NERA
ECONOMIC CONSULTING

Economic Impacts Resulting from Implementation of the RFS2 Program

Prepared for:

American Petroleum Institute

Report

July 27, 2015

Project Team/Authors

Paul Bernstein, Vice President

Bob Baron, Outside Consultant

Alyssa Lipshultz, Research Assistant

W. David Montgomery, Affiliated Consultant

Mei Yuan, Senior Consultant

The findings contained in this report may contain predictions based on current data and historical trends. Any such predictions are subject to inherent risks and uncertainties. In particular, actual results could be impacted by future events that cannot be predicted or controlled, including, without limitation, changes in business strategies, the development of future products and services, changes in market and industry conditions, the outcome of contingencies, changes in management, and changes in law or regulations. Neither API nor NERA accept responsibility for actual results or future events.

The opinions expressed herein are those of the authors and do not necessarily represent the views of NERA Economic Consulting or any other NERA consultant.

© NERA Economic Consulting

NERA Economic Consulting
1255 23rd Street NW
Washington, DC 20037
Tel: +1 202 466 3510
Fax: +1 202 466 3605
www.nera.com

Contents

EXECUTIVE SUMMARY 1
A. Past and Current Study Methodology 1
B. Results 1
C. Conclusions 2

II. INTRODUCTION 4
A. 2012 NERA RFS2 Study 5
B. Current Study: Scope and Study Objectives 6

III. BACKGROUND 7
A. RFS2 7
1. Nested Mandates 7
2. Implementation 8
3. Waivers 9
B. EPA's 2015 NPRM 9

IV. DESCRIPTION OF THE MODELS 12
A. Transportation Fuel Model 12
1. The Transportation Fuel Model is designed to Model RFS2 Program Characteristics 12
2. RFS Constraints: 13
3. Other Model Elements 13
B. N_{ew}ERA Macroeconomic Model 14
C. Model Integration 15
D. Analytical Methodology 15
E. Model Parameters 17
1. Fuel Prices 17
2. Supply Elasticities 18
3. Demand Elasticities 19
4. E85 19
5. Upper Bounds on Supply of Various Biofuels 20
6. Other Fuel Constraints and Assumptions 21

V. RESULTS 23
A. Study Results 23
B. The Dilemma with RFS2 23
C. Macroeconomic Impacts 24

VI. CONCLUSIONS 25

APPENDIX A. DETAILED MODEL DESCRIPTION 26
A. Transportation Fuel Model 26
1. Fuel Supply Curves 26
2. Demand Curves 26
4. Transportation Fuel Model is Designed to Model RFS2 Program Characteristics 27

5. RFS/RIN Constraints 27
6. Model Formulation 29
B. N_{ew}ERA Macroeconomic Model 30
1. Overview of the N_{ew}ERA Macroeconomic Model 30
2. Model Data (IMPLAN and EIA) 30
3. Brief Discussion of Model Structure 30

APPENDIX B. DETAILED TRANSPORTATION MODEL RESULTS FOR THE STATUTE SCENARIO 41

List of Figures

Figure 1: 2015 Gasoline and Diesel Results in Statute Scenario 2

Figure 2: Fuel Production and Blending Options for Meeting RFS2 Compliance 5

Figure 3: Applicable Volumes Specified in the Clean Air Act and the EPA's Proposed Volume Requirements (Billion Ethanol-Equivalent Gallons) 10

Figure 4: Comparison of EIA forecasted Biofuel Volumes and EPA's Proposed Volume Requirements (Billion Ethanol-Equivalent Gallons) 11

Figure 5: Baseline Fuel Price Ratios for Blended Gasoline and Diesels (Ratio on a GGE Basis of Biofuel to Conventional Fuel) 18

Figure 6: Fuels Institute's Top Quartile and EIA's E85 Sales Forecasts (Billion Gallons) 20

Figure 7: Maximum level of biofuels (Billion Gallons) 20

Figure 8: 2015 Gasoline and Diesel Results in Statute Scenario 23

Figure 9: AEO 2015 Reference Case Fuel Prices (2013$/Gallon) 27

Figure 10: EPA's Formulas for the RFS2 Percentage Mandates 28

Figure 11: EPA's Proposed Rule for RFS standards for 2015 and 2016 29

Figure 12: Circular Flow of Income 31

Figure 13: Standard N_{ew}ERA Model's Macroeconomic Regions 32

Figure 14: N_{ew}ERA Sectoral Representation in Core Scenarios 33

Figure 15: N_{ew}ERA Household Representation 34

Figure 16: N_{ew}ERA Electricity Sector Representation 35

Figure 17: N_{ew}ERA Trucking and Commercial Transportation Sector Representation 36

