Title: Policy Research Needs Relevant to Alternative Jet Fuels

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Gap/Problem statement

While a number of alternative fuel-related policies have been unveiled in recent years, there is limited understanding of their potential impact on the development and deployment of advanced alternative fuels, including alternative jet fuels. Thus, industry and government need to better understand the implications of current and anticipated alternative fuel policies on the advanced alternative jet fuel industry. Previous research regarding policy effects on first generation biofuels such as ethanol and biodiesel [1-5], may provide initial guidance as to the analyses of anticipated impacts of policies and regulations on advanced alternative fuels.

Background

While the alternative aviation fuel industry has progressed in recent years, the industry still faces challenges with respect to alternative fuel certification, environmental integrity, financial resources, and technology development. Future policies have the potential to ameliorate or exacerbate such challenges. Policies come in many forms. They can be mandatory or voluntary, and restrictive or promotional in nature. The range of policy types that apply to the alternative aviation fuel industry can include regulations, mandates, incentives, subsidies, and risk management tools. Most current policies do not deal directly with alternative jet fuels, but with alternative transportation fuels in general. Some even explicitly exclude alternative jet fuels. However, the Energy Independence and Security Act (EISA) of 2007 provides an example of a regulation with a direct link to alternative aviation fuels. The Act directs the federal government to purchase only alternative or synthetic fuels (including alternative aviation fuels) for which the contract specifies that the life cycle greenhouse gas emissions are and will continue to be less than or equal to those from equivalent conventional petroleum-based fuels (EISA Section 526).

EISA also amended the most important biofuel policy in existence today, the Renewable Fuel Standards (RFS), which is a mandate for particular volumes and types of alternative fuels. Regulations and mandates generally are enacted to correct some type of market failure. In similar fashion to the Clean Air Act, in which Congress mandated clean air regulations because it deemed the market alone would not achieve the desired outcome, the RFS is an example of Congress enacting a mandate when it was deemed that the market would not produce a socially desired outcome.

Common examples of market failures are public goods, externalities, and common pool resources. A commodity, such as an orange for example, is only available to a single person – two people cannot eat the same orange. It is, therefore considered a private good. A public good is one in which one person's consumption does not reduce the consumption of another. A public good, such as national security, is available at the same level and at the same time for the entire populace. For public goods, the market is unlikely to produce efficient results because no entity reaps an individual benefit from producing it, and there is strong incentive for "free riders" who do not contribute to the public good but benefit from it.

Negative externalities are unwanted costs incurred by those who did not take the action that caused the cost and for which there is no accounting in market price without regulation. A common example is air pollution, which is a side effect of industrial activities for which society bears the cost of health impacts and cleanup, rather than the emitter. Without regulation, firms have no incentive to reduce pollution because there is no cost paid by the firm when it pollutes. Regulations can help internalize such externalities.

A common pool resource is one in which there are no defined property rights for resource extraction giving everyone incentive to take out as much as they can, which can reduce or eliminate the resource over time (often called the "Tragedy of the Commons" [6]). Although the frequency of tragedies of the commons is debated [e.g., 7], concerns over such resources often leads to government intervention to ensure the longevity of a resource. For example, fisheries, a common pool resource, are often regulated to limit the catch of individual fishermen, so as to sustain the resource. These are just some examples of instances in which governments may choose to intervene with regulations or mandates when there may be a market failure.

Congress also provides subsidies or taxes to change market outcomes. Regulations and mandates commonly fix quantities (e.g., the level of air pollution, the level of renewable fuel provided (RFS), etc.), whereas subsidies and taxes are price mechanisms. Instead of regulating pollution, Congress could choose to tax it – putting a price on the pollution under the expectation that proper pricing will internalize the externality and result in the desired outcome. Generally, economists prefer price mechanisms to quantity mechanisms (regulations and mandates), largely for reasons of efficiency. Environmental non-governmental organizations often prefer quantity mechanisms because the level of pollution reduction or quantity of biofuel produced is more important to them. Generally, either price or quantity mechanisms can be used to achieve the same outcome, and sometimes both are used. Cap and Trade mechanisms can also be used, in which the level of outcome and markets are established to permit trading among firms. Carbon pollution can be managed either with a carbon tax or with a carbon pollution level ceiling with trading among firms to establish a carbon price. Firms that can achieve carbon reductions at a low cost and exceed their mandate can sell their extra emissions credits to firms for whom emission reductions are more costly.

