Barriers Impacting United States Advanced Biofuel Projects

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ABSTRACT

Although the 2005 EPAct was enacted to help bolster the emerging biofuel industry, 52% of advanced biofuel projects were closed or shut down by 2015. However, there are no complete lists of barriers that impeded these projects. The goal of this study was to develop a framework of barriers impeding success of advanced biofuel projects by conducting a literature review of barriers, spatial analysis of status, survey of barriers, and determination of coproducts and byproducts and their marketing and distribution barriers from the industry stakeholders.

The spatial analysis indicated 59 biofuel projects were attempted, and their Eastern and Western location by status was not a barrier. Using Grounded Theory, nine barriers were derived and aggregated in major categories, including product development, strategy, technology, competition, energy costs, funding, government, suppliers, and third-party relations. A contingency analysis was conducted relating their status to internal and external barriers, indicating no relationship between type of closing and type of barrier. Next, the number of barriers was expanded to 23, and a survey was conducted to gain knowledge on these barriers from industry stakeholders. When comparing the barriers by stakeholders, there were differences based on status, type, and technology of the projects. In addition, the survey and discussion identified 79 barriers different across years, type of industry (pilot, demonstration, or commercial), status (open, closed, or planning), and technology (thermochemical, biochemical, or hybrid). Forty-seven coproducts and byproducts and many unknown barriers to their marketability and distribution were determined and ranked by primary and secondary barriers. These extensive lists of barriers and coproducts will aid future biofuels projects in their planning, research, and development stages.

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List of Abbreviations

AB	Advanced Biofuel	G/B	Gallons Per Barrel
ABLC	Advanced Biofuel Leadership Conference	GHG	Greenhouse Gas
AEI	Advanced Energy Initiative	HCL	Hydrochloric Acid
BG	Billion Gallons	KW	Kilowatts
BCAP	Biomass Crop Assistance Program	MTBE	Methyl Tertiary-butyl Ether
BBD	Biomass-based Diesel	MG	Million Gallons
BTU	British Thermal Units	MESP	Minimum Ethanol Selling Price
LCFS	California Low Carbon Fuel Standard	NHTSA	National Highway Traffic Safety Administration
CAPEX	Capital Expenditures	NSF	National Science Foundation
CCS	Carbon Capture and Storage	OP	Obligated Party
CO2	Carbon Dioxide	OTAQ	Office of Transportation and Air Quality
CO	Carbon Monoxide	OPIS	Oil Price Information Service
CB	Cellulosic Biofuel	OPEX	Operational Expenditures
CWC	Cellulosic Waiver Credit	OPEC	Organization of the Petroleum Exporting Countries
CDX	Central Data Exchange	H3PO4	Phosphoric Acid .
CRF	Code of Federal Regulations	QAP	Quality Assurance Plan
CAFÉ	Corporate Average Fuel Economy	RGP	Reformulated Gasoline Program
DOD	Department of Defense	R	Renewable Content
DOE	Department of Energy	RFS	Renewable Fuel Standard
NaOH	Sodium Hydroxide	RF	Renewable Fuels
DMC	Direct Microbial Conversion	RIN	Renewable Identification Number
EIA	Energy and Information Administration	RVO	Renwable Volume Obligation
EC	Energy Content	REAP	Rural energy for America program
EISA	Energy Independence and Security Act	KOH	Simethyl Sulfoxide
EPACT	Environmental Protection Act	SSF	Simultaneous Saccharification and Fermentation
EPA	Environmental Protection Agency	H2SO4	Sulfuric Acid
EMTS	EPA Moderated Transaction System	KBD	Thousand Barrels Per Day
EV	Equivalence Value	USDA	United States Department of Agriculture
FTA	Federal Transit Administration	WBUS	Wood Bioenergy U.S.

CHAPTER 1. Introduction

1.1 Background for the Study

In the current fossil fuel–based energy infrastructure, supply is higher than demand, resulting in cheap fuel for consumers. The current excess of supply clouds the issues related to negative global environmental impacts and limited supply of fossil fuels (oil, coal, gas, and nuclear). U.S. culture is ingrained with behavioral patterns that reward short-term profits, while largely ignoring the development of long-term sustainable solutions. However, in recent years, the U.S. has gradually begun to shift away from fossil fuels and toward alternative and renewable fuel sources (Lane 2015a). As a result, a change in bio-environmental infrastructure is underway.

One such direction of change is toward the use of biofuel, defined as a fuel composed of wood or ethanol, or produced from biological raw materials (Merriam Webster 2016). Similarly, advanced biofuels (AB) are defined as "high-energy liquid transportation fuels derived from: low nutrient input/high per acre yield crops; agricultural or forestry waste; or other sustainable biomass feedstocks including algae. The term advanced biofuel means renewable fuel, other than ethanol derived from corn starch (Advanced Biofuels USA 2012)." First and second generation AB technologies are currently at the forefront of commercial production, with third generation technologies (i.e., Butanol, algae) increasing in prevalence. As biofuel is produced, coproducts and byproducts are also created during the process. The main coproducts of biofuel production are biochemicals; in some cases, the biochemicals are more valuable than the biofuel itself. As a result, AB industries are focusing more on investing in biofuel platform technologies, rather than singular biofuel technologies.

To move the U.S. toward energy security and reduce negative environmental impacts from greenhouse gases, the U.S. government created the Renewable Fuel Standard (RFS), which requires that transportation fuel includes 10% biofuel, produced from biological materials. The fossil fuel companies fought the RFS to maintain their market share of fuel interests. However, the growth of the Energy Information Administration (EIA), the Corporate Average Fuel Economy (Café) standards, the economic recession, and a lack of bio-infrastructure all affected net gasoline consumption. This led to an abundant fossil fuel supply and a shortfall in the biofuel needed for fuel blending (Lane 2015a). The U.S. government then attempted to support the production of biofuels by subsidizing AB production. However, AB subsidies maintain a short-term outlook, as they are focused on producing biofuel sufficient for meeting the mandated 10% ethanol requirement, rather than having a long-term goal of developing self-sustaining AB production.

1.2 Research Problem

Despite government subsidies and high demand for biofuel, 52% of advanced biofuel projects closed by 2015, and "unfortunately, after 9 years only a few advanced biofuel projects survive" according to Mendell and Lang (2012, 2013). At the beginning of this research, ten AB projects were producing biofuel, but they were not reaching commercial production economies of scale. Instead, their capital expenditures (e.g., inventory, machinery, intellectual property) and operational expenditures (e.g., operations, wages, and utilities) were exceeding their biofuel production profits, leading to net losses (Lane 2016b). In spite of government subsidies and a fuel standard that required biofuel, many of the AB projects were unsuccessful. What barriers are keeping advanced biofuel projects from succeeding?

1.3 Purpose of the Study

This study was an investigation of the factors that affect AB projects and an exploration of the barriers that impede success and the knowledge gap that those barriers represent. For this study, a barrier was defined as any factor impeding AB projects from achieving continuous sustainable biofuel production and delivery economies of scale. Specific approaches included spatial analysis, operational status, internal and external barriers, byproduct and coproducts determination, and marketing and distribution of byproducts and coproducts. The outcome of this research was a framework focused on AB barriers and their causal linkages. By understanding what factors affected successes and failures of AB projects, allowed for improving our ability to establish successful AB projects that have long-term viability.

1.4 Overview of the Thesis Document

Chapter 2 contains a qualitative literature review, a systematic examination of what information was available to build knowledge of the developing hypothesis. The information in the literature review helped inform the background of advanced biofuel projects and their status, type, technologies, government policies; mandates and incentives, and the market and distribution barriers of the byproducts and coproducts they produce.

Chapter 3 contains descriptions of the research methods used in this study, beginning with an examination of U.S. Eastern and Western 95° longitudinal aspects correlated to operational status of closed and shutdown projects, including a map of locations by operational status and comparisons by region. This map provided the opportunity to visually examine any causal factors from potential clustering of AB projects. Through a Grounded Theory approach, the critical barriers impacting AB projects were determined, based on data from a survey and stakeholder interviews. Finally, survey data were used to explore the marketing and distribution barriers related to the top coproducts and byproducts of the AB process.

Results of the research are presented in Chapter 4, including analyses of barriers by type, status, technology, and stakeholder group. By examining causal factors, a progression of internal and external primary barriers emerged that were specific to closed and shutdown AB projects. Additionally, Chapter 4 contains descriptions of barriers to coproduct and byproduct marketability and distribution.

Chapter 5 contains conclusions and recommendations that will be useful decision-making tools for AB projects attempting commercial production in 2016.

Many standard acronyms and abbreviations are used in this thesis and are common with the bioeconomy; a list of abbreviations and their meanings have been included to aid the reader.

CHAPTER 2. Literature Review

2.1 Advanced Biofuel Industry

Energy is fundamental to U.S. economic and environmental development leveraging the environmental bioeconomy stability with fossil fuel dependency. The term energy is diversified into three main categories: fossil, nuclear, and renewable. The main fossil fuels are petroleum, coal, natural gas, and nuclear material. They are currently nonrenewable and contribute to the accumulation of greenhouse gases (GHG), one of the causes of climate change. Fossil fuels, namely petroleum for transportation fuel, are being consumed at an increasing rate from diminishing finite reserves. One model estimates that, at the current usage rates, fossil fuel reserves of oil, coal, and gas will last approximately 35, 107, and 137 years, respectively (Shafiee and Topal, 2008). Other researchers have estimated that fossil fuel depletion will occur between the years 2100 and 2200 (Chiari and Zecca 2011). In comparison to the finite fossil fuels, renewable energy sources are able to sustainably replenish a biomass source yearly to create usable primary products and coproducts.

2.1.1 Feedstock Types

Biofuel is one such renewable energy source. “Biofuel is a fuel additive capable of increasing octane levels by blending it into the U.S. fuel supply, or can be used as a fuel in internal combustion engines” (Szczodrak, et al. 1996). The total renewable biofuel sector is currently diversified into first (1G), second (2G), and third (3G) generation lignocellulosic biomass forms of energy. For example, 1G is derived from corn and sugarcane, 2G advanced biofuel is derived from wood, grasses, municipal wastes, and crop residues, and 3G is derived from algae. Biomass is considered non-fossil fuel, living or non-living agricultural vegetation such as wood and grass crops. In this case, biomass is typically differentiated by dedicated wood and grass energy crops, and un-merchantable timber and waste. Lignocellulosic feedstock’s price currently ranges from \$50/ton to 80/ton of biomass (Fueling Growth 2013). Those feedstocks could be from un-merchantable timber, forest thinning’s (slash), sawdust, waste paper, mill residues, paper mill sludge, grasses, and grass variety residues. All biomass feedstock differs in moisture content and may have different costs. Dedicated energy crops are considered for energy use only. In this research, dedicated energy crops are categorized and differentiated as herbaceous crops (grasses) and wood-based crops. Herbaceous grass crops are harvested annually, with only the roots surviving the non-growth cold seasons (e.g., switchgrass, *Miscanthus*). Wood-based crops, including fast-growing trees such as poplar, are harvested on a three- to twelve-year rotation cycle; harvest rotation cycles for slower growing trees may be as long as 25 years.

For this research, non-food lignocellulosic biomass consisted specifically of biomass from wood and from grass varieties for the current purpose of substituting fossil petroleum–based fuels with renewable biofuel. Advanced biofuel is a contemporary liquid fuel for transportation produced primarily from cellulose and hemicellulose of renewable lignocellulosic biomass. It is derived from lignocellulose, which consists of three major components: cellulose, hemicellulose, and lignin. The cellulose and hemicellulose portions are the desired components for producing the highest value-added biofuel coproducts. "Lignocellulosic biofuel currently has the greatest potential for energy, being the most abundant and rapidly renewable resource produced by photosynthesis" (Moxley and Zhang 2007). The lignin portion typically becomes a process byproduct, but recently was considered a coproduct when blended as filler for wood products.

2.1.2 Advanced Biofuel Project Classification

The U.S. total renewable biofuels (TRF) projects are classified as pilot with costs ranging $9 million or less, demonstration project costs ranging $100 million or less, or commercial projects costs ranging $100 - 500 million (ABLC 2015; Mendell and Lang, 2012, 2013). These three project types are further divided into five operational status categories: cancelled, shutdown, under construction, planning, and operating. Cancelled projects are considered terminal. Shutdown projects were stopped and put on hold, but potentially could be restarted at a later time. Under construction projects are currently being built, and planning projects are in the research and development phase, prior to construction. For operating projects, construction was completed and attempts at biofuel production have begun. Mendell and Lang (2012, 2013) provided the only accessible publication covering a large portion of wood-based biofuel projects, separated by location, type, and status, from their Forisk-Wood Bioenergy U.S. (WBUS) database. They indicated 36 cancelled projects, 4 shutdown projects, and 12 projects in planning or construction stages, stating "75% have failed to advance" (Mendell and Lang 2012, 2013).

2.1.3 **Chemical Composition of Wood and Grass**

Lignocellulosic biofuel feedstocks value should be understood from a softwood and hardwood chemical composition perspective (Table 1). Wood consists of carbon (49%), hydrogen (12%), oxygen (44%), nitrogen (<.1%), and ash (0.2%-0.5%), (Cote et al. 1966).

Table 1 Average percent of hardwoods, softwoods, and grasses targeted to optimize lignocellulosic ethanol: Adapted from Cote 1966, data in red from Sun and Cheng 2002.

Major components:	Hardwood	Softwood	Switch Grass	Miscanthus Grass
Cellulose	40 - 45%	40 – 45%	45%	40%
Lignin	20 - 25%	26 – 32%	12 - 20%	25%
Hemicellulose:	24 - 40%	25 - 35%	31%	18%
Glucomannan	2- 5%			
Glucuronoxylan (primary)	15 – 30%			
Arabinoglucuronoxylan		5 – 10%		
Galactoglucomannan (primary)		20%		
Extractives	<10%	<10%		
Ash	0.1 – 0.5%	0.1 – 0.5%		

For now, focus is placed on the main three lignocellulosic components: cellulose, hemicellulose, and lignin, and their conversion to renewable fuel. Recalcitrance causes difficulty in separating the lignocellulose linkages and is a major cost to the industry. The primary desired component cellulose is considerably longer than the other lignocellulose components (hemicellulose and lignin). Cellulose consists of 10,000 dp (degree of polymerization length) of glucose units, compared to only 200 dp of hemicellulose units. The degree of polymerization of lignin is not fully understood yet; know that it is a highly branched structure encompassing the other two. Cellulose is highly crystalline (60% – 80%), tightly packed through inter-molecular hydrogen bonding, and extremely rigid due to intra-molecular hydrogen bonding. This keeps large water molecules from penetrating the structure. For utilization, it must be broken down into glucose molecules by strong acids, typically hydrochloric acid (HCl), sulfuric acid (H_2SO_4), or phosphoric acid (H_3PO_4), (Harmsen et al. 2010)

There are four types of hemicellulose, each amorphous allowing ease of solubility of water. This higher solubility is achieved by reduction of hydrogen bonding due their irregular orientation and partial acetylation of their hydroxyl groups. Hemicellulose is typically hydrolyzed by strong acids: dimethyl sulfoxide and dilute alkali (KOH and NaOH) (Rowell 2016). Lignin gives plants stiffness to grow upward toward the sun, while enabling the conduction of water and sealing cell walls. Lignin should be viewed as the bonding agent for cellulose and hemicellulose, since they do not naturally bond. Lignin is beneficial for lignocellulosic organic life due to its structural strength; however, it increases expenses for the biofuel industry.

2.1.4 **Advanced Biofuel Project Technologies**

There are three primary methods to create advanced biofuel and its coproducts: direct microbial conversion (DMC-biochemical), simultaneous saccharification and fermentation (SSF-thermochemical), or a hybrid of these techniques (Brown and Brown 2012). These two main approaches are further broken down into six secondary options for developing cellulosic biofuel: (1) catalytic pyrolysis and hydro-treating to hydrocarbons; (2) gasification and Fischer-Tropsch synthesis to hydrocarbons; (3) gasification and methanol-to-gasoline synthesis; (4) dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis to ethanol; (5) enzymatic hydrolysis to ethanol; and (6) consolidated bioprocessing (single-step enzyme production, hydrolysis, and fermentation) to biofuel according to Brown and Brown (2012).

2.1.5 **Byproducts and Coproducts**

The advanced biofuel production process yields byproducts and further processing generates subsequent coproducts (Table 2). Combining or improving byproducts can lead to desired coproducts. Unused byproducts increase expenses (Patton 2010), since they require disposal; as a result, increasing the value from byproducts and coproducts could help sustain a biofuel project (Closset et al. 2005). Vivekanandhan (2013) suggests that many of the biofuel industry small scale projects do not generally collect coproducts due to high opex costs foregoing added profit potential, while the opposite is true for commercial scale projects. The coproducts and byproducts are more valuable to reduce energy costs when burned for biofuel projects or are placed in landfill as waste (Poursorkhabi et al. 2013). Therefore, understanding harmful byproduct waste streams is economically and environmentally beneficial when planning scaling projects to reduce harmful impact (Patton, 2010; Soderholm and Lundmark 2009). According to Doherty et al. (2011) and Gellerstedt et al. (2010) providing value-add coproducts may lead to improved biorefinery financial success, and some coproducts could actually be more valuable than the biofuel itself (Patton 2010).

Table 2 Value-added coproducts and their markets from the production of advanced biofuel. (Adapted from Patton 2010, by Lyon 2013).

Product	Source	Process	Market
Gases and fuels			
Syngas	Biomass or lignin	Gasification	Production of ethanol, methanol, dimethyl ether, olefins, propanol, and butanol (Patton 2010; Petrus and Noordermeer 2006; Stewart 2008; Buaban *et al*. 2010)
Hydrogen	Lignin	Gasification	Fuel cells, industrial uses (Patton 2010)
Carbon dioxide	Sugars	Fermentation	Industrial uses, beverage, dry-ice (Patton 2010)
"Synthetic" gasoline and diesel	Pyrolytic lignin	Hydrotreating/ hydrocracking	Liquid fuels (Petrus and Noordermeer 2006; Stewart 2008; Buaban *et al*. 2010)
Lignin	Lignin	hydrolysis	Fuel for heat and electricity, fertilizer, wood adhesive, color additive, reinforcing filler, animal feed, yeast production (Patton 2010; Singh et *al.* 2010; Vivekanandhan *et al*. 2013)
Naphtha		Distillation	Fuel source, solvent
Organic acids			
Succinic acid	Glucose	Fermentation in high CO2	Food addictive, plastics, surfactants, detergents, solvents, textiles, and pharmaceuticals (Söderholm and Lundmark 2009)
Lactic acid	Glucose	Fermentation	Food and beverages, textiles (Patton 2010)
Acetic acid	Glucose	Fermentation	Food additive and industrial chemical, resins, fibers (Patton 2010)
Fumaric acid	Glucose	Fermentation	Food additive, production of resins and alcohols (Patton 2010)
Alcohols			
n-butenol	Glucose	Fermentation	Liquid fuel, food additive, solvent (Patton 2010)
Xylitol	Xylose	Hydrogenation	Sweetener (Patton 2010)
Aromatic compounds			
	Xylose, Arabinose	Dehydration	Solvents, pesticides, resins, liquid fuel (Patton 2010)
Benzene, toluene,xylene	Lignin	Catalysis	Solvents and intermediates for production of polymers and plastics, resins and adhesives, nylon (Patton 2010)
Olefins		Pyrolysis	Production of polyethylene (Patton 2010)
Macromolecules			
Cellulose nanofibers	Cellulose	Chemic-mechanical treatment, electro spinning	Structural composites, plastics, films (Patton 2010)
Polyhydroxyalkanoate	Glucose	Fermentation	Biodegradable plastic use in films, packaging, fibers, coatings, foams, and medical (Patton 2010)
Lignosulfates	Lignin	Sulfonation	Dispersants, emulsifiers, binders, sequestrants, adhesives, fillers, dust prevention (Patton 2010)
Carbon fiber	Lignin	Melt-spinning	Reinforcement for automotive plastics (Patton 2010)
High purity lignin	Lignin		Coatings, emulsifiers, gels, anti-microbial products (Patton 2010)
Other products			
Cellulose nanofibers	Cellulose	Hydrolysis	Animal feed (Patton 2010)
Protein	Protein		Animal feed (Patton 2010)
Biochar	Lignin	Combustion	Fuel, soil additive and carbon sequestration (Patton 2010)
Betulinol	Forest residues		Antioxidant (Söderholm and Lundmark 2009
Waxes			
Furfural	Pentose and hexoses	Hydrolysis	Food additive in vanilla, resins (Larsson *et al*. 1998 Gonçalves *et al*. 2013)
Suberin	Forest residues		Fatty acid (Söderholm and Lundmark 2009)

2.2 Factors Affecting the Advanced Biofuel Industry

2.2.1 Goals and Incentives Driving the Bioeconomy

There are a multitude of government policies using a push-type strategy to bring the bioeconomy technology to the marketplace. The Environmental Protection Agency (EPA), U.S. Department of Agriculture (USDA), Energy Information Administration (EIA), Department of Energy (DOE), and Department of Defense (DOD) have jointly developed these policies to drive the bioeconomy. According to Riedy (2015), the major goals, policy incentives, and providing agency driving the bioeconomy marketplace from Appendix F are:

- **To reduce GHG emissions and sequester carbon**
  - Advanced carbon capture and storage (DOE Grants for R+D)
  - FTA transit investment in GHG and energy reduction (Tigger) (DOT Grants)
- **To achieve greater energy efficiency**
  - Efficient clean fossil energy systems (DOE Grants)
  - Integrated biorefineries grants program (DOE Grants)
  - Advanced marine and hydrokinetic grant program (DOE Grants)
  - Clean energy fund (DOE Grants)
  - Clean diesel grant program (EPA Grants)
- **To integrate rural programs into efforts to increase energy security**
  - Transportation fuel and biofuels: Rural energy for America program (REAP) (USDA, Farm Bill)
- **To stimulate economic growth and development**
  - Federal Transit Administration (FTA) Clean Fuels (DOT Grants)
- **To obtain economically feasible conversion technologies**
  - Clean coal-to-liquid or gaseous fuel technologies grant program (NSF Grants)

According to the U.S. Department of Energy (2013a), the alternative biofuel sector now has four major "Presidential objective" drivers to bring their technology to the marketplace: (1) embolden alternative energy "science and discovery" methods that enhance U.S. energy security, (2) reduce dependence on fossil fuel industry with "secure energy", (3) reduce negative environmental "climate change" impact of GHGs, and (4) improve agricultural and rural program "economic prosperity" opportunities to stimulate and develop economic growth.

2.2.2 **Advanced Biofuel Policies**

Six main policies were created to bolster, develop, and implement the four incentives driving the bioeconomy. Sequentially, they are: (1) Clean Air Act 1970 – through current amendments, (NHTSA 2016) (2) Energy Policy Act of 2005 (EPAct) (U.S. DOE 2015b, U.S. EPA 2009), (3) Advanced Energy Initiative 2006 (The White House 2006), (4) Renewable Fuels Standards of Energy Independence and Security Act of 2007 (EISA) (U.S. DOE 2013, Sorda et al. 2010, U.S. EPA 2007), (5) California Low Carbon Fuel Standard (LCFS) (California Energy Commission 2016) (6) and Food, Conservation, and Energy Act of 2008, (U.S. DOE/EIA 2010).

The Clean Air Act of 1970 through Current

The EPA has been focused on reducing pollutants in transportation fuels since the early 1970's, starting with reducing lead in gasoline and eventually banning it in 1995. The EPA also improved pollution control mechanisms in cars under the Clean Air Act Amendments of 1990. Throughout the 1990's, smog was increasing throughout the country, particularly in the summer months. This led the EPA to regulate increasing the oxygen content in transportation fuels through the Reformulated Gasoline Program (RFG) in 1990. The RFG was designed to reduce GHG and carbon monoxide (CO) emissions content in the atmosphere, and it was only required for cities with high smog content. Methyl Tertiary Butyl Ether (MTBE) introduced in 1979 was used to meet the requirements of the original Clean Air Act of 1970 to increase oxygen content in the fuel supply. MTBE helped improve the fuel's function, lowering CO output to decrease air pollution. However, MTBE was damaging the U.S. water supply (Rogers 1990, EPA 2014, The American Cancer Society 2014).

Just prior to 2005, it was becoming apparent that MTBE had an economically viable replacement, by blending corn ethanol with fuel to achieve the higher mandated oxygen content. Additionally, tests showed that corn ethanol also increased octane content. This potential replacement and the 2005 EPAct implementation led to many states implementing bans on MTBE. The oil industry was not required to use MTBE for blending, and it is not currently federally regulated. However, MTBE was more economically feasible, since it could be moved through existing fuel infrastructure, whereas ethanol and other biofuels could not.

Energy Policy Act of 2005 (EPAct)

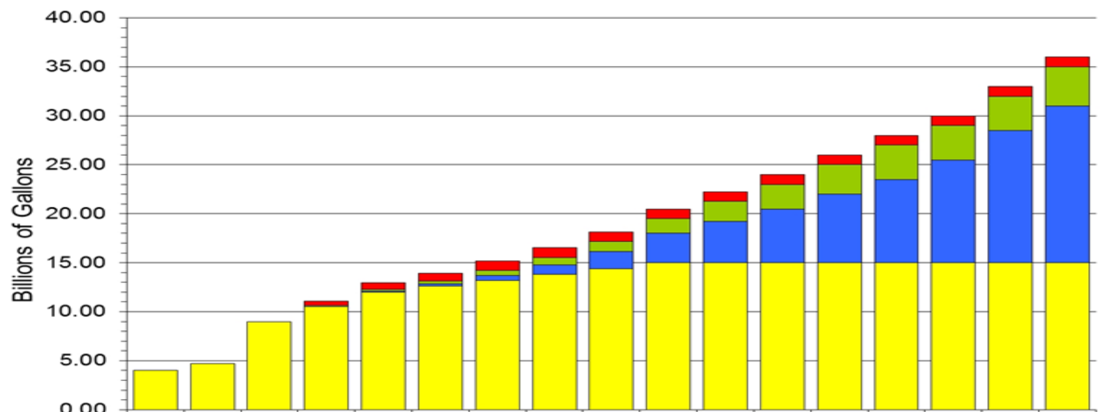
The 2005 EPAct financial policy incentives bolstered a second generation wave of advanced biofuel projects into the research and design stages, the beginning of the differentiated renewable fuel categories. The perceived growing demand for more transportation fuel and subsequent price control caused President George W. Bush in 2005 “to call for 7.5 billion gallons of biofuel to enter the supply by 2012; with the goal of guaranteeing approximately 5% of U.S. transportation fuel is biofuel based” (Moreira 2005). The EPAct and its Renewable Fuels Standard (RFS) became the main driver to incentivize new biofuel technologies to the marketplace.

The EPAct annually increased the volume of biofuel blending from 2006 to 2009 by over 2 billion gallons. Additionally the EPAct provided tax incentives and loan guarantees to drive alternative energy production, reduction in GHG emissions, and carbon capture and storage (CCS), (US DOE 2006c). The 2005 EPAct cancelled the original oxygen content requirements from the Clean Air Act, reformulated gasoline mandates, and incentivized fossil fuel companies to strongly explore available options for using ethanol instead of MTBE (The American Cancer Society 2014).

Advanced Energy Initiative 2006

President George W. Bush offered the Advanced Energy Initiative (AEI) during his State of the Union address in 2006. The AEI’s goal was to reduce 75% of U.S. dependence on fossil fuel–based imports over 20 years. This policy offered $150 million to bolster advanced biofuel technology development from waste products, in addition to the incentives in the 2005 EPAct (US DOE 2006c). Later that year, the DOE offered a new research plan, called “Breaking the Biological Barriers to Cellulosic Ethanol”. This plan created more opportunities to increase GHG reduction benefits of lignocellulosic biomass as an advanced biofuel. “This was in direct response to Secretary Bodman announcing an initiative to displace 30% of the nation’s 2004 transportation fuel usage by 2030, called the 30-30 initiative. The purpose was to motivate and jumpstart the alternative fuel industry to limited modifications to existing infrastructure, and current vehicle engine capabilities” (U.S. DOE, 2006c)

Renewable Fuels Standard of Energy Independence and Security Act of 2007 (EISA)
EISA legislation further modified the EPAct and AEI policies, with four main policy standards added in 2007 and signed into implementation in 2010. These drive advanced biofuel development stemming from the 2005 EPAct - RFS: Renewable Fuel Standard 2 (RFS-2 modified 2007; Figure 1), renewable volume obligations (RVO), renewable identification numbers (RINs), and the California Low Carbon Fuel Standard (California Energy Commission 2016, Fueling Growth 2013). These policy standards are revised yearly, attempting to achieve the renewable biofuel production economies of scale capacity goal of 36BG by 2022.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass-based Diesel				0.50	0.65	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other Advanced				0.10	0.20	0.30	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	3.50	3.50	4.00
Celulosic Advanced					0.10	0.25	0.50	1.00	1.75	3.00	4.25	5.50	7.00	8.50	10.50	13.50	16.00
Conventional Biofuels	4.00	4.70	9.00	10.50	12.00	12.60	13.20	13.80	14.40	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00

Figure 1 2007 EISA-RFS expectations through 2022: Source (Tyner 2015)

The modified EISA - Renewable Fuel Standard (RFS-2) policies increased the growth of the advanced bioeconomy technology pathways entering the marketplace (EPA, 2013). This incentivized further reductions in GHG emissions over petroleum and corn ethanol, by blending wood-, grass-, and algae-based biofuels with current fossil fuels. RFS-2 further incentivized the renewable biofuel requirements of 36 BG by 2022 (EPA 2010). The RFS was divided into four standards (Figure 1), each with its own annual renewable volume obligation (RVO), and required GHG% emission reductions obligation: (1) cellulosic biofuel, 60% GHG reduction, (2) biomass based diesel 50%, GHG reduction, (3) advanced biofuel, 50% GHG reduction, (4) conventional, 20% GHG reduction (corn ethanol in this category).

The blend wall was only hypothetical until it became a real barrier in 2012 (Figure 2). It is the maximum limit of a combination of total renewable fuels (TRF), advanced biofuel and corn ethanol combined, that can be blended into the fuel supply by year through 2022. The yellow represents corn ethanol and its proposed blend wall cap of 15BG. The other colors represent all remaining renewable fuel types, which are capped at 21BG in 2022. Blue represents cellulosic advanced, which is cellulosic biofuel and cellulosic diesel. Green is others advanced, which would include algae and sugar cane ethanol. Finally, red is biomass-based diesel (Schnepf 2013). The TRF is also representative of blending a maximum of 10% renewable fuels into the U.S. domestic transportation petroleum gasoline supply to achieve 87 Octane at the wholesale point before it is sold to consumers, who purchase the blended fuel. As technologies move toward commercial economies of scale in producing and delivering biofuel, another hurdle of declining usage is lowering the amount of fuel that is available yearly for blending. The realized steady decreasing consumption rate over time is due to the increasing efficiency of transportation vehicles and the recent economic downturn.

The Environmental Protection Agency (EPA) revises the annual RFS-2 renewable volume obligation (RVO) that are required for obligated parties (OP) and their targeted output production capacity goals, based on industry stakeholder capabilities, yearly achievements, produced and expected volumes, and projections from the Energy and Information Administration (EIA). OPs are producers or refiners acquiring renewable identification numbers (RINs) to satisfy obligation by producing, purchasing, or importing renewable fuels, or they purchase cellulosic waiver credits (CWCs) and RINs separately without the fuel to meet obligation. After the 2005 EPAct, four years passed during initial development attempts of advanced biofuel projects without RVO. Starting in 2010, there were expected yearly RVO increases in deliverable drop-in biofuels from all four categories. This was true until the theoretical blend wall for all categories became reality in 2012, shifting the focus in new directions, such as politics and new product platforms.

California Low Carbon Fuel Standard

During the 2007 implementation of EISA, the Low Carbon Fuel Standard (LCFS) was established by California. The LCFS requires reduction of carbon content levels within

California's drop-in fuel blends by 2020 (Fueling Growth 2013). The LCFS was established by the California Environmental Protection Agency (CEPA) as a more stringent standard to the EISA Renewable Fuel Standard (RFS) to move California to the forefront of environmental protection. The LCFS provided business incentives, bolstering opportunities for companies like Cool Planet and Byogy in California. For example, Cool Planet produces biofuel, and its byproduct biochar is turned into a moisture-retentive coproduct called Cool Terra. Cool Planet receives incentives related to reducing water usage and developing low carbon emissions; their approach led to a financial windfall from being first to market a new mandate-approved product.

The Food, Conservation, and Energy Act of 2008

The Food, Conservation, and Energy Act of 2008 (also called the 2008 Farm Bill) established grants, loan guarantees, and discretionary funds related to renewable energy and coproducts. For example, the Act provided grants for covering 30% of R+D and construction of advanced biofuel demonstration facilities and up to $250 million for building commercial-scale advanced biofuel projects. Lignocellulosic biofuel would qualify for $1.01 p/gal production tax credit for fuel used and produced in the U.S. Additionally, feedstock stakeholders under the Biomass Crop Assistance Program (BCAP) would qualify for up to $45 per ton financial assistance.

2.3 Recent Trends in the Advanced Biofuel Industry

After the year 2000, many unforeseen market changes occurred that affected fuel supply and demand (Figure 2). In 2012 to 2013 the blend wall threshold became a reality, with a recognized shortfall around 8BG, when 13.7BG of ethanol was consumed compared to the original 2005 RFS expectations (Morrison et al. 2014). In 2012 uncertainty was created with three major barriers: (1) the D6 corn ethanol industry was not allowed to blend more than 15BG on average into the U.S. fuel supply, (2) the 8 BG shortfall made the blend wall a reality and reduced the marketplace demand for an emerging industry to blend fuels, and (3) the reduced demand created tremendous political pressure for a legislative change.

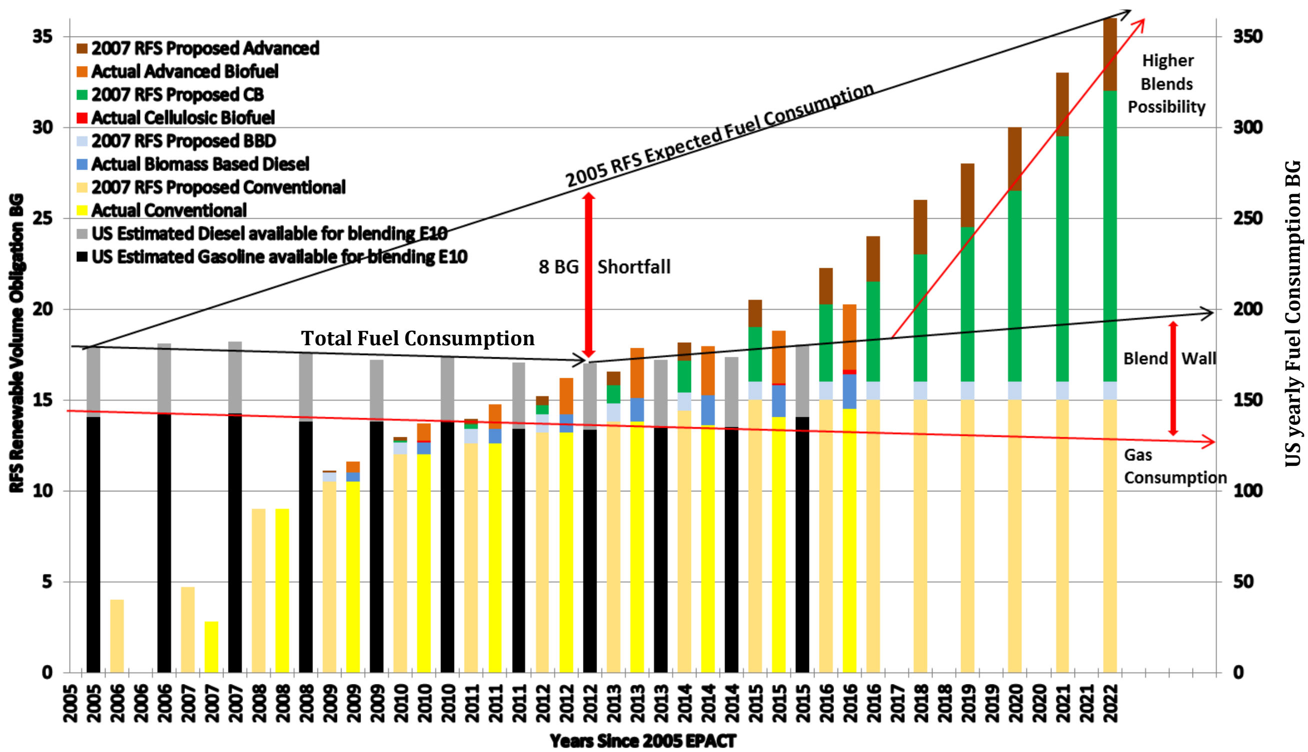


Figure 2 U.S. fuel consumption showing RFS actual and proposed yearly estimates, using EIA data available in Appendix G, (EPA 2016).

