Bioeconomy Survey Results Regarding Barriers to the United States Advanced Biofuel Industry

Jeremy Withers, Henry Quesada*, and Robert L. Smith

Although the 2005 Environmental Protection Act (EPAct) was enacted to bolster the emerging biofuel industry, 52% of advanced biofuel (AB) projects ended by 2015. However, there are no complete lists of internal and external barriers that can help to explain why these projects are failing. The goal of this study was to develop a list of barriers impeding advanced biofuel projects by conducting a survey of biofuel stakeholders. Based on a literature review and previous research, a list of 23 hypothesized internal and external barriers was elaborated. A survey was conducted to have industry stakeholders provide their perception on the list of hypothesized barriers. The perceptions of industry stakeholders were analyzed by dividing the sample in three different stakeholder groups: advanced biofuel industry members, government representatives, and a third category called others that included publishers, journalists, suppliers, and other related stakeholders to the industry. In addition, nonparametric statistical techniques were used to compare the perceptions of the groups. The most significant results indicated that *Technology issues* was considered as an internal barrier for the three groups while *Funding* and *Renewable Fuel Standards* were perceived as external barriers by the three groups too. In addition, the rating of barriers was further analyzed only by AB industry stakeholders in order to uncover more details on the perception of barriers that might be preventing the AB industry to prosper.

Keywords: Advanced biofuel barriers; Renewable fuel standard (RFS); Renewable volume obligation (RVO); Blend wall; Renewable identification numbers (RINs)

*Contact information: Department of Sustainable Biomaterials, Virginia Tech, Brooks Center mail code 0503, Blacksburg, VA 24061, USA; *Corresponding author: quesada@vt.edu*

INTRODUCTION

The U.S. government created the Renewable Fuel Standard (RFS) to move the U.S. toward energy security and reduce negative environmental impacts from greenhouse gases. The RFS requires that transportation fuel include a minimum 10% biofuel, produced from biological materials. The fossil fuel companies fought the RFS to maintain their market share of fuel interests (Coleman 2016). However, the growth of the Energy Information Administrations (EIA), Corporate Average Fuel Economy (CAFE) standards, the economic recession, and a lack of bio-infrastructure all affected net fuel consumption. This led to an abundant fossil fuel supply and a shortfall in the biofuel needed for fuel blending (Lane 2015). The U.S. government then attempted to support the production of biofuels by subsidizing advanced biofuel (AB) production (DOE 2015; EPA 2009). In this regard, the following list from (Reidy 2016) shows the most significant subsides grouped by objectives that have been developed:

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)

Research Problem

Despite government subsidies and high demand for biofuel, 52% of advanced biofuel projects were closed by 2015 (Withers *et al.* 2015). In addition, after 9 years only a few advanced biofuel projects survived according to Lang (2013a,b). At the beginning of this research in 2015, 10 AB projects were producing biofuel, but they were not reaching commercial production in a profitable way (Lane 2016a). In spite of government subsidies and a fuel standard that required biofuel, many of the AB projects were unsuccessful and showed significant net losses. This fact led to the question: What internal and external barriers are keeping advanced biofuel projects from succeeding?

Purpose of the Study

The purpose of this study was to investigate the perception of AB industry stakeholders on a hypothesized list of internal and external barriers affecting AB projects. For this study, a barrier was defined as any factor impeding AB projects from achieving continuous sustainable biofuel production and delivery of economies of scale. The specific approach was to capture the perceptions of stakeholder from the bioeconomy associated with advanced biofuel projects through a survey.

The outcome of this research has produced a framework focused on combined and individually contrasting government, academic, and bioeconomy AB stakeholder responses determining what internal and external factors affected failures of AB projects. This information improves the bioeconomic community's ability to establish successful parameters for AB projects to have long-term viability.

LITERATURE REVIEW

Biofuel projects can be divided into three generations by feedstock type: first generation (1G) is ethanol-corn and sugarcane, potential food; the second generation is advanced biofuel (2G) – consisting of wood, grass, crop residues, municipal solid waste; and 3G is algae and butanol (Buckley 2016). Feedstocks are typically in the $50 to $80 per ton range (Fueling Growth 2013). The present research is focused on 2G wood and grass. Wood and grass feedstock (lignocellulose) is typically separated by its major components in order of value: cellulose, hemicellulose, and lignin.

Policies Impacting Biofuels

A literature review was conducted, examining second generation advanced biofuel wood and grass internal and external project barriers to determine a progression of what has and is currently impeding their success. As of 2016, there were six policies driving the inception of advanced biofuels: These policies were created to bolster, develop, and implement the four incentives driving the bioeconomy. Sequentially, they are:

- Clean Air Act 1970 – through current amendments (NHTSA 2016)
- Energy Policy Act of 2005 (EPAct) (EPA 2009; DOE 2015)
- Advanced Energy Initiative 2006 (The White House 2006)
- Renewable Fuels Standards of Energy Independence and Security Act of 2007 (EISA) – EISA subparts: (a) Renewable identification numbers (RINs), (b) cellulosic waiver credits, (c) renewable volume obligations (ROV), (d) production tax credits, (e) grants administered by USDA, DOE, and EPA (U.S. EPA 2007; Sorda *et al*. 2010, U.S. DOE 2013; Riedy 2016)
- California Low Carbon Fuel Standard (LCFS) (California Energy Commission 2016)
- Food, Conservation, and Energy Act of 2008, the Farm Bill (EIA 2010)

There are a host of incentives for industry development of advanced biofuel and their secondary coproducts, such as the 2005 EPAct creating the Renewable Fuel Standard (RFS), and its modification with 2007 EISA and new components of RFS2: RVO, RINs, controlled under the Code of Federal Regulations section 80. The EPA, DOE, EIA, and USDA typically regulate the grants and incentives. These policies associated with the RFS, provided production tax credits and Research and Development (R+D) funding to promote energy security, reduced negative environmental impact, renewable fuel industry growth and replacement 35 billion gallons of fossil fuel with drop-in biofuel blends by 2022. The policy subsidies and incentives were the drivers for advanced biofuel project attempts from 2005 to 2015, and subsequent implementation barriers.

