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Making Regulatory Innovation Keep Pace with Technological Innovation

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MAKING REGULATORY INNOVATION KEEP PACE WITH TECHNOLOGICAL INNOVATION

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Recent world events are forcing us to reconsider the ways in which the energy needs of the U.S. can and should be met. In regards to renewable energy options in general, the public response to the nuclear crisis at Japan's Fukushima Daiichi power plant will likely stymie President Obama's call for an increase in our reliance on nuclear energy. Additionally, the increasing political unrest in the Middle East and North Africa is once again reminding us that solutions must be found to mitigate our heavy dependence on foreign-produced oil. Newly emerging liquid biofuels not only hold the promise of enhancing U.S. energy security in a sustainable fashion, but also provide the potential to mitigate climate changing greenhouse gas emissions and serve as a driver for rural economic development. Nevertheless, regulatory hurdles to their successful commercialization abound.

In this article, we provide a thorough normative analysis of the regulatory schemes incentivizing and governing the commercialization of biofuel-related technological innovations. We urge that regulatory innovation is needed to keep pace with these technological innovations and, in doing so, we build upon the established principles that regulatory burdens should not outweigh the harms they are intended to mitigate, and that regulatory innovation is often called for to efficiently capture the social value of regulated activities.

Next, we apply these insights via a detailed case study that focuses on biobutanol, an emerging biofuel with the potential to act as a socially optimal alternative to petroleum-based transportation fuels. This biobutanol case study not only describes

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and elaborates on the effects of the federal Renewable Fuel Standard, but also on the Clean Air Act's regulatory framework for the commercialization of new fuels and fuel additives. After analyzing these frameworks, we provide suggestions for distinct ways in which different forms of regulatory innovation will help mitigate unjustified regulatory hurdles to the commercialization of biofuel-based technological innovations and allow us to more efficiently capture their inherent social value. Our analysis and prescriptions also find resonance in the context of other emerging new fuels and bioenergy developments.

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> In a world seeking solutions to its energy, environmental, and food challenges, society cannot afford to miss out on the global greenhouse-gas emission reductions and the local environmental and societal benefits when biofuels are done right.[1]

I. INTRODUCTION

Energy policy in the United States continues to place a strong emphasis on incentivizing the use of biofuels in an effort to capture their social benefits of enhancing energy security, furthering environmental goals, and promoting rural development.[2] While the specific weights that policy debates place on these three benefits tends to be ever shifting, the increasing political unrest in the Middle East and North Africa, where roughly 39% of U.S. oil imports originate,[3] makes it abundantly clear that the pursuit of alternatives to petroleum-based fuels is of great societal value.[4] In light of the substantial unrest in this troubled region, President Obama has recently proposed a goal of cutting U.S. reliance on foreign oil by one-third in an effort to "secure our energy future."[5] A key way in which the President proposes to achieve this goal is to harness the "tremendous promise"

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1. David Tillman et al., *Beneficial Biofuels – The Food, Energy, and Environment Trilemma*, 325 SCIENCE 270, 270 (2009).

2. De Gorter & Just, *The Social Costs and Benefits of Biofuels: The Intersection of Environmental, Energy and Agricultural* Policy, 32 APPLIED ECON. PERSP. & POL'Y 4, 4 (2010) ("Biofuel policies are motivated by a plethora of political concerns related to reducing dependence on oil, improving the environment and increasing agricultural incomes."); *e.g.*, Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 202 (2007) (increasing the biofuel mandates of the federal Renewable Fuel Standard).

3. U.S. Energy Information Administration, EIA's Energy in Brief: How Dependant are We on Foreign Oil?, http://www.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm (last visited March 29, 2011).

4. *See* Barack Obama, Remarks by the President on America's Energy Security (March 30, 2011), *available at* http://www.whitehouse.gov/the-press-office/2011/03/30/remarks-president-americas-energy-security.

5. *Id.*

of renewable biofuels.[6]

Current regulatory schemes seeking to incentivize the increased use of biofuels take various forms. Federal income tax provisions financially reward the increased blending of biofuels[7] and agricultural programs subsidize the cultivation of the biomass feedstocks needed to produce them.[8] Most importantly, the federal Renewable Fuel Standard (RFS2) clearly leads the march by mandating the introduction of 36 billion gallons of biofuels into the U.S. fuel supply by 2022.[9] While existing legal scholarship focuses on the efficacy and efficiency of these incentivization schemes,[10] this focus only provides half the picture of how current regulatory regimes affect our ability to capture the social value inherent in expanded biofuel use.

In order to fully assess how existing regulatory frameworks affect the commercialization of biofuel-related technological innovations, we must not only analyze biofuels incentivization schemes, but also the frameworks that govern their lawful commercialization. At the federal level, the Clean Air Act (CAA) grants the U.S. Environmental Protection Agency (EPA) the sole authority to regulate the lawful commercialization of new fuels and fuel additives.[11] As biofuels are traditionally blended with gasoline before entering the retail fuel market, the CAA's regulatory framework not only governs their lawful commercialization as fuel additives, but also effectively grants the EPA the authority to set percentage-based limits for the lawful biofuel content of finished fuels.[12] Specifically, the CAA requires that new fuels must be "substantially

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6. *Id.; see also* THE WHITE HOUSE, BLUEPRINT FOR A SECURE ENERGY FUTURE (March 30, 2011), *available at*, http://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf.

7. *E.g.*, Alcohol, etc., used as fuel, 26 U.S.C. § 40 (2010) (setting out the alcohol mixture tax credit, alcohol tax credit, small ethanol producer tax credit, and cellulosic biofuel producer tax credit).

8. Biomass Crop Assistance Program, 7 U.S.C. § 8111 (2010).

9. Clean Air Act, 42 U.S.C. § 7545(o) (2010); *see also* Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule, 75 Fed. Reg. 14,670, 14,674 (March 26, 2010) [hereinafter RFS2 Final Rule] (to be codified at 40 C.F.R. pt. 80) (implementing the RFS2).

10. *See, e.g.*, Melissa Powers, *King Corn: Will the Renewable Fuel Standard Eventually End Corn Ethanol's Reign?*, 11 VT. ENVTL. L. 667 (2010) (discussing the negative environmental implications of corn ethanol and considering whether the regulatory changes made in the RFS2 efficiently will address these concerns).

11. 42 U.S.C. § 7545(a); *see infra* Part IV.B.

12. 42 U.S.C. § 7545(f); *see infra* Part IV.B.; Regulation of Fuels and Fuel Additives; Revised Definition of Substantially Similar Rule for Alaska, 73 Fed. Reg. 22,277, 22,281 (April 25, 2008) [hereinafter 2008 Substantially Similar Rule] (providing detailed specifications for finished fuels, which effectively govern the permissible blending limits for biofuels).

similar" to those used in the certification process for engine emissions control systems[13] and the EPA sets detailed specifications that finished fuels must comply with in order to be considered "substantially similar."[14] These specifications ultimately govern the volume of biofuel that can be blended in a finished fuel[15] and in the event that a specific biofuel blend does not comply with these specifications, the EPA must grant a fuel waiver in order for that specific blend to be lawfully commercialized.[16]

Since biologically produced ethanol is currently the most widely implemented biofuel in the U.S.,[17] it provides a nice example of how the CAA's regulatory framework for the commercialization of new fuels and fuel additives operates. Under the EPA's current specifications for "substantially similar" fuels, a finished fuel can only contain roughly 7% ethanol by volume.[18] In order for manufacturers to lawfully commercialize the fuel blend containing 10% ethanol and 90% gasoline (E10) that currently makes up an overwhelming majority the U.S. fuel supply,[19] the granting of a new fuel waiver by the EPA was required.[20] When ethanol manufactures sought to expand the market share for their product in 2009 by commercializing a 15% ethanol blend (E15), they again had to seek a fuel waiver, which the EPA recently conditionally granted.[21]

As the CAA's regulatory framework for new fuels and fuel additives effectively governs the volume of biofuels that can be lawfully blended in finished fuels, it also has the ancillary effect of moderating our ability to capture the social benefits produced by new biofuel-related technological innovations.

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13. 42 U.S.C. § 7545(f)(1)-(2).

14. *E.g.*, 2008 Substantially Similar Rule, *supra* note 12, at 22,281.

15. *See id.*

16. 42 U.S.C. § 7545(f)(4); *see infra* Part IV.B.

17. U.S. CONGRESSIONAL RESEARCH SERVICE, ETHANOL AND BIOFUELS: AGRICULTURE, INFRASTRUCTURE, AND MARKET CONSTRAINTS TO EXPANDED PRODUCTION 2 (March 16, 2007) [hereinafter CRS ETHANOL REPORT].

18. *See* 2008 Substantially Similar Rule, *supra* note 12, at 22,281.

19. *See* RENEWABLE FUELS ASSOCIATION, BUILDING BRIDGES TO A MORE SUSTAINABLE FUTURE: 2011 ETHANOL INDUSTRY OUTLOOK 11 (2011), *available at* http://www.ethanolrfa.org/page/-/2011%20RFA%20Ethanol%20Industry%20Outlook.pdf?nocdn=1.

20. Fuels and Fuel Additives: Gasohol; Marketability, 44 Fed. Reg. 20,777, 20,778 (April 6, 1979) [hereinafter E10 Waiver].

21. Partial Grant and Partial Denial of Clean Air Act Waiver Application Submitted by Growth Energy to Increase the Allowable Ethanol Content of Gasoline to 15 Percent; Decision of the Administrator, 75 Fed. Reg. 68,094, 68,143 (Nov. 4, 2010) [hereinafter E15 Waiver I]; Partial Grant of Clean Air Act Waiver Application Submitted by Growth Energy To Increase the Allowable Ethanol Content of Gasoline to 15 Percent; Decision of the Administrator, 76 Fed. Reg. 4,662, 4,682-83 (Jan. 28, 2011) [hereinafter E15 Waiver II]; *see infra* Part IV.B.2.b.

Therefore, it is of the utmost importance for us to consider whether the regulatory burdens created by this framework are normatively justified. In conducting this normative analysis, we are guided by the principles that: (1) the compliance-related burdens associated with a given regulatory scheme should not outweigh the harms that scheme is intended to prevent;[22] and (2) regulatory innovation is often called for in order to efficiently capture the social value inherent in a regulated activity.[23] Ultimately, we conclude that the burdens associated with the CAA's current regulatory framework for new fuels and fuel additives are not normatively justified.

Throughout this article, we develop, substantiate, and support our central thesis that regulatory innovation is needed to keep pace with biofuel-related technological innovations. In Part II, we set out the theoretical underpinnings of our analytical framework and provide the groundwork for our further analysis of the regulatory regimes affecting the successful commercialization of biofuels. We next provide an in-depth case study that focuses on biobutanol, a newly emerging biofuel with the potential to enter the U.S. market as a socially optimal transportation fuel alternative. Our case study begins by setting out the history, present state, and future of biobutanol's production, and then moves on to discuss its ability to increase social welfare through its distinct advantages as a transportation fuel. In Part IV, we detail the current regulatory framework for the commercialization of biobutanol, which involves both a thorough discussion of the RFS2 and an analysis of the CAA's regulatory framework for new fuels and fuel additives. This analysis culminates in Part V, where we conclude that the regulatory burdens created by this framework cannot be normatively justified and offer suggestions for various forms of regulatory innovation. Finally, in Part VI we take our focus off of biobutanol and briefly highlight how our thesis applies to biofuel-related technological innovations in general and, in Part VII, we conclude.

II. PRINCIPLES INFORMING THE REGULATORY FRAMEWORK FOR EMERGING FUELS

In order to develop our central thesis that regulatory innovation is needed to keep pace with biofuel-related technological innovations, we first set out the theoretical underpinnings of our analysis. At its most base level, our analysis rests firmly upon the established idea that the burdens of regulatory compliance

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22. *See* EUGENE BARDACH & ROBERT A. KAGAN, GOING BY THE BOOK: THE PROBLEM OF REGULATORY UNREASONABLENESS 6 (Temple Univ. Press 1982) ("[A] regulatory requirement is unreasonable if compliance would entail costs that clearly exceed the resulting social benefits.").

23. *See infra* Part II.B.

should not outweigh the harms that a given regulatory scheme is intended to mitigate.[24] Second, it also builds upon the notion that when technological innovations have the potential to increase social welfare, regulatory innovation is often called for in order to efficiently capture their social value.[25]

A. Regulatory Burdens

It is axiomatic that the compliance-related burdens associated with a given regulatory scheme should not outweigh the social harms that scheme is intended to mitigate.[26] This principle stems from basic economic concepts of efficiency and rests upon the presumption that regulations should seek to maximize social welfare.[27] To offer an oversimplified example, if we imagine that a particular regulatory scheme mitigates a social harm and thereby creates a social benefit valued at $10, but compliance with this scheme costs regulated entities $15, then this scheme is not efficient due to the fact that it results in a $5 net reduction in social welfare. In this situation, one could say that compliance with this regulatory scheme creates an unjustified burden and various types of regulatory innovation should be considered in an attempt to balance the scheme's burdens and harms to be mitigated. If these harms could be equally mitigated and the same level of social benefit could be attained via a regulatory scheme with compliance costs of $10 or less, the scheme would be efficient, as it would either result in no net reduction in social welfare or a net increase in social welfare. From these insights, we can conclude that in situations where regulatory burdens outweigh the social benefits they produce and in situations where less-costly regulatory schemes can obtain the same level of social benefit as more costly existing schemes, the consideration of various forms of regulatory innovation is

24. *E.g.*, BARDACH & KAGAN, *supra* note 22, at 6 ("[A] regulatory requirement is unreasonable if compliance would entail costs that clearly exceed the resulting social benefits.").

25. *See* Sara Tran, Expediting Innovation: The Quest for a New Sputnik Moment 6 (March 2011) (unpublished manuscript, on file with the authors) (arguing that patent-related regulatory obstacles should be mitigated in order to capture the social value inherent in emerging green technologies).

26. *E.g.*, Exec. Order No. 12,866, 50 Fed. Reg. 51,735 (Sept. 30, 1993) (directing federal agencies to consider "both the costs and benefits" of regulations and tailor their regulations "to impose the least burden on society"); BARDACH & KAGAN, *supra* note 22, at 6; LISA HEINZERLING & MARK V. TUSHNET, THE REGULATORY AND ADMINISTRATIVE STATE: MATERIALS, CASES, COMMENTS 494 (Oxford Univ. Press 2006) ("[R]egulatory 'failure' is often identified by looking at whether the costs of a regulation exceed its benefits."); Richard H. Pildes & Cass R. Sunstein, *Reinventing the Regulatory State*, 62 U. Chi. L. Rev. 1, 7 (1995) ("The modern regulatory state delivers insufficient benefits at unnecessarily high costs.").

27. *See* BARDACH & KAGAN, *supra* note 22, at 6.

well warranted.

While the above example suggests the application of a purely quantitative cost-benefit analysis to assess the efficiency of regulatory schemes, regulatory burdens and benefits can be difficult to quantify and, as such, qualitative assessments of costs and benefits are often resorted to..[28] In the context of environmental regulatory schemes, many scholars note that while the burdens of compliance might easily be quantified (e.g., the costs associated with seeking air permits and implementing pollution control technologies), many difficulties exist in assigning monetary values to the environmental benefits that flow from these schemes.[29] Ackerman and Heinzerling go as far as arguing that cost-benefit analysis "is a terrible way to make decisions" because it "cannot overcome its fatal flaw: it is completely reliant on the impossible attempt to price the priceless values of life, health, nature, and the future."[30] While we abstain from analyzing the merits of limiting any regulatory assessment of costs and benefits to purely quantitative terms, we subscribe to the fundamental notion that regulatory schemes should be quantitatively and qualitatively analyzed to assess whether the burdens they create are justified by the harms they are intended to mitigate.

Moreover, we posit that the efficacy of qualitatively assessing regulatory burdens and benefits is further bolstered in situations where regulated activities produce ancillary social benefits and value that are difficult to quantify. In typical quantitative cost-benefit analyses of regulatory schemes: (1) compliance costs are estimated; (2) benefits are monetized; (3) any future costs and benefits are appropriately discounted; and (4) the resulting costs and benefits are compared.[31] What is missing from this typical calculus is a mechanism to account for the ancillary social benefits that might be foregone as a result of regulatory costs deterring regulated activities. To exemplify this idea, imagine a hypothetical renewable energy technology that supplies a cost-competitive and completely

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28. Exec. Order No. 12,866, 50 Fed. Reg. 51,735 (Sept. 30, 1993) ("Each agency shall assess both the costs and the benefits of the intended regulation and, *recognizing that some costs and benefits are difficult to quantify*, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.") (emphasis added); Pildes & Sunstein, *supra* note 26, at 127 (arguing that traditional cost-benefit analysis should be split into one stage that focuses on a quantitative assessment and another that qualitatively assesses costs and benefits that are difficult to quatify).

29. *E.g.*, Frank Ackerman & Lisa Heinzerling, *Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection*, 15 U. Pa. L. Rev. 1,553, 1,578 (2002) (critiquing the use of cost-benefit analysis to assess environmental regulations based on the fact that "many benefits of environmental programs--including the prevention of many nonfatal diseases and harms to the ecosystem--either have not been quantified or are not capable of being quantified at this time.").

30. *Id.* at 1,583-84.

31. Ackerman & Heinzerling, *supra* note 29, at 1,556-60.

sustainable form of electricity generation, but nonetheless emits some degree of offending pollution. If regulations were put in place to mitigate the harms associated with this pollution that result in social benefits monetized to equal $10 and compliance costs of $10 for regulated entities, a traditional quantitative cost-benefit analysis would likely conclude that this regulatory scheme is justified. But what if this $10 compliance cost deters firms from implementing this new technology and society therefore loses the difficult to quantify value of enhancing its energy security (not to mention the job-creation potential of this technology and any other environmental benefits that might flow from its implementation)? Should we not somehow account for this foregone social value when we assess the costs of the regulatory scheme? Qualitatively describing and assessing all of the possible effects that a given regulatory scheme might produce better situates us to discern whether regulatory burdens truly outweigh intended benefits.

B. Capturing Social Value

The second theoretical principle on which we base our analysis is the emerging notion that when technological innovations result in the creation of social value, regulatory innovation is often called for to mitigate regulatory burdens in order to fully capture this value.[32] To demonstrate the efficacy of capturing social value, imagine a situation where an art museum and a gambling casino simultaneously catch fire. If the local fire fighting resources could not adequately respond to both fires, most would agree that these limited resources should be focused on the art museum and in the event that they are not, we would expect a public backlash calling for a change in the way fire fighting resources are allocated in the future. As we intuitively recognize the benefit of capturing social value, it logically follows that regulatory schemes should be designed in such a way as to efficiently capture it.

In application, the idea of federal agencies mitigating regulatory burdens in an effort to capture social value is not a new concept. As a means to capture the social value inherent in emerging green technologies, the U.S. Patent and Trademark Office has implemented its "Green Technology Pilot Program, which permits patent applications pertaining to environmental quality, energy conservation, development of renewable energy resources, and greenhouse gas

32. *E.g.*, Tran, *supra* note 25, at 6 (analyzing how the U.S. Patent and Trademark Office processes applications regarding renewable energy technologies and arguing that "expediting the review of socially-valuable applications is normatively justified as a measure to close the gap between the immense social benefits that these technologies bring and the private incentives to innovate and commercialize them").

emission reduction to be advanced out of turn for examination and reviewed earlier (accorded special status)."[33] Likewise, the Federal Energy Regulatory Commission has begun to issue short-term conditional permits for hydrokinetic energy projects in an effort to mitigate regulatory burdens and accelerate the development of these socially beneficial technologies.[34] In order to mitigate regulatory burdens and capture the social value of generic drugs, the Food and Drug Administration provides for their expedited review.[35]

While the two theoretical principles discussed above are distinct notions, they are somewhat intertwined in the way we apply them. When taken together, the idea emerges that when any given technological innovation enhances social welfare and the compliance-related burdens of the regulatory schemes governing its implementation outweigh the harms those schemes are intended to mitigate, then regulatory innovation is called for to both capture this social value and remove any unjustified regulatory hurdles. In the following Parts, we apply this insight to the regulatory schemes governing the commercialization of biobutanol, an emerging transportation fuel alternative. Of course, this analytical framework is equally applicable to technological innovations concerning other emerging biofuels.

III. CASE STUDY: BIOBUTANOL AS AN EMERGING FUEL

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33. Expansion and Extension of the Green Technologies Pilot Program, 75 Fed. Reg. 69,049, 69,049-50 (Nov. 10, 2010). *But see* Tran, *supra* note 25, at 12-16 (critiquing the Green Technology Pilot Program and arguing that it "represents a sideways step or even a step backwards").

34. Press Release, Federal Energy Regulatory Commission, FERC Issues First License for Hydrokinetic Energy Project (Dec. 20, 2007), *available at* http://www.ferc.gov/media/news-releases/2007/2007-4/12-20-07-H-1.asp; *see also* Federal Energy Regulatory Commission, FERC: Hydropower – Hydrokinetic Projects, http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics.asp (last visited March 22, 2011) (providing information on FERC's permitting process for hydrokinetic energy projects).

35. *See* Food and Drug Administration, FDA Ensures Equivalence of Generic Drugs, http://www.fda.gov/Drugs/EmergencyPreparedness/BioterrorismandDrugPreparedness/ucm134444.htm (last visited March 22, 2011) ("Generics are not required to replicate the extensive clinical trials that have already been used in the development of the original, brand-name drug. These tests usually involve a few hundred to a few thousand patients. Since the safety and efficacy of the brand-name product has already been well established in clinical testing and frequently many years of patient use, it is scientifically unnecessary, and would be unethical, to require that such extensive testing be repeated in human subjects for each generic drug that a firm wishes to market. Instead, generic applicants must scientifically demonstrate that their product is bioequivalent (i.e., performs in the same manner) to the pioneer drug.").

