Internal and External Barriers Impacting Non-Food Cellulosic Biofuel Projects in the United States

Jeremy Withers, Henry J. Quesada-Pineda,* and Robert Smith

Escalating demand, along with EPAct 2005, has led the United States government to assume a twofold leadership approach of energy security and environmental practices. This has initiated several important issues pertaining to cellulosic biofuel production. However, little is known about what is needed for the U.S. to lead long-term renewable energy security, how the US will develop and implement leading environmental energy practices, what supply capabilities and refining technologies are available to produce renewable fuels, and how funding can be used to adopt available technologies. This article examines geographical aspects, operational status, and barriers tending to prevent the successful commercialization of non-food cellulosic ethanol projects in the U.S. from secondary sources. Outcomes of this research can be used to further understand inhibitors that impact the production and commercialization of ethanol from non-food cellulosic sources.

Keywords: Non-food cellulosic biofuel; Biofuel barriers; Strategy issues

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

INTRODUCTION

A global environmental movement is currently underway to reduce fossil fuel dependency. This has certainly been the case in North America, specifically after 2005 when the United States Energy Policy Act (EPAct) (U.S. DOE 2014) was initiated with the goal of leading global energy security and combating growing energy problems by providing tax incentives and loan guarantees for energy production of various types. An important aspect of this legislation has been the support of non-food cellulosic biofuel projects as a way to decrease the production and use of fuel from food sources such as corn. Since the creation of EPAct 2005, 50 non-food cellulosic biomass projects have been attempted, with only a few surviving today.

The U.S.' commitment to exploration of cellulosic biofuel is due to future energy demands of global population density. In the short term, the U.S. average supply of food and fuel are tolerable; and long-term projections suggest escalating demand for food and energy for the foreseeable future. Escalating demand along with EPAct 2005 led the U.S. government to assume a twofold leadership approach of energy security and environmental practices. This has initiated several important issues pertaining to cellulosic biofuel production. For example, little is known about what is needed for the U.S. to be a leader in long-term renewable energy security, how the U.S. will develop and implement leading environmental energy practices, what the supply capabilities and refining technologies available to produce renewable fuels are, and how funding can be used to adopt available technologies. More importantly, there have been a large amount of reports indicating that cellulosic liquid biofuels are the best alternative to secure a sustainable source of energy without the compromises arising from food liquid biofuels such as corn-based ethanol. But the reality is showing that the task of producing commercial-scale cellulosic ethanol is very difficult with many different barriers and challenges that still need to overcome.

This research focuses exclusively on the non-food cellulosic biorefineries, specifically cancelled or shut down projects. This article examines geographical aspects, operational status, and barriers preventing the successful commercialization of non-food cellulosic ethanol projects in the U.S from secondary sources. Outcomes of this research can be used to further understand inhibitors that impact the production and commercialization of ethanol from non-food cellulosic sources. There are several non-food cellulosic biofuel projects announced to start in 2014, and these new projects can greatly benefit from the outputs of this research.

LITERATURE REVIEW

Non-Food Cellulosic Liquid Biofuel Basics

Non-food based cellulosic ethanol biofuel is a liquid fuel for transportation produced primarily from the lignin of renewable lignocellulosic biomass (Yang *et al*. 2006). For this study, non-food cellulosic biomass will consist specifically of woody biomass and grass varieties for the current purpose of substituting petroleum-based fuels with renewable ethanol biofuel. Ethanol biofuel can be also used is a fuel extender. It is capable of increasing octane content, or it can be used as a neat fuel in internal combustion engines (Gupta and Demirbas 2010) by blending it into the U.S. fuel supply. Lignocellulose consists of three major components: cellulose, hemicellulose, and lignin. Cellulose is the desired component for hydrolysis producing the highest value product for fermentation into sugars, which are then processed into ethanol. Cellulosic ethanol currently has the greatest potential for energy production, being the most abundant and rapidly renewable resource produced by photosynthesis (Moxley and Zhang 2007).

As of 2013, there are two primary methods to creating wood-based cellulosic ethanol; direct microbial conversion (DMC-biochemical) or simultaneous saccharification and fermentation (SSF-thermochemical). These two methods are further broken down into six secondary options for developing cellulosic biofuel: (i) catalytic pyrolysis and hydro-treating to hydrocarbons; (ii) gasification and Fischer-Tropsch synthesis to hydrocarbons; (iii) gasification and methanol-to-gasoline synthesis; (iv) dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis to ethanol; (v) enzymatic hydrolysis to ethanol; and (vi) consolidated bioprocessing (single-step enzyme production, hydrolysis, and fermentation) to ethanol (Brown and Brown 2012).

