Effectiveness of the Renewable Fuel Standard in Sparking Innovation in the Cellulosic Biofuels Industry

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ABSTRACT

The Renewable Fuel Standard ("RFS") was enacted in 2005 to increase energy independence within the United States by setting renewable fuel usage requirements, which would encourage innovation within the biofuels industry. The cornerstone of the regulation was the desire to spur innovation in the promising field of cellulosic biofuels. This program provides four categories of energy sources and mandates that producers meet the annual usage volumes set by the Environmental Protection Agency ("EPA"). In July of 2014, the EPA clarified the definition of "cellulosic biofuels" to include fuels that did not originally qualify under the RFS. This Article seeks to explain whether the RFS did in fact increase innovation within the cellulosic biofuels industry and whether the expansion of the cellulosic biofuel definition in 2014 impacted the number of patent applications and patents issued.

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INTRODUCTION

Since the 1970s, energy policies in the United States have been implemented to increase innovation and decrease energy dependence. The latest round of energy legislation, the Renewable Fuel Standards ("RFS"), was authorized under the Energy Policy Act ("EPAct") and signed into law on August 8, 2005.[1] The intention of the RFS is to reduce greenhouse gas ("GHG") emissions and expand the nation's renewable fuels sector, while advancing towards energy independence by promoting innovation within the renewable fuel industry.[2] This study analyzes one of the four renewable fuel categories under the RFS: cellulosic biofuel.[3] This Article further seeks to determine whether one indicator of

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1. Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (codified as amended in scattered sections of 16 U.S.C. and 42 U.S.C.); Federal Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program, 72 Fed. Reg. 83, 23,900 (May 1, 2007) (Codified at 40 C.F.R. pt. 80) [hereinafter RFS]; John W. Shikles, *Captive Consumer Paradox: The D.C. Circuit's Attempt to Bring Symmetry to Clean Air Act Incentives for Cellulosic Biofuel Production*, 20 J. ENV'T & SUSTAINABILITY L., 231, 233 (2015); EPA, *Renewal Fuel Standard Program*, https://www.epa.gov/renewable-fuel-standard-program (last visited Jan. 26, 2018) (noting that Renewable Fuel Standard was created under the Energy Policy Act of 2005, and was expanded under the Energy Independence and Security Act ("EISA") of 2007 to spark innovation in the U.S. development of renewable fuels).

2. Regulation of Fuels and Fuel Additives: RFS Pathways II, and Technical Amendments to the RFS Standards and E15 Misfueling Mitigation Requirements, 79 Fed. Reg. 138, 42,128 (July 18, 2014) (Codified at 40 C.F.R. pt. 80) [hereinafter RFS II]; *see* RFS, *supra* note 1, at 23,902; *see also* Aarian Marshall, *Biofuels Industry Highlights Innovation, Responds to Anti-RFS Campaign*, AGRIPULSE (Jan. 18, 2013), https://www.agri-pulse.com/articles/2522-biofuels-industry-highlights-innovation-responds-to-anti-rfs-campaign ("the RFS' high bar has created unprecedented innovation. That optimism (of RFS2) has spurred all those projects coming online soon across the US.").

3. KELSI BRACMORT, THE RENEWABLE FUEL STANDARD (RFS): CELLULOSIC BIOFUEL 7–5700, CONGRESSIONAL RESEARCH SERVICE (2015), https://www.lankford.senate.gov/imo/media/doc/The%20Renewable%20Fuel%20Standard%20Cellulosic%20Biofuels.pdf [hereinafter, BRACMORT, *RFS*]; *see also*

innovation—the number of patent applications and patents issued—suggests that the RFS has had a significant impact on cellulosic biofuel innovation.[4] Cellulosic biofuel production has historically not met the expectations of the RFS analysis.[5]

On July 18, 2014, the Environmental Protection Agency ("EPA") expanded the definition of "cellulosic biofuel" under the RFS to include various forms of methane derived from cellulose such as landfill gas and gas from digester operations.[6] This definitional expansion broadened the options for producing high value cellulosic biofuels by including gaseous fuels (primarily methane) derived from a variety of waste recovery biomass processes.[7] Some postulate that EPA made this change to "inflate[] cellulosic fuel production so that the numbers are more in line with their prediction of high cellulosic production."[8] The definition now includes production of "cellulosic biofuels" from technologies that existed prior to the EPAct of 2005.[9] EPA encouraged these gaseous technologies as far back as 1994—through the AgSTAR (1994) and Green Power Partnership (2001).[10] The inclusion of these existing gaseous processes raises concerns as to the impact of RFS on innovation in the liquid cellulosic biofuels market. While one can argue this point, cellulosic biofuel production has appeared to lag behind predictions and this has raised questions regarding the effectiveness of the RFS.[11]

Lee R. Lynd et al., *Cellulosic Ethanol: Status and Innovation*, 45 CURRENT OPINION IN BIOTECHNOLOGY 204 (2017), http://www.enchicorp.com/wp-content/uploads/2015/05/LyndetalCurrOpinBiotech2017.pdf.

4. *See* EPA, RENEWABLE FUEL STANDARDS PROGRAM (2016), https://www.epa.gov/laws-regulations/summary-energy-policy-act.

5. BRACMORT, *RFS*, *supra* note 3, at 1. ("Clearly the main economic obstacle to cost-competitive cellulosic biofuel production is the cost of conversion rather than the cost of feedstock. The key factor responsible for the high cost of processing cellulosic biomass using current technology is the recalcitrance of lignocellulose, that is, the difficulty of its conversion to reactive intermediates.").

6. RFS II, *supra* note 2, at 42,128.

7. KELSI BRACMORT ET AL., CELLULOSIC BIOFUELS: ANALYSIS OF POLICY ISSUES FOR CONGRESS, CONGRESSIONAL RESEARCH SERVICE (Oct. 14, 2010). It appears that this definitional expansion expands the definition of cellulosic beyond the original intent of increasing liquid-based cellulosic fuels such as ethanol and diesel, while the goal of the expansion is about clarifying the RFS program. RFS II, *supra* note 2, at 42,128. The text of the original rule did not allow this broad of a definition. However, the expansion of the definition seems to have changed the intent of the original definition at its core by including cellulosic by products not in the original rule. The EPA explains that these new pathways are included because they now meet the sixty percent reduction criteria that the RFS requires for a fuel to qualify as cellulosic. *Id.*

8. INST. FOR ENERGY RESEARCH, EPA MOVES GOALPOSTS WITH NEW DEFINITION FOR CELLULOSIC BIOFUELS, 1 (2014), http://instituteforenergyresearch.org/analysis/epa-moves-goalposts-new-definition-cellulosic-biofuels/ [https://perma.cc/P8SH-2CFD].

9. RFS II, *supra* note 2, at 42,130 (explaining the original definition of "cellulosic biofuel" was "renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and has lifecycle greenhouse gas emissions, as determined by the Administrator, that are at least 60 percent less than the baseline lifecycle greenhouse gas emissions.").

10. *See* EPA, AGSTAR: BIOGAS RECOVERY IN THE AGRICULTURE SECTOR (2017), https://www.epa.gov/agstar; BRACMORT, *RFS*, *supra* note 3, at 12.

11. *See* RFS II, *supra* note 2, at 42,133; BRACMORT, *RFS*, *supra* note 3, at 1.

It is unclear whether the pre-expansion definition was effective in spurring innovation and whether the expanded definition will do a better job of meeting the long-term goals regarding cellulosic biofuels production. To test the hypothesis that innovation has occurred as a result of the pre-expansion RFS, this Article presents an empirical analysis using patent data as the single measure of innovation.

There are two main methods to produce cellulosic biofuels—thermochemical (gasification) and biochemical.[12] The analysis will focus on the biochemical method, which uses enzymatic methods for breaking down the cellulose to reach the sugars necessary for the production of liquid biofuels supported by the original RFS.[13] This subset was chosen because it represents one of the two main methods and benefits the most from the development of a niche market, which encourages research investments.[14] A subsidiary analysis will evaluate the impacts of the change in definition of "cellulosic biofuel" on innovation in the liquid biofuels field as measured by patent applications and patents issued.

The Article proceeds as follows: Part I discusses the importance of cellulosic biofuel innovation to the energy industry of the United States. Part II analyzes the current state of the cellulosic biofuels industry and the changes that have occurred since the RFS was enacted. Part III explains the patent landscape within environmental and energy innovation. Part IV provides an empirical analysis of one indicative measure of innovation, the number of patents issued and filed, within the industry. Part V recommends that the EPA and Congress consider using this valuation method prior to future changes to definitions, if the goal is to encourage long-term innovation in biofuels. Part VI further recommends using unconventional strategies from other technology fields—such as cross-licensing patents and providing grants for research consortiums—to increase innovation.