As biobutanol is poised to be the next emerging biofuel with the potential to be much more socially-optimal than first-generation biofuels (i.e., corn ethanol), it serves as a perfect case study to develop our thesis that regulatory innovation is needed to keep pace with technological innovation. But before highlighting and analyzing the regulatory schemes affecting the commercialization of biobutanol as a transportation fuel alternative, it is important to frame this discussion with a general overview of biobutanol and the social benefits likely to flow from its use. First, the history of biobutanol production must be set out in order to fully appreciate why it is only now that biobutanol is looking like an attractive and viable option as a transportation fuel. Additionally, a discussion of biobutanol's advantages as a transportation fuel is also necessary to emphasize its ability to increase social welfare.

A. The History of Biobutanol Production

Biobutanol is the generic name for the different forms of butanol that can be derived from biological production processes that utilize biomass as a feedstock.[36] Specifically, the chemical butanol can take the form of four unique isomers: (1) *n*-butanol (or normal-butanol); (2) 2-butanol (or sec-butanol); (3) *i*-butanol (or iso-butanol); and (4) *t*-butanol (or tert-butanol).[37] Regardless of whether these forms of butanol are produced from petroleum (i.e., petrobutanol) or biomass feedstocks (i.e., biobutanol), the resulting butanols possess the same chemical properties.[38] While any one of these four isomers can be produced from petrochemical refinement, all but *t*-butanol can also be produced through various biological fermentation processes resulting in the production of biobutanol.[39]

The production of biobutanol spans back to 1910[40] and has been referred to as "one of the most important commercial fermentation processes in the mid-20th century."[41] Historically, the predominant method of producing biobutanol is

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36. G. Black et al., *Bio-butanol: Combustion Properties and Detailed Chemical Kinetic Model*, 157 COMBUSTION & FLAME 363, 363 (2010); S. Szwaja & J.D. Naber, *Combustion of n-Butanol in a Spark-Ignition IC Engine*, 89 FUEL 1,573, 1,573 (2010).

37. Poonam Singh Nigam and Anoop Singh, *Production of Liquid Biofuels from Renewable Resources*, 37 PROGRESS IN ENERGY & COMBUSTION SCI. 52, 60 (2011); Szwaja & Naber, *supra* note 34, at 1,573.

38. Szwaja & Naber, *supra* note 36, at 1,573.

39. Nigam & Singh, *supra* note 37, at 60.

40. D.F. Gibbs, *The Rise and Fall (. . . and Rise?) of Acetone/Butanol Fermentations*, 1 TRENDS IN BIOTECHNOLOGY 12, 12 (1983) (providing a detailed history of biobutanol fermentation processes).

41. Frances H. Arnold, *The Race for New Biofuels*, 2 ENGINEERING & SCI. 12, 15 (2008).

the acetone-butanol-ethanol (ABE) fermentation process, which utilizes a unique strain of bacteria as a biocatalyst to ferment naturally occurring starch and sugar feedstocks, and traditionally yields butanol, acetone, and ethanol in a ratio of 6:3:1 (by weight), respectively.[42] During World War I, this process achieved widespread commercial deployment, as it was the main method for producing the acetone required to make cordite, a smokeless powder used to propel artillery shells.[43] Production of butanol through the ABE fermentation process, for use by the chemicals industry, continued on a large scale until the 1950s, when petroleum-based production processes became more economically attractive.[44]

Although stagnate for the second half of the twentieth century, research interest in the ABE fermentation process has recently been rekindled due to the prospect of biobutanol serving as a alternative for petroleum-based transportation fuels.[45] As a result of innovations such as the identification of new biocatalyst strains that are capable of yielding greater amounts of butanol and acetone, the efficiencies of the ABE process are continually increasing.[46] Specifically, current ABE fermentation processes are reported to yield butanol, acetone, and ethanol in a ratio of 43:23:1 (by weight), respectively.[47]

Regardless of these significant enhancements in butanol yields, it is unlikely that biobutanol produced through the ABE process will prove viable as a transportation fuel. While the complexities of the RFS2 will be addressed later in this article, it is important to note that it creates a captive market for biofuels whose lifecycle greenhouse gas (GHG) emissions are shown to result in at least a

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42. Wu et al., *Assessment of Potential Life-Cycle Energy and Greenhouse Gas Emission Effects from Using Corn-Based Butanol as a Transportation Fuel*, 24 BIOTECH. PROGRESS 1,204, 1,205 (2008). *Clostridium acetobutylicum* is the traditional bacteria used as a biocatalyst in the ABE fermentation process. *Id.* As Chaim Weizmann developed the ABE fermentation process, it is also often referred to as the "Weizmann process." Gibbs, *supra* note 40, at 12. For a more detailed description of the ABE fermentation process, *see id*.

43. Arnold, *supra* note 41, at 15.

44. *Id.* Other factors leading to the downfall of ABE fermentation in the 1950s include the fact that the prices for feedstocks such as grain and molasses began to rise and the process resulted in a substantial amount of effluent that needed to be disposed of. Gibbs, *supra* note 40, at 13.

45. Liu et al., *Simulation of the Process for Producing Butanol from Corn Fermentation*, 48 INDUS. & ENGINEERING CHEMISTRY RES. 5,551, 5,551 (2009).

46. *Id.* *Clostridium beijerinckii* BA101, which was first developed in the early 1990s, is currently the biocatalyst of choice for ABE fermentation processes. Wu et al., *supra* note 42, at 1,205.

47. *Id.*

20% GHG reduction from conventional gasoline.[48] Bearing in mind that the successful commercialization of any biofuel is highly dependant on its ability to capitalize on the RFS2's captive market, researchers at Argonne National Laboratory have modeled the lifecycle GHG emissions associated with biobutanol produced through the ABE process and report widely varying results due to uncertainties regarding how to account for the acetone that is simultaneously produced.[49] In a subsequent analysis, these researchers assess the amount of feedstock and energy input required to produce corn-based biobutanol via the ABE process and conclude that "with the current [ABE fermentation] technology, corn butanol is not viable as a transportation fuel."[50] Likewise, researchers at Kansas State University also conclude that the production of biobutanol through the ABE fermentation process is not economically competitive with the biological production of ethanol, which is currently the most widely utilized biofuel in the U.S.[51]

As a likely result, firms striving to improve the ABE fermentation process and commercialize their technologies are currently marketing them as a means to

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48. *See* 40 C.F.R. § 80.1401 (2010) (using GHG reduction thresholds, which are determined through life cycle assessments, to define the different categories of renewable fuels that the RFS2 requires to be introduced into the U.S. fuel supply).

49. *See* Wu et al., *supra* note 42, at 1,207-12. For example, if acetone is accounted for based on the "product displacement" method, corn-based biobutanol produced through the ABE process is shown to result in a 56% GHG reduction from baseline gasoline. *Id.* at 1,210. Likewise, if the acetone is accounted for based on the "energy allocation" method, a 39% GHG reduction is shown. *Id.* On the other hand, if the acetone is regarded as a waste product due to the fact that the existing market for acetone is saturated, then corn-based biobutanol produced through the ABE process results in a 30% GHG increase from baseline gasoline. *Id.* Ultimately, the problem is that petroleum-based acetone is currently produced as a byproduct of phenol production and "[a]s demand for phenol continues to rise, petroleum acetone will be produced with or without the presence of bio-acetone." *Id.* at 1,212.

50. Liu, *supra* note 45, at 5,557. The researchers do go on to note that "[v]arious schemes at different steps of butanol production could lead to an effective reduction in the overall energy use of the butanol production process and, eventually, improved viability of corn butanol as a transportation fuel." *Id.*

51. Pfromm et al., *Bio-butanol vs. Bio-ethanol: A Technical and Economic Assessment for Corn and Switchgrass Fermented by Yeast or* Clostridium acetobutylicum, 34 BIOMASS & BIOENERGY 515, 522-23 (2010). It should be noted that when the Kansas State researchers conducted their modeling, they did not use the acetone, butanol, and ethanol yields produced from current ABE fermentation processes due to their notion that "a yield on a pure and easily metabolized substrate in a carefully constructed and often costly fermentation medium in a laboratory will likely be difficult to reproduce in an industrial scale fermentation on a natural substrate such as mash from dry-milled corn." *Id.* at 517. Instead, they assumed the traditional yield ratio of 6:3:1 for butanol, acetone, and ethanol. *Id.* at 518.

produce bio-chemicals, as opposed to stand-alone transportation biofuels.[52] A prime example of this business strategy is the current efforts of TetraVitae Bioscience.[53] Basing their technology around the use of a biocatalyst named *Clostridium Beijerinckii* BA 101, which was discovered by Professor Hans Blaschek at the University of Illinois,[54] TetraVitae Bioscience is marketing its ABE process innovations as a way to "efficiently convert an ethanol plant" to provide "an avenue into the paints, plastics, and personal care markets, with product values that are significantly higher than those of fuel."[55]

Also as a likely outgrowth of the issues associated with using biobutanol derived from the ABE process as a transportation fuel, research interest began to shift and focus on genetically engineering biocatalysts that ferment organic starches and sugars into only butanol.[56] The first major breakthrough came when James Liao's research lab at the University of California, Los Angeles (UCLA) genetically modified the *E. coli* bacteria to biologically produce isobutanol in yields "which [are] better than the best reported butanol production from any natural organism, even at the height of industrial butanol production."[57] More recently, Michelle C. Y. Chang, an assistant professor in chemistry at the University of California, Berkeley, further genetically modified the *E. coli* bacteria to biologically produce n-butanol in yields "about 10 times better than

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52. *E.g.*, TetraVitae Bioscience, Abundant Opportunities for Capital Deployment, http://www.tetravitae.com/explore/markets.php (last visited March 3, 2011) (emphasizing the bio-chemical market opportunities for *n*-butanol and acetone derived from biological production processes); *see* Jim Lane, *"Why Make a $2 Fuel When You Can Make a $5 Chemical" – Cobalt CEO Rick* Wilson, BIOFUELS DIGEST, March 16, 2011, http://biofuelsdigest.com/bdigest/2011/03/16/why-make-a-2-fuel-when-you-can-make-a-5-chemical-cobalt-ceo-rick-wilson/; Pfromm, *supra* note 49, at 523 (highlighting the argument that ABE fermentation products could be commercialized as bio-chemicals).

53. TetraVitae Bioscience, *supra* note 52.

54. TetraVitae Bioscience, Innovative Solutions for Today and Tomorrow, http://www.tetravitae.com/innovate/ (last visited April 2, 2011).

55. TetraVitae Bioscience, Adding Value to Corn and Sugarcane Ethanol Assets, http://www.tetravitae.com/integrate/ethanolassets.php (last visited April 2, 2011).

56. *See* David E. Ramey, *Butanol: The Other Alternative Fuel*, *in* AGRICULTURAL BIOFUELS: TECHNOLOGY, SUSTAINABILITY, AND PROFITABILITY 141 (Allan Eaglesham & Ralph W.F. Hardy eds.) (2007) (describing a fermentation process that yields only butanol); Arnold, *supra* note 42, at 16-19 (discussing recent technological advancements regarding genetically modified biocatalysts that only produce butanol); Wu et al., *supra* note 42, at 1,205 ("The latest development includes a patent application (DuPont, 2007) describing a strain that produces single-product butanol from biological feedstocks.").

57. Arnold, *supra* note 41, at 16-17.

current industrial microbe systems."[58]

In regards to the commercialization of these innovations, James Liao continued to build on his pioneering work, developed a new biocatalyst capable of converting naturally occurring sugars (e.g., those derived from corn) into isobutanol, and co-founded Gevo, a private firm currently in the process of trying to commercialize isobutanol as a transportation fuel.[59] As of the writing of this article, Gevo has demonstrated its technology "at a commercially relevant scale[,]" is in the process of retrofitting an ethanol production facility that it acquired in 2010, and "expect[s] to begin commercial production of isobutanol at the . . . facility in the first half of 2012."[60] From there, Gevo plans to license its technology to existing ethanol facilities in order to "capitalize on the approximately 20 billion gallons per year of operating ethanol production capacity worldwide."[61] As a sign of investor enthusiasm in this commercialization strategy, Gevo's initial public offering raised $123.3 million in March of 2011.[62]

Additionally, Butamax Advanced Biofuels (Butamax), a joint venture between BP and DuPont, has also made significant progress in developing biocatalysts that produce only isobutanol through the fermentation of organic starches and sugars.[63] Butamax is currently demonstrating its technology at a

58. ScienceCodex.com, Turning Bacteria Into Butanol Biofuel Factories, http://www.sciencecodex.com/turning_bacteria_into_butanol_biofuel_factories (last visited April 2, 2011); *see also* Bond-Watts et al., *Enzyme Mechanism as a Kinetic Control Element for Designing Synthetic Biofuel Pathways*, 7 NATURE CHEMICAL BIOLOGY 222, 222-227 (2011) (reporting the methods and results for Prof. Chang's recent breakthrough in the biological production of n-butanol).

59. Peter Fairley, *Bug Creates Butanol Directly from Cellulose*, TECH. REV., March 22, 2011, http://www.technologyreview.com/printer_friendly_article.aspx?id=36982; *see also* Gevo, http://www.gevo.com/ (last visited March 23, 2011).

60. Gevo, Commercialization Strategy, http://www.gevo.com/our-business/commercialization-strategy/ (last visited March 25, 2011).

61. *Id.*

62. Jim Lane, *Gevo Raises $123.3 Million in IPO After Underwriters Oversubscribe*, BIOFUELS DIGEST, March 16, 2011, http://biofuelsdigest.com/bdigest/2011/03/16/gevo-raises-123-3-million-in-ipo-after-underwriters-oversubscribe/. While Gevo initially offered 7,150,000 shares of common stock at $15 with a projection of raising $95.7 million, "after trading up nearly 10 percent on the first day of trading, the underwriters exercised their overallotment option bringing the total capital raised to $123.3 million" through the sale of 8.223 million shares. *Id.*; Press Release, Gevo, Gevo, Inc. Announces Pricing of Initial Public Offering (Feb. 9, 2011), *available at* http://ir.gevo.com/preview/phoenix.zhtml?c=238618&p=irol-newsArticle&ID=1526839&highlight=.

63. Press Release, Butamax Advanced Biofuels, Butamax Advanced Biofuels Adds to Strong Intellectual Property Portfolio with Latest Isobutanol Patent Grant (March 22, 2011) *available at*

production facility in Hull, England, intends to license its technology to existing ethanol production facilities, and has projected commercial deployment in 2012.[64] As you can guess, based on their similar commercialization strategies, the race between Gevo and Butamax to commercialize biobutanol is getting tense and while Gevo appeared to be inching ahead when the EPA officially registered its isobutanol as a lawful fuel additive in November of 2010,[65] Butamax secured a patent on its isobutanol production process from the U.S. Patent and Trademark Office in December of 2010 and is currently in the process of suing Gevo for patent infringement.[66] Moreover, Butamax secured another important patent in March of 2012 and boasts:

> "We are the only company to hold issued patents for this technology" . . . [and] "[b]y obtaining and protecting our intellectual property portfolio, we ensure the highest sustainable value for our customers and licensees. Because our technology is not dependent on on-going royalties to multitudes of third party technology providers, Butamax is able to provide higher financial returns for converting ethanol capacity to biobutanol production." Butamax owns all of its intellectual property and is the only company to offer ethanol producers a technology that is clear of third party rights and obligations. . . . "We are uniquely positioned to provide unfettered access to the most advanced technology for producing biobutanol. We will continue to secure for our customers and licensees the ability to modify their production capacity to ensure sustainable growth for the biofuels industry."[67]

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http://www.butamax.com/_assets/pdf/butamax%20march%2023%202011%20ip%20isobutanol%20patent%20grant.pdf; Press Release, Butamax Advanced Biofuels, Butamax Advanced Biofuels Announces Grant of Key Isobutanol U.S. Patent (Dec. 16, 2010), *available at* http://www.butamax.com/_assets/pdf/AdvancedBiofuelsAnnouncesGrantofKeyIsobutanolU.S.Patent.pdf.

64. Jim Lane, *Butamax Hits Milestone on Path Towards Commercial Biobutanol in 2012*, BIOFUELS DIGEST, Nov. 11, 2010, http://biofuelsdigest.com/bdigest/2010/11/11/butamax-hits-milestones-on-path-towards-commercial-biobutanol-in-2012/; Butamax Advanced Biofuels, *supra* note 63.

65. Press Release, Gevo, Gevo's Isobutanol Secures EPA Registration (Nov. 11, 2010), *available at* http://ir.gevo.com/preview/phoenix.zhtml?c=238618&p=irol-newsArticle&ID=1516201&highlight=.

66. Press Release, Butamax Advanced Biofuels, Butamax Files Patent Infringement Action Against Gevo, Inc. to Protect Biobutanol Intellectual Property (Jan. 14, 2011), *available at* http://www.butamax.com/_assets/pdf/butamax_press_release_140111.pdf.

67. Butamax Advanced Biofuels, *supra* note 63 (quoting Butamax Vice President and Chief Counsel Christine Lhulier).

Although neither Gevo or Butamax have released detailed lifecycle GHG assessments for their production processes, with the acetone and ethanol byproducts out of the picture, these assessments will likely look much more promising and could potentially solidify biobutanol's viability within the RFS2's captive market for biofuels.

Building on the development of biocatalysts that produce only biobutanol from starches and sugars, emphasis is now turning to genetically engineering biocatalysts that can produce biobutanol from cellulosic feedstocks.[68] Motivating this work is the fact that the production and use of cellulosic biofuels are reported to result in increased social benefits such as lower lifecycle GHG emissions, increased petroleum displacement, and reduced fuel costs.[69] In July of 2010, Gevo publicly announced that it had "successfully produced isobutanol from fermentable sugars derived from cellulosic biomass"[70] and while this is a significant achievement, the commercial viability of the process is likely contingent on the development of efficient methods for converting cellulosic biomass into fermentable sugars.[71] More recently, a collaborative effort between researchers in James Liao's lab at UCLA and Oak Ridge National Laboratory has announced the development of a new biocatalyst that produces isobutanol directly from cellulose in a single process step, which could not only lead to more cost effective cellulosic biobutanol production processes, but also open the door to cellulosic biofuels' potential to enhance social welfare through its promise of greater GHG emission reductions and petroleum displacement.[72] While the

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68. Arnold, *supra* note 41, at 17-18; Gevo, Our Science and Technology, http://www.gevo.com/our-business/our-science-and-technology/#future (last visited March 3, 2011) ("Gevo is developing a yeast biocatalyst that is specifically designed to efficiently produce isobutanol from the sugars derived from cellulosic biomass.").

69. Wendy Higashide et al., *Metabolic Engineering of* Clostridium Cellulolyticum *for Isobutanol Production from Cellulose*, APPLIED & ENVTL. MICROBIOLOGY, at 3 (forthcoming 2011), *available at* http://aem.asm.org/cgi/reprint/AEM.02454-10v1.

70. Press Release, Gevo, Technology Milestone Validates Gevo's Biocatalyst for Converting Cellulosic Sugars into Advanced Biofuels and Hydrocarbons (July 29, 2010), *available at* http://ir.gevo.com/preview/phoenix.zhtml?c=238618&p=irol-newsArticle&ID=1490100&highlight= (last visited March 3, 2011).

71. *See* Higashide et al., *supra* note 69, at 3 ("To meet [cellulosic biofuels'] potential, technological advances are needed to improve the conversion efficiency of the recalcitrant lignocellulose to fermentable sugars.").

72. *Id.* at 3-5; Fairley, *supra* note 59; Press Release, Oak Ridge National Laboratory, BESC Scores a First with Isobutanol Directly from Cellulose, March 7, 2011, *available at* http://www.ornl.gov/ornlhome/print/press_release_print.cfm?ReleaseNumber=mr20110307-00 (stating that the recent breakthrough in producing isobutanol directly from cellulose "represents across-the-board savings in processing costs").

biobutanol yields from the process are relatively low and they have yet to be demonstrated outside of the lab,[73] this innovation nonetheless foreshadows the future potential for the commercialization of cellulosic biobutanol. According to an interview given by Liao in March of 2011, this "proof of principle" is the most difficult stage of development, "the rest is relatively straightforward[,]" and this process could be ready for production "in as little as two years."[74]

B. The Social Value of Biobutanol

With an understanding of how biobutanol production processes have evolved to a point where they now appear to be viable as means to produce transportation fuels, the next important point to consider is what relevance this has from the perspective of increasing social welfare. As a general proposition, a shift toward increased reliance on biofuels, as alternatives to petroleum-based fuels, will create social value by increasing U.S. energy security, furthering environmental objectives, and promoting rural development.[75] Moreover, when we focus in on biobutanol, we see that it posses several unique advantages as a transportation fuel and, as such, when it is compared to traditional forms of biofuel, these advantages render its use more socially optimal. Due to the fact that biologically produced ethanol is currently the most widely used biofuel in the U.S.,[76] this section touches on comparative analyses between biobutanol and ethanol.

1. Energy Content

The relatively high energy content of biobutanol is likely its greatest advantage as a transportation fuel when compared to ethanol. On a British thermal units per gallon (BTU/gal) basis, the energy content of butanol has been reported to range from 83% to almost 96% that of gasoline.[77] By way of

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73. Higashide et al., *supra* note 69, at 14 (reporting the laboratory production of "an isobutanol titer of 660 mg/L").

74. Fairley, *supra* note 59 (quoting James Liao).

75. *See infra* Part V.B.