Thus there are many policy mechanisms that can be used to influence or even dictate outcomes if policy makers perceive that the market will not achieve desirable outcomes due to some type of market failure. In the biofuels arena, the RFS exists because Congress and the Bush administration perceived that biofuels provided environmental, national security, and rural development benefits that made their availability and use more desirable than what markets would produce and use on their own [8]. Another current biofuels assistance program, the Biomass Crop Assistance Program (BCAP) provides establishment and short term subsidies to those who produce biomass for conversion into bioenergy or biobased products (e.g., *Miscanthus* cultivars, *Camelina*) or harvest crop residues for conversion to cellulosic biofuels. Short term subsidies are designed to provide start-up assistance for a sector.

An important additional potential role of biofuels policies is to reduce private sector risk in making second generation biofuel investments. Risk reduction can be accomplished by a wide range of policies such as capital subsidies (in many forms), reverse auctions, and other mechanisms. Capital subsides can be capital cost sharing, loan guarantees, or other approaches. A reverse auction is a means of procuring biofuel at the lowest possible cost via a competitive auction mechanism. All the different mechanisms for reducing risk and stimulating investment in biofuels have different levels of effectiveness. Preliminary research suggests the reverse auction is more effective at reducing risk, but much more research is needed on this topic. Reverse auctions can be flat, indexed, with or without price collars, and we do not currently fully understand the impacts of each option.

The U.S. Navy Farm-to-Fleet program leverages a combination of risk management tools which include USDA feedstock subsidies, DOE loan guarantees or capital subsidies, and a reverse auction procurement process.

Current Status

A wide range of U.S. federal and state mandates and incentives have been implemented in the general biofuels arena. The excise tax exemption for corn ethanol, passed in 1978 and continued through 2011, was the first major incentive adopted at the federal level [8, 9]. There was also a biodiesel subsidy that ended in 2013. Neither of these directly affect the price or cost of alternative jet fuels. The major biofuels policy instrument today is the RFS, which does not specifically require alternative jet fuels, although alternative jet fuels can qualify for credits if the pathway is approved. Given its importance, a detailed summary of the current state of the RFS is provided below.

<u>The Renewable Fuel Standard (RFS)</u>

The RFS was initially created by the Energy Policy Act of 2005 and was then amended by the Energy Independence Act (EISA) of 2007. The RFS created in 2007 is sometimes referred to as RFS2, but we will use the term RFS in this paper. The EISA RFS contains four categories of biofuels, but has a nesting structure that makes it somewhat difficult to understand. The general flow of the nesting structure is shown in Figure 1.