These barriers have led to supply and demand fluctuations of renewable identification number (RIN) costs and being traded as commodities within the renewable and advanced biofuels pools (Figures 3, 4, and 5). The 2005 EPAct and 2007 EISA set RINs in motion in limited quantity; however, the market for RINs was not initiated until the first quarter of 2009. Crossing the threshold of the blend wall in 2012 caused the different renewables to be traded at comparable rates within the different D-categories for compliance by the end of that year, from anticipating higher futures with supply and demand (Figures 3 and 4). Carrying forward RINs from previous years created a surplus of available RINs, which altered market perceptions of the blend wall. This forced overall RINs to decline in value through 2014 and increase through 2015 (Figure 3). RINs increase in cost when supply will not fulfill the RFS mandate, which increases the value of buying biofuel instead of RINs. For example, D6 RINs were historically low until the end of 2012 prior to entering the threshold of the blend wall, which increased demand, lowered supply, and increased price. The blend wall was realized in 2012 and cost peaked in July of 2013. Heavy political pressure was then placed on the EPA to change the renewable volume obligations (RVO) within the Renewable Fuel Standard (RFS).

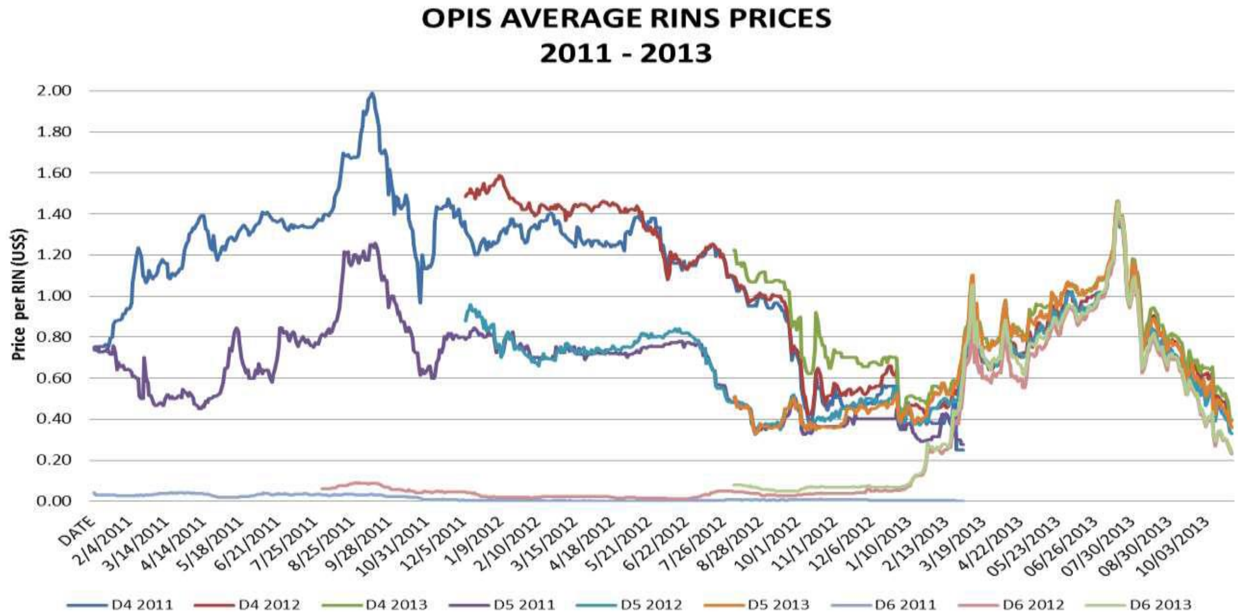


Figure 3 OPIS historical RIN prices. Dunphy (2013a)

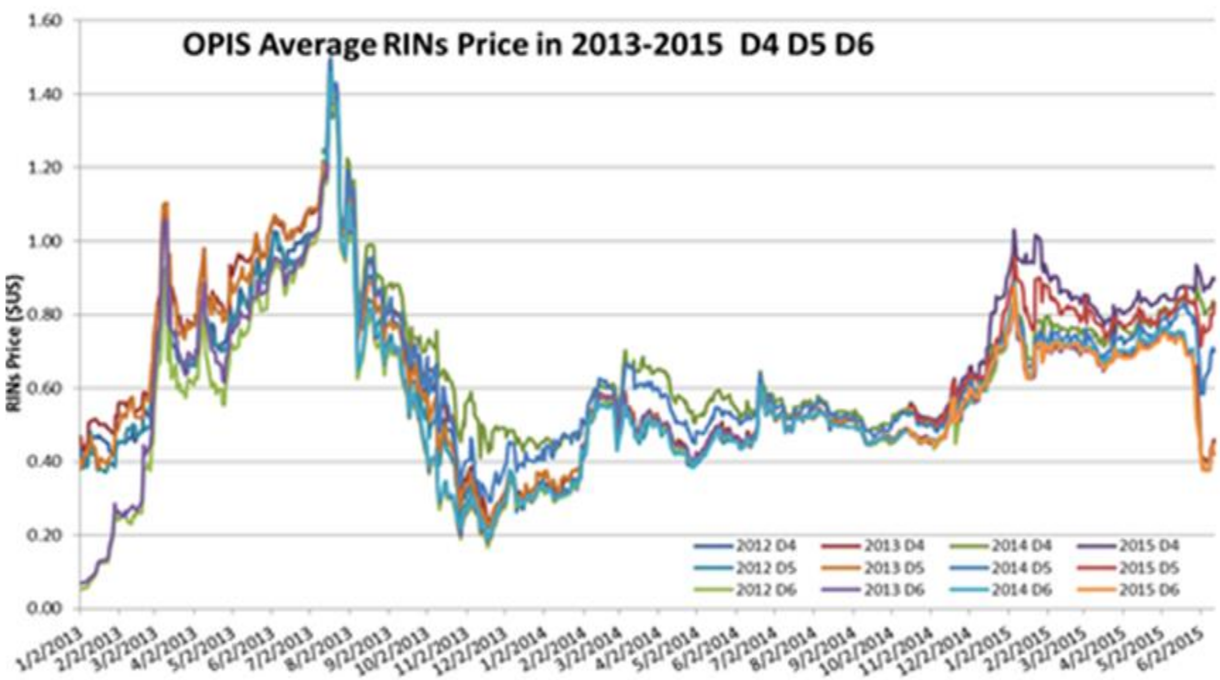


Figure 4 OPIS historical RINs values 2013 – 2015. Dunphy (2013a)

However, delays ensued with the release of the EPA, RFS- renewable volume obligations (RVO), which lasted from the end of 2013 to May 2016. This led to increased market uncertainty of production and created a major barrier between biofuel companies and the government with impending litigation. Advanced biofuel and biodiesel binding mandates in 2013 were fulfilled in the first half of the year, and the remainder became unbinding with free trade. The binding mandate led the E10 biofuel market to become saturated, which left E85 as the only market to blend excess biofuel. However, there was limited infrastructure (Flexfuel vehicles, fuel pump availability, E85 retail cost) for this market.

Market value increased in the Iowa and Minnesota corn region, where biofuel producers (mainly corn ethanol) could more easily sell E85 and biodiesel to acquire RINs, utilizing the nesting impact (Figure 5). Biodiesel became a substitute in the cellulosic categories, increasing the value of RINs for the first six months of 2013. The last half of 2013 led to biodiesel production outpacing demand, lowering the RIN value and subsequently lowering drop-in biofuel cost.

In 2014, the EPA brought in biogas under D3 RINs category, since the advanced biofuel cellulosic D3 category, including wood and grass biomass, was not close to meeting its mandated target (Male 2016). In 2015, the D3 category was then competitive, with 200 mg cellulosic ethanol equivalent biogas and 2 mg cellulosic. In June 2015, the RIN values are separating (Figure 4): D6 corn ethanol was overproduced and the mandated compliance was fulfilled, driving RINs to carry low value compared to advanced biofuels (Berven 2016). Sustainable advanced biofuel projects not only need to be cost competitive, but also need to recognize the Renewable Fuel Standard, renewable volume obligations (RVOs), and renewable identification numbers (RINs) value as major demand signals at the blend wall.

Advanced biofuel D3 and D7 cellulosic waiver credits (CWCs) were established by the EPA and the industry around 2010. CWCs allowed for reduction in renewable volume obligation (RVO) amounts when the required production amounts by obligated parties were not achieved. This inadvertently created a potential barrier between the fossil fuel and AB cellulosic D3 and D6 industry, allowing the oil industry to fear cellulosic projects failing. This fear bolstered the perception of potential reduced competition within the AB industry, decreasing supply and increasing the price they would be forced to pay. The oil companies, to the cellulosic industries' loss, now had the ability to purchase CWCs and not buy biofuels. The bioeconomy calls this the "Offramp" (Lane 2015a), deemed a quick exit from the Renewable Fuel Standard (RFS) regulations for the AB cellulosic D3 and D6 categories, and stakeholders who would otherwise have to purchase their RINs.

The impact of the fossil fuel companies buying CWCs and not biofuel reduced demand and value for RINs for the advanced biofuel cellulosic industry. This was further exacerbated by the early arrival of the blend wall and by unanticipated low blending volumes. The blend wall was now a major constraint with mandated renewable volume obligations (RVO) regulated by the EPA. The blend wall reduced available quantity for blending and was the primary industry bottleneck leading to many political debates and a new barrier: a division between the industry and government. The industry wanted more available demand, and the government indicated there is limited blending volume. Advanced biofuel projects stymied by the blend wall began changing their focus from producing fuel, switching to producing more profitable coproducts, such as chemicals, fragrances, and Succinic acids (Table 2). Reduced competition makes it more difficult for remaining companies if they cannot buy or make fuels to meet their U.S. mandate, leading to increases in RIN value and, ultimately, higher costs.

There are different renewable identification numbers (RINS) for each of these categories in the Renewable Fuel Standard (RFS). The pooling concept (Figure 5) is vital to understand the RFS-RIN's 5 D-coded categories of renewable fuels required to meet the current 2016 EPA renewable volume obligation (RVO). The RVO – Total Renewable Fuels (TRF) amounts change each year. For 2016, this figure indicates the TRF-RVO pool is currently 16.3BG and a combination of D5 and D6 pool totals. The D5 totals are determined from adding D3 + D4 + D5+ D7 + any CWCs needed for failing to meet advanced biofuel cellulosic obligation. Obligated Parties may have obligations in any or all of these categories that must be met each year. The D5 category includes all others, such as algae, that are not D3, D4, and D7.

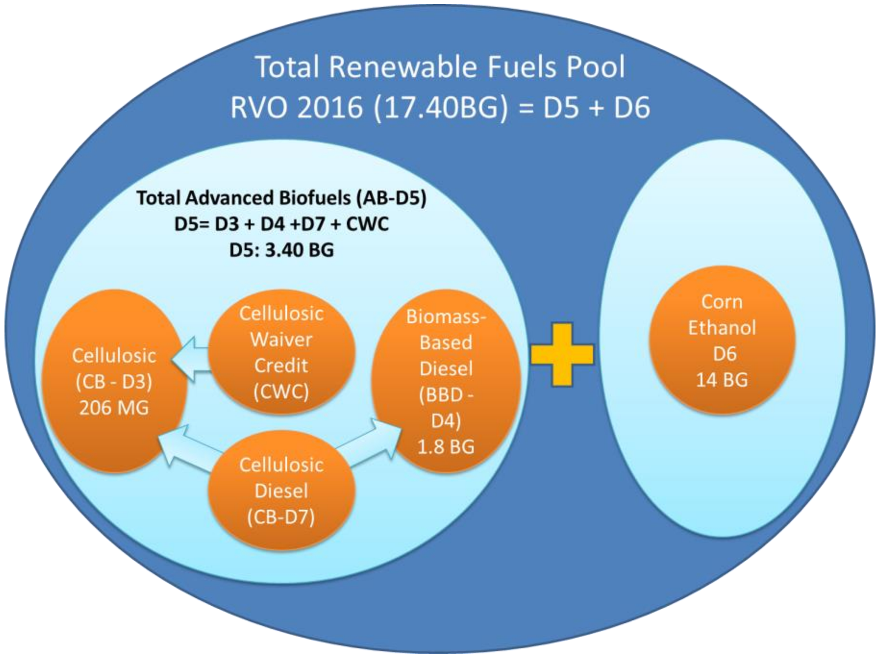


Figure 5 Total renewable fuels pool, modified from Dunphy (2013).

2.4 Potential Barriers to Commercialization

"The U.S. biofuel market potential is currently strong and with more than 1.3 billion tons of harvestable cellulosic biomass" (Growth Energy 2014). Although many advanced biofuel technologies have been proven at the pilot and demonstration levels, only a few are attempting to commercialize at production economies of scale. Even though there are strong policies supporting the development and commercialization of advanced biofuel, many of these projects are stymied at the blend wall until more refineries are able overcome barriers moving their stalled projects to production and commercialization. Amarasekara (2014) has suggested the following barriers: high capital risks, OPEC-based price distortions, constrained blending markets, policies, and technology challenges in lowering the minimum ethanol selling price. Janssen et al. (2013) suggested the barriers are high capital costs (higher than corn ethanol) and financing reliant on multiple sources of capital (private and governmental). Additionally, he suggested that successful projects have achieved advancing their technology efficiency and drivers such as policies and grants. Lu (2010) suggested that barriers are technology based on low process yields and high production costs. Cheng (2010) suggested barriers to production are technology-based high production costs. Sims et al. (2009) suggested barriers such as project closures due to low oil prices below $100/barrel, global financial situation, changing government support policies, immature processing technology, production costs, economic hurdles, and no clear choice for best technology pathway. Naik et al. (2009) suggested there are a number of technical processing barriers that need to be overcome before full potential production is possible. Zhu and Pan (2009) suggested that technological process scaling was a major barrier to commercial biofuel production. According to Bohlmann (2006), the early adopters of lignocellulosic technology were expected to carry the perceived risk of investment of uncertain technology, and that feedstock represents half of total production costs. According to Lynd et al. (2005), the barriers of technology and recalcitrance are major economic and operational challenges.

2.5 Discussion and Evaluation of the Literature

The literature review examined second generation advanced biofuel (AB) wood and grass project barriers to determine a progression of what has and is currently impeding their success. As of 2015, there were six policies driving the inception of advanced biofuels, and EISA carried the most focus toward developing biofuel projects while removing market share from the fossil industry. There are a host of incentives for industry development of AB, such as the 2005 EPAct creating the Renewable Fuel Standard, and its modification with 2007 EISA and new components of RFS2: RVO, RINs, and Code of Federal Regulations (CFR). These policies provided production tax credits and R+D funding to promote the Renewable Fuel Standard concept of replacing 35bg of fossil fuel with drop-in biofuel blends. The policy subsidies and incentives were the drivers leading to advanced biofuel (AB) project attempts from 2005 to 2015. AB projects are divided into three generations by feedstock type: 1G is corn and sugar cane; 2G is wood, grass, crop residues, and MSW; and 3G is algae and butanol. Those feedstocks are in the \$50 – \$80 p/ton range. This reasearch is focused on 2^G wood and grass. Wood and grass feedstock (lignocellulose) is typically separated by its major components in order of value: cellulose, hemicellulose, and lignin.

Currently, few advanced biofuel projects are producing biofuel, with none reaching sustainable commercial production economies of scale where biofuel project size to produce commercial-level biofuel was greater than costs. Some documents in the literature identified barriers, but the authors only focused on broad categories. The most inclusive documents provided a partial list of wood-based biofuel projects by type and status (Mendell and Lang 2012, 2013). In examining literature on barriers to advanced biofuel projects, the following ten main barriers were determined: (1) high capital risks, (2) OPEC-based price distortions, (3) constrained blending markets, (4) policy fluctuations, (5) financing, (6) production costs, (7) global financial situation, (8) economic hurdles, and (9) technology; efficiency, effectiveness, scaling, and (10) too many technology paths.

From the examination of literature, a progression of barriers was determined. Advanced biofuel barriers were initially caused by an over-efficient EPA Clean Air Act policy started in the 1970s. It was improved in 1975 through current with Café standards and further bolstered by the 2005 EPAct and 2007 EISA. Around the year 2000, Café standards led to more efficient cars and pollution output controls. At the same time, fossil oil barrel costs were fluctuating heavily, leading the U.S. government to seek new methods for energy security and simultaneous environmental protection through transportation fuel usage methods. Different Renewable Fuel Standard versions were discussed by the government before finally enacting the 2007 EISA. This enactment led to additional barriers.

Prior to 2005 EPAct, the corn ethanol industry was pre-established for close to 40 years, moving away from utilizing government subsidizes and close to achieving commercial production economies of scale. This subsidized pre-establishment was the first barrier to advanced biofuel and 3G biofuel technologies. The EPAct led to a second barrier: different subsidy and expectation levels among the renewable fuels types. The EPAct created the Renewable Fuel Standard (RFS), which forced the fossil fuel industry to relinquish approximately 10% yearly of the production output over the next 17 years until 2022. This created another barrier: a line drawn in the sand between OPEC-backed fossil fuel companies and government support of the emerging bioeconomy. Additionally, Methyl Tertiary Butyl Ether (MTBE) was increasingly being banned for environmental and health-related concerns, but fossil fuel companies needed the MTBE to increase the octane content of diesel and gasoline. MTBE was able to be transported in fossil fuel's current infrastructure, but biofuel has to be transported separately to the refinery and was more expensive. This was a third blow to the fossil fuel industry: reduction of their monopoly with market share percentage loss over time, MTBE could become banned with potential lawsuits, and unable to maximize delivery economies of scale without expensive upgrades to infrastructure for ethanol. These led to initial fossil infrastructure upgrades and supporting biofuel as a lubricant and octane enhancer with the 2005 EPAct.

The 2007 Energy Independence and Security Act and its modified RFS (EISA-RFS2) brought more specificity, policy incentive type drivers, and, subsequently, more barriers. The fossil fuel industry opposed the new RFS-2 and, to date, mounts continual media attacks to repeal the RFS. By 2007, the steady decline of fossil fuel consumption should have triggered more concern with the near-term potential for constrained blending markets. In 2012, the blend wall arrived; the advanced biofuel projects saturated market demand, with nowhere to put their fuel for blending above their mandate since D6- corn ethanol by itself was filling more fuel capacity than available. The blend wall led to the next major barrier: political involvement in an attempt to create demand. The government was forced to balance the fallout of subsidizing and building an industry with diminishing room to put their products as they strive to meet mandated production economies of scale.

Lack of infrastructure and lack of factual knowledge are the main barriers to the public not having enough Flex Fuel vehicles and ethanol pumps to maintain low gas prices. The main barrier to all groups is time; yes, time. Transportation fuel stations are willing to upgrade infrastructure (Love’s 2015) when the vehicles have upgraded technology. Republicans will not budge until the demand increases. Democrats cannot increase the infrastructure demand until they have control of the House and Senate. The vehicle demand will not increase until the vehicle infrastructure for higher blends is affordable. Advanced biofuel projects will have to receive subsidies until that happens. The public would not support another tax (i.e., carbon tax), while petroleum and gas prices are low (Coleman 2016, ABLC 2016). Therefore time is the overarching barrier with certainty, in an uncertain climate.

The knowledge gaps from the broad barrier categories are not precise enough to fully aid in developing an industry. Furthermore, 75% of AB projects have been lost since inception (Mendell and Lang 2012, 2013). No articles were found analyzing if AB location, status, or technology type was a barrier. A more inclusive in-depth paper focused on a barrier progression over time, divided by internal and external barriers, is needed. The Renewable Fuel Standard (RFS) appears to work for some and not for others, but for whom and why specifically? Examining the barriers across multiple bioeconomy groups, such as academia, government, biofuel publishers, advanced biofuel projects, and the remainder of the bioeconomy, was pivotal to determine a progression of barriers and how the level of understanding changes when moving outwards from the proprietary inner-workings of companies to the broader bioeconomy. No consolidated lists were found of coproducts and byproducts from 2G AB companies. The focus was mainly placed on their funding and technology issues, as if they are not utilizing their secondary products. But why?

Therefore, this research was deemed necessary due to the perceived advanced biofuel investment risk, investment potential in the bioeconomy, infrastructure need, and 75% loss of projects in less than 8 years. Additionally, a simplified understanding of internal and external barriers across and within industry stakeholders groups and market and distribution barriers of their products was needed to drive faster return on investment from reducing risk, as conditioned bioeconomy reinforcement. Determination of these knowledge gaps in a singular document will more quickly aid in bioeconomy collaboration maximizing the RFS-2 potential.

CHAPTER 3. Methods

3.1 Problem Statement

An estimated 75% of wood and grass advanced biofuel projects failed by 2013 (Mendell and Lang 2012, 2013), but little is known of the barriers and internal and external factors that contributed to these failures. The goal of this project was to describe stakeholders' perspectives on the main barriers to achieving sustainable commercial production economies of scale in the advanced biofuel industry. This study will provide insight into factors affecting success and failure of advanced biomass projects, generating more value-added methods to advance biofuel projects from the onset of research and design. The findings could help project managers reduce unexpected costs, time to achieving economies of scale, and bioeconomy investment through understanding of advanced biofuel barriers.

3.2 Research Questions

Analysis of the literature indicated that a map of all past and present wood and grass advanced biofuel (AB) projects locations by status, type, and technology did not exist in the public domain. Additionally, a list of critical barriers to reaching production economies of scale did not exist. Little was known about why advanced biofuel projects fail. This research was an attempt to provide important insights into the main barriers that have prevented AB projects from becoming commercially sustainable since the 2005 EPAct. Three research questions were developed to address the current knowledge gaps related to AB projects:

3.2.1 **Research question 1:** Does the location of advanced biofuel refineries east or west of 95° longitude impact their operational status since the 2005 EPAct?

3.2.2 **Research question 2:** What are the stakeholder perspectives on the main barriers to production of advanced biofuel by type, status, and technology?

3.2.3 **Research question 3:** What are the industry stakeholder perspectives on the barriers to marketability and distribution of byproducts and coproducts for U.S. advanced biofuel projects?

3.3 Theoretical Model

The operationalized model (Figure 6) provides the sequential process variables used, leading to discovery and determination of barriers (Table 10), the products produced (Table 17), and the marketability and distribution barriers (Table 16) impeding achieving advanced biofuel comercial production economies of scale.

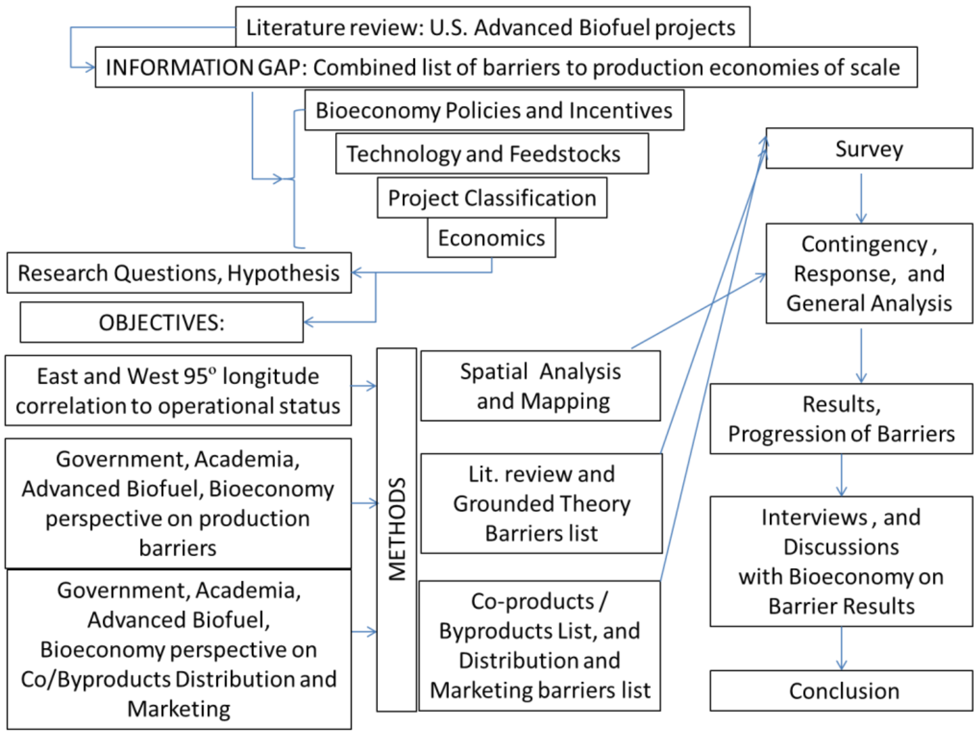


Figure 6 Operationalized model of pathway to determine barriers

3.4 Overview of Methods

The research for this study was conducted in three phases: spatial analysis and operational status, internal and external barriers, and marketing and distribution barriers of coproducts and byproducts. Phase one of the research identified how many wood and grass advanced biofuel projects have been attempted by their status, location, feedstock, and technology type. During phase two, a survey was developed that requested industry stakeholders to rank barriers on a Likert scale and provide coproducts' and byproducts' main and secondary barriers to marketing and distribution. A coproducts and byproducts list was provided to aid in stakeholder response. In phase three, after compiling survey responses, interviews were conducted to discuss the specific barrier responses with stakeholders.

3.5 Population

The population of interest for this research was all U.S. non-food lignocellulosic wood and grass advanced biofuel projects, government, academia, journalists, and others involved with this industry since the 2005 EPAct. For the purpose of this research, the following specific feedstock-type projects were of particular interest: un-merchantable timber, forest thinning's (slash), sawdust, waste paper, mill residues, paper mill sludge, and grass varieties.

Objective 1: Determine if the location of advanced biofuel refineries east or west of 95° longitude is correlated to their operational status since the 2005 EPAct."

3.5.1 Null Hypothesis

H_o: The advanced biofuel refinery operational status is correlated to their location east or west of 95° longitude (cancelled, shutdown, operating, planning, and under construction) since the 2005 EPAct.

3.5.2 Methods

The location, operational status, and demographics information for each project were determined by examining technical reports, peer-reviewed papers, trade journals, and newspapers. These were based on the biofuel industry terminology used in the Wood Bioenergy U.S. (WBUS) database according to Forisk Consulting (2013), along with acquired secondary sourced data from the literature review. The data were used to individually classify and code categories directly associated with advanced biofuel projects as follows: type (pilot, demonstration, and commercial), operational status (cancelled, shutdown, operating, planning, and under construction), demographic (project, name, and location), feedstock type used, and contact information.

The status category was used to classify the individual location of advanced biofuel projects by quantity count of each operational status category (cancelled, shutdown, operating planning, and under construction). Cancelled projects were considered terminal. Shutdown was a project that was stopped and put on hold; however, it could potentially be restarted at a later time. Operating projects are projects are those where construction was complete and the company was attempting to produce a biofuel product. Planning projects are considered to be in the R+D phase and before construction begins. Under construction projects are currently under construction.

A univariable U.S. map of each identified project status with subsequent locational distribution was developed using the Zeemaps® mapping tool. The map was then divided into two approximate equal regions (Eastern and Western) by a line at 95° longitude from Texas to Minnesota. This resulted in 21 states in the Western and 29 states in the Eastern region. Minnesota, Iowa, and Texas were considered in the western region, and Missouri was considered in the Eastern region. The map was used visually for determining clusters through spatial analysis (Koperski 1997, Openshaw 1990). Once the data were classified into a map by the previously mentioned categories, a statistical analysis was conducted to test the null hypothesis.

A contingency table (Appendix E) was developed to further explore the proportion of projects by established regions and operational status. Next, a Chi-Square contingency table analysis was conducted to further analyze potential relationships, and a Chi-Square response analysis test was performed to test the null hypothesis, comparing the Eastern and Western regions.

3.5.3 **Output**

- A detailed list of all determined U.S. advanced biofuel projects by a 95° longitudinal Eastern and Western distribution, operational status, contact information, and source of data information.
- A detailed list for the proportion of U.S. advanced biofuel projects operational status by determined Eastern and Western regions.
- Individual spatial mapping of all determined U.S. advanced biofuel projects by operational status and subsequent determined Eastern and Western regions.

3.6 **Objective 2:** Describe stakeholders' perspectives on the barriers to production of advanced biofuel by type, status, and technology.

3.6.1 Null Hypothesis

H_o: The barriers are the same for each stakeholder perspective by type (pilot, demonstration, and commercial), status (cancelled, shutdown, operating, planning, and under construction), and technology (biochemical, thermochemical, and hybrid).

3.6.2 Methods

Two main research methods were conducted to achieve this objective. First, Grounded Theory (Appendix C) was used to examine peer-reviewed papers, industry reports, technical reports, trade journals, and newspapers to detect barriers. To document and understand the open-coded statements from the reviewed documents, the Grounded Theory analytical technique to classify and categorize information was used. Initial open coding involves labeling, segmenting data, conceptualizing, and developing categories, and axial coding analyzes the most significant and frequent data from the initial coding, thus relating categories to subcategories (Charmaz 2006).

In the second component, a survey was developed to have these potential factors be reviewed by bioeconomy stakeholder experts (government, academia, advanced biofuel, publishers, and others). In addition, discussions with experts were conducted to clarify survey results. Representatives from academia were chosen from a pool of professors with peer-reviewed publications related to barriers impacting advanced biofuel projects. Industry members were chosen by direct requests of those projects that were classified as cancelled or shutdown. Government stakeholders were chosen by contacting the U.S. Department of Energy.

The survey included Likert-type questions, open-ended questions, and close-ended questions. The Likert-scale questions were developed for nine different constructs that were identified during the literature review. A scale from 1 to 5 was used, where 1 was strongly disagree and 5 was strongly agree. The constructs were product development, strategy, funding, suppliers, competitors, government, energy costs, and third-party relationships. The open-ended questions were designed to gather specific demographic information and point-of-view financial questions. Close-ended questions were used to ascertain remaining aspects of the projects. The survey in

Appendix A had four parts: demographics, financial barriers, technical barriers, and coproducts and byproducts.

Experts from academia, government, and the industry were asked to review and test the survey for clarity and content. The initial survey design was determined to be lengthy in sample testing and was shortened to two questions (Appendix B). Question 1 requested stakeholder perspective on the list of determined barriers via Likert scaling, and question 2 requested written response of providing primary and secondary ranking of coproducts and byproducts barriers to marketability and distribution. To implement the survey, the Tailored Design Method was chosen for data collection due to sample sizes and lack of peer-reviewed information. “The ordered procedures in this method will improve trust, perceptions, and positive response from the biofuel respondents” (Dillman 2000).

Respondents were initially asked to provide the stakeholder groups they are associated with: government, academia, biofuel industry, biofuel publishers, or other. If biofuel industry was not chosen, Qualtrics skip logic was activated to hide advanced biofuel projects industry demographic questions from all other respondents. If biofuel industry was chosen, the respondents were then asked to provide information on project type (pilot, demonstration, commercial), status (cancelled / shutdown, planning, under construction, operating), and technology type (thermochemical, biochemical, hybrid). The intent here was to acquire enough detailed responses to examine the advanced biofuel industry separately to compare it with other groups.

3.6.3 **Data Analyses**

The responses were reviewed for data consistency and internal reliability. Data consistency techniques include qualitative methods to make sure there were no missing data. A reliability test (Chronbach’s alpha) was conducted to check the internal consistency of all Likert questions of each individual construct in the survey (Gliem 2003).

Descriptive statistics were used to characterize the survey respondents to determine general trends in knowledge of the bioeconomy pertaining to advanced biofuel project sustainability. To explore high response to the survey, nonparametric tests were utilized. A contingency and multiple response analysis, with Chi-Square and a Fisher's exact test, were utilized to examine the central tendency (mean, median, mode) and viability of the ordinal data. To test the hypothesis, the data in each construct were examined as ordinal variables. The independent categorical variables were: type of stakeholders, AB project type, status, and technology. In all cases or comparisons, a contingency and a multiple response test were used for determining the statistical differences among the groups of the independent variables.

3.6.4 **Output**

- A secondary sourced list of determined internal and external barriers impeding advanced biofuel projects.
- Primary sourced list of internal and external barriers to advanced biofuel projects by demographics, technical, and financial categories.
- Validation and comparisons of barriers drawn from secondary sources vs. primary sources.

3.7 **Objective 3:** Describe the stakeholder perspectives on the barriers to marketability and distribution of byproducts and coproducts for U.S. advanced biofuel projects.

3.7.1 **Methods**

A list of potential byproducts and coproducts was determined from conducting the literature review. This list was incorporated into the survey in objective 2 to explore the perceptions of industry stakeholders on the barriers to marketability and distribution of coproducts and byproducts for advanced biofuels.

3.7.2 **Output**

- Primary and secondary sourced lists of determined byproducts' and coproducts' marketability and distribution barriers affecting advanced biofuel projects.
- Validation and comparisons of byproducts' and coproducts' marketability and distribution barriers drawn from secondary sources vs. primary sources.
- Primary ranking importance of byproducts' and coproducts' marketability and distribution barriers affecting advanced biofuel projects.

CHAPTER 4. Results

4.1 Spatial Analysis

The determined Eastern and Western distributions and operational statuses were used to identify significant barriers impeding the success of this type of industry and to identify states and regions that may be more beneficial to project sustainability. Determining total number of advanced biofuel projects, current operational status, and spatial distribution provided insight as to the initial question of how many projects have been attempted, locations of non-advancing projects, and the most economically beneficial and feasible places for U.S. biofuel project location.

Through this process, lists of cancelled and shutdown projects (Table 3) and projects that are in planning, under construction, and operating (Table 4) were developed from the WBUS database and modified with additional projects and changes in status (Mendell and Lang 2012, 2013). Some projects in planning are completing financing and are ready to undergo construction (Table 4). Zeachem is listed as shutdown, since they only use the plant in periodic batches, and they have been unable to secure a bridge loan to proceed to the next level. However, they are a viable company.

Table 3 Current Status of U.S. advanced biofuel wood and grass projects in the cancelled and shutdown phases (adapted from Mendell and Lang, 2013, 2014).

