, the pathway by which the ethanol is produced must be approved by the EPA. Each unique pathway designated by the EPA consists of a feedstock and process for each fuel type. Until recently, the only approved pathway qualifying bioethanol as an *Advanced Biofuel* was the "Brazilian model" of sugarcane-based ethanol. This encouraged U.S. blenders to import Brazilian ethanol; while the U.S. exports Gen 1 ethanol to Brazil. Based on the model used by the EPA, the net reduction of GHG emissions realized by this import/export scenario is a 50% reduction for Brazilian ethanol, less a 20% reduction for U.S. ethanol, or a net reduction of 30% in GHG emissions in the U.S. But this scenario is negative for the world. A <u>real</u> net GHG effect could easily be achieved with many Gen 1.5 options right here in the U.S.

A superior strategy for meeting the objectives of RFS2 would be to encourage the development of non-cellulosic *Advanced Biofuels* production in the U.S. to realize a significant reduction in GHG emissions domestically. There are strong reasons to be optimistic about this strategy. The EPA approved a new *Advanced Biofuel* pathway for grain sorghum-to-ethanol produced at plants using biogas in combination with combined heat and power (CHP) technology. A number of petitions for new bioethanol pathways are expected to qualify for *Advanced Biofuel* status, as well.

Gen 1.5 Ethanol is Discouraged under RFS2

Despite the many benefits of *Advanced Biofuels*, there is little incentive to develop them from non-cellulosic feedstocks in the U.S. due to the arbitrary Gen 2 restrictions imposed by RFS2. Technology to produce Gen 1.5 ethanol from a variety of feedstocks and a variety of pathways has been implemented in many plants globally. Building upon such technologies, it is straightforward to design bioethanol processes utilizing alternative feedstocks such as grain sorghum (milo), triticale, barley, wheat, industrial sweet potatoes, energy sugar beets, and others to meet *Advanced Biofuel* requirements. Revising RFS2 to encourage development of these alternatives is the most sensible strategy that will lead to genuine reductions in GHG emissions and genuine growth of the biofuels industry.

How Gen 1.5 Ethanol Bridges the Gap

There are two fundamental steps that need to be taken to encourage the development of *Advanced Biofuels* in the U.S. according to Clean Fuels Development Coalition (CFDC) Executive Director Doug Durante. The key to developing the next generation of biofuels is to solidify market demand. Mandates and requirements alone are not going to do it. As he noted in Congressional testimony, Durante points out that there must be somewhere to put the fuel and vehicles to use it, regardless of price. Flex-Fuel Vehicles and a variety of high-level ethanol blends would provide that market-based demand. Secondly, working within the structure of the RFS, programs could be amended to allow any feedstock that can demonstrate compliance with the true intent of the RFS to qualify as an *Advanced Biofuel* and essentially do away with the narrowly focused cellulosic requirement. Gen 1.5 ethanol developed from existing technology is ideal to bridge the gap and meet the demand for *Advanced Biofuels* today.

Additional incentives such as tradable credits above the 50% baseline could also be implemented to encourage development of Gen 1.5 and Gen 2 biofuels that would bring about even greater reductions in GHG emissions. This would create investor confidence and accelerate the development of biofuels technology by encouraging a much wider range of feedstocks. Legislation to encourage the development of non-cellulosic *Advanced Biofuels* today, utilizing known technology, will ensure steady progress into the future. Working within the framework of RFS2, all the benefits can still be realized by simply removing the requirement for cellulosic biofuels, and removing the cap on *Advanced Biofuels* from other feedstocks.

Rational Development

As soon as the regulatory framework is in place, the Gen 1.5 program will remove the handcuffs from the biofuels industry and allow rational development to occur. Concentrating first on bioethanol, existing technologies can be readily applied to develop Gen 1.5 projects that would meet the requirements for *Advanced Biofuel* status. One approach for identifying new *Advanced Biofuels* pathways is to design processes that are based on the "Brazil model". One such process is ethanol from sweet sorghum. Sweet sorghum has the advantage of requiring less water and other inputs than sugar cane, and it can be grown in wider geographies and climatic conditions. Like sugarcane, the biomass (bagasse) from sweet sorghum can be combusted

Figure 4 – Industrial Sweet Potato

for energy, which reduces the so-called carbon footprint. This "bagasse" is also a candidate feedstock for future Gen 2 fuels in the form of an evolutionary retrofit, when the technology is ready for commercialization.

Another strategy for identifying new pathways for Gen 1.5 bioethanol is to focus on the parameters in the EPA's model(s) used to estimate GHG and/or carbon emission levels. The factors that have the most significant effect on emissions calculations that can also be controlled are:

- Indirect land use change (ILUC)[4]
- Energy from fossil fuel sources used in a process
- CO2 emissions
- Co-products

Projects can then be designed to achieve the target GHG emission levels for *Advanced Biofuels* by optimizing the contribution of one or more of these factors to minimize the calculated emissions. The following are examples of existing technologies that can be incorporated into bioethanol projects to achieve the GHG emission levels:

- Decreased land usage
  - "energy crops" that yield higher energy density per acre, such as industrial sweet potatoes (Figure 4) or energy sugar beets (4x sugar/starch per acre compared to corn)
  - developing "energy-specific" starch- and sugar-based crops
  - planting secondary annual crops on existing crop land, such as winter cover crops
- Reduced energy usage in farming and production, with emphasis on reducing fossil energy
  - livestock integration with ethanol plants and biodigesters
  - biomass-fueled boilers
- Reduced CO2 emissions
  - CO2 collection or conversion
- Increased value of co-products
  - electrical co-generation
  - corn oil extraction

Figure 5 – Ethanol Plant with Livestock Integration

History has shown that real developments in the ethanol industry were not made overnight, and did not come as the result of government choosing the winners, but instead were the result of deliberate incremental steps by private entrepreneurs. The popular belief that commercial Gen 2 technology can be developed from Gen 1 in a single step is not realistic. A new path forward is needed for the advancement of renewable fuels to bridge the gap between corn-based ethanol and biofuels of the future. Gen 1.5 ethanol is that bridge, utilizing conventional processing technology to convert new sugar and starch sources to *Advanced Biofuels*. Congress and EPA can advance biofuels, if they so wish.

[1] https://www.federalregister.gov/articles/2010/03/26/2010-3851/regulation-of-fuels-and-fuel-additives-changes-to-renewable-fuel-standard-program#p-490

[2] http://www.epa.gov/otaq/fuels/rfsdata/2012emts.htm

[3] http://www.api.org/news-and-media/news/newsitems/2012/mar-2012/api-files-lawsuit-against-epa-for-unachievable-cellulosic-biofuel-requirements.aspx

[4] For further discussion on ILUC, refer to: Ethanol Across America White Paper, "Carbon Modeling and ILUC – Separating Fact from Fiction", Bill Roddy, Winter 2011.

KATZEN INTERNATIONAL, INC.

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