Currently, few advanced biofuel projects are producing biofuel, with none reaching sustainable commercial production economies of scale. The most inclusive document covering this topic provided a partial list of wood-based biofuel projects by type and status (Lang 2013a, b). Advanced biofuel technologies have moved forward

from the pilot and demonstration level scaling of technologies to only a few attempting to commercialize at production economies of scale (Solecki *et al*. 2013). 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.

Table 1. Biofuel Barriers

List of Barriers	Reference
Competition, energy costs, funding, government, product development, suppliers, strategy, technology, and third-party relations	Withers *et al*. 2015
High capital risks, OPEC-based price distortions, constrained blending markets, policies, and technology challenges in lowering the minimum ethanol selling price	Amarasekara (2014)
High capital costs (higher than corn ethanol) and financing reliant on multiple sources of capital (private and governmental). Successful projects have achieved advancing their technology efficiency and drivers such as policies and grants.	Janssen *et al*. (2013)
Funding, technology	Lang (2013 a, b)
Technology based on low process yields and high production costs	Lu (2010)
Barriers to production are technology-based high production costs	Cheng and Timilsina (2010)
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	Sims *et al*. (2009)
There are a number of technical processing barriers that need to be overcome before full potential production is possible	Naik *et al*. (2009)
Suggested that technological process scaling was a major barrier to commercial biofuel production	Zu and Pan (2009)
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	Bohlmann (2006)
The barriers of technology and recalcitrance are major economic and operational challenges	Lynd *et al*. (2005)

Knowledge gaps from the broad barrier categories are not precise enough to fully aid in developing an industry and its needed infrastructure. Furthermore, 75% of advanced biofuel projects have been lost since inception by 2013 (Lang 2013a, b). Currently, overall project loss is now 52% by the end of 2015 (Withers *et al*. 2015). A more inclusive in-depth research focused on 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. Table 1 shows a list of external and internal barriers that were identified from different sources.

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

EXPERIMENTAL

The population of interest for this research was all U.S. advanced biofuel projects, the government, academia, journalists, and others involved with this industry since the 2005 EPAct. 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 operational, cancelled, or shutdown and government stakeholders were chosen by contacting the U.S. Department of Energy. A survey was developed to ask these AB experts, to provide their perceptions on the impact of a list of internal and external barriers related to the AB industry. Based on the results of the literature review, a list of hypothesized barriers was prepared, and it is shown in Table 2.

Table 2. Determined Internal and External Barriers for Survey

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

Internal barriers are factors within the control of the organization such as resources, production processes, support processes, technology or strategic aspects that might be limiting the organization. External barriers are defined are factors related to policy, suppliers, competitors, demographic aspects or funding beyond the organization. Next, a justification and selection of these issues as external and internal barriers is provided.

The internal barrier, *Product development*, includes reasons from projects that did not pass the planning or construction phases. *Byproducts and coproducts* marketing barriers are related to promoting and selling issues with products. *Byproducts and coproducts distribution* internal barriers include supply chain disruptions and issues with products. *Continuous project growth* barrier is overall limiting factors to project growth, such as, unable to move out of the pilot stage to demonstration stage. The *Management* internal barrier includes comments relating to failed directing, coordination, planning, or controlling of a biofuel project. The *Strategy* barrier includes a failed plan or method of action to achieve the project mission. The *Technology conversion rate* barrier refers to equipment capabilities of biomass conversion to biofuel, and the last internal barrier was *Technology high titer and yield per ton*, which refers to concentration of biofuel produced per ton of biomass.

The second column of Table 2 shows the list of hypothesized external barriers. The *Competitor* barrier includes aspects such as import prices of biofuel and costs associated with rising daily expenses compared to competitors. *Funding* is the expectation to repay a loan secured with collateral or receive free grant money with agreement for specific purpose. *Suppliers* included issues such as fluctuating costs of lignocellulosic feedstock, supplier relations, or location. The government *DOE, EPA, and USDA pathway process* barriers include aspects related to regulations, policy, or government intervention in the development of this particular biofuel market. The *Production tax credits* barrier refers to incentives that provide financial support for producing biofuel. *Renewable fuel policy standards* refers to the overall policies promoting biofuel project inception in the market place. *Waiver credit* purchasing refers to issues in lieu of producing mandated amounts of biofuel from EPA. The *Energy costs* barrier includes the impact of energy prices on project success. *Renewable volume obligation (ROV)* is the EPA mandated amount of biofuel for each type of producer. The *Renewable identification numbers* (RINs) refer to issues with assigning numbers for each gallon of biofuel produced or sold in the U.S. And finally, *Third party relationships* barriers are determined based on issues a biofuel project may have with third-party developers.