	Table 1. Current Status of Wood-based projects in the U.S. (Adapted by author from WBU, Forisk Consulting-2013)						
	Technology type:	**Project Name**	**City**	**State**	**Project type**	**Status**	**Biomass utilized in fuel production**
1	Thermochemical	New Page Corp	Wisconsin Rapids	WI	Demonstration	Cancelled	Wood processing residue, and municapal waste
2	Thermochemical	New Page Corp	Escanaba	MI	Demonstration	Cancelled	Wood processing residue, and municapal waste
3	Thermochemical	Cello Energy	Bay Minette	AL	Commercial	Cancelled	Wood product
4	Thermochemical	Clear Fuels	Collinwood	TN	Commercial	Cancelled	Wood product
5	Thermochemical	Comm. Energy Systems	Clatskanie	OR	Commercial	Cancelled	paper waste
6	Biochemical	Coscata	Boligee	AL	Commercial	Cancelled	wood waste and bagasse
7	Thermochemical	Dynamotive	Willow Springs	MO	Commercial	Cancelled	wood by-products, woody residues from sawmills
8	Biochemical	Kior Bude	Bude	MS	Commercial	Cancelled	wood chips
9	Thermochemical	Newton Falls	Newton Falls	NY	Commercial	Cancelled	wood and agricultural waste
10	Biochemical	Rappaport Energy	Longview	WA	Commercial	Cancelled	waste wood
11	Biochemical	Raven Biofuels	Ackerman	MS	Commercial	Cancelled	Hardwood and softwood chips
12	Thermochemical	Rentech Rialto	Rialto	CA	Commercial	Cancelled	wood chips
13	Biochemical	Gulf Coast Cleveland	Cleveland	TN	Commercial	Cancelled	waste wood
14	Thermochemical	Flambeau River Biofuels	Park Falls	WI	Commercial	Cancelled	kraft alcohol sulfite black liquor, forest residues, wood waste
15	Biochemical	Range Fuels Inc.	Soperton	GA	Commercial	Cancelled	Wood waste, chips
16	Thermochemical	Frontline		MN	pilot	Cancelled	corn stalks, wood chips, forestry residues, wheat straw, grasses, rice husks
17	Biochemical	Virdia	Natchez	MS	Commercial	Cancelled	Woodchips
18	Biochemical	Virdia	Booneville	MS	Commercial	Cancelled	Woodchips
19	Biochemical	Virdia	Hattiesburg	MS	Commercial	Cancelled	Woodchips
20	Biochemical	Virdia	Grenada	MS	Demonstration	Cancelled	Woodchips
21	Biochemical	KiOR	Newton	MS	Commercial	Shut down	Woodchips
22	Biochemical	KiOR	Natchez	MS	Commercial	Shut down	Forestry residual - waste wood, chips
23	Biochemical	KiOR	Columbus	MS	Commercial	Shut down	Forestry residuals - waste wood, wood chips,
24	Biochemical	Old Town Fuel and Fiber	Old Town	ME	Demonstration	Shutdown	Forestry residuals
25	Thermochemical	Rentech & ClearFuels Product Demo Unit	Commerce City	CO	Pilot	Shut down	Wood waste and Bagasse
26	Thermochemical	ZeaChem Demo Plant	Boardman	OR	Pilot	Shut down	Hybrid Poplar, wheat straw, corn stover and cobs
27	Biochemical	Coskata Semi-Commercial Facility	Madison	PA	Pilot	Shut down	biomass, municipal solid waste,wood chips, switch grass corn stover
28	Thermochemical	Gulf Coast Energy	Livingston	AL	Pilot	Shut down	sawdust, waste sawlog
29	Thermochemical	Integrated Biorefinery Demo Project	Toledo	OH	Pilot	Shut down	Rice hulls and forest redsidues
30	Biochemical	Helios Scientific	Curwensville	PA	Pilot	Planning	Woody biomass

Table 4 Advanced Biofuel wood and grass projects in the planning, operational, and under construction phases (adapted from Mendell and Lang 2012, 2013)

	Technology type:	Project Name	City	State	Project type	Status	Biomass utilized in fuel production
30	Biochemical	Helios Scientific	Curwensville	PA	Pilot	Planning	Woody biomass
31	Biochemical	Optafuel	Wise	VA	Pilot	Planning	Woody biomass
32	Hybrid	Mercurius Biorefining	West Lafayette	IN	Pilot	Planning	sawdust, woody biomass
33	Biochemical	LanzaTech Freedom Pines	Soperton	GA	Demonstration	Planning	cellulosic waste streams
34	Thermochemical	Enerkem	Pontotoc	MS	Commercial	Planning	MSW and forest residues
35	Biochemical	BlueFire Renewables	Fulton	MS	Commercial	Planning	wood waste, sorted MSW
36	Biochemical	BlueFire Renewables	Lancaster	CA	Demonstration	Planning	wood and paper wastes, MSW, bagasse
37	Biochemical	Mascoma Kinross Cellulosic Ethanol	Kinross	MI	Commercial	Planning	Aspen and other hardwoods
38	Thermochemical	Frontline	Ames	IO	Demonstration	Planning	corn stalks, wood chips, forestry residues, wheat straw, grasses, rice husks
39	Thermochemical	Cool Planet Alexandria	Alexandria	LA	Commercial	Planning	Wood waste and forest byproducts
40	Biochemical	Sweetwater Energy	Stanley	WI	Commercial	Planning	Woody biomass
41	Thermochemical	Red Rock Biofuels	Lakeview	OR	Pilot	Planning	woody biomass
42	Biochemical	Applied Biorefinery Sciences LLC	Lyon Falls	NY	Pilot	Planning	woody biomass
43	Thermochemical	Gridley Project	Gridley	CA	Demonstration	Planning	Rice harvest waste, waste wood, waste biomass, food processing waste, sewage sludge
44	Thermochemical	Sundrop Fuels, Inc.	Alexandria	LA	Commercial	Planning	biomass
45	Biochemical	Stan Mayfield Pilot	Perry	FL	Pilot	Operating	Green wastes, crop residues, bagasse, and wood
46	Thermochemical	Haldor Topsoe Gas technology Inst.	Des Plaines	IL	Pilot	Operating	woody biomass
47	Biochemical	KiOR	Pasadena	TX	Demonstration	Operating	Forestry residuals - waste wood, wood chips
48	Biochemical	Mascoma	Rome	NY	Pilot	Operating	Forestry residuals - wood waste, paper sludge,switch grass corn stover
49	Thermochemical	Envergent Technologies	Kapolei	HI	Pilot	Operating	Corn Stover, Bagasse, Swichgrass, Forest Residues, Algae
50	Biochemical	Virent Biogasoline	Madison	WI	Pilot	Operating	Cellulose, corn stover, pine residuals
51	Thermochemical	Abengoa	Hugoton	KS	Commercial	Operating	Corn stover, Wheat straw, Switchgrass, milo stubble
52	Biochemical	Fiber right	Lawerenceville	VA	pilot	Operating	MSW, commercial waste, energy crops
53	Thermochemical	Ensyn	Canada/ US		Commercial	Operating	woody biomass
54	Thermochemical	Cool Planet Pilot	Camarillo	CA	Demonstration	Operating	Wood waste and forest byproducts
55	Hybrid	INEOS New Planet BioEnergy	Vero Beach	FL	Demonstration	Under Construction	MSW - municipal solid waste, straw, wood residues
56	Biochemical	American Process Inc Demo Plant	Thomaston	GA	Pilot	Under Construction	Variety of biomass
57	Biochemical	Am. Proc. -Alpena Prototype Biorefinery	Alpena	MI	Pilot	Under Construction	Hardwood derived hydrolyzate from existing mill board wastewater stream
58	Thermochemical	RTI International	Research Triangle	NC	Demonstration	Under construction	Woody Biomass
59	Thermochemical	Cool Planet Natchitoches	Natchitoches	LA	Commercial	Under Construction	Wood waste and forest byproducts

The number of biofuel projects has decreased steadily from its peak in 2011 (Figure 7), indicating that barriers to advanced biofuel projects were initiated during 2011 and led to a 50% decline project continuation. The number of advanced biofuel projects since 2010 continues to decline (Mendell and Lang 2012, 2013).

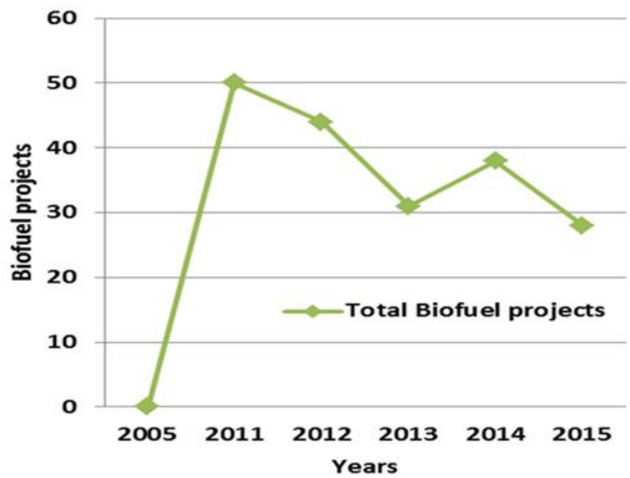


Figure 7 Total biofuel projects since 2005 EPACT

4.1.1 Location and Status of Projects

A total of 59 AB projects were identified and classified by project status (Figure 8). The distribution visually indicated a relationship by region and project status for the Eastern part of the U.S. and in Mississippi. The location analysis indicated that most of the advanced biofuel projects are located in the Eastern region, but the proportion rates of projects when comparing the Eastern and the Western regions does not show any significant difference between regions. Mississippi seems to have state policies designed to attract the industry (Figure 8). Other projects seem to be uniformly scattered in the Eastern region. In total, 19 projects were cancelled or shutdown. Of the 59 projects started since 2007, only 13 operating in 2015.

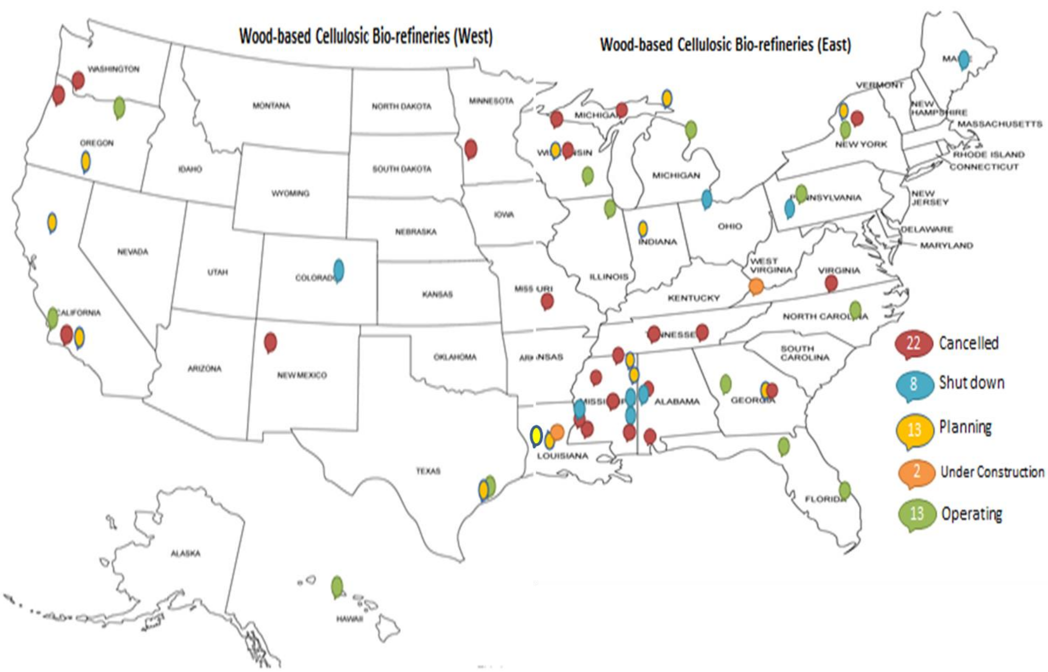


Figure 8 Map of all advanced biofuel projects since 2005

The contingency table analysis indicated that the majority of projects have been started in the Eastern region (n=41, 82%). Given that there could be a relationship between the regions and the status of projects, a test was conducted to test if the proportion of status of projects was the same for both regions (Figure 9). The results of the Chi-square test indicated that there was no significant relationship between regions and status of projects (p=0.3260).

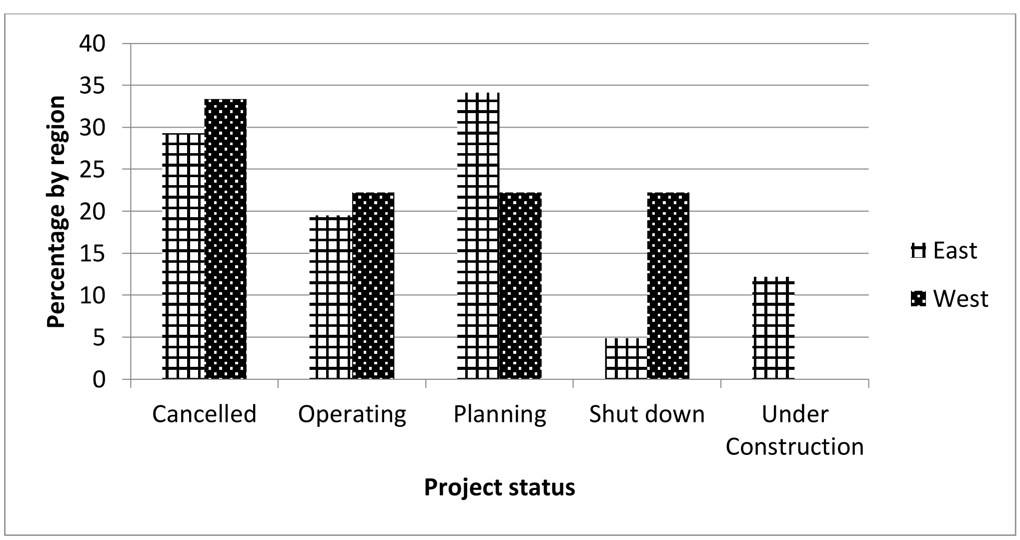


Figure 9 Status of advanced biofuel projects by regions

There are five stages of technology development for advanced biofuel projects (Figure 10). Each stage is representative of the feasibility of planning, financial constraints, proving conceptual design, and intellectual rights. Front end loading (FEL) refers to the project planning stages, and the Valley of Death is representative of where companies may struggle and potentially fail before achieving success (Figure 10). FEL 1 and FEL 2 are primarily R+D and trying to prove concepts as a fundable biochemical, thermochemical, or hybrid project with viable technology. During FEL 3 and FEL 4, extreme financial and technological burden come into play as costs soar into the hundreds of millions, attempting to achieve biofuel scaling of commercial production economies of scale. Finally, repeat the success. The average pilot plant typically costs $10 million or less, the average demonstration plant cost is less than $100 million, and a commercial plant cost varies from $100 - $500 million. Figure 11 shows the percentage of individual projects by technology status achieved from 2005 to current.

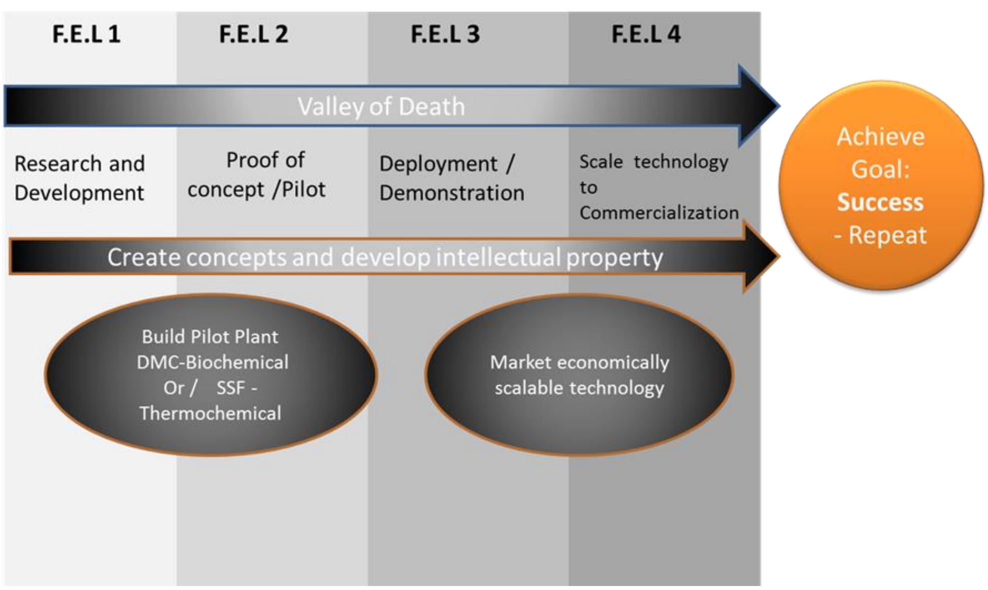


Figure 10 Stages of technology development adapted by author from (Fueling Growth 2008)

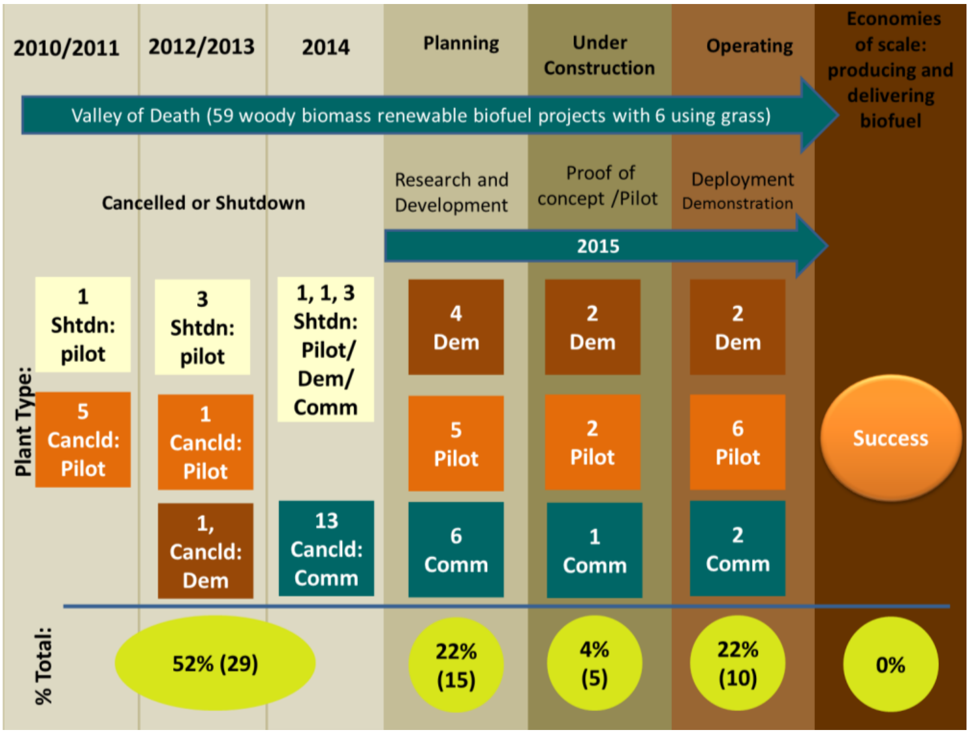


Figure 11 Front End Loading (F.E.L) project stages of technology development and percentage status

The barriers that have caused the many crests and valleys are deemed the "Valley of Death" (Figure 12) by the advanced biofuel industry. McCombs (2015) describes the Valley of Death as correlating to advanced biofuel operational barriers, as a wave cresting with inflated expectations, crashing to disillusionment, with those projects that survive attempting commercial economies of scale. The wave generally crests in the early stages and crashes after introduction while seeking additional scale-up funding. Finally, "those that achieve scaling of their concept and product tend to resurface while 50% of others tread in disillusionment (McCombs 2015)." In Figure 12, the Valley of Death is overlaying the cancelled and shutdown projects in the valley and those that resurfaced where the wave ends.

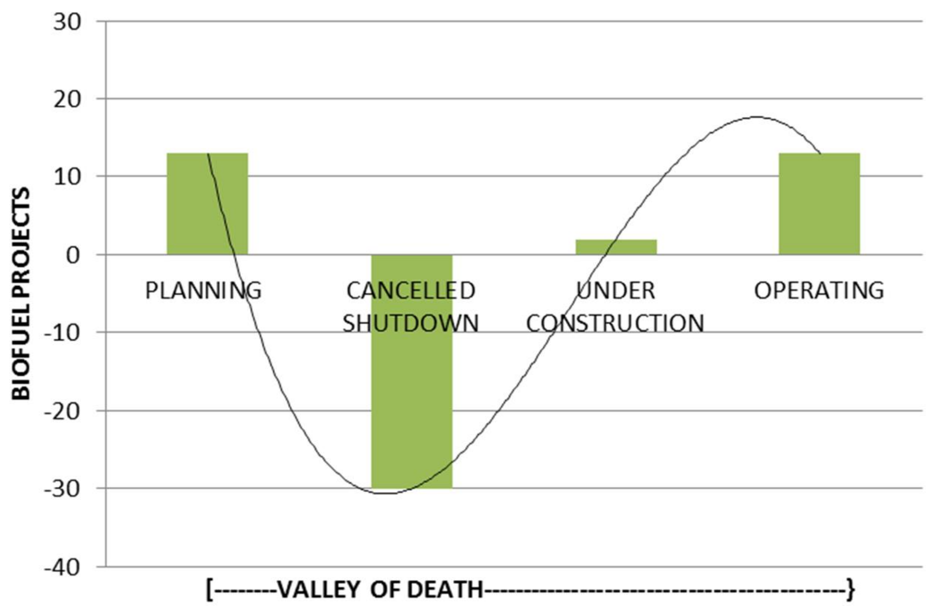


Figure 12 Biofuel Valley of Death by project type and status

4.2 Factor Development

4.2.1 Barrier Determination from Secondary Sources

Grounded Theory was used to determine internal and external barriers from public statements from advanced biofuel projects. Three internally coded categories of product development, strategy, and technology were identified, and six external barrier categories were identified: funding, competition, suppliers, government, energy costs, and third-party relationships. It was determined that the biofuel barriers fit into these categories and should be used in a survey to ascertain if academia, advanced biofuel, biofuel publishers, government, and others in the bioeconomy agree whether they are barriers. A starting point in data development for the determination of barriers for advanced biofuel projects was grounded in the foundation of the needed research. This was the primary barrier category which all subsequent secondary barrier categories are to be related.

Project industry stakeholder statements were used to determine previously identified barriers, such as technology, financing, policies, capex costs, opex costs, and energy costs. A barrier was determined when a participant stated a tangible obstacle impeding advanced biofuel project sustainability (success). A barrier was counted once per project, even if it appeared multiple times in a quote. The following quotes are provided as examples of how barriers were coded and extracted using Grounded Theory; see Appendix D for additional quotations from stakeholders associated with cancelled and shutdown lignocellulosic advanced biofuel projects.

1) Bill Roe (CEO Coskata) says: "We are limited to a maximum of 100 – 150 million gallons, about the size of a big ethanol plant. (technology)With a natural gas feed, much larger plants can be built(fossil fuel costs)….the debate over RFS2 is completely political at this time,(policy) leaving us unprepared to take the risk to sink major capital (financing) at this time in a project, and see RFS2 change markedly right in the middle of construction. (policy)" (Lane, 2012)
2) Flambeau CEO Butch Johnson in Oct. 2010 stated "Initially to move the project forward our true challenge will be funding.(financing) The D.O.E is providing an $80 million project grant, leaving investors to contribute $220 million…the agency has set terms that private investors would reject. (policies) Normally, they want 20% sponsor equity, but they are requesting we bring our equity up to 40% or 50% it kills your return on investment. (financing) (Brochu, 2010)

4.2.2 **Analysis of Primary Internal and External Factors**

Of the 19 unsuccessful advanced biofuel projects, 17 were analyzed to identify barriers that prevented their successful commercialization. A total of 22 barriers leading to failure were extracted and classified using Grounded Theory coding (Table 5). The list was determined to contain many similar broad categories and could lead to scope creep in the research. The list was further condensed into three primary internal barriers and six external causal mechanisms (Table 6).

Table 5 Grounded Theory determined barriers

BARRIERS	# OF TIMES STATED
Criteria changed	6
Dwelling age	1
Economics	3
Economy	3
Feedstock Costs for Biorefinery	2
Feedstock for Products	2
Fraud	1
Funding	14
Government Contracts	1
Import Prices	1
investors desiring near term profits	1
Investment risk aversion	2
Policy	1
Project economics	2
R+D	1
R+D Only no construction	3
Reduction in current energy costs	3
ROI	1
Technical	1
Technology scale-up to expensive	4
Technology used	3
Third party contracts	3
Total	**59**

Table 6 Primary and secondary internal and external barriers

INTERNAL BARRIERS	EXTERNAL BARRIERS
Product Development	Competition
Strategy	Funding
Technology	Suppliers
	Government
	Energy Costs
	Third party Relations

4.2.3 **Frequency of Internal Primary Factors or Barriers**

The internal primary categories that were developed to classify barriers were product development, strategy, and technology (Figure 13). The product development category includes reasons from projects that did not pass the planning or construction stage; only cancelled projects indicated this barrier as a reason for cancelling the project. The category strategy was defined as a change of scope in seeking profits in other type of business because profits were not foreseeable in the short term. The technology category included reasons that are representative of the technology attempted that could not be fully utilized to the individual project situation, projects that could not see an end to the scale-up costs, and projects that were intended to develop using old or current infrastructure.

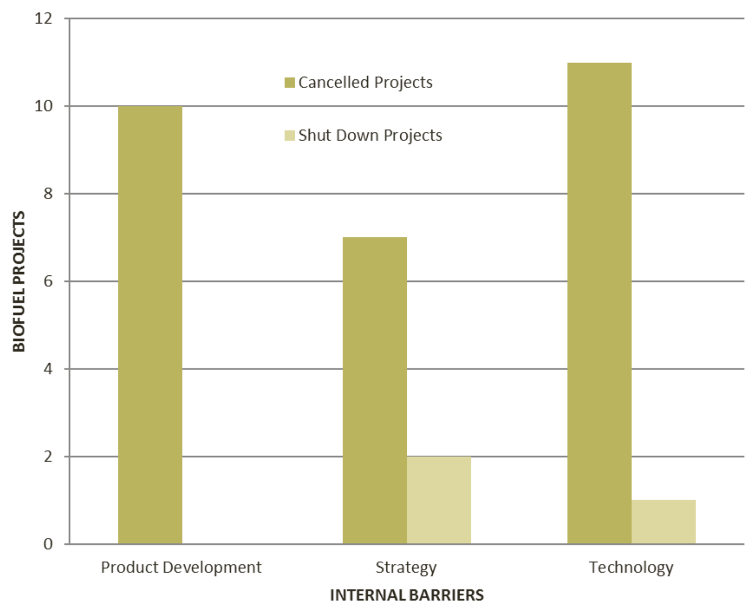


Figure 13 Internal factors affecting sustainability of cancelled and shutdown projects.

4.2.4 **Frequency of External Primary Barriers**

For external barriers, the following categories were identified during coding: funding, competition, suppliers, government, energy costs, and third-party relations (Figure 14). The funding classification for barriers is representative of not having enough financial resources to move forward and pressure to provide profits to maintain investor longevity and strength of company credibility. The competition category includes aspects such as import prices of biofuel and costs associated with rising daily expenses compared to competitors. Supplier aspects included issues such as fluctuating costs of lignocellulosic feedstock, supplier relations, or location. The government contracts category included aspects related to regulations, policy, or government intervention in the development of this particular biofuel market. Specific aspects that were found and classified under this category included future percentage costs associated with acquiring government assistance and the stringent government oversight to meet mandates of that agreement. The energy costs category includes the impact of energy prices (electricity, natural gas, and other fuels used in the production process). Most of the open code statements associated with this category were related to the need of reducing production costs, specifically energy consumption, to make the production of biofuel profitable. Finally, the external category third-party contracts are determined based on the relationships that this type of biofuel project have with third-party developers. Specifically, issues such as future percentage costs associated with acquiring a third party for their technology, expertise, and funding were included.

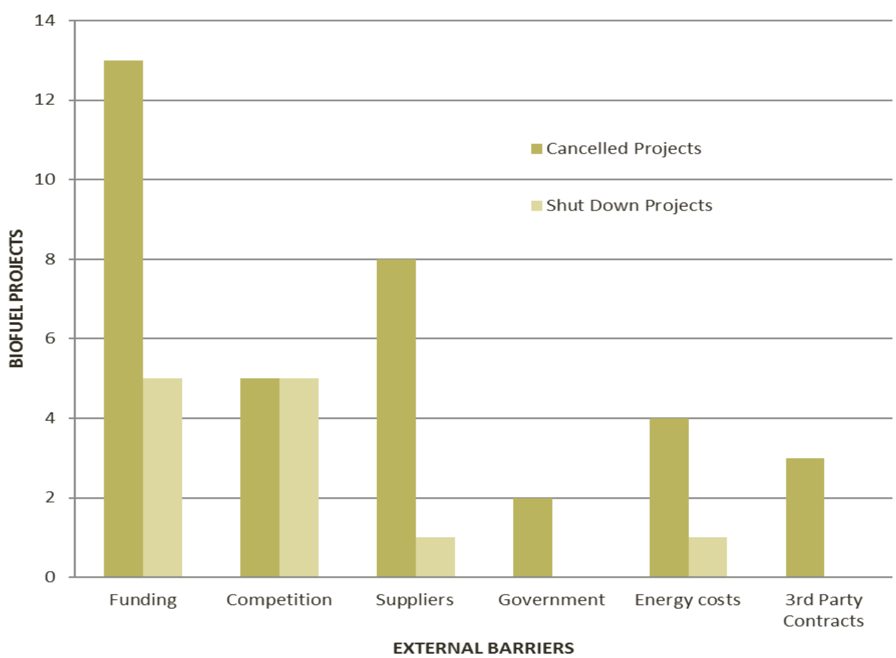


Figure 14 External factors affecting sustainability of cancelled and shut down projects

4.2.5 Comparison between Status and Type of Barriers

After extracting open-coded statements and classifying them as internal or external barriers and type of closing (cancelled or shutdown project), a contingency table analysis was conducted to test if the proportion of internal and external barriers were the same by type of closing (Table 7).

The Chi-Square test indicated no significant difference between the type of closing and the type of barrier (external or internal; p=0.0884). A contingency table analysis was not performed to explore relationships between the type of closing and specific barriers because some of the cells in the contingency table showed zero values.

Table 7 Contingency analysis to examine relationships between projects and barriers

Count, Column %, Row %	Cancelled projects	Shutdown projects	Count, Row %
External barriers	26, 41.27%, 78.79%	7, 70.00%, 21.21%	33, 45.21%
Internal barriers	37, 58.73%, 92.50%	3, 30.00%, 7.50%	40, 54.79%
Count, Column %	63, 86.30%	10, 13.70%	73, 100%

In addition, a multiple response analysis by type of closing was conducted to test if there are any differences in the response rates across type of closing (cancelled project or shutdown project). Each company that was cancelled or shutdown identified multiple barriers that led to failure; it is of interest to the research to test if the response rates on each type of closing are equal. To test for each response, it is assumed that the frequency count has a random Poisson distribution. The null hypothesis (response rates are the same across the type of closings) was tested using a Chi-Square test (Table 8). The most significant difference between cancelled projects and shutdown projects was found in the product development category; supplier, technology, competition, and third-party contracts were also significantly different. A significant difference means a positive result that the data is reliable with an existing relationship that may be relevant to this research. In this case, data results below .05 are considered to have a significant relationship in a category between the compared groups. No significant differences (with an alpha of 0.05) were found for the categories energy costs, funding, government, and strategy.

Table 8 Test of response rates by type of closing

Reason	Chi Square	Prob>Chi Square
Competition	6.93	0.0085*
Energy Costs	1.93	0.1650
Funding	3.68	0.0550
Government	2.77	0.0959
Product Development	13.86	0.0002*
Strategy	2.94	0.0863
Supplier	6.20	0.0013*
Technology	9.75	0.0018*
Third-Party Contracts	4.16	0.0414*
*Significant at an alpha level of 0.05		

4.2.6 **Analysis of factors based on surveys**

A survey (Appendix A) was specifically designed to determine respondents' opinions on barriers impeding the biofuel industry: demographic issues, financial, internal and external barriers, and coproducts and byproducts. Prior to sending the survey, it was determined from contacting initial respondents that it was too lengthy and time consuming. Fearing a low response rate, two primary questions were then chosen from the three most important sections of the survey, and the financial category was omitted. A final survey (Appendix B) of questions related to demographic, internal and external barriers, and coproducts and byproducts was chosen and sent with a cover letter to the participants in June 2015.

The survey received a 58% response rate. Eighty-four respondents were recorded in the shortened survey; 44 of those responses were deemed complete and viable. The distribution yielded an unbalanced sample of the population. The one biofuel publisher respondent was merged into the "others" category, and the academic respondents were merged into the "government" category. These merged categories helped provide anonymity to the responses. This resulted in three stakeholder categories (Table 9): government (N=11), others (N=16), and advanced biofuel projects (N=16). To ascertain more specific information, the previous barrier categories were expanded into 23 determined secondary categories (Table 10).

Table 9 Groups defined to secondary level analysis factors from survey

Stakeholders	Project type	Status	Technology
Academia/Government	Pilot	Open	Thermochemical
Industry	Demonstration	Closed	Biochemical
Others	Commercial	Planning	Hybrid

Table 10 Internal and external barriers

INTERNAL BARRIERS	
Primary Level	**Secondary Level**
Product development	Product development
Strategy	Byproducts marketing
Strategy	Byproducts distribution
Strategy	Coproducts marketing
Strategy	Coproducts distribution
Strategy	Continuous project growth
Strategy	Management
Strategy	Strategy
Technology	Technology conversion rate
Technology	Technology high titer and yield p/ton
EXTERNAL BARRIERS	
Competition	Competitors
Funding	Funding
Suppliers	Suppliers
Government	DOE pathway process
Government	EPA pathway process
Government	USDA pathway processes
Government	Production tax credits
Government	Renewable fuel policy standards
Government	Waiver credits
Government	Renewable volume obligation
Government	Renewable identification numbers
Energy costs	Energy costs
Third party relations	Third party relationships

Survey groups were asked to rank the barrier categories that have impeded the success of advanced biofuel projects on a 5-point Likert scale. The data were then separated by internal and external categories.

Respondents tended to agree on many of the internal barriers of agreement (Figure 15), including technology conversion rate (65%), technology high titer and yield per ton (63%), and strategy (41%). Heavy uncertainty was placed in continuous project growth. The categories of coproducts and byproducts distribution yielded fairly equal uncertainty and disagreement of being a barrier. The categories of coproducts and byproducts marketing, management, and product development yielded fairly equal distribution between disagreement, uncertainty, and agreement.

Table 44 in Appendix L shows mean, median, and mode from all groups' survey responses. The data were determined to be ordinal, and the scale values were not measurable on a continuous scale. Thus, examination was determined requiring use of median response only. The contingency tables median and quantiles were then examined from Appendix L, aggregated with Tables 44 and 45, shown in Table 11. Of note, strongly agree (5) and strongly disagree (1) were outside of the median measure of central tendency.

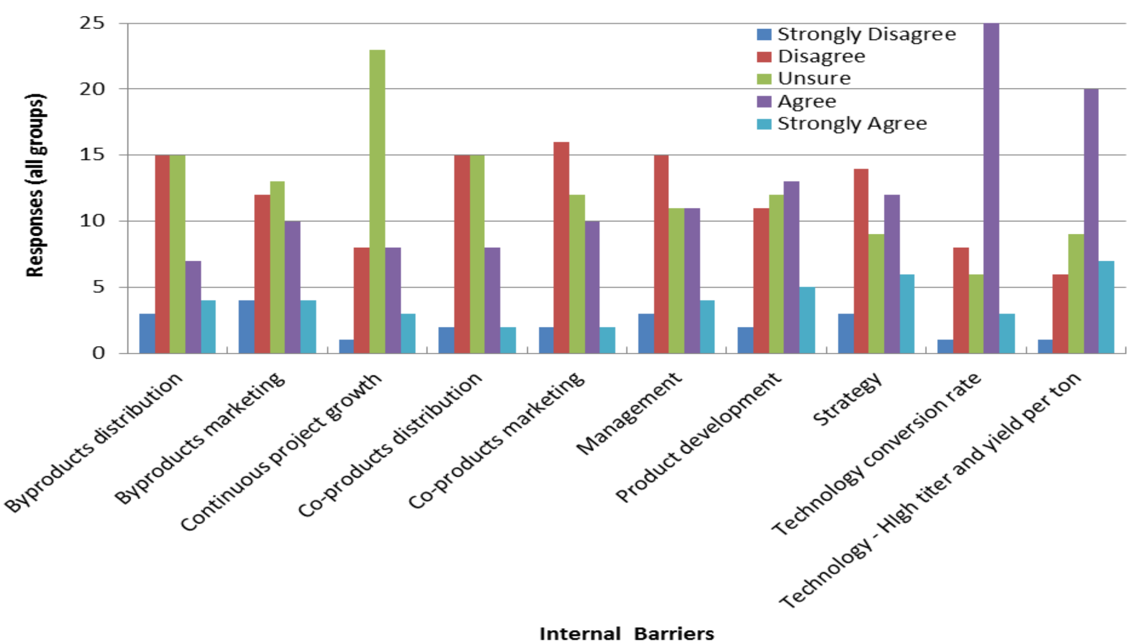


Figure 15 Survey responses to internal barriers

Table 11 Internal barriers; Median, Chi-Square, and Fisher's test

Reason: Internal Barriers	Biofuel	Government	Others	All Groups Combined	
	Median and (Quantiles 25%, 75%)			Pearson: P > ChiSquare	Fisher's Exact Two-sided Prob ≤ P
Product Development	3 (2, 4)	3 (2, 4)	3 (3, 4)	0.2351	0.2036
Byproducts Distribution	2 (2, 3)	3 (3, 4)	3 (2.25, 4)	0.3823	0.4186
Byproducts Marketing	2 (2, 3)	4 (2, 4)	3 (2, 3.75)	0.0886*	0.1101
Co-products Distribution	2 (2, 3)	3 (2, 4)	3 (2, 4)	0.2780	0.1720
Co-products Marketing	2 (2, 3)	3 (2, 4)	3 (2, 4)	0.7960	0.8063
Continuous Project Growth	3 (3, 4)	3 (2, 3)	3 (3, 3.75)	0.3924	0.4774
Management	2.5 (2, 3)	2 (2, 4)	3 (2.25, 4)	0.1694	0.2292
Strategy	2 (2, 4)	3 (2, 4)	3 (2, 4)	0.6891	0.7203
Technology Conversion Rate	3.5 (2, 4)	4 (2, 4)	4 (3.25, 4)	0.2334	0.1017
Technology High-Titer and Yield Per Ton	4 (2.25, 4)	4 (2, 4)	4 (3, 4.75)	0.3422	0.2968
*Significant at an alpha level of 0.1					

Results indicated that all groups tended to believe that technology conversion rate and technology high titer and yield per ton were significant barriers to advanced biofuel project success. Additionally, the government group believed that byproduct marketing is a significant barrier to project success, whereas advanced biofuel disagrees. However, the range in Table 11 would suggest some disagreement with the government's median response to this. Interestingly, uncertainty significantly increases moving up the internal scale: 20% uncertainty for biofuel, 50% for government, and 80% for others. This would suggest, that the further removed you are from projects trying to achieve economies of scale, the proprietary barrier-knowledge was less known. The government is heavily invested in financing biofuel projects, so their certainty would be less than the biofuel projects proprietary knowledge but more than the "others" category. Also of note, all groups are uncertain (3) on product development and continuous project growth; this directly relates with the RFS-blend wall issues and diminishing funding.