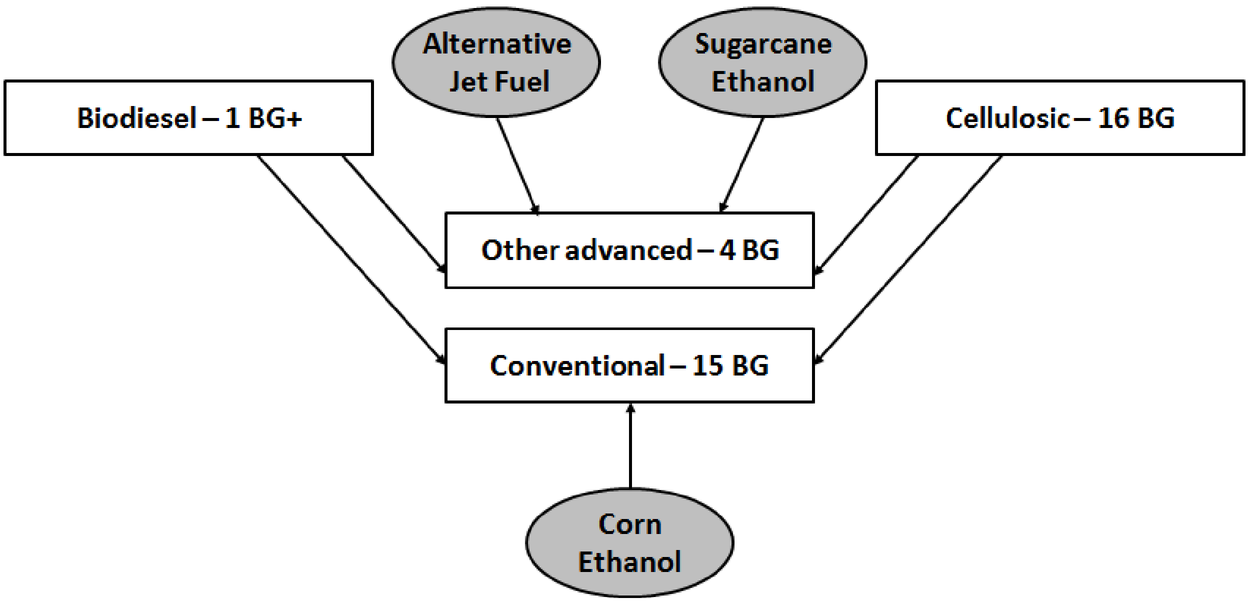
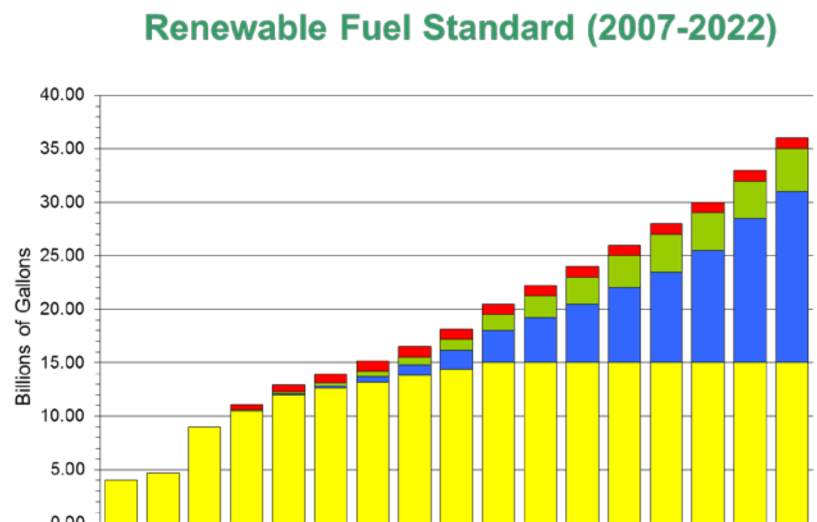


Figure 1. Nested RFS Structure

Figure 2 shows the evolution of the RFS levels through 2022 for each of the categories of biofuel. The overall level of required biofuels in 2022 is 36 billion gallons (BG) ethanol equivalent. However, with the nesting structure, it is possible to meet the different components of the RFS in many ways. It is important to note that the Environmental Protection Agency (EPA) has interpreted the RFS volume levels in Figure 1 as ethanol equivalent. For example, biodiesel has 1.5 times the energy of ethanol, so 1.28 billion gallons (BG) of biodiesel counts as 1.92 BG towards the overall RFS mandate. Below is a short definition of each of the four categories that also explains the nesting of the RFS components. Each of the categories must meet a GHG reduction target established in EISA. The law defines GHG emissions as follows:

> The term "life-cycle greenhouse gas emission" means the aggregate quantity of greenhouse gas emission (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel life cycle, 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 [10].

For each biofuel, the estimated emissions are compared with a 2005 gasoline baseline.



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

Figure 2. Renewable Fuel Standard

The following sections summarize the four categories and further explain the nesting of the RFS components.

- **Biodiesel** – the original maximum mandate for biodiesel was 1 BG, but EPA increased that level to 1.28 BG. The biodiesel category must reduce greenhouse gas (GHG) emissions by at least 50%, compared with the fossil fuel option as defined by the legislation and EPA. It can be transportation fuel, transportation fuel additive, heating oil, or jet fuel. It can be ester based diesel (e.g., from soybean oil), or non-ester renewable diesel (e.g., from cellulosic feedstocks). Biodiesel (as defined here) is required for the biodiesel part of the RFS. However, biodiesel can also be used to meet the other advanced category or the conventional biofuel category (e.g., corn ethanol).