I. CELLULOSIC BIOFUELS

A. WHAT ARE CELLULOSIC BIOFUELS?

As defined by the Clean Air Act, cellulosic biofuel is "a renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions . . . that are at least sixty percent less than the baseline lifecycle greenhouse gas emissions."[15] More

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12. RFS II, *supra* note 2, at 42,134.

13. *Id.*, *see also* Environmental Protection Agency, Regulation of Fuels and Fuel Additives: RFS Pathways II and Technical Amendments to the RFS 2 Standards, 78 Fed. Reg. 36,042, 36,047 (June 14, 2013) (codified at 40 C.F.R. Pt. 80).

14. RFS II, *supra* note 2, at 42,134.

15. Clean Air Act of 2007, 42 U.S.C. § 7545, (2012); *see also* Sarah Pearce, *EPA's Expanded Definition of Cellulosic Biofuels: A+ Grades for C- Performance*, AM. ENERGY ALLIANCE (Aug. 8, 2008), http://americanenergyalliance.org/2014/08/08/epas-expanded-definition-of-cellulosic-biofuels-a-grades-for-c-student-performance/#_edn4.

specifically, cellulosic biofuel is a liquid fuel or feedstock produced from cellulose, a material that comprises much of the mass of plants including grasses, wood, and municipal agricultural waste.[16] Cellulose is an organic matter found in plant walls that, along with hemicellulose and lignin, aid plants in having a rigid structure.[17] This rigid structure protects the vital nutrients and sugars necessary for plant life.[18] Cellulosic biofuels are derived from these sugars once enzymes, heat, or other means break down its rigid structure.[19] Cellulose is the most abundant biopolymer on earth,[20] and as such, it is desirable to be able to utilize this renewable source to provide fuel.[21] Feedstocks, an important Renewable Identification Number ("RIN") qualifying cellulosic biofuel, include agricultural residues, forestry residues, dedicated energy crops (such as switchgrasses), and urban sources of waste.[22] The critical aspect of this type of cellulosic fuel is that the feedstocks are non-food based,[23] including agricultural residues such as corn stover, and they do not decrease our food resources.[24] It is challenging to release the sugars in these feedstocks for conversion to ethanol.[25] Commercialization of these processes is a funding priority of the United States Department of Energy's Bioenergy Technologies Office.[26] Importantly, cellulosic ethanol is one particular

16. *Cellulos*e, MERRIAM-WEBSTER DICTIONARY (11th ed. 2016).

17. BRACMORT, *RFS*, *supra* note 3, at 14.

18. *Id.*; *see also*, U.S. ENVTL. PROT. AGENCY, CELLULOSIC CONTENT OF VARIOUS FEEDSTOCKS—2014 UPDATE (July 1, 2014), http://www.regulations.gov/document?D=EPA-HQ-OAR-2012-0401-0240 (citing *Glossary of Terms*, U.S. OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY, http://www.energy.gov/eere/bioenergy/glossary (last visited Jan. 26, 2018)).

19. BRACMORT, *RFS*, *supra* note 3, at 14.

20. Carlo R. Carere et al., *Third Generation Biofuels via Direct Cellulose Fermentation*, INT. J. MOL. SCI. 8 (2008), http://instituteforenergyresearch.org/analysis/epa-moves-goalposts-new-definition-cellulosic-biofuels/ [https://perma.cc/6C28-BLN2] (EPA standard of cellulosic biofuel).

21. RFS, *supra* note 1, at 23,915–23,917.

22. *Id.*

23. Under the RFS, agriculture residue is considered a non-food based source. The key factor is that the cellulosic fuel is created from products that are not primarily grown for food. The residues that are left in the field or removed during processing are not intended for consumption, so using those materials doesn't impact the amount of food that a farm produces. Another area that is looked at is the timber industry. One way of cutting trees is to cut the tree and the limbs off. Then they only take the whole logs for use. In this case, the material that is left is left to rot. The rotting material gradually decomposes and emits methane gas (natural gas) similarly to paper and wood products in a landfill. There is an additional problem with leaving the "slash" in the woods in that now must be controlled for forest fires because there is a substantial amount of fuel that can catch fire via a lightning strike, etc.

24. COMM. ON ECON. AND ENVTL. IMPACTS OF INCREASING BIOFUELS PROD., BD. ON AGRIC. AND NAT. RES., DIVISION ON EARTH AND LIFE STUDIES, BD. ON ENERGY AND ENVTL. SYSTEMS, DIVISION ON ENG'G AND PHYSICAL SCI., NAT. RESEARCH COUNCIL, CHAPTER 4: THE ECONOMICS AND ECONOMIC EFFECTS OF BIOFUEL PRODUCTION, RENEWABLE FUEL STANDARD: POTENTIAL ECONOMIC AND ENVIRONMENTAL EFFECTS OF US BIOFUEL POLICY, NAT. ACADEMIES PRESS 59 (2011), https://www.nap.edu/read/13105/chapter/6.

25. RFS, *supra* note 1, at 23,915 ("Cellulosic feedstocks (composed of cellulose and hemicellulose) are currently more difficult to convert to sugar than starches.").

26. *Strategic Plan for a Thriving and Sustainable Economy*, US DEP'T. OF ENERGY'S BIOENERGY TECH. OFFICES, (Dec. 2016), https://www.energy.gov/sites/prod/files/2016/12/f34/beto_strategic_plan_december_2016_0.pdf, [https://perma.cc/GP76-WWYU] [hereinafter *Strategic Plan*].

area of the overall category of cellulosic biofuel.[27] Others include cellulosic natural gas and cellulosic diesel.[28]

Cellulosic feedstocks offer many advantages over starch-based and sugar-based feedstocks.[29] They are abundant and can be used to produce cellulosic biofuels required by the RFS.[30] They are either waste products or purposefully grown energy crops harvested from marginal lands not suitable for other crops.[31] Less fossil fuel energy is required to grow, collect, and convert them to ethanol, and they are not used for human food. However, there are challenges with harvesting, collecting, and delivering cellulosic feedstocks. Researchers are studying these challenges to determine effective and affordable solutions to collect and deliver cellulosic feedstocks.

Potential ethanol yields from feedstocks are determined by their properties, which can be found in the Biomass Feedstock Composition and Property Database, or in the Energy Research Centre of the Netherlands' Phyllis database.[32] These cellulosic biofuels are intended to reduce GHG emissions; provide more consumer options for fuel; create agricultural development opportunities; and be a renewable fuel produced from locally sourced biomass.[33]

B. THE BIOFUELS INDUSTRY IN THE UNITED STATES

The biofuels industry is an emerging industry "with multiple competing candidate technologies, and it has not yet converged on a viable domain design."[34] The wide-range of these technologies has made it difficult for researchers to demonstrate steady progress of the overall industry despite the multitude of research and design efforts.[35] While the concept of bio-based fuels has existed for many decades, economics has limited its potential to replace fossil fuels without government support for several reasons.[36] First, one scholar found that "if cellulosic biofuel

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27. *Biofuels: Ethanol-Biodiesal Explained*, U.S. ENERGY INFO. ADMIN. (Sept. 28, 2016), http://www.eia.gov/energyexplained/?page=biofuel_ethanol_home [https://perma.cc/9AJL-39MB].

28. *Strategic Plan*, *supra* note 26.

29. RFS, *supra* note 1, at 23,915 ("While the cost and difficulty are a disadvantage, the cellulosic process offers the advantage that a wider variety of feedstocks can be used.").

30. COMM. ON ECON. AND ENVTL. IMPACTS OF INCREASING BIOFUELS PROD. ET AL., *supra note* 24.

31. *See* RFS, *supra* note 1, at 23,915.

32. Alternative Fuels Data Center, *Ethanol Feedstocks*, U.S. DEP'T. OF ENERGY (Aug. 23, 2016), http://www.afdc.energy.gov/fuels/ethanol_feedstocks.html.

33. *DuPont Celebrates the Opening of the World's Largest Cellulosic Ethanol Plant*, DUPONT (Oct. 20, 2015), http://www.dupont.com/products-and-services/industrial-biotechnology/advanced-biofuels/cellulosic-ethanol.html [https://perma.cc/XH6C-TFNR].