Further examination of individual Chi-Square and Fisher's p-value group data were examined at an alpha level of 0.1 individually by the 10 internal and 13 external barrier categories. First, a contingency analysis on the group ordinal data by the 10 secondary internal barrier categories was then conducted at 90% confidence; it was determined that byproducts marketing was the only internal category of significance (Table 11 and Appendix I). There was a dependent relationship between internal barriers and group type for byproduct marketing (p=0.0886, Table 11). A Fisher's exact test was then performed to verify accuracy and reliability, but no groups were noted as having a significant relationship depending on internal barriers. Therefore, at 90% confidence there was no relationship between government, others, and advanced biofuel based on response by the 10 internal barriers.

The groups also had similarities and differences in their views of external factors (Figure 16). Groups agreed that funding (91%), RFS (60%), and RVO (58%) were external barriers. Heavy uncertainty response was placed in DOE (42%), USDA (42%), EPA pathway processes (35%), waiver credits (42%), third-party relationships (40%), and suppliers (37%). The category of competitors (49%) yielded the highest level of disagreement as to whether it was a barrier.

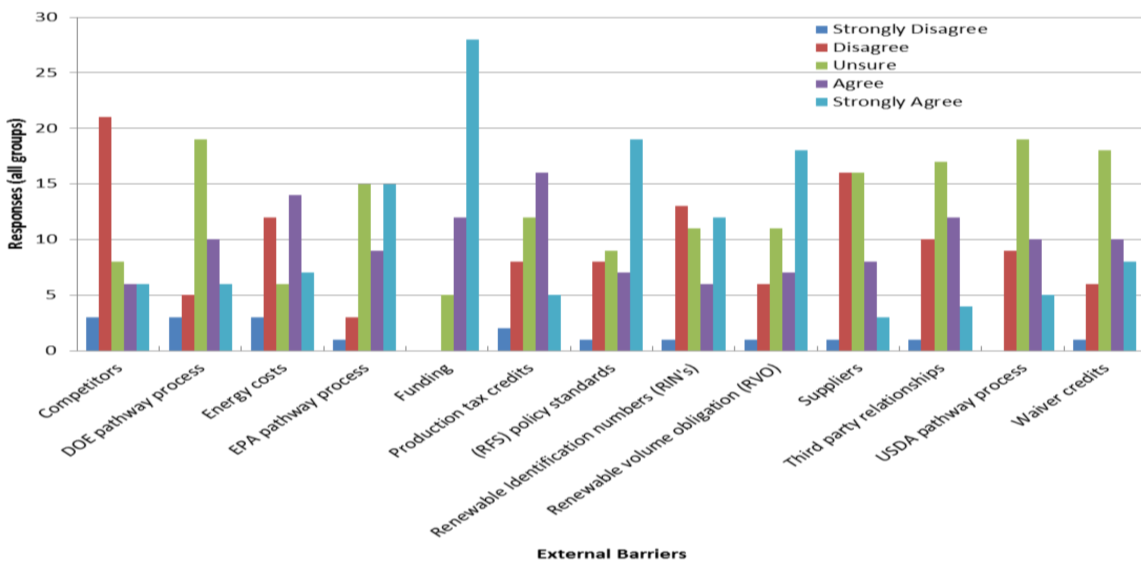


Figure 16 Survey responses to external barriers

Tables 44 and 45 in Appendix L show mean, median, and mode from all groups' survey responses. The contingency tables' external median and quantiles (Appendix J) were then aggregated with Tables 44 and 45, shown in Table 12. Of note, strongly disagree (1) was outside of the median measure of central tendency, 69% (9) biofuel, 23% (3) government, and 31% (4) others categories shared distribution of agree responses.

Table 12 External median and quantile response, by secondary level, and all groups

Reason: External Barriers	Biofuel	Government	Others	All Groups Combined	
	Median and (Quantiles 25%, 75%)			P > ChiSquare	Two-sided Prob ≤ P
Funding	5 (5, 5)	4 (4, 5)	4.5 (4, 5)	0.0858*	0.0676*
Suppliers	3 (2, 4)	3 (2, 4)	3 (2, 3)	0.5177	0.6844
Competitors	2 (2, 2.75)	3 (2, 5)	3 (2, 3.75)	0.0655*	0.1308
DOE Pathway Process	3.5 (3, 5)	3 (2, 3)	3 (3, 4)	0.1310	0.1599
EPA Pathway Process	4 (3.25, 5)	3 (3, 5)	3.5 (3, 5)	0.2202	0.1753
USDA Pathway Process	4 (2, 4)	3 (2, 3)	3 (3, 4)	0.0282*	0.0099*
Production Tax Credits	4 (2.25, 4)	3 (2, 4)	3 (3, 4)	0.6366	0.6131
RFS Policy Standards	4.5 (2, 5)	4 (3, 4)	4.5 (3, 5)	0.0222*	0.0198*
Waiver Credits	4 (3, 4)	3 (2, 3)	3 (3, 4.75)	0.0781*	0.0774*
Renewable Volume Obligations	5 (3.25, 5)	3 (2, 3)	3.5 (2.25, 4)	0.2627	0.2399
Renewable Identification Numbers	4 (2.25, 5)	2 (2, 3)	3 (2.25, 4)	0.2357	0.2659
Energy Costs	3 (2, 4)	4 (2, 5)	3 (2, 4)	0.4840	0.4830
Third Party Relationships	3 (2, 4)	3 (2, 4)	3 (3, 4)	0.2516	0.2027
*Significant at an alpha level of 0.1					

Results indicated that advanced biofuel tended to strongly agree that funding, RFS, and RVO were barriers to advanced biofuel project success, and lesser agreement that PTC, CWC, RINs, and pathway processes from EPA, DOE, and USDA are barriers. AB projects only disagree with competitors being a barrier and tended to have uncertainty with suppliers, energy costs, and third-party relationships. Government agreed that funding, RFS, and energy costs were barriers. The others category strongly agreed that funding and RFS were barriers, and lessor agreement that EPA and RVO were barriers. Uncertainty significantly increases moving up the external scale: 23% (3) uncertainty for biofuel, 69% (9) for government, and 69% (9) for others. Also of note, all groups are uncertain on suppliers and third-party relationships.

A contingency analysis on the group ordinal data was then conducted on 13 secondary external barrier (Table 12 and Appendix J). It was determined that funding (p=0.0858), competitors (p=0.0655), USDA pathway process (p=0.0282), RFS policy standards (p=0.0222), and waiver credits (0.0781) were the external categories of significance (Table 12). A Fisher's exact test was then performed on all categories; the Fisher's test determined that funding (p=0.0676), USDA pathway process (p=0.0099), RFS policy standards (0.0198), and waiver credits (p=0.0774) were significant external barriers.

4.3 **Advanced Biofuel Projects Individual Survey Responses**

The advanced biofuel industry was the focus of this research; therefore, further examination was conducted to explore their responses separately from other groups. They were independently asked to rank the internal and external categories that have impeded the success of many advanced biofuel projects on a 5-point Likert scale by all types, status, and technology.

4.3.1 **Internal Barriers**

The following internal distribution of Likert scale responses were recorded from 16 respondents (Figure 17). Participants generally agreed that internal barriers include technology yield per ton (56%) and technology conversion (50%). Heavy uncertainty was placed in continuous project growth (44%). Participants did not view the following categories as barriers: coproducts marketing (69%), coproducts distribution (56%), byproducts marketing (63%), byproducts distribution (63%), strategy (56%), management (50%), and product development (44%).

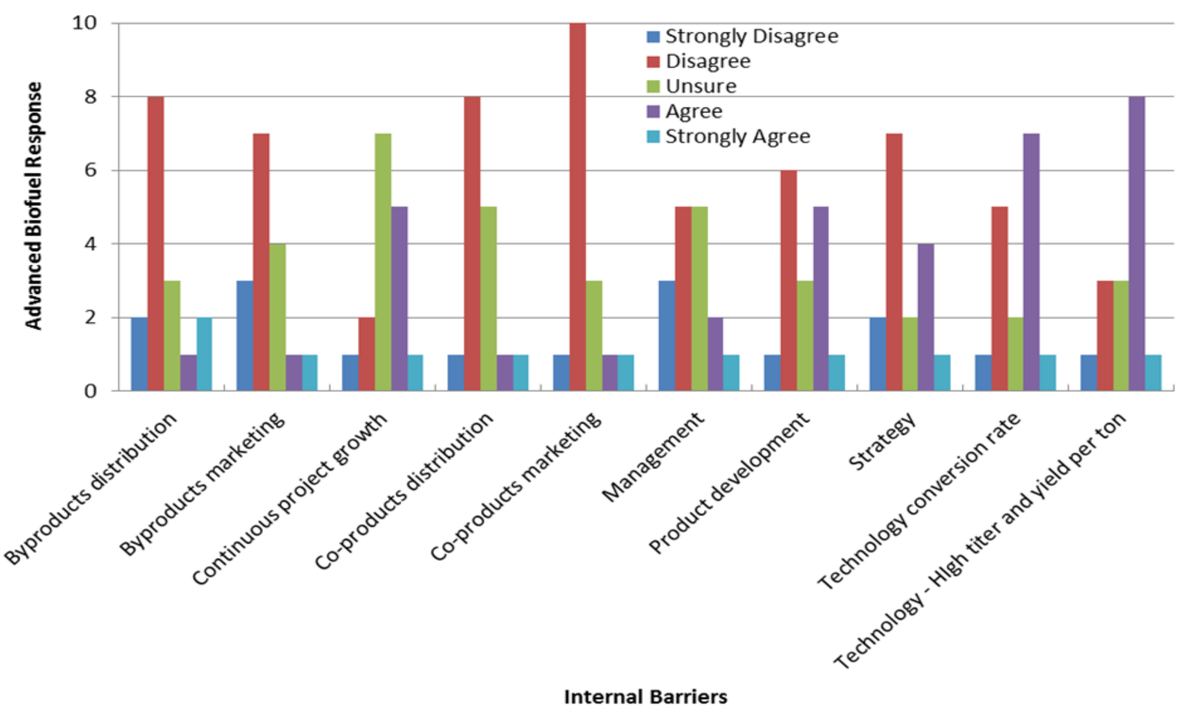


Figure 17 Advanced biofuel survey response to internal barriers

Median and quantiles were then examined (Appendix L). Internal median analysis (Table 13) showed that pilot was the only category without median disagreement responses. When examining by status and the technology group, biochemical differs significantly from hybrid and thermochemical responses. The results for status determined that commercial projects disagree that eight of the 10 internal factors are barriers to their success, while they are unsure about continuous project growth and technology yield per ton. Demonstration projects seem to have uncertainty or disagreement with the coproducts and byproducts categories, management, and strategy. Project growth and technology efficiencies were determined as barriers. Pilot projects were either uncertain or agreed that the factors were barriers to their projects, which was in direct contrast with commercial projects. Interestingly, uncertainty significantly decreases moving up the internal scale: 50% (5) pilot, 50% (5) demonstration, and 20% (2) commercial. Examining advanced biofuel projects by internal and status, closed projects agreed that continuous project growth and technology were barriers to their closing and management was not. Closed projects provided uncertainty across the remaining categories. Open projects agreed that product development, continuous project growth, and technology conversion and yield are barriers to their success. Byproducts and coproducts were stated as not being barriers. Open projects were uncertain with their management and strategy as being a barrier.

Table 13 Internal and external median quantiles by type, status, and technology

Median and (Quantiles 25%, 75%)	TYPE			STATUS			TECHNOLOGY		
INTERNAL BARRIERS	**Commercial**	**Demonstration**	**Pilot**	**Closed**	**Open**	**Planning**	**Biochemical**	**Hybrid**	**Thermochemical**
Product development	2	2.5	4	2.5	3.5	2.5	4	3	2
Byproducts marketing	2	2	3	2.5	2	2	4	3	2
Byproducts distribution	2	2.5	3	2.5	2	2	4	2	2
Co-products marketing	2	2	3	2.5	2	2	4	2	2
Co-products distribution	2	2.5	3	2.5	2.5	2	4	2	2
Continuous project growth	3	3.5	4	3.5	3.5	3	4.5	3	3
Management	2	2.5	3	2	2.5	2.5	2.5	3	2
Strategy	2	2.5	4	3	2.5	2	3.5	2	2
Technology conversion rate	2	3.5	4	4	3.5	2.5	4	2	4
Technology high titer and yield per ton	3	3.5	4	4	3.5	3.5	4	4	4
EXTERNAL BARRIERS	**Commercial**	**Demonstration**	**Pilot**	**Closed**	**Open**	**Planning**	**Biochemical**	**Hybrid**	**Thermochemical**
Competitors	2	3	3	2	2	2	4.5	1	2
Funding	5	5	5	5	5	5	5	5	5
Suppliers	2	2.5	4	2	3	2.5	4	3	2
DOE pathway process	3	4	4	4.5	3.5	3	4	3	4
EPA pathway process	4	5	4	3.5	4.5	4.5	5	4	4
USDA pathway processes	4	3.5	4	4	3.5	3.5	4	3	4
Production tax credits	4	4	4	3.5	4	3.5	4	4	4
Renewable fuel policy standards	3	5	4	3	4	5	5	2	5
Waiver credits	3	4	4	3.5	3.5	4	4.5	4	4
Renewable volume obligation	5	5	4	3.5	5	5	5	4	5
Renewable identification numbers	3	4.5	5	3.5	4	4	5	2	4
Energy costs	2	2	5	4	4	2	3.5	4	2
3rd party relationships	3	3	3	3.5	2.5	3	4	3	2

The results for internal and technology determined that biochemical projects agree that all internal categories, with the exception of management, are barriers to advanced biofuel projects. Biochemical projects contrast thermochemical projects on all categories except technology conversion and yield and continuous project growth. Hybrid projects disagree that technology conversion rate was a barrier, while biochemical and thermochemical agree it was a barrier. Hybrid and thermochemical mainly disagree or are unsure with byproducts marketing, and agree that coproducts and byproducts are barriers.

A more detailed examination of these data was then conducted by individual type, status, and technology. Additionally, the status category was condensed due to low cell values. The contingency category responses (Table 14) were determined to have no significant relationship depending on type or status. A Chi-Square test indicated there was an independent relationship between groups by type and status. A Fisher's exact test was then performed on these categories (Table 14); the Fisher's test determined accepting the null hypothesis of no difference.

Table 14 Advanced Biofuel: type, status, and technology internal contingency table

Secondary Categories						
INTERNAL	Type		Status		Technology	
Reason:	Pearson: P > ChiSquare	Fisher's Exact Two-sided Prob ≤ P	Pearson: P > ChiSquare	Fisher's Exact Two-sided Prob ≤ P	Pearson: P > ChiSquare	Fisher's Exact Two-sided Prob ≤ P
Product Development	0.506	0.735	0.797	0.940	0.104	0.168
Byproducts Distribution	0.624	0.458	0.734	0.924	0.207	0.074**
Byproducts Marketing	0.249	0.306	0.854	1.000	0.075**	0.109
Co-products Distribution	0.219	0.175	0.750	0.907	0.097**	0.145
Co-products Marketing	0.523	0.662	0.652	0.664	0.052**	0.028*
Continuous Project Growth	0.195	0.183	0.560	0.703	0.116	0.184
Management	0.642	0.848	0.652	0.864	0.734	0.919
Strategy	0.149	0.170	0.795	0.939	0.358	0.798
Technology Conversion Rate	0.423	0.643	0.714	0.911	0.081**	0.184
Technoogy High-Titer and Yield Per Ton	0.226	0.357	0.755	1.000	0.118	0.254
**Significant at an alpha level of 0.1						
*Significant at an alpha level of 0.5						

The technology group yielded a significant relationship for byproducts marketing, coproducts distribution, coproducts marketing, and technology conversion rate (Table 14). A Fisher's exact test was then performed on these categories; the Fisher's test determined that byproducts distribution (p=0.074) and coproducts marketing (p=0.028) were significant barriers.

4.3.2 **External Barriers**

The results were then examined for all external (type, status, and technology) responses (Figure 18). Advanced biofuel projects agreed that funding (100%), renewable volume obligation (75%), EPA pathway process (75%), and RFS and RINs (56%) were external barriers. Noticeable uncertainty was placed in DOE pathway process and waiver credits. The categories of competitors, energy costs, suppliers, and third-party relationships yielded fairly similar disagreement.

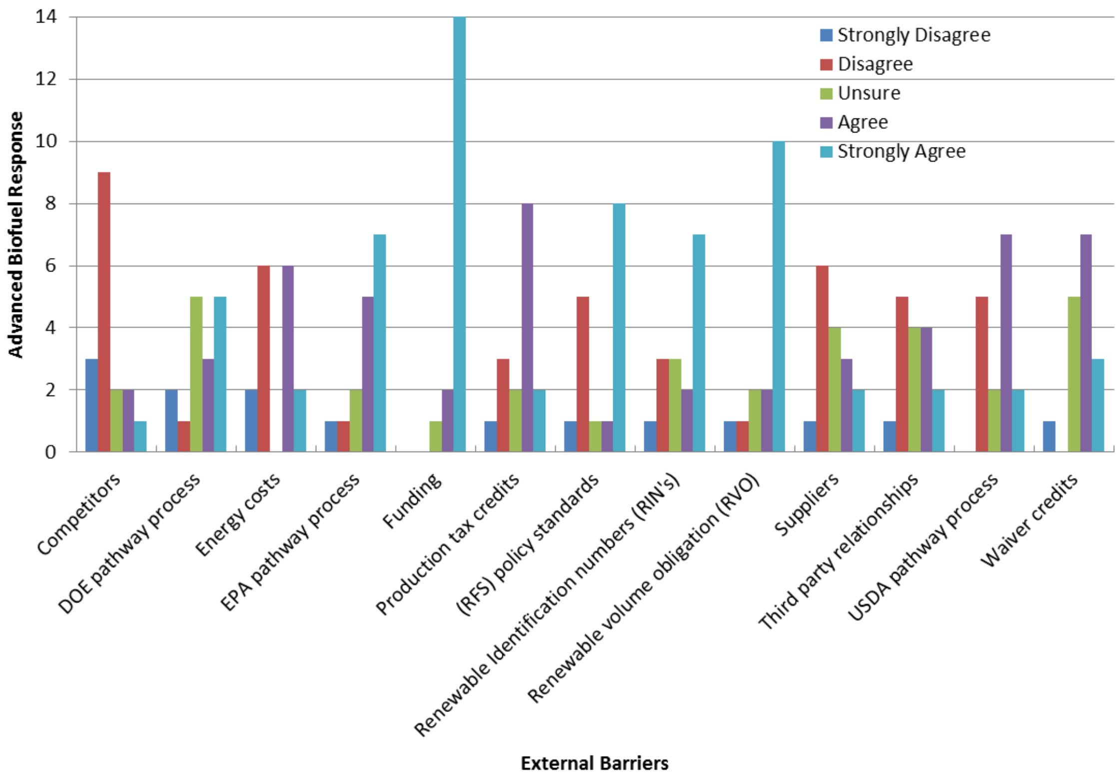


Figure 18 Advanced biofuel survey response to external barriers

External median and quantiles results (Table 13) were then examined. No major distribution differences of data for type or status was discernable. When examining by technology, the biochemical category agreed that the internal factors are barriers.

The results for type determined that commercial projects disagree that five of the 10 internal factors are barriers to their success: funding, EPA and USDA pathway processes, production tax credits, and RVO. They disagree with competitors, suppliers, and energy costs. Demonstration projects disagreed only with energy costs, and uncertainty only with competitors, suppliers, and third party relationships. Pilot projects provided that all categories except the uncertainty with competitors and third-party relationships were barriers. The three type categories provided the same agreement responses for DOE, USDA and EPA pathway processes, funding, production tax credits, and RVO. Finally, all were uncertain with third-party relationships.

The results for biofuel status determined that the barriers that affected closed projects were funding, DOE, USDA and EPA pathway processes, waiver credits, RVO, RINs, energy costs, and third-party relationships. They disagreed with competitors and suppliers being barriers, and were uncertain with RFS. Open projects of all statuses disagreed that competitors were a barrier. Additionally, all statuses agreed that DOE, EPA and USDA pathway processes, funding, PTC, waiver credits, RVO, and RINs were barriers to advanced biofuel projects. Interestingly, open and closed projects are both affected by energy costs, but those in planning disagree that it was a barrier for them.

The results for biofuel technology indicate all external factors are barriers to biochemical projects. Biochemical and thermochemical differ on competitors, suppliers, energy costs, and third party relationships. All technology types agree that EPA pathway process, PTC, waiver credits, and RVO are barriers to their projects. Hybrid projects disagree that competitors, RFS, and RINs are barriers to their projects. Hybrid and thermochemical projects disagreed that competitors was a barrier; however, biochemical and hybrid agree that Energy was a barrier.

A contingency analysis was performed on advanced biofuel type, status, and technology ordinal data by secondary external barrier categories to determine if there was any dependence between the proportions of internal barrier category responses (Table 15). No advanced biofuel projects were noted as having a significant relationship depending on status. Using a Chi-Square test with a determined p-value (above alpha) > alpha of 0.1, indicated there was an independent relationship between advanced biofuel and status. A Fisher's exact test was then performed on these categories (Table 15). The Fisher's test determined accepting the null probability ≤ P (above alpha 0.1) was viable for independence of response for these internal barriers by status.

Table 15 Advanced biofuel external contingency: type, status, and technology

Secondary Categories						
EXTERNAL	**Type**		**Status**		**Technology**	
Reason:	**Pearson: P > ChiSquare**	**Fisher's Exact Two-sided Prob ≤ P**	**Pearson: P > ChiSquare**	**Fisher's Exact Two-sided Prob ≤ P**	**Pearson: P > ChiSquare**	**Fisher's Exact Two-sided Prob ≤ P**
Funding	0.411	0.400	0.827	1.000	0.411	0.625
Suppliers	0.573	0.614	0.298	0.742	0.323	0.284
Competitors	0.025*	0.050*	0.826	1.000	0.005*	0.001*
DOE Pathway Process	0.332	0.589	0.460	0.539	0.282	0.272
EPA Pathway Process	0.823	0.916	0.427	0.460	0.345	0.452
USDA Pathway Process	0.636	0.583	0.517	0.833	0.209	0.217
Production Tax Credits	0.680	0.712	0.478	0.637	0.140	0.093**
RFS Policy Standards	0.572	0.857	0.164	0.253	0.444	0.546
Waiver Credits	0.269	0.261	0.241	0.359	0.411	0.469
Renewable Volume Obligations	0.642	0.851	0.234	0.146	0.127	0.056*
Renewable Identification Numbers	0.723	0.879	0.305	0.363	0.292	0.421
Energy Costs	0.040*	0.095**	0.273	0.461	0.074**	0.043*
Third Party Relationships	0.335	0.371	0.866	0.976	0.081**	0.016*
**Significant at an alpha level of 0.1						
*Significant at an alpha level of 0.5						

Advanced biofuel projects were noted as having a significant relationship depending on external barriers by type. Using a Chi-Square test with a determined p-value (0.025, 0.040) > alpha of 0.1, indicated there was an independent relationship between advanced biofuel by type. A Fisher's exact test was then performed on these categories (Table 15); the Fisher's test determined rejecting the null probability ≤ P (0.050, 0.095) at an alpha level of 0.1 was viable for dependence of response for these internal barriers by type. Additionally, there was a dependent relationship between advanced biofuel and technology by competitors (p=0.005), energy costs (p=0.074), and third-party contracts (p=0.081). A Fisher's exact test determined that competitors (p=0.001), tax credits (p=0.093), RVOs (p=0.056), energy costs (p=0.043), and third-party contracts (p=0.016) were significant barriers. The most significant difference across the three advanced biofuel types (biochemical, thermochemical, and hybrid) was competitors. This was indicative of one open commercial hybrid project and two commercial hybrid projects in planning that strongly disagreed that competitors are a barrier, with the remaining commercial projects not agreeing this was a barrier.

4.3.3 **Interview Results**

The survey responses provided differing opinions across survey groups; interviews were then conducted to clarify understanding of the opinions and barriers with the advanced biofuel advocacy groups and bioeconomy. Discussion results with the advanced biofuel groups match the survey barrier results and are directly in line with the current climate of uncertainty in the industry.

With the Renewable Fuel Standard (RFS), the blend wall created barriers in the political landscape, fossil fuel interests, and advanced biofuel. Organizations have been initiated to aid industry certainty across the RFS issues in Washington D.C. These groups have different agendas but a similar cause: unify the renewable fuels industry under the bioeconomy banner in spite of growing uncertainties. The government is very clearly divided on RFS between Republicans and Democrats, with Republicans less inclined to make RFS changes or increasing the E10 blend amount in 2015 or 2016.

This is currently a unique market situation for biofuels and strengthening the RFS. However, many biofuel companies are currently in litigation over different aspects of the RFS. The main results from the interviews and stakeholder presentations are listed below (quotes are listed in Appendix K):

1) RFS repeal does not have congressional support, Republican house and Senate will result in negative RFS changes, funding, project debt, lack of certainty in government programs, RVO uncertainty, renewal of tax incentives, CWC uncertainty, reduced project equity due to stalled offtake agreements due to perceptual risks. Mark Reidy, ACOR founder
2) RFS is working, EPA- RVO compliance is needed and should become an administrative function, certainty of minimum RIN value needed and indexed at the fluctuating price of oil, trying to compete with fossil fuel on an unlevel playing field, fossil ability to buy CWCs, EMTS numbers should be used and with February start dates instead of November. Jo Jobe, CEO, NBB

3) Inverse relationship between policy and uncertainty with project investment, EPA failure to consistently set RVO requirements. RFS Uncertainty, fluctuating fossil oil prices, ROI required in 7 years, lack of market, OP purchasing CWCs instead of fuel, the EMTS system actual production numbers should be used to reduce difficulty in setting the RVO numbers yearly. Mike McAdams – President of ABFA
4) EPA is where the focus needs to be placed to get the RFS back on track. RINs may not be needed past 2022 due to their uncertainty. Brooke Coleman, ED, ABBC
5) Reforming the RFS is too risky currently, with the close vote count not in advanced biofuels favor. Brent Erikson, EVP, BIO.

The fundamental agreements between the groups are CWCs and the EPA stalling needs to be improved to create certainty. The fundamental disagreements are an administrative fix of the RFS versus statutory change.

4.4 Byproducts and Coproducts

Survey question: In your opinion, what are the main and secondary barriers currently impeding the marketability and distribution of U.S. biofuel projects byproducts and coproducts produced from advanced biofuel projects?

Twenty-eight of 44 survey respondents provided usable data to this question, identifying barriers to coproduct marketability (N=27) and distribution (N=28), as well as byproduct marketability (N=28) and distribution (N=22; Table 16). Cost, financing, and public awareness were the main barriers across the four classifications. There are many similarities of response between the four categories of coproducts and byproducts marketability and distribution barriers, such as infrastructure, fossil industry control, public perception, and policy. Some responses are very similar to the 23 barrier categories sent out in the survey; however, many are unique to this research, such as sole source risk, heated rail car shortage, and flooding a niche market. The literature review byproducts and coproducts table was updated to add many new chemicals currently targeted with the advanced biofuel projects shift to develop platform technologies (Table 17).

Table 16 Byproducts and coproducts Marketability and Distribution survey results

Co-products Marketability		Co-products Distribution	
Main Barrier	**Secondary barrier**	**Main Barrier**	**Secondary barrier**
Bio integrity of supply chain	Access to capital	Competition and distribution restriction	Access to capital
Consumer awareness of larger societal benefits	Available Volume	Cost	Available Volume
Cost	Lack of benefit to producers	Financial Support	Competition
Finding high credit-worthy 3rd party for offtake	Limited market and competition from non renewable sources	Flooding a niche market	Consumer demand
GMO	Not being focused	Gmo isolation	Controlled by oil companies
Government Uncertainty	Obligated Parties	Government Uncertainty	Misinformation about the need for the industry as a whole
I did not know that enough co-products produced to be impeded	Perception of cost and efficacy	Immature supply chain infrastructure	Obligated parties
Lack of clear end user demand	Poor policy	Lack of clear end user demand	Product purity
Lack of incentives	Public ignorance	Limited volume	Requires heated tankers or rail cars for shipment
Low identified uses	Quality	Market fragmenttion	Small markets
Oversupply	Separation of water	No infrastructure	Market fragmentation
Process economics	Sole source risk	Oil industry	
Public Awareness		Poor policy	
Public perception		Requires additional fractionaction - no local fractionators	
Quality of F-T wax for use as wax		Scale match for bio integrity of chemicals	
Specifications		Unavailability	
Technology		Unclear markets breeds unclear distribution channels	

Byproducts Marketability		Byproducts Distribution	
Main Barrier	**Secondary barrier**	**Main Barrier**	**Secondary barrier**
Cost	Condtioning and transportation to markets	Controlled by oil companies	Consumer demand
Financing	Controlled by oil companies	Cost	Lack of Balance Sheets
GMO		Financing	Lack of benefit to producers
High value product development	Distance to market	Flooding a niche market	Lack of product knowledge by customers
I did not know that there were enough usable byproducts produced to be impeded	Investment	GMO isolation	Lack of true public education
Lack of awareness among public	Lack of Balance Sheets	Lack of awareness among public	Low Volume
Lack of clear end user demand	Lack of benefit to producers	Logistics	Unfamiarity
Lack of incentives	Limited Markets	Market demand	
Low identified uses	No perceived need	Marketing	
Low value wood ash	Not being focused	No infrastructure	
Low Volume	Poor policy	No local markets for ash	
No infrastructure		Oil industry	
Oversupply		Production technology	
Price		Transport cost	
Quality		Unclear markets breeds unclear distribution channels	
Specifications			
Technology			
Value proposition			

Table 17 Byproducts and coproducts survey results

Product	Source	Process	Market	Examples of Producing companies
Gases and Fuels				
Syngas	Biomass of lignin	Gasification	Production of ethanol, methanol, dimethyl ether, olefins, propanol and butanol (Patton 2010; Petrus and Noordermeer 2006; Stewart 2008; Buaban et al. 2010	
Hydrogen	lignin	Gasification	Fuel cells, industrial uses (Patton 2010)	
Carbon Dioxide	Sugars	Fermentation	Industrial uses, beverage, dry ice (Patton 2010)	Lanza Tech
Carbon Monoxide				Lanza Tech
Synthetic gasoline and diesel		Thermochemical / Hybrid	Liquid fuels	Joule, Sundrop, Envergent, Abengoa, Fiberight, Ensyn
Jet fuel		biochemical / Thermochemical / Hybrid		Envergnet, Frontline, GEVO, Fulcrum, Byogy, Vertimass, Virent, Lanza Tech
Methane		biochemical		Enerkem, Intrexon, Calysta, Siluria, Oberon, Kiverdi, Mango materials, Industrial microbes
Lignin	lignin	Hydrolysis	color additive, reinforcing filler, animal feedm, yeast production (Patton 2010; Singh et al. 2010; Vivekanandhan et al 2013	Renmatix
Naptha		Distillation	Fuel source solvent	Joule
Organic acids				
Succininc acid	Gluclose	Fermentation in high CO2	Food additive, plasticsm surfactants, detergents, solvents, textiles, and pharmaceuticals (Soderholm and Lundmark 2009)	Myriant, Riverdia, BioAmber, Novozymes, DSM
lactic acid polylatic acid	Gluclose	Fermentation	Food and beverages, textiles (Patton 2010)	Invista, Plaxica, Lanza Tech, IOC, Nature Works, Calysta, Direvo, Purac, Leaf Technologies, Myriant,
Acetic acid	Gluclose	Fermentation	Food additive and industrial chemicals, resins, and alcohols (Patton 2010)	Zeachem, American Process
Fumaric acid	Gluclose	Fermentation	Food additive, production of resins and alcohols (Patton 2010)	Novozymes, Myriant,
Oleic acid				
Acrylic acid				Myriant
Adipic acid				Renovia, verdezyne
Levulinic acid				GFB biochemical, mercurious
Alcohols				
n-buterol	Gluclose	Fermentation	Liquid fuel, food additive, solvent (Patton 2010)	
Xylitol	Xylose	Hydrogenation	Sweetner (Patton 2010)	ZuChem, Xylitol, Taurus
Sorbitol				joule
Arabinitol				
Product	**Source**	**Process**	**Market**	
Aromatic compounds				
Xylose, Arabinose		Deydration	Solvent, pesticides, resins, liquid fuel(Patton 2010)	Taurus, Dupont
Benzene, Toluene, Xylene	lignin	catalysis	Solvents, pesticides, resins, liquid fuel (Patton 2010)	Virent, GEVO, Avantium
Olefins		Pyrolysis	Production of polyethylene (Patton 2010)	SABIC, Byogy, INEOS
Biobenzene		catalytic	detergents, construction materials, and paints and coatings, (Virent 2015)	Virent, Anellotech's
Macromolecules				
Cellulose nanofibers	Cellulose	Chemical-mech treatment	Structural composites, plastics, films (Patton 2010)	
Polyhyroxyalkanoate	Lignin	Fermentation	Biodegradable plastic use in films, packaging, fibers, coatings, foams, and medical (Patton 2010)	
Lignosulfates	lignin	Sulfonation	Dispersants, emulsifers, binders, sequestrants, adhesives, fillers, dust prevention (Patton 2010)	
Carbon Fiber	lignin	Melt spinning	Reinforcement for automotive plastics (Patton 2010)	BETO
High purity Lignin	lignin		Coatings, emulsifiers, gels, anti-microbial products (Patton 2010)	

Table 17 continued:

Other products				
Cellulose nanofibers	Cellulose	Hydrolysis	Animal feed (Patton 2010)	
Protein	Protein		Animal feed (Patton 2010)	Cargill, Calysta, Valicor
Biochar	lignin	Combustion	Fuel, soil additive and carbon sequestration (Patton 2010)	Cool planet, Mercurious
Betulinol	Forest residues		Antioxidant (Soderholm and Lundmark 2009)	
Propanediol (PDO)	sugars	Fermentation	polyurethanes, solar thermal, unsaturated polyester resins, (Dupont 2015)	Dupont, Joule
Butanediol, Biobutadiene	Dextrose or Sucrose	Fermentation	Plastics, solvents, electronic chemicals, and elastic fibers (Genomatica 2015)	Joule, Myriant, Genomatica
N butanol:	Sugars	Fermentation	solvents, glycol ethers, acetate, acrylate (Green Biologics 2015)	Green Biologics, Dupont, GEVO
Polyethylene terephthalate (PET)	isobutanol	biochemical	Films and bottles for packaging, fibers for non-wovens, textiles, automotive resin.	Anellotech's, GEVO, Joule
Farnesene	plant sugars	Fermentation	Solvents, Emollients, Vitamins (Amris 2015)	Amyris, Intrexon, Chromatin
Polyamides	syngas	Fermentation	precurser for specialty plastics (Lanza Tech 2015)	Arkema, Avantium, Genomatica, Dupont, Terryl
5c and 6c sugars				GeoSyn fuels, Sweetwater Energy, Kakira, San Martinho, Cascades, Buriram, Applied Biorefinery
Omega 3's and 7's				Solarvest, Nature Works, Lanza Tech, IOC, Calysta, KD-Pharma, BioProcess Algae, Cellana
Waxes				
Furfural	Pentose and hexoses	Hydrolysis	Food additive in vanilla, resins (Larsson et al. 1998 Goncalves et al. 2013	Chempolis, Dupont, Glucan Biorenewables, Mercurious
Suberin	Forest residues		Fatty acid (Soderholm and Lundmark 2009)	

The advanced biofuels marketplace economics are based on adapting to change in a price-competitive renewable identification number (RIN) and cellulosic waiver credit (CWC) environment, while Renewable Fuel Standard (RFS) policies are drowning in politics and lawsuits. Interestingly, many of the wood and grass advanced biofuel projects were started just after the 2007 EISA, when oil prices were similar to where they are today, around $30.00 a barrel. The marketplace barriers start with CWCs as a barrier. The Environmental Protection Agency (EPA) mandates the renewable volume obligation (RVO) for each year to meet 10% of the U.S. drop-in biofuels into the fossil fuel supply (Figure 19). The CWCs were designed as a method to help RVO parties, such as cellulosic that could not meet the RFS mandate. With many cellulosic companies struggling to meet economies of scale, CWCs were a cheaper alternative to surviving through the Valley of Death. However, fossil companies could also purchase them instead of buying the cellulosic fuel products.