The survey applied to AB stakeholders included Likert-type questions to rate the hypothesized list of internal and external barriers. The scale for each statement was from 1 to 5, where 1 was “strongly disagree” and 5 was “strongly agree”. To implement the survey, the Tailored Design Method was chosen for data collection, and ordered procedures due to sample sizes and lack of peer-reviewed information (Dillman 2000). Besides asking experts for their perception on the barriers listed in Table 2, discussions with experts were conducted to clarify survey results.

The surveyed participants were initially asked to identify the stakeholder groups they are associated with: government, academia, biofuel industry, biofuel publishers, or any other. All stakeholders were asked to rank the barriers, but if the biofuel industry was chosen as the stakeholder group, the respondents were then asked to provide additional information related to their project type (pilot, demonstration, commercial), status (close, open and planning), and technology type (thermochemical, biochemical, hybrid). The intent here was to acquire additional details to examine the advanced biofuel industry separately.

Data Analyses

The responses were reviewed for data consistency and internal reliability. Data consistency techniques included qualitative methods to make sure there were no missing data. A reliability test (Cronbach's alpha) was conducted to check the internal consistency of all Likert questions of each individual construct in the survey (Janssen and 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 analyze the survey responses, nonparametric tests were utilized. A median test was used to compare the difference among the stakeholder groups. When differences were found, a Wilcoxon multiple comparison pair test was conducted to find the medians that were different. For the analysis of the subgroups within the AB industry stakeholder groups, a contingency table analysis was conducted to examine totals per columns and per row.

RESULTS AND DISCUSSION

Perceptions on Internal and External Barriers

The survey included questions related to demographic aspects in addition to the Likert statements on internal, and external barriers. The survey along with a cover letter was sent to a sample of 74 stakeholders in June of 2015 and resulted in a 58% response rate (43 viable responses). In order to keep a balanced number of respondents per group, the one biofuel publisher respondent was merged into the “Others” group, and the academic respondents were merged into the “Government” group. These merged categories helped provide anonymity to the responses. This resulted in three stakeholder groups (Table 3): Government (N = 11), Others (N = 16), and AB Industry (N = 16). The surveyed sample was asked to rate (on a 5-point Likert scale) a list of hypothesized internal and external barriers that are believed to be impeding the success of advanced biofuel projects.

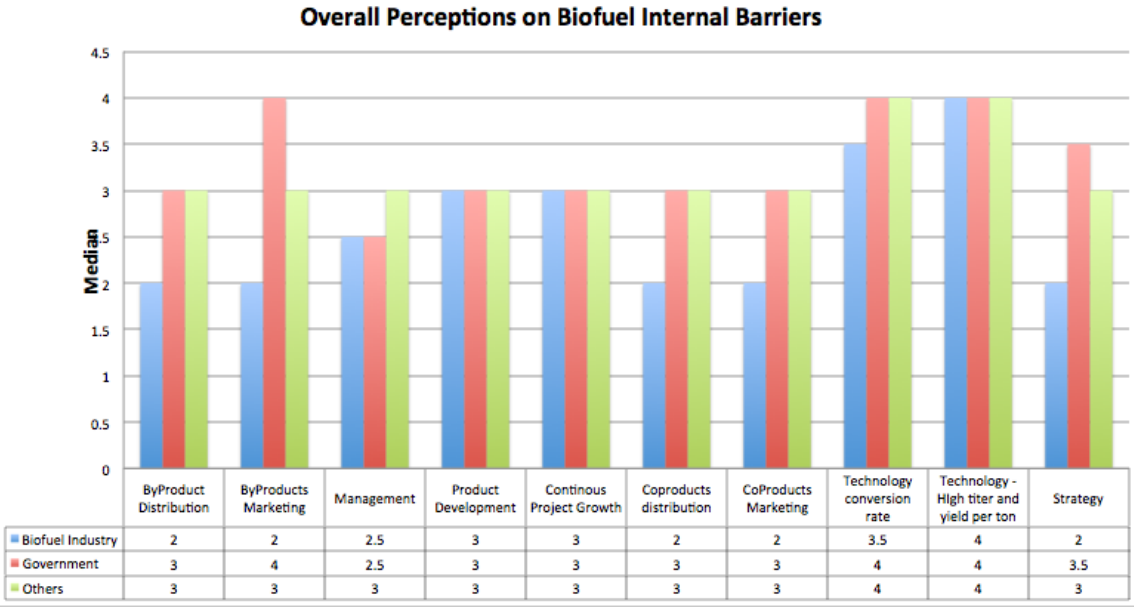
Perception on hypothesized internal barriers

As it is shown in Fig. 1, all of the respondents agreed that internal barriers *Technology conversion rate* and *Technology high titer and yield per ton* (Technology issues) are internal barriers (median higher than 3 for all groups). But the three groups together could not agree on which of the other predefined barriers were not perceived as

internal barriers (median smaller than 3 for all groups simultaneously). Nevertheless, the three groups together were unsure if *Product development*, and *Continuous project growth* could be rated as barriers or not (median equal to 3).

When looking at the perceptions of only the group Advanced Biofuel Industry, the ratings show that *Byproducts distribution*, *Byproducts marketing*, *Coproducts distribution*, and *Strategy* were not perceived as internal barriers (median less than 3). The Government group disagreed that *Management* was an internal barrier and agreed that *Byproducts Marketing* and *Strategy* were internal barriers (median higher than 3).