34. Stevan C. Albers, Annabelle M. Berklund & Gregory D. Graff, *The Rise and Fall of Innovation in Biofuels*, 34 NATURE BIOTECHNOLOGY 8, 814, 814 (2016), http://www.nature.com/nbt/journal/v34/n8/pdf/nbt.3644.pdf.

35. *Id.*

36. *See What Happened to Biofuels?*, THE ECONOMIST (Sept. 7, 2013) http://www.economist.com/news/technology-quarterly/21584452-energy-technology-making-large-amounts-fuel-organic-matter-has-proved-be [https://perma.cc/DD9X-8GQK]; COMM. ON ECON. AND ENVTL. IMPACTS OF INCREASING BIOFUELS PROD. ET AL., *supra* note 24, at 124; *see generally Economics of Biofuels*, U.S. ENVT'L

becomes commercially viable, land prices will increase."[37] Biofuels require physical land for their production, and dedicating these areas of land to biofuels increases competition and value of the land, which would require more government support.[38] Second, because of the difficulty in obtaining financing for environmental innovation, finance companies look for niche markets where there is a significant reward for the investment risk. Until the revisions, liquid cellulosic biofuels had a niche market, which had the potential to attract research investment.[39] Lastly, and of particular importance, when originally enacted, the RFS had startup companies racing to meet the cellulosic requirements, but many of these companies ultimately went bankrupt.[40]

C. DIFFICULTIES IN COMMERCIALIZATION

There are more failure stories in the cellulosic biofuels industry than there are success stories. This has led some to argue that cellulosic biofuels have not made innovative progress like they were originally thought to in the technology industry.[41] Determining the long-term viability of cellulosic biofuels is quite difficult because of the many factors that affect its future. Kelsi Bracmort notes in her review for the Congressional Research Service that "factors to consider include the uncertainty stemming from the EPA's implementation of the RFS, Congress's action on biofuel programs and tax incentives, industry's difficulty in producing cellulosic biofuel, and the unknown impact of current oil and gasoline prices."[42] All of these issues compound to make it difficult to advance research enough to make production facilities commercially viable.

Optimism abounds, but continued failures in the cellulosic industry make it increasingly difficult to obtain the necessary financing and loan guarantees. An example of this is the well-documented failure of Range Fuels in Soperton,

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Protection Agency (May 27, 2016), https://www.epa.gov/environmental-economics/economics-biofuels [https://perma.cc/YXB5-VJ8U] [hereinafter *Economics of Biofuels*].

37. COMM. ON ECON. AND ENVTL. IMPACTS OF INCREASING BIOFUELS PROD. ET AL., *supra* note 24, at 24.

38. Andrew Steer & Craig Hanson, *Biofuels are not a Green Alternative to Fossil Fuels*, THE GUARDIAN (Jan. 29, 2015), https://www.theguardian.com/environment/2015/jan/29/biofuels-are-not-the-green-alternative-to-fossil-fuels-they-are-sold-as.

39. *See* Laura Ruth, *Bio or Bust? The Economic and Ecological Cost of Biofuels*, 9 EMBO REPORTS 130, 133 (2008), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2246417/pdf/embor20086.pdf (explaining that "Nevertheless, biofuels are creating new regional and niche markets, and spawning opportunities for international collaborations."); *see generally* Erica Gies, *Cellulosic Ethanol and the Struggle to get Green Fuels to Market*, GREEN BIZ (Dec. 11, 2014), https://www.greenbiz.com/article/cellulosic-ethanol-next-best-green-fuel-yet-hit-market.

40. Steven Mufson, *Why Hasn't Cellulosic Ethanol Taken Over, Like it was Supposed to?*, WASH. POST (Nov. 8, 2013), https://www.washingtonpost.com/business/economy/why-hasnt-cellulosic-ethanol-taken-over-like-it-was-supposed-to/2013/11/08/b25b0d2c-466a-11e3-a196-3544a03c2351_story.html.

41. Am. Petroleum Inst. v. EPA, 706 F.3d 474, 476 (D.C. Cir. 2013) ("Congress provided for the possibility that the actual production would fall short of the stated requirements.").

42. BRACMORT, *RFS*, *supra* note 3, at 1.

Georgia.[43] This facility promised to produce cellulosic ethanol through thermolysis and received over seventy-five million dollars in federal funds and significantly more from other sources including the State of Georgia.[44] The promises were not met and the company filed for bankruptcy in late 2010.[45] This failure impacted the entire industry by making government more cautious when providing funding to commercialize new processes. One leading energy expert summarized the impacts of the Range Fuels failure, "if you go out there, and make claims and take taxpayer money and don't deliver, you hurt the ability to raise money for realistic projects and you sour taxpayers on biofuels."[46] Because of these "failures" and the slow advances within the industry, there are more unknowns in the future of cellulosic biofuels than there are predictive attributes.

II. THE STATUTORY BACKGROUND

The RFS was created under the Energy Policy Act of 2005 ("EPAct"), "which amended the [Clean Air Act ("CAA")]."[47] It required EPA to establish rules to implement a renewable fuels program. This EPAct used a variety of economic incentives, including grants, income tax credits, subsidies, and loans to promote

43. *The Range Fuels Failure*, BIOFUELS DIGEST (Dec. 5, 2011), http://www.biofuelsdigest.com/bdigest/2011/12/05/the-range-fuels-failure/; *see* US DEP'T. OF ENERGY, RANGE FUELS' SOPERTON PROJECT: A COMMERCIAL-SCALE BIOREFINERY CONVERTING BIOMASS INTO BIOFUELS AND POWER (July 2011), https://www1.eere.energy.gov/bioenergy/pdfs/ibr_commercial_rangefuels.pdf.

44. *The Range Fuels Failure*, *supra* note 43.

45. Almuth Ernsting, *Biofuel or Biofraud? The Vast Taxpayer Cost of Failed Cellulosic and Algal Biofuels*, INDEP. SCI. NEWS (Mar. 16, 2016), https://www.independentsciencenews.org/environment/biofuel-or-biofraud-the-vast-taxpayer-cost-of-failed-cellulosic-and-algal-biofuels/.

46. Dan Chapman, *Warnings Ignored in Range Fuels Debacle*, THE ATL. J. CONST. (Sept. 2, 2012), http://www.ajc.com/business/warnings-ignored-range-fuels-debacle/OGq6tJq3lEFyuXnZtFHZaO/ [https://perma.cc/XA7Y-84ZH].

47. Renewable Fuel Standard Program: Standards for 2017 and Biomass-Based Diesel Volume for 2018, 81 Fed. Reg. 34,778, 34,779 (proposed May 31, 2016) (internal citation omitted). The RFS program began in 2006 pursuant to the requirements of the CAA section 211(o) that were added through the Energy Policy Act of 2005. The EPA issued detailed rules on the program in April of 2007. The statutory requirements for the RFS were modified through "[t]he Energy Independence and Security Act of 2007, resulting in the publication of major revisions to the regulatory requirements on March 26, 2010." One of the major goals of EISA includes moving the United States towards "greater energy independence and security, to increase the production of clean renewable fuels." *Program Overview for Renewable Fuel Standard Program*, U.S. ENVTL. PROT. AGENCY, https://www.epa.gov/renewable-fuel-standard-program/program-overview-renewable-fuel-standard-program [https://perma.cc/5Y7D-WWLG] (last visited Jan. 26, 2018). In a January 2013 decision, the Court of Appeals for the District of Columbia vacated the 2012 cellulosic quota explaining that the EPAct cannot punish obligated parties for not using cellulosic quota biofuels if less than the required usage volumes are produced. API v. EPA, 706 F.3d 474, 481 (D.C. Cir. 2013) (citing 77 Fed. Reg. at 1334–35). As a result, the EPA reduced the 2013 cellulosic standard by a Direct Final rule in July 2014. Notably, the change to the definition came shortly after this court decision. The change in the definition came in July 2014 and the Decision was decided by the D.C. Circuit on January 23, 2013.

biofuel research and development.[48] The Energy Independence and Security Act of 2007 ("EISA") further amended the CAA by expanding the RFS program.[49] According to the EPA "[t]he EISA included similar incentives" to that of the EPAct.[50] In addition to the incentives provided directly by the CAA, EPAct, and EISA, other policies also encourage production of biofuels in the United States.[51] For example, tax credits currently support advanced biofuel—biofuels derived from feedstocks other than cornstarch—including cellulosic and biodiesel.[52]