Cellulosic feedstocks range from $50/dry-ton to $80/dry-ton of biomass (Fueling Growth 2013). Those feedstocks could be from: unmerchantable timber, forest thinning, sawdust, waste paper, mill residues, paper mill sludge, and grasses. Bio-refinery facilities generally use one of six secondary methods for conversion of cellulosic biomass to energy, multiple biofuels, chemicals, and waxes. All of the feedstock products have variable moisture content variable upon arrival and have potentially different impacts on costs to manufacture different products.

Bio-Based Fuel Goals in the U.S.

In response to concerns about oil dependency and the contributions of fossil fuel use to climatic change, the U.S. Department of Energy (DOE) has begun a research initiative to make 20% of motor fuels biofuel-based in 10 years and to make 30% of fuels bio-based by 2030 (Gunderson *et al*. 2008). The U.S. holds 3% of the world's petroleum reserves, yet it consumes 25% of the world's annual petroleum production (U.S. DOE 2006). With the transportation sector consuming close to 2/3 of the petroleum, this has led the U.S. to search for ways to supply the growing demand for fuel and subsequent price control. This growing demand led President George W. Bush in 2005 to call for 7.5 billion gallons of ethanol to enter the supply by 2012, which would guarantee that approximately 5% of the nation's fuel is biobased (Moreira 2005). Upon presenting the EPAct 2005, the DOE announced an initiative to increase that proportion, so that biofuels will replace 30% of the nation's transportation fuels by 2030; this effort is often known as the 30-30 initiative (U.S. DOE 2006). Following these changes in the bio-based fuel goal, in the 2007 State of the Union Speech, President Bush announced the ambitious "20 in 10 initiative" that calls for reducing gasoline demand 20% in 10 years by producing 35 billion gallons of ethanol (replacing 15% of gasoline), and improving the corporate average fuel economy standards to reduce demand by 8.5 billion gallons of gasoline, or 5% of the current demand in 2007 (Bush 2007).

Policy Impacting Bio-Based Fuels

There are three main policies added in 2007 that drive non-food cellulosic biofuel development (Fueling Growth 2013), stemming from the EPAct 2005: Renewable Fuel Standard (RFS), the Low Carbon Fuel Standard (LCFS), and the Renewable Identification Number's (RIN's).

The EPA is developing regulatory certainty to maintain and potentially increase strength in investment opportunities through implementing stringent mandates of the Renewable Fuel Standard (RFS). According to the EPA (EPA 2013), the modified RFS - RFS2 lays the foundation for achieving significant reductions of greenhouse gas emissions from the use of renewable fuels, for reducing imported petroleum, and encouraging the development and expansion of the nation's renewable fuels sector. However, cellulosic liquid biofuel project must be aware of the definition and restrictions of acceptable feedstocks to be used in liquid biofuels. The Low Carbon Fuel Standard (LCFS) is a performance standard that requires a gradual reduction in the carbon intensity of California's fuel mix between 2011 and 2020 according (Fueling Growth 2013). The LCFS was established by the California Environmental Protection Agency as a more stringent standard to the RFS to excel California to the forefront of environmental protection. The Renewable Identification Number's (RIN's) are assigned certificates to every gallon of cellulosic biofuel produced. According to Bloomberg, the credits (certificates) help the EPA to track whether refiners are meeting federal biofuel-use mandates (Parker 2013). The certificates are used for tracking completion of production and/or blending of cellulosic biofuel into the U.S. fuel supply. After blending is accomplished, the certificates can be traded within the industry or used to verify the fulfillment of Federal mandates.

Current Markets and Commercialization Issues

Currently, many advanced biofuel technologies have been proven at a small level. Companies must now access significant capital to build commercial-scale biorefineries and improve the economics of their production processes (Fuel Growth 2013). The overall market as of 2013 remained mainly within the U.S. borders for transportation and aviation fuel industry. The market for non-food based cellulosic ethanol is for now specifically location-based on either side of the plains, mainly the Eastern half. The market potential is strong, and with more 1.3 billion tons of harvestable cellulosic biomass (Growth Energy 2014) in the U.S. alone, these types of projects have strong economic and environmental potential. However, many of these projects are currently stagnant until more refineries could overcome internal and external barriers to move their stalled projects to production and commercialization.

Of the six different primary production systems, the abundance of initial options since 2005 has stalled the sustainable cellulosic biofuel bio-refinery process. With each plant costing an average of $200 million, investors are hesitant to invest in the wrong process or invest without large stake ownership. The initial technology phases of project execution tend to weed out the weakly financed and inadequately functioning concepts. Most of the projects may require Ph.D.-level expertise at all phases within the entire project, increasing the constant cost base of scaling the technology to be fully operational from the laboratory experimental phase.