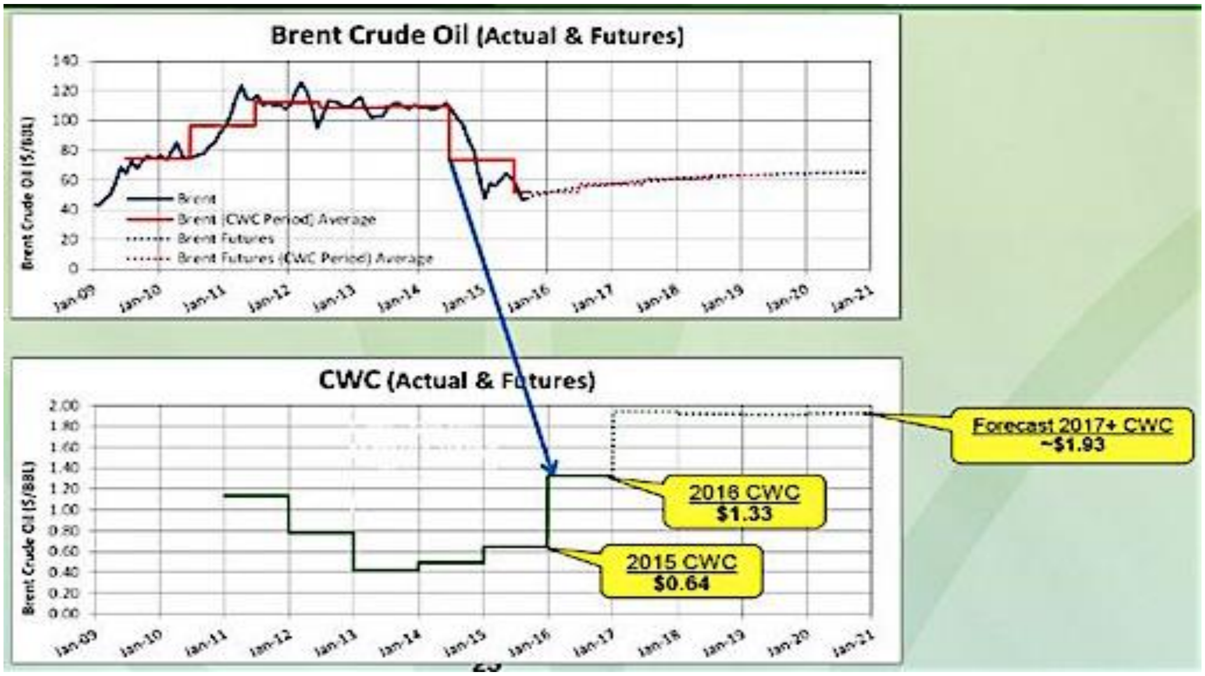


Figure 19 CWC versus oil price. **(**Foody, 2016)

4.4.1 **Distribution Barriers**

The distribution channel is full at the blend wall, stymied for biofuels, with some room for growth for diesel and aviation drop-in fuels. Many of the surviving alternative fuel companies are pushing their products upstream after meeting their mandate, with little reception. Excess ethanol has some market distribution channel outside of the U.S., but biodiesel currently does not. Biodiesel is shipped to Canada, but they cyclically ship the same amount back (Steockyl 2016).

To improve the distribution channels Steockyl (2016) suggested eliminating the blender tax credits (BTC) in favor of a producer tax credit (PTC) for U.S. refiners only. PTC was one of the determined barriers to biofuels projects. Distribution sustainability for biofuel projects was generally better at the commercial level. As stated by Feehery (2016): “It is better to go with larger scale economics because of scale in feedstock collection,” and by Cellana (2016) “Sustainability, requires making money at large scale.” If the goal of the biofuel projects is moving toward total collaboration, consumers may recognize and start paying a premium for sustainability. For corn and wood biofuel, large-scale production is needed; grass and municipal waste application may require smaller applications as they develop. Distribution of feedstock to facilities is generally conducted via truck in rural areas. The logistics barrier raises costs due to bulk density for natural resources (trees, stalks, grass, municipal solid waste). The conversion cost across companies may be as high as 50% of final product cost. The distribution exiting the plant is less of a cost barrier, since the product density has been converted to completely fill a volumetric shipping method (rail, truck, marine).

Rail cars are less expensive than trucking, but rural railroads are in decline and may also be a barrier to incoming and outgoing distribution. Additionally, heated rail cars are in limited supply and are more costly for projects shipping organic acids (e.g., acetic acid) and other coproducts that may have different freezing points. The rail cars are typically stem heated and must be steam cleaned when emptied, further increasing costs.

Batch distribution may become a barrier for projects, such as when diesel producers buy in batches and then try to turn multiple batches into a homogenous product. Time is required to test each batch before and after blending, increasing costs.

"To currently finance a plant you cannot count on sales from byproducts distribution," according to Foody (2016). Most plants are currently burning lignin as an energy source to generate power and have not fully explored other options of selling lignin as filler instead of burning. Successful byproduct sales seem to currently be co-location based for alternate usage from burning, such as Cool Planet blending their waste for value-added soil blending products.

CHAPTER 5. Discussion

5.1 Spatial Analysis

Spatial analysis determined 59 U.S. wood and grass advanced biofuel projects with the majority failing to advance, of which 82% are in the determined Eastern region and in forested areas. A cluster was present in Mississippi, including Blue Fire Renewables (1 commercial (C)), Enerkem (1 C), KIOR (3 C), Raven Biofuels (1 C), and Virdia (4 C and 1 demonstration). This cluster consisted of one demonstration project and mostly commercial projects with some in planning. Most of these projects were developed elsewhere and then were drawn to the Gulf Opportunity Zone (GO Zone) impressive incentives, vast forest supply, and many distribution channels. Despite utilizing GO Zone incentives, KIOR cancelled all MS interests due to technology issues and funding, Virdia was purchased for its technology patents from a foreign company, and Raven biofuels stock was devalued due to financial issues and unable to move forward. In spite of the abundant forest resources and economic incentives in Mississippi, the projects there were not more successful than in other locations; factors other than location appear to be influencing the success or failure of advanced biofuel projects.

5.2 Internal Barriers for Closed Projects

Technology barriers seem to be the common denominator for many of the projects that have been cancelled or shutdown. For example, New Page Paper's president and CEO Rick Willet in 2009 suggested that for continuation of their biofuel project, improvements were needed for the costs of installation of the Chemrec process and substantial investment to modify existing operations. Also, many of the biofuel projects were designed as a secondary business for paper mills. However, converted paper mills were not competitive against companies equipped with more modern and cost-efficient machinery (Austin 2008). Rising energy costs and foreign competition continue to hit the industry hard, and the potential of firms creating their own biofuel to feed their process or to commercialize has not been feasible or successful.

Product and development issues were found to be another reason why so many projects have been cancelled or shut down. In some cases, paper companies heavily invested in promised alternative energy breakthroughs that were still not ready for producing commercial biofuel when EISA 2007 was implemented. This was the case of Cello Energy (Kirby 2011, Lane 2011) and Parsons and Whittemore Enterprises. Similarly, Range Fuels started in 2007 and had fallen behind in production goals by 2009, only producing a wood alcohol fuel used in racing and industrial applications. The facility experienced technical problems with gasification and the system for feeding in biomass, never producing biofuel from biomass. Range Fuels closed their plant in January 2010 and filed for bankruptcy in September 2011 (Parker 2011, Investors Hub 2011).

The third internal reason for cancelling or shutting down biofuel projects was strategy issues. An example of strategic or criteria change was found with the case of Coskata, a biorefinery that was planned to be installed in Boligee, Alabama (GCD 2012). In 2012, the management decided to shut down the project due to the need for a different site with greater utilities infrastructure. Kior faced a similar situation; their plans to build five biorefinery sites in the Mississippi GO Zone changed when they decided to explore alternative locations (Mendell and Lang 2013, Hogan 2012). Another example was Rentech facility in Commerce City, Colorado, where the company decided to cancel its biofuel project to focus on nearer-term profitable growth opportunities, as it did not expect the market opportunity for alternative energy to improve materially in the U.S. within the next several years (Lane 2013c, Rentech Inc. 2013).

5.3 External barriers for Closed Projects

Out of the six primary external barriers to successful commercialization of advanced biofuel projects, funding issues were identified as the most significant barrier. An example of this barrier was Flambeau River Biofuel's situation, where a matching grant through the Department of Energy (DOE) required the company to increase equity of cost matching from 20% to 50%, and management determined to utilize lower risk ventures (Brochu, 2010). In a similar example, the Rentech Rialto project withdrew its DOE funding request due to loan guarantees from the DOE (Investors Hub 2011). This company stopped the project because it was believed that the Rialto project was not economically feasible under the current terms of the negotiation with the DOE (Kirby 2011, Businesswire 2010). Raven Biofuel and Gulf Coast Energy were also cancelled due to funding issues, specifically unfavorable project economics and insufficient financing (Mendell and Lang 2013). Funding is moving toward debt management as companies mature (Reidy

2016). The projects that are continuing forward have switched to platform technologies to produce more value-added chemicals with increased market certainty to receive funding. Funding is now associated with higher perceived risk of advanced biofuel companies struggling with low to no coproducts. Improved infrastructure is needed to drive growth in funding biofuel investment, such as Flex Fuel vehicles, increased octane content, and increased market share of coproducts.

In addition, the rising transportation cost for feedstocks to the production site created supplier issues. One of the biggest challenges of any new project in the path to independent energy is the managing of transportation costs (Siemers 2013). This continues to be important, even though prices of feedstock have dropped in some locations due to competitors closing operations (Mies 2013, Lane 2012). The Coskata biorefinery project in Boligee, Alabama also attributed its failure to the increased presence of natural gas in the market, which affected costs (Lane 2012). The New Page paper company indicated the effects of low-priced imported products as one of the reasons the company had to shut down its biofuel project (Austin 2008). Feedstock supply is abundantly available where projects are located, but prices may fluctuate with economic factors. A small change in price could exacerbate financial challenges caused by reduction in private investment.

Five of the cancelled or shutdown projects indicated energy cost issues prevented the projects from producing biofuel with acceptable production costs (Austin 2008, Siemers 2010). Electricity and fuel costs have increased considerably over the last five years. Energy costs are directly related to conversion and transfer due to the scale of the facilities. Wood biofuel commercial facilities are larger, requiring more investment than oil and natural gas commercial facilities. The majority of projects burn their lignin to reduce energy and disposal costs. For example, it is more cost effective for Iogen currently to burn their lignin byproduct to produce energy.

Government issues, including regulations and the lack of government incentives and support for alternative energy, have also contributed to the cancellation or shutting down of some biofuel projects (Lane 2013d, Rentech Inc. 2013, Fielding 2010). Third-party relations were also important, as some of the projects have developed partnerships with other companies to have access to patents, proprietary technology, distribution channels, or even feedstocks. However, in some cases the partnership has not worked out, ending up in litigation to solve the issues (Kirby 2011, Lane 2013d).

5.4 Advanced Biofuel Type, Status, and Technology

The technology category identified byproducts and coproducts, marketing and distribution, and technology conversion rate as barriers by type of technology. Technology conversion rate was less of a barrier for thermochemical projects. This may be due to fewer steps to thermochemically convert lignocellulose, compared to biochemical catalyst and enzyme lifespan issues in converting lignocellulose. Competitors were a barrier in pilot, demonstration, and commercial phases with biochemical and hybrid. Energy costs were not a barrier for pilot plants. That is logical at the small scale, where conversion and product development was the focus. Finally, third-party contracts were barriers for hybrid projects; this matches statements by Mike McAdams that 7-year return on investment was not enough time to establish a profitable facility and manage debt equity.

5.5 Advanced Biofuel Coproducts and Byproducts

By reviewing the literature, it was determined that there were 24 coproducts and byproducts produced from advanced biofuel projects. Many of initial biofuel projects were not focused on these secondary products, but instead focused on more pressing technology and funding issues. Forty-two percent of all projects are pilot and demonstration plants designed for testing purposes, with reduced focus on secondary outputs. The commercial facilities are realizing the value of their coproducts and are re-strategizing. For example, Virent Biogasoline, a commercial biofuel company impacted by the blend wall, changed its website to list available quantities of various coproducts they produce. Discussing survey results with the industry indicated there are at least 44 coproducts produced, nearly twice the number identified from the literature. This increase was based on companies currently stymied by blend-wall limitations that reduce demand to fund production economies of scale. These limitations drive stakeholders to consider new markets beyond biofuel to meet shareholder financial expectations. Advanced biofuel companies are currently focused on shifting to platform technologies, targeting higher value coproducts and the available funding arena (Berven,2016 and Reidy 2016).

A review of the literature did not discern any lists of barriers to the marketability and distribution of coproducts and byproducts. However, through the survey and interviews in this study, an extensive list of barriers was developed, including 27 coproducts marketability and 28 coproducts distribution barriers, and 28 byproducts marketability and 22 byproducts distribution barriers. The main barriers were cost, funding, fossil industry control of market, and public awareness.

The perceived need of coproduct and byproduct infrastructure to support the already subsidized industry was not expected. Nor did the industry expect to be stymied by the blend wall, the fossil fuel industry buying CWCs and lobbying against them, politics, or a slowly developing infrastructure. It would seem the advanced biofuel industry initially did not examine the end-user market demand and capabilities for additional byproducts and coproducts. The survey results indicated that byproduct and coproducts infrastructure was a niche market and saturated in the short term, since the industry was already shifting toward platform technologies. According to ABLC (2016), there was a 9% growth in premium renewable biochemicals in 2015, which implies that the shift to platform technology would potentially become a barrier, as well, in a niche market. Berven (2016) stated the industry is moving to produce and sell premium products. Selling premium products would imply the niche market barrier may only affect those in competition with advanced biofuels that already produce nonrenewable premium chemicals, such as the fossil fuel industry. The shift in this industry to compete at a multi-product platform level other than biofuel in new markets was an attempt to avoid sole source risk and maximize byproducts potential and funding.

Rural economic development was one of the three primary objectives established by the government. The survey results indicated that some projects face lack of heated distribution channels from declining rural rail systems. In the short term, premium coproducts, such as waxes, will have to be developed to offset the cost of changing perceived risk to increase demand for the revitalization of the heated rural rail infrastructure.

5.6 Progression of Barriers

The barriers discovered during literature review were combined with the barriers identified during the survey and interviews to create an overall list of 79 barriers impeding U.S. advanced biofuel projects (Table 18). Some barriers were already occurring before the onset of the 2005 EPAct (e.g., declining fuel consumption), and it appears they were overlooked or deemed irrelevant by most parties. With the government as the main driver of energy security, advanced biofuel projects sought large amounts of funding for entry into the new market. This led to more legislative specificity and incentives with the EISA 2007 (RFS-2) implementation. The new EISA policy lost support of the petroleum industry, leading to additional barriers affecting the industry by 2010: recession, failing technology, and fracking.

The bioeconomy stakeholders suggested the survey barriers affect the industry through technology, financing, politically, infrastructure, marketability, and distribution. These many barriers shifted the industry focus from struggling in the advanced biofuel Valley of Death, to producing coproducts as biochemical main products. The RFS has always been an artificial demand signal driving the performance of an emerging industry. The industry needs the RFS-mandated targets to be high to capture investment, based on producible quantities and market signal pulling demand. For example, “Diesel is currently outpacing ethanol in growth (demand signal), and the projects that are diversifying from biofuel into high value chemicals are experiencing an average of 6.5 times as much growth in revenues as advanced biofuels in 2012. Also, 9% of all chemicals today are being produced via biotechnology” (Erikson 2015). This demonstrates the shift from producing only biofuel to making biofuel and biochemical coproducts. Demand for biochemicals is creating a demand signal, pulling the bioeconomy to develop platforms of technology to sustain investment and positive perception.

Table 18 Progression of Barriers

	Initial Barriers prior to EPAct		Market
1	Potential MTBE-based lawsuits led to abandoning current functional fossil infrastructure	**42**	Blend wall arriving ten years early, at low volumes
2	Fossils industry resentment for market share loss stemming from the EPAct	**43**	Market demand shortfall of 13.7BG in 2015 from original expectations
3	The petroleum industry and 1G biofuels were pre-established	**44**	Biogas was added to cellulosic to meet mandate increasing competition
4	The 2G subsidies created an unbalanced playing field between; Petroleum, corn, and AB	**45**	EPA renewable volume obligation delays
5	Declining fuel consumption when it was expected to increase by the 350BG through 2022.	**46**	If fuel consumption or Octane content does not increase, the market for advanced biofuel is tapped out
	Barriers after EISA Implementation	**47**	Uncertainty of how many and when to buy RINs with EPA delayed RVO
6	Development during a time of recession	**48**	D6 RINs were worth more than wood, grass, or Algae RINs until 2013
7	Decreasing Petroleum prices	**49**	EPA financial penalties accrue, when mandates are not met
8	New fracking technologies	**50**	EPA labeled RIN market as buyer beware, due to RIN fraud
9	The ability of petroleum industry to buy CWCs instead of advanced biofuel	**51**	More Flexfuel cars and improved infrastructure needed to handle blends above E15
10	ROI timeline issues	**52**	The recession influences purchase of less expensive non Flexfuel cars while gas cost is low
11	All paper mills attempting biofuel add-ons failed with scale-up, none are attempting now.	**53**	Cars using higher Octane (E85 flex fuel) cost more, and their gas costs more per gallon
12	**Survey barriers**	**54**	Large fuel companies like Love's are poised and ready to provide the pump infrastructure however the public demand is missing
13	Product development	**55**	Public perception/education is negatively swayed by misnomers about ethanol
14	Byproducts marketing	**56**	Coproducts had little to no focus with the closed projects
15	Byproducts distribution	**57**	AB Failures along the way have drawn negative public perception of alternatives fuels
16	Coproducts marketing	**58**	Government tightened lending and third party ROI contracts after 2G failures

17	Coproducts distribution	**59**	2G failures and litigation have changed investor perception towards less risk with proven platform technologies, instead of singular ones
18	Continuous project growth	**60**	**Coproducts barriers**
19	Management	**61**	Cost
20	Strategy	**62**	Technology
21	Technology conversion and yield	**63**	Funding, access to capital
22	Technology conversion	**64**	Petroleum control of market
23	Technology high titer and yield	**65**	Public awareness, and consumer awareness of benefits
24	Competitors	**66**	Lack of end user demand, and identified uses
25	Funding	**67**	Oversupply
26	Suppliers	**68**	Flooding a niche market
27	Production tax credits	**69**	Perceived sole source risk
28	Energy costs	**70**	Perception
29	Third party relations	**71**	Lack of heated distribution channels
30	Renewable Fuel Standard	**72**	Infrastructure non-existent, and market fragmentation, unclear channels
31	RFS - cellulosic waiver credits	**73**	Lack of incentives for secondary products
32	RFS - Renewable Identification numbers	**74**	Bio-integrity of supply chain
33	RFS- renewable volume obligations	**75**	Government uncertainty
34	EPA pathway processes	**76**	Competition from non-renewable sources
35	DOE pathway processes	**77**	GMO isolation
36	USDA pathway processes	**78**	Misinformation about the industry
	Political	**79**	Timing
37	Increasing uncertainty of barriers across industry groups		
38	Petroleum companies lobby heavily against RFS		
39	Petroleum companies public persuasion campaigns against the RFS		
40	Advanced biofuel continuously funding litigation		
41	Industry is collaborating without a total industry stakeholder unified front		

5.7 Study Limitations

This study was limited by the availability of peer-reviewed and secondary articles on this recent and current topic. The lack of peer-reviewed articles increased the difficulty in determining the validity of sources used. Due to the relatively short time since the inception of the advanced biofuel projects, few peer-reviewed articles, books, and journals were available on the internal and external factors leading to impeding barriers of advanced biofuel projects. Some of the projects and their parent companies have been closed or shut down, and communication was no longer possible with those projects, such as Raven Biofuels. Information related to internal and external factors was considered proprietary and access to the barriers was restricted in many cases, such as for KIOR, which was undergoing litigation and restructuring. The mapping and figure development were based on all projects that could be located. Since many are now closed or shutdown, the available information was limited.

CHAPTER 6. Conclusions

In this research, it was determined that information on advanced biofuel projects needed to be aggregated to improve stakeholder and bioeconomy knowledge of industry barriers. Specifically, stakeholders needed detailed information on spatial factors affecting the biofuel industry, barriers impeding sustainability, a list of biofuel byproducts and coproducts, and subsequent marketability and distribution barriers of those byproducts and coproducts. This study met that need through a review of literature, results from the three research objectives, and discussions with bioeconomy leaders and experts.

The spatial analysis indicated regional location did not impact advanced biofuel projects by their operational status since the 2005 EPAct. This was indicated visually by map development of locations by status, with 82% of 59 project attempts are in the Eastern half of the U.S. In the Western half, the majority are in California, utilizing the LCFS additional program incentives. Mississippi had a cluster of projects, which were determined to be mostly commercial projects taking advantage of the Go Zone funding initiative and multiple distribution methods. Contingency analysis also verified regional location was not a barrier by project status and region. Advanced biofuel projects relied almost exclusively on two technologies: biochemical (50% of projects) and thermochemical (47%), with only two hybrid projects (3%).

The barrier analysis indicated the perspectives on barriers to production of advanced biofuel are different by stakeholder type, project type, status, and technology. The barrier impact changed across time and type of project. The closed projects faced the same barriers, however fewer barriers than the current projects now that the blend wall is a permanent factor. Discussions with bioeconomy industry representatives about the implications of the blend wall led to an improved RFS model and improved understanding of the system.

Literature, surveys, and interviews also informed the creation of an extensive list of secondary products and the barriers to marketability and distribution of byproducts and coproducts for U.S. advanced biofuel projects. The barriers have more differences between byproducts and coproducts marketing and distribution than similarities. The main primary barriers of coproducts and byproducts are: cost, funding, fossil control of market, and public awareness byproducts and coproducts barriers.

Further research is needed to incorporate all Total Renewable Fuels (TRF) projects types, beyond wood and grass. The verified barrier progression list should then be used to develop a more precise survey to determine more specificity with barrier impact on this industry. Additionally, a clear path of TRF misnomers should be researched to determine their impact on the development of the needed biofuel infrastructure. It would also be useful to know the exact expenses that biofuel companies have spent on each structure by type, location, and relevant feedstock costs in those areas.

Overall, timing is the main barrier to advanced biofuel projects. If the decline in fuel consumption was realized by all parties, the advanced biofuel group may not currently exist. However, the outcome of timing has created the realization that the remaining advanced biofuel projects are now rapidly moving to become advanced biochemical platform technology companies, quickly and annually claiming market share of global premium coproducts. They are well poised to either blend higher levels of biofuel and/or premium coproducts, dependent upon the full spectrum of petroleum barrel price and demand. Additionally, they are unifying their efforts to become a household lifestyle premium brand. Will the petroleum industry realize its marketing myopia and grow with the bioeconomy global brand, or will it inadvertently continue as the increasingly undesired environmentally unfriendly brand?

To move the bioeconomy forward faster, developing an incremental Green House Gas (GHG) carbon tax is needed on an incremental level to fund the developing infrastructure, public education, and factual perception to bolster the demand for biofuel and biochemicals. The funding is privately earmarked, ready, and in bearish stance, awaiting public demand. The information compiled in this study can aid the biofuel industry and the bioeconomy in future pursuits; it can provide guidance to inform R+D to reduce costs and improve perceived risk, increasing investment viability.

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CHAPTER 8. Appendixes

8.1 Appendix A: Questionnaire

Barriers Impacting advanced biofuel Projects in the United States

March 16, 2015

Hello, biofuel: industry, government, academia, and publishers,

I am a Graduate Research Assistant for the Sustainable Biomaterials Department at Virginia Tech, Forest Products Business Center. I am conducting research to find out the opinions of yourself and other experts on the internal and external barriers impacting the U.S. non-food, lignocellulosic, second generation biofuel industry since the 2005 EPAct.

In DC recently, many attendees of the advanced biofuel Leadership Conference (ABLC) 2015 suggested there is a dire need for collaboration among the U.S. alternative biofuel sector to drive innovation and embolden government biofuels policy. Collaborative d

I am simultaneously requesting the following sectors complete the included brief digital questionnaire, because of their extensive experience with U.S. non-food, lignocellulosic, second generation biofuel: fifty past and present second generation biofuel project owners and management; biofuel academia; biofuel publishers such as The Biofuels Digest, and Forisk; as well as many facets of government such as; DOE, USDA, EIA, EPA, NREL, DOD. Your answers are very important to the accuracy of this research in generating industry collaboration in a non-proprietary manner. If your sector or company has had any involvement in second generation biofuel, whether or not your sector or company is still involved in second generation biofuel, the acquired experience is vital to strengthen the entire industry.

Enclosed is a short digital questionnaire. It will take no more than 20 minutes to answer the questions. Please consider allowing me a brief conference call or in-person meeting with you to discuss the specific questions from the questionnaire. Of course, all answers are confidential and will be used only in combination with those of other executives, managers, academics, and government officials that complete this survey. Specific company and project names will not be used in the final report, only the project type pertaining to questions 1 through 6 in the attached questionnaire.

Participants will receive a free electronic version on the findings of this research, just check the request at the end of the questionnaire and write-in your preferred email for the response. I will be glad to send you a complimentary report when ready.

Please return the completed digital questionnaire by April 15, 2015. If you should have any questions, please contact me by phone at ---, LinkedIn, or email at --.

Thank you for your consideration,

8.1.1 Part 1. Demographics

1) Please classify which biofuel sector you are associated with.

 Government Academia Biofuel industry Biofuel publisher

 Other? __________________________

If **biofuel industry** was chosen please continue through entire document.

All others please start with question 11.

2) Please classify this project under the following non-food, lignocellulosic, biofuel status.

 Pilot project Demonstration project Commercial project

3) Please check the description which best describes your company's current non-food lignocellulosic biofuel project status.

- Cancelled / Shutdown
- Planning
- Under Construction
- Operating
- Scaled to commercialization not producing deliverable biofuel
- Scaled to commercialization producing and delivering biofuel
- Other____

4) (Is/ was) this project biochemical, thermochemical, or other _______________________________? Please circle answer or fill in the blank.

5) (Is / was) the location of this project a barrier to its success? Yes / No. Please circle answer. Barrier is defined as something that is impeding or impacting success to reaching non-food lignocellulosic biofuel commercial economies of scale

6) Which specific technology type (is/was) your company using for this non-food lignocellulosic biofuel project? Check which one applies.

- Catalytic pyrolysis and hydrotreating to hydrocarbons
- Gasification and Fischer-Tropsch synthesis to hydrocarbons
- Gasification and methanol to gasoline synthesis

- ☐ Dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis to ethanol
- ☐ Enzymatic hydrolysis to ethanol
- ☐ Single step enzyme production, hydrolysis and fermentation to ethanol

Other____

____

8.1.2 **Part 2: Financial:**

7) What was the minimum dollar price including renewable identification number (RIN) this project expected to sell their main biofuel product per gallon at the onset of research and design? ______________________.

8) If biofuel sales were achieved, what is the current (actual) or was the final biofuel selling price per gallon including (RIN) for this project? ______________________________. Was this final price a major barrier to the success of this project? Yes / No. Please circle answer.

9) Does this project burn its byproduct waste streams reduce costs? (Please circle answer) Yes / No. If yes, what average percent of energy costs does this projects waste stream currently generate towards electrical cost reduction ______________________________ ?

10) Please check yes or no in each box below for each sequential phase pertaining to capex and opex expenditures this project has been able to achieve. Leave the phases blank that have not been achieved. Capital expenditure (i.e. capex) is the expense incurred for purchasing fixed assets, inventory, machinery, and intellectual property. Operational expenditures (i.e. opex) are the money spent turning inventory in to throughput, operations, maintenance, wages, and utilities.

	Were the (capex) capitol expenditure costs higher than expected during any of the following four phases?	YES	NO
Phase 1:	Initial research and design		
Phase 2:	Proof of concept / pilot level		
Phase 3:	Deployment and demonstration level		
Phase 4:	Commercial, producing and delivering biofuel		
	Were the (opex) operational expenditure costs higher than expected during any of the following four phases?	**YES**	**NO**
Phase 1:	Initial research and design		
Phase 2:	Proof of concept / pilot level		
Phase 3:	Deployment and demonstration level		
Phase 4:	Commercial, producing and delivering biofuel		

11) Considering your own criteria, what has been the Renewable Identification Number (RIN) dollar amount expectation range for U.S. biofuel projects compared to the reality of dollar amount expectation? Please fill in the amount for expectation range and reality range.

Expectation range: $0.1 to $3.00 ________________________?

Reality range: $0.1 to $3.00 ___________________________?

Comment on expectation range versus reality range impacting the U.S. non-food biofuel industry:

____
____
____
____
____

12) Please rank in order the following literature review determined categories by largest financial expense to U.S. biofuel projects on a 1 through 20 scale since the 2005 EPAct. One (1) is / was the most expensive financial barrier, and twenty (20) is the least expensive for biofuel projects overall since 2005 EPAct.

Rank of categories impacting biofuel project success	Rank
Byproducts distribution	
Byproducts marketing	
Competitors	
Continuous project growth	
Co-products distribution	
Co-products marketing	
DOE pathway process	
Energy Costs	
EPA pathway process	
Funding	
Management	
Production tax credits	
Product Development	
(RFS) policy standards	
Suppliers	
Technology conversion rate	
Technology titer concentration	
Technology yield per ton	
Third party relationships	
USDA pathway process	

13) In your opinion, are patents the primary financial mechanism to sustain and acquire biofuel investors? NO / YES? (Please circle answer). **If you are associated with a biofuel company, please fill in the following additional question:** How many patents does your company hold towards the production of non-food lignocellulosic biofuel _______________?

14) In your opinion, what are the top three financial mechanisms to sustain investors over the life cycle of U.S. biofuel projects? ____

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8.1.3 **Part 3: Internal and External barriers**

15) The following categories have impeded the success of many U.S. non-food lignocellulosic biofuel projects. Check all categories on right that apply to biofuel projects. Strongly agree would imply a specific category would have strongly impeded a biofuel projects success since the onset of research and design.

Weight of categories impacting biofuel projects success	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Byproducts distribution					
Byproducts marketing					
Competitors					
Continuous project growth					
Co-products distribution					
Co-products marketing					
DOE pathway process					
Energy Costs					
EPA pathway process					
Funding					
Management					
Production tax credits					
Product Development					
(RFS) policy standards					
Suppliers					
Technology conversion rate					
Technology titer concentration					
Technology yield per ton					
Third party relationships					
USDA pathway process					

16) In your opinion, what has been the impact of government mandates and policies pertaining to U.S. biofuel projects ability to produce and distribute; non-food, lignocellulosic, biofuel coproducts and byproducts?

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17) In your opinion, what are the top 3 barriers currently impeding the marketability and distribution of U.S. biofuel projects byproducts and coproducts from non-food, lignocellulosic biofuel? In this context; *Marketability* is defined as the ability to be bought and sold. *Distribution* is defined as how products are distributed through a channel to consumer. *Barrier* is defined as something that is impeding or impacting success to reaching non-food, lignocellulosic, biofuel commercial economies of scale

8.1.4 **Byproducts and coproducts**

Byproduct barriers (Marketability)

1.____________________________________
2.____________________________________
3.____________________________________

Coproducts barriers (Marketability)

1.____________________________________
2.____________________________________
3.____________________________________

Byproduct barriers (Distribution)

1.____________________________________
2.____________________________________
3.____________________________________

Coproducts barriers (Distribution)

1.____________________________________
2.____________________________________
3.____________________________________

18) In your opinion, what are the top five (5) coproducts and byproducts generated for U.S. second generation biofuel projects? Some common coproducts and byproducts are provided. Please list from least to most profitable.

Coproducts:	**Byproducts:**
1.________________________	1.________________________
2.________________________	2.________________________
3.________________________	3.________________________
4.________________________	4.________________________
5.________________________	5.________________________

8.1.5 (Byproducts and coproducts advanced biofuel)

Gases and Fuels:
- ☐ Syngas
- ☐ Hydrogen
- ☐ Carbon Dioxide
- ☐ Drop in Diesel
- ☐ Naptha

Organic acids:
- ☐ Fumaric acid
- ☐ Lactic acid
- ☐ Acetic acid

Alcohols:
- ☐ N- butenol
- ☐ Xylitol

Macromoecules:
- ☐ Cellulose nanofibers
- ☐ Polyhydroxyalkanoate
- ☐ Lignosulfates
- ☐ Carbon fiber
- ☐ High purity Lignin

Aromatic compounds:
- ☐ Benzene
- ☐ Olefins

Waxes:
- ☐ Furfural
- ☐ Suberin

Other Products:
- ☐ Cellulose nanofibers
- ☐ Protein
- ☐ Biochar
- ☐ Betulinol
- ☐ BTEX _byproducts

- ☐ Please check this box to receive a copy of the research findings when completed. In addition, please add title and appropriate email address to receive a digital copy of the findings.___________________________________
- ☐ May I contact you for a brief interview on the specific questions within this questionnaire?
- ☐ Comments

8.2 Appendix B: Survey Sent to Industry

June 29, 2015

Hello Biofuel Industry,

THIS SURVEY HAS BEEN SHORTENED TO ONLY TWO QUESTIONS

Based on responses to the previous version, we have shortened our survey (now approximately 5 minutes) to glean only the most pertinent data while still respecting the time you are willing to spend in support of our research and in collaboration to advance the alternative biofuels industry. Please classify which biofuel sector you are associated with, then you will be directed to answer the two survey questions.

Certain respondents will also be asked to include basic demographic information.

8.2.1 **Part 1. Demographics**

1) Please classify which biofuel sector you are associated with.

☐ Government ☐ Academia☐ Biofuel industry ☐ Biofuel publisher

☐ Other? ___________________________

If **biofuel industry** was chosen please continue through entire document.

All others please start with question 11.

2) Please classify this project under the following non-food, lignocellulosic, biofuel status.

☐ Pilot project ☐ Demonstration project ☐ Commercial project

3) Please check the description which best describes your company's current non-food lignocellulosic biofuel project status.

- ☐ Cancelled / Shutdown
- ☐ Planning
- ☐ Under Construction
- ☐ Operating
- ☐ Scaled to commercialization not producing deliverable biofuel
- ☐ Scaled to commercialization producing and delivering biofuel
- ☐ Other____

4) Please classify this project under the following U.S. non-food, lignocellulosic, biofuel project status.
   - ☐ Pilot project
   - ☐ Demonstration project
   - ☐ Commercial project
   - ☐ Other____

8.2.2 **Question 1, Internal and External Barriers**

The following categories have impeded the success of many U.S. advanced biofuel projects. Check each category in your opinion how it has impeded U.S. non-food, lignocellulosic biofuel projects. Or if you are associated with a biofuel project, please check categories from your projects perspective. Strongly agree, would imply a specific category would have strongly impeded biofuel projects success since the onset of research and design.

FACTORS:	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Byproducts distribution					
Byproducts marketing					
Competitors					
Continuous project growth					
Co-products distribution					
Co-products marketing					
DOE pathway process					
Energy costs					
EPA pathway process					
Funding					
Management					
Production tax credits					
Product development					
Renewable Identification numbers (RIN's)					
(RVO) Renewable volume obligation					
(RFS) policy standards					
Strategy					
Suppliers					
Technology conversion rate					
Technology - High titer and yield per ton					
Third party relationships					
USDA pathway process					
Waiver credits					

8.2.3 **Question 2. coproducts** and Byproducts

In your opinion, what are the top 2 barriers currently impeding the marketability and distribution of U.S. biofuel projects byproducts and coproducts produced from non-food, lignocellulosic biofuel?