For the case of the Others group, their ratings indicated that this group was unsure on how to rate the hypothesized list of internal barriers (median equal to 3) except for Technology issues (*Technology Conversion Rate* and *Technology high titer and yield per* ton) that it was agreed to be a barrier, median higher than 3.



	ByProduct Distribution	ByProducts Marketing	Management	Product Development	Continous Project Growth	Coproducts distribution	CoProducts Marketing	Technology conversion rate	Technology - HIgh titer and yield per ton	Strategy
Biofuel Industry	2	2	2.5	3	3	2	2	3.5	4	2
Government	3	4	2.5	3	3	3	3	4	4	3.5
Others	3	3	3	3	3	3	3	4	4	3

Fig. 1. Survey responses to hypothesized internal barriers

A statistical comparison on the perception of internal barriers among the groups (Government, AB Industry and Others) was conducted to find the differences on the perceptions where the groups disagreed. For example, the *Byproducts Marketing* item was rated as a barrier by the Government group (median=4) but the Biofuel Industry group did not rated as a barrier (median=2) and the Government group was unsure (median=3).

Because the data were ordinal, a non-parametric test (Median test) was conducted to compare the responses among the groups where there was only disagreement. The median and the quantiles (as a measure of dispersion) for each group are shown in Table 3 for each hypothesized barrier. The null hypothesis that the medians were the same for each group was tested against the alternative hypothesis that at least one of the medians was different. When significant differences were found, the Wilcoxon test for multiple

pairs was used to separate the medians that were different. A significance level of 0.05 was used in all cases.

Results indicated that no differences were found among the groups on the perception of the hypothesized barriers *Byproducts Distribution, Coproducts Distribution, Management,* and *Strategy*. In all these cases the median ranged from 2 to 3, so it could be implied that these hypothesized internal barriers could not be confirmed as such by the groups. There were two cases where statistical differences were found. In the first case, the Government group perceived *Byproduct marketing* as a barrier but not the other two groups. In the second case, the AB Industry did not perceived *Co-products Marketing* as an internal barrier and the other two groups were unsure on how to rate it (Medians of 3 for both groups).

Table 3. All Groups Internal Barriers; Median, Chi-Square, and Fisher's test

Reason Internal Barriers	AB industry	Gov	Others	Median test (Prob>ChiSq.)	Wilcoxon test for Multiple pairs comparisons (p-value)
	Median and (Quantiles 25%, 75%)				
Byproducts Distribution	2 (2,3)	3 (3, 4)	3 (2.25, 4)	0.157	NA
Byproducts Marketing	2 (2, 3)	4 (2, 4)	3 (2, 3.75)	0.013*	Gov vs Biofuel (0.009*) Gov vs Others (0.268) Biofuel vs Others (0.046*)
Coproducts Distribution	2 (2,3)	3 (2, 4)	3 (2, 4)	0.222	0.1720
Coproducts Marketing	2 (2,3)	3 (2, 4)	3 (2, 4)	0.029*	Gov vs Biofuel (0.047*) Gov vs Others (0.891) Biofuel vs Others (0.044*)
Management	2.5 (2,3)	2 (2, 4)	3 (2.25, 4)	0.267	NA
Strategy	2 (2, 4)	3 (2, 4)	3 (2, 4)	0.320	NA
Significant at an alpha level of 0.05*					

Perception on hypothesized external barriers

Figure 2 compares the perceptions (medians) of the three groups on the hypothesized list of external barriers. All groups together perceived *Funding* and *RFS policy standards* (median>3) as external barriers. Also, the groups were unsure on *Suppliers* and *Third party relationships* (median=3). However, the groups disagreed on how to classify the external barriers *Competitors, DOE pathway process, Energy costs, EPA pathway process, Production tax credits, USDA pathway process, Waiver credits, Renewable volume obligation,* and *Renewable identification numbers*.

Similar to the previous section, a statistical test was conducted to test for differences only on the cases that the groups did not have a common agreement. In this case the null hypothesis is that all of the groups have the same perceptions relative to each external barrier. The medians and the quantiles of each group on each external barrier as presented in Table 4. A nonparametric test (median test) was conducted to test the null hypothesis and the Wilcoxon test for multiple pairs was performed to compare the pairs when differences were found.

