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Economic Impacts Resulting from Implementation of RFS2 Program

Prepared For:

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TERMINOLOGY

AEO	Annual Energy Outlook. An annual publication from the EIA that offers projections that can be used as a basis for examination and discussion of energy production, consumption, technology and market trends and the direction they may take in the future. This study used AEO2011.
CARB	California Air Resources Board
CGE	Computable General Equilibrium
Biodiesel	A type of biomass-based diesel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, and meeting the requirements of ASTM D 6751. A blend of biodiesel fuel with petroleum-based diesel fuel designated BXX, where XX represents the volume percentage of biodiesel fuel in the blend.
Biomass based diesel	Includes biodiesel and renewable diesel
Biofuel Producer or Importer	Generator of RINs at the point of biofuel production or the port of importation
Blending Percentage Standard	Ratio of renewable fuel volumes required by RFS2 and the total gallons of gasoline and diesel fuel that will be sold in the upcoming year
EIA	Energy Information Administration
EISA '07	Energy Independence and Security Act of 2007
EPA	United States Environmental Protection Agency
E0	Neat gasoline; 100% petroleum gasoline, does not contain ethanol
E10	A gasoline blend containing 10 percent ethanol by volume (E10)
E85	An ethanol/gasoline fuel blend containing a relatively high percentage of ethanol by volume and a relatively low percentage of petroleum hydrocarbons by volume. While its name connotes a blend of 85% ethanol and 15% gasoline, the ethanol content of E85 is seasonally adjusted to meet ASTM recommended specifications and to improve vehicle cold-start and warm-up performance. Following the EIA's practice, we will analyze E85 sales under the assumption that fuel sold as E85 consists of 74% ethanol and 26% gasoline by volume on a year-round average basis.

FFV	Fuel Flexible Vehicles: certified to use ethanol/gasoline blends containing up to 85 percent volume ethanol
$N_{ew}ERA$	NERA's proprietary macroeconomic model
Obligated Party	Companies that produce and/or import gasoline and/or diesel fuel
Reference Case	NERA Reference Case (no RFS2 mandate)
RFS2	Renewable Fuel Standard Per Energy Independence and Security Act of 2007
RINs	Renewable identification numbers (Credits for compliance with RFS2)
Scenario 1	NERA scenario with implementation of RFS2 and AEO Reference Case biodiesel supplies
Scenario 2	NERA scenario with implementation of RFS2 and AEO High Fuel Price case biodiesel supplies

Executive Summary

The American Petroleum Institute (API) commissioned NERA Economic Consulting (NERA) to conduct a study of the economics and compliance issues related to the implementation of the Renewable Fuel Standard (RFS2) per the Energy Independence and Security Act of 2007. NERA relied upon publically available information and NERA's proprietary economic modeling to develop the analysis. The study found that RFS2, in its current form, will likely become infeasible within the next three or four years, which would result in significant harm to the U.S. economy.

The RFS2 requires transportation fuel producers and importers (obligated parties) to incorporate specified volumes and categories of biofuels into their products annually. These mandates increase yearly, and collectively, require the use of 36 billion gallons of renewable fuels in 2022. Each year the annual total renewable fuel volume mandate is calculated as a percentage of the nation's total projected fuel consumption for the upcoming year. The renewable fuel volume obligation (RVO) for each obligated party is calculated by applying that percentage to the total annual volume of gasoline and diesel produced or imported by each obligated party during that year. Compliance with the RFS2 each year is demonstrated through "Renewable Identification Numbers" (RINs) which are unique identifiers attached to every gallon of renewable fuel produced or imported. Obligated parties submit RINs as evidence of meeting the annual RVO.

Table 1 lists the four primary mechanisms that obligated parties can use for compliance with the RFS2. In the early years of the RFS2 program, these mechanisms offered a workable means for compliance. However, as the RFS2 volume requirements increase, combined with higher vehicle fuel efficiencies, these mechanisms become less effective until the RFS2 reaches the point of infeasibility.

Table 1: Fuel Production and Blending Options for Meeting RFS2 Compliance

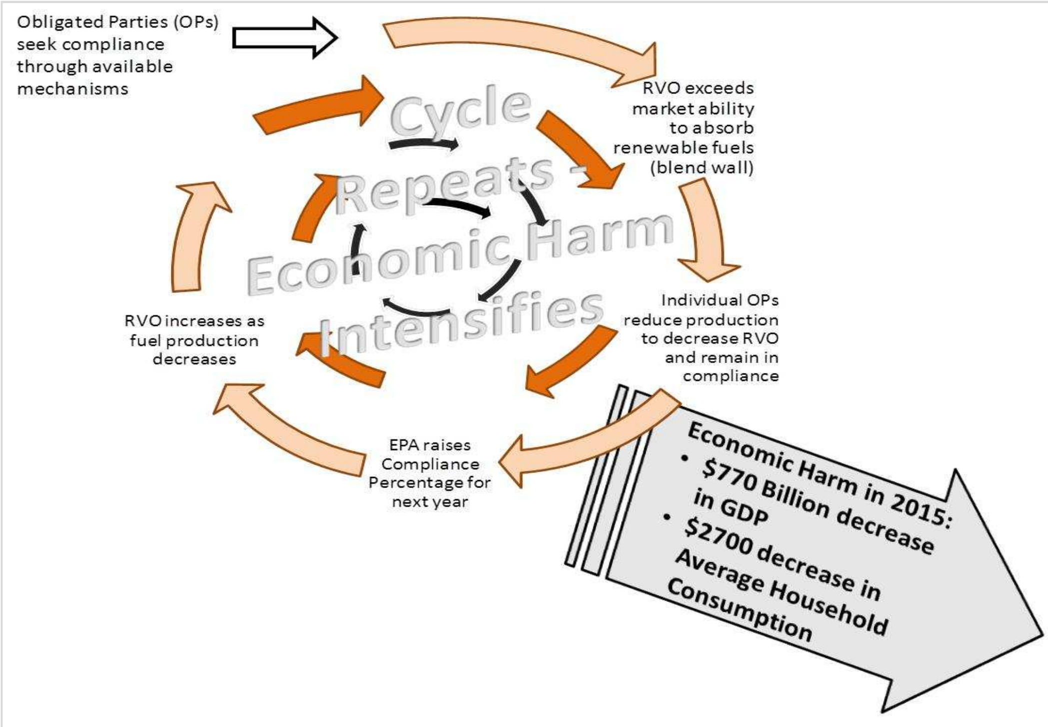
Compliance Mechanism	Limitation
Minimize production of E0	Demand for E0 will not completely disappear due to customer demand and limits on ethanol distribution
Increase production of E85	Demand for E85 will remain low due to limited E85 infrastructure, E85's low fuel economy, and consumer preference for conventional fuels
Increase use of biodiesel	The available volume of biodiesel is relatively small compared to the overall RFS2 requirement
Produce and market E15	Market penetration of E15 will be limited by vehicle warranty, retail infrastructure, misfueling, and general liability issues

As these mechanisms approach their limit, obligated parties will reach the point when biofuels cannot be incorporated into fuel products at the volumes necessary to meet the RIN obligation because of technological, infrastructure or market constraints.

This study finds that the RFS2 volume requirements will exceed the transportation fuel market's ability to absorb the biofuel volumes mandated within three to four years. At that point in time obligated parties will not be able to meet market demand for transportation fuel and still remain in compliance with the RFS2. Therefore, after exhausting all other available options for compliance, individual obligated parties, each acting independently, could be forced to reduce their RIN obligation by decreasing the volume of transportation fuel supplied to the domestic market – either by reducing production or exporting.

As domestic fuel supplies decrease, large increases in transportation fuel costs would ripple through the economy imposing significant costs on society. More specifically, as the RFS2 mandate is ratcheted up every year, the fuels market will be pushed into a death spiral shown in Figure 1. The death spiral depicts the economic harm that occurs as individual obligated parties act to remain in compliance with the program. Once the blend wall has been reached, the annual increase in the RVO results in decreased fuel availability and increased fuel costs to society. These increased fuel costs have a broad impact across the economy.

Figure 1: Economic Impact of Hitting the RFS2 Blend Wall: The Death Spiral



This process repeats itself yearly. As domestic supply continues to decline, the blending percentage obligation becomes increasingly untenable. Obligated parties rely on RINs acquired and carried forward from earlier years to meet compliance obligations. However, the findings and analysis of this report indicate that by 2015-2016 compliance with the RFS2 in its current form will likely be infeasible, which would result in significant damage to the economy.

The death spiral impact is seen most acutely in the diesel fuel market. The tightening of the diesel supply (up to 15% decline in 2015) causes large fuel cost increases to ripple through the economy, adversely affecting employment, income, consumption, and GDP. By 2015, the adverse macroeconomic impacts include a $770 billion decline in GDP and a corresponding reduction in consumption per household of $2,700.

I. Introduction

The American Petroleum Institute (API) commissioned a two-phase study of the economics and compliance issues resulting from the implementation of the Renewable Fuel Standard (RFS2) per the Energy Independence and Security Act of 2007. The RFS2 requires transportation fuel produces and importers (obligated parties) to incorporate specified volumes and categories of biofuels into their products annually. These mandates increase each year, and collectively, require the use of 36 billion gallons of renewable fuels in 2022. Each year the annual total renewable fuel volume mandate is calculated as a percentage of the nation's total projected fuel consumption for the upcoming year. The renewable fuel volume obligation (RVO) for each obligated party is calculated by applying that percentage to the total annual volume of gasoline and diesel produced or imported by each obligated party during that year. Compliance with the RFS2 each year is demonstrated through "Renewable Identification Numbers" (RINs) which are unique identifiers attached to every gallon of renewable fuel produced or imported. Obligated parties submit RINs as evidence of their compliance with the RVO.

A. Phase 1

API retained Charles River Associates (CRA) to conduct Phase I of the study.[1] The work concluded that the increasing volumes mandated by the RFS2 will eventually exceed the market's ability to absorb ethanol into petroleum fuel. That is, the RVO will eventually exceed the maximum feasible level of renewable fuel that can be contained on average in a gallon of petroleum transportation fuel given technological, behavioral, and infrastructure constraints. Using EIA's Annual Energy Outlook AEO 2011, the study estimated that the so-called blend wall (maximum concentration of ethanol of 10% that can be blended in gasoline and used by conventional gasoline-powered motor vehicles) will be reached by 2013.

To comply with the RFS2 mandates, obligated parties have increased production of E10 and E85 while minimizing production of E0 (pure gasoline). To the extent that biodiesel is available, obligated parties have blended biodiesel to produce B5. As the RFS2 mandated volumes for renewable fuels increase, however, these mechanisms reach their limit.

[1] Phase I study report: "Impact of the Blend Wall Constraint in Complying with the Renewable Fuel Standard," Charles River Associates, November 2, 2011.

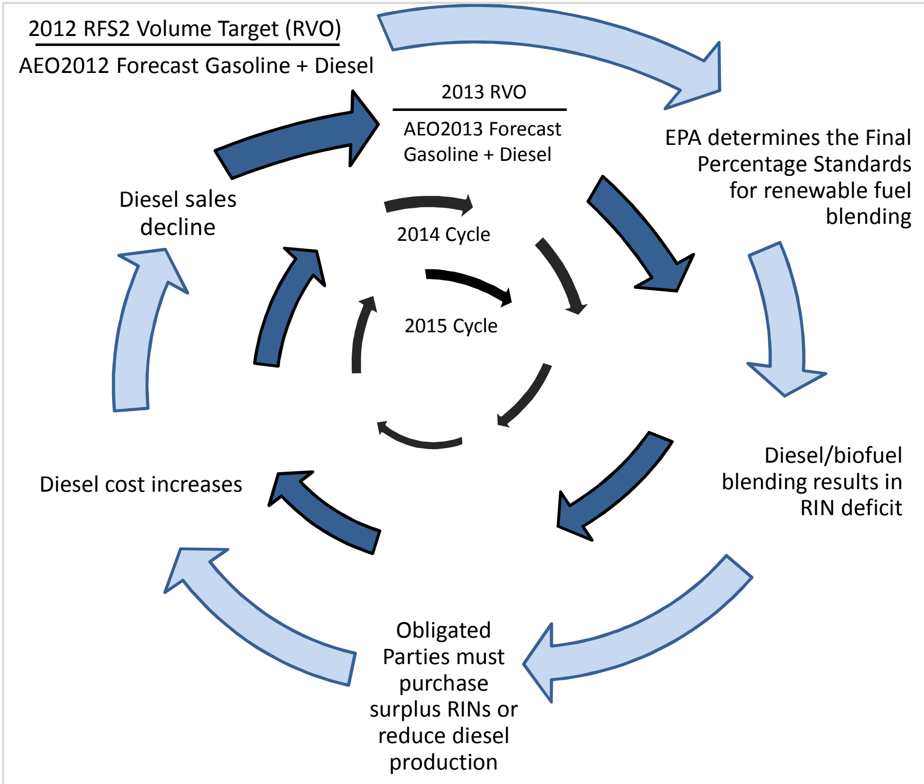
Table 2: Fuel Production and Blending Options for Meeting RFS2 Compliance

Compliance Mechanism	Limitation
Minimize production of E0	Demand for E0 will not completely disappear due to customer demand and limits on ethanol distribution
Increase production of E85	Demand for E85 will remain low due to limited E85 infrastructure, E85's low fuel economy, and consumer preference for conventional fuels
Increase use of biodiesel	The available volume of biodiesel is relatively small compared to the overall RFS2 requirement
Produce and market E15	Market penetration of E15 will be limited by vehicle warranty, retail infrastructure, misfueling, and general liability issues

The Phase 1 study concluded that as obligated parties exhaust these methods of compliance, they will eventually be forced to either decrease the production volumes or export product in order to reduce their individual biofuel obligation and meet RFS2 volume percentage requirements. These market shifts will initially result in a tightening of the diesel fuel supply followed by subsequent years of reductions in both the gasoline and diesel fuel supply. The shrinking domestic petroleum fuel supply coupled with expanding RFS2 requirements would result in making compliance increasingly more difficult and lead to significant economic impacts.

