From the Dump to the Pump: The Current State of Waste to Biofuels

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Viewed from a long-term perspective, the global transportation system relies almost entirely on waste, specifically the carbon-based remains of ancient plants and animals, to power its trains, planes, ships, and automobiles. Yet these fossil fuels are not typically regarded as waste material, but instead as natural resource commodities. In modern parlance, the term waste refers to materials that are discarded due to a lack of value. These economically appealing low-value and negative-value waste materials (or feedstocks) that can be converted into liquid and gaseous transportation fuels are environmentally appealing as well because they can reduce the soil and water impacts of waste. To evaluate the future of waste-derived fuels, it is necessary to consider the demanding nature of the nation's petroleum-based transportation system, survey the diverse range of waste feedstocks and conversion technologies, and assess the various federal and state policies that are shaping and driving the industry. It is the blend of practical attributes, market opportunities, and policy drivers that defines the industry.

To an aspiring fuel supplier, the market presents several essential facets: established fuels, distribution infrastructure, vehicles, and consumers. Ultimately, consumers form the demand center for the industry and determine the market for waste-derived fuels. Remarkably, the technology used by these consumers has changed little in over a century. In 1862, German inventor Nikolaus Otto built and sold a spark-ignited engine. While not the first to invent the contraption, Otto is generally regarded as the father of the modern gasoline engine. The spark-ignited engine was originally developed with four chambers, or cylinders. A gaseous mixture of a combustible liquid such as gasoline or ethanol is delivered into the cylinder and ignited with a spark that dramatically increases the pressure within the cylinder. Upon ignition, the force from the combustion (oxidation) pushes the cylindrical piston outward, which delivers power to the crankshaft, which in turn delivers power to the transmission. About thirty years after Otto's engine was developed, German inventor Rudolf Diesel built the first prototype of the compression ignition engine that still bears his name. Within the compression ignition or diesel engine, a less volatile distillate fuel is used. The harder-to-light diesel fuel oxidizes at pressure and delivers power more efficiently through the same mechanical system. One hundred and fifty years later, Otto's spark-ignited engine and Diesel's compression-ignited engine still dominate the transportation landscape. While both have been improved extensively in terms of efficiency and emissions, the core concepts remain unchanged.

The genius and allure of Otto's and Diesel's designs are revealed by considering the unique demands of the transportation sector compared with the more forgiving requirements of power generation. The generation of heat and electricity can occur at a chosen location, using large, stationary equipment. Coal can be delivered by the ton to a stationary plant. Natural gas can be shipped by pipeline to a power generation facility or to an individual's home for heating purposes. By contrast, an automobile must be fully mobile to achieve its purpose. While it can be temporarily connected to an energy source, the shorter the duration, the less inconvenienced the driver. The car's or truck's engine must be capable of developing torque (circular force) to rapidly drive the wheels over roads for either a few short miles or hundreds of miles in a single day. Since American drivers crave the freedom of the open road, the driver wants to go wherever she wants without first engaging in logistical energy planning for the trip. With about 230 million registered vehicles in the United States, the national interest requires clean-burning vehicles that will not cloud the landscape and endanger health with emissions. U.S. Department of Transportation, Research and Innovative Technology Administration, 2013 Pocket Guide to Transportation, *available at* www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/pocket_guide_2013_1.pdf. And because U.S. drivers consume between 337 million gallons of gasoline per day or about 4,300 gallons per second from sea to shining sea, the supply must be ubiquitous and plentiful to quench the country's daily thirst for transportation power. U.S. Energy Information Administration, Oil: Crude and Petroleum Products Explained, www.eia.gov/energyexplained/index.cfm?page=oil_home#tab2 (last visited Sept. 27, 2013).

The necessary refining and distribution system to supply America's demand for petroleum fuels did not develop overnight but instead is the nation's most infrastructure-rich industry with over a century of history. America's petroleum distribution network traces its roots to the same period as Otto and Diesel. The richest tycoon of all time, John D. Rockefeller, amassed his fortune by developing the greatest oil refining and distribution monopoly of all time, Standard Oil. During Rockefeller's time, when crude oil literally gushed from fields like Spindletop, oil bore much more resemblance to a waste stream than does today's $100 per barrel oil. The empire builder realized that the ample supply relative to demand would undermine the price of the commodity. Rockefeller's profits were made not in crude oil but in the sale of finished products: first kerosene, then gasoline, and diesel fuel. Favorable

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discount and exclusivity deals with the railroads allowed Rockefeller to move his product at rates that fundamentally undercut the competition. Rockefeller stealthily acquired the nation's refining assets in the late 1860s and 1870s and the distribution assets in the 1880s. By 1879, Standard Oil controlled approximately 90 percent of the country's refining assets.