In this context; the biofuel production process yields byproducts (low to no value) and further processing yields subsequent value added coproducts. Marketability is defined as the ability to be bought and sold. Distribution is defined as how products are distributed through a channel to consumer. Barrier is defined as something that is impeding or impacting success to reaching non-food, lignocellulosic biofuel commercial production economies of scale.

	COPRODUCTS		**BYPRODUCTS**	
	Main Barrier	Secondary Barrier	Main Barrier	Secondary Barrier
Marketabilty				
Distribution				

- ☐ Please check this box to receive a copy of the research findings when completed. In addition, please add title and appropriate email address to receive a digital copy of the findings.___________________________________
- ☐ May I contact you for a brief interview on the specific questions within this questionnaire?

8.3 **Appendix C: Grounded Theory Approach in Objective 2.**

Three literature gaps are further explored in an inductive Grounded Theory study, based on the factor development (procedure) methods in Constructing Grounded Theory, Charmaz (2006). This framework development procedure will aid in knowledge acquisition of critical factors; as well as, their influence and interaction on the non-food lignocellulosic biofuel industry. According to Charmaz (2006), Grounded Theory has evolved to accept two methods of approach, constructivist and objectivist. Constructivist focuses on more of a social context variables, interrelated experiences, and those participant relations, additional phenomena, and the researcher's point of view. In this case, the research framework is developed from a converse objectivist approach. Charmaz (2006) suggests that an objectivist approach is a *"positivist tradition"* with the data viewed as real, not focusing on how the data was produced. This assumes that data represent objective facts about a knowable world. The researcher finds them and discovers theory from them. Dr. Charmaz describes Positivism as, the scientific approach to knowledge determination of phenomena through observation and experimentation as a neutral observer, with the goal of prediction and study control.

Grounded Theory is a scholarly methodical approach for data collection and subsequent construction of a theory through data analysis from open-coded documents. This method allows the researcher to develop theory or thematic models from an initial set of data.
Glaser and Strauss (1967), developed Grounded Theory using social science practices to examining data before developing a hypothesis. Charmaz (2006), Dr. Charmaz is a leading theorist in utilization of Grounded Theory. She further developed Glaser and Strauss's explanation of Grounded Theory as a systematic, flexible, and ordered process to analyze qualitative data post hoc. Additionally, she further explained the different paths of social science and natural science that the theory is now traveling. Social Science Theory – *are analytical frameworks or paradigms used to examine social phenomena*, Elliot (2008). Natural Science Theory – the sciences collectively involved and concerned with the description, predication, and understanding of the physical world based on observational and empirical evidence of natural phenomena, *Dictionary.com (2015).* These two paths each are divided into constructivist and objectivist, as described in the introduction. In this case, Dr. Charmaz suggests understanding the positivist and interpretive meaning of theory itself is vital to developing a framework to proceed. Positivist approach according to Glaser (2003), Charmaz (2015) *emphasized the development of theoretical categories that serve as variables, assumes an indicator-concept approach, and seeks context-free but modifiable theoretical statements and using data resources with scope of explanatory power… and treating categories as an automatic result.* Interpretive approach is used more in social science, it is more conceptual and open to interpretation by the researcher.

8.3.1 **Collecting Data and Grounding Theory Coding**

According to Charmaz (2006), Grounded Theory will provide categories of analysis rather than predetermining them. The initial step to classify open-coded statements requires the definition of a series of axial codes. Quesada and Gazo (2007) determined the following axial codes to classify internal and external barriers (barriers) that impacted the competitiveness of renewable-based industries such as furniture industries. These axial codes were: product development, technology, strategy, funding, suppliers, competitors, government, energy costs, and third party relationships. Therefore; initial axial coding was used to classify barriers in this particular situation. All quoted statements that were classified by using Grounded Theory from statements in Appendix C.

This Grounded Theory data collection approach is guided by the suggested methods in Constructing Grounded Theory by Charmaz (2006). Grounded Theory coding of data is developed in two phases; initial coding focused and selective coding, explained respectively. Initial open coding involves labeling, segmenting data, conceptualizing, and developing categories. Focused axial coding analyzes the most significant and frequent data from the initial coding, thus relating categories to subcategories, Charmaz (2006). Data collection was conducted initially by a literature review for determination of knowledge acquisition of relevant information to this research, and subsequently coding was applied after the literature review as a prescribed mechanism for data coding. The initial coded data was cross-validated via survey response initially, then finally validated with a follow up interview with each survey response for additional knowledge acquisition, and overall cross-validation of collected data theoretical linkages (how the concepts are related in the development of a hypothesis) to operational linkages (empirical relation of concepts, data that supports the proposition).

In this case, the research framework at this point is now more guided and focuses on the natural science side from a positivist and objectivist approach, starting with qualitative data collection and not a hypothesis. Essentially, developing theoretical categories as barriers. These categorical linkages become facts about the knowable world from a natural science perspective, and then used to develop factual categorical linkage. The hypothesis is to be discovered from the latter analysis of the collected data in section 8 of this research.

8.4 **Appendix D:** Closed and Shutdown Advanced Biofuel Public Statements

Secondary sourced statements from advanced biofuel project management for internal and external sustainability indicator determination.

8.4.1 **New Page**

Forisk consulting states the barriers as: "Unfavorable project economics and insufficient financing were the primary reasons for the cancellations and shut-downs. (Mendal et. al 2013)" Barriers are supported by the following industry leaders statements:

1) New Page paper President and CEO Rick Willet in 2009 suggested for continuation of their biofuel project the following would have to improve; "Escalating cost of installation of the Chemrec process, substantial investment required to modify existing operations, demand has not developed in U.S. as in Europe for ethanol, costs of installation would need to be lower to be viable project, and current market prices for methanol and dimethyl ether would also need to improve."(NewPage 2009)
2) New Page Chairman and CEO Mark Suwyn sited in July 2009 the factors that led to closure of the biomass project; "The mill has been there since 1889 .closed due to the result of a weak economy, continued effects of low priced imported products, skyrocketing costs of economy, the coated paper market is being hit with a slowdown in demand as the uncertain economy is reflected in a reduction in print advertising." (Austin 2008)
3) "New Page's competitors situation in Europe is similar, as sited by New Page in the same article: "Competition in Europe UPM – Kymmene OYJ – Europe's 2nd largest papermaker, that company stating: Demand growth for paper in traditional markets has slowed down, overcapacity still exists in Europe. Additionally, here slowing economic growth imposes further challenges, prices of wood, energy and fuels have increased significantly in the last two years." (Austin 2008)
4) Anna Austin, writer for Biomass magazine in 2009 Stated the following factors for Paper mill biomass project closure as: "The problem converting the existing mills is that many pulp and paper mills are nearly a century old and simply cannot compete with companies that are equipped with more modern, cost efficient machinery. Developing a full–scale biorefinery could cost anywhere from $50 million to $200 million."(Austin 2008)
5) Kris Plamann, Director of Business Development for KauKauna, Wisconsin based Baisch Engineering, INC. which serves the pulp and paper industry, biofuels and other industries stated: "If the pulp and paper industry is to survive in this country, it will just look a lot

different" Really, it comes down to two questions for the mills in regard to how they are going to respond to the rising cost of energy. What can they produce in addition to paper and how can they come up with, or who can they partner with to raise the capital to create a biomass fired energy plant or biorefinery." (Austin 2008)

8.4.2 Cello

1) Cello Energy previously known as Forest Energy systems, a father and son company frauded paper mill investors, and Koshla bioenergy investments: Brenden Kirby writer for Al.com in 2011 stated: "Jack Boykin (owner) died suddenly after losing a multimillion dollar lawsuit brought on by the paper pulp maker Parsons and Whittemore Enterprises, that invested heavily in his promised alternative energy breakthrough. The plant never produced commercial quantities of biofuel.
2) Fraudulent claims against Boykin were proven two years later, in federal court –the facility never been completed and had produced just $17,000 worth of fuel. Lab testing showed that the fuel contained no biomass material. (Kirby 2011)"
3) In 2011, Billy McDaniel, Mayor of Metropolis stated "Jack Boykin told me that he had an operating plant now." Without mentioning judgments filed against him (Lane 2013)"
4) June 22, 2009 - According to a lignocellulosic ethanol market report published by research firm, ThinkEquity (John 2009): Koshla ventures invested $12.5mil into this venture also agreeing to fund a second and third plant in the contract."
5) "The EPA included Cello in its list to achieve the 50million gallon renewable fuel standard goal passed in the energy independence and security act of 2008 which states that: fuel sellers to use 100millgal of cell biofuel by 2010.(John 2009)"

8.4.3 Rappaport Energy with Longview Fiber

1) Rappaport Energy with Longview Fiber mothballed their biomass project. President Randy Nebel of Longview Fibre, April 2013 stated that "electricity is currently too low to put in a new boiler, but could move ahead in five years if rates increase."- also competitors in area have closed making feedstock prices more competitive.(Mies 2013)"
2) "Jan. 2010, Peter Moulson, a senior energy policy specialist with the Washington Commerce Dept said - transporting feedstock to plant costs an issue, and the challenge

for independent energy developers has been managing the cost of transporting it to a plant.(83)"

8.4.4 Flambeau River Biofuels

1) Flambeau CEO Butch Johnson in Oct. 2010 stated initially to move the project forward "Our true challenge will be funding the project (Brochu 2010)"
2) "The D.O.E is providing an $80million project grant, leaving investors to contribute $220million…the agency has set terms that private investors would reject. Normally, they want 20% sponser equity, but they are requesting we bring our equity up to 40% or 50%..it kills your return on investment (Brochu 2010)."
3) Bob Byrne, Flambeau River Biofuels president stated: "Investors could earn more by putting their money in less risky ventures…the D.O.E wants the loan tenured in 7 to 12 years…leaving the biorefinery with little to no operating capital…leaving investors without shorterm ROI."
4) Randy Stoeckel Flambeau president and general manager on Feb. 2013 stated: "The banking industry has changed, we have operated almost like a cash business, and when you have cyclical markets like the paper industry, that makes it very difficult to pay your bills and continue to make the necessary improvements to keep 300 jobs (Business North 2013)"

8.4.5 Newton Falls

1) "The biorefinery technology worked but the economics did not, said Park Falls Mayor Thomas Ratzlaff (Business, North 2013)."
2) Donald H Schnackel Vice President of Finance and Administration was looking for an immediate solution to reduce Newton Falls dependence on fuel oil. (Ellen 2010)"
3) Newton Falls was struggling due to economics of paper industry. "Newton Falls closed during attempt to fund biomass plant to reduce dependence on fuel oil.(Graham 2010)"

8.4.6 Coskata

1) Coskata on July 12, 2012, stated it will consider other locations for their biorefinery planned for Boligee, AL.(GCD 2012)"
2) According to Greene County Industrial Development Authority, they were notified by Coskata that due to the evolving nature of Coskata's first commercial project, their siting

criteria has changed and they currently need a site with greater utilities infrastructure than that found at Crossroads of America Park in Boligee, AL.(GCD 2012)"

3) On July 20, 2012 Coskatas' CEO Bill Roe stated, "The sea of natural gas is almost a problem, leading to historic price dislocation and a level of availability that has not been seen for a long time…We are not abandoning feedstock flexibility (Lane 2012)" of woody biomass.
4) Rich Troyer, Coskata's chief business officer, said "Coskata is not losing focus on woody biomass; it is still in our future (Lane 2012)" Roe says "that natural gas has moved to the front, as the first and most obvious feedstock that we can utilize for our commercialization strategy…With the Alabama project being 1/3 natural gas the change makes sense.(Lane 2012)"
5) Bill Roe additionally commented: "this is still liquid processing where we are processing syngas to fuel grade ethanol, and it is nearly identical to the design for our biomass conversion. We are simply changing the front end of the plant. (Lane 2012)"
6) Biofuels digest writer Jim Lane stated: "A 130 million gallon natural gas project costs the same as a 65mil gal woody biomass project… There are economies of scale, once the limiting factor of the transportation of biomass is removed…Technology is too expensive over the general small radius in which MSW can be profitably aggregated. Two, the technologies themselves are just reaching commercial demonstration scale. Three, they all could use a more affordable stream of optimized syngas.(Lane 2012)"
7) Bill Roe says: "we are limited to a maximum of 100 – 150 million gallons, about the size of a big ethanol plant. With a natural gas feed, much larger plants can be built….the debate over RFS2 is completely political at this time, leaving us unprepared to take the risk to sink major capital at this time in a project, and see RFS2 change markedly right in the middle of construction.(Lane 2012)"

8.4.7 Community Energy Systems

1) Community Energy Systems: An attempt to revitalize a failed ethanol plant with new biomass capabilities. No relevant data is available beyond the assumed funding and project economics to move forward with the concept.

8.4.8 **Rentech Rialto**

1) Rentech Rialto Project, "Suspended due to lack of Financing, Rentech has announced that it has withdrawn its applications to the U.S. Department of Energy (DOE) for loan guarantees for its Rialto Project. Rentech applied under the DOE's Section 1705 loan guarantee program; however, Rentech was notified that its 1705 application had been placed on hold by the DOE, and it considered applying under the DOE's Section 1703 loan guarantee program.
2) Rentech recently stated that it would no longer pursue project financing for its projects from the DOE loan guarantee programs. Rentech now believes that project financing for the Rialto Project will be unavailable at feasible terms, and the project has been terminated (Investors Hub 2011)."
3) Rentech - Clearfuels Collinwood: "There are a number of applications for this technology in other areas of the world for biomass to hydrogen, biomass to power and biomass to ethanol," noted Rentech-clearfuels VP for Investor Relations Julie Dawoodjee.
4) "We are considering how best to gain value from the wind down of our alternative energy business, while retaining rights to technologies that may serve us in the future.(Lane 2013b)"
5) Clear fuels is a joint project with Rentech. Rentechs' decision to invest elsewhere mothballed the Collinwood project.

8.4.9 **Dynamotive**

1) Dynamotive: Sept 2011 Willow springs was mentioned (Baines 2013), however never started. It is assumed due to lack of funding and project economics. No relevant information found.

8.4.10 **KIOR**

1) KIOR Fred Cannon, President and CEO stated in 2013 "with first production at Columbus, KIOR has technology with the potential to resurrect each and every shut down paper mill in the country and to replace imported oil on a cost effective basis while creating jobs. (Wood Bioenergy 2013)"

2) Kior stated plans to build five biorefinery sites in the Mississippi Gulf Opportunity Zone (GoZone). One was Bude, but Kior sited criteria change "since it was not fully committed to Bude and chose other locations. (Hogan 2012)"

8.4.11 **Raven Biofuels**

1) There is no relevant information for Raven Biofuels, as to why they cancelled. It is assumed lack of funding and project economics.

8.4.12 **Range Fuels**

1) According to Josie Garthwaite Range Fuels started in 2007 and by 2009 had fallen behind in production goals….only producing a wood alcohol fuel used in racing and industrial applications…the facility had run into technical problems with the gasifiers and the system for feeding in biomass, never producing biomass…Range Fuels closed the plant in January 2010, and filed for bankruptcy September 2011. (Garthwaite 2012)"
2) According to Mario Parker from Bloomberg in Dec. 2011 stated: "The Range Fuels plant was closed after a technical defect limited it to run at half rates and it produced lignocellulosic methanol, a fuel the Environmental Protection Agency doesn't consider eligible for use to meet federal biofuel targets….Range Fuels…missed its scheduled payment in Jan, 2011 triggering a default to the Agriculture Department loan…and further funding was suspended form the government….foreclosure ensued. (Parker 2011)"
3) According to Carrie Atiyeh, Director of Public Affairs for ZeaChem: "ZeaChem recently had to scale back plant operations in Boarrdman Oregon and let go a number of our valued employees because we were not able to secure a bridge-loan intended to carry ZeaChem into its next funding round. As a result of this unforeseen delay we could not avoid scaling back our operations, which we intend to be a short-term event….Operations have been temporarily minimized at the Boardman plant – it is not being sold. (Profita 2013)"
4) ZeaChem CEO Jim Imbler in March 2013 sited: "…lignocellulosic biofuel production in the U.S. is way behind federal targets….We're at the point now where it' not just the technology it is the ability to build it and finance it. There's a different set of skills

needed right now. You can have a neat process, but if you cannot build it doesn't do any good. (Profita 2013)"

8.4.13 **Rentech**

1) Acording to Rentech 2013, "it will cease operations, reduce staff, and mothball its R&D at the PDU, in Commerce City, CO. "Will focus on nearer-term profitable growth opportunities, is a direct result of the high cost to develop new technologies relative to current prices and lack of government incentives and regulations supporting alternative energy, particularly within the U.S., which have made it difficult for the company and other alternative energy companies to commercialize their technologies….it believes that company resources are better directed at opportunities that will produce more immediate returns, as it does not expect the market opportunity for alternative energy to improve materially in the U.S. within the next several years.(Lane 2013 Rentech 2013)"
2) "D. Hunt Ramsbottom, President and CEO of Rentech stated. "while our elimination of these positions is a difficult decision, today's actions will further position Rentech to drive value for shareholders by cutting R&D spending and focusing on business that generate strong returns, with ready markets and certainty of revenue. The investments we are considering have either immediate or near-term profitability, and will meet our disciplined investment criteria. (Rentech 2013)"

8.4.14 **Coskata**

1) Coskata semi-commercial, stated multiple factors leading to shutting down the biorefinery plant: "On January 12, 2012, the parties (Ineos and Coskata) signed a settlement agreement in which they agreed to dismiss all claims. Pursuant to the settlement, Ineos will receive from us a $2.5 million cash payment and 2,125,000 shares of Series D preferred stock, after which all the asserted claims will be dismissed, and a mutual release of future claims will become effective…"In addition, Ineos has the right to receive 2.5% of future ethanol royalties and license fees received by us from third parties who license our technology, subject to a cap with a net present value of $20 million, which will be increased based on future interest rates…We (Coskata) suspended continuous operations at Lighthouse due to the considerable costs associated with such operations and because our key objectives for operating the facility had been

met. We plan to install a natural gas reformer to ensure a continuous supply of syngas. Consistent with operations at our Lighthouse facility, we expect to operate this reformer on a nearly continuous basis. It is therefore likely that a portion of the ethanol produced at Phase I will not be considered renewable. The bottom line for Coskata: freedom to operate, and conserving cash through shutdown of the demonstration unit, which after 15,000 hours had likely yielded up all the engineering data needed for the first commercial plant. It is tough not to be able to work on demonstrating other feedstocks, but Coskata's focus is clearly on the first commercial facility, and taking on other challenges later. Tough business decisions, and a transformative technology: two reasons why Coskata has quietly emerged as a favorite among analysts looking at the IPO pipeline.(124)" Instead of non-food lignocellulosic biomass.

8.4.15 **Gulf Coast Energy**

1) Gulf Coast energy Livingston shut down as stated in an article by Michael Fielding of Public Works: "But now the plant sits idle, unable to secure either private financing or government assistance. Gulf Coast Energy needs $25 million to build a 1-mgd commercial ethanol plant. The city and company's joint request for $12.5 million of Alabama's $1.6 billion Energy Revolving Loan Fund stimulus allocation had been approved, and Hoover residents had OK'd a $12.5 million bond issue to raise the rest of the funding.
2) "There's enough wood waste in Hoover to make 400,000 gallons of ethanol a year," Mayor Tony Petelos told us last spring. A year later, though, he says that "trying to build a fully operational plant that's never been built before was tough." DOE turned down the city and company's joint request because they cannot prove a commercial plant would be viable. The reason: A 2000 DOE regulation defines commercial technology as "technology in general use in the U.S. marketplace." The technology must have been successfully deployed in at least three commercial projects, and a proposed project must have been running for at least five years. The Livingston plant began operating in 2008. Pruitt has pursued the issue since learning of the rejection in July 2009. "Here we have an internal regulation superseding subsequent Congressional action," he says. "I've never heard of a regulation overriding a law (Fielding 2010)."

Table 19 Barriers determined using Grounded Theory from closed project statements

New Page Corp	Dem	President Rick Willet	Escalating Cost of installation of the Chemrec process	Funding
New Page Corp	Dem	President Rick Willet	Escalating Cost of installation of the Chemrec process	Technology used
New Page Corp	Dem	President Rick Willet	Substantial investment required to modify existing operations. Costs of installation would need to be lower to be a viable project	Technology scale-up to exp.
New Page Corp	Dem			Feedstock for products
New Page Corp	Dem	CEO Mark Suwyn	EU over-capacity,…slowing economic growth imposes further challenges, such as price of wood, energy and fuels as increased significantly in the last two years….we are experiencing higher input costs for raw materials and transportation driven by oil and natural gas prices.	Feedstock for biorefinery
New Page Corp	Dem	Kris Plamann, Director of business Development for KauKauna	..Really it comes down to two questions: for the mills in regard to how they are going ot respond to the rising cost of energy.- what can they produce and ….financially partner with…. Anna Austin, obvious hurdles, some companies are beginning to venture down the biorefinery path by taking small steps, beginning with cutting energy costs.	Reduction in energy costs
New Page Corp	Dem		As biofuel gasification develops, United States energy policy evolves, and the economy improves, it is a possibility that New Page could revisit the technology in the future	R+D Only no construction
New Page Corp	Dem	President Rick Willet, CEO Mark Suwyn	Demand has not developed in U.S. as compared to EU….Current Market Prices for methanol and dimethyl ether would need to improve. Willet. Suwyn - closed due to the result of a weak economy. Suwyn - the coated paper market is being hit with a slowdown in demand as the uncertain economy is reflected in reduction in print advertising. At the same time experiencing higher input costs	Economy
New Page Corp	Dem			Third party contracts
New Page Corp	Dem	President Rick Willet		Government contracts

New Page Corp	Dem	CEO Mark Suwyn	closed due to; effects of low priced imports-coated paper market is being hit with a slowdown in demand as the uncertain economy is reflected in a reduction in print advertising.	Imports
New Page Corp	Dem	Anna Austin Biomass magazine	paper mills are nearly a century old and cannot compete with modern cost efficient machinery	Dwelling age
Cello Energy	Comm	Brendon Kirby AL.com	Jack Boykin (owner) died suddenly after losing a multimillion dollar lawsuit brought on by the paper pulp maker Parsons and Whittemore enterprises, that invested heavily in his promised alternative energy breakthrough. The plant never produced commercial quantities of biofuel. Fraudulent claims against Boykin were proven two years later, in federal court –the facility had never been completed and had produced just $17,000 worth of (non-biomass) fuel.	Funding / Fraud
Cello Energy	Comm	Brendon Kirby AL.com	Lab testing showed that the fuel contained no biomass material. (53, 54)" In 2011, Billy McDaniel, Mayor of Metropolis stated "Jack Boykin told me that he had an operating plant now." Without mentioning judgments filed against him.	Technology
Cello Energy	Comm		The EPA included Cello in its list to achieve the 50 million gallon renewable fuel standard goal passed in the energy independence and security act of 2008.	Third party contracts? (weak statement)
Clear Fuels	Comm		Clear fuels is a joint project with Rentech. Rentechs' decision to invest elsewhere mothballed the Collinwood project.	Funding
Clear Fuels	Comm			**Technology scale-up to expensive**
Clear Fuels	Comm	V.P. for investor relations Julie Dawoodjee	There are a number of applications for this technology in other areas of the world for biomass to hydrogen, biomass to power and biomass to ethanol," noted Rentech-clearfuels VP for Investor Relations Julie Dawoodjee. "We are considering how best to gain value from the wind down of our alternative energy business, while retaining rights to technologies that may serve us in the future.(	R+d only no construction

Clear Fuels	Comm		Clear fuels is a joint project with Rentech. Rentechs' decision to invest elsewhere mothballed the Collinwood project.	criteria changed
Comm. Energy Systems	Comm		An attempt to revitalize a failed ethanol plant with new biomass capabilities. No relevant data is available beyond the assumed funding and project economics to move forward with the concept.	Funding
Comm. Energy Systems	Comm			**R+d only no construction**
Comm. Energy Systems	Comm			**Criteria changed**
Coscata	Comm	CEO Bill ROE	we are limited to a maximum of 100 – 150 million gallons, about the size of a big ethanol plant. With a natural gas feed, much larger plants can be built….the debate over RFS2 is completely political at this time, leaving us unprepared to take the risk to sink major capital at this time in a project, and see RFS2 change markedly right in the middle of construction....leaving us unprepared to take the risk to sink major capital at this time in a project, and see RFS2 change markedly right in the middle of construction." 4 - Also it is particularly true the credit crunch and drying up of the markets was a factor; you cannot get money for projects, particularly for first-of-a-king technologies. They're not lending like they once did or will eventually, but you cannot hang everything on that. A lot of us in this space have been slower to bring our technologies forward than what was originally thought or promised.	Funding, scale-up, policy, risk
Coskata	Comm	CEO Bill ROE	that natural gas has moved to the front, as the first and most obvious feedstock that we can utilize for our commercialization strategy…With the Alabama project being 1/3 natural gas the change makes sense……..There are economies of scale, once the limiting factor of the transportation of biomass is removed	Feedstock costs, economics

Coskata	Comm	CEO Bill ROE	Technology is too expensive over the general small radius in which MSW can be profitably aggregated. Two, the technologies themselves are just reaching commercial demonstration scale. Three, they all could use a more affordable stream of optimized syngas....The technology is expensive over the generally small radius in which MSW can be profitably aggregated. Two, the technologies themselves are just reaching commercial demonstration scale. Three, they all could use a more affordable stream of optimized syngas.	Feedstock costs, Technology costs
Coskata	Comm	CEO Bill ROE	"Coskata, looking at CAPEX opportunities, political uncertainty, and the investor climate - switches to an "all natural gas feedstock" ....The sea of natural gas is almost a problem, leading to historic price dislocation and a level of availability that has not been seen for a long time…We are not abandoning feedstock flexibility.....The Coskata project always had a natural gas component, so in dropping the biomass component there is a lot cost that just falls away, Material handling, chipping, sizing, drying, gasification, gas clean up - all those unit costs come out....A 130 million gallon natural gas project costs the same as a 65million gallon woody biomass project.	Economics
Coskata	Comm	CEO Bill ROE		**R+d only no construction**
Coscata	Comm	Green County industrial development authority, Coskata, Bill Roe	We've chosen to be a technology provider rather than an operating company. 116 - According to Greene county industrial development authority, they were notified by Coskata that due to the evolving nature of Coskata's first commercial project, their siting criteria has changed and they currently need a site with greater utilities infrastructure than that found at Crossroads of America Park in Boligee, AL. Coskata - stated it will consider other locations for their biorefinery planned for Boligee. Bill Roe additionally commented: "this is still liquid processing where we are processing syngas to fuel grade ethanol, and it is nearly identical to the design for our biomass conversion. We are simply changing the	Criteria changed

			front end of the plant."	
Dynamotive	Comm		In Canada, the plants were generating negligible revenues and huge losses….lurched to a halt. The company did not even have enough money to produce financial statements…A cease trade order was issued against the company. The U.S. projects evaporated.	Funding
Dynamotive	Comm			**R+d only no construction**
Dynamotive	Comm			**Criteria changed**
Kior Bude	Comm			**Funding**
Kior Bude	Comm			**Technology scale-up to expensive**
Kior Bude	Comm			**R+d only no construction**
Kior Bude	Comm		One was Bude, but Kior sited criteria change "since it was not fully committed to Bude and chose other locations	Criteria changed
Newton Falls	Comm		Newton Falls closed during attempt to fund biomass plant to reduce dependence on fuel oil	Funding
Newton Falls	Comm			**Technology scale-up to expensive**
Newton Falls	Comm			**Feedstock for products**
			Newton Falls was struggling due to economics of paper industry.	Economics
Newton Falls	Comm	Donald H Schnackel Vice President of Finance and Administration	was looking for an immediate solution to reduce Newton Falls dependence on fuel oil.	Reduction in current energy costs
Newton Falls	Comm			**R+d only, no construction**
Rappaport Energy	Comm			**Funding**
Rappaport Energy	Comm			**Technology scale-up to expensive**

Rappaport Energy	Comm	President Randy Nebel, Peter Moulson, a senior energy policy specialist with the Washington Commerce Dept	Nebel - Also competitors in area have closed making feedstock prices more competitive. 83 -Moulson - transporting feedstock to plant costs an issue, and the challenge for independent energy developers has been managing the cost of transporting it to a plant	Feedstock for products
Rappaport Energy	Comm	President Randy Nebel	Electricity is currently too low to put in a new boiler, but could move ahead in five years if rates increase.	Reduction in current energy costs
Rappaport Energy	Comm	President Randy Nebel	Rappaport Energy with Longview Fibre mothballed their biomass project.	R+d only, no construction
Rappaport Energy	Comm		Has reduced its product mix form more than 200 products in 2006 to more than 70 currently, with a focus on lightweight and specialty grades.	Economy
Rappaport Energy	Comm			**Import Prices**
Raven Biofuels	Comm			**Funding**
Raven Biofuels	Comm			**R+d only no construction**
Raven Biofuels	Comm			**Criteria changed**
Rentech Rialto	Comm	Rentech statement	Suspended due to lack of Financing, Rentech has announced that it has withdrawn its applications to the U.S. Department of Energy (DOE) for loan guarantees for its Rialto Project	Funding
Rentech Rialto	Comm	Rentech statement	Rentech recently stated that it would no longer pursue project financing for its projects from the DOE loan guarantee programs. Rentech now believes that project financing for the Rialto Project will be unavailable at feasible terms, and the project has been terminated	Technology scale-up to expensive
Gulf Coast Cleveland	Comm			**Funding**
Gulf Coast Cleveland	Comm			**R+d only, no construction**
Gulf Coast Cleveland	Comm			**Criteria changed**
Flambeau River	Comm	CEO Butch Johnson	stated initially to move the project forward, Our true challenge will be funding the	Funding, third party

Biofuels			project stated initially to move the project forward, In Wisconsin, Business North is reporting on difficulties Flambeau River advanced biofuels is having securing a DOE loan guarantee. In Wisconsin, Business North is reporting on difficulties Flambeau River advanced biofuels is having securing a DOE loan guarantee. CEO Butch Johnson and president Bob Byrne of Flambeau River said that the DOE is requiring for a loan guarantee that the project bring its equity component up to 40-50 percent, and requested a loan term of 7 to 12 years. The execs said that the DOE would require all earnings for a period of 10 years, and leave investors with returns that would drop to as low a 6.5 percent per year after taxes. The result? For investors, a "bet on a future stream of cash that doesn't begin for 10 years." "They want the loan tenured somewhere between seven to 12 years, whereas the life expectancy of a plant like this is about 25 years," he explained. To repay that quickly, the biorefinery would be left with little or no operating capital. "If you had a bad year for any reason, or encounter unexpected costs, you'd end up jeopardizing the business by not having a cash cushion," Byrne said. Also, "The government would get everything the plant earns for 10 years. As an investor, you'd get nothing," Byrne said. "It is unlikely you'd get investors willing to bet on a future stream of cash that doesn't begin for 10 years. Most investors aren't that patient." The issue could be a matter of risk aversion, Johnson believes.	contracts, ROI, Investment risk aversion
Flambeau River Biofuels	Comm			**Technology used**
Flambeau River Biofuels	Comm			**Technology scale-up to exp.**

Flambeau River Biofuels	Comm			**feedstock for products**
Flambeau River Biofuels	Comm			**reduction in energy costs**
Flambeau River Biofuels	Comm	President Randy Stoeckel, Park Falls Mayor, Thomas Ratzlaff	The banking industry has changed, we have operated almost like a cash business, and when you have cyclical markets like the paper industry, that makes it very difficult to pay your bills and continue to make the necessary improvements to keep 300 jobs. Ratzlaff- The biorefinery technology worked but the economics did not	Economy
Flambeau River Biofuels	Comm	CEO Butch Johnson	The D.O.E is providing an $80million project grant, leaving investors to contribute $220million…the agency has set terms that private investors would reject. Normally, they want 20% sponsor equity, but they are requesting we bring our equity up to 40% or 50%....it kills your return on investment	Third party contracts, ROI
Flambeau River Biofuels	Comm			**Government Contracts**
Range Fuels Inc.	Comm	Joise Garthwaite	Range Fuels started in 2007 and by 2009 had fallen behind in production goals….only producing a wood alcohol fuel used in racing and industrial applications…the facility had run into technical problems with the gasifiers and the system for feeding in biomass, never producing biomass…Range Fuels closed the plant in January 2010, and filed for bankruptcy September 2011	Project economics / funding/R+D
Range Fuels Inc.	Comm	Mario Parker	According to Mario Parker from Bloomberg in Dec. 2011 stated: "The Range Fuels plant was closed after a technical defect limited it to run at half rates and it produced cellulosic methanol, a fuel the Environmental Protection Agency doesn't consider eligible for use to meet federal biofuel targets….Range Fuels…missed its scheduled payment in Jan, 2011 triggering a default to the Agriculture Department loan…and further funding was suspended form the government….foreclosure ensued.	Technical / Project economics / funding/R+D

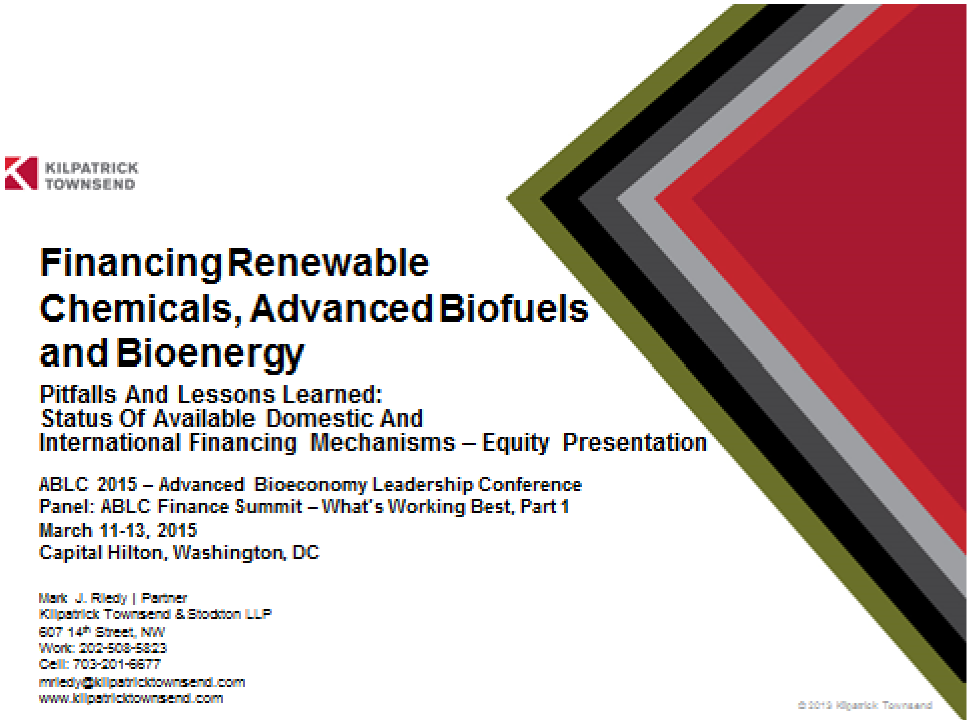
Rentech & ClearFuels Product Demo Unit	Pilot			**Funding**
Rentech & ClearFuels Product Demo Unit	Pilot		...is a direct result of the high cost to develop new technologies relative to current prices, and lack of government incentives and regulations supporting alternative energy, particularly within the U.S., which have made it difficult for the company and other alternative energy companies to commercialize their technologies…	Technology scale-up to expensive
Rentech & ClearFuels Product Demo Unit	Pilot			**Reduction in current energy costs**
Rentech & ClearFuels Product Demo Unit	Pilot	Rentech statement, D. Hunt Ramsbottom Pres.+ CEO Rentech	"Will focus on nearer-term profitable growth opportunities, - believes that company resources are better directed at opportunities that will produce more immediate returns, as it does not expect the market opportunity for alternative energy to improve materially in the U.S. within the next several years. - D. . "while our elimination of these positions is a difficult decision, today's actions will further position Rentech to drive value for shareholders by cutting R&D spending and focusing on business that generate strong returns, with ready markets and certainty of revenue. The investments we are considering have either immediate or near-term profitability, and will meet our disciplined investment criteria	Criteria changed
Rentech & ClearFuels Product Demo Unit	Pilot			**Feedstock for biorefinery**
Rentech & ClearFuels Product Demo Unit	Pilot		Today's actions will further position Rentech to drive value for shareholders by cutting R&D spending and focusing on business that generate strong returns, with ready markets and certainty of revenue. The investments we are considering have either immediate or near-term profitability, and will meet our disciplined investment criteria	investors desiring near term profits

ZeaChem Demo Plant	Pilot			Criteria changed
ZeaChem Demo Plant	Pilot	Carrie Atiyeh, Director of Public Affairs for ZeaChem:	Zeachem recently had to scale back plant operations in Boardman Oregon and let go a number of our valued employees because we were not able to secure a bridge-loan intended to carry ZeaChem into its next funding round. As a result of this unforeseen delays we could not avoid scaling back our operations, which we intend to be a short-term event….Operations have been temporarily minimized at the Boardman plant – it is not being sold	Funding
ZeaChem Demo Plant	Pilot	CEO Jim Imbler, Zeachem	Cellulosic biofuel production in the U.S. is way behind federal targets….We're at the point now where it' not just the technology it is the ability to build it and finance it. There's a different set of skills needed right now. You can have a neat process, but if you cannot build it doesn't do any good	Funding, economics
Coskata Semi-Commercial Facility	Pilot	Coskata statement	We (Coskata) suspended continuous operations at Lighthouse due to the considerable costs associated with such operations and because our key objectives for operating the facility had been met	Funding
Coskata Semi-Commercial Facility	Pilot	Coskata statement	We plan to install a natural gas reformer to ensure a continuous supply of syngas. Consistent with operations at our Lighthouse facility, we expect to operate this reformer on a nearly continuous basis. It is therefore likely that a portion of the ethanol produced at Phase I will not be considered renewable.	Criteria changed
Gulf Coast Energy	Pilot	Michael Fielding of Public Works:	"But now the plant sits idle, unable to secure either private financing or government assistance. A year later, though, he says that "trying to build a fully operational plant that's never been built before was tough." DOE turned down the city and the company's joint request because they cannot prove a commercial plant would be viable.	Funding

8.5 **Appendix E:** Contingency Table Development

According to Stockburger (1998), The rows and columns were summed and termed marginal frequencies. The vertical sum should equal the horizontal sum, equal to a single value (N), to be used later in Chi-Square analysis. The Chi-Square tests were performed on each contingency table by the following sequential steps: *Step 1*, each row value was labeled as observed in the left margin. Separately, each contingency table individual marginal row frequency was multiplied by each marginal column frequency and divided by the contingency N-value. (i.e. (each row * each column) / N-value. The newly calculated numeric value for each cell is placed under the observed numeric value. That value is then labeled in the left column under the word observed as the expected value. *Step 2*, the expected cell frequency was subtracted from the observed cell frequency for each cell. The calculated value was then placed in each cell under the expected value and labeled in the left margin as O-E, observed minus expected. Step 3, the O-E was then squared in each cell and placed under the preceding O-E value and labeled $(O\text{-}E)^2$ in the left margin. *Step 3*, the preceding step was then divided by the expected value for each cell and placed under the preceding value and labeled $(O\text{-}E)^2/E$. Step 4, each $(O\text{-}E)^2/E$ (Chi-Square statistic) was added together for a single value to be used in step 5. *Step 4*, the degrees of freedom (df) was then determined by multiplying one minus the number of rows times one minus the number of columns. *Step 5*, the N-value and the df-value were then used to look up the critical value of to determine the significance level. *Step 6*, that significance level was compared to the initial alpha level. *Step 7*, If the alpha level was higher than the significance level the null was rejected, otherwise it was accepted for each contingency table.