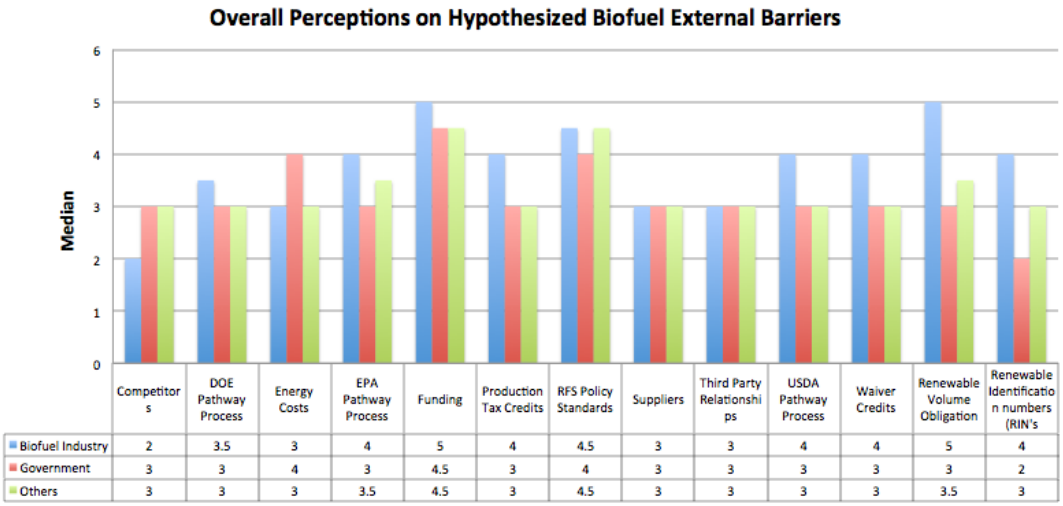


Fig. 2. Survey ratings to hypothesized external barriers

The results of the statistical comparison tests (Table 4) indicated that no differences were found among the groups for the hypothesized external barriers *Competitors, DOE pathway process, EPA pathway process, USDA pathway process, Production tax credits, Renewable volume obligation,* and *Renewable identification numbers*.

When looking at each individual group ratings in Table 4, the results indicate that the AB Industry group perceived the *DOE pathway process, EPA pathway process, Production tax credits, RSF policy standards, USDA pathway process, Waiver credits, Renewable volume obligation,* and *Renewable identification numbers* (median>3) as external barriers for successful commercialization of advanced biofuels. In addition, the Biofuel group did not perceive *Competitors* as an external barrier (median=2) but the Biofuel industry group was unsure on how to rate the item *Energy costs* (median=3). The

Government group disagreed that *Renewable identification numbers* (median=2) is an external barrier but was unsure on the other items in Table 4 (median=3). The group Others rated *EPA pathway process* as an external barriers (median=3.5), but it was unsure on the rest of the hypothesized barriers, where no differences were found.

Table 4. External Median and Quantile Response, By Secondary Level, and All Groups

Reason: External Barriers	AB Industry	Gov	Others	Median test (Prob>ChiSq.)	Wilcoxon test for Multiple pairs comparisons (p-value)
	Median and Quantiles (25%, 75%)				
Competitors	2 (2, 2.75)	3 (2, 5)	3 (2, 3.75)	0.128	NA
DOE pathway process	3.5 (3, 5)	3 (2, 3)	3 (3, 4)	0.120	NA
EPA pathway process	4 (3.25, 5)	3 (3, 5)	3.5 (3 ,5)	0.185	NA
USDA pathway process	4 (2 ,4)	3 (2, 3)	3 (3, 4)	0.133	NA
Production tax credits	4 (2.25, 4)	3 (2, 4)	3 (3, 4)	0.368	NA
Waiver credits	4 (3, 4)	3 (2, 3)	3 (3, 4.75)	0.051**	Gov vs Biofuel (0.031)** Gov vs Others (0.132) Biofuel vs Others (0.416)
Renewable volume obligation	5 (3.25, 5)	3 (2, 3)	3.5 (2.25, 4)	0.091**	Gov vs Biofuel (0.054)** Gov vs Others (0.846) Biofuel vs Others (0.214)
Renewable identification numbers	4 (2.25, 5)	2 (2, 3)	3 (2.25, 4)	0.121	NA
Energy costs	3 (2, 4)	4 (2, 5)	3 (2, 4)	0.926	NA
*Significant at an alpha level of 0.05 ** Significant at an alpha level of 0.1					

The perception on the items *Waiver credits* and *Renewable volume obligation* were found to be statistically different. In both cases, the AB Industry group rated them as external barriers but the other two groups were not sure (Table 4).

Analysis of Internal and External Barriers only by Respondents Classified as AB Industry Members

Out of the total responses (N=43), 16 respondents indicated their belonging to the Advanced Biofuels (AB) Industry group. One of the objectives of this research was to analyze the level of agreement or disagreement of only this group on the different internal and external barriers. The respondents that identified themselves in the AB industry group were also asked to indicate their type of project (commercial, demonstration, or pilot), status (closed, open or planning) and their type of technology (Biochemical, hybrid or thermochemical).

Perceptions of AB Industry group on Internal barriers

Table 5. Perception of Internal Barriers by AB Industry Subgroups

Groups	Subgroups		Internal Barriers										Total
		Sample size	ByProduct Distribution	ByProducts Marketing	Management	Product Development	Continous Project Growth	Coproducts distribution	CoProducts Marketing	Technology conversion rate	Technology - High titer and yield per ton	Strategy	
Type	Commercial	9	N	N	N	N	N	N	N	N	N	N	0
	Demonstration	4	N	N	N	N	Y	N	N	Y	Y	N	3
	Pilot	3	N	N	N	Y	Y	N	N	Y	Y	Y	5
Status	Closed	2	N	N	N	N	Y	N	N	Y	Y	N	3
	Open	8	N	N	N	Y	Y	N	N	Y	Y	N	4
	Planning	6	N	N	N	N	N	N	N	N	Y	N	1
Technology	Biochemical	2	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	9
	Hybrid	5	N	N	N	N	N	N	N	N	Y	N	1
	Thermochemica	9	N	N	N	N	N	N	N	Y	Y	N	2
Total			1	1	0	3	5	1	1	6	8	2	

Table 5 shows the ratings of internal barriers by AB industry subgroups Type, Status, and Technology. To obtain these results, the medians on each barrier per subgroup were obtained. Then a procedure was developed to classify as barriers all items that had a median larger than 3 (range from 1 to 5). The ones classified as internal barriers are shown in Table 5 with yellow background and red color font.