76. CRS ETHANOL REPORT, *supra* note 17, at 2.

77. Ramey, *supra* note 56, at 142 (reporting butanol to contain 104,854 BTU/gallon resulting in its energy density being 91% that of gasoline); Nigam & Singh, *supra* note 37, at 60 ("Butanol contains 110,000 BTUs per gallon, closer to gasoline's 115,000 BTUs" resulting in butanol's energy density being 96% that of gasoline); Wu et al., *supra* note 42, at 1,205 (reporting butanol's lower heating value to be 99,837 Btu/gal and its energy density to be 86% that of gasoline); BUTAMAX ADVANCED BIOFUELS, CALIFORNIA BIOBUTANOL MULTIMEDIA EVALUATION

comparison, the energy content of ethanol is consistently reported as being only 66% that of gasoline.[78] Even taking the conservative approach of considering biobutanol's energy content to be only 83% that of gasoline, if you compare the widespread implementation of a 16% by volume biobutanol blend (i.e., 16% biobutanol and 84% gasoline)[79] with the E10 blend that currently dominates the U.S. fuel market,[80] the biobutanol blend not only produces a slight increase in fuel economy for consumers,[81] but also displaces roughly twice as much fossil fuel from the U.S. fuel supply.[82] As you move up the scale of biobutanol's reported energy contents, these social benefits flowing from the use of biobutanol as a fuel additive obviously grow. If you take the most optimistic numbers for biobutanol's energy content, the widespread use of 100% biobutanol as a transportation fuel would obviously displace gasoline gallon for gallon, while at the same time, consumers would experience less than a 1.5% decrease in fuel economy compared to the E10 blends currently available.[83]

2. Infrastructure Compatibility

The second major advantage that biobutanol possesses as a transportation fuel alternative is the fact that it is much more compatible with current infrastructure than ethanol is.[84] If the "field-to-tank" macro-level infrastructure needed to bring a biofuel to market is considered to include the production of

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24 (2010), *available at* http://www.arb.ca.gov/fuels/multimedia/020910biobutanoltierI.pdf (reporting that the energy density of its iso-butanol is 83% that of gasoline based on its energy content being 95,400 BTU/gal).

78. *E.g.*, Wu et al., *supra* note 42, at 1,205 (reporting that ethanol possesses 76,330 BTU/gal resulting in its energy density being 66% that of gasoline).

79. To understand our selection of this blend for our example, *see infra* Parts IV.B.2.; V.C.1.

80. *See* RENEWABLE FUELS ASSOCIATION, *supra* note 19, at 11.

81. BUTAMAX ADVANCED BIOFUELS, *supra* note 77, at 24 ("The fuel energy content of a 16 volume% iso-butanol blend is approximately 112,300 BTU per gallon, and this is comparable to the energy content of an E10 blend which has an energy content of 111,500 BTU per gallon. This comparison of energy content between E10 and 16vol% iso-butanol implies that consumers will experience slightly better (<1%) fuel economy with the butanol blend compared to E10.").

82. *Id.* at 9 ("Biobutanol has a higher energy density than ethanol, allowing the iso-butanol in a 16vol% blend to displace about 13.6% of the hydrocarbon gasoline, while the ethanol in a 10vol% blend displaces only about 6.8% of the hydrocarbon gasoline.").

83. Nigam & Singh, *supra* note 37, at 60 ("Butanol contains 110,000 BTUs per gallon."); BUTAMAX ADVANCED BIOFUELS, *supra* note 77, at 24 (reporting the energy content of 10% ethanol blends to be "111,500 BTU per gallon").

84. *See, e.g.*, Nigam & Singh, *supra* note 37, at 60 (noting that biobutanol is compatible with existing fuel storage tanks and pipelines).

biomass feedstocks, the conversion of these feedstocks into biofuel, the distribution of the biofuel, and the end-use of the biofuel, then biobutanol is a true "drop-in" biofuel in that it has compatibilities with each of these stages. As such, the introduction of biobutanol into the U.S. fuel supply would not require the huge capital investment in infrastructure that would be necessary for expanded ethanol usage.[85]

As biobutanol can be produced from the same types of biomass feedstocks as conventional biofuels, it is compatible with existing biomass production infrastructure.[86] Cornstarch can be used as a feedstock for the fermentation of biobutanol in much the same way as it is for the production of ethanol.[87] Likewise, the wheat straw that serves as a traditional biofuel feedstock in Europe[88] and the sugarcane that is abundantly produced as a biofuel feedstock in Brazil[89] are also capable of being utilized as feedstocks for biobutanol production.[90] Moreover, the successful production of biobutanol from cellulosic feedstocks has been reported[91] and as innovations regarding cellulosic biobutanol conversion technologies continue to advance, it is projected that cellulosic materials derived from switchgrass, miscanthus, agricultural residues, and woody

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85. *See* U.S. DEPARTMENT OF AGRICULTURE, A USDA REGIONAL ROADMAP TO MEETING THE BIOFUELS GOALS OF THE RENEWABLE FUEL STANDARD BY 2022 13-17 (2010) [hereinafter USDA BIOFUELS ROADMAP]. The USDA projects that if the RFS2's mandates are to be satisfied by the use of ethanol, $12.006 Billion would have to be invested in railroad transportation infrastructure alone. *Id.* at 17. In addition, huge capital investments would also need to be made in retail fuel dispensing infrastructure to accommodate a greater use of ethanol. *See id*. at 15-16. Based on the EPA estimates, the USDA reports that the cost of purchasing a single ethanol-compatible fuel pump is $23,000 and the cost of retrofitting an existing fuel pump to accommodate ethanol is $11,775. *Id.* at 15. If an ethanol-compatible fuel storage tank must also be installed, these prices could rise to $122,000 per retail station. *Id.* at 16.

86. Nigam & Singh, *supra* note 37, at 62 (noting that biobutanol can be produced from corn, wheat, sugarcane, and sugar beets).

87. Wu et al., *supra* note 42, at 1,206 (discussing how production processes for corn-based biobutanol "could be similar to those that are part of corn ethanol production").

88. Nasib Qureshi et al., *Butanol Production from Wheat Straw by Simultaneous Saccharification and Fermentation Using* Clostridium beijerinckii: *Part I – Batch Fermentation*, 32 BIOMASS & BIOENERGY 168, 171 (2008) (reporting biobutanol yields from the fermentation of wheat straw).

89. *See* Arnold, *supra* note 41, at 14 (discussing the use of sugarcane to produce biofuels in Brazil).

90. *See* Press Release, Butamax Advanced Biofuels, Butamax Advanced Biofuels Progresses Plans to Bring Biobutanol to Market (Nov. 10, 2010), *available at* http://www.butamax.com/_assets/pdf/FinalAdvancedBiofuelsMarketsReleaseSanFranNov10.pdf (last visited Jan. 5, 2011) (announcing the opening of "a new laboratory to accelerate commercial designs for sugarcane-to-biobutanol in Paulinia, Brazil").

91. Higashide et al., *supra* note 69, at 5; Gevo, *supra* note 70.

biomass will be capable of conversion into biobutanol.[92] As a result of these compatibilities, a shift toward the production of biobutanol would not necessitate any dramatic change in the way biofuel stakeholders account for the production and availability of biomass feedstocks. While biomass feedstock production infrastructure no doubt needs to continue to develop and evolve, a shift towards the production of biobutanol would not present any new challenges that do not already exist.

In regards to biofuel production infrastructure, biobutanol can be produced at existing ethanol production facilities with very minimal modification.[93] The only retrofitting required is the modification of the facility's fermentation tank (to accommodate the use of a different biocatalyst) and the facility's distillation equipment.[94] As such, biobutanol production technologies are being marketed as "bolt-on" technologies that allow existing ethanol facilities to alternate back and forth between the production of ethanol and biobutanol[95] and, likely for strategic reasons, the firms attempting to market these technologies are presenting them as compliments to ethanol production as opposed to direct competition.[96] It remains to be seen whether or not this marketing approach will phase out if demand for biobutanol as a transportation fuel begins to grow, but in any event, the fact that biobutanol can be produced without the capital outlay necessary to build new

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92. *See* Arnold, *supra* note 41, at 17-18 (discussing technological advancements relating to the production of biobutanol from cellulosic feedstocks).

93. *See* Presentation, Butamax Advanced Biofuels, The Development of Butamax: A Case Study of the DuPont – BP Joint Venture to Develop Advanced BioButanol (2010), *available at* http://www.butamax.com/_assets/pdf/LLC_development.pdf (last visited Jan. 6, 2011) [hereinafter Butamax Presentation] (providing photographic representations of the modifications necessary to convert a traditional ethanol production facility to one that produces biobutanol); Gevo, *supra* note 60 (describing Gevo's process for retrofitting ethanol plants).

94. *See* Butamax Presentation, *supra* note 93.

95. *E.g.*, TetraVitae, Converting Corn Ethanol Assets to Produce Butanol and Acetone Economically Advantageous, http://www.tetravitae.com/integrate/ethanolassets.php (last visited Jan. 6, 2011) ("The modifications required to run TetraVitae's process maintain the ability of the plant to produce ethanol. In fact, the plant can switch back and forth between chemical and fuel production based on market conditions.").

96. *See* Butamax Advanced Biofuels, *supra* note 90 (announcing intention to "retrofit commercial scale ethanol plants and bring biobutanol to global transport fuel markets" and noting that "[b]iobutanol complements the success of the ethanol industry" and "provides benefits throughout the value chain including to ethanol producers, blenders and refiners"); Gevo, Gevo, Ethanol and the Future of Biofuels, http://www.gevo.com/our-business/gevo-supports-the-ethanol-industry/ (last visited March 3, 2011) ("We understand that our success depends on the continued success of the ethanol industry."); TetraVitae, Bridging Agriculture and Industry, http://www.tetravitae.com/integrate/ (last visited Jan. 6, 2011) (marketing its technology as providing "[e]thanol asset owners" with "[a]cess to a higher margin product portfolio").

production facilities is a huge advantage from an economic perspective and ultimately enhances the social value of biobutanol production.

As far as transportation fuel distribution is concerned, the fact that biobutanol is purported to be completely compatible with current infrastructure[97] is an enormous advantage when it is compared to ethanol. Due to biobutanol's low water solubility, it does not produce the microbial-induced corrosion of fuel distribution infrastructure that ethanol does[98] and, as such, biobutanol can be distributed through existing fuel pipelines and stored in existing fuel storage tanks.[99] By way of comparison, consider the great expense and GHG emissions that result from ethanol needing to be separately transported (by either tanker truck, rail, or barge) to fuel terminals before it can be blended with gasoline for distribution to fueling stations.[100] When the vast amounts of distribution infrastructure-related capital investment requisite for an increased societal use of ethanol are considered,[101] these advantages of biobutanol could result in economic ramifications that are nothing short of staggering.

Additionally, biobutanol is also more compatible than ethanol with existing internal combustion engines.[102] While flex-fuel vehicles remain the only segment of the U.S. automobile fleet that are currently compatible with high-level blends of ethanol,[103] research has demonstrated that biobutanol can be used in existing internal combustion engines without modification.[104] A study at Michigan Technological University conducted thorough testing on the use of butanol in unmodified engines and ultimately concluded that "*n*-butanol can directly substitute for gasoline either as a neat fuel [i.e., 100% butanol] or blended from a combustion and energy density perspective for fuel for a [spark ignited] engine because of the similar thermo-physical properties."[105] In application, Dr. David Ramey drove an unmodified 1992 Buick 10,000 miles across the U.S. in 2007 using nothing but butanol for fuel and surprisingly reported an increase in miles per gallon fuel efficiency despite butanol having a lower energy content

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97. *E.g.*, Nigam & Singh, *supra* note 37, at 60 ("Butanol . . . can be shipped and distributed through existing pipelines and filling stations.").

98. Wu et al., *supra* note 42, at 1,205.

99. Nigam & Singh, *supra* note 37, at 60

100. *See* CRS ETHANOL REPORT, *supra* note 17, at 9.

101. USDA BIOFUELS ROADMAP, *supra* note 85, at 17; *see supra* text accompanying note 85.

102. *See* Szwaja & Naber, *supra* note 36, at 1,573.

103. *See* CRS ETHANOL REPORT, *supra* note 17, at 9.

104. Szwaja & Naber, *supra* note 36, at 1,573 ("Butanol . . . can be demonstrated to work in the [internal combustion] engine designed for use with gasoline without modification.").

105. *Id.* at 1,582.

than gasoline.[106]

3. Co-Product Values

Finally, biobutanol has several significant co-product values that render its production more economically attractive than ethanol.[107] If technological innovations advance to the point where biobutanol can be viably produced through the ABE fermentation process, a huge market exists for the acetone that is simultaneously produced.[108] On the other hand, if biobutanol is produced through fermentation techniques that yield no other chemicals, the butanol itself can be marketed as a commercial solvent[109] or further refined to produce valuable co-products such as polymers, molded plastics, rubbers and other chemicals.[110] Not only could these co-products provide increased revenue streams for biofuel producers, but since they are traditionally derived from fossil fuel refinement, the possibility to displace greater volumes of petroleum also exists.[111] From an economic and environmental perspective, the production of biobutanol could produce a societal win-win situation.

4. Potential Shortcomings

Despite the many advantages of biobutanol when compared to ethanol, it does possess a few less desirable characteristics as a transportation fuel.[112] First,

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106. Ramey, *supra* note 56, at 137 ("My Buick averages 22 mpg with gasoline, whereas it averaged 25 mpg . . . on 100% butanol.").

107. *See* TetraVitae, Butanol Acetone – Great Building Blocks for Commercial Use, http://www.tetravitae.com/innovate/productmarketopportunities.php (last visited Jan. 6, 2011) (diagramming how butanol can serve as a chemical building block for the production of commercial coatings, packaging, and molded plastics).

108. *See* TetraVitae, *supra* note 52 ("acetone has global demand of 5.7 million tons and growth of 4% a year"); *but see* Wu et al., *supra* note 42, at 1,212 (noting that if the production of biobutanol from ABE fermentation reaches commercial scale, the market for acetone would be flooded and prices would be dramatically reduced).

109. Nigam & Singh, *supra* note 37, at 61.

110. Gevo, Our Markets, http://www.gevo.com/our-business/our-markets/ (last visited March 3, 2011).

111. *See id.* ("We expect Gevo's isobutanol can provide chemical companies with an alternative to petroleum-based butenes with advantages in cost, predictability and life cycle profile.").

112. *See* U.S. ENVIRONMENTAL PROTECTION AGENCY, RENEWABLE FUEL STANDARD PROGRAM (RFS2) REGULATORY IMPACT ANALYSIS 74 (2010), *available at* http://www.epa.gov/otaq/renewablefuels/420r10006.pdf [hereinafter RFS2 REGULATORY IMPACT ANALYSIS].

the EPA reports that biobutanol is more expensive to produce than ethanol,[113] but this higher production cost could very well be offset by the higher sale price it can likely demand due to its higher energy content.[114] Also, biobutanol tends to have a high viscosity that might make it harder to dispense through existing retail station fuel pumps.[115] This being said, if one considers the fact the high-level ethanol blends also require unique fuel pumps,[116] this fact might put biobutanol on a level playing field with ethanol as opposed to be considered a negative characteristic. Finally, there are also concerns about the lower octane of biobutanol, which might result in higher refining costs.[117] Put in simple terms, as octane decreases, refining costs tend to increase[118] and while ethanol has a high blending octane of approximately 115, the blending octane of butanol tends to range from 87-94.[119] Specifically, the octane number for *n*-butanol is reported as 87 and that of isobutanol is 94,[120] which likely explains why companies seeking to commercialize biobutanol as a transportation fuel are focusing on isobutanol.[121]

IV. CURRENT REGULATORY FRAMEWORK FOR THE COMMERCIALIZATION OF BIOBUTANOL

With an understanding of the current state of biobutanol production and its advantages as a transportation fuel, we turn to a discussion of the two main regulatory schemes that will likely affect its successful commercialization. First, we look at the federal Renewable Fuel Standard and discuss its potential to incentivize both the increased use of biobutanol and technological innovations in its production. Next, we address the Clean Air Act's regulatory framework for the commercialization of new fuels and fuel additives, which effectively governs the lawful blending limits for biobutanol and arguably creates unjustified hurdles for its commercialization.

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113. *Id.*

114. *See supra* text accompanying note 77.

115. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 74.

116. USDA BIOFUELS ROADMAP, *supra* note 85, at 13-16 (discussing the unique fuel pumps required to dispense fuel blended with higher levels of ethanol).

117. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 75.

118. *See id.*

119. *Id.*

120. *Id.*

121. *E.g.*, Gevo, *supra* note 60.

A. The Renewable Fuel Standard

The federal Renewable Fuel Standard (RFS2)[122] is clearly one of the most important regulatory schemes affecting the successful commercialization of any new from of biofuel. It not only creates a captive market for different forms of biofuels by explicitly mandating their introduction into the U.S. fuel supply,[123] but the intricately detailed definitions that it provides for its different categories of renewable fuels also serve as a de facto incentivizing scheme for technological innovations in their production.[124] While this case study focuses on biobutanol, the following section provides a general overview of the RFS2 that is equally applicable to other forms of biofuels.

1. Overview

Before discussing the RFS2's specific treatment of biobutanol, it is important to first have a general understanding of the standard's background and how it operates. The EPA implemented the original Renewable Fuel Standard (RFS1)[125] as a result of a congressional mandate within the Energy Policy Act of 2005[126] and although the EPA finalized its regulations for the RFS1 in May of 2007,[127] Congress drastically changed the program with the enactment of the Energy Independence and Security Act of 2007 (EISA).[128] As a result, the EPA began the rulemaking process for the RFS2 in May of 2009[129] and ultimately

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122. Renewable Fuel Standard, 40 C.F.R. §§ 80.1400 – 80.1468 (2010).

123. 40 C.F.R. § 80.1405 (setting out volume percentages for the different categories of renewable fuels that must be introduced into the U.S. fuel supply).

124. 40 C.F.R. § 80.1401 (setting out the definitions used for purposes of the RFS2). Because the RFS2 defines its different categories of renewable fuels by their ability to reduce GHG emissions, which is calculated based on LCAs that account for the energy used in different biofuel production processes, these definitions incentivize biofuel producers to improve their production processes in order to enhance their finished fuels capacity to reduce GHG emissions. *See id.*

125. 40 C.F.R. § 80.1100 et seq.

126. Energy Policy Act of 2005, Pub. L. No. 109-58, § 1501, 119 Stat. 1067 (2005).

127. Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, 72 Fed. Reg. 23,900 (May 1, 2007).

128. *See* Energy Independence and Security Act of 2007, Pub. L. No. 110-140, §§ 201-203 (2007) (altering the definitions for the different categories of renewable fuels and mandating new volumes to be introduced into the U.S. fuel supply).

129. Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Proposed Rule, 74 Fed. Reg. 24,904, 24,904 (May 26, 2009).

issued a final rule for the RFS2 in March of 2010.[130] This section will provide a general overview of how the RFS2 operates by discussing its renewable fuel categories, the designation of renewable fuel pathways, renewable fuel volume obligations, and the way in which it is complied with through the use of Renewable Identification Numbers (RINs).

a. Renewable Fuel Categories and Pathways

While most who casually follow the biofuels industry are aware that the RFS2 mandates the introduction of 36 billion gallons of renewable fuels into the U.S. fuel supply by 2022, few are aware that this overall mandate is actually comprised of a system of four unique nested mandates that apply to four different categories of renewable fuels.[131] Specifically, the RFS2's total "renewable fuel" requirement includes a distinct volume requirement for "advanced biofuels," which in turn includes distinct requirements for "cellulosic biofuels" and "biomass-based diesel."[132] While the specific volume requirements for these four different types of fuels will be addressed in the following sub-section, as a foundation for discussing them, it is important to first understand the way in which these fuel categories are defined and how distinct renewable fuel pathways are designated for unique biofuel production processes.

The four categories of renewable fuels set out in the RFS2 are essentially defined by the biomass feedstocks they are derived from and their ability to reduce GHG emissions from a baseline, which is set as the total lifecycle GHG emissions from either gasoline or diesel sold as transportation fuel in 2005.[133] In order to determine what category of renewable fuel a given biofuel is placed in, the EPA first assesses the biofuel's lifecycle GHG emissions[134] by using complex

130. RFS2 Final Rule, *supra* note 9, at 14,670.

131. *Id.* at 14,674.

132. *Id.* (providing a graphical representation of how the total renewable fuel requirement is broken down by renewable fuel type).

133. 40 C.F.R. § 80.1401 (2011) (providing definitions for the types of renewable fuel covered by the RFS2). Specifically, "baseline lifecycle greenhouse gas emissions is defined as "the average lifecycle greenhouse gas emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005." *Id.* In determining these baselines, the EPA relies on "the 2005 petroleum baseline model developed by the National Energy Technology Laboratory (NETL)." RFS2 Final Rule, *supra* note 9, at 14,874 (citing Department of Energy: National Energy Technology Laboratory. 2009. NETL: Petroleum-Based Fuels Life Cycle Greenhouse Gas Analysis— 2005 Baseline Model).

134. "Lifecycle greenhouse gas emissions" are defined as "the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the

models that account for the emissions associated with: (1) feedstock production; (2) land use change; (3) feedstock transport; (4) biofuel production; (5) biofuel transportation; and (6) vehicle tailpipe exhaust.[135] The results from this assessment are then compared to the relevant baseline to determine the lifecycle GHG reduction percentage achieved. Based on this reduction percentage, the EPA classifies the biofuel within one of the RFS2's four renewable fuel categories and designates a "fuel pathway" for the biofuel, which sets out production requirements that must be complied with by any manufacturer who wishes for its biofuel to satisfy the RFS2 mandate that corresponds with that category of renewable fuel.[136] In promulgating the final rule for the RFS2, the EPA established fourteen different fuel pathways for known biofuel production processes[137] and the regulations for the RFS2 provide a means for biofuel producers to petition the EPA to establish new fuel pathways based on their unique production processes.[138]

Renewable fuels are the overarching and most broadly defined category of

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full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential." Clean Air Act, 42 U.S.C. § 7545(o)(1) (2010).

135. RFS2 Final Rule, *supra* note 9, at 14,765-83 (detailing the GHG emissions modeling used for the RFS2). For a further discussion of the many controversies and uncertainties associated with the inclusion of indirect land use change (ILUC) values in these lifecycle GHG emission assessments, *compare* Daniel A. Farber, *Land Use Change, Uncertainty, and Biofuels Policy*, 2011 U. ILL. L. REV. (forthcoming March, 2011) (analyzing the EPA's treatment of ILUC and concluding that although EPA has acted in good faith, it should nonetheless develop better methods of dealing with the uncertainty associated with ILUC), *with* David Zilberman et al., *On the Inclusion of Indirect Land Use in Biofuel Regulation*, 2011 U. ILL. L. REV. (forthcoming March, 2011) (arguing that policymakers should not mandate the inclusion of ILUC values due to the uncertainties associated with them).