In Figure 2 this effect is depicted as a death spiral of the diesel fuel market. Each year obligated parties must absorb increasing volumes of biofuels into declining volumes of petroleum fuel without exceeding the approved percent blending limits. In each of the years under review in this study, the previous year's reduced forecast for diesel fuel demand exacerbates compliance hurdles for the following year, resulting in economic harm to trucking and commerce first and eventually impacting the U.S. economy as a whole.

Figure 2: Death Spiral Effect on the Diesel Fuel Market from the RFS2



This process repeats itself yearly. As domestic supply continues to decline, the blending percentage obligation becomes increasingly unattainable. Obligated parties rely on RINs acquired and carried forward from earlier years to meet compliance obligations. However, the findings and analysis of this report indicate that by 2015-16 compliance with the RFS2 would become infeasible and result in significant damage to the economy.

Phase II of the study builds on the findings of Phase I and quantifies the economic impacts of complying with the RFS2 requirements.

B. Phase II

For Phase II of the study, API retained NERA Economic Consulting (NERA) to analyze the potential impacts on the transportation fuels market and the U.S. economy resulting from complying with the RFS2. NERA relied upon publically available information and NERA's proprietary economic modeling to develop the analysis.

NERA used two proprietary models: NERA's transportation fuel model and the N_{ew}ERA macroeconomic model. These models were run[2] to quantify the economic impacts from implementation of the RFS2. Specifically, the transportation fuel model estimates the amount of fuel produced for and consumed by the transportation sector, and explicitly estimates the demand for E0, E10, E85, B0, and B5. The N_{ew}ERA macroeconomic model[3] simulates all economic interactions in the U.S. economy, including those among industry, households, and the government.

The macroeconomic impacts of the RFS2 mandate on the U.S. economy were estimated through the year 2015. These results show large increases in transportation fuel costs and disruptions to the transportation fuel supply that will ripple adversely through the economy. From 2012 to 2014, the higher transportation diesel fuel costs will have the biggest and most immediate impact on the economy. The cost to move raw materials and finished goods about the country will increase. This increased cost will be passed through to consumers in the form of higher costs on finished goods and services and, as a result, consumption per household will drop. Although labor earnings initially rise, such an increase is modest compared to the loss in consumption, as labor earnings are unable to offset the higher costs for goods. In the near term, investment and production is temporarily accelerated in anticipation of rising prices and GDP increases, but this shift is unsustainable and by 2014, GDP declines by more than $250 billion.

In 2015, the economic impacts worsen. In addition to the negative impact of higher costs for finished goods and services caused by rising diesel fuel costs, gasoline costs increase as a result of RSF2. Consumers are left with fewer dollars to spend on other goods and services, resulting in lower consumption. Lower levels of consumption lead to declining production of goods and services that consumers would have otherwise purchased. In 2015, the consumption per household declines by about $2,700 per year from baseline levels, with total U.S. consumption declining by about $340 billion. Since there is lower demand for finished goods

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2 The macroeconomic model was connected to the transportation fuel model through a one-way link in which the macroeconomic model incorporated the fuel cost increases of the transportation model.

3 The N_{ew}ERA macroeconomic model uses the resulting scenario fuel prices from the transportation fuel model. Then the N_{ew}ERA macroeconomic model is run to assess the economy wide impacts of the changes in fuel prices. Since the transportation model becomes infeasible in 2015 under Scenario 1, we could not run the N_{ew}ERA macroeconomic model over the 2012 to 2015 time horizon. Therefore, the following impacts are reflective of Scenario 2, but these should be considered as a lower bound of what might occur.

and services, the need for workers to provide those goods and services drops. As a result of the smaller size of the economy, workers would earn $580 billion less (Table 3). These negative impacts are also reflected by the loss in GDP of $770 billion dollars.

Table 3: Changes in Consumption, Labor Income, and GDP Relative to Baseline (2010$)

	2012	2013	2014	2015
Change in Average Consumption per Household	-$1,200	-$1,200	-$1,300	-$2,700
Change in Consumption (Billions)	-$150	-$140	-$160	-$340
Change in Labor Income (Billions)	$24	$42	$27	-$580
Change in GDP (Billions)	$43	$50	-$270	-$770

Source: NERA N_{ew}ERA model results.

The remainder of this report provides details on the models used, the reference cases, and the detailed results of the modeling analysis. The appendices provide descriptions of the RFS2 program and model details.

II. Background

A. RFS2

Congress first established a Renewable Fuel Standard (RFS) in 2005 with the enactment of the Energy Policy Act of 2005 (EPACT). Two years later, Congress passed the Energy Independence and Security Act of 2007 (EISA '07) which superseded and greatly expanded the biofuels blending mandate. This expanded RFS is referred to as RFS2, which applies to all transportation fuel used in the United States—including diesel fuel intended for use in highway motor vehicles, non-road, locomotive, and marine diesel.[4] RFS2 introduces four new major distinctions from RFS:

1. RFS2 increases the mandated usage volumes and extends the time frame over which the volumes ramp up to 2022;
2. RFS2 subdivides the total renewable fuel requirement into four separate but nested categories—total renewable fuels, advanced biofuels, biomass-based diesel, and cellulosic biofuel—each with its own volume requirement or standard;
3. Biofuels qualifying under each nested category must achieve certain minimum thresholds of lifecycle greenhouse gas (GHG) emission performance, with certain exceptions applicable to existing facilities; and
4. All renewable fuel must be made from feedstocks that meet the new definition of renewable biomass, including certain land use restrictions.

1. Nested Mandates

Because of the nested nature of the biofuel categories, any renewable fuel that meets the requirement for cellulosic biofuels or biomass-based diesel is also valid for meeting the overall advanced biofuels requirement. Thus, any combination of cellulosic biofuels or biomass-based biodiesel would count toward the advanced biofuels mandate, thereby reducing the potential need for imported sugarcane ethanol to meet the "other" advanced biofuels mandate. Similarly, any renewable fuel that meets the requirement for advanced biofuels is also valid for meeting the total renewable fuels requirement. As a result, any combination of cellulosic biofuels, biomass-

[4] Heating oil, jet fuel, and fuels for ocean-going vessels are excluded from RFS2's national transportation fuel supply; however, renewable fuels used for these purposes may count towards the RFS2 mandates.

based biodiesel, or imported sugarcane ethanol that exceeds the advanced biofuel mandate would reduce the potential need for corn-starch ethanol to meet the overall mandate.

2. Waivers

The EPA Administrator has the authority to waive the RFS requirements, in whole or in part, if, in his/her determination, there is inadequate domestic supply to meet the mandate, or if "implementation of the requirement would severely harm the economy or environment of a State, a region, or the United States."[5] Further, under certain conditions, the EPA Administrator may waive (in whole or in part) the specific carve-outs for cellulosic biofuel and biomass-based diesel fuel.[6] Furthermore, EISA '07 requires that EPA evaluate and make an appropriate market determination for setting the cellulosic standard each year.

3. Implementation

Under EISA '07, the U.S. Environmental Protection Agency (EPA) is responsible for implementing regulations to ensure that transportation fuels sold in the United States contain a minimum volume of renewable fuels in accordance with the four nested volume mandates of the RFS2. Compliance with the RFS2 is demonstrated by the use of RINs.[7]

A RIN is generated by a biofuel producer or importer at the point of biofuel production or the port of importation. Each gallon of ethanol generates one RIN. Biodiesel generates 1.5 RINs per gallon. RIN generators must register with the EPA. After a RIN is created by a biofuel producer or importer, it must be reported to the EPA. RINs are transferable.

Congress determines the total renewable fuel volume that must be incorporated into the nation's fuel supply each year—referred to as a RVO. The EPA translates the RVO into blending percentage standards that are used by obligated parties to determine their individual

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5 Clean Air Act section 211(o)(7)(A)(i).

6 For example, in February 2010 EPA waived most of the 2010 cellulosic biofuel carve-out—EISA '07 had set the mandate at 100 million gallons but EPA lowered the requirement to 6.5 million gallons, more than 90% less than scheduled by EISA '07. Then, in July 2010, EPA lowered the 2011 RFS for cellulosic biofuels to a range of 5 to 17.1 million gallons. EPA cited a lack of current and expected production capacity, driven largely by a lack of investment in commercial-scale refineries. In 2011, EPA waived more than 98% of the cellulosic biofuel volume EISA "07 required for 2012.

7 For tracking purposes, each RIN has a unique 38-character number that is issued (in accordance with EPA guidelines). Each RIN identifies which of the four RFS categories—total, advanced, cellulosic, or biodiesel—the biofuel satisfies. In addition, a biodiesel RIN has an equivalence value of 1.5 when being used as an advanced biofuel.

RVO.[8] This percentage standard represents the ratio of renewable fuel volumes required by RFS2 to the projected total gallons of gasoline and diesel fuel that will be sold in the upcoming year. The EPA relies on projections from the Department of Energy's Energy Information Administration (EIA) for the information to estimate the expected total gallons sold.

Companies that refine or import gasoline or diesel transportation fuel for the retail market are obligated to include a quantity of biofuels equal to the percentage of their total annual fuel sales. At the end of the year, each obligated party must have enough RINs to show that it has met its share of each of the four mandated standards.

If an obligated party has met its mandated share and has acquired surplus RINs, it can sell the extra RINs to another party or it can hold onto the RINs for future use (to be used the following year, but the previous year's RINs can comprise only up to 20% of the current year's obligation).[9]

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8 The blending percentage standard is computed as the total amount of renewable fuels mandated under RFS2 to be used in a given year expressed as a percentage of expected total U.S. transportation fuel use. This ratio is adjusted to account for the small refinery exemptions. A separate ratio is calculated for each of the four biofuel categories.

9 A RIN would not be viable for any year's RVO beyond the immediately successive year; thus giving it essentially a two-year lifespan. For any individual company, up to 20% of the current year's RVO may be met by RINs from the previous calendar year.

III. Description of the Models

This study used NERA's proprietary transportation fuel model and its $N_{ew}ERA$ macroeconomic model. These models were run interactively[10] to quantify the economic impacts from RFS2 that are reported in this study. This section describes both models. A more detailed description of the models, including a model formulation is provided in Appendix B.

A. Transportation Fuel Model

The transportation fuel model is a partial-equilibrium model designed to estimate the amount of fuel produced for and consumed by the transportation sector. The model maximizes the discounted present value of household consumption (a measure of household value) subject to meeting the RFS2 program fuel requirements and satisfying the transportation sector's demand for fuel while not violating any transportation sector infrastructure constraints.

The model is calibrated in the near term to the EIA's Short-Term Energy Outlook (STEO) for September 2011 and in the long term to the AEO 2011 forecast, with a few minor adjustments to ensure that the E10 blend wall is not violated.

1. The Transportation Fuel Model is designed to Model RFS2 Program Characteristics

The transportation fuel model was customized to simulate the impacts resulting from the RFS2 program. The model solves in one-year time steps, and has a flexible time horizon. For purposes of this analysis, the first endogenous year is 2012 and the last year is 2015. The model solves for the demand of the following finished fuels: E0 (100% petroleum gasoline), E10 (gasoline containing at most 10% ethanol by volume), E85 (assumed to contain 74% ethanol by volume), and diesel fuel may contain up to 5% biomass based diesel or B5. The model also solves for the following fuel components used in the production of the above finished fuels: petroleum gasoline, corn ethanol, sugar ethanol, cellulosic ethanol, petroleum diesel, and biodiesel.

The model combines the six fuel components into the four finished fuels, which can be consumed by motor vehicles subject to the following constraints:

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[10] The macroeconomic model was connected to the transportation fuel model through a one-way link.

- Minimum E0 use held to 5% of total transportation fuel consumption to represent incomplete market conversion to E10 and preference of some consumers for E0;
- Conventional vehicles can consume either E0 or E10;
- Flexible fuel vehicles (FFVs) can use E0, E10 or E85; and
- Commercial trucks/buses, ships, and trains are allowed to use up to a 5% blend of biodiesel.

2. RFS/RIN Constraints:

The model accounts for the minimum annual volume of biofuel sales required under the RFS2 program by including constraints on three types of biofuels:

- Biomass-based diesel;
- Advanced biofuel (includes cellulosic biofuels, biomass-based diesel, and sugar ethanol); and
- Renewable fuel (includes advanced biofuel and corn ethanol).

For this analysis, we assume that cellulosic biomass will continue to be commercially available only in very limited quantities, and as a result, EPA would continue to grant a waiver. This assumption avoids the debate about the economic and technical feasibility of producing cellulosic fuel[11] because this analysis assumes ample supplies of corn and sugar ethanol to meet the RFS2 mandates. As a result, there is no need for cellulosic ethanol to meet the non-cellulosic RFS2 targets.

As discussed in detail in Appendix B, the fuel supply curves capture all pertinent technological issues (penetration rate, availability, and cost) for the different fuels. Similarly, the fuel demand curves capture the loss in utility from having to reduce travel and also the loss in welfare from fuel scarcity. Different scenarios were modeled, as discussed in section E. The change in economic activity between the scenarios and the baseline provides the economic impacts of the RFS2 policy.

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[11] There is a secondary effect of assuming no measurable supplies of cellulosic biomass. Assuming no significant amount of cellulosic biomass production necessitates the production of additional amounts of biodiesel and sugar-based ethanol to meet the advanced biofuel requirement, and this affects costs.

The model also incorporates constraints on the availability of various finished fuels to account for both consumer acceptance and infrastructure issues. The sales of E85 are limited based on these issues. Biodiesel sales are limited by supply of biodiesel feedstocks.

B. N_{ew}ERA Macroeconomic Model

The N_{ew}ERA macroeconomic model is a forward-looking dynamic computable general equilibrium model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government. The macroeconomic and energy forecasts that are used to project the benchmark year going forward are calibrated to AEO 2011 produced by the EIA. Because the model is calibrated to an internally-consistent energy forecast, the use of the model is particularly well suited to analyze economic and energy policies and environmental regulations.