Figure 18: N_{ew}ERA Other Production Sector Representation 36

Figure 19: NewERA Resource Sector Representation 37

Figure 20: Quantities in Statute Scenario (Billion Gallons, Unless Otherwise Noted) 41

Figure 21: Cost to Consumer in Statute Scenario (2013$/gallon) 42

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 AEO2015.
BOB	Blendstock for Oxygenate Blending
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
NPRM	EPA's 2015 Notice of Proposed Rule Making
Obligated Party	Obligated Party Companies that produce and/or import gasoline and/or diesel fuel
RFS2	Renewable Fuel Standard Per Energy Independence and Security Act of 2007
RINs	Renewable identification numbers (Credits for compliance with RFS2)
RVO	Renewable Volume Obligation
Statute Scenario	Total renewable fuels and advanced biofuels at EISA '07 statute levels and biomass-based diesel at June 2015 NPRM levels for 2015-2017 and held constant at 2017 levels for 2018-2022. Cellulosic biofuel set at June 2015 NPRM levels for 2015-2016 and held at 2016 volume for 2017-2022
STEO	EIA's Short Term Energy Outlook

EXECUTIVE SUMMARY

The American Petroleum Institute (API) commissioned NERA Economic Consulting (NERA) to conduct a study of the potential transportation sector and macroeconomic impacts of the U.S. Renewable Fuel Standard (RFS2) Program on the economy. NERA[1] relied upon publically available information and NERA's proprietary economic modeling to develop the analysis.

A. Past and Current Study Methodology

In 2012, NERA released its first study of RFS2.[2] In that study, NERA analyzed the economic and compliance issues related to the implementation of RFS2. That study, like the current study, assumed the renewable fuel volume obligation (RVO) for total renewable fuel, advanced biofuels, and biomass-based diesel in each year would be equal to the volumes specified in the Energy Independence and Security Act of 2007 (EISA '07).[3]

In this study, NERA similarly considers the following scenario:

> Statute Scenario: Total renewable fuel and advanced biofuel volumes are set equal to EISA '07 statute levels. Biomass-based diesel volumes are set equal to June 2015 NPRM volumes for 2015-2017 and held constant at 2017 levels for 2018-2022. Cellulosic biofuel volumes are set equal to the June 2015 NPRM volumes for 2015-2016 and held at the 2016 volume for 2017-2022.

B. Results

As shown in Figure 1, when the required volume of total renewable fuel is equal to the EISA '07 statute requirement, the Statute Scenario exhibits a decrease in gasoline and diesel demand vs. EIA and outrageously high consumer costs that are evident immediately, i.e, in 2015. The 2015 statutory requirement would require about 30%[4] more RINs to be generated than were generated in 2014. In order to achieve the associated required blending percentage for obligated parties with the supply of available RINs requires about a 30% reduction in gasoline and diesel volumes from expected demand in 2015. To achieve this reduction in gasoline and diesel demand requires that costs increase by roughly $90 and $100 per gallon more than today's costs, respectively.

[1] All results and observations are based on information at the time of the report. To the extent that additional information becomes available or the factors upon which our analysis is based change, our opinions could subsequently be affected.

[2] Economic Impacts Resulting from Implementation of RFS2 Program, Prepared for the American Petroleum Institute, October 2012.

[3] The study assumed that cellulosic biofuel requirements were waived each year.

[4] EPA proposes 15.9 billion RINs for 2014. The statute requires 20.5 billion RINs in 2015.

Figure 1: 2015 Gasoline and Diesel Results in Statute Scenario

	Volume (Billion Gallons)	Cost to Consumer ($/Gallon)
Gasoline[5]	93	$92
Diesel	40	$103

Source: NERA analysis.

The price increases in gasoline and diesel are accompanied by a reduction in demand for the transportation fuels. Since the transportation sector is interconnected with other sectors in a way that the transportation services are consumed by other sectors, the fuel cost increase creates the spillover effects that ripple through the economy. Higher diesel fuel costs increase the cost to move raw materials and finished goods around the country, thus eventually making everything that directly or indirectly depends on transportation services more costly. Likewise the higher gasoline prices leave consumers with less disposable income. As a result of these impacts, consumption of goods and services declines. All of these impacts lead to severe economic harm.