8.6 Appendix F: Financing Renewable Chemicals, Advanced Biofuels and Bioenergy, By Mark Riedy, Partner Kilpatrick Townsend and Stockton LLP. ACOR founder.



8.7 Appendix G: RFS Yearly Requirements with Gas and Diesel Consumption Yearly

Table 20 EPA Finalized RVO and U.S. fuel consumption in billion gallons per year (E.P.A 2016)

	Actual Conventional	2007 RFS Proposed Conventional	Actual Biomass Based Diesel	2007 RFS Proposed BBD	Actual Cellulosic Biofuel	2007 RFS Proposed CB	Actual Advanced Biofuel	2007 RFS Proposed Advanced	US Estimated Gasoline available for blending (E10)	US Estimated Diesel available for blending (E10)
2005		0		0		0		0		
2005			0		0		0		140.41	38.05
2006		4		0		0		0		
2006			0		0		0			
2006									141.84	39.12
2007		4.7		0		0		0		
2007	2.78		0		0		0			
2007									142.35	39.80
2008		9		0		0		0		
2008	9		0		0		0			
2008									138.18	37.53
2009		10.5		0.5		0		0.1		
2009	10.5		0.5		0		0.6			
2009									137.92	34.15
2010		12		0.65		0.1		0.2		
2010	12		0.65		0.1		0.95			
2010									137.90	35.58
2011		12.6		0.8		0.25		0.3		
2011	12.6		0.8		0.0066		1.35			
2011									134.18	36.16
2012		13.2		1		0.5		0.5		
2012	13.2		1		0.0085		2			
2012									133.46	36.34
2013		13.8		1		1		0.75		
2013	13.8		1.28		0.006		2.75			
2013									134.50	53.60
2014		14.4		1		1.75		1		
2014	13.61		1.63		0.033		2.67			
2014									135.20	55.30
2015		15		1		3		1.5		
2015	14.05		1.73		0.123		2.88			
2015									140.30	56.60
2016		15		1		4.25		2		
2016	14.5		1.9		0.23		3.61			
2016		15		1		5.5		2.5		
2017										
2018		15		1		7		3		
2018										
2019		15		1		8.5		3.5		
2019										
2020		15		1		10.5		3.5		
2020										
2021		15		1		13.5		3.5		
2021										
2022		15		1		16		4		

8.8 Appendix H: The Code of Federal Regulations for Advanced Biofuel Projects

The Code of Federal Regulations Section 80-Chapter1-Subchapter C-Part 80- Subpart M, for the Renewable Fuel Standard is divided as follows: source: GPO (2015)

80.1400 Applicability.

80.1401 Definitions.

80.1402 [Reserved]

80.1403 Which fuels are not subject to the 20% GHG thresholds?

80.1404 [Reserved]

80.1405 What are the Renewable Fuel Standards?

80.1406 Who is an obligated party under the RFS program?

80.1407 How are the renewable volume obligations calculated?

80.1408-80.1414 [Reserved]

80.1415 How are equivalence values assigned to renewable fuel?

80.1416 Petition process for evaluation of new renewable fuels pathways.

80.1417-80.1424 [Reserved]

80.1425 Renewable Identification Numbers (RINs).

80.1426 RINs generated and assigned to batches of renewable fuel by renewable fuel producers or importers?

80.1427 How are RINs used to demonstrate compliance?

80.1428 General requirements for RIN distribution.

80.1429 Requirements for separating RINs from volumes of renewable fuel.

80.1430 Requirements for exporters of renewable fuels.

§80.1431 Treatment of invalid RINs.

80.1432 Reported spillage or disposal of renewable fuel.

80.1433-80.1439 [Reserved]

80.1440 What are the provisions for blenders who handle and blend less than 250,000 gallons of renewable fuel per year?

80.1441 Small refinery exemption.

80.1442 What are the provisions for small refiners under the RFS program?

80.1443 What are the opt-in provisions for noncontiguous states and territories?

80.1444-80.1448 [Reserved]

80.1449 What are the Production Outlook Report requirements?

80.1450 What are the registration requirements under the RFS program?

80.1451 What are the reporting requirements under the RFS program?

80.1452 What are the requirements related to the EPA Moderated Transaction System (EMTS)?

80.1453 What are the product transfer document (PTD) requirements for the RFS program?

80.1454 What are the recordkeeping requirements under the RFS program?

80.1455 What are the small volume provisions for renewable fuel production facilities and importers?

8.9 Appendix I: Internal Barrier Contingency Analysis

The agreement, disagreement, and unsure response rates for product development from Table 21 are; (strongly agree 4 + agree 13 = 40% agreement), (strongly disagree 2 + disagree 11 = 31% disagreement), Unsure 29%, out of 43 responses. The overall group response that product development is a barrier: Biofuel 38% agreement, and 38% disagreement. Government group 36% agreement, and 45% disagreement. Others 47% agreement, and 7% disagreement.

Table 21 Contingency for combined groups by product development (Internal)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 50.00%, 6.25%	6, 54.55%, 37.50%	3, 25.00%, 18.75%	5, 38.46%, 31.25%	1, 25.0%, 6.25%	16	**38**	**38**
Governement	1, 50.00%, 9.09%	4, 36.36%, 36.36%	2, 16.67%,18.18%	4, 30.77%, 36.36%	0. 0.00%, 0.00%	11	**36**	**45**
Others	0. 0.00%, 0.00%	1, 9.09%, 6.67%	7, 58.33%, 46.67%	4, 30.77%, 26.67%	3, 75.00%, 20.00%	15	**47**	**7**
Column Total:	2	11	12	13	4	**42**		
% response:	**31%**		**29%**	**40%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1022	Pearson	10.445	0.2351	Fisher's Exact:	0.0000102500	0.2036

The agreement, disagreement, and unsure response rates for byproduct distribution from Table 22 are; (strongly agree 4 + agree 6 = 23% agreement), (disagreement strongly disagree 3 + disagree 15= 42% disagreement), unsure 35%, out of 43 responses. The overall group response that byproduct distribution is a barrier: biofuel 19% agreement, and 63% disagreement. Government group 27% agreement, and 27% disagreement. Others 25% agreement, and 31% disagreement.

Table 22 Contingency for combined groups by byproducts distribution (Internal)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	2, 66.67%, 12.50%	8, 53.33%, 50.00%	3, 20.00%, 18.75%	1, 16.67%, 6.25%	2, 50.00%, 12.50%	16	**19**	**63**
Governement	0, 0.00%, 0.00%	3, 20.00%, 27.27%	5, 33.33%, 45.45%	3, 50.00%, 27.27%	0, 0.00%, 0.00%	11	**27**	**27**
Others	1, 33.33%, 6.25%	4, 26.67%, 25.00	7, 46.67%, 43.75%	2, 33.33%, 12.50%	2, 33.33%, 12.50%	16	**25**	**31**
Column Total:	3	15	15	6	4	**43**		
% response:	**42%**		**35%**	**23%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0834	Pearson	8.543	0.3823	Fisher's Exact:	0.0000253500	0.4186

The agreement, disagreement, and unsure response rates for Byproduct Marketing from Table 23 are; (strongly agree 4 + agree 10 = 33% agreement), (strongly disagree 4 + disagree 12 = 37% disagreement), unsure 30%, out of 43 responses. The overall group response that Byproduct Marketing is a barrier: Biofuel 13% agreement, and 63% disagreement. Government group 64% agreement, and 18% disagreement. Others 31% agreement, and 25% disagreement.

Table 23 Contingency for combined groups by byproducts marketing (Internal)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	3, 75.00%, 18.75%	7, 58.33%, 43.75%	4, 30.77%, 25.00%	1, 10.00%, 6.25%	1, 25.00%, 6.25%	16	**13**	**63**
Governement	0, 0.00%, 0.00%	2, 16.67%, 18.18%	2, 15.38%, 18.18%	6, 60.00%, 54.55%	1, 25.00%, 9.09%	11	**64**	**18**
Others	1, 25.00%, 6.25%	3, 25.00%, 18.75%	7, 53.85%, 18.18%	3, 330.00%, 18.75%	2, 50.00%, 12.50%	16	**31**	**25**
Column Total:	4	12	13	10	4	**43**		
% response:	**37%**		**30%**	**33%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1076	Pearson	13.749	0.0886	Fisher's Exact:	0.0000023770	0.1101

The agreement, disagreement, and unsure response rates for Coproducts Marketing from Table 24 are; (strongly agree 2 + agree 10 = 29% agreement), (strongly disagree 2 + disagree 16 = 43% disagreement), unsure 30%, out of 43 responses. The overall group response that coproducts Marketing is a barrier: Biofuel 13% agreement, and 69% disagreement. Government group 36% agreement, and 27% disagreement. Others 40% agreement, and 27% disagreement.

Table 24 Contingency for combined groups by coproducts marketing (internal)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 50.00%, 6.25%	10, 62.50%, 62.50%	3, 25.00%, 18.75%	1, 10.00%, 6.25%	1, 50.00%, 6.25%	16	**13**	**69**
Governement	0, 0.00%, 0.00%	3, 18.75%, 27.27%	4, 33.33%, 36.36%	4, 40.00%, 36.36%	0, 0.00%, 0.00%	11	**36**	**27**
Others	1, 50.00%, 6.67%	3, 18.75%. 20.00%	5, 41.67%, 33.33%	5, 50.00%, 33.33%	1, 50.00%, 6.67%	15	**40**	**27**
Column Total:	2	16	12	10	2	**42**		
% response:	**43%**		**29%**	**29%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
42	8	0.1007	Pearson	9.819	0.28%	Fisher's Exact:	0.0000173900	0.172

The agreement, disagreement, and unsure response rates for coproducts distribution from Table 25 are; (strongly agree 3 + agree 7 = 24% agreement), (strongly disagree 2 + disagree 15 = 40% disagreement), unsure 36%, out of 43 responses. The overall group response that coproducts distribution is a barrier: Biofuel 13% agreement, and 56% disagreement. Government group 27% agreement, and 27% disagreement. Others 33% agreement, and 33% disagreement.

Table 25 Contingency for combined groups by coproducts distribution (Internal)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 50.00%, 6.25%	8, 53.33%, 50.00%	5, 33.33%, 31.25%	1, 14.29%, 6.25%	1, 33.33%, 6.25%	16	**13**	**56**
Governement	0, 0.00%, 0.00%	3, 20.00%, 27.27%	5, 33.33%, 45.45%	2, 28.57%, 18.18%	1, 33.33%, 9.09%	11	**27**	**27**
Others	1, 50.00%, 6,67%	4, 26.67%, 26.67%	5, 33.33%, 33.33%	4, 57.14%, 26.67%	1, 33.33%, 6.67%	15	**33**	**33**
Column Total:	2	15	15	7	3	**42**		
% response:	**40%**		**36%**	**24%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
42	8	0.0457	Pearson	4.633	0.7960	Fisher's Exact:	0.000167	0.8063

The agreement, disagreement, and unsure response rates for continuous project growth from Table 26 are; (strongly agree 3 + agree 8 = 26% agreement), (strongly disagree 1 + disagree 8 = 21% disagreement), unsure 53%, out of 43 responses. The overall group response that continuous project growth is a barrier: Biofuel 38% agreement, and 19% disagreement. Government group 9% agreement, and 36% disagreement. Others 25% agreement, and 13% disagreement.

Table 26 Contingency for combined groups by continuous project growth (Internal)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	2, 25.00%, 12.50%	7, 30.43%, 43.75%	5, 62.50%, 31.25%	1, 33.33%, 6.25%	16	**38**	**19**
Governement	0, 0.00%, 0.00%	4, 40.00%, 36.36%	6, 26.09%, 54.55%	1, 12.50%, 9.09%	0, 0.00%, 0.00%	11	**9**	**36**
Others	0, 0.00%, 0.00%	2, 25.00%, 12.50%	10, 43.48%, 62.50%	2, 25.00%, 12.50%	2, 66.67%, 12.50%	16	**25**	**13**
Column Total:	1	8	23	8	3	**43**		
% response:	**21%**		**53%**	**26%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0845	Pearson	8.432	0.3924	Fisher's Exact:	0.00012	0.4774

The Agreement, Disagreement, and Unsure response rates for management from Table 27 are; (strongly agree 3 + agree 8 = 26% agreement), (strongly disagree 1 + disagree 8 = 21% Disagreement), unsure 53%, out of 43 responses. The overall group response that management is a barrier: Biofuel 38% agreement, and 19% disagreement. Government group 9% agreement, and 36% disagreement. Others 25% agreement, and 13% disagreement.

Table 27 Contingency for combined groups by management (Internal)

Column Total:	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	3, 100%, 18.75%	5, 33.33%, 31.25%	5, 45.45%, 31.25%	2, 18,18%, 12.50%	1, 33.33%, 6.25%	16	**19**	**50**
Governement	0, 0.00%, 0.00%	6, 40.00%, 54.55%	1, 9.09%, 9.09%	4, 36.36%, 36.36%	0, 0.00%, 0.00%	11	**36**	**55**
Others	0, 0.00%, 0.00%	4, 26.67%, 25.00%	5, 45.45%, 31.25%	5, 45.45%,31.25%	2, 66.67%, 12.50%	16	**44**	**25**
Column Total:	3	15	11	11	3	**43**		
% response:	**42%**		**26%**	**33%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.10955	Pearson	11.612	0.1694	Fisher's Exact:	0.00001051	0.2292

The agreement, disagreement, and unsure response rates for strategy from Table 28 are; (strongly agree 5 + agree 12 = 40% agreement), (strongly disagree 3 + disagree 14 = 40% disagreement), unsure 21%, out of 43 responses. The overall Group response that strategy is a barrier: Biofuel 31% agreement, and 56% disagreement. Government group 45% agreement, and 27% disagreement. Others 44% agreement, and 31% disagreement.

Table 28 Contingency for combined groups by strategy (Internal)

Column Total:	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	2, 66.67%, 12.50%	7, 50.00%, 43.75%	2, 22.22%, 12.50%	4, 33.33%, 25.00%	1, 20.00%, 6.25%	16	**31**	**56**
Gov / Academia	1, 33.33%, 9.09%	2, 14.29%, 18.18%	3, 33.33%, 27.27%	4, 33.33%, 36.36%	1, 20.00%, 9.09%	11	**45**	**27**
Others	0, 0.00%, 0.00%	5, 35.71%, 31.25%	4, 44.44%, 25.00%	4, 33.33%, 25.00%	3, 60.00%, 18.75%	16	**44**	**31**
Column Total:	3	14	9	12	5	**43**		
% response:	**40%**		**21%**	**40%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0524	Pearson	5.626	0.6891	Fisher's Exact:	0.00005461	0.7203

The agreement, disagreement, and unsure response rates for technology conversion rate from Table 29 are; (strongly agree 3 + agree 25 = 65% agreement), (strongly disagree 1 + disagree 8 = 21% disagreement), unsure 14%, out of 43 responses. The overall group response that technology conversion rate is a barrier: Biofuel 50% agreement, and 38% disagreement. Government group 73% agreement, and 27% disagreement. Others 75% agreement, and 0% disagreement.

Table 29 Contingency for combined groups by technology conversion rate (Internal)

Column Total:	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	5, 62.50%, 31.25%	2, 33.33%, 12.50%	7, 28.00%, 43.75%	1, 33.33%, 6.25%	16	**50**	**38**
Gov / Academia	0, 0.00%, 0.00%	3, 37.50%, 27.27%	0, 0.00%, 0.00%	7, 28.00%, 63.64%	1, 33.33%, 9.09%	11	**73**	**27**
Others	0, 0.00%, 0.00%	0, 0.00%, 0.00%	4, 66.67%, 25.00%	11, 44.00%, 68.75%	1, 33.33%, 6.25%	16	**75**	**0**
Column Total:	1	8	6	25	3	**43**		
% response:	**21%**		**14%**	**65%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1458	Pearson	10.474	0.2334	Fisher's Exact:	0.0000223	0.1017

The agreement, disagreement, and unsure response rates for technology high titer and yield per ton from Table 30 are; (strongly agree 7 + agree 20 = 63% agreement), (disagreement strongly disagree 1 + disagree 6 = 16% disagreement), unsure 21%, out of 43 responses. The overall group response that technology high titer and yield per ton is a barrier: Biofuel 56% agreement, and 25% disagreement. Government group 64% agreement, and 27% disagreement. Others 69% agreement, and 0% disagreement.

Table 30 Contingency for combined groups by Technology High Titer and yield (Internal)

Column Total:		Strongly Disagree	Disagree		Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel		1, 100%, 6.25%	3, 50.00%, 18.75%		3, 33.33%, 18.75%	8, 40.00%, 50.00%	1, 14.29%, 6.25%	16	**56**	**25**
Gov / Academia		0, 0.00%, 0.00%	3, 50.00%, 27.27%		1, 11.11%, 9.09%	5, 25.00%, 45.45%	2, 28.57%, 18.18%	11	**64**	**27**
Others		0, 0.00%, 0.00%	0, 0.00%, 0.00%		5, 55.56%, 31.25%	7, 35.00%, 43.75%	4, 57.14%, 25.00%	16	**69**	**0**
Column Total:		1	6		9	20	7	**43**		
% response:		16%			21%	63%				
N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P		
43	8	0.0995	Pearson	9.001	0.3422	Fisher's Exact:	0.00003054	0.2968		

8.10 Appendix J: External Barrier Contingency Analysis

Contingency for combined groups by the 13 external categories: funding, competitors, USDA pathway process, RFS policy standards, and waiver credits are the external categories of significance, and are examined individually as follows.

The agreement, disagreement, and unsure response rates for Funding from Table 31 are; (strongly agree 63 + agree 28 = 91% agreement), disagreement 0%, unsure 11%, out of 43 responses. The overall response is indicative of biofuel 100%, government group 91%, and others, 8% in agreement that Funding is a barrier, and further verified by receiving zero disagree responses.

Table 31 Contingency for combined groups by Funding (External)

LIKERT Scale: Count, Column%, Row %		Strongly Disagree	Disagree		Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel					0, 0.00%, 0.00%	2, 16.67%, 12.50%	14, 51.85%, 87.50%	16	**100**	**0**
Government					1, 25.00%, 9.09%	5, 41.67%, 45.45%	5, 18.52%, 45.45%	11	**91**	**0**
Others					3, 75.00%, 18.75%	5, 41.67%, 31.25%	8, 29.63%, 50.00%	16	**81**	**0**
Column Total:					4	12	27	**43**		
% Response:		0%	0%		9%	91%				
N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P		
43	4	0.1254	Pearson	8.162	0.0858	Fisher's Exact:	0.000497	0.0676		

The agreement, disagreement, and unsure response rates for production tax credits from Table 32 are; (strongly agree 5 + agree 16 = 49% agreement), (strongly disagree 2 + disagree 8 = 23% disagreement), unsure 28%, out of 43 responses. The overall group response that production tax credits are a barrier: biofuel 63% agreement, and 25% disagreement. Government group 36% agreement, and 36% disagreement. Others 44% agreement, and 13% disagreement.

Table 32 Contingency for combined groups by PTC (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 50.00%, 6.25%	3, 37.50%, 18.75%	2, 16.67%, 12.50%	8, 50.00%, 50.00%	2, 40.00%, 12.50%	16	**63**	**25**
Gov/Academia	1, 50.00%, 9.09%	3, 37.50, 27.27%	3, 25.00%, 27.27%	3, 18.75%, 27.27%	1, 20.00%, 9.09%	11	**36**	**36**
Others	0, 0.00%, 0.0%	2, 25.00%, 12.50%	7, 58.33%, 43.75%	5, 31.25%, 31.25%	2, 40.00%, 12.50%	16	**44**	**13**
Column Total:	2	8	12	16	5	**43**		
% Response:	**23%**		**28%**	**49%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0555	Pearson	6.095	0.6366	Fisher's Exact:	0.00005545	0.6131

The agreement, disagreement, and unsure response rates for suppliers from Table 33 are; (strongly agree 2 + agree 8 = 23% agreement), (strongly disagree 1 + disagree 16 = 40% disagreement), unsure 37%, out of 43 responses. The overall group response that suppliers are a barrier: biofuel 31% agreement, and 44% disagreement. Government Group 27% agreement, and 36% disagreement. Others 13% agreement, and 38% disagreement.

Table 33 Contingency for combined groups by suppliers (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	6, 37.50%, 37.50%	4, 25.00%, 25.00%	3, 37.50%, 18.75%	2, 100%, 12.50%	16	**31**	**44**
Gov/Academia	0, 0.00%, 0.00%	4, 25.00%, 36.36%	4, 25.00%, 36.36%	3, 37.50%, 27.27%	0, 0.00%, 0.00%	11	**27**	**36**
Others	0, 0.00%, 0.00%	6, 37.50%, 37.50%	8, 50.00%, 50.00%	2, 25.00%, 12.50%	0, 0.00%, 0.00%	16	**13**	**38**
Column Total:	1	16	16	8	2	**43**		
% Response:	**40%**		**37%**	**23%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0732	Pearson	7.177	0.5177	Fisher's Exact:	0.000245	0.6844

The agreement, disagreement, and unsure response rates for competitors from Table 34 are; (strongly agree 6 + agree 6 = 28% agreement), (disagreement strongly disagree 3 + disagree 21 = 56% disagreement), unsure 16%, out of 43 responses. The overall group response that competitors are a barrier: biofuel 19% agreement, and 75% disagreement. Government group 45% agreement, and 45% disagreement. Others 25% agreement, and 44% disagreement.

Table 34 Contingency for combined groups by competitors (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	3, 100%, 18.75%	9, 42.86%, 56.25%	1, 14.29%, 6.25%	2, 33.33%, 12.50%	1, 16.67%, 6.25%	16	**19**	**75**
Gov/Academia	0, 0.00%, 0.00%	5, 23.81%, 45.45%	1, 14.29%, 9.09%	1, 16.67%, 9.09%	4, 66.67%, 36.36%	11	**45**	**45**
Others	0, 0.00%, 0.00%	7, 33.33%, 43.75%	5, 71.43%, 31.25%	3, 50.00%, 18.75%	1, 16.67%, 6.25%	16	**25**	**44**
Column Total:	3	21	7	6	6	**43**		
% Response:	**56%**		**16%**	**28%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1228	Pearson	14.688	0.0655	Fisher's Exact:	0.00000509	0.1308

The agreement, disagreement, and unsure response rates for DOE pathway process from Table 35 are; (strongly agree 6 + agree 10 = 37% agreement), (strongly disagree 3 + disagree 5 = 19% disagreement), unsure 44%, out of 43 responses. The overall group response that DOE pathway process is a barrier: biofuel 50% agreement, and 19% disagreement. Government group 18% agreement, and 36% disagreement. Others 38% agreement, and 6% disagreement.

Table 35 Contingency for combined groups by DOE pathway process (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	2, 66.67%, 12.50%	1, 20.00%, 6.25%	5, 26.32%, 31.25%	3, 30.00%, 18.75%	5, 83.33%, 31.25%	16	**50**	**19**
Gov/Academia	1, 33.33%, 9.09%	3, 60.00%, 27.27%	5, 26.32%, 45.45%	2, 20.00%, 18.18%	0, 0.00%, 0.00%	11	**18**	**36**
Others	0, 0.00%, 0.00%	1, 20.00%, 6.25%	9, 47.37%, 56.25%	5, 50.00%, 31.25%	1, 16.67%, 6.25%	16	**38**	**6**
Column Total:	3	5	19	10	6	**43**		
% Response:	**19%**		**44%**	**37%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1137	Pearson	6	0.131	Fisher's Exact:	0.000006108	0.1599

The agreement, disagreement, and unsure response rates for EPA pathway process from Table 36 are; (strongly agree 15 + agree 9 = 56% agreement), (strongly disagree 1 + disagree 3 = 9% disagreement), unsure 35%, out of 43 responses. The overall group response that EPA pathway process is a barrier: biofuel 75% agreement, and 13% disagreement. Government group 36% agreement, and 18% disagreement. Others 50% agreement, and 0% disagreement.

Table 36 Contingency for combined groups by EPA pathway process (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	1, 33.33%, 6.25%	2, 13.33%, 12.50%	5, 55.56%, 31.25%	7, 46.67%, 43.75%	16	**75**	**13**
Gov/Academia	0, 0.00%, 0.00%	2, 66.67%, 18.18%	5, 33.33%, 45.45%	1, 11.11%, 9.09%	3, 20.00%, 27.27%	11	**36**	**18**
Others	0, 0.00%, 0.00%	0, 0.00%, 0.00%	8, 33.33%, 50.00%	3, 33.33%, 18.75%	5, 33.33%, 31.25%	16	**50**	**0**
Column Total:	1	3	15	9	15	**43**		
% Response:	**9%**		**35%**	**56%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1059	Pearson	10.685	0.2202	Fisher's Exact:	0.0000213	0.1753

The agreement, disagreement, and unsure response rates for renewable volume obligation from Table 37 are; (strongly agree 18 + agree 7 = 58% agreement), (strongly disagree 1 + disagree 6 = 16% disagreement), unsure 26%, out of 43 responses. The overall group response that renewable volume obligation is a barrier: biofuel 75% agreement, and 13% disagreement. Government group 45% agreement, and 27% disagreement. Others 50% agreement, and 13% disagreement.

Table 37 Contingency for combined groups by RVO (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100.00%,6.25%	1, 16.67%, 6.25%	2, 18.18%, 12.50%	2, 28.57%, 12.50%	10, 55.56%, 62.50%	16	**75**	**13**
Gov/Academia	0, 0.00%, 0.00%	3, 50.00%, 27.27%	3, 27.27%, 27.27%	3, 42.86%, 27.27%	2, 11.11%, 18.18%	11	**45**	**27**
Others	0, 0.00%, 0.00%	2, 33.33%, 12.50%	6, 54.55%, 37.50%	2, 28.57%, 12.50%	6, 33.33%, 37.50%	16	**50**	**13**
Column Total:	1	6	11	7	18	**43**		
% response:	**16%**		**26%**	**58%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0882	Pearson	10.033	0.2627	Fisher's Exact:	0.00002063	0.2399

The agreement, disagreement, and unsure response rates for renewable identification numbers from Table 38 are; (strongly agree 12 + agree 6 =42% agreement), (strongly disagree 1 + disagree 13 = 33% disagreement), unsure 26%, out of 43 responses. The overall group response that renewable identification numbers are a barrier: biofuel 56% agreement, and 25% disagreement. Government group 18% agreement, and 55% disagreement. Others 44% agreement, and 25% disagreement.

Table 38 Contingency for combined groups by RINs (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	3, 28.08%, 18.75%	3, 27.27%, 18.75%	2, 33.33%, 12.50%	7, 58.33%, 43.75%	16	**56**	**25**
Gov/Academia	0,0.00%, 0.00%	6, 46.15%, 54.55%	3, 27.27%, 27.27%	0, 0.00%, 0.00%	2, 16.67%, 18.18%	11	**18**	**55**
Others	0,0.00%, 0.00%	4, 30.77%, 25.00%	5, 45.45%,31.25%	4, 66.67%, 25.00%	3, 25.00%, 18.75%	16	**44**	**25**
Column Total:	1	13	11	6	12	**43**		
% response:	**33%**		**26%**	**42%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0945	Pearson	10..437	0.2357	Fisher's Exact:	0.000019	0.2659

The agreement, disagreement, and unsure response rates for energy costs from Table 39 are; (strongly agree 7 + agree 14 = 50% agreement), (strongly disagree 3 + disagree 12 = 36% disagreement), unsure 14%, out of 42 responses. The overall group response that energy costs are a barrier: biofuel 50% agreement, and 50% disagreement. Government group 55% agreement, and 27% disagreement. Others 47% agreement, and 27% disagreement.

Table 39 Contingency for combined groups by energy costs (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	2, 66.67%, 12.50%	6, 50.00%, 37.50%	0, 0.00%, 0.00%	6, 42.86%, 37.50%	2, 28.57%, 12.50%	16	**50**	**50**
Gov/Academia	0 , 0.00%, 0.00%	3, 25.00%, 27.27%	2, 33.33%, 18.18%	3, 21.43%, 27.27%	3, 42.86%, 27.27%	11	**55**	**27**
Others	1, 33.33%, 6.67%	3, 25.00%, 20.00%	4, 66.67%, 26.67%	5, 35.71%, 33.33%	2, 28.57%, 13.33%	15	**47**	**27**
Column Total:	3	12	6	14	7	**42**		
% response:	**36%**		**14%**	**50%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.0801	Pearson	7.498	0.484	Fisher's Exact:	0.000023	0.4843

The agreement, disagreement, and unsure response rates for third party relationships from Table 40 are; (strongly agree 3 + agree 12 = 35% agreement), (strongly disagree 1 + disagree 10 = 26% disagreement), unsure 40%, out of 43 responses. The overall group response that third party relationships are a barrier: biofuel 38% agreement, and 38% disagreement. Government group 36% agreement, and 36% disagreement. Others 31% agreement, and 6% disagreement.

Table 40 Contingency for combined groups by third party relationships (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	5, 50.00%, 31.25%	4, 23.53%, 25.00%	4, 33.33%, 25.00%	2, 66.67%, 12.50%	16	**38**	**38**
Gov/Academia	0, 0.00%, 0.00%	4, 40.00%, 36.36%	3, 17.65%, 27.27%	4, 33.33%, 36.36%	0, 0.00%, 0.00%	11	**36**	**36**
Others	0, 0.00%, 0.00%	1, 10.00%, 6.25%	10, 58.52%, 62.50%	4, 33.33%, 25.00%	1, 33.33%, 6.25%	16	**31**	**6**
Column Total:	1	10	17	12	3	**43**		
% response:	**26%**		**40%**	**35%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1011	Pearson	10.195	0.2516	Fisher's Exact:	0.000026	0.2027

The agreement, disagreement, and unsure response rates for USDA pathway process from Table 41are; (strongly agree 12 + agree 23 = 35% agreement), disagreement 21%, Unsure 44%, out of 43 responses. The overall response is indicative of group response that USDA Pathway is a barrier: biofuel 56% agreement, and 31% disagreement. Government group 9% agreement, and 27% disagreement. Others 31% agreement, and 6% disagreement.

Table 41 Contingency for combined groups by USDA pathway process (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel		5, 55.56%, 31.25%	2, 10.53%, 12.50%	7, 70.00%, 43.75%	2, 40.00%, 12.50%	16	**56**	**31**
Government		3, 33.33%, 27.27%	7, 36.84%, 63.63%	0, 0.00%, 0.00%	1, 20.00%, 9.09%	11	**9**	**27**
Others		1, 11.11%, 6.25%	10, 52.63%, 62.50%	3, 30.00%, 18.75%	2, 40.00%, 12.50%	16	**31**	**6**
Column Total:		9	19	10	5	**43**		
% Response:	**0%**	**21%**	**44%**	**35%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	6	0.1621	Pearson	14.134	0.0282	Fisher's Exact:	0.0000017450	0.0099

The agreement, disagreement, and unsure response rates for RFS Policy Standards from Table 42 are; (strongly agree 42 + agree 16 = 58% agreement), (strongly disagree 2 + disagree 19 = 21% disagreement), unsure 21%, out of 43 responses. The overall group response that RFS Policy Standards are a barrier: biofuel 56% agreement, and 38% disagreement. Government group 64% agreement, and 18% disagreement. Others 56% agreement, and 6% disagreement.

Table 42 Contingency for combined groups by RFS Policy Standards (External)

LIKERT Scale: Count, Column%,	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 100%, 6.25%	5, 62.50%, 31.25%	1, 11.11%, 6.25%	1, 14.29%, 6.25%	8, 44.44%, 50.00%	16	**56**	**38**
Government	0, 0.00%, 0.00%	2, 25.00%, 18.18%	2, 22.22%, 18.18%	5, 71.43%, 45.45%	2, 11.11%, 18.18%	11	**64**	**18**
Others	0, 0.00%, 0.00%	1, 12.50%, 6.25%	6, 66.67%, 37.50%	1, 14.29%, 6.25%	8, 44.44%, 50.00%	16	**56**	**6**
Column Total:	1	8	9	7	18	**43**		
% Response	**21%**		**21%**	**58%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1483	Pearson	17.871	0.0222	Fisher's Exact:	0.0000010130	0.0198

The agreement, disagreement, and unsure response rates for waiver credits from Table 43 are; (strongly agree 8 + agree 10 = 42% agreement), (strongly disagree 1 + disagree 6 = 16% disagreement), unsure 42%, out of 43 responses. The overall group response that waiver credits are a barrier: biofuel 63% agreement, and 6% disagreement. Government group 18% agreement, and 36% disagreement. Others 38% agreement, and 13% disagreement.