The 2005 EPAct amendment requires the EPA, in consultation with the Department of Agriculture and the Department of Energy, to implement the post 2012 RFS standards. Of the numerous requirements set forth in the Act, the amendment includes requirements for the EPA to establish annual fuel volumes.[53] The EPA has struggled to meet this requirement in a timely manner, in part because of the lower-than-expected production levels of cellulosic biofuels. As part of its efforts to meet the requirement, the EPA sets the RFS volume requirements annually.[54] The annual standards are based on the statutory targets, which the EPA must evaluate, and in some cases, adjust annually.[55]

A. THE RENEWABLE FUEL STANDARD

As previously explained, the RFS Program is a national policy that requires a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil or jet fuel. The program requires the EPA to "promulgate regulations to ensure transportation fuel sold or introduced" in the United States "contains an increasing measure of renewable fuel through 2020."[56] When Congress introduced the cellulosic biofuel requirement in 2007, there was no commercial production at all. Despite this lack of production, Congress assumed significant innovation in the industry and mandated sales of one-hundred million gallons

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48. *Economics of Biofuels, supra* note 36; NAT'L RESEARCH COUNCIL, COMMITTEE ON ECON. & ENVTL. IMPACTS OF INCREASING BIOFUELS PRODUCTION, RENEWABLE FUEL STANDARD: POTENTIAL ECONOMIC AND ENVIRONMENTAL EFFECTS OF U.S. BIOFUEL POLICY (2011), https://www.nap.edu/resource/13105/Renewable-Fuel-Standard-Final.pdf.

49. 2012 Renewable Fuel Standards, 77 Fed. Reg. 1, 320, 325.

50. *Economics of Biofuels*, *supra* note 36; NAT'L RESEARCH COUNCIL, *supra* note 48.

51. *Economics of Biofuels*, *supra* note 36 (The Energy Independence and Securities Act of 2007 requires "[t]o limit GHG emissions, the Act states that conventional renewable fuels (corn starch ethanol) are required to reduce life-cycle GHG emissions relative to life-cycle emissions from fossil fuels by at least 20 percent, biodiesel and advanced biofuels must reduce GHG emissions by 50 percent, and cellulosic biofuels must reduce emissions by 60 percent.").

52. *Id.*

53. *Program Overview for Renewable Fuel Standard Program*, *supra* note 47*; see* RFS, *supra* note 1, at 23902–23903 (Section 1501 of the EPAct amended the CAA and provides the statutory basis for the RFS in Section 211(o). It further requires that the EPA establishes a program to ensure the pool of gasoline sold contains specific volumes of renewable fuel each year beginning in 2006).

54. RFS, *supra* note 1, at 23903.

55. *Renewable Fuel Annual Standards*, U.S. ENVTL. PROT. AGENCY (June 8, 2017), https://www.epa.gov/renewable-fuel-standard-program/renewable-fuel-annual-standards [https://perma.cc/BT6J-RZX4].

56. API v. EPA, 706 F.3d at 475.

TABLE 1
QUALIFYING FUEL PATHWAYS[63]

Category	Percentage Lifecycle GHG Reduction to Meet
Biomass-Based Diesel	50%
Cellulosic Biofuel (produced from cellulose, hemicellulose, or lignin)	60%
Advanced Biofuel (produced from qualifying hemicellulose, except corn starch)	50%
Renewable (or Conventional) typically ethanol derived from cornstarch	20%

in 2010, 750 million in 2011, and half a billion in 2012.[57] Recognizing technological challenges, Congress provided that the EPA would determine the "projected volume of cellulosic biofuel production" for a calendar year to be made no later than November thirtieth of the prior year.[58] Congress provided little guidance on implementation, however, and thus left the EPA to resolve any issues that arise.

The four renewable fuel categories under the RFS are: (1) cellulosic biofuel, (2) biomass-based diesel, (3) advanced biofuel, and (4) total renewable fuel.[59] Each of these pathways is associated with a percent reduction in carbon dioxide emissions from the baseline petroleum fuel (*see* Table 1). The statute provides for certain volumes of each of these four renewable categories from the years 2009–2020. However, as authorized by the CAA, the EPA may adjust the cellulosic biofuel category, on an annual basis.[60] The ability to adjust the annual number for cellulosic biofuels was based on the understanding that while the rule seeks to encourage innovation, research and development of cellulosic biofuels may take a significant amount of time.[61] As such, the RFS requires that cellulosic biofuel be produced from cellulose, hemicellulose, or lignin, and that it must meet a sixty percent lifecycle GHG reduction.[62]

57. *Id.* at 476.
58. *Id.*
59. *Program Overview for Renewable Fuel Standard Program*, *supra* note 47.
60. *Id.*
61. 81 Fed. Reg. 34,779, *supra* note 47.
62. *Id.*
63. *Program Overview for Renewable Fuel Standard Program*, *supra* note 47.

B. RENEWABLE IDENTIFICATION NUMBERS

The RFS is "a market-based compliance system in which obligated parties" are required to "submit credits to cover their obligations."[64] Compliance with the RFS is measured by Renewable Identification Numbers ("RINs").[65] The RIN "shows that a certain volume of renewable fuel was produced or imported."[66] RINs act like credits and are generated when a batch of biofuel is created.[67] Once the biofuel is produced, a RIN is assigned to the batch. The RIN can either be kept with the batch of fuel as it moves through the fuel market or it can be separated from the fuel. If the RINs are separated from the fuel, they enter the energy market and operate like commodities.[68] Just like the four main categories of commodities—energy, metals, livestock or meat, and agriculture—RINs can be bought, sold, and traded.[69] RINs are tracked by a thirty-eight-character number issued, as required by EPA guidelines, by the biofuel producer or importer at the point of biofuel production or port of importation.[70] Each obligated party (primarily petroleum producers) must have a certain number of RINs in hand at the end of each year.[71] Production levels dictate the number of RINs; however, these numbers are vulnerable to fraud.[72] The importance of RINs was brought to fruition with the definitional expansion of "cellulosic biofuel" highlighted in this Article.

C. THE RFS CHANGES

In 2014, the EPA expanded the definition of what counts as "cellulosic biofuel" for purposes of the RFS. In doing so, the EPA allowed certain production processes, such as liquid cellulosic biofuels, to qualify under the "cellulosic biofuel" RIN, which they did not qualify for prior to this change.[73] In the 2014 revision, the EPA determined that the definition of cellulosic biofuels was ambiguous enough to cause confusion regarding what qualified for RINs under the cellulosic standard.[74] To clarify this ambiguity, the EPA specified additional processes, which met the sixty percent reduction from baseline.[75] Prior to the July 2014

64. BRENT D. YACOBUCCI, CONG. RESEARCH SERV., R42824, ANALYSIS OF RENEWABLE IDENTIFICATION NUMBERS (RINS) IN THE RENEWABLE FUEL STANDARD (RFS) (2013).
65. *Id.*
66. RFS, *supra* note 1, at 23908.
67. YACOBUCCI, *supra* note 64, at 1.
68. *Id.*
69. *Id.*; RFS, *supra* note 1 at 23908.
70. YACOBUCCI, *supra* note 64, at 3.
71. *Id.*
72. *Id.* at 11–14.
73. RFS, *supra* note 1 at 23908.
74. The EPA has the authority to act under the RFS. RFS II, *supra* note 2, at 42130.
75. Clean Air Act of 2007, 42 U.S.C. § 7545 (2012). Title II of the Clean Air Act, section 211, and regulations at 40 C.F.R. pt. 79, 80. "The Clean Air Act requires EPA to set the RFS volume requirements annually. The annual standards are based on the statutory targets. EISA requires EPA to

definitional change, only cellulose, hemicellulose, and lignin fell within the definition of "cellulosic biofuel." After the July 2014 definitional change, feedstocks that are mostly cellulosic content—meaning they are fuel made from the biogenic portion of separated municipal solid waste—now count as if they were made entirely from cellulosic material. In all circumstances, the cellulosic content has a required lifecycle GHG reduction of at least sixty percent.[76] From a statutory interpretation standpoint, using the phrase "predominately composed of cellulosic content" provides the Agency with flexibility in determining what compounds qualify.[77] While this may be concerning from a separation of powers perspective, it allows the Agency experts to make that determination when necessary.[78] Regardless of the broad language used, the EPA provides some examples of feedstocks qualifying as cellulosic biofuel under the RFS.[79] These feedstocks include (1) corn stover; (2) wood chips; (3) miscanthus; and (4) biogas.[80] Notably, biogas was explicitly enumerated as a qualifying feedstock, provided the process also meets the carbon dioxide reduction goal.[81] The next Part explains one way of measuring the impact of the definitional expansion.