C. Conclusions

Based upon NERA's modeling of the transportation sector and the overall economy for implementing the RFS2 biofuel volume requirements, NERA concludes:

- In 2015 and beyond, it is not feasible to achieve the statute volumes of total renewable fuel required under EISA '07. The current level of gasoline demand, the blend wall limiting the share of ethanol that can be blended into the gasoline pool, and the lack of non-ethanol biofuels limit the market potential for total renewable biofuels. Similarly the current market potential for higher ethanol content gasoline like E85 and E15 is too small to have an immediate impact on the amount of ethanol that the gasoline market can absorb.

- Only by the EPA invoking its two different waiver authorities[6] to issue a waiver for cellulosic ethanol and the same deduction for the total renewable biofuels and advanced biofuel volumes requirements as well as a general waiver for both advanced biofuels and total renewable fuels would allow the RFS2 to be feasible.

- NERA's conclusion that it is infeasible to achieve the statute volumes for total renewable fuels in 2015 and beyond is consistent with NERA's findings from its 2012 study, which also found that if the EPA retained the EISA '07 statute volumes, severe economic harm

[5] For this figure, gasoline includes E0, E10, and E85. Therefore, the gasoline price is the weighted average price of E0, E10, and E85.

[6] The cellulosic ethanol waiver allows EPA to reduce applicable volumes for cellulosic biofuels and apply the same reduction to the total renewable biofuels and advanced biofuel volumes requirements. The general waiver allows EPA to reduce volumes for any renewable fuel if there is inadequate supply.

would result in the 2015 to 2016 time frame. Infeasibility has not occurred yet because EPA has recognized the blend wall and is proposing volumes below the statute levels.

Economic harm: When the required biofuel volume standards are too severe, as with the statute scenario, the market becomes disrupted because there are an insufficient number of RINs to allow compliance. "Forcing" additional volumes of biofuels into the market beyond those that would be "absorbed" by the market based on economics alone at the levels required by the statute scenario will result in severe economic harm.

II. INTRODUCTION

The American Petroleum Institute (API) commissioned NERA Economic Consulting (NERA) to analyze the potential impacts on the transportation fuels market and the U.S. economy resulting from complying with the statutory volumes under the Renewable Fuel Standard (RFS2)[7] through 2022. NERA relied upon publically available information and NERA's proprietary economic modeling to develop the analysis.

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 each year and collectively require the use of 36 billion gallons of renewable fuels in 2022. Each year, the EPA is supposed to assess for the next year whether or not the statutory volumes prescribed under EISA '07 are achievable. If not, the EPA has the authority to lower the annual fuel mandate for each class of renewable fuel. 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.

Figure 2 lists the four primary mechanisms that obligated parties can use to comply with the RFS2. To comply with the RFS2 mandates, obligated parties have increased production of E10 and E85 while minimizing production of E0 (pure gasoline). As the RFS2 mandated volumes for renewable fuels increase, however, these mechanisms reach their limit.

[7]RFS2 was part of the Energy Independence and Security Act of 2007 ("EISA '07").

Figure 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
Increase production of E85	Demand for E85 will remain low due to limited E85 infrastructure, E85's low fuel economy, and limited consumer preference for E85
Increase use of biomass-based diesel	The available volume of biomass-based diesel is relatively small compared to the overall RFS2 requirement. The infrastructure to blend biomass-based diesel is limited.
Produce and market E15	Market penetration of E15 will be limited by vehicle warranty, retail infrastructure, misfueling, and general liability issues

When obligated parties exhaust these methods of compliance, they will eventually be forced to either decrease their 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 negative economic impacts.

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.

A. 2012 NERA RFS2 Study

In 2012, NERA released its first study of RFS2.[8] In that study, NERA analyzed the economic and compliance issues related to the implementation of RFS2. That study, like the current study, assumed that in each year the renewable fuel volume obligation (RVO) for total renewable fuel, advanced biofuels, and for biomass-based diesel would be equal to the volumes specified in EISA '07.[9] In other words, the study assumed that the EPA decided not to exercise its authority to reduce the RVO requirements in any year for three of the four biofuel categories; the only exception was cellulosic biofuel. The study found that if the RVO remained at the levels called for in EISA '07 that RFS2 would likely become infeasible in three to four years (2015 or 2016),

[8] Economic Impacts Resulting from Implementation of RFS2 Program, Prepared for the American Petroleum Institute, October 2012.