When examining the Totals by columns in Table 5, the results show that out the 10 hypothesized internal barriers, the most significant across the three groups were *Technology conversion rate*, *Technology high titer*, and *Yield per ton* (Technology issues), with a tally of 8 and 6 respectively. The second highest tally was for the internal barrier *Continuous project growth* (5 marks) and the third highest tally was *Product development* (3 marks).

When looking at the Totals per row in Table 5, it can be seen that the group that perceived the highest number of internal barriers was the Biochemical subgroup (Technology group) with 9 out 10 possible barriers. The only item not classified, as an internal barrier by this group, was *Management*. The subgroup with the second highest number of barriers was the Pilot (Status group) with 5 counts. For this subgroup other than Technology issues, *Strategy*, *Continuous project growth*, and *Product development*

were also considered barriers. The subgroups Planning (Status group) and Hybrid (Technology group) only classified one item as an internal barrier out of ten possible.

Perceptions of AB Industry group on external barriers

The same procedure that was used to classify internal barriers by subgroups was used to also identify external barriers. When looking at the totals by columns in Table 6, the results show that *EPA pathway process*, *Funding*, *Production tax credits*, and *Renewable volume obligations* were voted by all subgroups (9 marks out 9) as external barriers. In second place the items *Waiver Credits* and USDA *Pathway Process* were classified as external barriers (8 marks in total out of 9) by all groups with the exception of the Commercial (Type group) and the Hybrid subgroups (Technology group) respectively. The least voted items were *Suppliers* and *Competitors*, with 2 and 1 marks respectively. The only subgroups that classified *Suppliers* as an external barrier were the Pilot and the Biochemical subgroups and the only subgroup that classified Competitors as an external barrier was the Biochemical subgroup.

Table 6. Perception of External Barriers by AB Industry Subgroups

Groups	Subgroups		External Barriers													
		Sample size	Competitors	DOE Pathway Process	Energy Costs	EPA Pathway Process	Funding	Production Tax Credits	RFS Policy Standards	Suppliers	Third Party Relationships	USDA Pathway Process	Waiver Credits	Renewable Volume Obligation	Renewable Identification numbers (RIN's	Total
Type	Commercial	9	N	N	N	Y	Y	Y	N	N	N	Y	N	Y	N	5
	Demonstration	4	N	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
	Pilot	3	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	11
Status	Closed	2	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	10
	Open	8	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	10
	Planning	6	N	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	8
Technology	Biochemical	2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	13
	Hybrid	5	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	N	6
	Thermochemica	9	N	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
Total			1	6	5	9	9	9	6	2	2	8	8	9	7	

When looking at the row totals in Table 6, it can be seen that the subgroup Biochemical (Technology group) classified all 13 items as external barriers. However, an important insight here is that the sample size for this subgroup was only 2. The subgroup Pilot (Type group) perceived that 11 out of the 13 items were external barriers. The only items not classified by this subgroup as external barriers were *Third party relationships* and *Competitors*. The groups Closed and Open (both in Status group) came in third place in number of identified external barriers both with 10 marks out of 13. The Closed subgroup did not see *Competitors, RFS policy standards,* and *Suppliers* as external barriers; while the Open subgroup did not perceived *Competitors, Suppliers* and *Third party relationships* as external barriers. An additional consideration here is that the sample size for subgroup Closed is only 2, same as the Biochemical group.

Discussion

For any business organizations there are internal and external factors that could be impeding commercial success of their products or services. The AB industry is not different than any other business or industry sector. Since the inception of the different government initiatives to promote the development and commercialization of AB, the industry has not been able to scale up to appropriate commercialization levels. Many

projects have started out with support from state and federal organization and investors but at 2016 none of the projects have been able to achieve successful level of financial stability. Even though across the nation and other international locations, researchers have been able to develop efficient methods, technologies and systems to produce AB from non-food cellulosic biomass, there are many questions that arise from the fact that for this industry the transition to commercial stage has been problematic.

This research aims to investigate the most significant internal and external barriers for AB projects in the United States that could be preventing successful commercial of AB. A hypothesized list of internal and external barriers was prepared based on a literature review. A sample of AB stakeholders was created that included AB industry members, government officials, academics in the area of AB and other stakeholders including publishers, journalists, suppliers and the general public.

The groups that were surveyed unanimously rated *Technology issues* (internal barrier) as the most important internal barrier preventing AB industries to achieve successful levels of commercialization. When the sample was separated by groups (AB industry, Government, and Others) it was found that *Technology issues* was the only internal barrier identified by the AB industry group. This is actually an important result that might indicate that the technology to efficiently and effectively transform lignocellulose material into advanced biofuels is still in early stages. Therefore, companies will need to put more effort into developing technologies that can scale-up processes to achieve commercial stages.

For the Government group, the most significant internal barriers were Technology *issues*, *Strategy*, and *Byproducts marketing.* For the Others group, only *Technology issues* was rated as an internal barrier. The Government group includes government representatives running federal agencies supporting the AB industry as well as academicians producing new knowledge on AB issues. It seems the Government group considers that the strategic aspects of the AB industry could be improved to increase their success of the AB industry operation. This could be an opportunity for AB Industries to rethink their business strategies in order to increase their chances to succeed. An important part of the AB industry is also the proper way to market and distribute Byproducts, and this is also being perceived by the Government group as problematic or not being effective.