For this study, the N_{ew}ERA model runs from 2012 to 2015 in one-year increments. The model includes five energy and seven non-energy sectors: energy sectors include crude oil, oil refining, natural gas extraction and distribution, coal, and electricity; the non-energy sectors include agriculture, commercial transportation (excluding trucking), energy intensive sectors, manufacturing, motor vehicle production, services, and trucking.

The macroeconomic model incorporates all production sectors and final demands of the economy and is linked through terms of trade. The effects of policies are transmitted throughout the economy as all sectors and agents in the economy respond until the economy reaches equilibrium. The ability of the model to track these effects and substitution possibilities across sectors makes it a unique tool for analyzing policies such as those involving energy and environmental regulations. These general equilibrium substitution effects, however, are not fully captured in a partial-equilibrium framework or within an input-output modeling framework. The smooth production and consumption functions employed in this general-equilibrium model enable gradual substitution of inputs in response to relative price changes thus avoiding “all-or-nothing” solutions.

Business investment decisions are informed by future policies and outlook. The forward-looking characteristic of the model enables businesses and consumers to determine the optimal savings and investment while anticipating future policies with perfect foresight. The alternative approach on savings and investment decisions is to assume agents in the model are myopic, and thus have no expectations for the future. Though both approaches have their limitations, the latter approach can lead the model to produce inconsistent or incorrect impacts from an announced future policy.

C. Model Integration

The economic impacts of the RFS2 program were determined using the following methodology:

1. Using the transportation fuel model, the baseline and scenarios were run to determine the effect on fuel prices resulting from the RFS2 requirements for increased use of biofuels. The imposition of the RFS2 program leads to changes in fuel prices from the EIA baseline.
2. Using the N_{ew}ERA macroeconomic model, the resulting changes in fuel prices were translated into taxes (or subsidies) on gasoline and diesel that yield the same fuel price changes as seen in the transportation fuel model.

D. Analytical Methodology

All cases were run using NERA's transportation fuel model, which allowed us to simulate the dynamics of RFS2 compliance and the use of surplus RIN carryovers, and the methodology that EPA uses each year to determine the minimum percentages of the different categories of biofuels delineated in the RFS2 standard that fuel suppliers must use.

The transportation fuel model determined the impact of the RFS2 mandate on the quantities of finished gasoline (E0, E10, and E85) and diesel consumed in the transportation sector. In addition, the model calculated volumes of individual biofuels blended in the finished gasoline (corn ethanol, sugar ethanol, and cellulosic ethanol) and diesel. The N_{ew}ERA macroeconomic model then determined the impact on the U.S. economy of meeting the RFS2 mandate. The results were expressed in terms of well-known economic parameters: changes in consumer purchasing power, GDP, and labor earnings.

Implementation of the RFS2 may create a dynamic that can be characterized as a "death spiral," in which higher costs in the current year lead to lower demand, which in turn lead to higher costs in the next year and so on. NERA's transportation fuel model represents this process by solving in a recursive dynamic fashion. That is, the model minimizes the cost of compliance for the current year, through the use and value of surplus RINs that were carried forward. Therefore, the years are linked through the RINs. For example, the available surplus RINs at the beginning of 2012 represents 1.69 billion gallons of renewable fuel, which is the estimated amount of surplus RINs at the end of 2011 based on AEO 2011 fuel consumption data. After defining the RINs available at the beginning of 2012 and calibrating the model's supply and demand curves to the AEO's forecasted 2012 values, the model was solved with the RFS2 constraints and other infrastructure constraints for the year 2012.

The RINs available at the end of 2012, or the number of RINs carried forward to 2013, equals the RINs available at the beginning of 2012 (1.69 billion gallons) plus the difference between the number of RINs generated and the number of RINs submitted for compliance during 2012. The model will store RINs or use RINs in 2012 until either the value of a surplus RIN equals the marginal cost of complying with the RFS2 mandate or surplus RINs are depleted. This process is repeated for each successive year.

If any of the RFS2 or infrastructure constraints bind, then the average fuel price may rise to cause a switch in fuel consumption patterns which results in an increase of the percentage of renewable fuel sales to the level required by the RFS2 constraint. An increase in average fuel prices would cause a drop in the equilibrium level of fuel consumption from the EIA's forecast. The value of the elasticity of demand has a significant effect on the relationship between the increase in fuel price and decline in fuel demand. The more elastic the demand curve, the less prices need to move to induce consumers to reduce their demand and thus the easier and less costly it is to meet the RFS2 targets. As the absolute value of the elasticity of demand declines, demand becomes more inelastic and the cost of compliance increases.

Once finished with 2012, the model then solves for 2013. However, instead of using the EIA's forecast for 2013 energy consumption, the values to which the model calibrates its energy consumption are adjusted based on the model's 2012 solution values for energy consumption. Assuming that the RFS2 constraint binds for 2012, the forecasted fuel sales volumes will differ in 2012 from that of the EIA's forecast.

To be conservative regarding the costs of the RFS2 mandate, we allow surplus RINs to be exhausted over the model horizon. Retaining RINs for later years would raise program costs in the near term. This is because the transportation sector would need to consume higher percentage levels of biofuels in the near term instead of relying on the RINs generated in prior years to assist the sector in complying with RFS2. Allowing the RINs to be consumed in the near term (*e.g.*, 2014-2015 timeframe) rather than retaining RINs after 2015 allows obligated parties to meet the mandates with lower volumes of renewable fuels and hence reduces the burden of the policy.

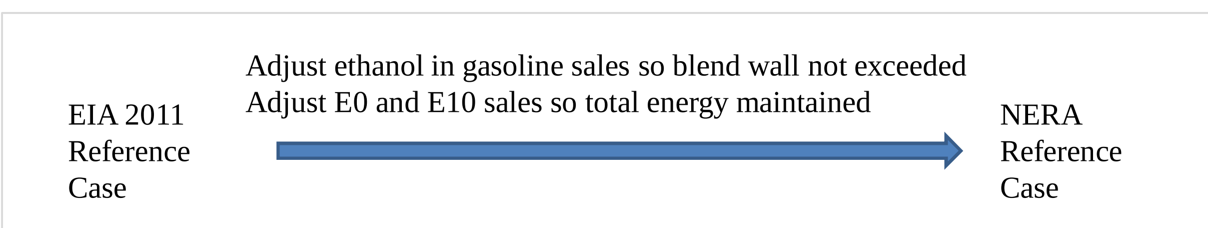
E. Description of Reference Case and Two Modeling Scenarios

To analyze the economic impacts of the RFS2 mandate, it was necessary to develop a Reference Case in which the RFS2 was not in force and a set of scenarios in which RFS2 was assumed to be fully implemented. Then by comparing the scenarios to the Reference Case it is possible to isolate the effects of the RFS2 mandate. This section first discusses the construction of the Reference Case and then describes the assumptions underlying each of the two scenarios.

1. Reference Case

The Reference Case is based upon AEO 2011 projections of transportation fuel supply, demand and prices, but with some modifications (Figure 3). Unlike EIA, our Reference Case limits the amount of ethanol in the gasoline pool to not violate the blend wall, and reduces the level of E0 sales. Our Reference Case includes the AEO 2011forecast for both biodiesel (which is less than that required under RFS2) and E85 consumption. Although the mix of fuel in our Reference Case differs from that in the EIA's AEO 2011 Reference Case, we maintain consistency with EIA's forecast of total energy (or vehicle-miles traveled, VMT) consumed in the transportation sector.

Figure 3: Development of the NERA Reference Case

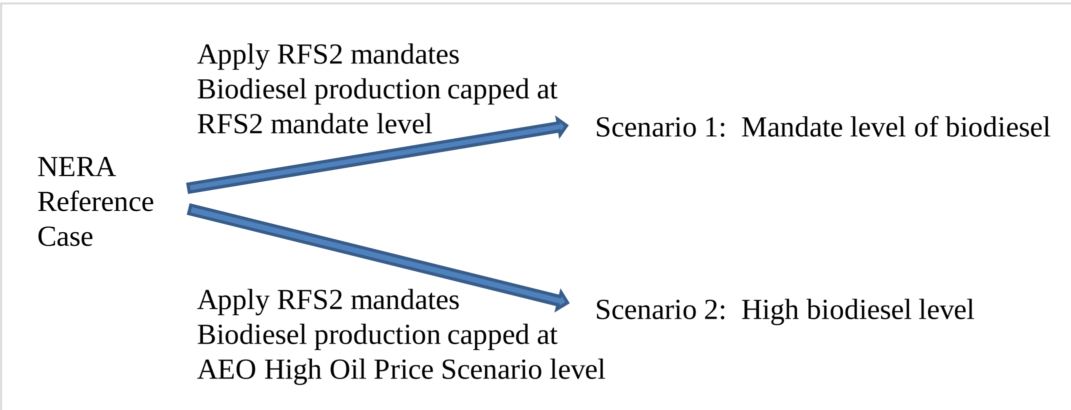


2. Modeling Scenarios

Our scenarios (Figure 4) used the same assumptions as the Reference Case with the added constraint that in each year obligated parties must comply with the RFS2 program requirements while still not violating the blend wall. A gallon of biodiesel is worth 1.5 RINs.

Also, the volume of biodiesel sales forecast in the EIA's Reference Case can only make up a percentage of biodiesel in diesel that is far below the B5 blending limit. Therefore, one way for obligated parties to increase the percentage of biofuels in their total fuel sales is to increase the amount of biodiesel they blend with conventional diesel. However, biodiesel production levels are quite uncertain.

Figure 4: Characterization of Scenarios 1 and 2



NERA developed two scenarios that differed only in their estimate of the availability of biodiesel supplies in the next four years (2012 through 2015). Scenario 1 limited use to no more than that proposed by EPA in their 2012 RFS2 NPRM. Scenario 2 limited biomass based diesel use to that forecast in the EIA AEO 2011 High Oil Price Scenario. These estimates are intended to bracket the likely range of biomass based diesel availability. The range of biomass based diesel availability is shown in Table 4.

- Scenario 1 – Biomass based diesel production is capped at the limit proposed by EPA in their 2012 RFS2 NPRM. This level reflects the levels used in the Phase I analysis.
- Scenario 2 - Biomass based diesel production capped at level in AEO 2011 High Oil Price Case.

Table 4: Range of Biomass Based Diesel Availability (Billions of Gallons per Year)

	2012	2013	2014	2015
Reference Case	0.92	1.07	1.07	1.23
Scenario 1	1.00	1.28	1.28	1.28
Scenario 2	1.35	1.74	1.66	1.90

Source: NERA analysis and EIA's Annual Energy Outlook 2011.

F. Model Parameters

1. Fuel Prices

All fuel prices are national, annual averages over multiple grades of fuel. Our Reference Case prices for finished products (gasoline and diesel) are the same as those forecast in the AEO 2011 Reference Case. The NERA Reference Case prices for individual types of biofuels were developed using a variety of sources and are expressed relative to petroleum gasoline or diesel prices. These relative prices are shown in Table 5, and the logic and sources upon which these relative prices are based are described below.[12]

Table 5: Reference Case Fuel Price Ratios for Blended Gasoline and Diesels (Ratio on a GGE[13] Basis of Biofuel to Conventional Fuel)[14]

	2010	2011	2012	2013	2014	2015
Gasoline	1.00	1.00	1.00	1.00	1.00	1.00
Corn Ethanol	1.86	1.78	1.72	1.61	1.58	1.49
Sugarcane Ethanol	2.08	2.00	1.92	1.81	1.77	1.67
Cellulosic Ethanol	2.62	2.48	2.41	2.23	2.13	2.01
Diesel	1.00	1.00	1.00	1.00	1.00	1.00
Soy-Based Biodiesel	1.74	1.66	1.7	1.66	1.65	1.64

Source: EIA's AEO 2011, EIA, California Energy Commission, IHS Glocal Insight, American Trucking Association, and NERA analysis.

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12 The gasoline and diesel prices are taken from the AEO 2011 forecast.

13 Gasoline gallon equivalent basis; fuels GGE are adjusted by relative heating value to petroleum gasoline.

14 All price ratios are national, annual averages over multiple grades of fuel. For gasoline, the grades include regular unleaded, 89 octane unleaded, and premium unleaded.

Corn Ethanol:

- Ratio of corn ethanol to gasoline is from the AEO 2011 Reference Case, Table A12. We assumed a corn price equal to the average $/bushel price from January 1, 2008 through September 1, 2011 (or $5.00/bushel). We took the capital, operations, and maintenance costs from the EIA.[15] Summing up all of these costs yielded the forecasted price for corn ethanol.
- Sugar Ethanol: Ratio of sugar ethanol prices to gasoline prices taken from California Energy Commission statistics.[16]
- Cellulosic Ethanol: Ratio of cellulosic ethanol prices to gasoline prices based on EIA's cost build up.[17] To estimate this cost, we averaged two EIA forecasts – one based on the capital cost for cellulosic ethanol and the other based on the capital cost for biodiesel gasification. However, the future cost of cellulosic ethanol is uncertain.[18]
- Soy-Based Biodiesel: Ratio of soy-based biodiesel to petroleum diesel prices taken as average of historical spot prices. We calculated the averages based upon three sources: IHS Global Insight, the American Trucking Association's August 2011 comments on the EPA's proposed RFS2 rule, and the average ratio of spot SME B100 to spot ultra-low sulfur petroleum diesel from 2009 through 2011.[19]

2. Supply Elasticities

In addition, supply elasticities were derived by using fuel price and fuel supply information from EIA's AEO 2011 Reference and High Oil Price Cases. These two cases provided time series for the prices and quantities of the different fuels. The price elasticity of

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15 Statton, Mac, "Development of Production Costs as a Driver for the National Energy Modeling System," Energy Information Administration, Presentation at International Fuel Ethanol Workshop, June 29, 2011.