[9] The study assumed that cellulosic biofuel requirements were waived each year.

resulting in significant harm to the U.S. economy. Since the time of our first study, the EPA in subsequent rulemaing(s) acknowledged the existence of the blend wall[10] and that the statute requirement for renewable fuel volumes is infeasible.[11] As a result, the EPA has proposed lower targets in its current Notice of Proposed Rulemaking (NPRM).

B. Current Study: Scope and Study Objectives

API retained NERA Economic Consulting (NERA) to update its analysis of the potential impacts on the transportation fuels market and the U.S. economy resulting from complying with the RFS2 statutory volumes. NERA relied upon publically available information and NERA's proprietary economic modeling to develop the analysis.

In this study, NERA considers the following scenario:

- Statute: Total renewable fuel and advanced biofuel volumes are set equal to EISA '07 statute levels. Biomass-based diesel volumes are set equal to June 2015 NPRM volumes for 2015-2017 and held constant at 2017 levels for 2018-2022. Cellulosic biofuel volumes are set equal to the June 2015 NPRM volumes for 2015-2016 and held at the 2016 volume for 2017-2022.

NERA used updated versions of its two proprietary models that were used in the earlier study: NERA's transportation fuel model and the N_{ew}ERA macroeconomic model. These models were run[12] 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 and blended diesel. The N_{ew}ERA macroeconomic model[13] simulates all economic interactions in the U.S. economy, including those among industry, households, and the government.

[10] "The proposal seeks to put the RFS program on a steady path forward – ensuring the continued growth of renewable fuels while recognizing the practical limits on ethanol blending, called the ethanol 'blend wall.'" EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volume, Office of Transportation and Air Quality, EPA-420-F-13-048, p. 1, November, 2013.

[11] "Due to constraints in the fuel market to accommodate increasing volumes of ethanol, along with limits on the availability of non-ethanol renewable fuels, the volume targets specified by Congress in the Clean Air Act for 2014, 2015, 2016 cannot be achieved." EPA Proposes Renewable Fuel Standards for 2014, 2015, and 2016, and the Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA-420-F-15-028, p. 2, May, 2015.

[12] 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.

[13] 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 in the Scenario, we could not run the N_{ew}ERA macroeconomic model past 2015.

III. 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.[14] 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 diesel 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-based diesel, or imported sugarcane ethanol that exceeds the advanced biofuel mandate would reduce the potential need for corn-starch ethanol to meet the overall mandate.

[14] Renewable fuels used in ocean-going vessels cannot count toward RFS2 mandates. Renewable fuels used in heating oil and jet fuel do count towards the RFS mandates.

2. 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.[15]

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. Because of the higher energy content per gallon than ethanol, biodiesel generates 1.5 RINs per gallon; similarly renewable diesel generates between 1.5 and 1.7 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 has determined the total renewable fuel volume that must be incorporated into the nation's fuel supply each year—referred to as an RVO. However, under its waiver authorities, the EPA may reduce the RVO for a given year. The EPA translates the RVO into blending percentage standards that are used by obligated parties to determine their individual RVO.[16] 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 consumed in the US 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 carryover 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).[17]

[15] For tracking purposes, each RIN has a unique 38-character number that is issued (in accordance with the EPA guidelines). Each RIN identifies which of the four RFS categories—total, advanced, cellulosic, or biodiesel—the biofuel satisfies.

[16] 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.

[17] 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.

3. Waivers

EPA has the authority to reduce the volume requirements from their statutory targets based upon the availability of qualifying renewable fuels and other factors.[18] There are two authorities in the statute that are applicable: the cellulosic waiver authority and the general waiver authority. When the EPA uses its authority under the cellulosic waiver authority to lower the applicable volume of cellulosic ethanol,[19] it also has the authority to reduce the target for other affected renewable fuels (advanced biofuels and total renewable fuels) by the same amount or less. Second, under the general waiver authority, EPA can reduce the applicable volume of an individual renewable fuel if it determines that either there is "inadequate supply" or "implementation of the requirement would severely harm the economy or environment of a State, a region, or the United States."[20]

B. EPA's 2015 NPRM

EISA '07 requires that the EPA set annual standards for the RFS2 program by November 30 of each year for the following year. However, the EPA last set annual RFS2 standards in 2012 for 2013. The EPA proposed standards for 2014 in November 2013 but did not finalize requirements.[21] It was not until May 2015 that the EPA released a new proposal to establish the annual percentage standards for cellulosic biofuel, biomass-based diesel, advanced biofuel and total renewable fuels for the years 2014, 2015, and 2016.[22] The EPA also proposed required volumes of biomass-based diesel for 2017.