136. *See* 40 C.F.R. § 80.1426(f), Table 1 (2011) (providing a table of the modeled fuel pathways and the production processes that satisfy them).

137. *Id.*

138. 40 C.F.R. § 80.1416. A party may petition the EPA to assess a new fuel pathway if: (1) the new pathway has not yet been evaluated by the EPA; (2) "[t]he renewable fuel pathway has been determined by the EPA not to qualify for [renewable fuel category designation] and the party can document significant differences between their fuel production processes and the fuel production processes already considered by the EPA"; or (3) "[t]he renewable fuel pathway has been determined to qualify for a certain [renewable fuel category designation] and the party can document significant differences between their fuel production processes and the fuel production processes already considered by the EPA." 40 C.F.R. § 80.1416(a). The regulations also set out detailed requirements for the types of information that must be included in the requisite petition. 40 C.F.R. § 80.1416(b).

biofuels included in the RFS2's mandates.[139] Specifically, a renewable fuel is defined as a "[f]uel that is produced from renewable biomass[,] . . . that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel, heating oil, or jet fuel[, and] . . . [h]as lifecycle greenhouse gas emissions that are at least 20 percent less than baseline lifecycle greenhouse gas emissions."[140] Thus far, the EPA has established six different fuel pathways that result in the production of biofuels that are classified only as renewable fuels for purposes of the RFS2.[141] While five of these fuel pathways involve the production of ethanol, the remaining pathway is modeled for the production of butanol from cornstarch.[142]

Within the RFS2's overarching category of renewable fuels, three sub-categories exist.[143] "Advanced biofuels" make up the broadest of the three sub-categories and are defined as "renewable fuel[s], other than ethanol derived from cornstarch, that ha[ve] lifecycle greenhouse gas emissions that are at least 50

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139. *See* 40 C.F.R. § 80.1401 (setting out the definitions for the RFS2).

140. *Id*. To provide contextual support for this definition, "renewable biomass" is defined as including:

> (1) Planted crops and crop residue harvested from existing agricultural land cleared or cultivated prior to December 19, 2007 and that was nonforested and either actively managed or fallow on December 19, 2007.
>
> (2) Planted trees and tree residue from a tree plantation located on non-federal land (including land belonging to an Indian tribe or an Indian individual that is held in trust by the U.S. or subject to a restriction against alienation imposed by the U.S.) that was cleared at any time prior to December 19, 2007 and actively managed on December 19, 2007.
>
> (3) Animal waste material and animal byproducts.
>
> (4) Slash and pre-commercial thinnings from non-federal forestland (including forestland belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States) that is not ecologically sensitive forestland.
>
> (5) Biomass (organic matter that is available on a renewable or recurring basis) obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, in an area at risk of wildfire.
>
> (6) Algae.
>
> (7) Separated yard waste or food waste, including recycled cooking and trap grease, and materials described in [40 C.F.R.] § 80.1426(f)(5)(i).

Id.

141. 40 C.F.R. § 80.1426(f), Table 1 (2010) (providing a table of the modeled fuel pathways and the production processes that satisfy them).

142. 40 C.F.R. § 80.1426(f), Table 1. The fuel pathway for the production of butanol involves the fermentation of corn starch through a dry mill process that uses natural gas, biomass or biogas for process energy. *Id.*

143. RFS2 Final Rule, *supra* note 9, at 14,674.

percent less than baseline lifecycle greenhouse gas emissions."[144] The EPA has currently modeled four fuel pathways that comply with this definition for advanced biofuels.[145] The remaining sub-categories include "biomass-based diesel" and "cellulosic biofuels."[146] Biomass-based diesel is defined as:

> a renewable fuel that has lifecycle greenhouse gas emissions that are at least 50 percent less than baseline lifecycle greenhouse gas emissions and[:] . . . [(1) i]s a transportation fuel, transportation fuel additive, heating oil, or jet fuel[; (2) m]eets the definition of either biodiesel or non-ester renewable diesel[; and (3) i]s registered as a motor vehicle fuel or fuel additive under 40 CFR part 79, if the fuel or fuel additive is intended for use in a motor vehicle.[147]

Thus far, the EPA has only modeled two different pathways for biomass-based diesel.[148] Finally, a cellulosic biofuel is defined as a "renewable fuel derived from any cellulose, hemi-cellulose, or lignin that has lifecycle greenhouse gas emissions that are at least 60 percent less than the baseline lifecycle greenhouse gas emissions"[149] and the EPA has modeled three fuel pathways for this category.[150] As these categories of biofuels, and their corresponding volume obligations, are nested, a fuel that satisfies either the definition for cellulosic biofuel or biomass-based diesel, also qualifies as an advanced biofuel and any fuel that qualifies as an advanced biofuel, also qualifies as a renewable fuel.[151]

b. Volume Obligations

When Congress enacted EISA, it amended the CAA to include precise yearly volume obligations for the four categories of biofuels (with the exception of biomass-based diesel) that must be introduced into the U.S. fuel supply through

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144. 40 C.F.R. § 80.1401.

145. RFS2 Final Rule, *supra* note 9, at 14,795-96.

146. *Id.* at 14,674.

147. 40 C.F.R. § 80.1401. Biodiesel is defined as "a mono-alkyl ester that meets ASTM D 6751 (incorporated by reference, see [40 C.F.R.] § 80.1468)." *Id.* Non-ester renewable diesel is defined as "renewable fuel which is all of the following: (1) [a] fuel which can be used in an engine designed to operate on conventional diesel fuel, or be heating oil or jet fuel[; and] (2) [n]ot a mono-alkyl ester." *Id.*

148. RFS2 Final Rule, *supra* note 9, at 14,795-96.

149. 40 C.F.R. § 80.1401.

150. RFS2 Final Rule, *supra* note 9, at 14,795-96.

151. For a graphical representation of how the four unique mandates are nested, *see* Presentation, Seth Meyer, *Biofuel Markets and Policy Implications*, at 9, *available at* http://bioenergy.illinois.edu/news/biorefinery/pp_meyer.pdf.

2022.[152] While the total mandate for renewable fuels rises steadily from year-to-year and the percentage of this mandate that is to be satisfied by the use of cellulosic biofuels, and consequently advanced biofuels generally, also rises, the volume of the overall mandate that can be satisfied by fuels only classified as renewable fuels plateaus at 15 billion gallons a year in 2015.[153] To use 2022 as an example, the introduction of 36 billion gallons of total renewable fuel is mandated, of which 21 billion gallons must be advanced biofuels, leaving a 15 billion gallon gap that can be satisfied with fuels classified solely as renewable fuels or additional volumes of advanced biofuels.[154] Of the 21 billion gallons of advanced biofuels that are mandated, 16 billion gallons must be cellulosic biofuels and an as-yet-to-be-determined volume must be biomass-based diesel.[155] If less than 5 billion gallons of biomass-based diesel is mandated for 2022, an advanced biofuel gap will exist that can be satisfied by fuels categorized only as advanced biofuel, additional volumes of cellulosic biofuels, or additional volumes of biomass-based diesel.[156] While the CAA sets out these unique volumes for each year through 2022, the EPA is granted authority to modify the advanced biofuel and total renewable fuel volumes if the projected volume of cellulosic fuel to be produced in the following year is less than that mandated.[157]

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152. Clean Air Act, 42 U.S.C. § 7545(o)(2) (2010); Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 202 (2007). Volumes for biomass-based diesel were only set through 2012. 42 U.S.C. § 7545(o)(2)(i)(IV).

153. 42 U.S.C. § 7545(o)(2)(B)(i). For a graphical representation of the four unique mandates, *see* Seth Meyer, *supra* note 151, at 3.

154. 42 U.S.C. § 7545(o)(2)(B)(i).

155. *Id.*

156. *See id*.

157. *Id.* at § 7545(o)(7)(D). If the projected production volumes for cellulosic biofuels are lower than those mandated, the EPA must lower the cellulosic biofuels mandate, but retains discretion to modify the advanced biofuel and renewable fuel mandates "by the same or a lesser volume." *Id.* When the EPA set the volume obligations for 2011, it opted to retain the renewable fuel mandate set out in the CAA despite the fact that cellulosic biofuel production projections were far below the specified mandate. Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards, 75 Fed. Reg. 76,790, 76,791-93 (Dec. 9, 2010) [hereinafter RFS2 2011 Final Rule] (to be codified at 40 C.F.R. pt. 80). In doing so, the EPA reasoned that:

> we believe that the 0.8 billion gallon [biomass-based diesel] standard can indeed be met. Since biodiesel has an Equivalence Value of 1.5, 0.8 billion physical gallons of biodiesel would provide 1.20 billion ethanol-equivalent gallons that can be counted towards the advanced biofuel standard of 1.35 billion gallons. Of the remaining 0.15 billion gallons (150 million gallons), 6.0 million gallons will be met with cellulosic biofuel. Based on our analysis . . . , we believe that there are sufficient sources of other advanced biofuel, such as additional biodiesel,

c. Renewable Identification Numbers

While the complex issues associated with the use of Renewable Identification Numbers (RINs) to comply with the RFS2's volume obligations are better left for a subsequent paper, only a basic understanding is necessary to provide a groundwork for the biobutanol-related issues explored here. In essence, the assignment and retiring of RINs is the mechanism through which obligated parties comply with the RFS2's volume obligations.[158] At the production level, the RFS2 requires renewable fuel producers to assign unique RINs to each batch of renewable fuel that they produce[159] and, among other things, each RIN must indicate the volume of renewable fuel covered by it and the fuel's associated "D code," which is assigned based on the relevant category of renewable fuel that is covered by the unique RIN.[160] When an obligated party under the RFS2 purchases this renewable fuel and introduces it into commerce, the obligated party retires that RIN and reports this to the EPA to show compliance with its relevant RFS2 volume obligation for that particular type of renewable fuel.[161]

An important twist on the way volumes of renewable fuels are indicated by RINs involves the use of "equivalence values."[162] When the EPA first implemented the RFS1, it made a justifiable interpretation that it was allowed to assign equivalence values to the different forms of renewable fuel based on their energy content compared to ethanol.[163] The idea is that "the use of Equivalence Values based on energy content [is] an appropriate measure of the extent to which a renewable fuel [will] replace or reduce the quantity of petroleum or other fossil fuel present in a fuel mixture."[164] Thus far, the EPA has assigned an equivalence value of 1.0 for ethanol, 1.3 for butanol, 1.5 for biodiesel, and 1.7 for non-ester

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> renewable diesel, or imported sugarcane ethanol, such that the standard for advanced biofuel can remain at the statutory level of 1.35 billion gallons.

Id. at 76,792.

158. *See* Renewable Fuel Standard, 40 C.F.R. § 80.1426 (describing how RINs are generated); 40 C.F.R § 80.1451 (describing how obligated parties comply with the RFS2's volume requirements).

159. 40 C.F.R. § 80.1426. As of February 17, 2011, 344 renewable fuel producers have been certified to issue RINs for purposes of the RFS2. U.S. ENVIRONMENTAL PROTECTION AGENCY, RFS2 REGISTERED RENEWABLE FUEL PRODUCER LIST (Feb. 17, 2011), *available at* http://www.epa.gov/otaq/regs/fuels/fuelsregistration.htm.

160. 40 C.F.R. § 80.1426.

161. 40 C.F.R. § 80.1415.

162. *See id*. (explaining how equivalence values are used for the RFS2)

163. RFS2 Final Rule, *supra* note 9, at 14,709.

164. *Id.*

renewable diesel.[165] In practice, when a renewable fuel producer generates RINs for a given batch of fuel, it multiplies the actual volume covered by each RIN times the relevant equivalence value and the product is the volume of renewable fuel that is contained in the RIN for purposes of compliance with the RFS2's volume obligations.[166] For example, if a producer produces 1 physical gallon of biobutanol, the volume of renewable fuel reported in its RIN would be 1.3 gallons.

Finally, it is also important to note that after a given RIN is separated from a gallon of renewable fuel, it is freely tradable on the open market.[167] If an obligated party under the RFS2 purchases and introduces more gallons of renewable fuel than it is mandated to for a given year, that party is permitted to sell its excess RINs to another obligated party that might not have satisfied its mandated volume obligation.[168] Additionally, if an end-user of biofuel who is not obligated under the RFS2 purchases biofuel from a producer, that end-user can also separate the RINs and freely sell them to obligated parties and thereby reduce its overall cost of purchasing the biofuel (e.g., if the market values a given one gallon RIN at $0.25 and an end-user purchases a gallon of biofuel covered by that RIN for $1.00, the end-user can sell that RIN and reduce the overall cost of that gallon to $0.75).[169] It is in this sense, that the RFS2 can potentially incentivize the use of renewable fuels by non-obligated parties.[170]

2. *Current Treatment of Biobutanol*

As previously noted, only one biobutanol fuel pathway has been modeled for purposes of the RFS2.[171] This pathway is based on using cornstarch as a feedstock and has been designated as resulting in a "renewable fuel" classification.[172] In order for a biobutanol production process to comply with this

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165. 40 C.F.R. § 80.1415(b).

166. 40 C.F.R. § 80.14126(f)(2)(i).

167. *See* RFS2 2011 Final Rule, *supra* note 157, at 14,731-33 (explaining how the EPA Moderated Transaction System (EMTS) operates in regards to parties trading RINs).

168. *See id.*

169. *See id.*; Luke Geiver, *Biodiesel RIN Prices Reach New Highs, Could be Headed Higher*, BIODIESEL MAGAZINE, Feb. 16, 2011, http://www.biodieselmagazine.com/articles/7611/biodiesel-rin-prices-reach-new-highs-could-be-headed-higher (discussing how the actual cost of a gallon of biodiesel is lowered based on the purchasers ability to subsequently sell its RIN).

170. *See id.*

171. RFS2 Final Rule, *supra* note 9, at 14,872.

172. *Id.*

pathway, it must involve a dry mill fermentation process that uses natural gas, biomass, or biogas for process energy.[173] Based on its lifecycle GHG assessment for this pathway, which merely assumed the same feedstock impacts as for corn ethanol and made adjustments for biobutanol production processes and its higher energy content,[174] The EPA concludes that biobutanol produced in accordance with these pathway requirements results in a lifecycle GHG reduction of roughly 31% compared to the lifecycle GHG emissions from baseline gasoline.[175] It is also important to note that due to the uncertainties associated with the indirect land use change values included in the EPA's assessment, this 31% GHG reduction is merely the midpoint of a range and "[t]he 95% confidence interval around that midpoint ranges from a 20% reduction to a 40% reduction."[176]

Before moving on, the importance of biobutanol being assigned an equivalence value of 1.3 for purposes of compliance with the RFS2 should be re-emphasized.[177] This equivalence value has the effect of reducing the actual volume of renewable fuels that a given obligated party must introduce into commerce in order to comply with the RFS2's mandates.[178] To use an overly simplified example, if an obligated party is mandated to introduce 130 gallons of renewable fuel, the party could either utilize 130 actual gallons of traditional ethanol (based on its equivalence value of 1.0) or 100 actual gallons of biobutanol (based on its equivalence value of 1.3). Even if each gallon of biobutanol were priced higher than a gallon of ethanol, it is possible that this cost increase could be offset by the money saved as a result of having to transport and blend fewer actual gallons in order to comply with the RFS2. While a formal economic analysis cannot be carried out until a producer attempts to bring a form of biobutanol to market and data becomes available, it is very likely that the higher equivalence value assigned to biobutanol for purposes of compliance with the RFS2 provides yet another advantage when it is compared to traditional ethanol.

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173. *Id.* The dry mill fermentation process involves hammer milling whole corn "to the required size followed by liquification, saccharification, fermentation, and downstream separations." Srinivasan Rajagopalan et al., *Enhancing Profitability of Dry Mill Ethanol Plants*, 120 APPLIED BIOCHEMISTRY & BIOTECHNOLOGY 37, 37-38 (2005).

174. RFS2 Final Rule, *supra* note 9, at 14,678. ("Since the feedstock impacts are the same as for ethanol from corn starch, the assessment for biobutanol reflects the differing impacts due to the production process and energy content of biobutanol compared to that of ethanol.").

175. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 473.

176. *Id.*

177. Renewable Fuel Standard, 40 C.F.R. § 80.145(b)(3) (2010).

178. *See* RFS2 Final Rule, *supra* note 9, at 14,709 (describing how the RIN volumes for a batch of renewable fuel is calculated by multiplying actual volume by the relevant equivalence value).

3. The Prospect of Biobutanol as an Advanced Biofuel

The fact that biobutanol is currently classified only as a "renewable fuel" for purposes of the RFS2 presents a major hurdle to its successful commercialization.[179] As traditional corn-based ethanol can only qualify as a renewable fuel[180] and existing U.S. production capacity is on track to saturate the limited captive market for renewable fuels under the RFS2,[181] there is little incentive for producers to invest the capital necessary to upgrade their facilities to output biobutanol so long as it only qualifies as a renewable fuel. On the other hand, the RFS2's captive markets for advanced biofuels and cellulosic biofuels are far from saturated[182] and if new fuel pathways for biobutanol could be established that result in designations as either advanced biofuels or cellulosic biofuels, these captive market could provide an incentive for producers to invest the capital necessary to produce biobutanol. Since current biobutanol production processes are being marketed as "bolt-on" technologies that allow producers to alternate back and forth between production of ethanol and biobutanol,[183] once the RFS2's captive market for renewable fuels inevitably becomes saturated by corn ethanol, producers' sunk costs in their existing facilities would be given new life if they were also able to produce a form of biobutanol classified as either an advanced biofuel or cellulosic biofuel.

a. U.S. Corn-Based Biobutanol

As Gevo and Butamax both intend to market their biobutanol innovations

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179. *See* 40 C.F.R. § 80.1426(f).

180. 40 C.F.R § 80.1401 (providing definitions for the categories of renewable fuels in such a way that traditional corn-based ethanol can only qualify as a "renewable fuel").

181. *See* RFS2 2011 Final Rule, *supra* note 157, at 76,793 (requiring 13.95 billion gallons of renewable fuels to be introduced in 2011); Press Release, Renewable Fuels Association, 2010 Annual Ethanol Production = 13.23 Billion Gallons (Feb. 28, 2011), *available at* http://www.ethanolrfa.org/news/entry/2010-annual-ethanol-production-13.23-billion-gallons/ (last visited March 4, 2011).

182. *See* RFS2 2011 Final Rule, *supra* note 157, at 76,792 (indicating that "there are sufficient sources of other advanced biofuel, such as additional biodiesel, renewable diesel, or imported sugarcane ethanol, such that the" advanced biofuel mandate can be met). While the EPA predicts that the advanced biofuel mandate can be met with imported sugarcane ethanol, this fuel is subject to an import tariff that substantially raises its cost. *See* Omnibus Reconciliation Act of 1980, Pub. L. No. 96-499, 94 Stat. 2599 (1980) (imposing a $0.54 per gallon tariff on imported ethanol). As such, the market would likely be very receptive to alternatives and is therefore not saturated.

183. *See supra* text accompanying notes 93-95.

as a way for corn ethanol producers to retrofit their facilities to produce corn-based biobutanol,[184] we first consider the prospect for this form of biobutanol to qualify as an advanced biofuel. While corn-based biobutanol outputted from a minimally retrofitted ethanol facility would qualify as a renewable fuel so long as its production process complies with the requirements of the existing RFS2 fuel pathway for biobutanol,[185] it could also qualify as an advanced biofuels if the requisite 50% GHG reduction threshold could be established to support the designation of a new fuel pathway.[186] Although the GHG reduction potential of any biofuel is highly contingent on the energy efficiencies of the unique processes used to produce it and these vary from plant to plant,[187] based on the GHG reduction range that the EPA calculated for the current biobutanol pathway, as little as a 10% additional reduction could suffice to reach 50% reduction threshold required to be classified as an advanced biofuel.[188] On the one hand, if a newer and more energy efficient ethanol plant were retrofitted to produce biobutanol, it is possible that the outputted biobutanol could be demonstrated to satisfy the 50% GHG reduction threshold without the need for any additional modifications to the production facility. On the other hand, in order for an older and less efficient ethanol facility to be able to produce biobutanol that qualifies as an advanced biofuel, the facility would not only have to be retrofitted for biobutanol production, but would also likely have to implement additional forms of advanced process technologies such as corn oil fractionation, corn oil extraction, raw starch hydrolysis, or membrane separation.[189] Alternately, efforts are currently

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184. *See supra* Part III.A.

185. *See* 40 C.F.R. § 80.1426(f), Table 1 (2010).

186. *See* 40 C.F.R. § 80.1401 (defining "advanced biofuel").

187. *See* Presentation, Michael Wang, Updated Well-to-Wheels Results of Fuel Ethanol with the GREET Model, at 15 (Sept. 11, 2007), *available at* http://www.usbiomassboard.gov/pdfs/biofuel_presentation_at_detroit_workshop_09_07kw.pdf (last visited March 4, 2011) (indicating that 57% of the "life-cycle fossil energy use" for corn grain ethanol is attributable to the actual production of ethanol).

188. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 427 (indicating that due to the uncertainties associated with indirect land use change values, the GHG reduction potential of the currently modeled biobutanol production process "ranges from a 20% reduction to a 40% reduction").