16 California Energy Commission, "2011 Integrated Energy Policy Report," February 2012.

17 Statton, Mac, "Development of Production Costs as a Driver for the National Energy Modeling System," Energy Information Administration, Presentation at International Fuel Ethanol Workshop, June 29, 2011.

18 Because we assume the RFS mandate for cellulosic ethanol will be waived, cellulosic ethanol is likely to be irrelevant in our analysis as long as its price is sufficiently greater than that of sugar ethanol, for sugar ethanol will be the ethanol of choice to meet the advanced biofuels mandate, and corn and sugar ethanol will be used in the production of E10 and E85 to help meet the overall biofuel requirement.

19 Kruse, John, "Biodiesel Production Prospects for the Next Decade," IHS Global Insight's Agriculture Group, March 2011; Moskowitz, Richard, "American Trucking Associations' comment on the EPA's proposed Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards," August 2011; and Chicago spot prices for ultra-low sulfur diesel and B100.

supply for each fuel is derived by dividing the percentage change in quantity of fuel demanded by the percentage change in fuel price. The percentage change in quantity and price are computed by comparing the difference between the fuel consumed and the price of fuel, respectively, in the AEO High Oil Price and Reference Cases. The elasticity of supply varies slightly from year to year, but on average, the elasticity of supply is about 0.4 for corn ethanol and 1.2 for sugar ethanol and soy-based biodiesel. The elasticity for petroleum fuels is 0.8.[20]

3. Demand Elasticities

The model has a demand curve for each finished fuel – E0, E10, E85, and diesel. The functional form of these curves is identical to that of the fuel supply curves. For the demand curves, the elasticity is the fuel's own-price elasticity of demand. Because this analysis concerns itself only with the next few years, the demand curves' elasticity equaled that of Dahl's estimate for short-term elasticity of -0.1.[21]

4. E85

Our characterization of the potential for E85 sales in the Phase II research is built upon the initial research on E85 performed as part of the Phase I study. The Phase I study evaluated the different factors affecting E85 demand. The Phase I research concluded that future demand for E85 is not limited by the number of FFVs, but instead factors such as consumer reluctance to purchase a new fuel and lack of infrastructure. Consumer reluctance stems from the lower fuel economy and limited range of E85. Economic theory suggests and the EPA acknowledges, E85 would have to be priced at a discount to gasoline to induce cost conscious FFV owners to buy E85 instead of gasoline. Progress in overcoming the lack of retail infrastructure is likely to be slowed by the relatively high investment costs and uncertain returns facing the parties that will be required to install the necessary infrastructure, particularly in the case of the numerous small and independent business people that own individual retail fuel stations.

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[20] Paltsev, Sergey, John M. Reilly, Henry D. Jacoby, Rishard S. Eckaus, James McFarland, Marcus Sarofim, Malcolm Asadoorian, and Mustafa Babiker, "The MIT Emissions and Prediction and Policy Analysis (EPPA). Model Version 4," August 2005.

[21] Dahl, C.A., "A survey of energy demand elasticities for the developing world," *Journal of Energy and Development* 18(I), 1—48, 1994.

For the Phase II analysis, our estimate of potential E85 availability is constructed based upon an optimistic set of assumptions about the issues affecting E85 sales. We assumed that there were no consumer acceptance issues. We assumed that new E85 retail stations would be strategically located in areas proximate to where FFV vehicles operated so that there was no distance penalty for FFVs to travel to an E85 station.

We based our estimates of potentially available E85 solely upon how quickly new E85 retail stations could be built. The Phase I research identified historical data on the level of new station construction. Table 6 shows the number of new stations built by year for the period from 2005 through 2011. During this period on average, there were about 340 stations built annually and the growth rate for new stations declined. For the period from 2012 through 2015 we optimistically assumed that new E85 station construction would grow at a rate of 25% per year. We also assumed that the volume of E85 sales per station would grow about 2.5 times during the period from 2012 to 2015. Table 7 presents our projection for maximum E85 sales as compared with the EIA's forecast of expected E85 sales.

Table 6: Number of E85 Stations Built Annually (2005 through 2011)

	# of E85 Stations	
	Total	**Annual Change**
2005	436	
2006	762	326
2007	1,208	446
2008	1,644	436
2009	1,928	284
2010	2,142	214
2011	2,442	300

Source: United States Department of Energy, Alternative Fuels Data Center, http://www.afdc.energy.gov/afdc/data/docs/alt_fueling_stations_fuel.xls.

Table 7: Sales of E85 (Billions of Gallons)

	2012	2013	2014	2015
AEO 2011 Forecast	0.06	0.07	0.08	0.09
Maximum Potential E85 Sales	0.54	0.99	1.7	2.6

Source: EIA's AEO 2011, NERA N_{ew}ERA model results.

5. RIN Banking

RIN banking in this report represents how surplus RINs can be carried from one compliance period to the next by an obligated party. Based upon EIA's AEO 2011 Table 11, we estimated that as of the beginning of January 2012, there were collectively 1.69 billion surplus RINs available. We refer to these RINs as the initial inventory of RINs available for compliance.

To arrive at this estimate, we first analyzed how many RINs were available at the end of 2010, which was the first year the policy was in effect and then assessed how many RINs were carried forward from 2010 to 2011 and then from 2011 to 2012.

The AEO 2011 shows that for 2010 13.64 billion RINs were generated in the U.S.[22] The mandate requires 12.95 billion RINs for 2010; hence there was a surplus of 0.69 billion RINs. Since 0.69 billion RINs represents less than 20% of the target renewable fuel volume, all surplus RINs could be banked or carried forward for use in the following year. Therefore, we assume that at the beginning of 2011, there were 0.69 billion RINs available to be used. In 2011, the EIA estimates that 14.95 billion RINs were generated in the U.S., while only 13.95 billion RINs were needed to comply with the regulation. Therefore, there would have been a surplus of 1billion RINs for 2013 (again this is less than 20% of the target so the full quantity could be banked). Adding this to the beginning of the year bank yields a 2011 end-of-year bank of 1.69 billion RINs. This figure becomes the number of RINs in the bank at the beginning of 2012 (Table 8).

[22] AEO 2011, Table 11. Ethanol production is equivalent to 13.18 billion physical gallons (13.18 billion RIN gallons) and biodiesel production is equivalent to 0.31 billion physical gallons (0.465 billion RIN gallons).

Table 8: Computation of Available RINs at the Beginning of 2012 (Billions)

	2010	2011	2012
RINs Available at the Beginning of the Year	0.00	0.69	1.69
RFS2 Total Renewable Fuel required	12.95	13.95	15.20
RINs Generated	13.64	14.95	
Surplus RINs at End of Year	0.69	1.00	
20% Max RIN Carryover Allowed into Next Year	2.79	3.04	
RINs Available at the End of the Year	0.69	1.69	

Source: EIA's AEO 2011 and NERA analysis.

6. Cellulosic Biofuel

As discussed earlier, EPA can waive the RFS2 requirement, in whole or in part, if there is an inadequate supply to meet the mandate. With respect to the cellulosic biofuels mandate, there is an established track record by EPA of substantially reducing the cellulosic biofuel requirement because of the lack of commercially-available production. In 2010 and 2011, there were no cellulosic biofuel RINs generated. For 2012, EPA has reduced the requirement for cellulosic biofuels to less than 10 million gallons from the 500 million gallons required under RFS2.

As a result of the lack of progress in developing commercially-available supplies of cellulosic biomass and the technical and economic hurdles that remain with the production of cellulosic ethanol, and the time required to build and put into service biomass-to-liquids facilities,[23] we concluded that it was unlikely that cellulosic biofuels will be used in any appreciable quantities during our forecast horizon.

7. Other Fuel Constraints and Assumptions

The Reference Case imposed both the gasoline blend wall (no more than 10% ethanol) as well as the biodiesel blend limit (no more than 5% biodiesel). We allowed petroleum gasoline either to be blended with ethanol to make E10 or E85, or to be sold as neat gasoline (E0). A review of EIA data from May 2008 through April 2012 showed that E0 reached a low of about 5% in April 2012. The more gasoline that is used to produce E0 means that there is less to be

[23] Phase I report, p. 16.

blended with ethanol, and hence the more difficult it would be to comply with RFS2. To be conservative in our assessment of the compliance costs of RFS2, we assume that in the Reference Case, the share of gasoline used to produce E0 can drop to as little as 5%. This is consistent with April 2012 data generated by EIA.[24]

G. Analytical Methodology

The two scenarios were analyzed using NERA's transportation fuel model, which allowed us to simulate the dynamics of the RIN banking and the methodology that EPA uses each year to determine the minimum percentage of the different categories of biofuels delineated in the RFS2 standard that fuel suppliers must use. The transportation fuel model determined the impact of the RFS2 mandate on the transportation sector using the quantities of finished gasoline (E0, E10, and E85) and diesel consumed. In addition, the model calculated volumes of individual biofuels blended in the finished gasoline (corn ethanol, sugar ethanol, and cellulosic ethanol) and diesel (biodiesel). The N_{ew}ERA macroeconomic model then determined the impact on the U.S. economy of meeting the RFS2 mandate. The results are expressed in terms of common economic parameters: changes in GDP, labor earnings, and consumer purchasing power.

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[24] EIA Weekly Refiner and Blender Net Production data available at: http://www.eia.gov/dnav/pet/pet_pnp_wprodrb_dcu_nus_w.htm. Access date: May 31, 2012.

IV. Results

A. The Dilemma with RFS2

There is a fundamental problem with the RFS2 mandate: the blending percentage standard for total renewable fuel will eventually exceed the maximum feasible level of renewable fuel that can be contained on average in a gallon of transportation fuel given the technological, market, and infrastructure constraints in the economy.

In 2015, the total renewable fuels volume mandate requires that renewable fuels make up 11% of the total gallons of transportation fuel sold (see Table 9). This exceeds the volume that can be blended in E10 and diesel, which comprise more than 95% of the fuel market.[25] The only transportation fuel with a renewable fuel blending percentage above 11% is E85, but as was discussed earlier, it is unlikely that more than 2.6 billion gallons could be sold in 2015 when the total transportation fuel demand is estimated to be approximately 180 billion gallons.

Table 9: RFS2 Mandated Total Biofuels Percentage and the Maximum Percentage of Renewable Fuel in Finished Fuel in Diesel, E85, and E10

	2012	2013	2014	2015
RVO as Percentage of Total Finished Fuel Sales	8.4%	9.0%	9.8%	11.0%
Max Diesel Biofuel % (Blending biodiesel at 5% is accounted as 7.5% for compliance with total renewable fuel volume standard)	5.0%	5.0%	5.0%	5.0%
Max E85 Biofuel %	74.0%	74.0%	74.0%	74.0%
Max E10 Biofuel %	10.0%	10.0%	10.0%	10.0%

Source: NERA assumptions and analysis.

In order to meet the RFS2 target in 2015, RINs that were banked in prior years must be used. However, as the banked RINs become exhausted, the value of RINs will increase as will the cost

25 E10 can contain no more than 10% ethanol. E85 is assumed to contain 74% ethanol on an annual average basis. Diesel can contain no more than 5% biodiesel. Biodiesel, however, earns 1.5 RIN credits for each gallon, so a 5% volumetric blend equates to 7.5% biodiesel on a RIN basis.

of gasoline and diesel. This will result in the drastic cut in sales of diesel, E10, and E0 so that E85 becomes a much larger share of the transportation fuel market.[26]

B. RFS2 Implementation

RFS2 requires that at the end of each year, obligated parties have enough RINs to meet their RVO. An obligated party can increase its number of RINs by increasing the amount of biofuels blended into its current fuel volumes. Additionally, an obligated party can acquire RINs by purchasing either biofuel from a biofuel producer or RINs from another obligated party. The lack of surplus RIN supply results in high RIN value and reduced total fuel demand so that the ratio of RINs to physical gallons increases. Conversely, if additional RINs are not available for purchase, an obligated party may have no option other than to reduce its total volume of fuel produced so that its current stock of RINs is sufficient to meet its RVO. It is likely that over time an obligated party would be forced to do some combination of both acquiring surplus RINs and reducing the volume of fuel produced to meet its RVO.

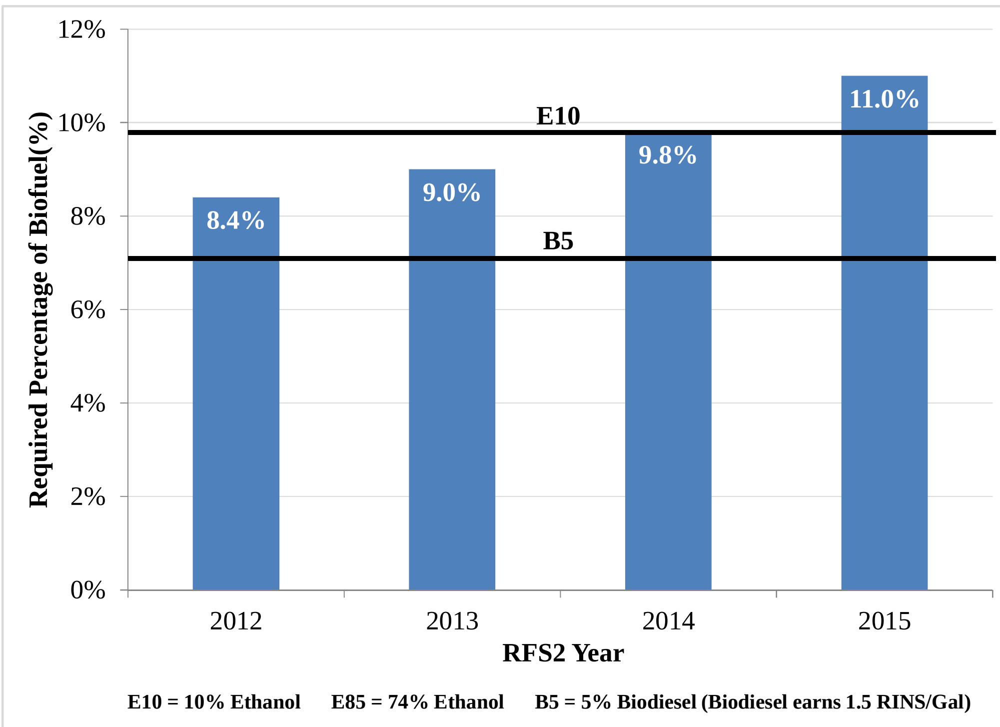
Each obligated party will choose its optimal compliance path based upon the cost of RINs, the market response to changes in fuel cost, technology limitations on blending biofuels with petroleum, and infrastructure and consumer acceptance issues surrounding increasing E85 sales. An obligated party may first try to blend more biofuels into its transportation fuels in order to acquire RINs. For the motor gasoline fuels, this increase is accomplished by increasing the share of ethanol in motor gasoline by blending more ethanol into conventional gasoline (limited by the blend wall), increasing production of E10 in the early years, or increasing production of E85. For diesel, increasing the content of biofuels means adding more biodiesel into the finished diesel fuel (limited by a 5% blending maximum). The ability of obligated parties to increase the blending percentage of biofuels is limited by the availability of biodiesel, blending and infrastructure constraints, and the size of the E85 market.