III. PATENTS AS ONE INDICATOR OF INNOVATION

The basis for patent rights lie explicitly in the United States Constitution, which states, "the Congress shall have Power . . . to promote the Progress of Science and useful Arts."[82] These rights have allowed for a *quid pro quo* of patent

evaluate and in some cases, adjust the standards. EPA establishes the standards through a notice-and-comment rulemaking process with opportunity for public comment and stakeholder engagement. The Clean Air Act requires the standards be finalized by November 30th of the year preceding the compliance year. For the cellulosic standard, EPA sets cellulosic standard based on EIA projections, EPA's own market assessment, and on information obtained from the notice and comment process. For the biomass-based diesel standard, EPA must determine the applicable volume of biomass-based diesel "at least 14 months prior to the year in which the volume will be required." *Renewable Fuel Annual Standards*, *supra* note 55; RFS II, *supra* note 2, at 42130.

76. *Renewable Fuel Annual Standards*, *supra* note 55.

77. RFS II, *supra* note 2, at 42130.

78. The Agency is provided authority from the Executive branch as an administrative agency.

79. *Renewable Fuel Annual Standards*, *supra* note 55.

80. *Id.*

81. *Id.*

82. U.S. CONST. art. I, § 8, cl. 8. Importantly, valuating innovation through the patent system allows for incremental changes to occur and for policymakers to determine whether their goals are being met. ORG. FOR ECON. CO-OPERATION AND DEV. [OECD], *Towards a Measurement Agenda for Innovation, Measuring Innovation: A New Perspective* (2010), https://www.oecd.org/site/innovationstrategy/45392693.pdf. One output indicator of innovation is the number of patent applications and patents issued before and after a policy change, which is designed to encourage innovation. Daniel J. Gervais, *The Regulation of Inchoate Technologies*, 47 HOUS. L. REV. 665, 683 (2010) ("An inchoate technology reacts to both market changes and regulation, and the market reacts to technological and regulatory changes."). An advantage of this is that patent data measures the intermediate outputs of the inventive process—in contrast to data on research and design expenditures that only measure input. Ivan Haščõicõ & Mauro Migotto, OECD, *Measuring Environmental Innovation Using Patent Data: Policy Relevance* 16 (2015), http://www.oecd-ilibrary.org/docserver/download/5js009kf48xw-en.pdf?expires=1515865302&id=id&accname=guest&checksum=31C81AA8FE7CBD3A651772C2C81FBC49

rights; an inventor discloses their invention in exchange for the exclusive right to their discoveries for a certain period of time. Whether such incentives are valued in the environmental and energy context has not been widely evaluated.[83] In recent years, many studies have investigated the impact of environmental policy on innovation through both econometric studies and case studies.[84] Many of the current empirical studies have methodological gaps. In the case of this Article, research and development in environmental and energy industries is scarce.[85] In contrast, patent data is readily available and provides a rich set of information to the user and includes information such as the assignee or company, the inventors, the date of invention, the geographic location, as well as the technological aspects of the invention itself.[86]

Because patent data measures intermediate outputs of the inventive process, patents have long been used as one measure of innovation, and "have a close [if not perfect] link to innovation."[87] There is a strong correlation between patents and other indicators of innovative activity such as Research and Development ("R&D") expenditures or new product introductions.[88] In the area of evaluating public policy effects on innovation, patent counts—specifically patent applications—are one suitable indicator.[89] An important reason for this is that "patents are an output measure of innovation activity as

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[https://perma.cc/28GX-PNWQ]. *See* CORNELL UNIVERSITY, INSEAD, AND WIPO, THE GLOBAL INNOVATION INDEX 2016: WINNING WITH GLOBAL INNOVATION (2016) [hereinafter WIPO INNOVATION INDEX 2016]; Mark D. Shtilerman, *Pharmaceutical Inventions: A Proposal for Risk-Sensitive Rewards*, 46 INTELL. PROP. L. REV. 337, 338 (2006). These rights are available worldwide through various national and regional patent offices. In the United States, patent rights are afforded only after an inventor has developed a new invention and met the statutory requirements of patentability. USPTO, GENERAL INFORMATION CONCERNING PATENTS, https://www.uspto.gov/patents-getting-started/general-information-concerning-patents#heading-4 (last visited Jan. 26, 2018) (statutory conditions for obtaining a patent include patent eligible subject matter, novelty, and non-obviousness). This patent system offers many advantages to businesses and the number of patent applications and the number of patents issued serve as one indicator of a successful public policy initiative. As such, patent data can aid in determining whether an Agency policy is working as intended.

83. There is scarce literature evaluating policies and their impact on patent data particularly in environmental and energy research.

84. Joëlle Noaillya & Svetlana Batrakova, *Stimulating Energy-Efficient Innovations in the Dutch Building Sector: Empirical Evidence from Patent Counts and Policy Lessons*, 38 ENERGY POL'Y 7803, 7805 (2010).

85. *Id.*

86. *Id; see also USPTO Search Data Base*, USPTO, https://www.uspto.gov/patents-application-process/search-patents (last visited Mar. 30, 2018).

87. Noailly & Batrakova, *supra* note 84, at 7806; Haščõicõ & Migotto, *supra* note 82, at 14; *see also* WIPO INNOVATION INDEX 2016, *supra* note 82.

88. Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28(4) J. OF ECON. LITERATURE, 1661–1707 (1990); William S. Comanor & F.M. Scherer, *Patent Statistics as a Measure of Technical Change*, 77 J. POL. ECON. 392 (1969); John Hagedoorn & Myriam Cloodt, *Measuring Innovative Performance: Is There an Advantage in Using Multiple Indicators?*, 32 RES. POL'Y 1365 (2003).

89. Kristoffer Bäckström et al., *Public Policies and Solar PV Innovation: An Empirical Study Based on Patent Data*, LULEÅ UNIVERSITY OF TECHNOLOGY 1, 4 (2014).

opposed to" R&D expenditures.[90] Although patents as a metric are helpful for measuring innovation, the value of "patents is very heterogeneous: only few patents will lead to successful applications, while many will never be used."[91] In brief, patents reflect the actual invention "and are thus more likely to reflect product and end-of-pipe technologies, rather than process inventions."[92] One useful resource is the OECD Patent Statistics Manual, which provides a useful description of patent systems and guidelines on how to work with that data.[93]

Two schools of thought exist on whether patent applications and issued patents can serve as indications of innovation. The first school of thought suggests that licensing patents are not a good indicator of innovation,[94] while others reject that suggestion finding that all types of patent data help measure innovation.[95] While these analytical limitations exist, some "studies support a relationship between the drive for renewable energy technology and increased patenting."[96] These conflicting opinions seem to be just that—opinions that suggest there are more than one way to measure innovation depending on the market and the newness of the technology examined.[97]

IV. PATENT DATA AND THEORETICAL FRAMEWORK

A. THEORETICAL FRAMEWORK

The number of patent applications and patents issued may help explain whether the RFS has increased innovation within the cellulosic biofuel industry. However, the commercialization of patented cellulosic biofuels has been limited, and the 2014 expansion of the term "cellulosic biofuel" may have curbed

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90. *Id.*

91. Noailly & Batrakova, *supra* note 84.

92. *Id.*

93. *See* OECD PATENT STATISTICS MANUAL, http://www.oecd.org/sti/inno/oecdpatentstatisticsmanual.htm (last visited Jan. 26, 2018).

94. Daniel R. Cahoy, *Inverse Enclosure: Abdicating the Green Technology Landscape*, 49 AM. BUS. L. J. 805, 829–30 (2012) (saying that "researchers are using the patent landscape as a measure of innovation" as an imperfect measure, but that "a substantial; increase in patent acquisition can have an innovation impact, in and of itself.").

95. Gene Quinn, *Flawed Survey Erroneously Concludes Patent Licensing Does not Contribute to Innovation*, IPWATCHDOG (Feb. 22, 2015), http://www.ipwatchdog.com/2015/02/22/flawed-survey-erroneously-concludes-patent-licensing-does-not-contribute-to-innovation/id=54985/ [https://perma.cc/835U-3T6Y]; *see* Petra Moser, *How Do Patent Laws Influence Innovation*? Evidence from Nineteenth-Century World's Fairs, 95(4) AM. ECON. REV. 1214, 1236 (Sept. 2005).