Standard Oil was first challenged for its monopolistic behavior in 1890 under the Sherman Antitrust Act, but it took two decades for the government to break up Rockefeller's empire. Even after the breakup in 1911, the remnants of Standard Oil endured and provided the foundation for America's vibrant modern oil industry. These familiar names echo into the present-day oil market. Standard Oil of New Jersey became Esso and later Exxon. The New York division of Standard Oil became Mobil. Standard Oil of California became Chevron. Standard Oil of Indiana ultimately became Amoco. Atlantic and Conoco were also remnants of the empire. Outside the United States, the great foreign oil companies British Petroleum and Royal Dutch Shell were also developing drilling rig, pipeline, and refinery assets by Rockefeller's day.

In the century since the demise of Standard Oil, the American petroleum industry has continued to expand its capabilities to meet the growing demand of America's transportation needs. Much of this remarkable system is invisible to the consumer and includes crude oil exploration and extraction; the refinement of crude oil into finished fuels, lubricants, and chemicals; and the wholesale distribution of finished fuels via an extensive pipeline, barge, terminal, and rack system. These finished fuels are then sold to consumers via retail gasoline stations that exist throughout the country. The retail stations may be independent or branded to one of the minor or major petroleum companies. The station owner must comply with a litany of state and federal regulations pertaining to fuel quality, dispensing of product, safety, taxation, water quality, and air quality.

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It is within this practical context that the waste-derived fuels of the twenty-first century succeed or fail. In order to supply into the mainstream U.S. transportation market, the fuel must be approved for use in conventional gasoline or diesel vehicles, meet fuel-quality specifications, be available nationwide via the retail distribution network, and compete with conventional fuels on price, quality, and energy content.

Until recently, these practical hurdles were simply too high for waste-derived fuels to overcome. Simply put, petroleum-based liquid fuels dominate the market because they have a massive first-mover advantage and are fit for purpose. Crude oil has been plentiful in the United States for over a century with the country still reigning supreme as the world's largest oil producer of all time on a cumulative basis. America's free market economy has assured that this natural resource has been efficiently developed, priced at competitive prices, subjected to rigorous quality control, and made available to retail customers at gas stations and truck stops throughout the country. Even after Hubbert's Peak (the peak of American oil production that was forecast with uncanny accuracy by a former Shell engineer) was reached in 1970 and America became primarily dependent on imported foreign crude oil, petroleum fuels remained a remarkable bargain in the United States until the twenty-first century.

Three fundamental and interrelated policy drivers converged in the early twenty-first century to open the door to alternatives to petroleum fuels, including waste-derived fuels. The first was increased concern regarding America's dependence on foreign oil and exposure to supply disruptions, typically summarized as energy security. The second factor was increased evidence that climate change was occurring as a result of rapid combustion of the earth's long-term carbon reserves, referenced as global warming. The third factor was based on economic concerns and focused on redirecting the dollars exported to purchase foreign crude oil to instead support America's farm economy, referenced as farm policy.

These policy drivers supported the development of a wide range of alternative fuels. As one might expect from the nature of the policy drivers and America's economy, the most favored of these alternative fuels used agricultural products as feedstocks. Of course, farm products do not meet the standard definition of waste. Farm products are instead agricultural commodities and, most typically, food. Yet from the beginning, it has been America's farmers that have opened the door for waste-derived fuels to enter the U.S. marketplace. Only the farm industry possessed sufficient scale, political clout, and perseverance to penetrate the challenging market of U.S. transportation fuel. For these same reasons, it is U.S. agricultural waste, particularly cellulosic ethanols, that has been the most successful waste-derived fuel in terms of policy support. However, due to the practical issues previously discussed, the greatest success story from a volume perspective has been biodiesel from used cooking oil and animal fats. As the most successful waste-derived biofuel in the marketplace, waste oil biodiesel provides an excellent case study for examining market entry and policy factors.

Biodiesel Clears Regulatory Barriers

Prior to entering the marketplace, any waste-derived fuel must first comply with the requirements of the Clean Air Act (CAA) pertaining to on-road fuels and fuel additives. Under section 211 of the CAA (42 U.S.C. § 7545), any manufacturer that plans to sell designated fuels and fuel additives in the United States must first register them with the U.S. Environmental Protection Agency (EPA), through the program of fuel and fuel additive registration, codified at 40 C.F.R. pt. 79, and known as FFARs. Registration with EPA under FFARs is the required first step and must be completed prior to other registrations. The registration number a product receives under the fuel and fuel additive registration program is required in order to register under the other fuel regulatory programs.