Producing E85 gives obligated parties the greatest surplus RINs per gallon of fuel sold. E10 gallons generate a small amount of surplus RINs through 2014. On the other hand, diesel

[26] In our analysis the ethanol blend wall is reached in 2012-2013. However, the severe economic impacts do not occur until 2015-2016. The reason is that in 2012 – 2014 obligated parties acquire as many RINs as is feasible in anticipation of being unable to meet the RFS2 requirements in later years. The result is that the excess RINs postpone the severe economic impacts that result when obligated parties can no longer acquire the number of RINS required to comply with RFS2 mandated volumes and thus are forced to limit supplies of gasoline and diesel.

always generates a deficit in RINs. Obligated parties that sell diesel in the U.S. must always acquire additional RINs beyond those generated through biodiesel blending because the percentage of biodiesel in diesel is below the total renewable fuels blending percentage obligation. Increasing the biodiesel content in finished diesel reduces the number of RINs that need to be purchased to offset the deficit. Hence all available biodiesel supplies are purchased by obligated parties, but biodiesel supplies are limited.

Figure 5: RIN Obligations



Source: NERA analysis.

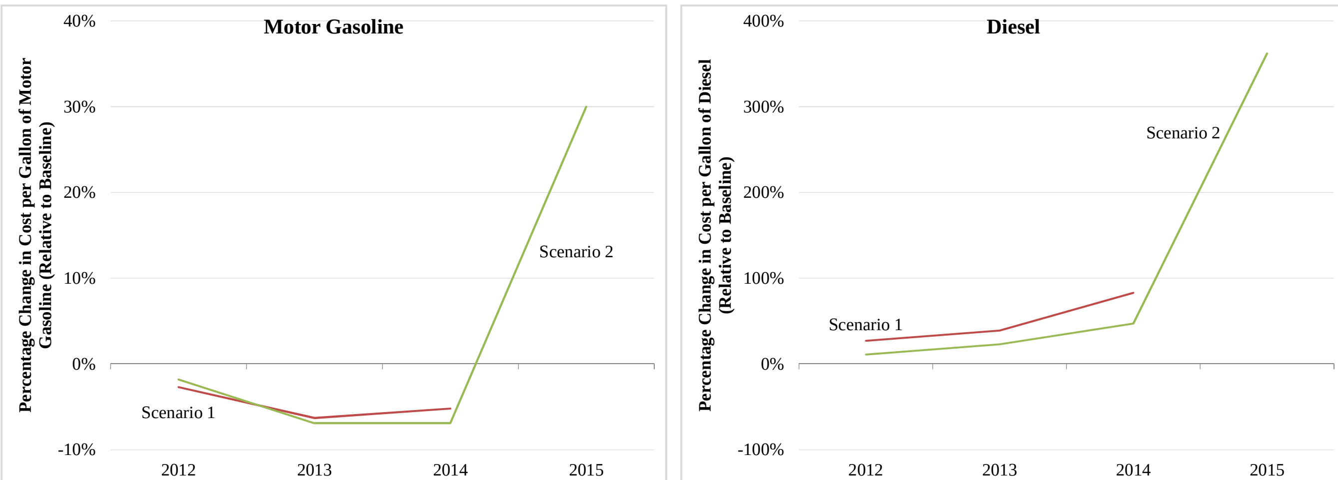
As a result, diesel can be thought of as incurring a RIN deficit and gasoline, for the first few years at least, as creating a surplus of RINs. The value of RINs that must be purchased separately is reflected in the cost of the finished gasoline or diesel.[27] If a fuel requires the purchase of RINs, such as with diesel, the cost of the finished product will increase. If the

[27] The value of a gallon of diesel equals the cost to produce diesel plus the price of additional RINs that must be purchased to meet the blending percentage standard. The value of gasoline (E10 or E85) equals the cost to produce E10 or E85 less the price of excess RINs that the fuel generates and can be sold. The RIN market equilibrates at the point where the marginal value of selling one more gallon of diesel equals the value of selling one more gallon of E10 or E85.

production of a fuel generates surplus RINs that can be sold, such as with E85 and E10 early on, then the cost of the finished product will decrease.

By 2015, however, E10 is no longer generating surplus RINs. In fact, it cannot generate enough RINs to meet its own blending percentage obligation. As a result, the gasoline cost increases significantly reflecting the shortage of RINs available (see Figure 6).

Figure 6: Percentage Change in Cost per Gallon of Motor Gasoline and Diesel



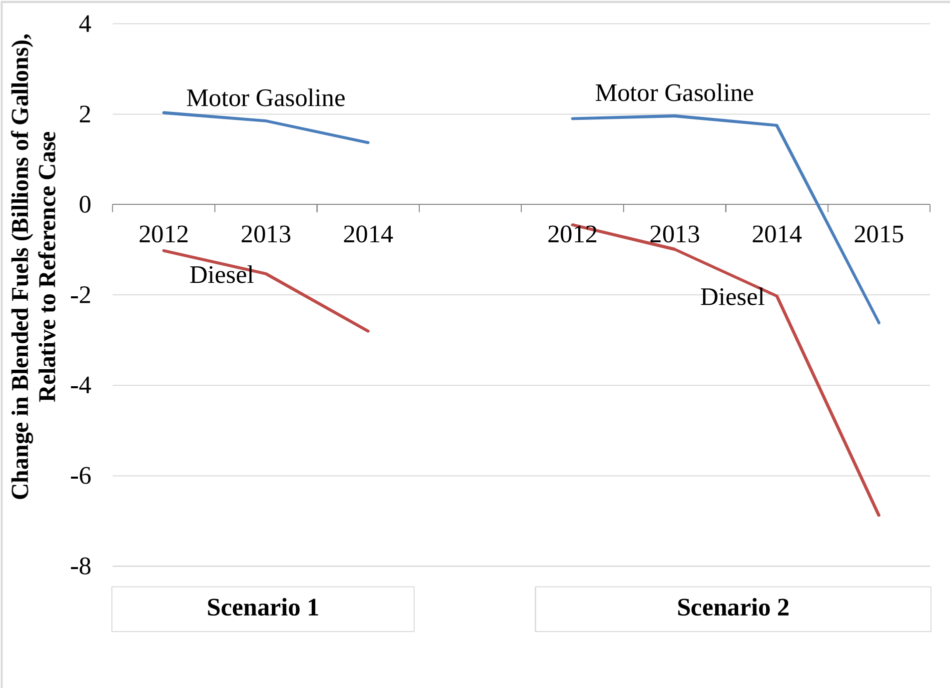
Source: NERA N_{ew}ERA model results.

As RINs become scarcer, fewer gallons of fuels that require additional RINs can be produced. Since the economy still demands these transportation fuels, the value of the RIN will increase to the point that the cost of the fuel, which includes the cost of the necessary RINs, results in the demand equilibrating with the supply of fuel. Consequently the cost to produce fuels that require the purchase of additional RINs increases (*e.g.*, diesel), and the cost to produce fuels that generate surplus RINs declines (*e.g.*, E85).

Diesel costs increase by 45% to 80% in 2014 for Scenarios 2 and 1, respectively; and the cost of diesel increases by over 300% in 2015 in Scenario 2. These cost increases match up with a drop in sales of 2 to 3 billion gallons in 2014 for Scenarios 2 and 1, respectively; and a decline of 7 billion gallons in 2015 for Scenario 2, which represents a decline of over 15% from the Reference Case.

On the other side, blended fuels that generate surplus RINs experience a decline in fuel costs, which induces greater sales. Motor gasoline sales increase by roughly 2 billion gallons from the Reference Case for all years between 2012 and 2014. In 2015, motor gasoline sales decline by at least 3 billion gallons from Reference Case levels (see Figure 7).

Figure 7: Change in Blended Fuels Sales (Motor Gasoline and Diesel)



Source: NERA N_{ew}ERA model results.

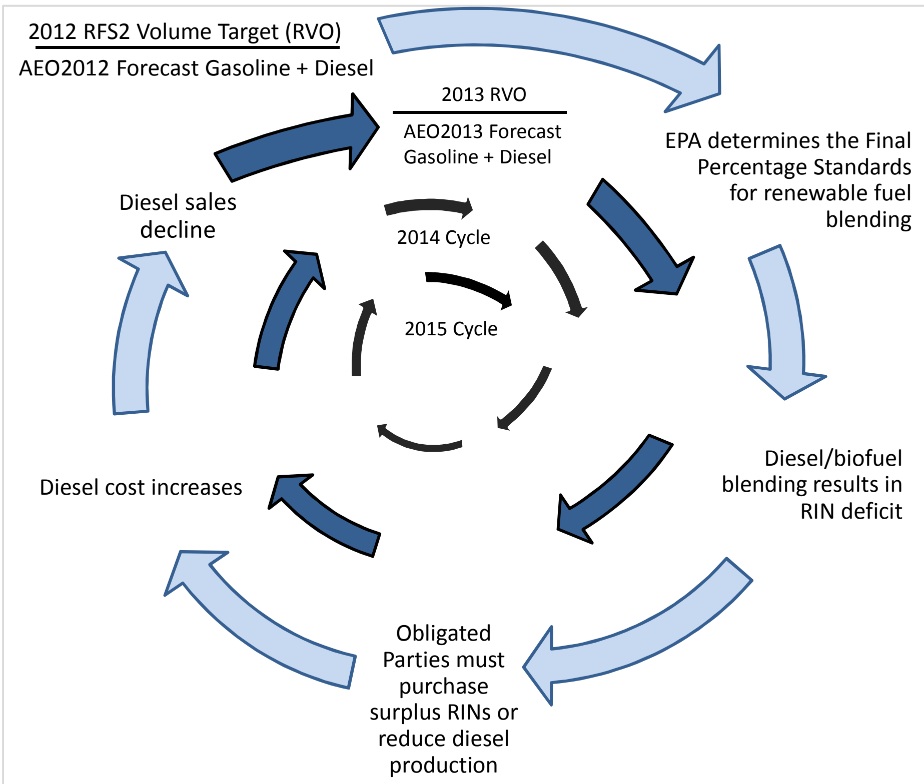
However with time this approach of increasing E10 sales and reducing diesel sales to comply is not sustainable. As illustrated in Figure 5, the originally targeted blending percentage standard for total renewable fuel[28] increases with time. From 2012 through 2014 the blending percentage standard is less than 10%, which is lower than the gasoline blend wall limit. But as the blending percentage standard increases, this contribution of E10 to producing surplus RINs shrinks. This shrinkage occurs at the same time that the gap increases between the total RVO and the total RINs collected from blending biodiesel. In other words, as fewer excess RINs are being generated more RINs are demanded. Thus to comply with the total biofuels mandate the reduction in diesel sales would become so large that it would lead to such severe rationing of diesel so as to cause extreme disruption in the commercial transportation sector. It is this growing gap between RIN supply and RIN demand that causes the approach to be unsustainable by 2015-16.

[28] Originally targeted blending percentage standard equals the total renewable fuel volume as required by EISA '07 divided by EIA's 2011 forecast for transportation fuel demand.

C. Diesel Death Spiral

An unintended consequence of the regulatory procedures for determining compliance is the potentially self-destructive way in which the annual blending percentage standards are determined. Figure 8 schematically presents the series of steps which result from EPA setting greater blending percentage obligations that cause an increasingly steep decline in diesel sales and lead to unattainable compliance obligations and supply disruptions.

Figure 8: Progression of the Diesel Death Spiral



As specified in EISA ’07, each year EPA calculates the next year’s blending percentage standards as the ratio of the targeted biofuel volumes to the EIA’s forecast for total transportation fuel sales in the next year. To comply with the blending percentage obligations, obligated parties have several options:

- Sell more E85;
- Increase the ethanol content in gasoline;
- Sell less E0; and
- Increase the biomass-based diesel content in diesel.

Each of these options has limitations. As the Phase I study concluded, there is limited consumer acceptance of E85 and limited infrastructure from which to dispense E85. The blending of ethanol into gasoline is restricted by the blend wall. Higher ethanol blends such as E15 are unlikely to be widely sold in the near future. E0 sales are unlikely to fall below 5% of total gasoline sales in the next several years, and there is a limited amount of biodiesel that can be cost-effectively produced.

In order to meet the blending percentage obligation, obligated parties would be forced to change the mix of fuels they sell to the extent that is possible in order to acquire enough RINs to meet the RFS2 mandates. All obligated parties would sell as much E85 and blend as much biodiesel into diesel as possible because of the relatively high RINs per gallon these actions generate: 0.74 RINs per gallon of E85 (typical), which compares to only 0.1 RINs for E10 and zero for E0. Biomass based diesel earns 1.5 RINs/gallon, or 0.075 RINs, when blended to make a gallon of B5.