189. Corn oil fractionation increases fermentation efficiencies through "a process whereby seeds are divided in various components and oils are removed prior to fermentation." 40 C.F.R. § 80.1401. Corn oil extraction increases efficiencies through "the recovery of corn oil from the thin stillage and/or the distillers grains and solubles produced by a dry mill [fermentation process], most often by mechanical separation." *Id.* Raw starch hydrolysis is "the process of hydrolyzing corn starch into simple sugars at low temperatures, generally not exceeding 100 °F (38 °C), using enzymes designed to be effective under these conditions. *Id.* Membrane separation increases

underway to genetically modify corn in such a way that it enhances the efficiencies of alcohol fermentation processes and if these varieties take hold, they will also contribute to the overall GHG reduction potential of corn-based biobutanol.[190]

Also moderating that ability of corn-based biobutanol to qualify as an advanced biofuel is Congress' clear disdain for biofuels derived from cornstarch feedstocks.[191] For purposes of the RFS2, corn-based ethanol is explicitly exclude from being able to qualify as an advanced biofuel and while this exclusion only applies to "ethanol derived from corn starch," it is likely that when the definition for advanced biofuels was drafted, corn-based biobutanol was not contemplated and Congress' intent was focused on not wanting to expand the market for corn-based biofuels in general.[192] Nonetheless, under the RFS2's current definition for advanced biofuels, corn-based biobutanol could qualify as long as the requisite 50% GHG reduction threshold can be established.[193]

b. Brazilian Sugarcane-Based Biobutanol

In addition to focusing on existing corn ethanol production facilities, Butamax has also announced an intention to pursue Brazilian sugarcane as a feedstock for the production of biobutanol.[194] In contrast to the issues associated with corn-based biobutanol qualifying as an advanced biofuel, it is likely that Brazilian sugarcane-based biobutanol would easily qualify. Currently, ethanol derived from sugarcane is the only biofuel to be designated as an advanced biofuel for purposes of the RFS2[195] and when the EPA evaluated the GHG reduction potential for sugarcane ethanol, it concluded, "the midpoint of the range of results is a 61% reduction in GHG emissions compared to the gasoline baseline" and "[t]he 95% confidence interval around that midpoint results in a

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production efficiencies through "the process of dehydrating ethanol to fuel grade (> 99.5% purity) using a hydrophilic membrane." *Id.*

190. *See* Philip Brasher, *USDA Approves Corn Engineered for Biofuel Use*, DESMOINESREGISTER.COM, Feb. 11, 2011, http://www.desmoinesregister.com/article/20110212/BUSINESS01/102120315/USDA-approves-corn-engineered-for-biofuel-use (describing a genetically modified variety of corn, developed by Syngenta, which "contains an enzyme called amylase that reduces the energy requirement of turning the grain into [biofuel]").

191. *See, e.g.*, 40 C.F.R. § 80.1401 (defining the RFS2's four categories of biofuels in such a way that corn ethanol can only qualify as a renewable fuel).

192. *See id.*

193. *See id.*

194. Butamax Advanced Biofuels, *supra* note 90.

195. 40 C.F.R. § 80.1427 table IV.

range of a 52% reduction to a 71% reduction compared to the gasoline 2005 baseline."[196] Also of import that when the EPA modeled the GHG reduction potential for the existing biobutanol pathway, it merely imported the feedstock values for cornstarch and modified the analysis for biobutanol's production processes and energy content.[197] This methodology resulted in corn-based biobutanol showing a greater GHG reduction potential than corn-based ethanol.[198] If the EPA follows this same analytical approach in evaluating the requisite pathway application that would need to be submitted for Brazilian sugarcane-based biobutanol, it is likely that the resulting GHG assessment would show a greater GHG reduction potential than sugarcane ethanol and, as such, the sugarcane-based biobutanol would easily satisfy the requisite 50% reduction threshold necessary to be designated as an advanced biofuel.

c. Cellulosic Biobutanol

While no firms are currently projecting the near-term commercialization of cellulosic biobutanol, recent technological innovations in its production warrant its mention here.[199] As previously discussed, researchers have developed a biocatalyst capable of producing biobutanol from cellulosic feedstocks and predict that this innovation could be commercialized in as little as two years.[200] While any guess at the GHG reduction potential of the biobutanol production processes that might result from this innovation would be pure speculation, it is important to note that cellulosic biobutanol would obviously qualify as a cellulosic biofuel so long as the requisite 60% GHG reduction threshold could be established.[201] As the RFS2 volume obligations for cellulosic biofuels are mandated to increase and there is a current dearth of these fuels commercially available,[202] there is a huge incentive to develop cellulosic biobutanol innovations and capitalize on this captive market.

196. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 477.

197. RFS2 Final Rule, *supra* note 9, at 14,678 ("Since the feedstock impacts are the same as for ethanol from corn starch, the assessment for biobutanol reflects the differing impacts due to the production process and energy content of biobutanol compared to that of ethanol.").

198. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 468-74.

199. *See supra* Part III.A.

200. *Id.;* Fairley, *supra* note 59.

201. *See* Clean Air Act, 42 U.S.C. § 7545(o)(1)(E) (2010).

202. *See* RFS2 2011 Final Rule, *supra* note 157, at 76,791-93.

B. The Clean Air Act

While the RFS2's regulatory framework mandates the introduction of biofuels into the U.S. fuel supply and thereby incentivizes their production, the Clean Air Act's (CAA) framework for the regulation of new fuels and fuel additives presents significant hurdles to their lawful commercialization.[203] As biofuels are traditionally blended with gasoline to produce finished fuels that are ultimately made available for retail sale, the successful commercialization of biobutanol is most affected by the so-called "substantially similar prohibition" in § 211(f) of the CAA, which states:

> it shall be unlawful for any manufacturer of any fuel or fuel additive to first introduce into commerce, or to increase the concentration in use of, any fuel or fuel additive for use by any person in motor vehicles manufactured after model year 1974 which is not *substantially similar* to any fuel or fuel additive utilized in the certification of any model year 1975, or subsequent model year, vehicle or engine . . . .[204]

While this prohibition obviously turns on the meaning of the phrase "substantially similar," the CAA does not define it and, instead, leaves it to the discretion of the EPA to determine what constitutes a substantially similar fuel or fuel additive.[205] As we will see, the way in which the EPA defines a "substantially similar" fuel effectively governs the lawful blending limit for biobutanol as a fuel additive, as well as any other form of biofuel used as a blending additive. But the story does not end here as the CAA provides a safety valve whereby manufacturers can petition the EPA for a waiver of the substantially similar prohibition.[206] Specifically, § 211(f)(4) of the CAA provides that:

> [t]he Administrator, upon application of any manufacturer of any fuel or fuel additive, may waive the [substantially similar] prohibition[] . . . if he determines that the applicant has established that such fuel or fuel additive or a specified concentration thereof, and the emission products of such fuel or fuel additive or specified concentration thereof, will not cause or contribute to a failure of any emission control device or system (over the useful life of the motor vehicle, motor vehicle engine, nonroad engine or nonroad

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203. *See* 42 U.S.C. §§ 7545(a)-(f).

204. 42 U.S.C. § 7545(f)(1) (emphasis added).

205. *See* 2008 Substantially Similar Rule, *supra* note 12, at 22,281 (providing the most recent definition of "substantially similar").

206. 42 U.S.C. § 7545(f)(4).

> vehicle in which such device or system is used) to achieve compliance by the vehicle or engine with the emission standards with respect to which it has been certified . . . .[207]

As the CAA requires all fuel additives to be registered by the EPA prior to commercialization,[208] these requirements are implemented by regulations that require fuel additive registration applications to "demonstrate that the fuel additive, when used at the recommended range of concentration, is substantially similar to any fuel additive included in a fuel utilized in the certification of any 1975 or subsequent model year vehicle or engine, or that the manufacturer has obtained a waiver."[209] These requirements produce unique regulatory paths to the commercialization of biobutanol, which impart various percentage-based caps on its lawful blending limit as a transportation fuel additive.

1. Commercialization Under the Substantially Similar Rule

The first regulatory path to the commercialization of biobutanol as a transportation fuel additive involves registering it for use in a blending percentage that results in a finished fuel that complies with the EPA's so-called "Substantially Similar Rule," which sets out the detailed requirements that finished fuels must comply with in order to satisfy the substantially similar prohibition.[210] While the EPA has made several revisions to its Substantially Similar Rule since the prohibition was first introduced with the CAA amendments of 1977,[211] with respect to permissible biobutanol blending limits, the current

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207. *Id.* Prior to the enactment of the Energy Independence and Security Act of 2007, the requisite "cause or contribute" showing did not have to be made in regards to nonroad engines and vehicles. 42 U.S.C. § 7545(f)(4) (2005); *see also* Energy Independence and Security Act of 2007, Pub. L. No. 110-140 (2007). Furthermore, the waiver provision used to provide that "[i]f the Administrator [of the EPA] has not acted to grant or deny an application under this paragraph within one hundred and eighty days of receipt of such application, the waiver authorized by this paragraph shall be treated as granted." 42 U.S.C. § 7545(f)(4) (2000).

208. 42 U.S.C. § 7545(a) ("no manufacturer or processor of any such fuel or additive may sell, offer for sale, or introduce into commerce such fuel or additive unless the Administrator has registered such fuel or additive").

209. 40 C.F.R. § 79.21(h) (2010).

210. *See* 2008 Substantially Similar Rule, *supra* note 12, at 22,281 (providing the most recent definition of "substantially similar").

211. Guidelines for Fuel Additive Waivers, 43 Fed. Reg. 11,258, 11,258 (March 17, 1978) [hereinafter Fuel Waiver Guidelines] (noting that the substantially similar prohibition was added by the Clean Air Act Amendments of 1977). The EPA's initial attempt at providing a definition for "substantially similar" merely stated that:

Substantially Similar Rule provides that "fuels containing aliphatic ethers and/or alcohols (excluding methanol) must contain no more than 2.7 percent oxygen by weight."[212] As biobutanol is an aliphatic alcohol and has a relatively low oxygen weight, the current Substantially Similar Rule results in an effective cap of only

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> [a] fuel additive is not substantially similar to any fuel additive used in the certification of any model year 1975 or subsequent model year vehicle or engine under section 206 of the Clean Air Act (as amended), if: (a) Such fuel additive contains any element other than an impurity which is not specified for use in the fuel utilized in the certification of any model year 1975 or subsequent model year vehicle or engine, or (b) the chemical structure of the additive is not identical to the chemical structure of any additive specified for use in the certification of any model year 1975, or subsequent model year vehicle or engine.

Id. In 1980, The EPA issued a more precise Substantially Similar Rule, *see* Fuels and Fuel Additives; Definition of Substantially Similar, 45 Fed. Reg. 67,443, 67,446-47 (Oct. 10, 1980), but altered it again in 1981 to provide:

> EPA will treat a fuel or fuel additive for general use in light-duty vehicles manufactured after model year 1974 as substantially similar to any fuel or fuel additive utilized in the certification of any model year 1975, or subsequent model year vehicle or engine under section 206 of the Act, i.e., "substantially similar," if the following criteria are met. (1) The fuel must contain carbon, hydrogen, and oxygen, nitrogen and/or sulfur, exclusively, in the form of some combination of the following: (a) hydrocarbons; (b) aliphatic ethers; (c) aliphatic alcohols other than methanol; (d)(i) up to 0.3 percent methanol by volume; (ii) up to 2.75 percent methanol by volume with an equal volume of butanol, or higher molecular weight alcohol; (e) a fuel additive at a concentration of no more than 0.25 percent by weight which contributes no more than 15 ppm sulfur by weight to the fuel. (2) The fuel must contain no more than 2.0 percent oxygen by weight. (3) The fuel must possess, at the time of manufacture, all of the physical and chemical characteristics of an un- leaded gasoline as specified by ASTM Standard D 439 (or applicable Emergency Standard if one has been instituted) for at least one of the Seasonal and Geographical Volatility Classes specified in the standard. (4) The fuel additive must contain only carbon, hydrogen, and any or all of the following elements: oxygen, nitrogen, and/or sulfur.

Fuels and Fuel Additives; Revised Definition of "Substantially Similar," 46 Fed. Reg. 38,582, 38,586 (July 28, 1981) [hereinafter 1981 Substantially Similar Rule].

212. 2008 Substantially Similar Rule, *supra* note 12, at 22,281 (April 25, 2008). The increase in allowable oxygenate weight from 2.0 percent by weight to the current limit of 2.7 percent by weight was made by the EPA in 1991 in response to a petition filed by the Oxygenated Fuels Association. *See* Regulation of Fuels and Fuel Additives; Definition of Substantially Similar, 56 Fed. Reg. 5,352, 5,352-56 (Feb. 11, 1991) [hereinafter 1991 Substantially Similar Rule].

11.5% by volume for biobutanol blending.[213] While the EPA, upon its own initiative, could easily raise the oxygen weight percentage allowed under its Substantially Similar Rule or a biobutanol manufacturer could petition it to do so,[214] recent decisions by the EPA have indicated an arguably unjustified preference for dealing with increased blending limits for biofuels through the more burdensome fuel waiver process.[215]

Although higher lawful blending limits for biobutanol would allow us to better capture its inherent social value, registration of biobutanol for use in a concentration of 11.5% by volume pursuant to the current Substantially Similar Rule is unfortunately the regulatory commercialization path of least resistance.[216] Once the production of biobutanol reaches commercial scale, manufacturers will either be constrained by this 11.5% blending limit, have to endure the uncertainty that results from trying to commercialize a higher blend pursuant to an existing fuel waiver,[217] or endure the greater uncertainty and emissions testing costs that coincide with seeking a new fuel waiver.[218] As of the writing of this article, Gevo's isobutanol is the only recently developed form of biobutanol to have been successfully registered with the EPA and it is likely that Gevo opted to initially register it for use in a concentration of 11.5%.[219]

[Insert Figure 1]

2. Commercialization Pursuant to a Fuel Waiver

The remaining two regulatory paths to the commercialization of

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213. U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center: What is Biobutanol?, http://www.afdc.energy.gov/afdc/fuels/emerging_biobutanol_what_is.html (last visited March 4, 2011); *see also* Figure 1.

214. *See* 1991 Substantially Similar Rule, *surpa* note 212, at 5,352-56 (revising the definition of substantially similar to increase the allowable oxygenate content in response to a letter submitted by the Oxygenated Fuels Association).

215. *See* E15 Waiver I, *supra* note 21, at 68,143 (referring to the conditional grant of a waiver to allow 15% ethanol blending and refusing to amend the Substantially Similar Rule to allow for 12% ethanol blending).

216. *See* Figure 1.

217. *See infra* Part IV.B.2.a.; Figure 2.

218. *See* E15 Waiver I, *supra* note 21, at 68,100-01 (describing the required vehicle fleet testing and the EPA's method of review for new fuel waivers); *see infra* Part IV.B.2.b; Figure 3.

219. *See* Gevo, *supra* note 65. While Gevo has not announced what concentration of isobutanol was successfully registered with the EPA and the EPA does not make this information publicly available, it is the authors' belief that had a concentration greater than 11.5% been successfully registered, Gevo would have boasted the result.

biobutanol both involve the CAA § 211(f)(4) fuel waiver process.[220] In order for biobutanol to be lawfully commercialized for use in greater than an 11.5% blend, a manufacturer would either have to seek registration by the EPA pursuant to some previously granted fuel waiver or file an application for a new fuel waiver.[221] As the following sections demonstrate, each of these regulatory paths involves a unique set of uncertainties, which arguably produce unjustified regulatory burdens to the successful commercialization of high-level biobutanol blends and thereby lessen our ability to efficiently capture their inherent social value.

a. Existing Fuel Waivers

As existing § 211(f)(4) fuel waivers that have been granted by the EPA are applicable to all similarly situated manufacturers,[222] the second regulatory path to the commercialization of biobutanol involves registration in a concentration that complies with an existing waiver.[223] To provide a reference point for the pool of existing waivers, the EPA has processed twenty-five different fuel waiver requests since the substantially similar prohibition was implemented and of these, eleven were denied, six were granted, five were conditionally granted, two were withdrawn by the applicant, and one was granted without decision by operation of law.[224] While it is likely that none of the granted waivers explicitly contemplates the blending of biobutanol as a fuel additive, two of them set out conditions that arguably permit it to be blended in concentrations up to 16% by volume ("Bu16").[225]

The first such waiver was conditionally granted in 1985 as a result of an application submitted by E.I. DuPont de Nemours & Co., Inc. for a methanol-gasoline fuel blend ("DuPont Waiver").[226] While the EPA imposed eight

220. Clean Air Act, 42 U.S.C. § 7545(f)(4) (2010).

221. *See id.*; Figures 2 and 3.

222. Fuel Waiver Guidelines, *supra* note 211, at 11,258 ("Any waiver granted to one manufacturer will be applicable to and manufacturer similarly situated.").

223. *See* Figure 2.

224. U.S. ENVIRONMENTAL PROTECTION AGENCY, WAIVER REQUESTS UNDER SECTION 211(f) OF THE CLEAN AIR ACT (1995), *available at* http://www.epa.gov/oms/regs/fuels/additive/waiver.pdf; E15 Waiver I, *supra* note 21, at 68,094.

225. *See* Fuels and Fuel Additives; Waiver Application, 53 Fed. Reg. 3,636, 3,636-38 (Feb. 8, 1988) [hereinafter Octamix Waiver]; Fuels and Fuel Additives; Waiver Decision; E.I. Du Pont de Nemours & Co., Inc., 50 Fed. Reg. 2,615, 2,615-16 (Jan. 17, 1985) [hereinafter DuPont Waiver].

226. DuPont Waiver, *supra* note 225, 2,615-16.

conditions on the granting of the waiver, the two conditions relevant to biobutanol blending provide that "(1) [t]he final fuel [must] consist[] of a *maximum* of 5.0 volume percent methanol, a *minimum* of 2.5 volume percent cosolvent (ethanol, propanols, GTBA, and/*or butanols*) in unleaded gasoline; [and] (2) [a] maximum concentration of up to 3.7 weight percent oxygen in the final fuel [must be] observed."[227] Roughly three years later, the EPA granted the Octamix Waiver, filed by the Texas Methanol Corporation, on condition that:

> (1) [t]he final fuel consists of a *maximum* of 5 percent by volume methanol, a *minimum* of 2.5 percent by volume cosolvent in unleaded gasoline. The cosolvents are any one or a mixture of ethanol, propanols, *butanols*, pentanols, hexanols, heptanols and octanols . . . ; [and] (2) [a] maximum concentration of up to 3.7 percent by weight oxygen in the final fuel is observed . . . .[228]

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227. *Id.* at 2,615 (emphasis added). The remaining conditions are that:

> (3) DuPont's proprietary corrosion inhibitor formulation, DGOI-100, is blended in the final fuel at 41.3 milligrams per liter (mg/l); (4) The final fuel meets ASTM D439-83 Standard Specifications for Automotive Gasoline (a copy of which is in the Docket), with the qualification that Test Method D323 for RVP be replaced by the test method attached hereto as Appendix B; (5) The finished gasoline-alcohol fuel meets the fuel volatility specifications of the Evaporative Index as follows: EI=0.85 RVP+0.14 (percent evaporated at 200° F)-0.32 (percent evaporated at 100° F). EI is not to exceed 12.0 psi in ASTM Class A areas, 12.9 psi in Class B areas, 13.1 psi in Class C areas, 14.6 psi in Class D areas, and 15.0 psi in Class E areas; (6) The final fuel must meet the maximum temperature for phase separation as specified in Appendix C using the test method for water tolerance contained therein; (7) The fuel manufacturer takes all reasonable precautions to ensure that the finished fuel is not used as a base gasoline to which other oxygenated materials are added; (8) Specifications for alcohol purity attached to the decision document as Appendix D are met.

Id.

228. Octamix Waiver, *supra* note 225, at 3,636-38 (emphasis added). The waiver further requires that:

> (3) Petrolite's proprietary corrosion inhibitor formulation, TOLAD MFA-10, is blended in the final fuel at 42.7 milligrams/liter; (4) The final fuel must meet ASTM D439-85a Standard Specifications for Automotive Gasoline . . . , with the qualification that Test Method D323 for RVP be replaced by the "dry" test method described in ASTM D-2 Proposal P-176, Proposed Specification for Automotive Spark Ignition Fuel, Annex A.3 or by automatic apparatus described in Annex A.4 of the D-2 Proposal 176 . . . ; (5) The final fuel must meet the maximum temperature for phase separation as specified in ASTM D-2 Proposal P-176, Table 4 using the test method for water tolerance contained in Annex A.5 . . . ; (6) The fuel manufacturer must take all reasonable precautions, including identification and description of the product on shipping manifests, to ensure

As the conditions set out in these waivers merely place a ceiling on the amount of methanol that can be blended and a floor on the amount of butanol allowed as a cosolvent, they arguably permit 0% methanol to be blended and as high a percentage of butanol as can be accomplished within the confines of the finished fuel containing no more than 3.7% oxygen by weight.[229] Based on the fact that biobutanol is an oxygenate with a relatively low weight, it is arguable that these conditions allow for the lawful commercialization of Bu16 and, as such, Butamax has publicly indicated an intention to seek registration by the EPA of Bu16 under the Octamix Waiver.[230]

Despite these two waivers seeming to encompass Bu16, the probability of its successful registration and commercialization pursuant to one of the two waivers is anything but certain.[231] Although both of these waivers explicitly contemplates the blending of "butanol," they both refer to it as a "cosolvent," which the EPA could opt to argue indicates that at least some amount of methanol is required to be blended in the finished fuel.[232] Moreover, as no fuel additive manufacturer has ever attempted to register a completely new form of biofuel under an existing waiver, there is simply no precedent for how the EPA might respond to this approach. What is known is that granted fuel waivers are applicable to all manufacturers[233] and the EPA is without authority to revoke a waiver once it has been granted.[234] As such, it would seem that if a biobutanol

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> that the finished fuel is not used as a base gasoline to which other oxygenated materials are added, provided, however, that up to two percent by volume of methyl tertiary butyl ether (MTBE) will be allowed in the base stock to which the alcohols are added if the MTBE is present only as a result of commingling in transport and storage, not purposefully added as an additional component to the alcohol blend; [and] (7) Specifications for alcohol purity . . . are met.

Id. at 3,637. The EPA later modified the third condition to read "[a]ny one of the following two corrosion inhibitor formulations must be included: (a) Petrolite's corrosion inhibitor formulation, TOLAD MFA-10, blended in the final fuel at 42.7 mg/1; OR, (b) DuPont's corrosion inhibitor formulation, DMA-67, blended in the final fuel at 31.4 mg/1." Modification of a Fuel Waiver Granted to the Texas Methanol Corporation, 53 Fed. Reg. 43,768, 43,768-69 (Oct. 28, 1988) [hereinafter Modification to Octamix Waiver].

229. *See* DuPont Waiver, *supra* note 225, at 2,615-16; Octamix Waiver, *supra* note 225, at 3,636-38.

230. BUTAMAX ADVANCED BIOFUELS, *supra* note 77.

231. *See* Figure 2.