The original FFARs program was very simple. Established in 1975, the program required manufacturers to provide only basic fuel and fuel additive data, including commercial identifying information, range of concentration, purpose-in-use, and chemical composition. 40 Fed. Reg. 52,011 (Nov. 7, 1975) (codified at 40 C.F.R. pt. 79). However, EPA bolstered the program substantially in 1994 by establishing additional registration requirements pursuant to section 211(b)(2) and (e) of the CAA. *See* 42 U.S.C. § 7545(b)(2) and (e). The final rule adopted by EPA in 1994 mandated the study and testing of fuel and fuel additives to evaluate any potential adverse effects prior to registration. Fuels and Fuel Additive Registration Regulations; Final Rule, 59 Fed. Reg. 33,092 (June 27, 1994) (codified at 40 C.F.R. pt. 79).

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Biodiesel is a fuel produced from biomass that closely resembles diesel fuel. In order to access the U.S. transportation fuels market, biodiesel first had to obtain FFARs approval and then had to establish an ASTM specification. Initially, it was not the used cooking oil or rendering industry that enabled biodiesel to clear these hurdles. Biodiesel in the United States was conceived by the American Soy Association (ASA). During the 1990s, the ASA was seeking new markets for soy oil so that the agricultural commodity's value would not plummet when supply was plentiful. The ASA recognized that the fuel market was robust and deep and invested millions of dollars in completing the FFARs process for biodiesel. The Tier 1 testing, involving speciated emissions, was completed at Southwest Research Institute with biodiesel tested in pure (B100) and 20 percent blended form with petroleum diesel (B20). The testing showed that B100 and B20 biodiesel provided significant reductions in unburned hydrocarbons, particulate matter, and polyclic aromatic hydrocarbons compared with petroleum diesel but slightly increased nitrogen oxide (NO_x) emissions. NBB/USEPA Tier I Health and Environmental Effects Testing for Biodiesel Under the Requirements for USEPA Registration of Fuels and Fuel Additives (40 C.F.R. pt. 79, Sec 21 1 (b)(2) and 21 1 (e)), Final Report (Mar. 1998), *available at* www.biodiesel.org/reports/19980301_gen-063.pdf. Tier II testing was completed at Lovelace Respiratory Research Institute and showed no evidence of mutagenicity, increased toxicity, mortality, or other health risks. National Biodiesel Board, Tier 2 Testing of Biodiesel Exhaust Emissions, Final Report (May 22, 2000), *available at* www.biodieselgear.com/documentation/NBB_EPA_Tier2_report.pdf.

On a parallel track, the biodiesel industry pursued an ASTM specification for the fuel. At the time of biodiesel's provisional specification, ASTM referred to the American Society of Testing and Materials. Since that time, the organization has changed its name to ASTM International to reflect its growing work internationally. ASTM International is a standards-based organization that uses volunteer committees and a consensus approach to establish industry standards. In the fuels sector, ASTM International is highly respected. A fully approved permanent ASTM specification is the key to market access, with ASTM standards built into everything from original equipment manufacturers' warranty requirements to state and federal tax credits and regulations pertaining to fuel. Using B20 biodiesel as an example, the ASTM process and standard enabled the fuel to break into the heavy-duty transportation realm once fleet managers were sufficiently assured that the use of the fuel would not jeopardize the warranties of their vehicles. The biodiesel industry achieved a provisional specification in 1999 (PS 121-99) and obtained a full specification in 2002 (D6751). The current petroleum diesel specification (D975) provides for the integration of up to 5 percent biodiesel blend levels (B5) as being in conformity, which was a substantial achievement by the biodiesel industry.