In its NPRM, the EPA states that it believes the statutory volumes for renewable fuels set by Congress for the years 2014, 2015, and 2016 cannot be met as a result of lower than expected gasoline consumption, the inability of the fuel markets to absorb increasing volumes of ethanol, and limits on the availability of non-ethanol renewable fuels. Because the EPA has concluded that the 2014-2016 statutory levels are not achievable, the EPA is exercising its waiver authority to reduce the volume requirements for renewable fuels for these years. For 2014, the EPA proposes to reduce the volume requirements to levels that were actually produced and consumed.

---

[18] Cellulosic Waiver Authority: If the EPA determines that the projected volume of cellulosic biofuel production for the following year is less than the applicable volume provided in the statute, then the EPA must reduce the applicable volume. General Waiver Authority: the EPA Administrator may reduce the applicable volume if it is determined that implementation of the requirement would severely harm the economy or the environment of a State, regions or the United States; or there is an inadequate domestic supply, Clean Air Act section 211(o)(7)(A)(i)).

[19] EPA has waived more than 97% of the cellulosic biofuel volume requirement through 2013. The Agency has not yet promulgated cellulosic biofuel volumes for later.

[20] Clean Air Act section 211(o)(7)(A)(i).

[21] EPA Proposes 2014 Renewable Fuel Standards, 2015 Biomass-Based Diesel Volume, Office of Transportation and Air Quality, EPA-420-F-13-048, November, 2013.

[22] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA-HQ-OAR-2015-0111; FRL-9927-28-OAR, May, 2015.

For 2015 and 2016, the EPA proposes applicable volumes for renewable fuels that are less than statutory requirements, but reflect what the EPA characterizes as "ambitious increases in both advanced biofuels and total renewable fuel in comparison to 2014 levels." Furthermore, EPA does not intend for the proposed standards to "intentionally draw down the current bank of carryover RINs." Rather, EPA maintains that carryover RINs should not be considered when setting annual compliance targets and acknowledges that preserving the current volumes of carryover RINs will be "important" in addressing "future uncertainties and challenges."[23]

Figure 3 compares the EPA's proposed targets with the statutory requirements specified in the EISA '07. The proposed cellulosic biofuel target is less than 1% of the statutory requirement. This reduction reflects the fact that cellulosic technology has not progressed at a commercial scale as was envisioned. RFS2 was in part intended to incent the private sector to develop new technologies to advance cellulosic biofuels. This has not occurred. The total renewable fuel proposed volume is also lower than the statutory requirement reflecting the lack of growth in gasoline demand and the limitations in ethanol use due to the blend wall. For 2014, proposed total renewable fuel volumes were more than 2 billion gallons fewer than the statute requirements.[24] In 2015 and 2016, the EPA's proposed volume requirements are more than 4 billion gallons fewer than the statute obligations. The EPA's proposed advanced biofuel volumes are also reduced. However, the EPA's proposed volumes for biomass-based diesel exceed the minimum statute levels and show significant and positive growth throughout the period.

Figure 3: Applicable Volumes Specified in the Clean Air Act and the EPA's Proposed Volume Requirements (Billion Ethanol-Equivalent Gallons)

	2014		2015		2016		2017	
	Statute	EPA	Statute	EPA	Statute	EPA	Statute	EPA
Cellulosic Biofuel	1.75	0.033	3.0	0.106	4.25	0.206	5.5	
Biomass-Based Diesel	≥1.0	1.63	≥1.0	1.7	≥1.0	1.8	≥1.0	1.9
Advanced Biofuel	3.75	2.68	5.5	2.9	7.25	3.4	9.0	
Renewable Fuel	18.15	15.93	20.5	16.3	22.25	17.4	24.0	

All values are ethanol-equivalent on an energy content basis, except for BBD which is in actual billion gallons.

The EPA's proposed volume targets generally exceed EIA's forecasts for biofuel use. Figure 4 compares the EPA's proposed targets with EIA forecasts for biofuel production converted to categories consistent with the EPA biofuel categories. The EPA's proposed volumes for total renewable fuels exceeds EIA Reference Case forecasts by 1 billion ethanol equivalent gallons in

[23] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA–HQ–OAR–2015–0111; FRL–9927–28–OAR, p. 33130, June, 2015.