Even though there is strong policy supporting the development and commercialization of non-food liquid cellulosic biofuels in the U.S., an examination of the current status of liquid biofuel projects suggests that there might be a series of internal and external issues preventing the successful commercialization of non-food cellulosic biofuels. Therefore, the goal of this research is to determine and analyze the operational status of U.S. non-food cellulosic biofuel projects since the 2005 U.S. EPAct and to examine the factors preventing the commercialization of non-food cellulosic biofuels.

METHODS

The target population for this research is all non-food cellulosic projects that have started in the U.S. since the EPAact came out in 2005. The geographical location and operational status of each particular project was determined by carefully examining technical reports, peer-reviewed papers, trade journals, and newspapers. According to Schabengerger and Gotway (2004), a map may be defined in this context as spatial analysis with the domain as the entire U.S. To map the geographical location of the non-food cellulosic biofuel projects, a digital map was developed using Zeemaps, a low cost hands-on-internet map making source for continuously updatable map making. Based on the terminology used in the biofuel industry, the following categories were defined by Mendell and Lang (2013) to classify the status of all non-food cellulosic biofuel projects: planning, under construction, cancelled, shut down, or operating. All categories of current status were color coded differently in order to improve visual discrimination when using the mapping tool.

The determination of the factors impacting the commercialization of the biofuel projects was conducted by using grounded theory (Bowen 2006) procedures. In this particular case, there is little information about the factors that impact successful commercialization of non-food cellulosic biofuel projects. This method allows the researcher to develop theories or models from an initial set of data, such as documents and other secondary sources of information. Based on previous studies on factors impacting competitiveness of business in general (Quesada and Gazo 2007), the following axial codes were developed to classify the internal and external barriers from secondary sources: product development, technology, strategy, funding, suppliers, competitors, government, energy costs, and third party relationships. Contingency tables were used to explore and test the proportion of projects by each type of operational status and also by region of the

U.S. In addition, a multiple respond analysis is conducted to test if the differences in the reasons or categories for failure are the same across the type of closings (cancelled project or shut down project).

RESULTS AND DISCUSSION

Results

Geographic location and status of projects

The map shown below in Fig. 1 is divided into two regions, the Eastern and Western U.S. This line is arbitrary, and only meant to represent the general location where non-food cellulosic biofuel projects are located. The quantity of projects by status is numerically stated within color-coded areas of each legend and within the map. A total of 50 projects were identified and classified under one of the pre-determined project statuses Mendell and Lang (2013). The geographical distribution in Fig. 1 suggests that there might a relationship by region and project status. Therefore, a contingency table analysis is conducted to further analyze this potential relationship.