In terms of external barriers, *Funding* and *RSF policy standards* were rated by all groups as the most significant external barriers impacting the AB industry. *Funding* is moving towards debt management as companies mature, according to 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 and AB policy (*RSF Policy Standards*) are needed to drive growth in funding biofuel investment, such as Flex Fuel vehicles, increased octane content, and increased market share of coproducts. According to Berven (2016): "Some politicians are unwilling to raise the E10 number to E15, that leaves seeking more end users and increasing market share of coproducts. A larger platform of products is where the market is shifting, while building the bioeconomy

infrastructure for biofuels. The chemicals in the fuel supply we replace are the most expensive chemicals to refine. We don't have to be lower than the price of wholesale gasoline; we need to be lower than the price of the chemicals we replace in the fuel supply, Butane, Polyline, Zylene. That's why we are 10% of the fuel supply today; the oil companies make more money selling our products than they do making and selling their own."

When looking at the group AB industry only, it was found that besides Funding and RSF Policy Standards; *RINs, RVO, USDA pathway process, Waiver credits, Production tax credits, EPA pathway process*, and *DOE pathway process* were also considered as external barriers preventing successful commercialization of AB. All of these external barriers are related to policy and tax credits that somehow are being perceived by the AB industry as barriers for the AB industry to move forward. It is not clear in detail why these hypothesized barriers were actually rated as such, but the perceptions of the AB industry is that the Government could be doing some better in terms of AB policy and AB tax credits. In contrast, the Government group only sees *Energy costs* in addition to *Funding* and *RSF policy standards* as external barriers. However, it is not clear how *Energy Costs* could be preventing the AB industry to succeed if energy production costs continue to be one of the lowest in the world.

Other than *Funding* and *RSF policy standards*, the Others group also perceived *RVO* and *EPA pathway process* as external barriers for the AB industry. Out of the four rated external barriers, three are connected to policy issues. This is aligned with the perception of the AB industry group in terms that better policy could lead to improve the success rates of the industry.

There has been an important conversation on the impact of suppliers and competitors on the AB Industry. Suppliers are key for the industry, but the AB industry did not rated *Suppliers* as barriers. At least those in the industry do not see this as a problem. This could imply that feedstock suppliers must be meeting expectations in terms of quality, volume, prices, and lead times. The other two groups were unsure to classify *Suppliers* as a barrier. The case of competitors is similar to suppliers, where the AB industry group did not rate *Competitors* as a barrier. It is known that AB prices must be equal or less than fossil fuels to be able to be competitive. At the time of the survey, fossil fuel prices were similar to those of renewable fuels and it is not clearly understood that the AB industry group did not perceive Competitors as a barrier preventing the AB industry to become successful. When looking internally at the subgroups in the AB industry group, it was found that the only subgroups that consider *Suppliers* as an external barrier were the Biochemical and Pilot subgroups. In addition, the only subgroup that considered *Competitors* as an external barrier was the subgroup Biochemical.

CONCLUSIONS

1. A hypothesized list of internal and external barriers potentially impacting the AB industry in the United States was compiled from a literature review. The list is important because it could be used as a baseline for similar investigations in the future.

2. The results indicated the most significant internal barrier for the AB industry and the Others groups is *Technology issues*. For the Government group the most significant internal barriers were *Technology issues*, *Strategy*, and *Byproducts marketing*
3. The AB industry group perceived *Funding, RSF policy standards, RINs, ROV, USDA pathway process, Waiver credits, Production tax credits, EPA pathway process*, and *DOE pathway process* as external barriers.
4. In the case of Government group, the following were rated as external barriers: *Funding, RSF policy standards*, and *Energy costs.*
5. For the Others group, the following were rated as external barriers: *Funding, RSF policy standards*, and the *EPA pathway process.*
6. The analysis conducted within the AB industry group (Type, Status, and Technology) indicated that out of 9 subgroups, only the subgroup Biochemical classified *Competitors* as an external barrier, while only the subgroups Biochemical and Pilot classified *Suppliers* as an external barrier.

REFERENCES CITED

Amarasekara, A. (2014). *Handbook of Cellulosic Ethanol (1st ed.)*, John Wiley and Sons, Hoboken, NJ, USA.

Berven, D. (2016). "Conference proceedings for POET - Crude vs. biofuel," *Advanced Bioeconomy Leadership Conference*, Grand Hyatt, Washington D.C., USA.

Bohlmann, G. M. (2006). "Process economic considerations for production of ethanol from biomass feedstocks," *Industrial Biotechnology* 2(1), 14-20 DOI: 10.1089/ind.2006.2.14

Buckley, T. (2016). "Sustainability of biofuels: Future generations," *Biomass Magazine*, (http://biomassmagazine.com/articles/2070/sustainability-of-biofuels-future-generations), Accessed 09 April 2016.

California Energy Commission (2016). "Low carbon fuel standard," (http:// www.energy.ca.gov/low_carbon_fuel_standard/), Accessed 17 May 2016.

Cheng, J., and Timilsina, G. (2011). "Status and barriers of advanced biofuel technologies: A review," *Renewable Energy Journal* 36(12), 3541-3549.

Coleman, B. (2016). "A policy update, Advanced Biofuels Business Council," *Advanced Bioeconomy Leadership Conference*, Washington, D.C.

Dillman, D. A. (2000). "*Mail and Internet Surveys: The Tailored Design Method*," Wiley, New York, NY.