[24] The EPA proposes to use what it has determined to be the actual domestic use as the requirement for 2014. Thus the EPA considers 15.93 billion ethanol equivalent gallons as the actual use of total renewable fuels in 2014.

2015 and 2.1 billion ethanol equivalent gallons in 2016. The EPA's proposed volumes for total renewable fuels exceed EIA High Oil Price Case forecasts by 0.1 billion ethanol equivalent gallons in 2015 and 0.9 ethanol equivalent gallons in 2016. The EPA's cellulosic biofuel volumes are roughly twice those forecasted by EIA. With biomass-based diesel for the years 2015 and 2016, the EPA's proposed volumes exceed forecasted volumes in the EIA's AEO reference case but are less than volumes in the EIA's High Oil Price case. In 2017, the EIA forecasts in both cases exceed the EPA's proposed volumes for biomass-based diesel.

Figure 4: Comparison of EIA forecasted Biofuel Volumes and EPA's Proposed Volume Requirements (Billion Ethanol-Equivalent Gallons)

		EPA Proposed Requirement	AEO Reference	AEO High Oil Price
2015	Cellulosic Biofuel	0.106	0.043	0.041
	Biomass-Based Diesel (BBD)	1.70	1.60	1.89
	Advanced Biofuel	2.90	2.46	2.88
	Renewable Fuel	16.3	15.3	16.2
2016	Cellulosic Biofuel	0.206	0.097	0.093
	Biomass-Based Diesel (BBD)	1.80	1.65	2.03
	Advanced Biofuel	3.40	2.60	3.15
	Renewable Fuel	17.4	15.3	16.5
2017				
	Biomass-Based Diesel (BBD)	1.90	2.16	2.16

EIA does not report sugar ethanol imports. All values are ethanol-equivalent on an energy content basis, except for BBD which is in actual billion gallons.

IV. DESCRIPTION OF THE MODELS

A. Transportation Fuel Model

The transportation fuel model is a recursive partial-equilibrium model designed to estimate the amount of fuel produced for and consumed by the transportation sector. The model maximizes the sum of producers' surplus (a value to producers from producing fuels) and consumers' surplus (a measure of household value from fuel consumption) 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 such as the blend wall, blend limit for biodiesel, and RFS2's RVOs.

The model is calibrated in 2015 and 2016 to the EIA's Short-Term Energy Outlook (STEO) for May 2015 and to the AEO2015 Reference forecast for 2017 through 2022, with a few minor adjustments to the consumption of some biofuels to reduce the EIA forecasted values that occur because of the existence of the EIA assuming the presence of an RFS policy.

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

We customized the transportation fuel model 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 2015, and the last year is 2022. 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 that may contain up to 5% biodiesel. 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, renewable diesel, cellulosic diesel, and biodiesel. The model also includes an exogenous forecast for biogas consumption in CNG vehicles.

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

- E0 use must be greater or equal to 2.5% of the sum of E0 and E10 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 that consume diesel are allowed to use up to a 5% blend of biodiesel.

2. RFS Constraints:

The model accounts for the minimum annual volume of biofuel sales required under the RFS2 scenario considered 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 all above biofuel, corn ethanol, and imported renewable diesel).

For this analysis, we assume that cellulosic biofuels will continue to be commercially available only in very limited quantities, and as a result, the EPA would continue to grant a cellulosic waiver. This assumption avoids the debate about the economic and technical feasibility of producing cellulosic fuels[25] 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.

3. Other Model Elements

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.

The model also incorporates constraints on the feedstocks of the finished fuels and on the finished fuels themselves. For the feedstocks, there are upper limits on the amount of biodiesel, renewable diesel, biogas, sugar ethanol, and cellulosic ethanol that can make it into the diesel or gasoline pools. For these feedstocks there are quantity limits as well as limits as to how much ethanol can be blended with petroleum gasoline and how much biodiesel can be blended with petroleum diesel. The blend wall for gasoline is set at 10% and the blend limit for diesel is set at 5%.

Furthermore, there are limits on the availability of various finished fuels to account for both consumer acceptance and infrastructure issues. The sales of E0 and E85 are limited based on these issues. E0 must comprise at least 2.5% of the sum of E0 and E10; whereas the model places an upper limit on the amount of E85 that can be consumed in each year.

[25] 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.