96. Cahoy, *supra* note 94, at 825; *see also* Robert M. Margolis & Daniel Kammen, *Evidence of Under-Investment in Energy R&D in the United States and the Impact of Federal Policy*, 27 ENERGY POL'Y 575, 579 (1999) (empirical research demonstrating the basic correlation between R&D funding and patents in the energy sector and finding that public policy plays a major role in encouraging innovation).

97. Overall, empirical studies indicate a positive effect of public policy on innovation in the energy and environmental sector through measuring patent data. Bäckström et al., *supra* note 89.

optimism for innovation in this field.[98]

B. LIMITATIONS IN PATENT DATA

While patent data has many beneficial components for analyzing energy technology and innovation, there are limitations in the use of such data as a sole indicator of innovation. Some limitations of using patent count data as an indicator of innovation include:

(1) all inventions are not patented;
(2) some technologies are not patentable;
(3) patents represent only the practical application of ideas, not general advances in knowledge;
(4) patents represent inventions—not activities and investments to commercialize new technology; and
(5) patents have widely varying commercial value and therefore significance with respect to innovation.[99]

However, while limitations exist, they are not so limiting as to render the use of patents and patent applications useless in measuring innovation. Without using the patent data, innovation in fields of emerging technology may go unstudied for years.[100] This is particularly important within the cellulosic industry. Patent data is the main data that can be used to measure innovation. While there are other indicators, such as the amount of research dollars poured into the industry, the specific dollar amounts put into the research cannot be accurately determined easily since there is no standard way to account for various types of investment within the industry.[101]

C. DATA AND PROCESS OF CELLULOSIC BIOFUEL PATENTS IN THE UNITED STATES

Prior research of the cellulosic biofuel industry and patents are extremely limited. Most of the "research" is either a simple literature review, or is focused on an economic issue, such as cost of production or market based incentives to

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98. The purpose of this Article is to initiate discussion about whether the expansion of the policy was the best way to promote innovation towards energy independence. The Author realizes that there are constraints and that this study is relatively narrow.

99. NAT. ACAD. OF SCI., INDUSTRIAL RESEARCH AND INNOVATION INDICATORS: REPORT OF A WORKSHOP, CHAPTER 6, MEASURING OUTPUTS AND OUTCOMES OF INNOVATION (1997), https://www.nap.edu/read/5976/chapter/6.

100. Patent data is available where other data is lacking. While trying to find the best measurement for this field of technological innovation, patent data has remained constantly available unlike the other potential variables for measurement explained in this Article.

101. *See* David Biello, *Whatever Happened to Advanced Biofuels?*, SCI. AM. (May 26, 2016), https://www.scientificamerican.com/article/whatever-happened-to-advanced-biofuels/.

produce.[102] To inform both a descriptive and empirical analysis, this Article uses the United States Patent & Trademark Office ("USPTO") online advanced search database, which maintains data for both patent applications and patents issued within the United States to create the data sets necessary for this study.[103] The database is updated weekly and has the most accurate information available. One important advantage of this data is that the USPTO issues patents in the US and maintains the site. The database, however, does not provide data sets specifically for cellulosic biofuels, and therefore, this study used various search terms to create the data sets. The Boolean search terms also return better results than the International Patent Classification ("IPC") used by The World Intellectual Property Organization ("WIPO").[104] While "hemicellulose" appears in four IPC codes—C08b 37/14, C08L 5/14, C09D 105/14, and C09K 105/14—these classifications do not capture all the terms necessary for this analysis.[105] Due to inconsistencies in patentability requirements between countries, this analysis focuses strictly on the US patents.[106] A summary of the annual-based data is in Table 2.

D. BOOLEAN SEARCH TERMS USED

In this study, the main variable used to measure spurred innovation was the number of patents issued from month-to-month and on an annual basis. The data set was taken by searching the Advanced Patent Search tool listing the

102. Warren Clarke, *What Do Patents Tell Us About Innovation?*, DEEP CENTER (Mar. 11, 2015), http://deepcentre.com/blog/what-do-patents-tell-us-about-innovation.

103. USPTO, *supra* note 86. The USPTO webpage also maintains the site for a variety of other purposes.

104. S*ee also* WIPO INNOVATION INDEX 2016, *supra* note 82.

105. Monika Zikova, Patent Classification Advantages, WIPO Webinar (July 11–12, 2013), http://www.wipo.int/export/sites/www/tisc/en/doc/patent_classification_advantages.pdf. Recognizing the disadvantages of the patent classification include: (1) that it is potentially complex; (2) it may not be detailed enough for all areas of technology; (3) it may not be available for all documents; (4) it may not be specific enough for a particular search; and (5) it may not be applied consistently. Further, the patent classifications are not specific enough for the particular search because the analysis of the required results for the specific enzymes necessary to release sugars from the cellulose—the fiber that forms plant structure—and the search requires more advanced search capabilities. *Id*.

106. A similar but less rigorous analysis was performed on WIPO data found at the PATENTSCOPE website for China and Japan, but the analysis was beyond the scope of this study. PATENTSCOPE, https://patentscope.wipo.int/search/en/advancedSearch.jsf (last visited Mar. 30, 2018). The Author compiled Patent Cooperation Treaty ("PCT") data for China and Japan. Because of the variations in patent requirements across countries, the data set could not accurately be used to measure differences between the PCT applications prior to the RFS and after the RFS with United States patent data. The variability between patent requirements in various regions led to an analysis beyond the scope of this study, however, it did provide support for at least one benefit that could come from patent harmonization—uniform and standardized data for analytical purposes. *See generally Protecting Your Investments Abroad: Frequently Asked Questions About the Patent Cooperation Treaty (PCT)*, WIPO, http://www.wipo.int/pct/en/faqs/faqs.html (last visited Jan. 26, 2018) ("The PCT is an international treaty with more than 145 Contracting States. The PCT makes it possible to seek patent protection for an invention simultaneously in a large number of countries by filing a single "international" patent application instead of filing several separate national or regional patent applications.").

TABLE 2
SUMMARY: TOTAL US PATENT APPLICATIONS FILED AND ISSUED

	Pre-RFS	Post-RFS
Patents Issued[107]	114	2,604
Patent Applications[108]	182	3,219

TABLE 3
BOOLEAN SEARCH TERMS USED

USPTO Codes	1. ISD/[month]/[day]/[year->[month]/[day]/[year] AND hemicellulose AND fuel AND enzymes. 2. APD/[month]/[day]/[year->[month]/[day]/[year] AND hemicellulose AND fuel AND enzymes.

available patents hosted by the USPTO patent search database, which provides both the number of patents issued and number of patent applications submitted from 1976 through the current date. The database uses "search strings to identify a representative slice of relative inventions."[109] To get an accurate number of patents, various search terms were tested, but the most thorough and inclusive search code used Boolean search operators.[110] To accurately get the data per month and per year for both the patent applications and issued patents specific search terms were created and those search terms are denoted in Table 3. In Table 3, the term "ISD" refers to issued patents, while "APD" refers to patent applications.

While conducting the USPTO search, the Boolean search allowed the generation of issued patents within a set range of dates. Because the dates were set, the research could determine the data for pre-RFS enactment and post-RFS enactment. The dates for the month-to-month analysis started with the first day of the month and ended with the last day of that month, while the dates for the annual patents issued ran from August 8th of a year to August 8th of the following year, the day the RFS became effective. The data is split into patents issued and patent applications in multiple sets of data in order to accurately depict the patent landscape.

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107. The data for Pre-RFS is from January 1, 1976 through August 8, 2005, while the data for post-RFS is from August 8, 2005 through October 8, 2017.

108. The data for Patent applications has only been published since March 2001. Thus, the data for Pre-RFS is from August 8, 2001 through August 8, 2005 and the data post-RFS is from August 8, 2005 through October 8, 2017.

109. Cahoy, *supra* note 94, at 824.

110. Boolean Operators allow a more precise search than using standard search terms.

E. LIMITATIONS OF THE DATA SET

One limitation with this data set is that it is not a large group set for the post-definitional change in "cellulosic biofuel." The data available for post-RFS definitional changes is limited to forty data points—the months after the change was made through October 2017. To maintain a fair sample size, the months before the RFS enactment were limited to match the forty data points. Another important limitation is that in some instances innovators may be opting for trade secret rights instead of patent rights.[111] Because trade secrets are not disclosed to the public like patent data, this study cannot capture potential innovation where inventors opted for a traded secret instead of a patent.