Gliem, J., and Gliem, R. (2003). "Calculating, interpreting, and reporting Chronbach's alpha reliability coefficient for Likert-type scales," *2003 Midwest Research to Practice Conference in Adult, Continuing, and Community Education*, Ohio State University, Columbus, OH, pp. 82-88.

Janssen, R., Turhollow, A., Rutz, D., and Mergner, R. (2013). "Production facilities for second generation biofuels in the U.S., and the EU – Current status and future

perspectives," *Biofuels, Bioproducts, and Biorefining* 7, 647-665. DOI: 10.1002/bbb.1451

Lane, J. (2015). Personal communication, *Advanced Bioeconomy Leadership Conference*, Washington, D.C.

Lane, J. (2016a). "KIOR: The inside true story of a company gone wrong," (http://www.biofuelsdigest.com/bdigest/2016/05/17/kior-the-inside-true-story-of-a-company-gone-wrong/17/), Accessed 01 May 2016.

Lang, A. (2013a). "Wood bioenergy: The rise and fall of wood-based biofuels, Part II," *Forisk Consulting*, (http://forisk.com/blog/2013/04/16/the-rise-and-fall-of-wood-based-biofuels-part-i/), Accessed 11 January 2015.

Lang, A. (2013b). "Wood bioenergy: The rise and fall of wood-based biofuels, Part II," *Forisk Consulting*, (http://forisk.com/blog/2013/07/20/wood-bioenergy-the-rise-and-fall-of-wood-based-biofuels-part-ii/), Accessed 11 January 2015.

Lu, N., and Rice, R. (2010). "Demand drivers and price supports for biofuel use as fuel in the United States: A brief review," *Forest Products Journal* 60(2), 126.

Lynd, L. R., van Zyl, W. H., McBride, J. E., and Laser, M. (2005). "Consolidated bioprocessing of cellulosic biomass: An update," *Current Opinion in Biotechnology* 16(5), 577-583. DOI: 10.1016/j.copbio.2005.08.009

Naik, S., Goud, V., Rout, P., and Dalai, A., (2009). "Production of first and second generation biofuels: A comprehensive review," *Renewable and Sustainable Energy Review Journal* 14(2), 578-597. DOI: 10.1016/j.rser.2009.10.003

National Highway Traffic Safety Administration. (2016 March). "CAFÉ – Fuel Economy," (http://www.nhtsa.gov/fuel-economy), Accessed 11 March 2016.

Reidy, M. (2016). "Policies that drive the bioeconomy," *Advanced Bioeconomy Leadership Conference*, Washington, D.C.

Sims, R., Mabee, W., Saddler, J., and Taylor, M. (2009). "An overview of second generation biofuel technologies," *Bioresource Technology* 101(6), 1570-1580. DOI: 10.1016/j.biortech.2009.11.046

Solecki, M., Scodel, A., and Epstein, B. (2013). *Advanced Biofuel Market Report 2013*, (http://www.fuelinggrowth.org/wp-content/uploads/2013/09/E2-Biofuel-Market-Report-2013.Final_.pdf), Accessed 11 December 2015.

Sorda, G., Banse, M. and Kemfert, C. (2010). "An overview of biofuel policies across the world," *Energy Policy* 38(11), 6977-6988. DOI: 10.1016/j.enpol.2010.06.066

The White House (2006). "The Advanced Energy Initiative," (https://georgewbush-whitehouse.archives.gov/ceq/advanced-energy.html), Accessed 13 November 2015.

U. S. Department of Energy (DOE) (2007). "Timeline of events 2007," (http://energy.gov /management/timeline-events-2007), Accessed 01 August 2015.

U. S. Department of Energy (DOE) (2013, February). "3rd. annual MSW to Biofuels Summit, Orlando, FL," (http://energy.gov/sites/prod/files/2014/04/f14/duff msw_to_biofuels_ summit.pdf), Accessed 01 December 2015.

U. S. Department of Energy (DOE) (2015). "The Energy Policy Act of 2005," (http://energy.gov/eere/femp/articles/energy-policy-act-2005), Accessed 11 August 2015.

U. S. Energy Information Administration (EIA) (2010). "Annual energy outlook 2010," (http://www.eia.gov/oiaf/aeo/pdf/0383(2010).pdf), Accessed 21 January 2015.

U. S. Environmental Protection Agency (EPA) (2007). "Summary of the Energy Independence and Security Act. (https://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act), Accessed 18 August 2015.

U. S. Environmental Protection Agency (EPA) (2009). Renewable Fuel Standard (RFS). (http://www.epa.gov/otaq/fuels/renewablefuels/index.htm), Accessed 13 August 2015.

Withers, J., Quesada-Pineda, H. J., and Smith, R. (2015). "Internal and external barriers impacting non-food cellulosic biofuel projects in the United States," *BioResources* 10(3), 3874-3889. DOI: 10.15376/biores.10.3.3874-3889

Zu, J., and Pan, X., (2009). "Woody biomass pretreatment for cellulosic ethanol production: technology and energy consumption evaluation," *Bioresource Technology Journal* 101(13), 4992-5002. DOI: 10.1016/j.biortech.2009.11.007.

Article submitted: July 17, 2016; Peer review completed: November 25, 2016; Revised version received and accepted; February 18, 2017; Published: February 27, 2017.
DOI: 10.15376/biores.12.2.2846-2863