- **Cellulosic advanced biofuel** – only biofuels produced from cellulosic feedstocks such as corn stover, miscanthus, switchgrass, forest residues, or short rotation woody crops can count in this category. Cellulosic biofuels must be shown to reduce GHG emissions by 60%. By 2022, 16 BG of cellulosic biofuels are required. Since that is ethanol equivalent, if the biofuel were jet fuel, the volume would be 9.8 BG, which is less than half the current jet fuel consumption. While no other type of biofuel can meet this category, cellulosic biofuels could in principle meet the entire 36 billion gallon ethanol equivalent RFS, if at least 1.28 BG were renewable diesel. However, progress in developing the cellulosic biofuel industry has been slow, and EPA has been forced to waive most of the RFS volumetric requirement each year because the product does not exist. For example, in 2013 the RFS calls for 1 BG of cellulosic biofuels, but that has been reduced to 14 million gallons – the amount EPA expects to be available in 2013 [11]. So far, each year the EPA has reduced the cellulosic mandate to near zero, but it has not reduced the overall renewable fuel mandate. For example, even though the cellulosic category was reduced from 1 BG to 14 million gallons in 2013, the overall mandate remains at 16.55 BG. Thus, the shortfall in cellulosic biofuels must be made up by extra biodiesel or non-cellulosic advanced biofuels. However, for 2014 the EPA has proposed reducing the overall mandate as well, but the proposal was not finalized as of 10 October 2014.

One other important point in the cellulosic category is that in any year that EPA waives any part of the cellulosic RFS, blenders have an option to buy their way out of blending instead of actually blending [10, 12]. To buy out of blending, obligated parties must purchase a credit from EPA plus purchase an advance biofuels Renewable Fuel Identification Number (RIN). Each category of biofuels has a separate RIN, and there are blending obligations for each category for each obligated party. Obligated parties essentially are gasoline and diesel refiners for the domestic market and gasoline and diesel importers. One other characteristic of the RINs market that bears mentioning is that RINs for up to 20% of the blending obligation can be carried forward to the next year and used later. In practice what this means is that any carried forward RINs are used in the subsequent year, and RINs for that year replace the RINs that were used to be carried forward to the next year. In other words, even though the regulations state that the RINs must be used in the next year, in fact they can be continuously rolled forward.

The price for the credit in 2013 was $0.42/gal, and a representative 2013 price of an advanced biofuel RIN was $0.95/gal. The formulae for calculating the credit is actually contained in the EISA [10]. Thus, the total cost of buying out of the RFS obligation was about $1.37/gal. As of May 20, 2013, wholesale gasoline was $2.90/gal, so the maximum one would pay for cellulosic biofuel is $4.27/gal gasoline equivalent. At present, there is no cellulosic biofuel that can be produced without subsidy for that price. The advanced RIN in 2014 has averaged about half the 2013 level, so the off-ramp buy-out is now much less expensive. The consequence of this "off ramp" is that the cellulosic part of the RFS is not really a binding mandate, as it can be financially more favorable for the obligated parties to purchase advanced biofuel RINS to meet the cellulosic requirement.

- **Other advanced** – this category can be a wide range of biofuels that reduce GHG emissions at least 50%. Sugarcane ethanol, biodiesel and cellulosic biofuels that meet the GHG reduction standards qualify for this "other advanced" category. Some alternative jet fuels would likely fall into this category, such as hydroprocessed esters and fatty acids (HEFA) from animal fats or vegetable oils. Recently, EPA approved sorghum ethanol produced under certain conditions. According to EISA definitions, corn ethanol cannot be used for this category.

- **Conventional biofuels** – this category is the only one that permits corn based ethanol. It requires a reduction in GHG emissions of at least 20%. However, ethanol plants that were in operation or under construction as of December 2007 are grandfathered. The RFS level was 13.8 BG in 2013 will reach 15 BG in 2015 and will remain at that level. In addition to corn ethanol, any of the other biofuel categories also can be used to meet the conventional biofuels category. In fact, technically, there is no mandate for corn ethanol. For example, for 2013, there was an overall mandate of 16.55 BG, of which 2.75 had to be some form of advanced biofuel (1.0 cellulosic, 0.75 other advanced, and 1.0 biodiesel from Figure 2). The difference between the overall mandate of 16.55 and the sum of the advanced biofuels, 2.75 BG, was the 13.6 BG amount that could be filled with corn ethanol.