232. *See* DuPont Waiver, *supra* note 225, at 2,615-16; Octamix Waiver, *supra* note 225, at 3,636-38.

233. Fuel Waiver Guidelines, *supra* note 211, at11,258 ("Any waiver granted to one manufacturer will be applicable to and manufacturer similarly situated.").

234. Am. Methyl Corp. v. EPA, 749 F.2d 826, 840 (1984) (holding that once the EPA has granted a § 211(f)(4) waiver, it is without authority to reconsider or revoke the waiver and can

manufacturer attempts to register its product for use in a 16% concentration pursuant to the DuPont Waiver or the Octamix Waiver, the EPA would have no authority to reject the application so long as the finished fuel complies with the explicit conditions of the waiver. Ultimately, in the absence of official guidance by the EPA as to their position on the registration and commercialization of Bu16 pursuant to an existing waiver, we can only wait and see the outcome of any future registration attempt.

In the event that the EPA opts to allow a biobutanol manufacturer to register its product for use in a 16% concentration pursuant to one of these waivers, additional uncertainty results from the possibility that a private party could potentially attempt to legally challenge the underlying waiver based on the commercialization of Bu16.[235] Despite the EPA's repeated assertion that a petition for judicial review of a § 211(f)(4) fuel waiver must be filed within 60 days of its publication,[236] the CAA provides that "if such petition is based solely on grounds arising after such sixtieth day, then [it] shall be filed within sixty days after such grounds arise."[237] Thus, if the EPA opts to register a form of biobutanol for use in a 16% concentration under an existing waiver, it is possible

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only further regulate pursuant to "the more exacting substantive and procedural safeguards contained in section 211(c)"). In a passage as relevant today as when it was written in 1984, Judge Wilkey reasoned that:

> Like the sword suspended by a hair above the courtier Damocles, the Administrator's claimed revocation authority would pose an ever-present threat to the marketing of new fuels, fostering great uncertainty in the business community. Technologically-advanced fuels could be taken off the market at any time, and neither specified hearing procedures nor rules of repose would cabin the Administrator's discretion. This risk is hardly typical of commercial operations in a regulated economy. Moreover, because the manufacturer's product is assumed undeserving of waiver, the presumption is against the continued existence of his business even if his waiver is challenged with evidence gathered years after heavy capital investment-an extraordinary risk for a commercial entity to bear, as agency counsel conceded at oral argument. Because a manufacturer could never know ex ante whether his product would be available for sale for a sufficient time to recoup his initial investment, he might well decide not to risk his capital in the first place. As a consequence, the public and this nation would suffer from lack of innovation in fuels and fuel additives, to the ultimate detriment of air quality and our national security.

Id.

235. *See* Clean Air Act, 42 U.S.C. § 7607(b)(1) (2010); *see also* Figure 2.

236. *E.g.*, Modification to Octamix Waiver, *supra* note 228, at 43,769 ("judicial review of this action is available only by the filing of a petition for review in the U.S. Court of Appeals for the District of Columbia Circuit within 60 days of the date of publication of this notice").

237. Clean Air Act, 42 U.S.C. § 7607(b)(1) (2010).

that a party could attempt to argue that since the underlying waiver contemplated a methanol blend,[238] this registration serves as newly arising grounds to challenge the original grant of the waiver.[239] When one considers the considerable backlash to the EPA's recent decision to conditionally grant a waiver allowing for the commercialization of E15,[240] this type of legal maneuvering to challenge Bu16 is very likely.

[Insert Figure 2]

b. New Fuel Waiver

The final regulatory path to the commercialization of biobutanol involves seeking a new § 211(f)(4) fuel waiver.[241] Although any attempt to commercialize blends greater than Bu16 would require a new waiver, this path could also be necessitated for blends greater than 11.5% in the event that the EPA refuses to allow commercialization pursuant to an existing waiver or a private party successfully challenges registration under an existing waiver.[242] While this path involves the greatest level of regulatory burden,[243] the commercialization of higher-level biobutanol blends obviously allows us to magnify this fuel's ability to enhance social welfare.

[Insert Figure 3]

A simple reading of § 211(f)(4) gives the impression that the cards are insurmountably stacked against the waiver applicant.[244] The EPA not only has discretion to grant or deny the waiver application, but the applicant bears the heavy burden of showing that the waiver fuel "will not cause or contribute to a failure of *any* emission control device or system . . . ."[245] As a literal reading of

238. *See* DuPont Waiver, *supra* note 225, at 2,615-16; Octamix Waiver, *supra* note 225, at 3,636-38.

239. *See* 42 U.S.C. § 7607(b)(1).

240. *See, e.g.*, Staff Writers, *Diverse Coalition Files Lawsuit to Overturn EPA's 'E15' Decision*, BIOFUEL DAILY, Nov. 22, 2010, http://www.biofueldaily.com/reports/Diverse_Coalition_Files_Lawsuit_To_Overturn_EPA_E15_Decision_999.html.

241. *See* 42 U.S.C. § 7545(f)(4); *see also* Figure 3.

242. *See* Figure 2.

243. *See* Figure 3.

244. *See* 42 U.S.C. § 7545(f)(4).

245. *Id.*

this burden would require applicants to impossibly establish the negative proposition that "no vehicle or engine will fail to meet emissions standards to which it has been certified," the EPA allows applicants to utilize two less stringent methods of proof based on its reasoning that "Congress contemplated a workable waiver provision."[246] First, applicants are permitted to use "reliable statistical sampling and fleet testing protocols" to establish their burden of proof.[247] Alternately, applicants can develop a "reasonable theory regarding emissions effects . . . , based on good engineering judgment," and then conduct testing to confirm this theory, provided that the testing produces enough data for statistical analyses.[248]

When the EPA assesses a new fuel waiver application, it conducts an "emissions impact analysis" that concentrates on four major areas, which add additional layers of complexity to the requisite showing needed to carry the fuel waiver applicant's burden.[249] First, the EPA requires data demonstrating the immediate and long-term effects that the waiver fuel has on exhaust emissions and, second, data is also required to demonstrate the waiver fuel's immediate and long-term effects on evaporative emissions.[250] While analysis of long-term effects for both exhaust and evaporative emissions requires burdensome data covering the entire useful lives of the vehicles and engines in the test fleet, the EPA purports to allow the less burdensome approach of "back-to-back" emissions testing "[i]f the fuel is predicted to have only an immediate effect."[251] Third, the

246. E15 Waiver I, *supra* note 21, at 68,100.

247. *Id.*

248. *Id.*

249. *See id.*

250. *Id.* When the EPA looks at evaporative emissions, it considers both diurnal evaporative emissions (i.e., "emissions [that] occur when motor vehicles are not operating and experience the change in temperature during the day, such as while parked") and running loss evaporative emissions (i.e., those that "occur while motor vehicles are being operated"). *Id.* at 68,096.

251. *Id.* at 68,100. The EPA notes that "[b]ack-to-back testing involves measuring, sequentially, the emissions from a particular vehicle, first operated on a base fuel not containing the waiver request fuel or fuel additive and then on a base fuel containing the additive or the waiver request fuel." Application for Methyl Tertiary Butyl Ether, 44 Fed. Reg. 122,242, 122,244 n. 9 (March 6, 1979). This approach is permitted when it is predicted that "the emissions effects of the fuel or fuel additive are immediate and remain constant throughout the life of the vehicle or engine when operating on the waiver fuel." E15 Waiver I, *supra* note 21, at 68,100. On the other hand:

> if the fuel or fuel additive affects the operation of the engine or related emission control hardware in a physical manner (e.g., operating temperatures, component interaction, chemical changes, increased permeation, and materials degradation) that might lead to emissions deterioration over time, test data is needed to

EPA also requires the submission of data that demonstrates how compatible the waiver fuel is with vehicle and engine materials due to its reasoning that "[m]aterials compatibility issues can lead to substantial exhaust and evaporative emissions increases."[252] Finally, the EPA also requires the applicant to submit data demonstrating the effects of the waiver fuel on the driveability and operability of vehicles and engines.[253] While it could seem like the consideration of driveability and operability is an unjustified stretch of the EPA's statutory mandate to assess whether a waiver fuel "will . . . cause or contribute to a failure of any emission control device or system,"[254] the EPA reasons that "[a] change in the driveability of a motor vehicle that results in significant deviation from normal operation (i.e., stalling, hesitation, etc.) could result in increased emissions" and "concerns exist if the consumer or operator tampers with the motor vehicle in an attempt to correct the driveability issue since consumers may attempt to modify a motor vehicle from its original certified configuration."[255]

As if accumulating fleet testing results and data regarding each of these four areas were not burdensome enough, when Congress enacted EISA in 2007, it made several changes to § 211(f)(4) that create additional regulatory burdens associated with the fuel waiver process.[256] Up until the enactment of EISA, fuel waiver applications only had to address the fuel's effects on vehicle engines, were not subject to formal notice and comment rulemaking, and were granted by operation of law if the EPA did not act within 180 days of application receipt.[257] Now, all § 211(f)(4) fuel waivers: (1) must address effects on "motor vehicle[s], motor vehicle engine[s], nonroad engine[s] [and] nonroad vehicle[s]"; (2) are

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> demonstrate that the long-term durability of the emissions control system is not compromised by the fuel or fuel additive such that it would cause or contribute to the engines or vehicles failing to meet their emissions standards.

Id. If long-term durability testing is required, "[e]ach car in the test fleet should accumulate 50,000 miles." Fuel Waiver Guidelines, *supra* note 211, at 11,259.

252. E15 Waiver I, *supra* note 21, at 68,100. The EPA elaborates that "[i]n most cases, materials incompatibility issues show up in emissions testing; however, there may be impacts that do not show up due to the way the testing is performed or because the tests simply do not capture the effect, especially if materials compatibility effects are determined to result with use of the new fuel or fuel additive over time. The EPA has required applicants to demonstrate that new fuel or fuel additives will not have materials compatibility issues." *Id.* (citing Application for Methyl Tertiary Butyl Ether (MTBE), 44 Fed. Reg. 1,447 (Jan. 5, 1979)).

253. *Id.* at 68,100.

254. Clean Air Act, 42 U.S.C. § 7545(f)(4) (2010).

255. E15 Waiver I, *supra* note 21, at 68,100-01.

256. *See* Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 251 (2007).

257. 42 U.S.C. § 7545(f)(4) (2006).

subject to formal notice and comment rulemaking; and (3) are not subject to becoming effective by operation of law.[258] Additionally, the EPA now has 270 days to act after receiving a fuel waiver application.[259] Some might find it odd that the same piece of legislation that established the RFS2 and increased federal mandates for renewable fuels, simultaneously made it more burdensome for new forms of biofuels to be commercialized in high-level blends.

A brief look the two main ethanol-related fuel waivers that the EPA has considered highlights how burdensome the new fuel waiver process has become. On June 19, 1978, the Illinois Department of Agriculture and Gas Plus, Inc submitted a new fuel waiver application to the EPA for a fuel consisting of 90% gasoline and 10% ethanol (E10).[260] One hundred and eighty days later, the waiver, which paved the way for the most widely used biofuel in the U.S., was granted by operation of law because the EPA "elected not to act to grant or deny the waiver" and notice was given in a two-page publication in the federal register.[261] In contrast, when Growth Energy and fifty-four distinct ethanol manufacturers submitted a fuel waiver application for E15 to the EPA in March of 2009,[262] the EPA sought public comment on a laundry list of issues,[263]

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258. 42 U.S.C. § 7545(f)(4) (2010).

259. *Id.*

260. E10 Waiver, *supra* note 20, at 20,778.

261. *Id.* at 20,777-78.

262. E15 Waiver I, *supra* note 21, at 68,095.

263. Notice of Receipt of a Clean Air Act Waiver Application to Increase the Allowable Ethanol Content of Gasoline to 15 Percent; Request for Comment, 74 Fed. Reg. 18,228 (April 21, 2009). Specifically, the EPA sought:

> comment and data that will enable EPA to: (a) evaluate whether an appropriate level of scientific and technical information exists in order for the Administrator to determine whether the use of E15 will not cause or contribute to a failure of any emission control device or system over the useful life of any motor vehicle or motor vehicle engine (certified pursuant to section 206 of the Act) to achieve compliance with applicable emission standards; (b) evaluate whether an appropriate level of scientific and technical information exists in order for the Administrator to determine whether the use of E15 will not cause or contribute to a failure of any emission control device or system over the useful life of any nonroad vehicle or nonroad engine (certified pursuant to sections 206 and 213(a) of the Act) to achieve compliance with applicable emission standards; . . . (c) evaluate whether an appropriate level of scientific and technical information exists in order for the Administrator to grant a waiver for an ethanol-gasoline blend greater than 10 percent and less than or equal to 15 percent by volume[; and . . .] (d) all legal and technical aspects regarding the possibility that a waiver might be granted, in a conditional or partial manner, such that the use of up to E15 would be restricted to a subset of gasoline vehicles or engines that

subsequently extended the original thirty day comment period to ninety days,[264] received approximately 78,000 comments,[265] and issued its decision, nearly two-years after application receipt, in two separate federal register publications that spanned fifty-seven pages and twenty-two pages, respectively.[266] Although the EPA first conditionally granted the E15 waiver for "[model year] 2007 and newer light-duty motor vehicles, light-duty trucks, and medium duty passenger vehicles[,]" it subsequently announced its conditional grant for "model year (MY) 2001 through 2006 light-duty motor vehicles (passenger cars, light-duty trucks and medium-duty passenger vehicles)."[267] In doing so, the EPA refused to rely on the twelve "recent comprehensive independent third-party studies by both governmental and private groups" supplied by the applicants,[268] and instead relied primarily on a catalyst study carried out by the U.S. Department of Energy (DOE).[269]

V. THE NEED FOR REGULATORY INNOVATION: THE CASE OF BIOBUTANOL

In applying our theoretical principles[270] to the case of biobutanol, the need for regulatory innovation to keep pace with technological innovation is clear. First, when we focus on the commercialization of high-level biobutanol blends, the regulatory burdens created by the CAA paths to commercialization[271] outweigh the harms they are intended to prevent and, as such, this regulatory scheme is inefficient and its burdens unjustified. Second, these unjustified

> would be covered by the waiver, while other vehicles or engines would continue using fuels with blends no greater than E10.

Id. at 18,229-30.

264. Notice of Receipt of a Clean Air Act Waiver Application to Increase the Allowable Ethanol Content of Gasoline to 15 Percent; Extension of Comment Period, 74 Fed. Reg. 23,704 (May 20, 2009).

265. E15 Waiver I, *supra* note 21, at 68,099.

266. *See* E15 Wavier I, *supra* note 21, at 68,149-50 (conditionally granting the E15 waiver for "[model year] 2007 and newer light-duty motor vehicles, light-duty trucks, and medium duty passenger vehicles"); E15 Waiver II, *supra* note 21, at 4,662 (conditionally granting the E15 waiver for "model year (MY) 2001 through 2006 light-duty motor vehicles (passenger cars, light-duty trucks and medium-duty passenger vehicles)").

267. E15 Waiver II, *supra* note 21, at 4,662-83.

268. Growth Energy, Application for a Waiver Pursuant to Section 211(f)(4) of the Clean Air Act for E-15, at 12-13, 35, *available at* http://growthenergy.ehclients.com/images/reports/WaiverApplication09.pdf.

269. E15 Waiver I, *supra* note 21, at 68,124.

270. *See supra* Part II.

271. *See* Figures 1, 2, and 3.

regulatory burdens prevent us from efficiently capturing the social value inherent in the widespread implementation of high-level biobutanol blends and liquid biofuels in general. Therefore, as developed below, the regulatory improvements that we urge are normatively justified.

A. Regulatory Burdens

As technological innovations continue to bring us closer to the wide-scale commercialization of biobutanol as a transportation fuel alternative,[272] it is imperative that inefficient regulatory schemes do not stymie the lawful commercialization of socially optimal high-level blends. Unfortunately, our analysis reveals that the existing CAA regulatory framework for new fuels and fuel additives does just that. When we focus on biobutanol and assess the burdens that this regulatory scheme creates, we see that biobutanol is either relegated to a sub-optimal low-level blend under the EPA's current Substantially Similar Rule, faced with the uncertainty associated with attempting to commercialize higher-level blends under an existing fuel waiver, or subjected to the high costs and greater uncertainty associated with seeking a new fuel waiver to allow higher blending limits.[273] Moreover, if we take into account the fact that the widespread use of biobutanol has significant social value and how these benefits might go unrealized as a result of the regulatory costs disincentivizing firms from opting to produce biobutanol, the overall burdens associated with the current regulatory scheme are magnified.

While the CAA's regulatory framework for new fuels and fuel additives is ultimately put in place to ensure that those with the potential to significantly increase pollutant emissions are not lawfully commercialized,[274] the commercialization of high-level biobutanol blends poses little threat in this regard. First of all, it has been shown that the emissions resulting from 16% biobutanol blends are very similar to those resulting from 10% ethanol blends,[275] which have been widely used in the U.S. for over thirty years with no adverse effect on emissions.[276] If we extrapolate this data, it is likely that the emissions associated with the use of a 24% biobutanol blend would be similar to those

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272. *See supra* Part III.A.

273. *See supra* Part IV; *see also* Figures 1, 2, and 3.

274. *See* Clean Air Act, 42 U.S.C. § 7545(f) (2010).

275. BUTAMAX ADVANCED BIOFUELS, *supra* note 77, at 32-35, 66.

276. *See* E10 Waiver, *supra* note 20, at 20,777 (giving notice that "a waiver of the prohibitions and limitations of section 211(f) of the Clean Air act (Act), 42 U.S.C. 7545(f), as amended, was granted for Gasohol, a fuel consisting of 90% unleaded gasoline and 10% ethyl alcohol, by operation of the Act").

resulting from the 15% ethanol blend conditionally approved by the EPA for use in newer vehicles.[277] Therefore, when we focus on the commercialization of high-level biobutanol blends, we see that the burdens created by the current CAA paths to commercialization clearly outweigh the harms they are intended to mitigate. As such, these regulatory burdens are unjustified and some form of regulatory innovation is called for.

B. Capturing Social Value

Additionally, the commercialization and widespread implementation of high-level biobutanol blends would create social value, which regulatory innovation could allow us to better capture. By mitigating unjustified regulatory hurdles to the expanded use of biobutanol and other biofuels, social welfare is enhanced through their ability to promote rural economic development, produce environmental benefits, and enhance U.S. energy security. In regards to their ability to positively effect rural development goals, the notion is simple. Since the biomass feedstocks needed to produce liquid biofuels are cultivated in rural areas, an expansion in the use of biofuels will increase demand for these biomass feedstocks and act as a driver for rural economic development. Moreover, the facilities needed to convert these biomass feedstocks into biofuels will likely be sited in rural areas, for logistical reasons, and this too will act as a driver for rural economic development.

In addition to promoting rural economic development, regulatory innovation will also allow us to better capture the environmental benefits likely to flow from the expanded use of biobutanol and other liquid biofuels. The EPA has found that anthropogenic GHG emissions endanger the public health and welfare, due to their contribution to global climate change,[278] and as the production and use of biobutanol has been shown to result in lower GHG emissions than both petroleum fuels and first-generation biofuels (i.e., corn-based ethanol),[279] its

277. E15 Waiver I, *supra* note 21, at 68,094; E15 Waiver II, *supra* note 21, at 4,662.

278. Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Final Rule, 66,496, 66,496 (Dec. 15, 2009) ("The Administrator [of the EPA] finds that six greenhouse gases taken in combination endanger both the public health and the public welfare of current and future generations. The Administrator also finds that the combined emissions of these greenhouse gases from new motor vehicles and new motor vehicle engines contribute to the greenhouse gas air pollution that endangers public health and welfare under CAA section 202(a).").

279. RFS2 REGULATORY IMPACT ANALYSIS, *supra* note 112, at 472-73 ("The results for this corn butanol scenario are that the midpoint of the range of results is a 31% reduction in GHG emissions compared to the gasoline 2005 baseline. The 95% confidence interval around that

commercialization and implementation will produce the social benefit of helping to reduce these harmful GHG emissions. While we do not suggest that an increase in our reliance on liquid biofuels will serve as the sole answer to global climate change mitigation, it nonetheless contributes to these efforts and therefore produces social value that regulatory innovation would allow us to better capture.

An increase in our use of liquid biofuels also has the important effect of enhancing social welfare by furthering the national priority of reducing our reliance on fossil fuels and thereby enhancing U.S. energy security.[280] The U.S. is currently heavily dependant on the use of fossil fuels, consuming roughly 18.8 million barrels of oil per day.[281] The first major issue resulting from this reliance involves the notion that fossil fuels are a finite resource and at some point, world oil production will peak.[282] Although estimates of exactly when world oil production will peak, or already has peaked, range from 2004 to 2047, no one questions the notion that at some time in the not-so-distant future, we will reach a point at which half of the world's oil reserves have been harvested and production rates are therefore incapable of increasing.[283] As such, our reliance on fossil fuels is not sustainable in the long term and an increase in our reliance on renewable biofuels will allow us to both adapt to this reality and mitigate its consequences. In the words of President Obama, we "cannot afford to bet our long-term prosperity, our long-term security on a resource that will eventually run out, and even before it runs out will get more and more expensive to extract from the ground."[284]

The second major way in which our heavy reliance on fossil fuels threatens U.S. energy security involves the fact that over half of the current U.S.

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midpoint ranges from a 20% reduction to a 40% reduction compared to the gasoline baseline . . . ."); *id.* at 467 ("The results for this corn ethanol scenario are that the midpoint of the range of results is a 21% reduction in GHG emissions compared to the gasoline 2005 baseline. The 95% confidence interval around that midpoint ranges from a 7% reduction to a 32% reduction compared to the gasoline baseline . . . .").

280. THE WHITE HOUSE, *supra* note 6.

281. U.S. Energy Information Administration, EIA's Energy Brief: How Dependant Are We on Foreign Oil?, http://www.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm (last visited March 29, 2011).