Aided by the specification, the biodiesel industry's market penetration was highly effective, with use of the fuel increasing 1,000-fold in less than a decade from less than 500,000 gallons in 1999 to 678 million gallons in 2008. Energy Information Agency, Monthly Biodiesel Production Report (Oct. 2010), *available at* www.eia.gov/biofuels/biodiesel/production/archive/2009/2009_12/table1.pdf. The predominant U.S. feedstock during this rapid decade of growth was virgin soy oil. However, the market penetration was so effective that the soy oil market was fundamentally changed. While the market had dropped as low as \$0.15 per pound in the 1990s, since 2010, soy oil has consistently stayed above \$0.30 per pound. TradingCharts.com, 2009 Soybean Oil Historical Prices/Charts, *available at* http://futures.tradingcharts.com. The bullish market for soy oil made the commodity less feasible as a pure feedstock for biodiesel. This has driven biodiesel producers to diversify into other feedstocks, including used cooking oils (UCO), yellow grease, and animal fats. Depending on one's definition of waste, biodiesel produced from these feedstocks, and particularly UCO, constituted the first commercially successful waste-derived fuel in the country. The National Biodiesel Board was farsighted and inclusive in its FFARs and ASTM activities and had successfully obtained approvals that extended to UCO, yellow grease, and animal fats rather than just soy oil. Thus, producers and the industry were effectively able to diversify feedstocks as the market demanded without returning to the federal regulatory process and the rigorous engineering review process of ASTM International.

Policy Drivers Supporting Biodiesel and Waste-derived Biofuels

The first significant support for biodiesel was found in an amendment to the Energy Policy Act of 1992. The 1992 Act was intended to reduce the country's reliance on foreign imported petroleum. It mandated that federal and state fleets acquire an escalating percentage of alternatively fueled vehicles when new vehicle procurements were made. These requirements were typically satisfied through the acquisition of compressed natural gas, propane, or electric vehicles. In 1998, the 1992 Act was amended to authorize the generation of alternative fuel vehicle credits through the purchase of biodiesel at blend levels of B20 or higher, subject to certain limitations. Thus fleet managers who preferred to maintain diesel fleets could avoid a portion of the vehicle acquisition requirement by fueling existing vehicles with B20 biodiesel. While the B20 blend was significantly more costly per gallon than petroleum diesel, the incremental cost of the B20 was typically less than the premium associated with an alternative vehicle purchase. The 1998 amendment may be regarded as a fuel mandate type program, driven by an energy security policy objective.

The next major boost for the waste biodiesel industry occurred in the tax code. In 2005, the industry received its first blender's credit. Under the program, for every gallon of biodiesel blended into petroleum diesel fuel, the "blender of record" received a $1.00 tax credit. Depending on the year of the program, this credit was either refundable or nonrefundable. The refundable credit was preferred by blenders since such a credit did not require that the blender have a commensurate tax liability. To the extent that the credit exceeded the blender's tax liability, the blender would receive a check from Treasury for the credit received. While the blender's credit was highly valuable to the industry, it introduced its own uncertainties. In particular, the blender's credit was typically only established for a one-year period and not always prior to the beginning of the year. This policy may be regarded as a tax incentive, paying down the cost of the fuel to enable the expansion of the industry and the benefit of economies of scale.

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In 2005, there was a sea change in federal policy designed to expand the use of renewable fuel in the United States. This new policy initiative established the regulatory landscape in which waste-derived fuels such as waste-based biodiesel must now participate. The original Renewable Fuel Standard (RFS1) was adopted by EPA to implement the provisions of the Energy Policy Act of 2005, which added section 211(o) to the CAA. Since its inception, the RFS program has mandated an increasing amount of renewable fuel in the U.S. petroleum fuel marketplace. Under RFS1, the fuel marketplace was measured only by gasoline sales, and the percentage requirements were relatively modest. The typical compliance fuel was ethanol made from cornstarch. However, one of the longer-term goals of the program was to incentivize the use of waste-derived fuels, particularly cellulosic fuels made from agricultural waste. Fuels perceived to be particularly environmentally friendly (including cellulosic ethanol from wood, agricultural waste, and municipal solid waste) were entitled to generate credits at a multiplied rate per gallon. The obligated parties under RFS1 were petroleum refiners and importers of gasoline. These parties were required to generate sufficient RFS credits (the credits are known as Renewable Identification Numbers or RINs) to show that they had complied with their percentage obligations measured against the gallons of gasoline that they sold into the marketplace for the compliance period. To the extent that their own sales generated excess RINs, these RINs could be sold to other market participants subject to various restrictions.

Passed by Congress in 2007, the Energy Independence and Security Act (EISA) served as the legislative vehicle for RFS2. With the passage of EISA, Congress made several important revisions to the prior system. These revisions generally became effective on July 1, 2010. RFS2 expanded the renewable volume obligations of obligated parties beyond on-road gasoline to include all transportation fuel. The RFS has always used a percentage requirement across the underlying fuel pool (e.g., the 2010 obligation was 8.25 percent of the defined fuel pool). Previously this percentage requirement was measured against only the on-road gasoline pool. With RFS2, the fuel pool was expanded to include gasoline and diesel fuels for on-road, off-road, locomotive, and domestic marine sectors. Hawaii, Alaska, and U.S. territories can choose whether to opt into the program. Hawaii has since opted into the RFS program consistent with Hawaii's aggressive renewable energy policies, while Alaska remains outside the scope of the program.