As described earlier, the RFS is enforced by creating blending obligations for each type of biofuel. The blending obligations are based on market share for the type of fuel. For example, if you are a refiner or importer, and you have 10% of the gasoline market, for 2013 with a 13.8 BG total obligation for corn ethanol, you would be required to blend 1.38 BG. To satisfy this blending obligation, you would need to supply to EPA, at the end of the year, the RINs demonstrating that you have blended 1.38 BG of corn ethanol or other biofuels that can count in that category.

Although alternative jet fuels may be based on cellulosic or other advanced biofuel feedstocks and may achieve the required GHG reductions, currently there is no mandate within RFS that applies to jet fuel – the mandate is specifically for surface transportation fuels. However, advanced alternative jet fuels from approved pathways can be used to generate RINS and thus can be counted toward fulfillment of blending obligations under RFS.

State of Understanding of Alternative Fuel-Related Policies

There have been numerous studies on the impacts of the biofuel subsidies and RFS [1, 2, 13, 14]. Most of the research has been on first generation biofuels. Much of the work on second generation biofuels is still in the grey literature. MIT, Purdue and many others have led numerous studies on technical and economic aspects of second generation biofuels, including jet fuels. The conclusion of most of these studies is that while the technologies have medium and longer term potential, they are not yet ready for commercialization without government intervention. Also, to date, very few studies have incorporated uncertainty in either the techno-economic analysis or the environmental impacts assessments.

The RFS is under increasing attack from various parties. Bills have been introduced to eliminate or substantially modify the RFS. Thus, it is prudent to evaluate and understand the implications of a wide range of possible changes that might occur.

Solvability and Approaches

The alternative aviation fuel industry would certainly benefit from a deeper understanding of the effectiveness of a range of different policies in supporting development and commercialization of alternative jet fuels. Most of the potentially viable policy options are already on the table or have been considered or used. Following are some of the options that could be considered:

- Loan guarantee
    - Access to low cost agriculture loans
- Tax Credits for:
    - Farmers
    - Crop processers (i.e., crush facilities)
    - Technology providers/developers
- First mover or early adopter development grants
- Crop Insurance for cellulosic feedstocks
- Fast track and product manufacturer/supplier incentives on crop protection product labeling/approvals
- End User off-take agreements – Private Sector
- Expansion of Master Limited Partnership (MLP) legislation to include biofuels
- Per gallon or per BTU product subsidy
- Changes in the RFS to reduce options for avoiding use of alternative fuels
- Reverse auction based on off-take contract
- Reverse auction based on capital subsidy

Some of these are discussed further to provide a brief summary of how they work and the advantages and disadvantages of each.

Loan guarantee

The loan guarantee has been used quite a bit for biofuels and other renewable energy sources. The federal government guarantees some portion of the loan required to get a plant built. Terms differ from one program to another, but normally the government requires equity investment to go along with the loan guarantee. The loan guarantee normally results in a lower cost of capital. It has also been criticized by some as a policy rewarding failure. A loan guarantee awards failure in the sense that the policy payout occurs only when the firm defaults on its debt. For advanced biofuel facilities it is not clear, due to the large capital investment required, to what extent the loan guarantee will be a viable policy instrument.

Product subsidy

Historically, biofuel subsidies have varied through time and by product. The last remaining biofuel subsidy was for cellulosic biofuel, and it expired at the end of 2013. If a subsidy were to be used in the future, basing the subsidy on energy content instead of volume could be considered. That approach is technology neutral in that it is bio-energy content that gets subsidized rather than a physical unit of a specific type of biofuel.

RFS changes

The current RFS for cellulosic biofuel (the only category with this provision that allows blenders to buy their way out of blending the cellulosic biofuel) is not really a mandate. It is unclear whether this "off-ramp" provision of the RFS might be modified in the future to enforce the mandate more rigorously. So far, supporters and opponents of the RFS have been reluctant to open it up to change because, once opened, it is hard to predict how it would evolve.

Reverse auction based on off-take contract

The reverse auction has been proposed as a means of getting a few cellulosic biofuel plants built and operating in the near term. The military has shown some interest in this approach. In a reverse auction, the buyer, say the Air Force, would specify that it wants some quantity of a biofuel delivered to a certain point each year for a fixed number of years. The winning bidder would be the qualified bidder who bid the lowest price. The reverse auction provides price certainty to the biofuel producer and the purchaser. Especially early on, it is likely that the biofuel would be more expensive than fossil fuel. However, given the competitive process, the wedge between biofuel and fossil fuel would be as low as possible because it would be determined by a competitive auction. No one would bid without a good estimate of the costs of their conversion technology. They also likely would have provisional contracts for feedstock supply with local farmers.