The difference between the renewable fuel volumes mandated by the RFS2 program and the RINs generated through blending of biofuels into finished products represents the surplus or shortfall in RINs. If obligated parties continued to supply the same volumes of gasoline and diesel fuel, they would not be able to blend enough biofuel, or purchase enough surplus RINs, to remain in compliance with RSF2. This shortage in RINs puts upward pressure on RIN values (Table 10). For Scenario 1, in 2015 the program becomes infeasible, so there is no RIN value listed in the table.

Table 10: RFS2 Mandated Total Biofuels Percentage and Associated RIN Values

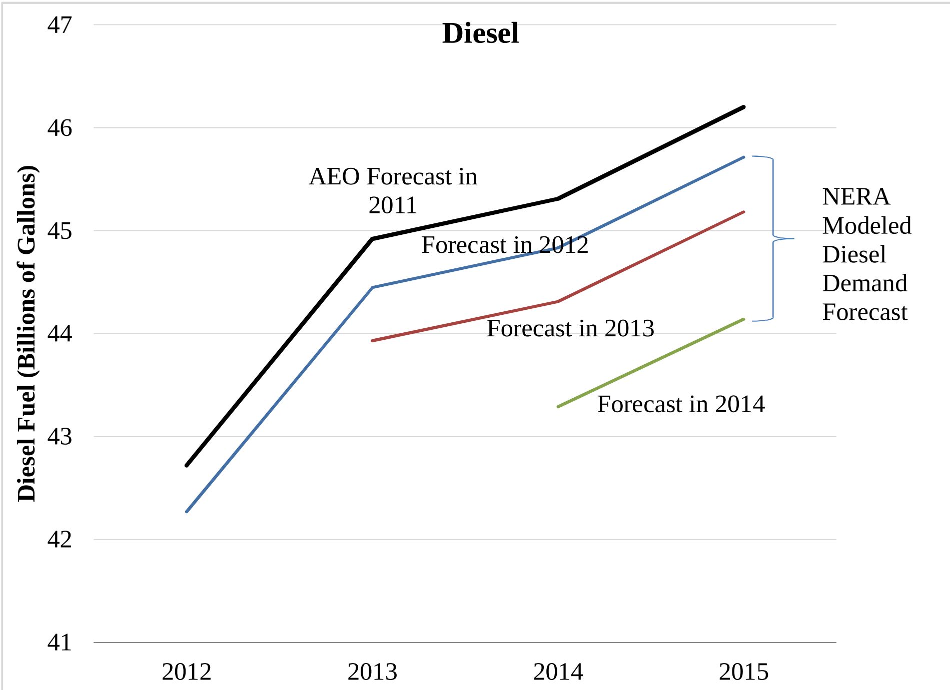
	2012	2013	2014	2015
Renewable Volume Obligation as Blending Percentage	8.4%	9.0%	9.8%	11.0%
RIN value Scenario 1 (2010$/RIN)	$10	$14	$27	Note 1
RIN value Scenario 2 (2010$/ RIN)	$5	$10	$17	$100

Note 1: Model solution for Scenario 1 in the year 2015 was infeasible.

Source: NERA analysis and N_{ew}ERA model results.

The cost of the RINs is borne by the obligated party and leads to higher costs and lower sales (effectively rationing) for fuels that require additional RINs. The cost of RINs also depends on the supply of RINs, which depends greatly on the supply of excess RINs from gasoline sales. During the first few years, the result is that the cost of diesel increases because this fuel requires RINs and the cost of E10 and E85 declines since these fuels produce excess RINs. The higher cost dampens demand for diesel, which results in the EIA lowering its forecast for diesel sales. The lower forecast for demand, means that the next year's blending percentage obligation becomes higher than it would have been, resulting in additional pressure on obligated parties who blend diesel to acquire even more RINs. This process repeats each year. The reduced diesel demand forecasting is depicted in Figure 9. The top black line represents the AEO diesel demand for 2011. As the cost of diesel rises, demand declines in subsequent years. The declining demand forecasted through NERA modeling is shown in order for 2012, 2013, 2014 years by the blue, red, and green lines, respectively.

Figure 9. Declining Diesel Demand Forecasting (2012 – 2015)



Source: NERA N_{ew}ERA model results.

Eventually the RFS2 total renewable fuel target increases to the point that it is no longer possible to satisfy the mandate through the available compliance mechanisms. As a result, the blending percentage obligation becomes infeasible.

D. The Role of Banked RINs

Table 11 displays the shortfall or surplus of RINs from selling a gallon of diesel, E10, or E85. The shortfall for diesel depends on the scenario studied, because the amount of biodiesel differs by scenario. Under Scenario 2, more biodiesel is available and consequently blended with petroleum diesel to yield more RINs per gallon of finished diesel than in Scenario 1. Since the E10 blend wall is reached in both scenarios for all years, the RIN shortfall and surplus are the same across scenarios as is the E85 RIN surplus. The level of E10's RIN deficit or surplus suggests how great demand for previously banked RINs will be.

Table 11: RIN Deficit or Surplus per Gallon of Fuel Sold (RIN/Gallon of Fuel)

		2012	2013	2014	2015
Diesel	Scenario 1	-0.048	-0.045	-0.053	
	Scenario 2	-0.036	-0.030	-0.040	-0.038
E10	Both Scenarios	0.016	0.010	0.002	-0.010
E85	Both Scenarios	0.66	0.65	0.64	0.63

Source: NERA N_{ew}ERA model results.

One way obligated parties may lessen the problems created by the gap between maximum RINs generated by blending B5 diesel and the total renewable fuel blending percentage obligation is to purchase or use RINs that have been banked from previous years. Depending upon the circumstances in a given year, obligated parties may choose to either acquire additional RINs or use RINs that they acquired in the previous year. The availability of RINs reserved for later use depends critically on the surplus RINs generated through the production of E10.

Table 11 shows that the surplus RINs decline dramatically to almost zero in 2014 and becomes negative in 2015. Therefore, in the first two years, it may be possible to increase the number of banked RINs, but by 2014 only sales of E85 would contribute anything meaningful to the surplus RIN supply. From 2014 surplus RIN inventories would be drawn down in an effort to make up for the shortfall in RINs created by diesel sales.

Table 12 shows the decline of surplus RINs over time. The table illustrates that in the early years obligated parties will acquire more RINs than they need for compliance (*i.e.*, they will add RINs to their RIN bank) and use these banked RINs in the later years: from 2013 onward in Scenario 1 and from 2014 onward in Scenario 2. This market behavior is reflective of the value of RINs early on being relatively inexpensive compared to the value of RINs later when the RFS2 mandates become more stringent. The total of cumulative banked RINs increases until 2013 in Scenario 1. In Scenario 2 the total increases until 2014 because there are more RINs available from the blending of biodiesel into finished diesel in Scenario 2. The subsequent exhaustion of the RIN surplus portends an impending collapse in terms of the RFS mandate leading to an infeasible outcome in the fuels market.

Table 12: Cumulative Total of Surplus Banked RINs in Billions

		Scenario 1	Scenario 2
2012	Starting RIN Surplus	1.69	1.69
	Surplus RINs Produced	0.16	0.67
	RINS Used	0.00	0.00
	End of Year RIN Surplus	1.85	2.36
2013	Starting RIN Surplus	1.85	2.36
	Surplus RINs Produced	0.00	0.29
	RINS Used	0.40	0.00
	End of Year RIN Surplus	1.45	2.65
2014	Starting RIN Surplus	1.45	2.65
	Excess RINs Produced	0.00	0.00
	RINS Used	1.45	0.92
	End of Year RIN Surplus	0.00	1.73
2015	Starting RIN Surplus	NA	1.73
	Surplus RINs Produced	NA	0.00
	RINS Used	NA	1.73
	End of Year RIN Surplus	NA	0.00

Source: NERA N_{ew}ERA model results.

E. RFS2 Program Will Eventually Fail

With time the RFS2 requirements become more stringent and options for complying become more limited: the blend wall is encountered, E85 is sold at maximum levels, and biodiesel production is fully exhausted. The result is that the demand for RINs exceeds the supply, which causes RIN values to increase and obligated parties to draw down their bank of RINs. Eventually the surplus of RINs is depleted (Table 12).

With surplus RINs depleted at the end of 2014 for Scenario 1, obligated parties must meet the total biofuels obligation percentage of close to 11% in 2015 through the blending and sale of E0, E10, E85, and B5 diesel. There are no surplus RINs from previous years that can be used. The 11% RVO target exceeds the ethanol content in E10, which means that E85 sales must greatly increase to make up for the shortfall. But the market infrastructure and consumer acceptance limits E85 sales causing surplus RINs from E85 sales to be scarce. To remain in compliance, obligated parties would have to drastically curtail their sales of diesel and E10. Table 13 shows that if the supply of gasoline and diesel were reduced by over 50% from the EIA's Reference Case, then obligated parties could comply with RFS2. Clearly, this is an infeasible result. In addition, this result leads to far fewer biofuel gallons (9.4 billion gallons) being sold compared with the 2015 RFS total renewable fuel volume mandate of 20.5 billion gallons. As reported in Table 10, the model solution was infeasible for 2015 for scenario 1. Table 13 illustrates the unrealistic changes in fuel consumption that would have to take place for the RFS2 policy to be achievable.

Table 13: RFS2 Collapse for Scenario 1

	Renewable Fuel per Gallon (%)	Fuel Sales (Billion Gallons)	RINs (Billions)	EIA Reference Scenario 2015 Levels (Billion Gallons)	% Reduction in Fuel Scenario 1 vs. EIA
Obligation %	11.0%				
E85	74%	2.6	1.9		
Diesel	7.5%	20	1.5		
E10	10%	60	6.0		
E0	0%	3.0			
Motor Gasoline				140	53%
Diesel				46.2	57%
Total		85.6	9.4	186.2	

Source: NERA N_{ew}ERA model results.

In scenario 2, this infeasibility is delayed until 2016 because the additional biodiesel supplies allow about 1.7 billion RINs to be carried forward from 2014 and to be used in 2015.

Exhausting the bank of RINs in 2015 fails to prevent the escalation of diesel costs, and they increase by over 300% from the Reference Case.

F. Economic Impact of RFS2

The macroeconomic impacts of the RFS2 mandate on the U.S. economy were estimated through the year 2015. The estimates show that the increasing demand for and escalating cost of RINs causes dramatic increases in the cost of diesel and ultimately, the cost of gasoline by 2015. These higher costs ripple through the economy, collectively harming economic growth.

From 2012 through 2014, the higher diesel fuel costs increase the cost to move raw materials and finished goods about the country. This increased cost will be passed through to consumers of finished goods and services. As a result, consumption of goods and services declines. The lower gasoline prices in this time period slightly offset the negative impacts on consumption from the higher diesel prices.[29]

In the 2012 to 2014 time frame, labor earnings increase, but their increase is modest compared to the loss in consumption, as labor earnings are unable to offset the higher costs for goods.[30] In the near term, investment and production is temporarily accelerated in anticipation of rising costs, and GDP increases, but this shift is unsustainable. By 2014 GDP declines by more than $250 billion.

In 2015, the economic impacts worsen. In addition to the negative impact of higher costs for finished goods and services caused by rising diesel fuel costs, gasoline costs increase relative to the baseline as a result of RSF2. Consumers are left with fewer dollars to spend on other goods and services resulting in lower consumption. Lower consumption translates into less need for the production of other goods and services that consumers would have otherwise purchased.

The combined effect of less money consumers have available to spend with the higher cost for finished goods and services means that consumption declines even further. By 2015, consumption per household declines by about $2,700 per year and total consumption declines by about $340 billion. Since there is lower demand for finished goods and services, there is less need for workers to provide those goods and services. As a result, workers would earn $584

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29 Consumers are affected by higher diesel prices which are reflected through increases in the costs of goods and services.

30 Increases in biofuel production lead to increases in labor demand.

billion less as a result of the smaller size of the economy resulting from the implementation of RFS2 (Table 14). These negative impacts are also expressed by the loss in GDP of $770 billion.

Table 14: Changes in Consumption per Household, Consumption, Labor Income and GDP Relative to Baseline (2010$s)

	2012	2013	2014	2015
Change in Average Consumption per Household ($/Household)	-$1,200	-$1,200	-$1,300	-$2,700
Change in Consumption (Billions of $s)	-$150	-$140	-$160	-$340
Change in Labor Income (Billions of $s)	$24	$42	$27	-$580
Change in GDP (Billions of $s)	$43	$50	-$270	-$770

Source: NERA N_{ew}ERA model results.

V. Conclusions

The RFS2 mandate as currently written is likely infeasible given the current technological, infrastructure and market constraints of the transportation sector. The fuel capability of the existing fleet, the infrastructure of the fuel distribution system and limited compliance mechanisms are some of the factors that undermine the viability of the RFS2. As obligated parties seek to comply with the RFS2, the mandates lead to unintended consequences that have dramatic and potentially long-term negative impacts on the motor fuel industry's ability to meet market demand and on the economy as a whole. As it becomes increasingly difficult for obligated parties to generate sufficient RINs to comply with the blending percentage obligation targets from RFS2, very large increases in transportation fuel costs ripple through the economy causing negative macroeconomic impacts. Depending on biodiesel availability, this collapse occurs in 2015 to 2016 timeframe. By 2015, the adverse macroeconomic impacts include a $770 billion decline in GDP and a corresponding reduction in consumption per household of $2,700.