Table 43 Contingency for combined groups by waiver credits (External)

LIKERT Scale: Count, Column%, Row %	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Responses	% Agree	% Disagree
Biofuel	1, 1.00%,6.25%	0, 0.00%, 0.00%	5, 27.78%, 31.25%	7, 70.00%, 43.75%	3, 37.50%, 18.75%	16	**63**	**6**
Governement	0, 0.00%, 0.00%	4, 66.67%, 36.36%	5, 27.78%, 45.45%	1, 10.00%, 9.09%	1, 12.50%, 9.09%	11	**18**	**36**
Others	0, 0.00%, 0.00%	2, 33.33%, 12.50%	8, 44.44%, 50.00%	2, 20.00%, 12.50%	4, 50.00%, 25.00%	16	**38**	**13**
Column Total:	1	6	18	10	8	**43**		
% response:	**16%**		**42%**	**42%**				

N	DF	RSquare (U)	Test	ChiSquare	Prob>ChiSq	Test	Table Probability (P)	Two-sided Prob ≤ P
43	8	0.1299	Pearson	14.143	0.0781	Fisher's Exact:	0.0000048220	0.0774

8.11 **Appendix K: Advanced Biofuel Industry Group Public Statements**

On July 23, 2013 at the Capitol in Washington DC, the Energy and Commerce Committee convened to discuss the RFS uncertainty and the theoretical E10 blend wall with: "*American Petroleum Institute, American Fuel & Petrochemical Manufacturers, Renewable Fuels Association, Advanced Biofuels Association, Union of Concerned Scientists Clean Vehicles Program, Growth Energy, The Alliance of Automobile Manufacturers, Briggs & Stratton Corporation, AAA, Society of Independent Gasoline Marketers of America and National Association of Convenience Stores, National Biodiesel Board, National Corn Growers Association, National Chicken Council, National Council of Chain Restaurants, Environmental Working Group, and Professor Chris Hurt from Purdue's Department of Agricultural Economics*" Lane (2013b).

This meeting provided the government with many factors that are impeding the advanced biofuels industry. Here are the top 10: 1) Various associations are divided between a legislative or an administrative RFS policy fix, such as releasing RVOs on time as mandated. 2) Declining gasoline usage is lowering the theoretical blend wall and its' impact on Total renewable fuels (D3 – D7codes). Impacting the market conditions of actual demand for the renewable for blending. 3) D6 is approaching the 15BG blend wall cap, leading to accelerated rate within the oil industry to purchase RINs in anticipation of increased demand to secure RINs 4) Entry into the biofuel market is voluntary at your own risk. 5) Republicans openly stated that in 2013 there are not enough votes for a full RFS repeal. 6) Republicans believe repeal of the RFS would crush the advanced biofuel industry 7) Congress is interested in working with the industry, but not currently increasing the blend wall 8) Democrats suggested lowering the RVO in the D3, D7 categories to reflect current capabilities by 2022. 9) E15 and E85 are not popular with the public. Current U.S. infrastructure lacks demand and enough vehicles for Flex-fuel E85 fueling stations vehicles keeping E85 from being competitive with gasoline. 10) The RFS certainty is needed to drive the market in the long-term to develop a competitive higher octane infrastructure.

In 2014 and 2015 in Washington DC, the Advanced Bioeconomy Leadership Conference (ABLC) was held. Increasing CEO industry leader attendance by year is noted. The following list of attendees represents a broad spectrum of the bioeconomy promoting alternative biofuels. *"The Top 100 People in Bioenergy, the leaders of the 50 Hottest Companies in Bioenergy, The leaders of the 30 Hottest Companies in Renewable Chemicals and Biobased materials, the heads of every major bioeconomy industry trade association, the most active strategic and venture investors; the top public equity analysts; plus, institutional investors, sovereign wealth funds, hedge funds, private equity, Policy leaders from the legislature; DOE, USDA, EPA and the Pentagon; plus state-level officials in development and policy; plus, global leadership from the UN and other international agencies, Supply chain leaders — professional and technical services, feedstock's, technology and more. The currency of compliance. Companies blend into gasoline or diesel fuel making two marketable commodities: 1) blended fuel, 2) the separated RIN*" Lane (2015a).

Dr. Wallace Tyner, Purdue at the ABLC conference 2015, "*EPA 2014 proposal, deals with most of the problems on the RFS. Biofuel advocates say it goes too far in accommodating the blend wall. Interest groups wanting to kill the RFS say it does not go far enough*." He further provided the following 9 factors as major barriers impeding the biofuel industry: 1) The blend wall and reduction in the amount available for blending, 2) Transportation structure has to be improved to make higher blending desired. 3) Exploration into developing aviation biofuels for the DOD for survival. 4) 8BG shortfall is due to the recession and consuming less fuel, more efficient vehicles, and better standards. 5) More capacity than capability. 6) *"When the market perceives the blend wall to be binding, RIN prices rise. With higher RIN prices, it could become attractive to market more e85." 7)* RIN prices fluctuating with supply and demand, currently bringing RINs as commodities that trade within the different D-categories for compliance and anticipated forward need. 8) Rail car shortages due to shipping of shale oil increasing costs 9) Oil companies don't want to reconfigure their refineries again for higher octane levels.

According to the EPA (p. wescot feed outlook) factors affecting supply and demand of RINs are: Prices for crude oil, Equilibrium quantities, Production costs, Legislative and regulatory issues, EPA imposed penalties for RFS compliance, Uncertainty of new legislation to modify the RFS due to market constraints (Blend wall), Operations of the market and market relationships with the new RIN concept.

According to Sandra Dunphy "RINderella", RIN specialist for Weaver and Associates, the following are main barriers for advanced biofuel over the last two years: 1) The uncertainty of RINs value at the blend wall, 2) RFS and the blend wall *3)* Congress's assumption of increasing demand and need for higher volumes of fuel. 4) Lower demand with fuel efficient vehicles 5) No place to put the excess renewable fuel the industry is ready to deliver from the AB pool. 6) "From Jan 2013 *to July / August 2013,* RINs increased as much as 14%, *equivalent of 70,000 to $1,000,000. 7)Courts vacated the 2010 CWC, and refunded the 2011 payments CWC due to lack of production 8*) RIN fraud: QAP assurance plans implemented, 9) For *producers RIN price often represents the profit margin for the producer, if RIN prices are low, smaller non-integrated producers struggle. 10) At the end of 2013, 5% of vehicles on road today are approved by manufactures to run on E15 11) Blenders have to have the infrastructure to accommodate the renewable fuel and be able to blend it. (*integrated) 12) *Ethanol cannot move through pipeline so rail and truck transport is most common (cost/safety) 13)* Lawsuits are common place against the government: *Lawsuits begin once RVO's are issued in Federal register, by the time there is a ruling, 2015 production records will be history. 14) RVO calculations: In past years, an OP would not use D4 or D5 RIns to satisfy its D6 obligation category because the price of D6s was low relative to those other Dcodes(i.e. $.04/RIN v $.5/RIN. Now that D3,4,5 or D7 RIns to satisfy its Renewable Fuels RVO category. 15) QAPs quality assurance plans: to level the playing field: third party audit of U.S. and foreign BF production facilities."*

"The renewable Fuel standard one (RFS-1) was supported by the oil industry in 2005. The primary reason was using ethanol as an octane enhancer to replace the banned MTBE product, and use of biodiesel as a lubricating agent conversely improving the availability of premium fossil diesel, Currently, the oil industry does not support the modified RFS-1 to the new RFS-2 mandate, mainly based on increases in quantity the fossil industry would be required to purchase. This has negative implications for the expected yearly increasing RVO amounts for the developing U.S. bioeconomy industry: Advanced, biodiesel, cellulosic biofuel, and corn ethanol. according to Brooke Coleman" (ABBC-*AEC).*

8.11.1 **Advanced Biofuel Industry Associations Market Impact**

The arduous challenges from politics and fossil fuel interests directly impact the advanced biofuel industry; leading to the need for alternative biofuel industry association's to collaborate on various aspects of the industry market. Sklar, (2015) suggested that the following broad based renewable and environmental coalition is needed to strengthen the market stance of the bioeconomy against negative fossil interests towards the RFS:

1) Education coalitions, 2) Biochemical material science coalitions, 3) Sustainable landuse coalitions 3) Recycling and biorefinery coalitions- repurpose waste for productive sustainable use, 4) Local and regional community power alliances, 5) Environmental justice coalitions,

All associations provided the following highly specific barriers first quarter of 2015 prior to the EPA releasing the 2014, 2015, 2016 RFS-RVO amounts.

According to Mark Riedy, ABLC 2015, ACOR founder*, "an RFS repeal does not have Congressional support at present. A Republican house and Senate may result in serious RFS changes."example:* such as the entry of nonrenewable coal derived products, or changing the EISA – RFS-2 back to the original RFS-1 standards to appease the fossil industry. An exemplar 70 slide presentation of note on financing the bioeconomy is Mark Riedy's: Financing Renewable Chemicals, advanced biofuels and Bioenergy, 2015. Appendix F, has the contact information for requesting this detailed presentation.

8.11.2 **Industry Associations Divided on RFS**

The industry is currently divided with whether or not the RFS program is functionally beneficial. On one side the fossil industry and biofuel opponents suggest that the RFS law is not working and needs repealing. One the other side the proponents suggest it is not the law. Jo Jobe CEO of the NBB and Brooke Coleman, ED of the AEC, agree on that the law is not broken, and the RFS is working. Jo Jobe suggests that "*changing the law is not the problem it is getting the EPA to comply with the law. The current biofuel obligated parties don't have exact targets, since the EPA has not ruled on past due RVO."*

According to direct quotes from Mike McAdams President of the advanced biofuels Association (ABFA) at the ABLC conference 2015 The RFS doesn't work for three reasons:

"1)Inverse relationship between the policy and uncertainty and the members ability to raise the investment capital. Repeatedly missing deadlines to set annual RFS requirements and reducing those requirements to statutory levels. It has created significant uncertainty and causes ambiguity for advanced and cellulosic companies to simply evaporate.

2)The calendar working against us. Even if your company has a business plan that works with $50. oil barrel oil cost and at today's RIN values. Capital markets put us ……with the RFS will exist after 2022. There is a reason that most of us take a 30 year mortgage, but today's RFS uncertainty would have the lender requiring most of you to finance your facility and pay off your total in just 7 years.

3)Another concern is the lack of market for the companies actually making the cellulosic and advanced fuels. Let's say your company manages to overcome the obstacles and produces a cellulosic biofuel. Perversely with EPA's current implementation, it is usually a better deal for the obligated parties to purchase a refundable waiver credit from the EPA than it is to buy your actual gallons with the cellulosic credit attached. That is why 33million gal. cellulosic RINs were left on the sidelines in 2014. Because it was cheaper for oil companies to buy the EPA cellulosic waiver credit than to take the risk of buying the actual credit attached to the RIN.

He further stated, after working with the EPA since 2009 in an attempt to get away from and get pathways approved and feedstocks approved, annual volume requirements released on time, only to frequently be told from the agency that governs that they do not have sufficient legal authority to get the job done. It has become clear that statutory changes need to be made to the RFS. That is why the members of the ABFA are now calling on congress to pass legislative fixes that will solve these problems."

According to Brooke Coleman of the ABBC, "*the oil industry's biggest fear is a political coalition between agriculture, the heartland, and innovation…. to maintain the 5th of the fuel industry wrestled from the oil industry…. This thing is off the tracks at the EPA, but give the EPA a chance to get it on the tracks….the president has now pulled the proposal off the table, the conversations we were having about the importance of having obligated parties is different."* He further suggests that the White House was not interested in setting RIN values around a $1.00 in 2007, and was considering closing the program. He also implied that we may not need RINs past 2022 because of the uncertainty that comes with it.

According to Jo Jobe, CEO of NBB*, "Congress spent two years holding multiple hearings, and they have requested white papers on each specific issue brought about from both sides. The ABA believes that the time is now to reform the RFS. The ABA association plans to actively call on congress to reform the RFS program in 2015."*

The AEC's, ED, Brooke Coleman, conversely suggests "*that the ABFA and ABBC are separated on this issue, we don't believe that going back to Capitol Hill is the way to solving our problems."* The ABFA believes that a political change is needed and the AEC believes is can be improved more simply from an administrative approach, since there currently are not enough RFS reform votes.

According to BIO's, EVP, Brent Erikson, "*we believe that any proposal to reform the RFS is extremely risky at this point; the vote count is very close on Capitol Hill, opening up the bill risks losing another one. Senator Jim Leanhoff is going to request a vote count, the votes are not there to bring the issues."*

The EPA already is legally aware that they are behind. Attempting to take it to Congress to force EPA to implement law will not solve the current problem the biofuel projects face. In 2013 the EPA was brought to federal district court over the issue and admonished for being behind. Currently the EPA is attempting to meet there own self-imposed deadline to have the RVO set for 14,15,2016 finalized this year

The fundamental agreements between the two groups are that CWCs, pathway resolution, and the EPA stalling, all needs to be improved. The fundamental disagreements are an administrative fix of the RFS versus statutory change.

Joe Jobe, CEO of NBB suggests:

"*1)We need a minimum RIN value for cellulosic fuels that will provide enough certainty and stability for our member to build facilities and innovative products. Because we are competing against the fossil fuels produced at cash cost already built and fully depreciated facilities. Cellulosic RIN values should already be indexed at the price of oil to provide support when the oil is a $50 than at $100.*

2)Congress should show their support for advanced and cellulosic fuels by making it clear that it extends wel beyond 2022 to provide sufficient time to develop this industry, and again we cannot pay off a plant in just seven years.

3)We need to remove the loophole that allows the oil industry to opt out of buying cellulosic gallons with its credit in leiu of buying a waiver credit.

4)Use the actual production numbers off the EMTS system. Reset the start time form Nov. 30th to mid Feb. when final numbers are available. Will convert the RVO task to an administrative function"

According to the President of ABA, Mike McAdams: *"after the current mess of setting the annual volume requirements, we have advocated for over a year to simply utilize the actual production numbers off the EPA Moderated Transaction System* (*EMTS) system."* The EMTS was initiated on July 1, 2010. EPA (2015b)

"Reset the start times from November 30th to mid-February when the final numbers are available. Doing so will eliminate the difficulty in setting the RVO numbers each year in terms of a simple administrative function rather than a long drawn out debate that requires a long process that has lasted for over two years."

Financing the biofuel project concepts is a major barrier and perceptual risk for all parties. According to Mark Riedy, the following factors are currently expected to impede and conversely drive biofuel project investment in 2015:

Impeding: "*Lack of funds at all project levels, Project debt***,** *Lack of certainty in government programs (ex: RFS)***,** *Congress must extend 55 tax incentives on a long term basis before expiration, and consider investment tax credits, renewable volume obligations (RVO) are still uncertain in 2015***,** *D-3 Rin credit waivers are based on 2013 amount of $0.42, which is now outdated, Stalling long-term offtake agreements, thus reducing project equity."*

Drive: "*Creative financing***,** *Tax incentives***,** *RFS if certainty is achieved across the board***,** *DOE, USDA loan guarantees with project disclosure***,** *AAA rated government loan guarantees to enhance non-investment grade project debt, Covered bonds, with credit enhanced pools of* *mortgages. But attempting to shift to AAA rated credit enhanced treasury strips, new insurance policies covering: technology, feedstock, and offtake agreements"*

According to Jim Lane Biofuels Digest at the ABLC conference, 2015: "*There's a cost advantage to bringing molecules and processes to the marketplace, and everybody benefits when they are cost advantaged in the long term and not price advantaged. So, May sell at market price. The oil price debacle this year, oil is up 24% in the first quarter of this year (2015 inflation rate) This shows the volatility in our sector because the dependence on a single set of molecules coming from a single barrel often form a limited number of suppliers. On the Power side biogas, coal , nuclear, methane, wind solar,… power bill going up and down – when you use more. But mostly stays the same. Why when diversification of sources. and diversification of uses therefore we don't have the volatility on the backend either. You are seeing diversification and separation of new technologies some will succeed and some will fail. The dept of energy has funded only one technology that has failed 16 times and funded it again for the 17th. (FRACKING). that is what you are seeing in this a lot of failure… filled with amazing technology, the tech will be seen again on the other side under new guises smarter and better. The DOE has been building a case and becoming better at what it does… that goes for a lot of industries. Diversification of product and sources new technologies coming aboard, technologies and economics are getting better."*

8.12 Appendix L: Median Quantiles by; Type, Status, and Technology

Table 44 All groups internal and external, Mean, Median, and Mode

Secondary level	**Mean**			**Median**			**Mode**		
	Biofuel	**Gov.**	**Others**	**Biofuel**	**Gov.**	**Others**	**Biofuel**	**Gov.**	**Others**
Product development	3	3	4	3	3	3	2	2,4	3
Byproducts marketing	2	4	3	2	3	3	2	4	3
Byproducts distribution	3	3	3	2	4	3	2	3	3
Coproducts marketing	2	3	3	2	3	3	2	3,4	3,4
Coproducts distribution	3	3	3	2	3	3	2	3	3

Continuous project growth	3	3	3	3	3	3	3	3	3
Management	3	3	4	2.5	2	3	2,3	2	3,4
Strategy	3	3	4	2	3	3	2	4	2
Technology conversion rate	3	4	4	3.5	4	4	4	4	4
Technology high titer and yield per ton	3	4	4	4	4	4	4	4	4
Competitors	2	3	3	2	3	3	2	2,4	2
Funding	5	4	5	5	4	4.5	5	4,5	5
Suppliers	3	3	3	3	3	3	2	2,3	3
DOE pathway process	4	3	4	3.5	3	3	3,5	3	3
EPA pathway process	4	3	4	4	3	3.5	5	5	3
USDA pathway processes	3	3	4	4	3	3	4	2	3
Production tax credits	3	3	4	4	3	3	4	2,3,4	3
Renewable fuel policy standards	4	4	4	4.5	4	4.5	5	4	5
Waiver credits	4	3	4	4	3	3	4	3	3
Renewable volume obligation	4	3	4	5	3	3.5	5	2,3,4	3,5
Renewable identification numbers	4	3	4	4	2	3	5	2	3
Energy costs	3	4	3	3	4	3	2,4	2,4,5	3,4
3rd party relationships	3	3	4	3	3	3	2	2,4	3

Table 45 Advanced Biofuel Internal and External Median Quantiles

Median and (Quantiles 25%, 75%)	TYPE			STATUS			TECHNOLOGY		
INTERNAL BARRIERS	**Commercial**	**Demonstration**	**Pilot**	**Closed**	**Open**	**Planning**	**Biochemical**	**Hybrid**	**Thermochemical**
Product development	2 (2, 4)	2.5 (2, 3.75)	4 (3, 5)	2.5 (2, 3)	3.5 (2, 4)	2.5 (2, 4)	4 (3, 5)	3 (1.5, 4)	2 (2, 4)
Byproducts marketing	2 (1.5, 2.5	2 (1.25, 2.75)	3 (3, 5)	2.5 (2, 3)	2 (1.25, 3)	2 (1.75, 3.25)	4 (3, 5)	3 (1, 3.5)	2 (2, 2.5)
Byproducts distribution	2 (2, 2.5)	2.5 (1.25, 4.5)	3 (2, 5)	2.5 (2, 3)	2 (2, 4.5)	2 (1.75, 3.25)	4 (3, 5)	2 (1.5, 4.5)	2 (2, 2)
Co-products marketing	2 (2, 2.5)	2 (2, 2.75)	3 (2, 5)	2.5 (2, 3)	2 (2, 2.75)	2 (1.75, 3.25)	4 (3, 5)	2 (1.5, 3.5)	2 (2, 2)
Co-products distribution	2 (2, 2.5)	2.5 (2, 3)	3 (3, 5)	2.5 (2, 3)	2.5 (2, 3)	2 (1.75, 3.25)	4 (3, 5)	2 (1.5, 3.5)	2 (2, 3)
Continuous project growth	3 (2, 3)	3.5 (3, 4)	4 (4, 5)	3.5 (3, 4)	3.5 (2.25, 4)	3 (2.5, 3.25)	4.5 (4, 5)	3 (1.5, 4)	3 (3, 3.5)
Management	2 (1, 3.5)	2.5 (2, 3)	3 (2, 4)	2 (1, 3)	2.5 (2, 3.75)	2.5 (1.75, 3.5)	2.5 (2, 3)	3 (1.5, 4)	2 (1.5, 3.5)
Strategy	2 (2, 2.5)	2.5 (1.25, 3.75)	4 (4, 5)	3 (2, 4)	2.5 (2, 3.75)	2 (1.75, 4)	3.5 (2, 5)	2 (1.5, 3.5)	2 (2, 4)
Technology conversion rate	2 (2, 4)	3.5 (2.25, 4)	4 (4, 5)	4 (4, 4)	3.5 (2, 4)	2.5 (1.75, 4)	4 (3, 5)	2 (1.5, 4)	4 (2, 4)
Technology high titer and yield per ton	3 (2, 4)	3.5 (3, 4)	4 (4, 5)	4 (4, 4)	3.5 (2.25, 4)	3.5 (1.75, 4)	4 (3, 5)	4 (1.5, 4)	4 (2.5, 4)
EXTERNAL BARRIERS	**Commercial**	**Demonstration**	**Pilot**	**Closed**	**Open**	**Planning**	**Biochemical**	**Hybrid**	**Thermochemical**
Competitors	2 (1, 2)	3 (2, 4)	3 (2, 5)	2 (2, 2)	2 (2, 3.75)	2 (1, 2.5)	4.5 (4, 5)	1 (1, 3)	2 (2, 2)
Funding	5 (5, 5)	5 (5, 5)	5 (4, 5)	5 (5, 5)	5 (5, 5)	5 (4.75, 5)	5 (5, 5)	5 (5, 5)	5 (4.5, 5)
Suppliers	2 (2, 4)	2.5 (2, 3)	4 (3, 5)	2 (1, 3)	3 (2, 4)	2.5 (2, 4.25)	4 (3, 5)	3 (2, 4)	2, (2, 4)
DOE pathway process	3 (2, 4.5)	4 (3, 5)	4 (2, 5)	4.5 (4, 5)	3.5 (3, 4.75)	3 (1, 5)	4 (3, 5)	3 (1, 4)	4 (3, 5)
EPA pathway process	4 (2.5, 5)	5 (4.25, 5)	4 (3, 5)	3.5 (3, 4)	4.5 (4, 5)	4.5 (1.75, 5)	5 (5, 5)	4 (1.5, 5)	4 (3.5, 5)
USDA pathway processes	4 (2, 4)	3.5 (2.25, 4.75)	4 (2, 5)	4 (4, 4)	3.5 (2, 4.75)	3.5 (2, 4)	4 (3, 5)	3 (2, 4)	4 (2, 4)
Production tax credits	4 (2, 4)	4 (3.25, 4.75)	4 (2, 5)	3.5 (3, 4)	4 (2.5, 4.75)	3.5 (1.75, 4)	4 (3, 5)	4 (2.5, 4)	4, (2, 4)
Renewable fuel policy standards	3 (2, 5)	5 (2.75, 5)	4 (2, 5)	3 (2, 4)	4 (2, 5)	5 (1.75, 5)	5 (5, 5)	2 (1.5, 4.5)	5 (2, 5)
Waiver credits	3 (3, 4.5)	4 (4, 4)	4 (3, 5)	3.5 (3, 4)	3.5 (3, 4.75)	4 (3.25, 4.25)	4.5 (4, 5)	4 (2, 4)	4 (3, 4.5)
Renewable volume obligation	5 (2.5, 5)	5 (5, 5)	4 (3, 5)	3.5 (3, 4)	5 (3.5, 5)	5 (3.25, 5)	5 (5, 5)	4 (1.5, 4.5)	5 (4, 5)
Renewable identification numbers	3 (2, 5)	4.5 (3.25, 5)	5 (3, 5)	3.5 (2, 5)	4 (3, 5)	4 (1.75, 5)	5 (5, 5)	2 (1.5, 5)	4 (3, 5)
Energy costs	2 (1.5, 4)	2 (2, 3.5)	5 (4, 5)	4 (4, 4)	4 (2, 4.75)	2 (1.75, 2.5)	3.5 (2, 5)	4 (1, 4)	2 (2, 4)
3rd party relationships	3 (2, 4)	3 (1.5, 3.75)	3 (2, 5)	3.5 (3, 4)	2.5 (2, 4)	3 (2, 4.25)	4 (3, 5)	3 (2.5, 4)	2 (2, 4)

8.13 Appendix M. EISA Calculations

8.13.1 EISA Calculations: EMTS, RVO, RINs, CWC, D category equivalence values

Renewable Identification Numbers (RINs) and Cellulosic Waiver Credits (CWCs)

Renewable Identification Numbers (RINs) and differentiated D-coded categories were generated by the government to identify renewable biofuel groups under the RFS guidelines. Total Renewable Biofuels, which contains the total of all D-coded categories, are shown in Table 46. These include biofuel produced in the U.S. and imported from renewable biomass, in an attempt to reduce fossil fuel consumption under the RFS and tracked by the EPA using RIN certificates per batch or gallon. Under CFR 80.1450, the RIN certificates are assigned to batches of renewable lignocellulosic biofuel produced: "a batch of renewable fuel consists of a measured and identifiable biofuel by volume amount identified each calendar year and not to exceed 99,999,999 RINs per batch. A batch can be as small as one RIN. Each large or small batch of fuel must be produced within a calendar month under a single RIN volume designation" (EPA, May 2015).

Table 46 CFR 80.1426, D-coding for categories of renewable fuels for producing RINs

TOTAL RENEWABLE FUELS:	
Cellulosic biofuel	D3
Biomass-based diesel	D4
Advanced biofuels	D5
Conventional (corn ethanol)	D6
Cellulosic diesel	D7

To sell renewable biofuel in the U.S., a RIN is required and must be registered in the EPA moderated transaction system (EMTS). The EMTS became operational in 2010 as a method for the EPA to regulate the development of renewable fuel volumes and the transfer of the ownership of RINs monthly and annually. All parties trading in RINs are required to be registered through the Central Data Exchange (CDX) and the Office of Transportation and Air Quality EMTS (OTAQ-EMTS) ((EPA-RFS2, 2015, EPA-EMTS, 2015, EPA-basic, 2015).

According to CFR 80.1425, RINs may only be assigned to renewable biofuel batches for transportation, heating oil, and jet fuel for import and export. Producers of biofuel under these three categories are further differentiated into the following two categories, and are not required to produce RINs: small producers, producing less than 10,000 gal/yr; and temporary new producers (3 years or less), producing less than 125,000 gal/yr. Any project producing biofuel that doesn't fall into these two previous categories must produce a RIN or RINs per batch. The certificates are used for monitoring completion of minimum levels of production and or blending of lignocellulosic biofuel into the U.S. fuel supply. For example, to qualify for the EPA category of cellulosic biofuel D3 and D7, the fuel must come from any renewable non-food lignocellulosic feedstock and perform at 60% minimum Green House Gas (GHG) reduction compared to fossil fuel (Cornell-CFR, 80.1425, 2015). After blending is accomplished, the certificates and ownership of the RIN designated fuel may be traded within the industry as a commodity or used to verify the fulfillment of Renewable Fuel Standard (RFS) mandates.

According to Sandra Dunphy (2013), the biofuel industry's "RINderella," the RIN process is a system consisting of five steps generally lasting a minimum of four months, leading up to the EPA annual compliance date on February 28.

1) "RINs are generated at production facilities and/or from renewable importers
2) RINs are then transferred at no cost to purchaser or blender with the sale of renewable fuel
3) Final purchaser then blends renewable fuel and petroleum fuel making transportation fuel for sale, at this point the RIN is separated from the renewable fuel and also for sale.
4) The Blender then sells the separated RINs to obligated parties and/or other investors buying on margin.
5) Obligated Parties (OP) use the RINs for annual compliance to the EPA."

Table 47 shows the EMTS collected data through 2015, divided further by year in Figure 5, with the exclusion of D6 corn ethanol to improve visual representation of the advanced biofuel Industry. Otherwise you would not be able to see them.

The advanced biofuel (AB) cellulosic categories of D3 and D7 in Figure 19 now appear for the time in 2014 and continuing into 2015 in the millions not yet achieving billions. The EPA has been granted the ability to reduce the required annual volumes of alternative fuels, in this case AB- cellulosic. According to CFR 80.1456, the EPA is required to offer CWCs to biofuel producers during any year the RVO is reduced. The EPA offers CWCs to help regulate OPs, equal to the mandated biofuel annual RVO, when biofuel companies have a shortfall within meeting their annual EPA compliance report. CWCs may only be used for the year in question and not traded. Biofuel producers may carry their RIN or CWC shortfall to the next succeeding year but must satisfy both years, RINs and CWCs combined mandated requirements carried forward, according to U.S. EPA-Standard guidance (2015).

Table 47 EMTS data for 2010 to 2015 combined, source: (EPA-RINS to date, 2015)

Fuel (D Code)	Assignments	Total Generated	Total Retired	Total Available	
				Locked	Unlocked
Cellulosic Biofuel (D3)	Assigned	49,429,724	70,364	0	2,302,122
	Separated	NA	55,073	1,678,442	45,323,723
Biomass-Based Diesel (D4)	Assigned	1,226,657,924	1,382,060	15,971,256	237,920,031
	Separated	NA	55,004,168	25,481,381	890,899,028
Advanced Biofuel (D5)	Assigned	39,620,283	16,824	0	12,432,782
	Separated	NA	0	227,258	26,943,419
Renewable Fuel (D6)	Assigned	7,263,303,205	77,862,949	1,912,473	684,729,225
	Separated	NA	177,753,341	229,095,619	6,091,949,598
Cellulosic Diesel (D7)	Assigned	173,731	0	0	0
	Separated	NA	17,373	0	156,358
Total RINs Assigned and Separated		8,579,184,867	312,162,152	274,366,429	7,992,656,286

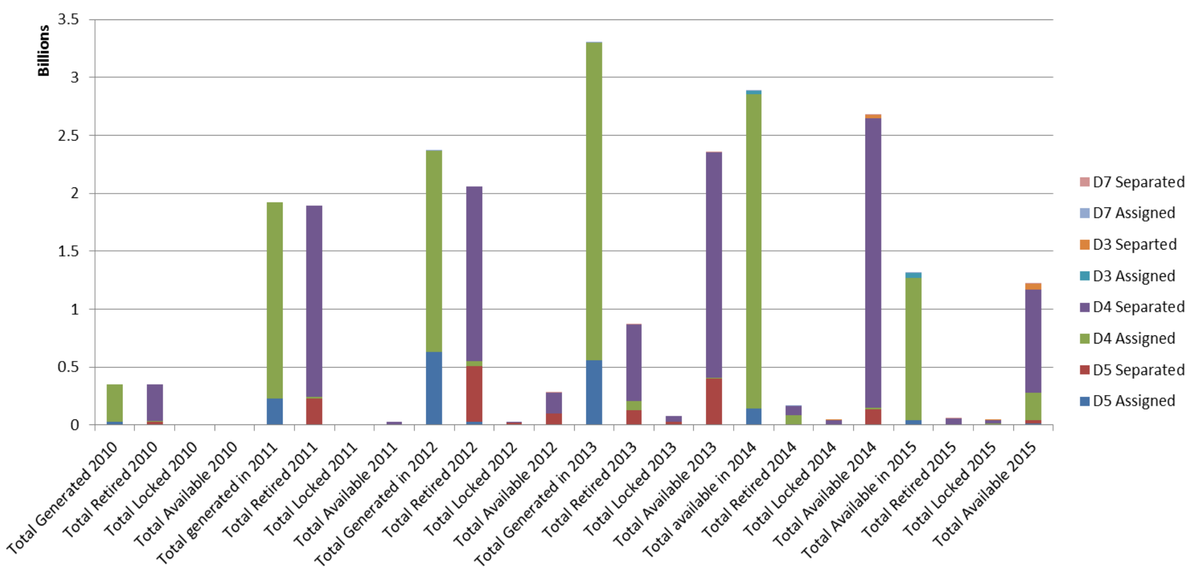


Figure 20 EMTS data separated yearly since incepted, source: EPA-RINS to date (2015)

The EPA anticipates RIN price increases to drive blenders to increase volumes, having the ability to sell the blended fuel and RIN separately. RINs are therefore expected to carry low value for D categories when producing at production economies of scale to meet RVO. "When the biofuel is more costly than nonrenewable fuels, however, needed to meet RFS standards or must be blended in greater volumes to be economic, the RIN value should increase to a point at which firms will increase biofuel blending*" (*EIA-RINs and RVOs, 2015).

8.13.1.1 **EISA renewable volume obligation (RVO) calculation, CFR 80.1407**

The renewable volume obligation (RVO) percent by D-coded categories is calculated using equation 1 and offered to the public by December yearly. Oil Price Information Service (OPIS) is used to determine the denominator (Cornell 2015).

Equation 1 RVO calculation

$$\textbf{RVO calculation \%} = \frac{\textbf{Actual RVO, individually by each D-code category}}{\textbf{U.S. gasoline and diesel projected consumption for next year}}$$

8.13.1.2 **EISA Renewable Identification Numbers (RINs) Calculation CFR 80.1426**

RINs are calculated by determining D-code renewable volume obligation (RVO) and using OPIS data, (Cornell 2015).

Equation 2 RIN calculation

Total RIN cost = RVO, which is RINs amount required * RIN daily closing price

8.13.1.3 **Example RIN Value Calculation to Determine Profit**

In Table 48, OPIS values are put to hypothetical numbers to demonstrate fluctuating RIN values and profit margins. If current RIN price is $0.40 while gasoline sells for $2.00 gallon, the demand for D6 corn ethanol net cost is close to gasoline's value. If D6 is sold at $2.50, subtracting the RIN value you derive $2.10 net cost for the renewable gasoline and $0.10 cents higher per gallon. For advanced biofuel with a current RIN value of $0.50, the demand for the fuel would be equal to the demand for gasoline at $2.00 and more valuable than D6. Advanced biofuel cannot currently be produced cheaper than fossil fuel; this has led the value of the RIN to be the profit margin for all advanced biofuels and a major barrier. Low RIN values only work if there is demand and a place to increasingly put fuels with no blend walls.

Table 48 RIN value calculation example

Pool Type	Wholesale Price p/g	RIN value	Net Cost p/g	Demand compared to gasoline
Corn ethanol D6	$2.50	0.4	$2.10	Close
Corn ethanol D6	$2.50	0.25	$2.25	Low
Advanced D5	$2.50	0.5	$2.00	Equal / high
Advanced D5	$2.50	0.25	$2.25	Low
Gasoline	$2.00		$2.00	Equal

8.13.1.4 **Biofuel Refiners Cost Per Gas or Diesel Gallon.**

The biofuel refiners cost is based on daily RINs and OPIS value calculation:

Compliance cost / Refiners production for year or day. The renewable biofuel refiner would likely purchase throughout the year. The following calculation is shown as purchasing all RINs in one day to meet the needs for the year. After calculating the total RIN cost using OPIS pricing, the RINs required (times) the RIN unit price is the total RIN cost for that day. For example, if you were to calculate the average cost per renewable gas and diesel gallon for a 100kbd refiner for February 2015 for the entire year needs, use the following equation; otherwise change the calculation to accommodate for one day. (Dunphy-NEB, 2013)

Equation 3 Biofuel Refiners Cost Per Gas or Diesel Gallon. Based on RINs and OPIS value

2014 RIN cost + 2015 RIN cost rounded up to nearest million (Compliance cost)

-- Divided by --

1000 barrels per day * 42 gallons from each barrel * producing 365 days per year.

This calculation is based on using the entire oil barrel; however, it is different for every refiner. For example, a barrel of crude oil contains 42 gallons, of which 31 gallons are usable to produce: 19 gallons of gasoline and 12 gallons of diesel fuel are possible. Other combinations of coproducts and byproducts are also possible from a barrel (EIA, 2014).

8.13.1.5 **Equivalence Value (EV) Chart to Calculate Different D Category Types, CFR 80.1415**

Different gallon quantities of fuel are created from a barrel of oil and gas varieties. This led to the creation of equivalence values to level the playing field across the biofuel production stakeholders, available in Table 49.

"Where: equivalence value for the renewable fuel, rounded to the nearest tenth.

R= renewable content of the renewable fuel. This is a measure of the portion of a renewable fuel that came from renewable biomass expressed as a fraction, on an energy basis.

EC = energy content of the renewable fuel, in BTU per gallon (lower heating value)" (Cornell, 2015).

Table 49 Equivalence values for renewable fuel conversion

Ethanol	**1**
Biodiesel	**1.5**
Butanol	**1.3**
Non-ester renewable diesel	**1.7**
77,000 BTU biogas	**1**
22.6 Kw -hr electricity	**1**

Equation 4 Biofuel equivalence values

Calculation: EV = (R/0.972) * (EC/77,000)

8.13.1.6 **Price of Cellulosic Wavier Credits Calculation, CFR 80.1456**

"The EPA uses inflationary data provided by the Bureau of Labor and Statistics in relation to 2008, under the Clean Air Act to regulate the price of CWCs based on the greater or $0.25 per CWC, or $3.00 minus gasoline wholesale price" (Cornell, 2015).