282. *See generally* S.H. Mohr & G.M. Evans, *Peak Oil: Testing Hubbert's Curve via Theoretical Modeling*, 17 NAT. RESOURCES RES. 1 (2008) (discussing the idea of peak oil and explaining a theoretical model for when world oil production might peak).

283. *See id.*

284. Barack Obama, *supra* note 4.

oil supply is imported from foreign nations.[285] More importantly, roughly 39% of American oil imports are derived from North Africa and the Persian Gulf,[286] an increasingly unstable region. On a global basis, this region produces more than one-third of the world's daily supply of liquid fuels.[287] As the geo-political situation in this region of the world continues to experience profound upheavals, President Obama has recently noted that the energy security of the U.S., not to mention the entire global community, is increasingly threatened.[288] Moreover, as the political turmoil in this unstable region will no doubt increase the overall cost of oil, our heavy reliance on it will potentially result in profound negative economic consequences.[289] As President Obama puts it:

> In an economy that relies so heavily on oil, rising prices at the pump affect everybody – workers, farmers, truck drivers, restaurant owners . . . . Businesses see rising prices at the pump hurt their bottom line. Families feel the pinch when they fill up their tank. And for Americans that are already struggling to get by, a hike in gas prices really makes their lives that much harder. It hurts. If you're somebody who works in a relatively low-wage job and you've got to commute to work, it takes up a big chunk of your income. You may not be able to buy as many groceries. You may have to cut back on medicines in order to fill up the gas tank. So this is something that everybody is affected by.[290]

As an increase in our use of domestically produced liquid biofuels will mitigate these negative economic effects that result from our heavy reliance on foreign oil, their social value is clearly of great importance.

Finally, liquid biofuels' ability to increase social welfare is highlighted when they are considered within the context of renewable energy in general. When President Obama delivered his 2011 State of the Union Address, he noted that in regards to the optimal mix of renewable energy technologies, "[s]ome

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285. U.S. Energy Information Administration, EIA's Energy Brief: How Dependant Are We on Foreign Oil?, http://www.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm (last visited March 29, 2011).

286. *Id.*

287. U.S. Energy Information Administration, Liquid Fuels Production in Middle Eastern and North African Countries, http://www.eia.doe.gov/todayinenergy/detail.cfm?id=690 (last visited March 29, 2011).

288. Barack Obama, *supra* note 4.

289. *See generally* U.S. Energy Information Administration, Economic Effects of High Oil Prices, http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2006analysispapers/efhop.html (last visited March 29, 2011).

290. Barack Obama, *supra* note 4.

folks want wind and solar. Others want *nuclear*, clean coal and natural gas. . . . we will need them all."[291] Despite this call for an increase in our reliance on nuclear energy, public support for this form of energy took a dramatic turn for the worse as a result of witnessing the nuclear crisis at Japan's Fukushima Daiichi plant in the wake of the devastating tsunami that struck the nation on March 11, 2011.[292] As such, it is unlikely that the U.S. public will support an expanded reliance on nuclear energy and other forms of renewable energy, such as biofuels, will need to be further emphasized. Even President Obama recognized as much when he prefaced his recent call for an increased reliance on biofuels by stating that "[t]he situation in Japan leads us to ask questions about our energy sources."[293]

C. Regulatory Innovations

Upon concluding that some form of regulatory innovation is needed to mitigate the unjustified regulatory hurdles to the commercialization of high-level biobutanol blends and allow us to better capture their inherent social value, we now turn to the question of what form this regulatory innovation should take. First, we address a simple form of regulatory innovation that is capable of being implemented within the existing CAA regulatory framework. Next, we describe a form requiring Congressional action to alter the existing framework.

1. Innovation Within the Existing Regulatory Framework

The simplest form of regulatory innovation that would allow us to capture the inherent social value of high-level biobutanol blends and mitigate the unjustified hurdles to its commercialization would be for the EPA to increase the 2.7% oxygenate weight limit currently allowed under its outdated Substantially Similar Rule.[294] Ethanol blended with gasoline in a concentration of 10% results

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291. President Barack Obama, State of the Union Address (Jan. 25, 2011), in 157 Cong. Rec. H457-62 (daily ed. Jan. 25, 2011) (emphasis added), *available at* http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address.

292. *See* Michael Grunwald, *The Real Cost of Nuclear Power*, TIME, March 28, 2011, at 39 (noting that as a result of "[t]he chaos at the Fukushima Daiichi nuclear plant[,]" the already stalled "U.S. atomic revival" will be further stymied); *see also* Jeffery Kluger, *Fear Goes Nuclear*, TIME, March 28, 2011, at 35 (providing an overview of the nuclear crisis at Japan's Fukushima Daiichi nuclear plant).

293. Barack Obama, *supra* note 4.

294. 1991 Substantially Similar Rule, *supra* note 212, at 5,352 (providing the most recent substantive change to the EPA's defintion of "substantially similar").

in the finished fuel containing approximately 3.7% oxygen by weight[295] and this blend has been lawfully commercialized for over thirty years with no adverse effect on vehicle emissions.[296] Moreover, for the past twenty years, a limit of 3.7% oxygen by weight in finished fuel has essentially been the gold standard by which the EPA has conditionally granted new fuel waivers for alcohol-based fuels.[297] Based on the EPA's extensive experience with finished fuels containing 3.7% oxygen by weight, not to mention the fact that the conditionally granted E15 waiver found no adverse effects on newer vehicles from a fuel containing 5.5% oxygen by weight,[298] there is no reason why it should not update its Substantially Similar Rule to allow a 3.7% limit across the board for all alcohol-based fuels. While the EPA could sit back and wait for a biobutanol manufacturer to initiate a petition to revise the rule,[299] there is nothing preventing it from revising the rule on its own volition.[300] As the EPA has noted in past revisions to its Substantially Similar Rule, if some type of fuel blend emerges that produces adverse emissions effects despite complying with the 3.7% oxygen by weight limit, the EPA can always fall back on its CAA § 211(c) authority to regulate that specific fuel.[301]

If the EPA were to revise its Substantially Similar Rule to increase the allowable oxygenate weight percentage in finished fuel to 3.7%, this revision would effectively make it lawful to register and commercialize Bu16 without the

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295. 1981 Substantially Similar Rule, *supra* note 211, at 38,584.

296. E10 Waiver, *supra* note 20, at 20,777.

297. *See* DuPont Waiver, *supra* note 225, at 2,615 (granting waiver on condition that "[t]he gasoline-alcohol fuel is composed of a maximum of 3.7 weight percent fuel oxygen"); Octamix Waiver, *supra* note 225, at 3,637(granting waiver on condition that "[a] maximum concentration of up to 3.7 percent by weight oxygen in the final fuel is observed").

298. E15 Waiver I, *supra* note 21, at 68,103 ("E15, for the first time, would add significantly more oxygen to the fuel, up to around 5.5% by weight oxygen depending on the density of the gasoline to which ethanol is added."); *id*. at 68,124 ("EPA believes there is strong evidence that [model year] 2007 and newer light-duty motor vehicles will not exceed there emission standards over their useful life when operated on E15."); E15 Waiver II, *supra* note 21, at 4,682 ("EPA believes the evidence supports the conclusion that [model year] 2001–2006 light-duty motor vehicles will not exceed their emission standards over their [full useful life] when operated on E15.").

299. *See*, *e.g.*, 1991 Substantially Similar Rule, *supra* note 212, at 5,352 (revising the Substantially Similar Rule in response to a letter requesting the EPA to do so).

300. *See id.* at 5,354 (indicating that "EPA may also revise its definition of 'substantially similar' if it sees fit); 1981 Substantially Similar Rule, *supra* note 211, at 38,582-86 (revising the definition of substantially similar in the absence of a formal request to do so).

301. 1991 Substantially Similar Rule, *supra* note 212, at 5,354 ("[I]f at a later point EPA determines that any specific blend of aliphatic alcohols, ethers or combination thereof is considered appropriate for section 211(c) regulation, then today's determination will be no bar to such action."); *see also* Clean Air Act, 42 U.S.C. § 7545(c) (2010).

need for the unjustified costs and uncertainties associated with attempting to register it under either an existing fuel waiver or a new fuel waiver.[302] This simple step would both mitigate these unjustified regulatory burdens and allow us to better capture the social benefits that will flow from the lawful commercialization of this high-level biobutanol blend.

[Insert Figure 4]

2. Changes to the Existing Regulatory Framework

An alternate form of regulatory innovation would require Congressional action to create a streamlined process whereby biofuels capable of satisfying the RFS2's volume obligations are eligible for a "fast track" review of any new fuel waiver applications that might be sought to increase their lawful blending limits.[303] By "fast track," we are not suggesting anything drastic, but merely a return to the general way in which the fuel waiver process operated prior to the recent revisions enacted with EISA.[304] Specifically, a new sub-section could be added to CAA § 211(f) that allows the manufacturer of any fuel or fuel additive that has been assigned a D code for purposes of the RFS2 (i.e., successfully designated as either a renewable fuel, advanced biofuel, cellulosic biofuel, or biomass-based diesel), to submit a fuel waiver application that: (1) only needs to address the emissions-related effects that the finished fuel has on the types of engines that the applicant wishes to seek approval for (i.e., specific types of motor vehicles, motor vehicle engines, nonroad engines or nonroad vehicles); (2) is not subject to formal notice and comment rulemaking; and (3) is subject to being granted by operation of law if the EPA does not act within 180 days of receiving the waiver application. In the event that the EPA grants the waiver, it would only be applicable to the commercialization of the finished fuel for use in the types of engines specified in the application and the EPA could require misfueling conditions in much the same way as it did with the conditional grant of the E15 waiver.[305] As the EPA must determine that any given biofuel produces at least a

302. *Supra* Part IV. *Compare* Figure 4, *with* Figures 1, 2, and 3.

303. *See* Figure 5.

304. *See* 42 U.S.C. § 7545(f)(4).

305. E15 Waiver I, *supra* note 21, at 68,150 (requiring "[r]easonable measures for ensuring that any retail fuel pump dispensers that are dispensing a gasoline produced with greater than 10 vol% ethanol and no more than 15 vol% ethanol are clearly labeled for ensuring that consumers do not misfuel the waivered gasoline-ethanol blend into vehicles or engines not covered by the waiver").

20% GHG reduction prior to assigning it a D code for purposes of the RFS2,[306] this fast track process would only apply to biofuels that have previously been shown to enhance social welfare. As all other new fuels and fuel additives would remain subject to the safeguards of the current fuel waiver process,[307] we are not calling for deregulation, but merely for a form of regulatory innovation that allows us to better capture the associated social benefits and bring regulatory burdens in line with the harms they are intended to prevent.

[Insert Figure 5]

Regardless of whether or not this fast track process is put in place, an additional method for lessening the regulatory burden associated with the commercialization of high-level biobutanol blends would be for the DOE to begin conducting detailed testing of their effects on the durability of emissions control systems. Subsequent to the enactment of EISA in 2007, the DOE began its "Intermediate Ethanol Blends Emissions Controls Durability Program" to study the emissions-related effects of ethanol blends greater than 10%[308] and when the EPA conditionally granted the E15 waiver, it was the results from this program that it primarily relied on.[309] Moreover, the EPA's stated reason for its nearly two-year delay in issuing a decision on the E15 waiver was that it was waiting "until the DOE test program was completed."[310] If this can properly be interpreted as the EPA viewing testing performed by the DOE as the gold standard for establishing the requisite burden of proof for granting a new fuel waiver, then it would be highly beneficial for the DOE to begin testing high-level biobutanol blends as soon as possible. With the DOE testing to rely on, the regulatory burdens associated with any future fuel waiver applications for high-level biobutanol blends would be somewhat mitigated and we would be better

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306. 40 C.F.R. § 80.1401 (2010) (defining the RFS2's four categories of biofuels in such a way that any form of biofuel eligible to satisfy its mandates must achieve at least a 20% GHG reduction from baseline gasoline or diesel fuel); *see* 40 C.F.R. § 80.1416 (describing the application process for a new RFS2 fuel pathway, which results in the EPA assigning a D code to the pathway).

307. *See* 42 U.S.C. § 7545(f).

308. E15 Waiver I, *supra* note 21, at 68,105.

309. *Id.* at 68,124.

310. *Id.* at 68,095; *see also* U.S. Environmental Protection Agency, Letter to Growth Energy, Nov. 30, 2009, *available at* http://www.epa.gov/otaq/regs/fuels/additive/lettertogrowthenergy11-30-09.pdf (informing Growth Energy that the EPA's decision on the E15 waiver will be delayed until the DOE testing is complete).

able to exploit their ability to increase social welfare.

VI. BIOFUEL-RELATED REGULATORY INNOVATION IN GENERAL

While this article focuses on applying our analytical framework for regulatory innovation to schemes directly affecting the successful commercialization of biobutanol, the principles and insight we develop are equally applicable to other biofuel-related regulatory schemes. As an increased use of any form of biofuel enhances social welfare, all regulatory frameworks affecting their expanded use should be assessed to determine whether the regulatory burdens they create are justifiable and whether some form of regulatory innovation is called for in order to efficiently capture their social value. Although a thorough normative analysis of additional regulatory schemes affecting the expanded use of liquid biofuels is better left for future work, we highlight a few brief examples to solidify the idea that regulatory innovation is needed to keep pace with technological innovations and efficiently capture the social benefits they generate.

The Biomass Crop Assistance Program (BCAP) is a key regulatory scheme that seeks to help develop the biofuels industry by providing financial subsidies to agricultural producers who opt to cultivate renewable biomass feedstocks that are to be converted into biofuels.[311] An important way the BCAP operates is by providing dollar-for-dollar matching payments (capped at $45) to producers that are based on the dry ton rate that biomass conversion facilities pay for their biomass.[312] To provide an overly simplified example, if a biomass conversion facility purchases 10 dry tons of biomass from a producer at a rate of $42 per dry ton, that producer can seek a BCAP matching payment of $420.[313] One important catch is that in order for a biomass producer to directly receive a BCAP matching payment, it must maintain ownership and the risk of loss for the

311. *See* Biomass Crop Assistance Program, 7 C.F.R. § 1450.3(a) (2010). The BCAP also provides subsidies for the cultivation of renewable biomass that is to be converted into heat, power, or biobased products. *See* 7 C.F.R. § 1450.2 (setting out the definitions the apply to BCAP). For further discussion and analysis of the legal and regulatory issues surrounding BCAP, *see* Jody M. Endres, Timothy A. Slating & Christopher J. Miller, *The Biomass Crop Assistance Program: Orchestrating the Government's First Significant Step to Incentivize Biomass Production for Renewable Energy*, 40 ENVTL. L. REP. 10,066 (2010).

312. 7 C.F.R. § 1450.106. For purposes of the BCAP, a biomass conversion facility is defined as "a facility that converts or proposes to convert renewable biomass into heat, power, biobased products, or advanced biofuels." 7 C.F.R. § 1450.2

313. *See* 7 C.F.R. § 1450.106.

biomass from pre-harvest through delivery to the biomass conversion facility.[314] If you look at this regulatory framework in the context of the biomass supply chain requisite for a large biofuel production facility, this regulatory hurdle is arguably unjustified because the burdens it creates outweigh its benefits. As a result of this ownership requirement, a large biofuel production facility would have to enter into biomass procurement agreements with each individual producer in order for them to directly receive any BCAP matching payments.[315] While biofuel producers would likely prefer to lower their transaction costs by entering into a single contract with a biomass aggregator, who in turn enters into contracts with individual biomass producers, this arrangement breaks the chain of ownership and precludes the biomass producers from being able to receive matching payments. In order to sidestep this regulatory hurdle, the parties would need to incur additional transaction costs to frame their contracts in such a way that: (1) the aggregator takes ownership of the biomass prior to harvest; (2) the biomass producer harvests the biomass as an agent of the aggregator (or else foregoes profiting from harvesting activities); (3) the aggregator delivers the biomass to the conversion facility; (4) the aggregator receives the BCAP matching payment; and (5) the aggregator somehow contractually passes the value of the matching payment back to the biomass producer. While this approach will no doubt produce additional transaction costs, the regulatory goal of ensuring that matching payments only issue to biomass producers for biomass that is actually delivered to a conversion facility, could just as easily be accomplished by providing a mechanism whereby biomass producers are allowed to sell their biomass to aggregators and only receive matching payments upon written documentation of the aggregator's delivery of the biomass to a conversion facility. This form of regulatory innovation would mitigate the unjustified regulatory hurdle regarding the BCAP's strict ownership requirements and allow for the more efficient capture of the social value inherent in incentivizing the production of biomass feedstocks for biofuels.

Our final example of how regulatory innovation is needed to keep pace with emerging biofuel-related technological innovations involves the way Congress chooses to define advanced biofuels in the regulatory schemes it creates. As we note in Part IV, the RFS2 seeks to incentivize the commercialization of

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314. 7 C.F.R. § 1450.2 ("Eligible material owner, for purposes of the matching payment, means a person or entity having the right to collect or harvest eligible material, who has the risk of loss in the material that is delivered to an eligible facility and who has directly or by agent delivered or intends to deliver the eligible material to a qualified biomass conversion facility . . . .").

315. *See id.*

advanced biofuel, which Congress chose to define as "renewable fuel, other than *ethanol* derived from corn starch . . . ."[316] In contrast, when Congress enacted the 2008 Farm Bill, which authorizes the Advanced Biofuel Payment Program (ABPP),[317] it opted to exclude *any* fuel derived from corn kernel starch from its definition of advanced biofuel.[318] As such, when the U.S. Department of Agriculture (USDA) finally got around to implementing the ABPP in March of 2011,[319] it was constrained by this under inclusive definition. If we return our focus to biobutanol and consider the fact that the ABPP is intended to incentivize the production of advanced biofuels by making direct "payments to eligible producers to support and ensure [their] expanding production[,]"[320] we see that the exclusion of *any* fuel derived from corn kernel starch completely misses the opportunity to capture the inherent social value in emerging types of biofuels. Moreover, it appears as though the 2008 Farm Bill's definition of advanced biofuel is the result of either poor or simply uninformed drafting.[321] Although the definition generally states that "the term 'advanced biofuel' means fuel derived from renewable biomass other than corn kernel starch[,]" it goes on to provide that "the term 'advanced biofuel' *includes* . . . biofuel derived from sugar and starch (other than *ethanol* derived from corn kernel starch) . . . [and] *butanol* or other alcohols produced through the conversion of organic matter from renewable biomass."[322] While corn-based biobutanol fits squarely within the definition's statement of inclusions, it is nonetheless excluded by the general statement that advanced biofuels cannot be derived from corn kernel starch.[323] When a commenter on the USDA's proposed rule for the ABPP pointed out this ambiguity and reasoned that biobutanol should qualify for payments under the program, the USDA responded that this interpretation is foreclosed by the 2008 Farm Bill's definition for advanced biofuel. We are left with another prime example of how regulatory innovation is needed to keep pace with biofuel-related

316. Clean Air Act, 42 U.S.C. § 7545(o)(1)(B) (2010) (emphasis added); *see supra* Part IV.A.3.a.

317. Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246, § 9005, 122 Stat. 1651 (to be codified at 7 U.S.C. § 8105).

318. *Id.* at § 9001(3).

319. Advanced Biofuel Payment Program; Interim Rule, 76 Fed. Reg. 7,936, 7,936 (Feb. 11, 2011) [hereinafter ABPP Interim Rule] (implementing the Advanced Biofuel Payment Program, effective March 14, 2011).

320. Bioenergy Program for Advanced Biofuels, 7 U.S.C. § 8105(b) (2010).

321. *See* Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246, § 9001(3), 122 Stat. 1651 (to be codified at 7 U.S.C. § 8105).

322. *Id.* (emphasis added).

323. *See id.*

technological innovations.[324]

VI. CONCLUSION

As current regulatory burdens affecting the commercialization of emerging biofuel innovations are disproportionate to the harms they are intended to mitigate, regulatory innovation is needed to address these unjustified burdens. The forms of regulatory innovation we suggest will not only do this, but will also produce the ancillary effects of incentivizing firms to adopt recent technological innovations and develop additional new innovations. These points become clear if we turn our focus to biobutanol. As the firms currently seeking to commercialize biobutanol innovations are intending to do so via licensing them to existing ethanol producers,[325] the regulatory innovations we suggest will incentivize these producers to adopt these innovations by clearly signaling that a larger market for biobutanol exists[326] and the regulatory burdens associated with expanding this market have been mitigated.[327] For instance, we not only urge the EPA to facilitate the lawful commercialization of Bu16 by revising its outdated Substantially Similar Rule to allow finished fuels to contain up to 3.7% oxygen by weight,[328] but we further urge Congress to mitigate the burdens associated with seeking new fuel waivers for all emerging biofuels that have had their production pathways successfully designated for purposes of the RFS2.[329] Moreover, once increased lawful blending limits are established for biobutanol, they will apply to all forms, regardless of how they are produced,[330] and therefore enhance the RFS2's ability to incentivize new technological innovations in order to capitalize on the growing captive markets it creates for advanced biofuels and cellulosic biofuels.[331] When we take our focus off of biobutanol, the regulatory innovations we suggest will also produce these effects in regards to other emerging forms of biofuels.

Most importantly, the regulatory innovations we suggest will also allow us

324. ABPP Interim Rule, *supra* note 319, at 7,957.

325. *Supra* Part III.A.

326. *Supra* Part V.C.1.; *see also* Figure 4.

327. *Supra* Part V.C.2.

328. *Supra* Part V.C.1.

329. *Supra* Part V.C.2.; *see also* Figure 5.

330. The idea here being that once an applicable legal blending limit is established for biobutanol (e.g., Bu16), this blending limit will apply to all biobutanol regardless of whether it is produced from corn, sugarcane, cellulosic biomass, etc.