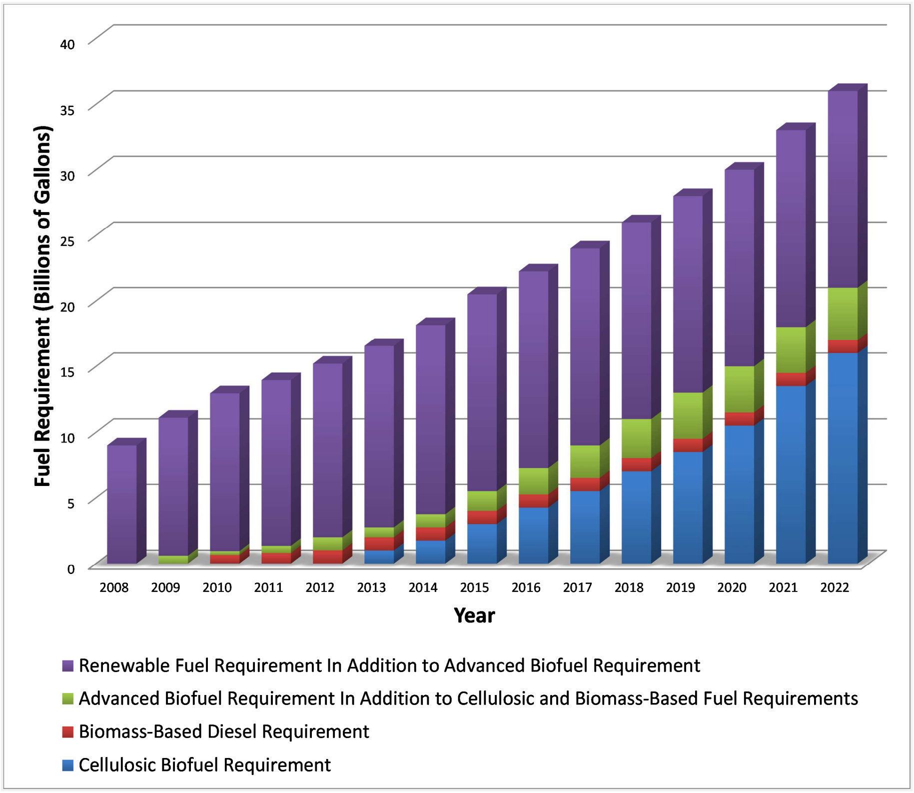
Appendix A: Renewable Fuels Standard Description

A. Renewable Fuel Standard (RFS2)

Congress first established a Renewable Fuel Standard (RFS1) in 2005 with the enactment of EPACT. Two years later, Congress passed EISA ‘07 which included RFS2 that increased the volume mandates of renewable fuels and expanded the transportation fuel mix beyond gasoline.

RFS2 became effective in 2010 and applies to all transportation fuel used in the United States—including diesel fuel intended for use in highway motor vehicles, non-road, locomotive, and marine diesel. As shown in Figure 10, RFS2 consists of four nested mandates for the minimum volume of renewable fuels contained in the transportation fuels sold in the United States. These mandates increase each year, and collectively, require the use of 36 billion gallons of renewable fuels in 2022.

Figure 10: EISA '07 Renewable Fuel Standard 2008-2022



Notes:
Cellulosic biofuel requirments were reduced per waiver approval by EPA for 2010-2012:
2010: 100 million gallons reduced to 6.5 million gallons
2011: 250 million gallons reduced to 6.6 million gallons
2012: 500 million gallons reduced to 8.65 million gallons

Biomass-based Diesel requirement for 2013-2022 has yet to be determined by the EPA but shall be no less than 1 billion gallons. This graph assumes 1 billion gallons per year in 2012-2022.

Each of the four nested mandates (biofuel categories) has its own lifecycle GHG minimum emission reduction requirements and annual volume mandate.

- Total renewable fuel is produced from renewable biomass and must reduce GHG emissions by at least 20% from the baseline value.
- Advanced biofuel is a subcategory of renewable fuel having a lifecycle GHG emission at least 50% less than the baseline value.
- Biomass-based diesel is a subcategory of advanced biofuel, and includes biodiesel or renewable diesel fuel having a lifecycle GHG emission at least 50% less than the baseline value.
- Cellulosic biofuel – a subcategory of advanced biofuel, and includes fuel produced from cellulose, hemicelluloses or lignin and having a lifecycle GHG emission at least 60% less than the baseline value.

Because of the nested nature of the biofuel categories, any renewable fuel that meets the requirement for cellulosic biofuels or biomass-based diesel is also valid for meeting the overall advanced biofuels requirement. Similarly, any renewable fuel that meets the advanced biofuel requirement is also valid for meeting the total renewable fuel mandate.

By November 30 of each year, EPA sets for the following year the blending percentage standard for total renewable fuel, advanced biofuel, biomass-based diesel, and cellulosic biofuel by dividing the volumetric mandates for each biofuel category by the projected annual transportation fuel demand forecasted by EIA.

Renewable fuel producers and importers generate credits in proportion to the amount and type of renewable fuel produced/imported – these credits are called RINs.

Transportation fuel producers and importers ("obligated parties") must acquire sufficient RINs to demonstrate compliance. Their compliance requirement is based on the amount of gasoline and diesel they refine or import. The number of required RINs, for each renewable fuel category, is calculated by multiplying the blending percentage standard for that year as set by EPA with the volume of gasoline or diesel obligated parties produce or import in that year.

Fuels sold that contain less than the blending percentage standard incur a RIN deficit, and fuels that contain more than the blending percentage standard accrue surplus RINs. The overall annual blending percentage standard is met if the surplus RINs generated from fuels containing greater than the required percentage are sufficient to offset the RIN deficits from fuels containing less than the required percentage. An obligated party is in compliance with RFS2 if its supply of RINs for each of the four renewable fuel categories equals or exceeds its fuel sales times the EPA's stated blending percentage standard for each renewable fuel category.

Fuels currently sold into the U.S. market include E0 and E10 gasoline, B0 and B5 diesel and E85, an alternative fuel containing greater than 50% ethanol by volume. E10 is the predominant fuel in the market, when the ethanol volume requirement is greater than what can be achieved by blending E10, the E10 blend wall has been reached, and the blend wall will restrict the greater use of renewable fuels.

Most biodiesel fuel is consumed in blended diesel fuels in which petroleum-based diesel fuel constitutes 95 percent or more of the blend by volume. The most common of such blends is B5 (five percent biodiesel by volume). Most diesel engine manufacturers and automakers continue to recommend the use of blends not greater than five percent. These requirements effectively create a B5 blend limit that is analogous to the E10 blend wall.

Original equipment manufacturers design and warranty engines and vehicles consistent with the E10 specification. Vehicle manufacturers have stated that use of fuels with higher ethanol content would void their warranty on existing vehicles with the exception of FFVs, which can accommodate ethanol gasoline blends with as much as 85% by volume ethanol.

EPA has approved two partial waivers, that together, allow E15 in vintage 2001 on-road vehicles and newer. For reasons described in the report, however, volumes of E15 are not considered to be materially significant. For example, the EIA in its recent Short-Term Energy Outlook assumed zero E15 demand in 2012 and 2013.[31]

[31] "This forecast assumes that E15 (gasoline blended with 15 percent ethanol by volume) does not yet reach the market. Consequently, U.S. ethanol production is projected to exceed the volume that can easily be used in the U.S. liquid fuels pool, so the Nation will continue to be a net exporter of ethanol over the next two years." Energy Information Administration, Short Term Energy Outlook, p. 10, May, 2012.

Appendix B: Detailed Model Description

This analysis used the linked system of NERA's proprietary bottom-up transportation fuel model and its N_{ew}ERA macroeconomic model. This section describes these two models.

A. Transportation Fuel Model

The transportation fuel model is a partial equilibrium model designed to estimate the amount of fuel produced for and consumed by the transportation sector with and without the RFS2 mandate in place. The model maximizes the sum of consumers' and producers' surplus subject to meeting the RFS2 program fuel requirements and satisfying the transportation sector's demand for fuel while not violating any transportation sector infrastructure constraints.

1. Input Data Assumptions for the Model Baseline

The fuel sales forecast for the gasoline market is based upon the AEO 2011 Reference scenario. Table 15 reports the EIA's forecast for petroleum gasoline and ethanol sales as well as E85. To be optimistic about the ability of obligated parties to meet the RFS2 mandate, we assume that the level of E0 sales is only five percent of the total petroleum gasoline sales. Until recently, this percentage has been above 10% (see Phase I report). Applying this assumption to the AEO's forecast yields the following forecast for E0, E85, and petroleum and ethanol in the remaining motor gasoline fuel (Table 15).

Table 15: September 2011 STEO and AEO 2011 Reference Scenario – Sales of Gasoline Fuels (Billions of Gallons, Unless Otherwise Noted)

Fuel (Billions of Gallons or %)	2012	2013	2014	2015
E0	6.28	6.29	6.28	6.27
Petroleum in E10	119.24	119.54	119.40	119.22
Ethanol in E10	15.01	15.25	15.48	15.72
% Ethanol in E10	**11.2%**	**11.3%**	**11.5%**	**11.7%**
E85	0.06	0.07	0.08	0.09

Source: EIA's AEO 2011 and EIA's STEO September 2011.

The fundamental problem with the EIA's forecast is that the percentage of ethanol in E10 exceeds the blend wall of 10%. In 2012, the share of ethanol in E10 is forecasted to be 11.2%. To eliminate this infeasibility, we adjusted the sales of ethanol and petroleum in E10 so that the modified E10 would comply with the E10 blend wall while the overall total energy content in motor gasoline remained the same. That is, the forecast used in the model maintains the total energy demanded on an MMBtu basis for travel (Table 16).

Table 16: NERA Reference Case Sales of Gasoline Fuels (Billions of Gallons Unless Noted Otherwise)

Fuel (Billions of Gallons or %)	2012	2013	2014	2015
E0	6.28	6.29	6.28	6.27
Petroleum in E10	120.35	120.77	120.79	120.78
Ethanol in E10	13.37	13.42	13.42	13.42
% Ethanol in E10	**10.0%**	**10.0%**	**10.0%**	**10.0%**
E85	0.06	0.07	0.08	0.09

Source: NERA Analysis.

The AEO's 2011 forecast without modifications is used for the petroleum diesel and biomass based diesel sales forecast (Table 17).

Table 17: NERA Reference Case Sales of Diesel Fuels (Billions of Gallons)

	2012	2013	2014	2015
Petroleum Diesel	41.8	43.9	44.2	45.0
Biomass based diesel	0.92	1.07	1.07	1.23
Effective Biodiesel %	2.2%	2.4%	2.4%	2.7%

Source: EIA's AEO 2011 and NERA analysis.

For the forecasts for the volume of biofuel components in motor gasoline, we disaggregate the ethanol production into corn, cellulosic, and sugar ethanol (see Table 18). Sugar ethanol consumption is based on the Food and Agricultural Policy Research Institute's (FAPRI's) 2011 Outlook. We use the EIA's forecast for cellulosic ethanol. Corn-based ethanol equals the sum of ethanol used in E10 and E85 less cellulosic and sugar ethanol consumption.

This assumption is optimistic because it gives higher volumes for sugar ethanol. Ethanol use in E10 and E85 is inferred from Table 18.

Table 18: NERA Reference Case Sales of Biofuels in Motor Gasoline (Billions of Gallons)

	2012	2013	2014	2015
Corn Ethanol	12.60	12.22	11.16	10.49
Sugar Ethanol	0.81	1.25	2.33	3.00
Cellulosic Ethanol	0.01	0.01	0.01	0.01

Sources: Food and Agricultural Policy Research Institute for sugar ethanol imports.

Note: Corn ethanol = Ethanol in E10 + Ethanol in E85 – Sugar Ethanol – Cellulosic Ethanol

The forecasts for fuel price ratios are based upon a number of data sources. The gasoline and diesel prices come from AEO's 2011 Reference forecast. For corn ethanol we built up the prices from the EIA's work. We assumed a corn price equal to the average $/bushel price from January 1, 2008 to September 1, 2011 (or $5.00/bushel). We took the capital, operations, and maintenance costs from the EIA.[32] Summing up all these costs yielded the forecasted price for corn based ethanol. The price of sugar ethanol is assumed to be $1.00 to $1.50 per gallon higher than neat gasoline based on recent actual price differentials between the two fuels.[33] The cost of cellulosic ethanol is uncertain.[34] To estimate this cost, we averaged two EIA forecasts – one based on the capital cost for cellulosic ethanol and the other based on the capital cost for biodiesel gasification.[35] For biodiesel, we made use of three sources: Global Insights, the American Trucking Association's comment on the EPA's proposed rule entitled: *Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards*, and the average ratio of spot SME B100 to spot ultra-low sulfur petroleum diesel from 2009 through 2011.

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32 Statton, Mac, "Development of Production Costs as a Driver for the National Energy Modeling System," Energy Information Administration, Presentation at International Fuel Ethanol Workshop, June 29, 2011.

33 California Energy Commission, "2011 Integrated Energy Policy Report," February 2012.

34 Because we assume the RFS mandate for cellulosic ethanol will be waived, cellulosic ethanol is likely to be irrelevant in our analysis as long as its price is sufficiently greater than that of sugar ethanol, for sugar ethanol will be the ethanol of choice to meet the advanced biofuels mandate, and corn and sugar ethanol will be used in the production of E10 and E85 to help meet the overall biofuel requirement.

35 Statton, Mac, "Development of Production Costs as a Driver for the National Energy Modeling System," Energy Information Administration, Presentation at International Fuel Ethanol Workshop, June 29, 2011.

All price ratios are national, annual averages over multiple grades of fuel. For gasoline, the grades include regular unleaded, 89 octane unleaded, and premium unleaded (Table 19).

Table 19: Baseline Fuel Price Ratios for Blended Gasoline and Diesels (Ratio on a GGE Basis of Biofuel to Conventional Fuel)

	2010	2011	2012	2013	2014	2015
Gasoline	1.00	1.00	1.00	1.00	1.00	1.00
Corn Ethanol	1.86	1.78	1.72	1.61	1.58	1.49
Sugarcane Ethanol	2.08	2.00	1.92	1.81	1.77	1.67
Cellulosic Ethanol	2.62	2.48	2.41	2.23	2.13	2.01
Diesel	1.00	1.00	1.00	1.00	1.00	1.00
Soy-Based Biodiesel	1.74	1.66	1.7	1.66	1.65	1.64

Source: NERA assumptions.