V. EMPIRICAL SPECIFICATIONS AND RESULTS

A. EMPIRICAL SPECIFICATIONS

In order to determine whether the RFS program spurred innovation in the cellulosic biofuels industry, multiple data sets were created to organize the information. The data analysis was a longitudinal design, measuring patent applications and issued patents over time. The analyses consisted of taking the means of the time series data at the three intervals of time—pre-RFS, phase I RFS, and post-definitional 2014 RFS. When creating the data set, the years and months were numbered from 1-*n* denoting the independent variable, and the number of patents issued or filed was denoted as "Y," the dependent variable.

1. Means of Data Sets: Changes in Applications and Issued Patents Post 2014 "Cellulosic Biofuel" Change

To account for the differences in patent applications and issued patents before and after the July 2014 expansion of the definition "cellulosic biofuel," the means were taken from all data sets. At the time of this analysis, only forty data points post-2014 RFS exist—the months running from July 2014 through October 2017.[112] To ensure the data is representative, the forty months prior to the definitional change were also used—March 2011 through June 2014.[113] The arithmetic mean of the set of data was calculated by adding the sum of all the data values (χ) and dividing that number by the number of values (n). This Article relies on the following formula traditionally used to calculate the mean ($\bar{x}$):

111. It is not known how many, if any, inventors hold trade secrets in this area of technology.

112. Since the change in the RFS in July 2014, there were only forty months through October 2017 that could provide a data set.

113. To have representative data sets that were not skewed, the months measured prior to the RFS definitional change were the forty months from May 2012 through June 2014. This allowed for the post-RFS change and pre-RFS change patent data to have the same number of data points.

$$\bar{\chi} = \frac{\sum \chi}{\eta}$$

TABLE 4

MEAN OF PATENTS ISSUED AND PATENT APPLICATIONS

	Mean of Patents Issued	Mean of Patent Applications Filed
Before Definitional Change	21.5	32
After Definitional Change	29.925	11.275

The mean was taken on both the patents issued and patent applications filed before the change and after the change, which resulted in four separate data points.[114] The results are shown in Table 4.

After finding the mean for the data sets, the results indicate that the number of patent applications decreased significantly after the definitional change. In contrast, the increase in issued patents can be explained by the time and research it takes to get a patent application to issue.[115] The period from filing a patent application to fruition of that patent is usually around three years.[116] Because issued patents have some lag, in this scenario, the drastic decrease in the number of applications filed is the best number to evaluate whether the definitional change increased or decreased innovation.

Next, the mean was calculated at the interval between the date of enactment of the RFS in August 2005 and the date of the definitional change in June 2014. Both months of the definitional change and the first month of enactment were excluded from the mean to prevent data overlap with the previous analysis.

2. Visual Analysis

The data was analyzed on a year-to-year basis to determine whether the information required further research. The first set of data is patents issued from August 8, 1976 to August 8, 2005. This number represents the number of patents issued for those years prior to the enactment of the RFS. The second set of data

114. The formula used to take this mean, or average, was the average of the data points from the forty months before and forty months after the RFS.

115. *See* Gene Quinn, *An Overview of the US Patent Process*, IP WATCHDOG (Mar. 15, 2014), http://www.ipwatchdog.com/2014/03/15/an-overview-of-the-u-s-patent-process-2/id=48506/ (explaining that for a non-provisional patent application, it typically takes at least twelve to eighteen months before an examiner will review the application).

116. Dennis Crouch, *Average Patent Application Pendency*, PATENTLY-O (Dec. 12, 2011), https://patentlyo.com/patent/2011/12/average-patent-application-pendency.html.

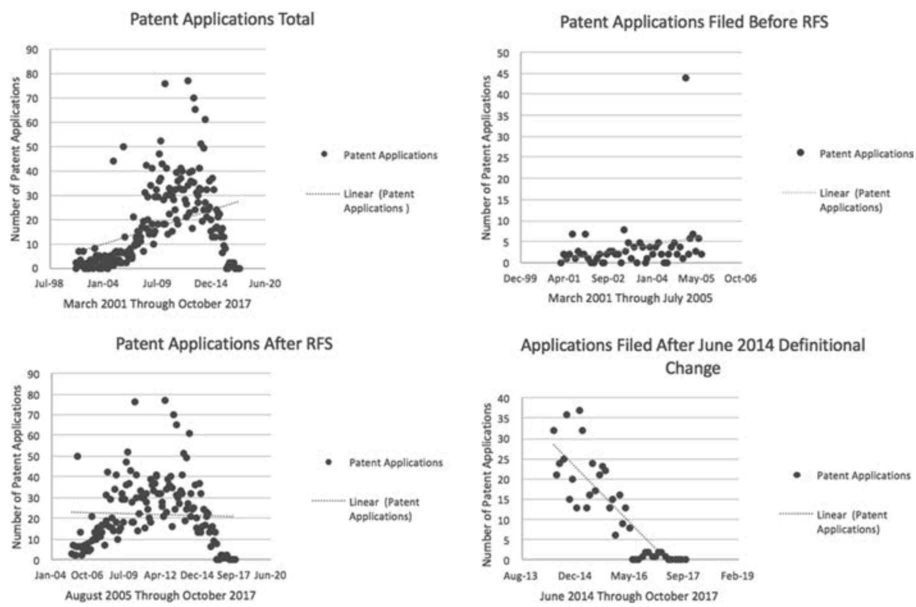

FIGURE 1: Changes in Patent Applications Over Time.

uses the number of patents issued from August 8, 1976 to October 8, 2017. The third data set runs from August 8, 2005 to October 8, 2017.[117]

3. The Longitudinal Data

The available data used in the analysis was measured on a month-to-month basis from January 1, 1993 leading up to the enactment of the RFS through October 31, 2017.

B. SUMMARY OF RESULTS

The goal of the RFS was to increase innovation of biofuels and drive the United States towards energy independence. The data shows that the RFS was effective in increasing innovation, particularly within the cellulosic biofuels industry. The sheer number of patent applications suggests that innovation is occurring. However, the results also demonstrate that after the July 2014 definitional expansion of "cellulosic biofuel," the rate of innovation decreased significantly.

117. The number of patents issued was limited as data availability for patents issued begins in 1976. The number of patent applications filed was more limited and data was only available beginning in 2001. The patent data on the USPTO site for issued patents is available from 1976 forward. The patent data available on the USPTO site for patent applications is available from 2001 forward.

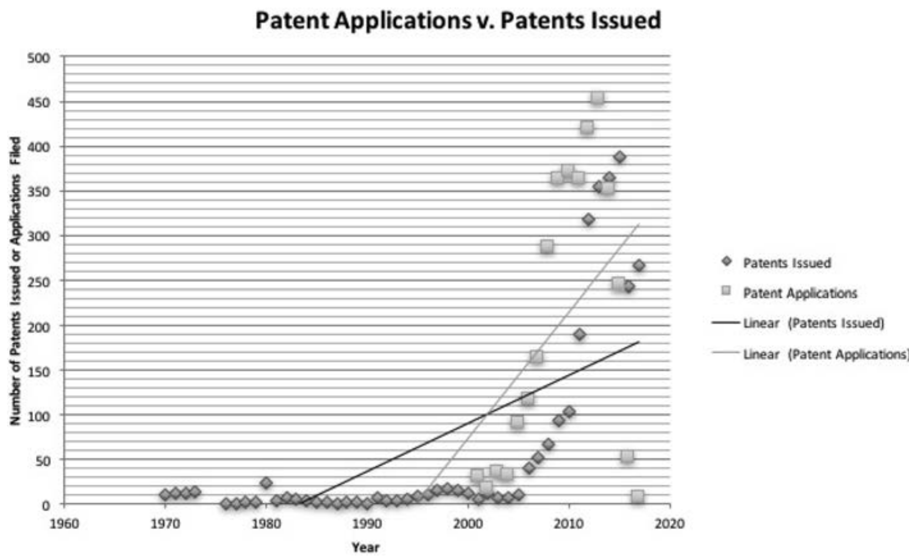

FIGURE 2: Patent Applications v. Patents Issued.