B. N_{ew}ERA Macroeconomic Model

The N_{ew}ERA macroeconomic model used for the current study is a static computable general equilibrium model of the United States. Compared to a forward-looking dynamic model that assumes perfect foresight with more certainty about the policy trend in the long term, the static model is well suited for the policy with the great uncertainty like the current RFS policy as exhibited by the EPA's delay in setting the 2014 and 2015 standards. 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 AEO2015 Reference case 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 2015 to 2022 (or the last year in which the bottom-up transportation model finds a feasible solution) 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 the current period policies and market forces. The myopic characteristic of the static model determines the optimal consumption and investment based on only the relative price changes in the current period thus agents have no expectation for the future. The alternative approach on savings and investment decisions is to assume the agents in the model have perfect foresight over the horizon. That is, to anticipate what will happen in the future can change the consumption-investment decision today. Though both approaches have their limitations, the former approach better reflects market expectations and responses to the RFS2 policy given all the uncertainty about future targets, the time lags in defining future targets, and the limited horizon for which future targets have been defined.

Consumers in the model are represented by a single regional representative household. The representative household derives utility from both consumption of goods and services,

transportation services, and leisure. The model also represents federal and regional/state level governments. The government collects federal and state taxes to support its expenditures.

We balance the international trade account in the N_{ew}ERA model by constraining changes in the current account deficit over the model horizon. The condition is that the net present value of the foreign indebtedness over the model horizon remains at the benchmark year level. This prevents distortions in economic effects that would result from perpetual increase in borrowing, but does not overly constrain the model by requiring current account balance in each year.

The N_{ew}ERA model is based on a unique set of databases constructed by combining economic data from the IMPLAN 2008 (MIG Inc. 2010) database and energy data from the Energy Information Administration (EIA's) Annual Energy Outlook 2015 (AEO 2015). The IMPLAN 2008 database provides Social Accounting Matrices (SAMs) for all states for the year 2008. These matrices have inter-industry goods and services transaction data; we rebuild the SAM and merge the economic data with energy supply, demand, and prices consistent with *AEO2015* from EIA.

The N_{ew}ERA model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include gross regional product, consumption, investment, disposable income and changes in income from labor, capital, and resources.

More details of the model structure are presented in Appendix B.

C. Model Integration

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

- Using the transportation fuel model, the baseline and statute scenarios were run to determine the effect on fuel prices resulting from the RFS2 requirements for increased use of biofuels.

- 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.

- To ensure consistency between the transportation fuel model and the N_{ew}ERA macroeconomic model, we also calibrated the macroeconomic model in terms of relevant elasticities such that for a given scenario, the macro model experiences the same quantity and price impacts in the transportation sectors as in the transportation fuel model.

D. Analytical Methodology

The scenario was 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

the 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 and E10), 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 (biodiesel and renewable diesel). The N_{ew}ERA macroeconomic model then determined the impact on the U.S. economy of meeting the RFS2 mandate given the price and volume responses to the modeled RFS program forecasted by the bottom-up transportation sector model. The results are 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 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 solves for the mix of feedstocks and finished fuels that minimizes the cost of compliance with RFS2 for the current year, through the use and value of surplus RINs that were carried forward and the carrying forward of RINs for the following year. Therefore, the years are linked through the RINs.

RIN carryover in this report represents how surplus RINs can be carried over from one compliance period to the next by an obligated party. We assume that as of the beginning of January 2015 the D6 RIN carryover bank was 1.8 billion gallons.[26] We refer to these RINs as the initial inventory of RINs available for compliance. After defining the RINs available at the beginning of 2015 and calibrating the model's supply and demand curves to the AEO's forecasted 2015 values, the model was solved with the RFS2 constraints and other infrastructure constraints for the year 2015.

The RINs available at the end of 2015, or the number of RINs carried forward to 2016, equals the RINs available at the beginning of 2015 (1.8 billion gallons) plus the difference between the number of RINs generated and the number of RINs submitted for compliance during 2015

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

[26] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA–HQ–OAR–2015–0111; FRL–9927–28–OAR, p. 33130, June, 2015.

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 2015, the model then solves for 2016. However, instead of using the EIA's forecast for 2016 energy consumption, the values to which the model calibrates its energy consumption are adjusted based on the model's 2015 solution values for energy consumption. Assuming that the RFS2 constraint binds for 2015, the forecasted fuel sales volumes will differ in 2015 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., by 2022) rather than retaining RINs after 2022 allows obligated parties to meet the mandates with lower volumes of renewable fuels and hence reduces the burden of the policy.