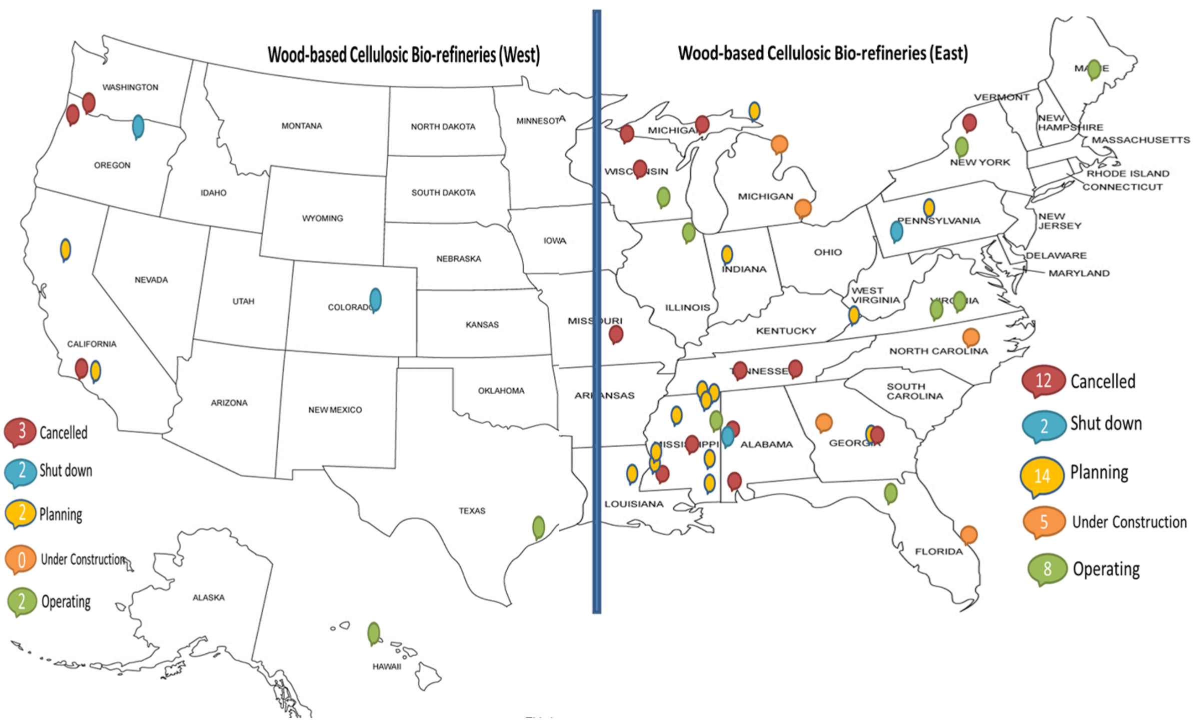

Fig. 1. Map of all non-food based cellulosic biofuel projects since 2005 (Lang 2014; Mendell and Lang 2013)

The contingency table analysis indicates that the majority of projects have been started in the East region (n=41, 82%). Given that there could be a relationship between the regions and the status of projects, a test was conducted to determine whether the proportions of the projects' statuses were the same for both regions (Fig. 2). To test whether the proportions are equal on each cell, a Chi Square test was performed. The results of the test indicate ($p=0.3260$) that there was no statistical evidence (with a significance level of 0.05) to reject the null hypothesis of no relationship between regions and project statuses.

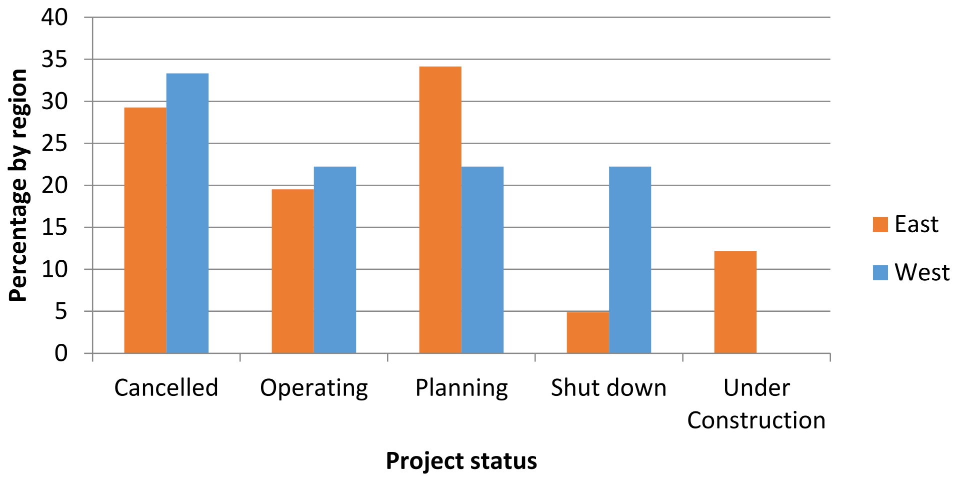

Fig. 2. The proportion of status of projects by regions

Internal and external barriers impacting non-food cellulosic biofuel projects

A total of 17 out of the 19 unsuccessful non-food cellulosic biofuel projects were analyzed to identify barriers that prevented commercialization of biofuels. In total, 70 reasons or barriers leading to failure were classified using grounded theory coding of the internal and external barriers. The internal categories that were developed to classify barriers were: product development, strategy, and technology. Other potential internal categories that were identified as part of the axial coding included: cost, human resources, and distribution. However, the open coding in the sources that were studied did not relate to the last three. For the case of external barriers, the following categories were identified as axial coding to classify open coding statements: funding, competition, suppliers, government, energy costs, and third party relations. These categories were identified in the literature (Quesada and Gazo 2007) as potential external factors that might impact the sustainability of a business.

The projects were classified in any of two groups: cancelled projects or shut down projects. Cancelled projects have been terminated. Shut down projects were stopped and put on hold but potentially could be restarted at a later time.

Figure 3 shows the number of internal reasons by type of closing (cancelled or shut down) since 2005. The product development category includes reasons from projects that did not pass the planning or construction stage. Only cancelled projects indicate this was a barrier; this reason was mentioned a total of 10 times. The category strategy is defined as a change of scope in seeking profits in other types of business since profits were not foreseeable in the short term. This reason was mentioned 9 times (7 by cancelled and 2 by shut down projects). The technology category included reasons regarding attempted technology that could not be fully utilized to the individual project's situation, projects that could not see an end to the scale-up costs, and projects that were intended to be developed using old/current infrastructure. For this particular internal barrier, there were a total of 12 mentions (11 by cancelled and 1 by shut down projects) of the 17 projects that were analyzed.