One of the key complexities introduced by RFS2 was the expansion from the single type of fuel and RIN credit that existed under RFS1 with a corresponding percentage requirement to four standards with four corresponding RIN percentage requirements. Each of these fuel categories includes a performance threshold in terms of greenhouse gas (GHG) reduction as well as additional requirements. The GHG reduction is measured relative to the biofuel's petroleum counterpart. In other words, the GHG performance of ethanol products is measured against that of conventional gasoline, and the GHG performance of biodiesel is measured against conventional diesel fuel. Each category of fuel generates a distinct type of RIN, with a particular D code. The four types of biofuel that exist under RFS2 are (1) cellulosic biofuel, which must provide at least a 60 percent GHG reduction; (2) biomass-based diesel, which must provide at least a 50 percent GHG reduction; (3) advanced biofuel, which must provide at least a 50 percent GHG reduction; and (4) renewable fuel, which must provide at least a 20 percent GHG reduction.

The RFS program does not place restrictions on additional GHG programs providing additional value to the producer. As one might expect, California has developed its own parallel GHG reduction program that provides an additional revenue stream to waste-derived biofuel producers. California's Global Warming Solutions Act of 2006 (AB 32) established the state's goal of reducing GHG emissions in the state to 1990 levels by 2020. The statute charged the California Air Resources Board (CARB) with developing and implementing regulations in multiple sectors to achieve that goal. In January 2007, then Governor Arnold Schwarzenegger issued Executive Order S-01-07 calling on CARB to determine whether a low-carbon fuel standard could be adopted under AB 32 to reduce the carbon intensity of California's transportation fuels by at least 10 percent by 2020.

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In April 2010, CARB adopted a final set of regulations that is now codified at Cal. Code Regs. tit. 17, §§ 95,480–95,490 (the Low Carbon Fuel Standard or LCFS). The LCFS applies to transportation fuels that are "sold, supplied, or offered for sale in California" and "any person who as a regulated party . . . is responsible for a transportation fuel in a calendar year." The LCFS applies to a wide range of transportation fuels and technologies, including liquid and gaseous fuels such as biodiesel, hydrogen, and biomethane. While comparable to the RFS, there are significant variations between the programs. Unlike the RFS, California's program does not require that the feedstock qualify as a renewable biomass. All fuels, including petroleum-based fuels, are scored on the same GHG scorecard.

The LCFS reduces gas GHG emissions by regulating the full life-cycle carbon intensity (CI) of transportation fuels used in California. The CI score of a fuel reflects not only GHG emissions created at the time of combustion, but also the GHG emissions associated with its extraction and refining, its transport to California, and any indirect land use change attributed to the feedstock based on GHG land use modeling. Regulated parties (petroleum refiners and importers) must meet an annual standard for CI that decreases more rapidly in the later years of the program. The increasingly difficult CI requirements and the ability to bank credits drive value for biodiesel producers that supply low-CI biodiesel into California.

Other Waste-derived Fuels Strive to Deliver

The waste-derived biodiesel industry was uniquely well situated to succeed due to the generous role that the soy industry played in its development. The soy industry funded the expensive FFARs review and approval process, negotiated the ASTM International specification process, won tax credits and RFS policy support for the fuel, and introduced it to the marketplace. Other waste-derived fuels must find similar routes to success in the U.S. market.