2. Fuel Supply Curves

To address the changes in fuel production from the baseline, we use separate supply curves for each fuel. The elasticity of the supply dictates how the prices of fuels change with changes in production. In particular, they help determine how costly it is to expand biofuel production above the Reference Case levels.

Each supply curve is benchmarked to the NERA Reference Case, which is a slight modification of the EIA's Reference Case. The Reference Case price and quantity are denoted by $(Q_0(t),P_0(t))$. Each supply curve is also defined by an elasticity that is estimated from several data points from the EIA's Reference and High Oil Price scenarios. Each supply curve has the following functional form:

$$Q(t)/Q_0(t) = (P(t)/P_0(t))^{elasticity}$$

Formulation of the supply curves is such that the model replicates the Reference Case if no RFS2 mandate is imposed. For each year, the benchmark datum point for the biodiesel supply curve is derived from the EIA's reference scenario projections for fuel quantities and prices. The benchmark datum point for the corn ethanol supply curve comes from our adjusted EIA reference scenario (NERA Reference Case) for quantities and the EIA's cost analysis. For sugar ethanol, we used the EIA's demand forecast and the ARB's cost ratio of sugar ethanol to corn ethanol. Table 17, Table 18, and Table 19 report the prices and quantities to which the supply curves were calibrated.[36]

The own price elasticity for each fuel is derived by dividing the percentage change in quantity of fuel demanded by the percentage change in fuel price. The percentage change in quantity and price are computed by comparing the difference between the fuel consumed and price of fuel, respectively, in the AEO high oil price and reference scenarios. The elasticity of supply varies a bit from year to year, but on average, the elasticity of supply is about 0.4 for corn ethanol, 1.2 for sugar ethanol and biodiesel. The elasticity for petroleum fuels was is 0.8.[37]

3. Demand Curves

The model has a demand curve for each final fuel – E0, E10, E85, and diesel. The functional form of these curves is identical to that of the fuel supply curves. For the demand curves, the elasticity is the fuel's own price elasticity of demand. Because this analysis concerns itself only with the next few years, the demand curves' elasticity equaled that of Dahl's estimate for short-term elasticity of -0.1.[38]

These curves are calibrated to the demand data in Table 16 and Table 17. The EIA's AEO 2011 Reference Case provides the gasoline and diesel prices to which the demand curves' initial prices are calibrated (Table 20). As with the supply curves, the demand curves are structured so that the model replicates the NERA Reference Case level of demand for each fuel in the absence of the RFS2 mandate.

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[36] The previous section provides more detail on how the forecast prices were derived.

[37] Paltsev, Sergey, John M. Reilly, Henry D. Jacoby, Rishard S. Eckaus, James McFarland, Marcus Sarofim, Malcolm Asadoorian, and Mustafa Babiker, "The MIT Emissions and Prediction and Policy Analysis (EPPA). Model Version 4," August 2005.

[38] Dahl, C.A., "A survey of energy demand elasticities for the developing world," *Journal of Energy and Development* 18(I), 1—48, 1994.

Table 20: AEO 2011 Reference Case Fuel Prices ($/Gallon)

Fuel	2012	2013	2014	2015
Gasoline	2.82	2.97	3.05	3.13
Diesel	2.92	2.97	3.02	3.08

Source: EIA's AEO 2011.

4. Transportation Fuel Model is Designed to Model RFS2 Program Characteristics

The transportation fuel model was customized to simulate the impacts resulting from the RFS2 program. The model solves in one-year time steps and has a flexible time horizon. The first endogenous year is 2012. The model tracks the sale of the following fuels: E0 (100% petroleum gasoline), E10 (gasoline containing at most 10% by volume ethanol), E85 (assumed to contain 74% ethanol by volume), and diesel (containing at most 5% biodiesel). The model also tracks the use of the following fuel components in the production of the above finished fuels: petroleum gasoline, corn ethanol, sugar ethanol, cellulosic ethanol, petroleum diesel, and biodiesel.

The model combines the six fuel components into the four end-use fuels, which can be consumed by specific vehicle types:

- Minimum E0 use held to 5% to represent incomplete market conversion to E10 and preference of some consumers for E0;
- Conventional vehicles can consume either E0 or E10;
- FFVs can use E0, E10, or E85; and
- Commercial trucks/buses, ships, and trains are allowed to use diesel, which has up to a five percent mix of biodiesel (B5).

5. RFS/RIN Constraints

The model includes three biofuel constraints to account for the minimum annual volume of biofuel sales required under the RFS2 program:

- Biomass based diesel;
- Advanced biofuel (includes cellulosic biofuels, biomass-based diesel, and sugar ethanol); and
- Renewable fuel (includes advanced biofuel and corn ethanol).

For this analysis, we omit the RFS2 constraint for cellulosic ethanol under the assumption that the EPA would continue to grant a waiver because cellulosic biofuels will be commercially available only in very limited quantities. This assumption avoids the debate about the economic and technical feasibility of producing cellulosic biofuel[39] and is likely optimistic given the current difficulty procuring cellulosic biofuel supplies. Since this analysis assumes ample supplies of corn and sugar ethanol to meet the RFS2 mandates, there is no need for cellulosic ethanol to meet the non-cellulosic RFS2 targets.

Therefore, we model the following three RFS2 constraints, which are defined in the EPA's Final Rule for the Regulation of Fuels and Fuel Additives.

Figure 11: EPA's Formulas for the RFS2 Percentage Mandates[40]

$$\mathrm{Std}_{\mathrm{BBD},\,i} = 100\% \times \frac{\mathrm{RFV}_{\mathrm{BBD},\,i} \times 1.5}{(G_i - RG_i) + (GS_i - RGS_i) - GE_i + (D_i - RD_i) + (DS_i - RDS_i) - DE_i}$$

$$\mathrm{Std}_{\mathrm{AB},\,i} = 100\% \times \frac{\mathrm{RFV}_{\mathrm{AB},\,i}}{(G_i - RG_i) + (GS_i - RGS_i) - GE_i + (D_i - RD_i) + (DS_i - RDS_i) - DE_i}$$

$$\mathrm{Std}_{\mathrm{RF},\,i} = 100\% \times \frac{\mathrm{RFV}_{\mathrm{RF},\,i}}{(G_i - RG_i) + (GS_i - RGS_i) - GE_i + (D_i - RD_i) + (DS_i - RDS_i) - DE_i}$$

39 We note that there is a second- or third-order effect of assuming no measurable cellulosic supplies. Assuming no significant amount of cellulosic ethanol production necessitates additional amounts of biodiesel and sugar based ethanol to meet the advanced biofuel requirement, and this affects costs and compliance.

40 http://www.gpo.gov/fdsys/pkg/FR-2012-01-09/pdf/2011-33451.pdf, at p. 19.

The final standards for 2012 are provided below in Table 21.

Table 21: EPA's Final Rule for RFS standards for 2012[41]

Fuel	Percentage
Cellulosic biofuel	0.002% to 0.01%
Biomass-based diesel	0.91%
Advanced biofuel	1.21%
Renewable fuel	9.21%

Source: EPA.

6. Model Formulation

The following text describes the transportation fuel model – its objective function and constraints - at a high-level.

Maximize: Consumer Surplus + Producer Surplus + Value of RIN Bank

Subject to: RFS2 advanced biofuel constraint (% requirement)

RFS2 biodiesel constraint (% requirement)

RFS2 total biofuel constraint (% requirement)

Blend wall constraint for E10 not to exceed 10% ethanol

Blend wall constraint for diesel not to exceed 5% biodiesel

Limit on E85 sales based on Phase I findings for penetration of E85 stations

Lower bound on E0 sales as a fraction of total sales (calibrated to baseline levels)

Upper bound on biodiesel production

RIN bank(t) = RIN bank(t-1) + RIN Deposit(t) – RIN withdrawal(t) t = 2012, …, 2015

RIN bank cannot exceed 20% of biofuel sales…

Consumer Surplus = the area under the demand curve for each delivered fuel (*e.g.*, E0, E10, *etc*.)

[41] EPA's Section I on pg. 1323 of the EPA's Final Rule for the Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards. Table I.A. 3-2.

Producer Surplus = the area under the supply curve for each fuel component (*e.g.*, corn ethanol, biodiesel, *etc*.)

RIN bank in 2012 equals the carryover of RINs from 2011.

The supply curves capture the technological issues (penetration rate, availability, and cost) for the different fuels. The demand curves for fuel capture the loss in utility from having to reduce travel and also the loss in welfare from having to switch fuels. The RFS constraint is applied only in the RFS2 scenarios. The change in economic activity between the scenario and the baseline provides the economic impacts of the RFS policy.

The models for the reference and high biofuel scenarios differ only in the upper bound for the amount of biodiesel production. Table 22 reports these levels.

Table 22: Maximum Amount of Biomass Based Diesel That Can be Produced (Billions of Gallons)

Scenario	2012	2013	2014	2015
Reference Scenario	1.00	1.28	1.28	1.28
High Biodiesel Scenario	1.35	1.74	1.66	1.90

Source: EIA's AEO 2011 and NERA analysis.

The sales of E85 are limited by how quickly the E85 fueling infrastructure can be expanded. At the end of 2011, there were only about 2,400 stations that sold E85. This small volume resulted in E85 making up only about 1% of all potential FFV fuel purchases. By allowing the addition of E85 pumps in retail stations to increase at a rate far faster than that in recent history (1,000 stations per year versus about 400 stations per year from 2006 through 2010), yields about 6,400 stations by 2015. Given people's propensity to seek out E85 stations if they have a FFV, we assume that this level of stations translates into the following bound on E85 sales (see Phase I report for more details). Table 23 shows that this upper limit on E85 sales is quite optimistic relative to the EIA's forecasted E85 sales.

Table 23: Sales of E85 (Billions of Gallons)

	2012	2013	2014	2015
AEO 2011	0.06	0.07	0.08	0.09
Maximum	0.54	0.99	1.7	2.6

Source: EIA's AEO 2011 and NERA N_{ew}ERA model results.

B. Macroeconomic Model in N_{ew}ERA Modeling System

The N_{ew}ERA macroeconomic model is a forward-looking dynamic computable general equilibrium model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government. The economic interactions are based on the IMPLAN 2008 database for a benchmark year, which includes regional detail on economic interactions among 440 different economic sectors. The macroeconomic and energy forecasts that are used to project the benchmark year going forward are calibrated to the most recent AEO produced by the EIA. Because the model is calibrated to an internally-consistent energy forecast, the use of the model is particularly well suited to analyze economic and energy policies and environmental regulations.

For this study, the N_{ew}ERA macroeconomic model was set to run from 2012 to 2015 in one year time steps. We aggregated all the states into one U.S. region since the RFS2 program is a nationwide policy. We then aggregated the 440 sectors into five energy and seven non-energy sectors: energy sectors include crude oil, oil refining, natural gas extraction and distribution, coal, and electricity; the non-energy sectors include agriculture, commercial transportation (excluding trucking), energy intensive sectors, manufacturing, motor vehicle production, services, and trucking.

The N_{ew}ERA model incorporates EIA energy quantities and energy prices into the IMPLAN Social Accounting Matrices. This in-house developed approach results in a balanced energy-economy dataset that has an internally consistent energy benchmark data as well as IMPLAN consistent economic values.

The macroeconomic model incorporates all production sectors and final demands of the economy and is linked through terms of trade. The effects of policies are transmitted throughout the economy as all sectors and agents in the economy respond until the economy reaches equilibrium. The ability of the model to track these effects and substitution possibilities across sectors and regions makes it a unique tool for analyzing policies such as those involving energy and environmental regulations. These general equilibrium substitution effects, however, are not fully captured in a partial equilibrium framework or within an input-output modeling framework. The smooth production and consumption functions employed in this general equilibrium model enable gradual substitution of inputs in response to relative price changes thus avoiding all or nothing solutions.

Business investment decisions are informed by future policies and outlook. The forward-looking characteristic of the model enables businesses and consumers to determine the optimal savings and investment while anticipating future policies with perfect foresight. The alternative approach on savings and investment decisions is to assume agents in the model are myopic, thus have no expectations for the future. Though both approaches are equally unrealistic to a certain extent, the latter approach can lead the model to produce inconsistent or incorrect impacts from an announced future policy.

The CGE computable general equilibrium modeling tool such as the N_{ew}ERA macroeconomic model can analyze scenarios or policies that call for large shocks outside historical observation. Econometric models are unsuitable for policies that impose large impacts because these models' production and consumption functions remain invariant under the policy. In addition, econometric models assume that the future path depends on the past experience therefore fail to capture how the economy might respond under a different and new environment. For example, an econometric model cannot represent changes in fuel efficiency in response to increases in energy prices. However, N_{ew}ERA macroeconomic model can consistently capture future policy changes that envisage having large effects.

The N_{ew}ERA macroeconomic model is also a unique tool that can iterate over sequential policies to generate consistent equilibrium solutions starting from an internally consistent equilibrium baseline forecast (such as the AEO Reference Case). This ability of the model is particularly helpful to decompose macroeconomic effects of individual policies. For example, if one desires to perform economic analysis of a policy that includes multiple regulations, the N_{ew}ERA modeling framework can be used as a tool to layer in one regulation at a time to determine the incremental effects of each policy.

C. Integration of Models

To estimate the economic impacts of the RFS2 program on the overall economy, we established a one way linkage between the bottom-up transportation model and the top-down macroeconomic model. We first ran the reference and high biofuel scenarios through the transportation fuel model. The imposition of the RFS2 program leads to fuel price increases from the baseline without this program. For the top-down macroeconomic model, we translated the resulting higher fuel prices by applying a tax on gasoline and diesel that yields the same fuel price increase as seen in the bottom-up transportation fuel model.

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