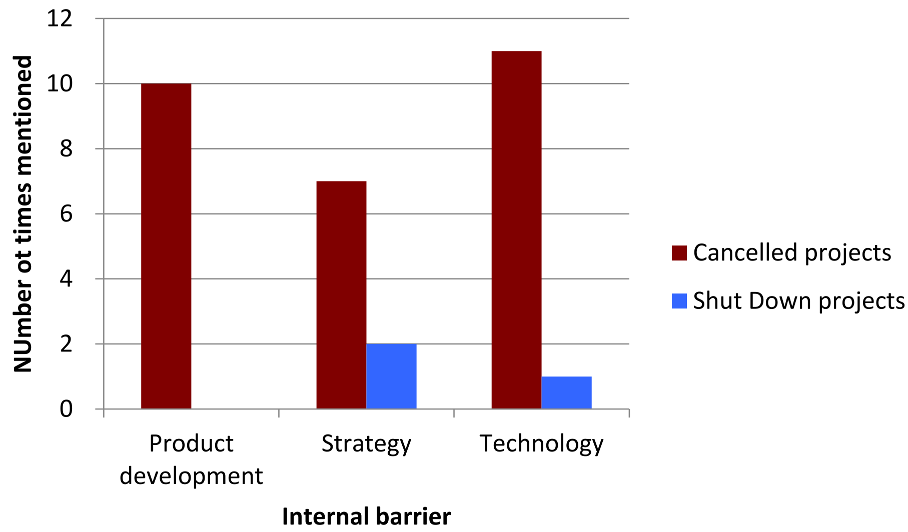

Fig. 3. Internal factors affecting sustainability of cancelled and shut down projects

Below in Fig. 4, the number of external barriers by type of closing is presented. Open code from the 17 reviewed projects was used to classify external reasons by any of the six previously defined categories, and data are shown by shut down or cancelled project.

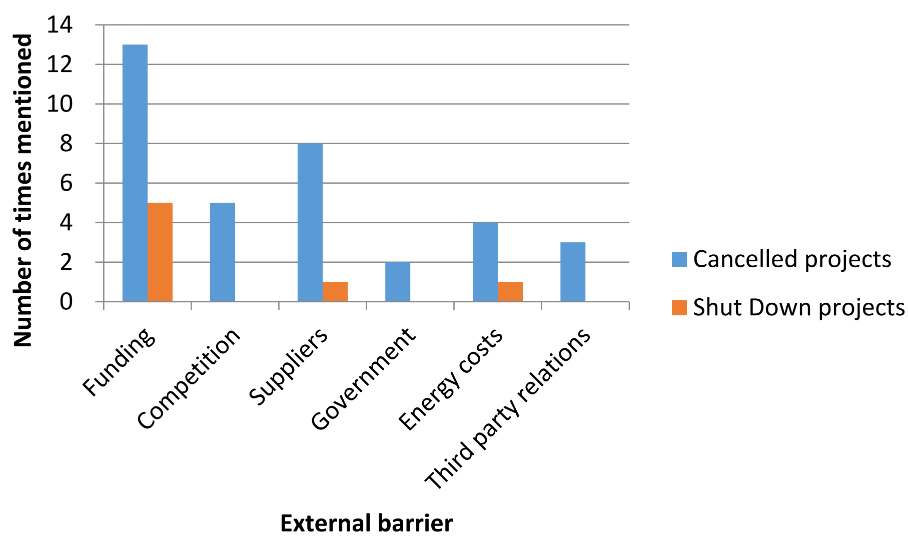

Fig. 4. External factors affecting sustainability of cancelled and shut down projects

The funding barrier indicates projects that did not have enough financial resources to move forward and were pressured to provide profits to maintain investor longevity and the strength of company credibility. Under this particular category, 13 open code statements were classified under cancelled projects and 5 statements under shut down projects. The category competition includes aspects such as import prices of biofuels and costs associated with rising daily expenses compared to competitors. For this specific classification, 5 open code statements related to competition were classified under cancelled projects. Open code statements related to suppliers were found a total of 8 times by cancelled projects and just one time by shut down projects. Supplier issues include fluctuating costs of cellulosic feedstock, supplier relations, or location. The category government contracts includes regulations, policy, or government intervention in the development of this particular biofuel market. Specific aspects that were found and classified under this category include future percentage costs associated with acquiring government assistance, and the stringent government oversight to meet mandates of that agreement. Only 2 open code statements were found that were related to this category by cancelled projects.