The most interesting of these fuels from a policy perspective is cellulosic ethanol. Similar to waste-derived biodiesel, cellulosic ethanol enjoyed strong support from both the U.S. corn industry and the well-established ethanol industry. The FFARs process was completed decades ago for ethanol, and the fuel also has well-established ASTM specifications. From a policy standpoint, cellulosic ethanol has received comparable tax credit benefits to biodiesel, typically $1.01 per gallon. Within the RFS program, cellulosic ethanol has its own category: cellulosic biofuel that must be made with cellulosic, hemi-cellulosic, or lignin feedstock. The cellulosic biofuel category was anticipated to be the largest category of advanced biofuels with the 2013 requirement set at 1 billion gallons in EISA by Congress in 2007. Yet the practical challenge of converting cellulosic material into ethanol has proven daunting and expensive. In addition, EISA and the RFS2 regulations defined cellulosic ethanol more narrowly than RFSI in regard to the use of wood residue and municipal solid waste. As a result, there were no cellulosic biofuel RINs available in the U.S. market in 2012, and EPA adjusted the 2013 requirement downward to 6 million gallons in 2013. In determining its 2013 standard, EPA reviewed the current status of the cellulosic ethanol industry with particular attention to the work done by the Energy Information Agency. EPA identified two production facilities that were at the cusp of producing ethanol from agricultural residues: Abengoa and EdeniQ. These companies plan to use corn stover and corn kernel fiber respectively. EPA did not include any estimate for their output in 2013; however, as neither facility was deemed sufficiently close to commissioning. EPA also noted two foreign producers commissioning commercial-scale facilities. Beta Renewables has since begun production in its 12-million gallon a year facility in Crescentino, Italy, using agricultural waste as feedstock. Enerkem is constructing a 10-million gallon per year plant in Edmonton, Alberta, that is scheduled to begin production of ethanol from postsorted municipal waste in 2014. EPA did not include either of these plants in its 2013 rule because neither is anticipated to supply cellulosic ethanol to the United States in 2013.

In the cellulosic category, it has been other fuels and feedstocks rather than a cellulosic ethanol from agricultural waste that have delivered the first gallons to market. The first cellulosic fuel to generate RINs has unexpectedly been diesel fuel rather than ethanol. The Texas based KiOR, Inc. has developed a process to convert wood waste streams into a biocrude that is integrated as a feedstock at a refinery. EPA has estimated that KiOR will deliver 5 to 6 million RINs in 2013 based on production from its Columbus, Mississippi, plant. In addition, INEOS Bio has developed a process to produce cellulosic ethanol from vegetative waste that it is deploying at its facility in Vero Beach, Florida, that began production on July 31, 2013. Under RFS2, the waste must be sorted and all recyclable components must be separated in order for the fuel to generate RINs. The details of the sorting process and documentation of it must be included in a waste feedstock plan that is approved by EPA in order for the plant to be registered under the program. The other companies that EPA reviewed in the cellulosic category for 2013 were Ensyn Corp. (a Delaware company that plans to produce heating oil from woody biomass) and Fiberight LLC (a Maryland company that plans to produce ethanol from municipal solid waste).

Another waste-derived ethanol market participant of note is Parallel Products, a company that has provided liquid waste recycling at two plants located in Lexington, Kentucky, and Ontario, California, for over a decade. Parallel Products' position in the marketplace is unique as the company recovers expired beverages, including beer, wine, and spirits, and reprocesses the feedstock into fuel-grade ethanol. The ethanol produced qualifies as advanced biofuel under RFS2 as it reduces GHG emissions by at least 50 percent measured against a gasoline baseline.

A more recent market entrant is biogas derived from waste materials. While the U.S. transportation industry has long favored Otto's and Diesel's engines as the technologies of choice, the relative bargain of natural gas has recently supported the expansion of compressed natural gas (CNG) and liquid natural gas (LNG) vehicle fleets. While these fuels lack the energy density and simplicity of liquid fuels, the massive price discount on an energy basis of natural gas as compared to liquid fuels has been sufficient to motivate large fleets to migrate to more expensive CNG and LNG vehicles to capture the long-term energy cost savings. As CNG and LNG fleets have proliferated, biogas has gained access to the transportation market. Biogas is typically derived from the anaerobic digestion of waste streams including landfills, cow manure, and municipal wastewater. It has an extremely attractive GHG profile with CARB currently rating its carbon intensity at a mere 15 percent of petroleum diesel's output. Similarly, EPA is reviewing a landfill gas-to-biogas pathway as a potential cellulosic biofuel based on the contents of the landfill. During the first half of 2013, EPA reports that biogas generated over 8 million RINs, suggesting that another waste-to-energy transportation fuel is beginning to achieve significant success.

Thus we are beginning to see pilot to small-scale commercial production facilities deploy a wide range of technologies to convert agricultural, municipal, and wood waste into fuel. Depending on how one defines waste, perhaps one hundred million gallons per year of these waste-derived fuels are already being utilized in conventional vehicles, displacing imported petroleum, shrinking landfills, and reducing GHG emissions. The next decade presents great promise and challenge for companies in this unique industry as a daunting combination of commodity price relationships, policy support, and technological hurdles subject their particular feedstocks, technologies, and fuels to the ultimate road test.