The reverse auction could facilitate the construction of some facilities. Currently, the U.S. Department of Defense does not have the necessary authorization from Congress to use this approach for longer term contracts. One approach to stimulating construction of plants would be to use a reverse auction, but limit the number of plants or the quantity of fuel for which the auction could be applied. That approach would limit budget exposure and ensure a clear sunset for government support. A current limit on the reverse auction approach is that it is unknown how well it would work with new high risk technologies. Much more research needs to be done on the expected risk reduction with reverse auction and other policy alternatives.

Future research on these policy options must be done to account for uncertainty in the analysis. Since investor risk is a major barrier impeding development of a viable alternative jet fuels industry, we must be able to compare the extent to which alternative policies can reduce investor risk.

Benefits to Industry as a Whole

It will be quite difficult to get private sector investment in alternative jet fuels without policies aimed at reducing risk for the private sector. The most compelling policy research need is a thorough examination of policy options, such as those mentioned in this paper, aimed at determining the extent to which each succeeds in reducing investor risk. For a new industry, such as alternative jet fuels, there is risk throughout the supply chain. Different policies likely will be needed to reduce farmer risk, investor risk, purchaser risk, etc. There has not been a systematic analysis of risk reduction policies either at each stage of the supply chain or for the supply chain as a whole. If we can reduce supply chain risk, it will be much easier to attract venture capital and private finance.

References

1. Taheripour, F. and W.E. Tyner, *Welfare Assessment of the Renewable Fuel Standard: Economic Efficiency, Rebound Effect, and Policy Interactions in a General Equilibrium Framework*, in *Modeling, Dynamics, Optimization and Bioeconomics I, Springer Proceedings in Mathematics & Statistics 73*, A. Pinto and D. Zilberman, Editors. 2014, Springer-Verlag: Switzerland. p. 613-632.
2. Tyner, W. and F. Taheripour, *Biofuels, Policy Options, and Their Implications: Analyses Using Partial and General Equilibrium Approaches.* Journal of Agricultural & Food Industrial Organization, 2008. **6**(2): p. Article 9.
3. Tyner, W.E., *The Integration of Energy and Agricultural Markets.* Agricultural Economics, 2010. **41**(6).
4. Tyner, W.E. and F. Taheripour, *Policy Options for Integrated Energy and Agricultural Markets.* Review of Agricultural Economics, 2008. **30** (3): p. 387-396.
5. Tyner, W.E., F. Taheripour, and D. Perkis, *Comparison of Fixed Versus Variable Biofuels Incentives.* Energy Policy, 2010. **38**: p. 5530-5540.
6. Hardin, G., *The Tragedy of the Commons.* Science, 1968. **162**: p. 1243-1248.
7. Ostrom, E., *Beyond Markets and States: Polycentric Governance of Complex Economic Systems.* Nobel Price Lecture, 2009. **December 8, 2009**.
8. Tyner, W.E., *The US Ethanol and Biofuels Boom: Its Origins, Current Status, and Future Prospects.* BioScience, 2008. **58**(7): p. 646-53.
9. National Research Council, *Renewable Fuel Standard: Potential Economic Effects of U.S. Biofuel Policy*. 2011, National Academy of Sciences.
10. U.S. Congress, *Energy Independence and Security Act of 2007*, in *H.R. 6, 110 Congress, 1st session.* 2007.
11. Agency, U.S.E.P., *Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards.* Federal Register, 2013. **78**(26): p. 9282-9308.
12. Tyner, W.E., *Cellulosic Biofuels Market Uncertainties and Government Policy.* Biofuels, 2010. **1(3)**: p. 389-91.

13. Tyner, W.E. and R.A. Simmons, *Chapter 6. Biofuels*, in *Understanding the Global Energy Crisis*, E. Coyle and R.A. Simmons, Editors. 2014, Purdue University Press: West Lafayette, IN.
14. U.S. Environmental Protection Agency, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, Office of Transportation and Air Quality, Editor. 2010: Wahsington, D.C. p. 1120 pp.