The category energy costs 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. Four open statements were classified in this category by cancelled projects and just 1 by shut down projects. Finally, the external category *Third party contracts* is determined based on the relationships that these types of biofuel projects have with third party developers. Specifically, issues such as future percentage costs associated with acquiring a third party for their technology, expertise, funding, *etc*. were included. A total of three open statements were classified under this category, all associated with cancelled projects.

After extracting open code statements and classifying them as internal or external barriers and by types of closing (cancelled or shut down), a contingency table analysis was conducted to test if the proportion of internal and external barriers is the same by type of closing. The result of the analysis is shown in Table 1. The Chi-Square test (p=0.0884) indicates that there is no relationship between the type of closing and the type of barrier (external or internal) when using a significance level of 0.05. 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 1. Contingency Table to Analyze Relationships between Projects and Barriers

Count, Column %, Row %	Cancelled projects	Shut down 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 whether there are any differences in the responses rates across type of closing (cancelled or shut down). As indicated earlier, each company that was cancelled or shut down provided multiple responses (barriers that led to failure). It is of interest to test whether the response rates on each type of closing are the same or not. 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) is tested using a Chi Square test.

Results of the test are presented in Table 2. The most significant difference across the two groups (cancelled project and shut down project) was found in the product development category. The second most important difference was found in the supplier category, and the third most significant difference was found in the technology category.

The competition and third party contracts complete the top five of most significant differences across the groups in this study. No significance difference (with an alpha of 0.05) were found for the categories energy costs, funding, government, and strategy.

Table 2. 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		

Discussion

All sustainable cellulosic projects undergo internal and external failures along their path to commercialization, yet despite the known risk the projects still march forward. These risks are painful and continue to reduce private interest and investment in non-food cellulosic biofuel projects. The pathway is becoming more focused, but with increasing obstacles such as government regulations, supply price fluctuations, commercial scaling of technology, supplier locations, and lackluster support for the fossil fuel industry continue to slow down the path to commercialization of this business. These factors force evolving companies to search for funding and stakeholder control of technology. As shown by this analysis, all companies (including the ones still in operation or planning) have struggled through the different project stages or statuses.

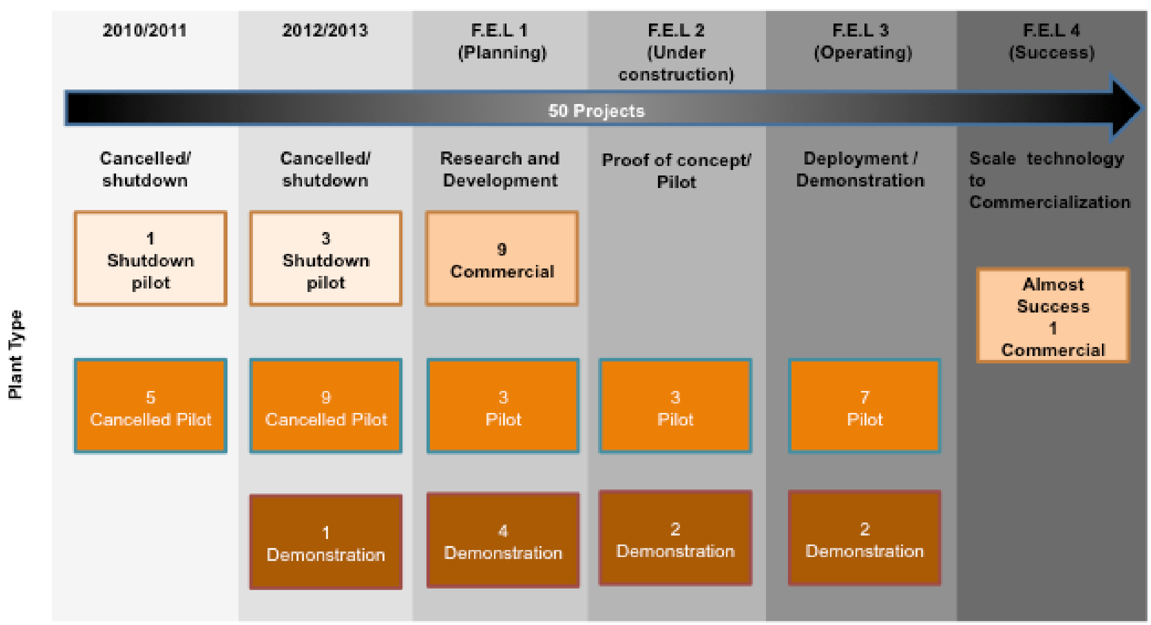

Fig. 5. Front end loading (F.E.L) stages since 2007

Since 2007, 50 North American non-food cellulosic biofuel projects have been started and are currently in one of the four phases of front end loading (F.E.L.) commercialization. Currently, 38% (19) are cancelled or shut down, 32% (16) projects are in planning (F.E.L. 1), 10% (5) are under construction (F.E.L 2), 14% (7) are in deployment/demonstration (F.E.L. 3), and (1) in scale technology to commercialization (F.E.L 4). None have made it to complete commercialization success (Fig. 5).