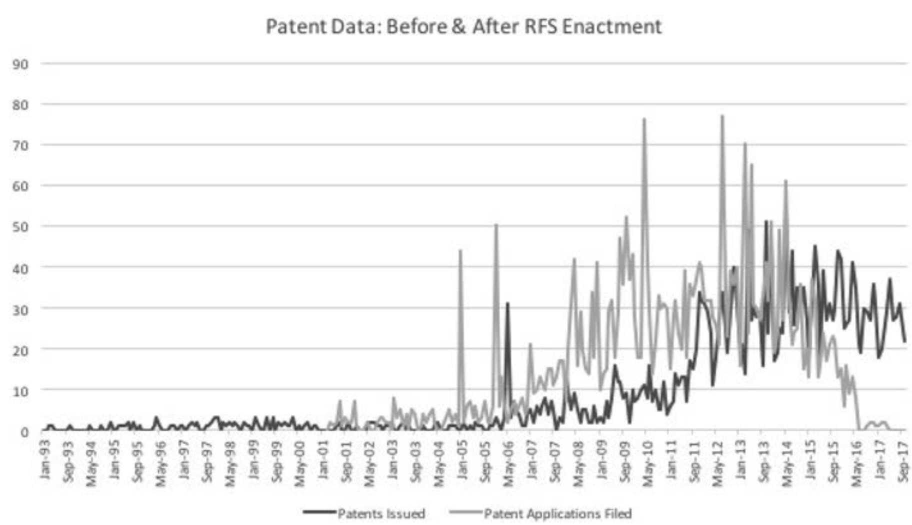

FIGURE 3: Patent Applications v. Patents Issued From 1993 to 2017.

Figure 1 shows patent applications filed at four different time series. The top left graph represents the total number of patent applications from March 2001 through October 2017. These are all the available data points representing patent applications. The top right graph shows the total number of patent applications filed from March 2001 through July 2005. Third, the bottom left graph represents the total number of patent applications filed from August 2005 through October

2017. Lastly, the bottom right graph represents the number of patent applications filed from June 2014 through October 2017.

Using the forty months of data available following the definitional expansion, multiple interpretations can be drawn about whether this change decreased innovation. First, the number of monthly patent applications filed slowly declined. Second, two years after the change was made, for the months of June, July, and August of 2016, zero patent applications were filed matching the search terms. Again, from May to October 2017 zero patent applications were filed. The results show that for the 146 months after the RFS was enacted, and before the definitional change, there was significant innovation within the cellulosic biofuels industry, and that innovation decreased after the definitional change. While there were only forty months of data available at the time of this analysis, such a dramatic change in patent applications indicates that the change had a significant impact on the desire to patent such technology.

The descriptive data results of this analysis demonstrate that the number of patent applications filed, and patent applications issued, starkly increased after the RFS was enacted. While this cannot be the sole determinant of innovation being driven by the policy, it is strong evidence that the pre-2014 amendment policy was working to encourage innovation.[118] The analysis of patents issued is inconclusive due to the length of time between filing the patent application and the time at which the patent issues.

VI. POLICY CONSIDERATIONS MOVING FORWARD

Interest in researching and filing for patents in the area of cellulosic biofuel post-RFA is significant. Two ways to continue cellulosic biofuel research in order to advance towards energy independence could include (1) cross-licensing patents within the industry;[119] or (2) providing grants for research consortiums like those already established in the pharmaceutical industry, which allow for collaboration between researchers by sharing research.[120] Cross-licenses are typical between companies that hold patents

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118. A line graph is the simplest way to represent time series data. It uses trend lines to show how a dependent and independent variable change. The dependent variable plotted on the horizontal axis, which in this case is the year.

119. A cross-license agreement is a contract between two companies that grants each the right to practice the other's patents. In other words, it is a bilateral agreement in which two firms choose not to enforce intellectual property rights between them. Alberto Galasso, *Broad Cross-Licensing Agreements and Persuasive Patent Litigation: Theory and Evidence from the Semiconductor Industry*, LSE STICERD Research Paper No. E145, at 2 (July 2007), https://ssrn.com/abstract=1158322.

120. There are already numerous grants available for collaborative research in the environmental and energy markets. *See, e.g., Bridging Research Interactions Through Collaborative Development Grants in Energy*, U.S. DEP'T OF ENERGY, https://energy.gov/eere/solar/bridging-research-interactions-through-collaborative-development-grants-energy (last visited Jan. 26, 2018) ("The DOE Bridging Research Interactions through collaborative Development Grants in Energy ("BRIDGE") program funds collaborative research teams to significantly lower the cost of solar energy systems. The teams can

over different aspects of the same product.[121] Entering into cross-licensing agreements provides companies with the stability of knowing they can avoid litigation over infringement disputes.[122]

The results of the data analyses indicate that the niche market of the cellulosic biofuel industry was increasing as a result of the RFS incentives. However, when the definition of "cellulosic biofuels" expanded, it appears that the EPA stepped back from encouraging the niche market in return for larger quantities of cellulosic fuel under the new definition. Going forward, there are significant policy considerations for the entire industry in regards to whether the RFS definition should allow for gaseous forms of cellulose.[123]

First, the EPA should consider whether allowing the new types of cellulosic landfill producers to qualify for a RIN under "cellulosic biofuel" will hinder overall use of landfills. Landfill owners may be less inclined to promote recycling since they can now put more cellulose into fuels to qualify for a RIN. Cellulose in the landfills, for example, is needed to create biogas. If paper and trees are continuously taken out of landfills, then less gas will be produced and landfill gas capture may not be economically viable. In addition, a lack of landfill owners promoting recycling may cause landfills to fill faster than originally anticipated, since cellulosic materials may now supersede landfill space allocated for non-recyclable material. Second, gaseous renewable fuel producers may qualify for more than one RIN without doing any innovative activity. This seems unfair given that one of the purposes of the RFS is to promote innovation within the cellulosic industry. Lastly, and most importantly, the question arises as to whether the EPA has made the definitional change to "cellulosic biofuel" as a result of Congressional backlash. The EPA has been criticized publicly for many efforts that they have implemented.[124] This type of criticism may lead the experts who

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access the tools and staff expertise at existing DOE Office of Science research facilities so fundamental scientific discoveries can be rapidly transitioned to existing product lines and projects. The BRIDGE program provides engineers and scientists developing solar technologies with the tools and expertise of the Department's Office of Science research facilities, including major facilities for x-ray and neutron scattering, nanoscale science, advanced microcharacterization, environmental molecular sciences, and advanced scientific computing. This collaborative approach will accelerate innovations to lower the cost of solar technologies.").

121. *Chapter 3: Antitrust Enforcement and Intellectual Property Rights: Promoting Innovation and Competition*, U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N (Apr. 2007), https://www.justice.gov/atr/chapter-3-antitrust-analysis-portfolio-cross-licensing-agreements-and-patent-pools.

122. Such agreements have many advantages including: (1) no need to spend excess time and resources developing independent technology; (2) companies see profit sooner because development and production of products moves faster; (3) and royalty-based cross-licenses let money accumulate until the product is making a profit.

123. *EPA Moves Goalposts with New Definition for Cellulosic Biofuels*, INST. FOR ENERGY RESEARCH (Oct. 16, 2014), https://instituteforenergyresearch.org/analysis/epa-moves-goalposts-new-definition-cellulosic-biofuels/.

124. *See* David Shepardson, *U.S. Congress Criticizes EPA, Michigan Over Flint Water Crisis*, REUTERS (Mar. 15, 2016) https://www.reuters.com/article/michigan-water/u-s-congress-criticizes-epa-michigan-over-flint-water-crisis-idUSL2N16N1CJ; Alex DeMarban, *House Committee Investigation*

are granted authority to act to work more cautiously and weigh political pressures against their better judgment. This sort of internal agency compromise may be more deferential than it should, due to non-expert criticisms. This shows that advances in liquid cellulosic biofuels were slower than EPA expected and may have weighed on the decision to institute change.

CONCLUSION

This Article introduced a new data set containing thirty years of patent data for the examination of technological innovation within the cellulosic biofuels industry. The data has been constructed using the available data on the USPTO advanced search databases and shows that post-RFS innovation took a dramatic upward turn about three years after the effective date of the RFS. While this data is limited, it shows a correlation between innovative cellulosic activity and changes to the RFS. While the production rates of cellulosic biofuels were below expectations prior to 2014, the public policy of the RFS did encourage innovation in the enzymatic biofuels, but the modifications to the definition in 2014 has dampened the enthusiasm for continuing that trend.

Criticizes EPA Role in Alaska's Pebble Mine Prospect, ALASKA DISPATCH NEWS (updated on Sept. 28, 2015), http://www.adn.com/environment/article/house-oversight-investigation-criticizes-epa-role-pebble-prospect/2015/11/05/.