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A parametric analysis of future ethanol use in the light-duty transportation sector: Can the US meet its Renewable Fuel Standard goals without an enforcement mechanism?

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AUTHOR-HIGHLIGHTS

- At current commodity prices, the LDV fleet will not use enough biofuel to meet RFS2.
- RFS2 can be met through the promotion of flex-fuel vehicles and their use of E85 fuel.
- The gasoline-E85 price premium is the key factor in encouraging biofuel consumption.
- RFS2 is satisfied at extreme oil prices (at least $215/barrel).
- This oil price encourages biofuel use in the RFS2 timeframe, but not in the long run.

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ABSTRACT

The modified Renewable Fuel Standard (RFS2) prescribes a volume of biofuels to be used in the United States transportation sector each year through 2022. As the dominant component of the transportation sector, we consider the feasibility of the light-duty vehicle (LDV) parc to provide enough demand for biofuels to satisfy RFS2. Sensitivity studies show that the fuel price differential between gasoline and ethanol blendstocks, such as E85, is the principal factor in LDV biofuel consumption. The numbers of flex fuel vehicles and biofuel refueling stations will grow given a favorable price differential. However, unless the feedstock price differential becomes extreme (biomass prices below $100 per dry ton and oil prices above $215 per barrel), which deviates from historical price trends, LDV parc biofuel consumption will fall short of the RFS2 mandate without an enforcement mechanism. Additionally, such commodity prices might increase biofuel consumption in the short-term, but discourage use of biofuels in the long-term as other technologies that do not rely on any gasoline blendstock may be preferable. Finally, the RFS2 program goals of reducing fossil fuel consumption and transportation greenhouse gas emissions could be achieved through other pathways, such as notable improvements in conventional vehicle efficiency.

1. Introduction

Over the past decade, the transportation sector generated more greenhouse gases (GHGs) from the combustion of fossil fuels than any other end-use sector in the US, with light-duty vehicles (LDVs) accounting for the largest share (U.S. Environmental Protection Agency, 2012; U.S. Energy Information Administration, 2012). Alternative vehicles and advancements in renewable fuels offer potential for reducing fossil fuel use and per-mile GHG emissions. Concerns regarding the security and the environmental impacts of fossil fuel use are some of many reasons that have stimulated interest in the increased use of renewable alternative transportation fuels. Biomass-based fuels represent an attractive alternative to petroleum-based fuels in terms of potential GHG reduction, their domestic production, and their compatibility with current LDV engines in the form of ethanol-gasoline blendstocks (U.S. Department of Energy, 2013). In addition to these benefits, domestically produced biofuel generates economic activity, often times within rural communities. This economic activity is represented by thousands of sustained jobs and by millions of dollars in worker salaries and in tax revenue (Burnes et al., 2005; Parcell and Westhoff, 2006). Although the biofuel industry currently relies

Abbreviation: CAFE, corporate average fuel economy; CI, diesel-fueled compression ignition; CNG, compressed natural gas; EV, electric vehicle; EXX, XX% ethanol by volume; FFV, flex fuel vehicle; GGE, gallon gasoline equivalent; GHG, greenhouse gas; ICE, internal combustion engine; LDV, light duty vehicle; PHEV, plug-in hybrid electric vehicle; RFS, Renewable Fuel Standard (2005); RFS2, Renewable Fuel Standard (2007); SI, gasoline-fueled spark ignition; VMT, vehicle miles traveled (per vehicle)

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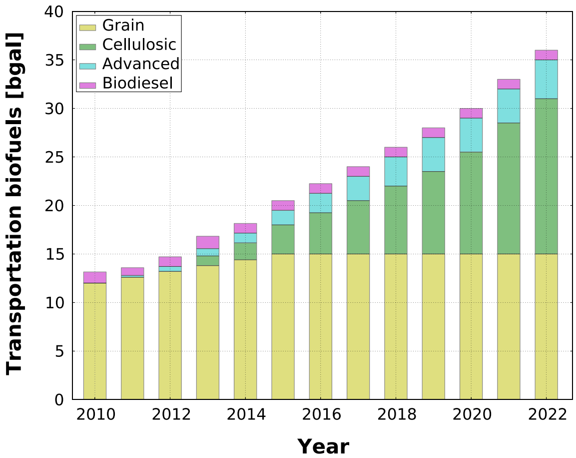

Fig. 1. The RFS2 biofuels mandate (Schnepf and Yacobucci, 2012).

upon government subsidies for survival, this economic activity has a significant impact on these local communities.

In response to interest in biofuels, US policy makers enacted the Renewable Fuel Standard (RFS) in 2005 which established mandated minimum biofuels usage requirements for the transportation sector (109th Congress of the United States of America, 2005). In 2007, the RFS mandate was revised and expanded to require the use of 36 bgal of biofuels annually by the end of 2022, which would displace expected petroleum use by 13.6 bgal (after accounting for energy density differences and the petroleum required for biofuels production) and reduce annual transportation sector GHG emissions by 138 million metric tons (MMT) (Sissine, 2010; Yacobucci and Capehart, 2008). This expanded biofuels requirement (RFS2) includes a maximum of 15 bgal of grain starch-derived ethanol, a 16 bgal minimum of cellulosic-derived biofuels, a 1 bgal minimum of biodiesel, and an additional 4 bgal minimum of other advanced biofuels (Fig. 1). Each biofuel category also has specific life cycle GHG restrictions (Schnepf and Yacobucci, 2012). The advanced biofuel category provides an innovative opportunity for the development of new alternative transportation fuels, such as drop-in replacements for gasoline, that meet the RFS2 GHG requirements. As a backup mechanism, this category may also be satisfied by either additional biodiesel or cellulosic biofuels if newly developed options are not available.