Project status and geographical location

The geography location analysis indicated that most of the non-food cellulosic biofuel projects are located in the East region, but the proportion rates of projects when comparing the East and the West region does not show any significant difference between regions. States such as Mississippi seem to have an excellent policy to attract the industry, as Fig. 1 shows. Other projects seem to be uniformly scattered across the other states in the East. In total, 19 projects have either cancelled or shut down. Out the 50 projects started since 2007, only 10 are currently operating in any of the two regions. These operating projects are still operating at some level of proof of concept or demonstration, but they have not been able to successfully commercialize biofuels.

Internal barriers leading to failure

Reasons for cancelling or shutting down a project were classified as either being internal or external barriers. Projects cancelled or shut down for internal reasons were categorized as product development, strategy, and technology.

Technology barriers seem to be the common denominator for many projects that have been cancelled or shut down. For example in 2009, New Page Paper's President and CEO, Rick Willet, suggested that in order to continue their biofuel project, the following would have to improve: costs of installation of the Chemrec process and substantial investment to modify existing operations (Kirkbride McElroy 2009). Also, many projects were designed as a secondary business for a paper mill. One problem has been that, in many cases, converting an existing paper mill is not competitive against companies that are equipped with more modern and cost-efficient machinery (Austin 2008). Ten years ago, it was thought that biofuel projects would be a great secondary business for the paper industry to survive and to increase their competitiveness; however, the results have not met the expectations. Rising energy costs continued to hit the industry hard, and the potential to create their own biofuel to feed the process or to commercialize has not been realized.

Product development issues were found to be the second reason why so many projects have been cancelled or shut down. In some cases it was found that paper companies heavily invested in promised alternative energy breakthroughs that were still not ready to produce commercial biofuel. This was the case of Cello Energy (Lane 2011) and Parsons and Whittemore Enterprises (Kirby 2011). Another example is Range Fuels, a company that 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. These setbacks led to never producing biofuel from biomass to the point that Range Fuels closed the plant in January 2010 and filed for bankruptcy September 2011 (Parker 2011; Investors Hub 2011).

The third most common reason for cancelling or shutting down was strategy. An example of strategic or criteria change was found in the case of Coskata, a planned biorefinery to be installed in Boligee, AL (GCD 2012); in 2012, the management decided to shut down the project due to the need for a different site with greater utility infrastructure. A similar situation was faced by Kior, who planned to build five biorefinery sites in the Mississippi Gulf Opportunity Zone, but they decided to explore alternative locations (Hogan 2012; Wood Bioenergy 2013). Another example is the Rentech facility in Commercy City, CO, where they decided to cancel a biofuel project after the management refocused on nearer-term profitable growth opportunities (Lane 2013b). Rentech believed that company resources were better directed at opportunities that would produce more immediate returns, as it did not expect the market opportunity for alternative energy to improve materially in the U.S. within the next several years (Lane 2013b; Rentech Inc. 2013).

External barriers leading to failure

Out the six barriers that prevent the successful commercialization of non-food cellulosic biofuel projects, funding issues were identified as the most significant (Fig. 3). An example of this barrier can be found in Flambeau River Biofuel's situation, where a matching grant through the DOE required the company to increase equity of match cost from 20% to 50% (Brochu 2010). The company's management qualified this potential move as high risk, and the company was certain that investors would like to put their money in less risky ventures (Brochu 2010). A similar example, the Rentech Rialto project, withdrew its DOE funding request due to low guarantees from the DOE (Investors Hub 2011). This company stopped the project because it believed that the Rialto project was not economically feasible under the current terms of the negotiation with the DOE (Businesswire 2010; Kirby 2011). Raven Biofuel and Gulf Coast Energy are two other projects that were cancelled due to funding issues, specifically unfavorable project economics and insufficient financing (Mendell and Lang 2013).