331. *Supra* Part IV.A.

to more efficiently capture the social value inherent in biofuels "done right."[332] When you consider the increasing political unrest in the Middle East and North Africa, the desirability of pursuing alternatives to petroleum-based fuels comes clearly into focus. If we increase the lawful blending limits for biofuels to the optimal point where their use does not produce negative emissions effects, we will further reduce our reliance on foreign-produced oil and thereby enhance U.S. energy security. Additionally, as emerging advanced biofuels and cellulosic biofuels come on-line, increased blending limits for these fuels will enhance the environmental benefits they produce through their greater potential to reduce climate changing GHG emissions. At the same time, increasing the markets for these fuels will not only act as a boon for rural economic development, but also produce green jobs generally. As U.S. Secretary of Energy Steven Chu stated in response to a recent innovation in the production of cellulosic biobutanol, "[w]e need to act aggressively to seize this opportunity and win the future."[333] In other words, we must embrace the regulatory improvements that we have proposed so that legal innovation can keep pace with technological innovation.

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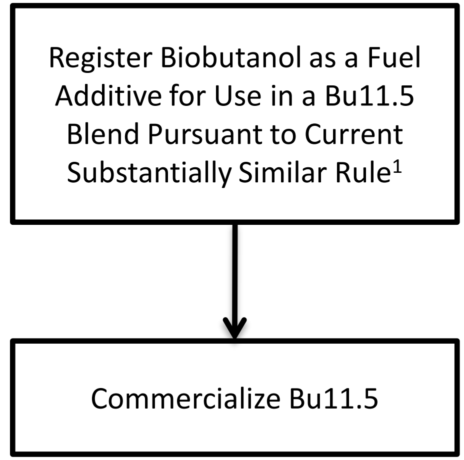
332. *See* Tillman et al., *supra* note 1, at 270.

333. Press Release, U.S. Department of Energy, Energy Department Announces New Advance in Biofuel Technology (March 7, 2011) (quoting Steven Chu), *available at* http://www.energy.gov/news/10163.htm.

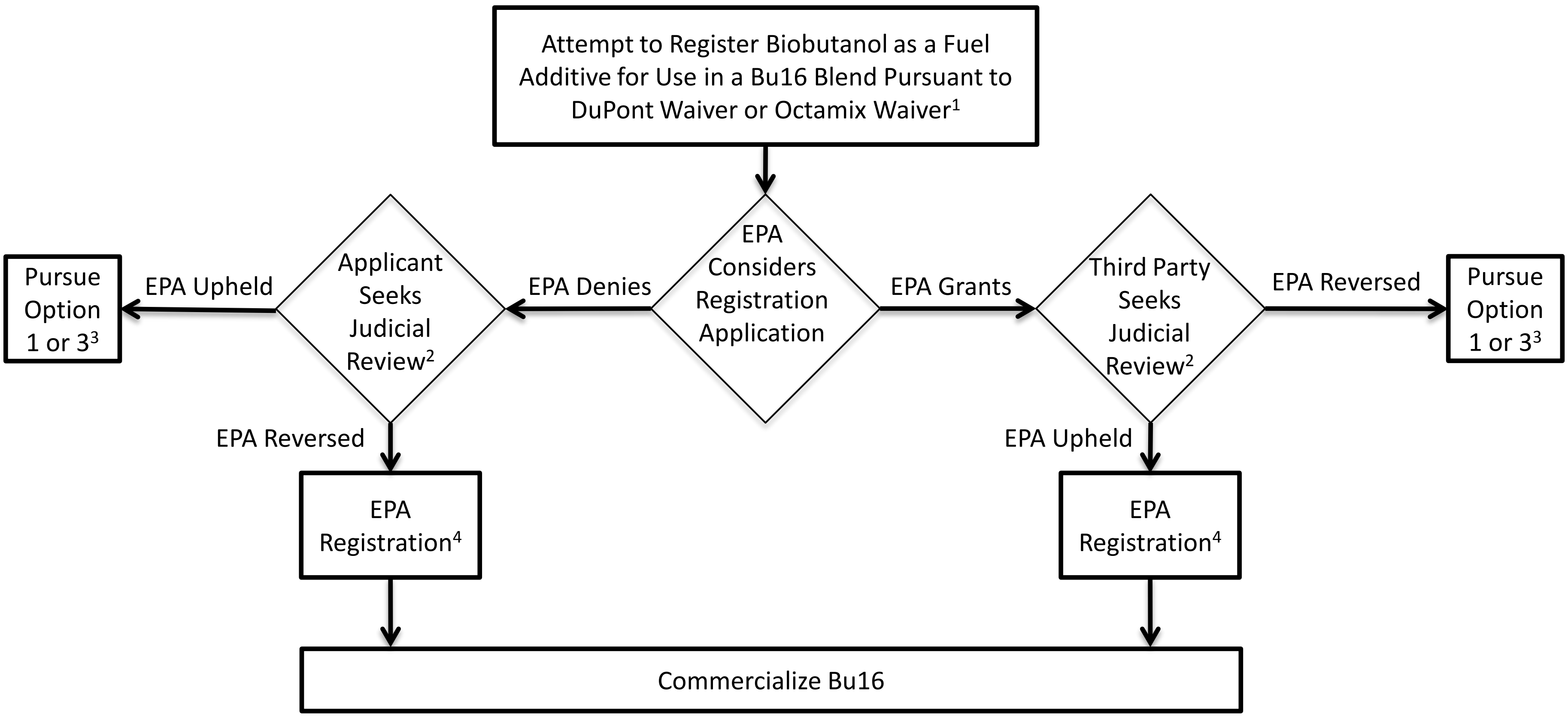
Figure 1: Option 1 for the Commercialization of Biobutanol Under the Existing Clean Air Act Regulatory Framework



Notes:

1. *See* Clean Air Act, 42 U.S.C § 7545(a) (2010) (requiring fuel additives to be registered with the EPA); 42 U.S.C. § 7545(f)(1) (prohibiting the commercialization of fuels that are not "substantially similar" to fuels used by the EPA in its vehicle emissions certification process); 40 C.F.R. § 79.20(h) (2010) (requiring fuel additive registration applications to demonstrate that when the additive is used in its recommended concentration, it results in a finished fuel that is "substantially similar"); Regulation of Fuels and Fuel Additives, Revised Definition of Substantially Similar Rule for Alaska, 73 Fed. Reg. 22,277, 22,281 (April 25, 2008) (providing that in order for fuels containing aliphatic alcohols to be considered "substantially similar[,]" they "must contain no more than 2.7 percent oxygen by weight"). As biobutanol is an aliphatic alcohol with a relatively low oxygen weight, the current Substantially Similar Rule allows it to be lawfully blended with gasoline so long as the finished fuel contains no more than 11.5 percent biobutanol by volume (i.e., Bu11.5).

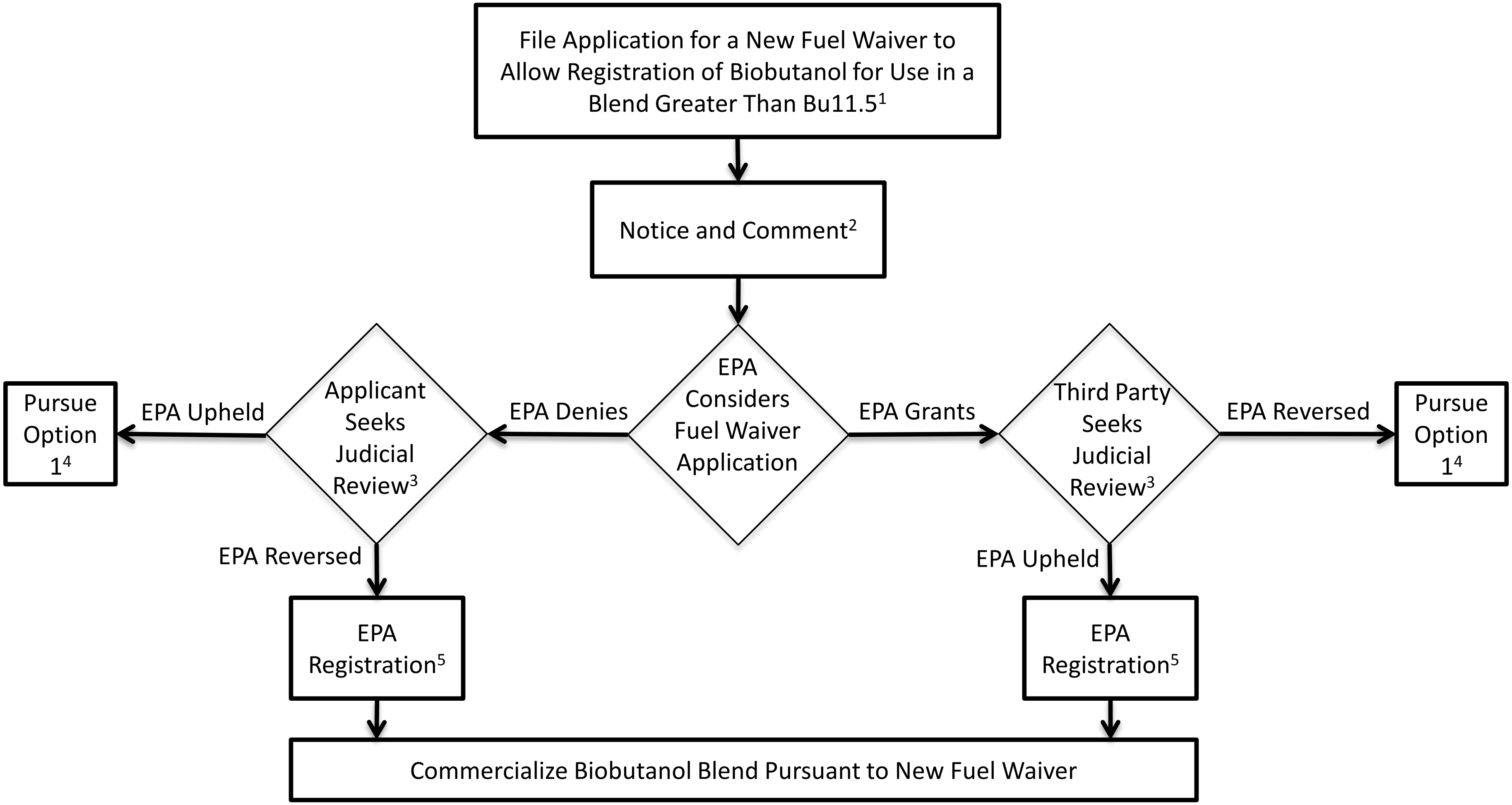
Figure 2: Option 2 for the Commercialization of Biobutanol Under the Existing Clean Air Act Regulatory Framework



Notes:

1. *See* Clean Air Act, 42 U.S.C § 7545(a) (2010) (requiring fuel additives to be registered with the EPA); 42 U.S.C. § 7545(f)(1) (prohibiting the commercialization of fuels that are not "substantially similar" to fuels used by the EPA in its vehicle emissions certification process); 42 U.S.C. § 7545(f)(4) (providing a statutory mechanism whereby fuel or fuel additive manufacturers can submit an application to the EPA seeking a waiver of the substantially similar prohibition); 40 C.F.R. § 79.21(h) (2010) (requiring fuel additive registration applications to demonstrate that when the additive is used in its recommended concentration, it results in a finished fuel that is either "substantially similar" or a fuel waiver has been granted by the EPA); Fuels and Fuel Additives, Waiver Decision, 50 Fed. Reg. 2,615, 2,615-16 (Jan. 17, 1985) (granting the "DuPont Waiver[,]" which allows the lawful commercialization of finished fuels consisting of a "maximum of 5.0 volume percent methanol" and "a minimum of 2.5 volume percent cosolvent (. . . butanols)[,]" so long as a "maximum concentration of up to 3.7 weight percent oxygen in the final fuel is observed"); Fuels and Fuel Additives, Waiver Application, 53 Fed. Reg. 3,636, 3,636-38 (Feb. 8, 1988) (granting the "Octamix Waiver[,]" which allows the lawful commercialization of finished fuels consisting of a "maximum of 5 percent by volume methanol" and "a minimum of 2.5 percent by volume cosolvent . . . [including] butanols[,]" so long as a "maximum concentration of up to 3.7 percent by weight oxygen in the final fuel is observed"). As the conditions set out in the DuPont and Octamix Waivers merely place a ceiling on the amount of methanol that can be blended and a floor on the amount of butanol allowed, they arguably permit 0% methanol to be blended and as high a percentage of butanol as can be accomplished within the confines of the finished fuel containing no more than 3.7% oxygen by weight. As biobutanol is an oxygenate with a relatively low weight, these conditions arguably allow for the lawful commercialization of Bu16.
2. *See* 42 U.S.C. § 7607(b)(1) (providing for judicial review of any "control or prohibition" promulgated by the Administrator of the EPA pursuant to § 7545 of the Clean Air Act).
3. *See* Figure 1 or Figure 2.
4. *See* 42 U.S.C § 7545(a) (requiring fuel additives to be registered with the EPA).

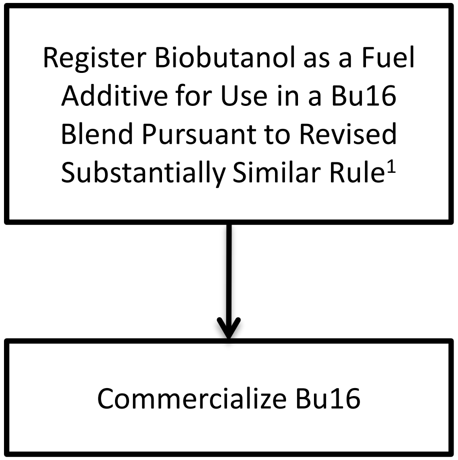
Figure 3: Option 3 for the Commercialization of Biobutanol Under the Existing Clean Air Act Regulatory Framework



Notes:

1. *See* Clean Air Act, 42 U.S.C § 7545(a) (2010) (requiring fuel additives to be registered with the EPA); 42 U.S.C. § 7545(f)(1) (prohibiting the commercialization of fuels that are not "substantially similar" to fuels used by the EPA in its vehicle emissions certification process); 42 U.S.C. § 7545(f)(4) (providing a statutory mechanism whereby fuel or fuel additive manufacturers can submit an application to the EPA seeking a waiver of the substantially similar prohibition); 40 C.F.R. § 79.20(h) (2010) (requiring fuel additive registration applications to demonstrate that when the additive is used in its recommended concentration, it results in a finished fuel that is either "substantially similar" or a fuel waiver has been granted by the EPA); Regulation of Fuels and Fuel Additives, Revised Definition of Substantially Similar Rule for Alaska, 73 Fed. Reg. 22,277, 22,281 (April 25, 2008) (providing that in order for fuels containing aliphatic alcohols to be considered "substantially similar[,]" they "must contain no more than 2.7 percent oxygen by weight"). As biobutanol is an aliphatic alcohol with a relatively low oxygen weight, the current Substantially Similar Rule allows it to be lawfully blended with gasoline so long as the finished fuel contains no more than 11.5 percent biobutanol by volume (i.e., Bu11.5). Therefore, in order to lawfully commercialize a biobutanol blend greater than Bu11.5, a new fuel waiver must be sought from the EPA.
2. *See* 42 U.S.C. § 7545(f)(4) (requiring "public notice and comment" prior to the EPA issuing a decision regarding new fuel waivers).
3. *See* 42 U.S.C. § 7607(b)(1) (providing for judicial review of any "control or prohibition" promulgated by the Administrator of the EPA pursuant to § 7545 of the Clean Air Act).
4. *See* Figure 1.

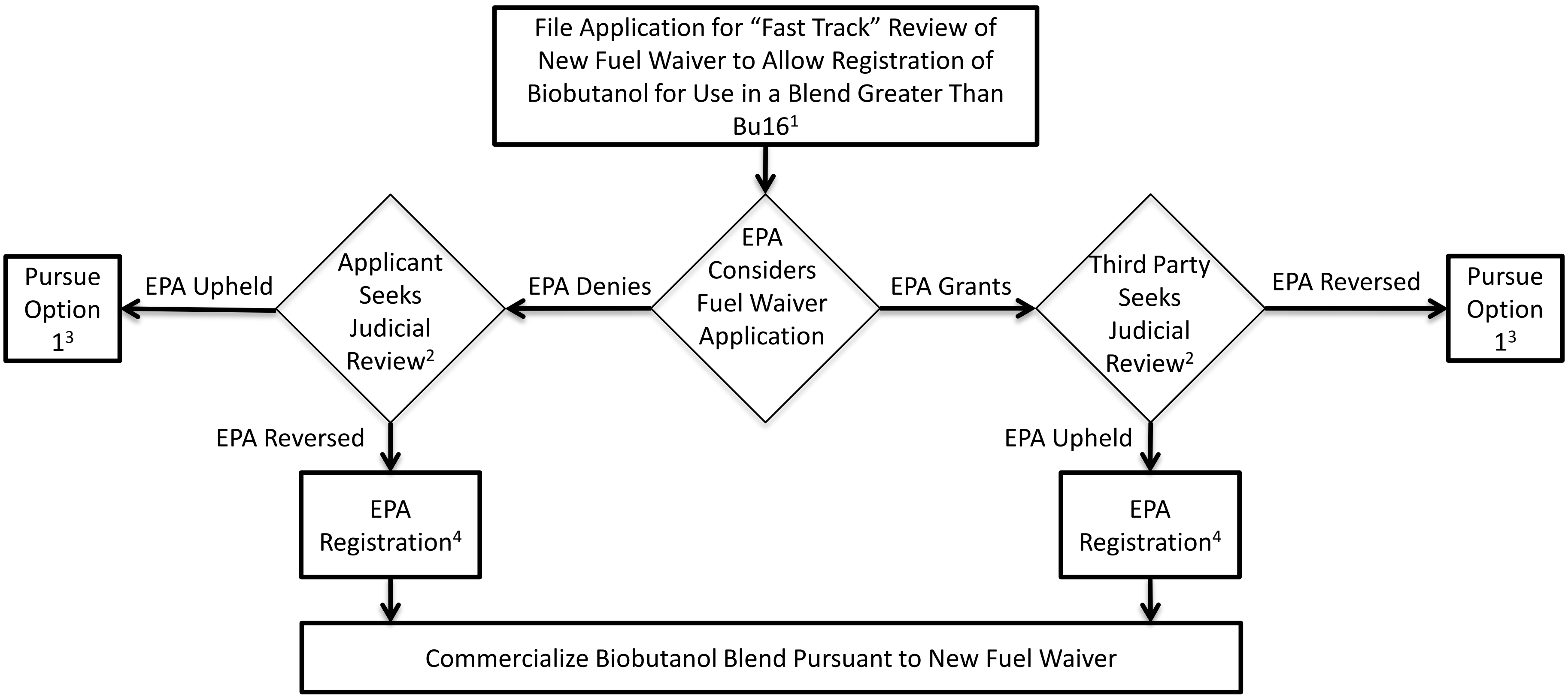
Figure 4: Option 1 for the Commercialization of Biobutanol After Adoption of Our Proposed Regulatory Changes



Notes:

1. *See* Clean Air Act, 42 U.S.C § 7545(a) (2010) (requiring fuel additives to be registered with the EPA); 42 U.S.C. § 7545(f)(1) (prohibiting the commercialization of fuels that are not "substantially similar" to fuels used by the EPA in its vehicle emissions certification process); 40 C.F.R. § 79.20(h) (2010) (requiring fuel additive registration applications to demonstrate that when the additive is used in its recommended concentration, it results in a finished fuel that is "substantially similar"); Regulation of Fuels and Fuel Additives, Revised Definition of Substantially Similar Rule for Alaska, 73 Fed. Reg. 22,277, 22,281 (April 25, 2008) (providing that in order for fuels containing aliphatic alcohols to be considered "substantially similar[,]" they "must contain no more than 2.7 percent oxygen by weight"). As our proposed regulatory change would involve updating the Substantially Similar Rule to allow fuels containing aliphatic alcohols to have up to 3.7 percent oxygen by weight and biobutanol is an aliphatic alcohol with a relatively low oxygen weight, our proposed revision to the Substantially Similar Rule would allow biobutanol to be lawfully blended with gasoline so long as the finished fuel contains no more than 16 percent biobutanol by volume (i.e., Bu16).

Figure 5: Option 2 for the Commercialization of Biobutanol After Adoption of Our Proposed Regulatory Changes



Notes:

1. *See* Clean Air Act, 42 U.S.C § 7545(a) (2010) (requiring fuel additives to be registered with the EPA); 42 U.S.C. § 7545(f)(1) (prohibiting the commercialization of fuels that are not "substantially similar" to fuels used by the EPA in its vehicle emissions certification process); 42 U.S.C. § 7545(f)(4) (providing a statutory mechanism whereby fuel or fuel additive manufacturers can submit an application to the EPA seeking a waiver of the substantially similar prohibition); 40 C.F.R. § 79.20(h) (2010) (requiring fuel additive registration applications to demonstrate that when the additive is used in its recommended concentration, it results in a finished fuel that is either "substantially similar" or a fuel waiver has been granted by the EPA). Our proposal for a "fast track" review of new fuel waivers for emerging biofuels is conditioned on the fuel first having a fuel pathway successfully designated for purposes of the federal Renewable Fuel Standard (RFS2). *See* 40 C.F.R. § 80.1416 (2010) (providing a regulatory mechanism whereby biofuel producers can petition the EPA to have a new fuel pathway designated for purposes of RFS2); 40 C.F.R. § 80.1426(f), Table 1 (providing a table of the existing fuel pathways for purposes of RFS2). The only ways in which our "fast track" review differs from the existing fuel waiver process is that it: (1) would not necessitate formal notice and comment; (2) would allow applicants to specify which types of engines the waiver fuel will be used in and thereby allow them to only submit emissions testing results associated with those types of engines; and (3) would make these new fuel waivers subject to being granted by operation of law in the event that the EPA does not act within 180 days of receiving the waiver application. *See* 42 U.S.C. § 7545(f)(4). As our first proposed regulatory change allows Bu16 to be lawfully commercialized under a revised Substantially Similar Rule, our proposed "fast track" review would only be necessitated in the event that a biobutanol manufacturer wishes to register it for use in a blend greater than Bu16. *See* Figure 4.
2. *See* 42 U.S.C. § 7607(b)(1) (providing for judicial review of any "control or prohibition" promulgated by the Administrator of the EPA pursuant to § 7545 of the Clean Air Act).
3. *See* Figure 4.
4. *See* 42 U.S.C § 7545(a) (requiring fuel additives to be registered with the EPA).