The degree to which the RFS2 mandate will be satisfied remains uncertain. This uncertainty stems from unknown future rulemaking by decision makers, technology challenges of producing biofuels at scale, infrastructure challenges in distributing the mandated biofuel, and economic uncertainties of biofuel pricing. Several studies and reports to date have begun to investigate these challenges and their impact on satisfying the RFS2 mandate. Their findings are summarized in the following paragraphs.

Currently, the Environmental Protection Agency (EPA) enforces RFS2 by issuing an annual rulemaking for national blending requirements for gasoline and diesel fuel refiners, blenders, and importers. Some flexibility is built into the mandate, such that a fuel refiner, blender, or importer that produces more than their EPA-mandated volume of biofuels in a year can sell their excess volume to others via the Renewable Identification Number (RIN) system (Schnepf and Yacobucci, 2012). Despite this flexibility, inconsistency in the regulatory enforcement of the rulemaking has created much uncertainty among the fuels community. According to the rulemaking, small volumes of cellulosic biofuels were expected to enter the fuel market beginning in 2010 (Environmental Protection Agency, 2010a). However, the EPA has waived the majority of the cellulosic component of the RFS2 biofuels requirement for 2010, 2011, and 2012 due to an anticipated lack of production capacity stemming from a lack of commercial-scale investment (Environmental Protection Agency, 2010a,b, 2012). These waivers suggest a high degree of uncertainty on the part of the biofuels industry to produce cellulosic biofuels at scale, as well as uncertainty in the rulemaking's ability to sufficiently foster and maintain an emerging cellulosic biofuels market. These waivers also weaken the enforceability of RFS2. In general, RFS2 is a difficult program to enforce as the EPA can only mandate blending rules, but cannot force consumers to use biofuels. Furthermore, the fuels market will not comply with any government regulation unless there is a strong enforcement mechanism.

To meet the RFS2 mandate in the next 10 years, a significant increase in biofuel production from cellulosic feedstocks must occur. Although several technology pathways to convert cellulosic biomass to liquid fuels are known, uncertainty exists surrounding the capacity of the biofuels industry to produce the volumes required by the RFS2 mandate (Schnepf and Yacobucci, 2012; National Research Council, 2011). Cellulosic biomass feedstocks include non-grain derived plant materials such as agricultural crop residues, wood, and grasses, among others. Biochemical and thermochemical conversion pathways are currently being researched and developed to produce biofuels from cellulosic biomass sources. Biochemical conversion of cellulosic material consists of pre-treatment, hydrolysis, fermentation, and distillation processes, but each has unique technology challenges and are active areas of research (National Petroleum Council, 2012). Thermochemical conversion pathways of cellulosic biomass involve the non-combustion volatilization of biomass to a synthetic gas, or *syngas*, that could be used as a fuel itself, or further processed into synthetic forms of conventional fuels including methanol, hydrogen, or ethanol (Gonzalez et al., 2012). This conversion pathway, commonly referred to as gasification, is still in infancy and all variations of the pathway remain active areas of research. For both biochemical and thermochemical pathways, uncertainty noted in the literature and in historical evidence indicates that these conversion methods of cellulosic biomass to ethanol are not yet to scale (Humbird et al., 2011). Although published resource assessments imply that existing cellulosic feedstock supplies are sufficient to meet the RFS2 cellulosic demand, commercial scale cellulosic ethanol conversion operations did not exist in the US in 2010 (U.S. Department of Energy, 2011; National Research Council, 2011). These technology barriers would need to be addressed in order for cellulosic biomass conversion pathways to play a significant role in fuel production for the LDV parc (where *parc* refers to the entire light-duty vehicle stock on the road). In contrast, starch grain-based biomass to ethanol conversion methods such as dry milling and wet milling are well-established. Challenges associated with a dramatic increase in demand using these pathways would likely be related to policy changes, infrastructure, or commodity economics.

Uncertainty also exists in the nation's capacity to build the infrastructure necessary to support the RFS2 mandate (Schnepf and Yacobucci, 2012). Gasoline infrastructure, consisting predominately of pipeline networks (Wang, 2012), is organized to bring fuel from coastal areas, where it is imported and/or refined, to inland states. In contrast, biofuel transportation would most likely occur in the opposite direction, with production occurring near biomass sources in the Midwest followed by transport to meet demand in populated coastal areas (US Department of Agriculture, 2007). Thus, the two fuels are unlikely to share an infrastructure network. Additionally, some biofuels, such as pure ethanol or high ethanol content gasohol blends, are chemically corrosive to gasoline pipelines and storage containers, and therefore would require a separate network or significant upgrades to existing pipelines (Schnepf, 2012). Capital costs associated with new biofuels