Second on the list of most important external barriers are supplier issues. An accepted statement on supplier issues regards the rising transportation costs for moving feedstocks to the production site. One of the biggest challenges for any new project attempting to produce independent energy is the managing of transportation costs (Siemers 2013). This continues to be important, even though, in some locations, the prices of feedstock have dropped due to competitors closing operations (Lane 2012; Mies 2013). The third most important barrier leading to cancellation or shutting down were competition issues. The Costkata biorefinery project in Boligee, AL also attributed its failure to the abundant presence of natural gas in the market, which led to price dislocation and ready availability of natural gas (Lane 2012). The New Page paper company also indicated the effects of low priced imported products as one of the reasons the company had to shut down its biofuel project (Austin 2008). Price competition from corn ethanol could be also impacting the financial feasibility of some of proposed projects. Feedstock supply is abundantly available where projects are or were located, but their prices may fluctuate with economic factors. A small change in price could close some refineries already in a financial crisis, struggling from reduction in private investment.

The last three barriers that were identified were energy costs, third party relations, and government issues. Five of the cancelled or shut down projects indicated that energy cost issues are preventing projects from producing biofuel within acceptable production costs (Austin 2008; Siemers 2010). In general, companies impacted by this barrier have indicated that the costs of electricity and fuels have increased considerably over the last five years. In terms of government issues, it seems the lack of government incentives, regulations, and assistance supporting alternative energy, particularly within the U.S., have also led to the cancellation or shutting down of some biofuel projects (Fielding 2010; Lane 2013a; Rentech Inc. 2013). Third Party relations were also important, as some of the projects developed partnerships with other companies in order to have access to patents, proprietary technology, distribution channels, or even feedstocks. However, in some cases the partnership did not work out, and the initial partners have ended up in litigation to solve the issues (Kirky 2011; Lane 2013a).

The number of energy biomass projects have been declining (including liquid biofuels) since 2010, according to Lang (2014). However, little is known about the reasons as to why they fail. Learning from their failures has not been a focus of research within the world of academia or in industry at large. This research provides important insights on the main barriers that have prevented biofuel projects from becoming commercially successful.

Creating a path for successful cellulosic ethanol projects

The success for cellulosic liquid biofuel plants requires a not so simple combination of internal and external factors. Internally, the industry seems to be impacted by *technology, product development,* and *strategic* barriers. *Technology* and *product development* are key aspect that could help to develop less costly enzymes and decrease production costs at factory level (Gies 2014). *Strategic issues* are fundamental in order to consider not just the production of liquid biofuel as the main source of revenue but the commercialization of byproducts and co-products from the cellulosic liquid biofuel process.

Funding and *supplier* issues are the main external barriers preventing this industry to become successful. *Funding* is critical for this industry to gain momentum, and there has not been a shortage of funding since the creation of the introduction of EPAct 2005. As a new and immature industry, state and federal support is important to continue to support new projects, create market acceptance, and develop the proper policy to regulate the industry and its competitor products. For example, the blending and production of corn-based ethanol is capped today to certain levels and these regulations could impact non-food-based liquid biofuels production in the future by limiting the access to the market.

On the other hand, *supplier issues* are related to the cost of feedstocks and facility location. Cellulosic liquid biofuel projects are very sensitive to small changes in feedstock costs, and selecting a location that increases logistical costs is not sustainable. To avoid this, a large number of federal funded projects conducted in higher education institutions have developed effective optimization models that consider location, type of biomass, transportation costs, storage, and even distribution costs to help industry to find the right location for their facilities. These optimization models can be easily adapted to particular situations, and different locations under various scenarios can be modeled.

CONCLUSIONS

1. The three main policies that have triggered the development of non-food cellulosic ethanol projects are the Renewable Fuel Standard (RFS), the Low Carbon Fuel Standard (LCFS), and the Renewable Identification Number's (RIN's), which all stem from the EPAct 2005 policy.

2. There is an abundance of available technology to convert cellulosic biomass to energy and fuel. Only six of those technologies are generally considered for private investment and development of refineries.
3. Since 2005, 50 non-food cellulosic biofuel projects have been started in the U.S; 19 of these projects have been cancelled (terminated) or shut down (put on hold). None of the projects have been able to successfully commercialize biofuel to date.
4. Most of the projects (41) were started in the Eastern region of the U.S. Access to biomass and different specific state policies have been the main driver for the difference, compared to the Western region (only 9). A Chi Square test indicates that the proportion of the different stages was not significant when comparing the East and the West regions.
5. The main internal barriers impacting the sustainability of non-food cellulosic biofuel projects in the U.S. have been technology, product development, and strategic issues.
6. The main external barriers have been funding, suppliers, competitors, energy costs, government, and third party issues.
7. When comparing the proportion of internal and external barriers by type of closing, no statistical evidence was found indicating a difference.
8. A multiple response test was conducted to identify the most important barriers. Product development, supplier, and technology issues were identified as the most important based on a statistical test.

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