E. Model Parameters

1. Fuel Prices

All fuel prices are national, annual averages over multiple grades of fuel. Our baseline prices for finished products (gasoline and diesel) are the same as those forecast in the AEO2015 Reference Case. The NERA baseline 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 Figure 5, and the logic and sources upon which these relative prices are based are described below.[27]

[27] The gasoline, diesel, and corn ethanol prices are taken from the AEO 2015 Reference case.

Figure 5: Baseline Fuel Price Ratios for Blended Gasoline and Diesels (Ratio on a GGE[28] Basis of Biofuel to Conventional Fuel)[29]

	2015	2016	2017	2018	2019	2020	2021	2022
Corn Ethanol	1.38	1.19	1.47	1.44	1.42	1.34	1.34	1.31
Sugarcane Ethanol	1.59	1.37	1.69	1.65	1.63	1.54	1.54	1.51
Cellulosic Ethanol	2.23	1.92	2.36	2.32	2.28	2.16	2.17	2.12
Soy-Based Biodiesel	1.92	1.69	1.65	1.65	1.65	1.62	1.60	1.58
Renewable Diesel	1.93	1.69	1.65	1.65	1.65	1.62	1.60	1.58

Source: EIA's AEO2015, EIA, California Energy Commission, and NERA analysis.

Ethanol:

- Ratio of corn ethanol to gasoline is from the AEO2015 Reference Case, Table A12.
- Sugar Ethanol: Ratio of sugar ethanol prices to gasoline prices taken from California Energy Commission statistics.[30]
- Cellulosic Ethanol: Ratio of cellulosic ethanol prices to gasoline prices based on EIA's cost build up.[31] However, the future cost of cellulosic ethanol is uncertain.

Soy-Based Biodiesel: Ratio of soy-based biodiesel to petroleum diesel prices based upon EIA's cost buildup modified for current soy bean prices.[32]

Renewable Diesel: Ratio of renewable diesel to petroleum diesel prices based upon EIA's Cost buildup modified for current feedstock prices.[33]

2. Supply Elasticities

In addition, supply elasticities were derived by using fuel price and fuel supply information from EIA's AEO 2011 and AEO 2015 Reference and High Oil Price Cases. These cases provided time series for the prices and quantities of the different fuels. The price elasticity of 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 2.0 for soy-based biodiesel. Because sugar ethanol exported to the U.S. is a small percentage of the total sugar ethanol produced, we assume a high supply elasticity of 4 for this fuel. The elasticity for

[28] Gasoline gallon equivalent basis; fuels GGE are adjusted by relative heating value to petroleum gasoline.
[29] 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.
[30] 2011 Integrated Energy Policy Report, California Energy Commission, February, 2012.
[31] Assumptions to AEO2014, Table 11.9.
[32] Assumptions to AEO2014, Table 11.9.
[33] Assumptions to AEO2014, Table 11.9.

petroleum fuels is 0.8.[34] To account for the ability of the market to respond more over time, the supply elasticities increase by 5% per year.

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. The E10 and diesel demand curves' elasticity for 2015 is set equal to Dahl's estimate for short-term elasticity of -0.1.[35] To allow for the trade-off between E10 and E0 for conventional vehicles and E10 and E85 for FFVs, we assume a demand elasticity of -0.5 for E0 and E85. To account for the ability of the market to respond more over time, the supply elasticities increase by 10% per year.

4. E85

The Fuels Institute undertook a study of E85.[36] They extensively reviewed historical sales. From this analysis, they developed forecasts of future E85 sales based on assumptions about the penetration of E85 stations and the throughput at stations that sell E85. We based our estimates of potentially available E85 solely upon Fuels Institute's Top Quartile Scenario. This scenario assumes every E85 retail station has the ability to match the performance of the Top Quartile of stores reported in the Fuels Institute sample. These stores sold on average 364 gallons of E85 per day. The model forecasts potential daily E85 volume of 619 gallons per store by 2023. Applying this per store E85 daily sales forecast to the total number of E85 stores, the model forecasts that by 2023 such a market could generate 2.2 billion gallons of E85 sales.[37]

Figure 6 reports the Fuels Institute's Top Quartile forecast and the EIA's AEO 2015 Reference Case forecast. Comparing the two forecasts shows that the Top Quartile forecast is extremely optimistic compared to the EIA's forecast. Using the Top Quartile forecast does not fully account for consumer reluctance of consuming E85, which stems from the lower fuel economy and limited range of E85. Therefore, the Top Quartile forecast serves as an optimistic upper level on E85 sales.

[34] Paltsev, Sergey, John M. Reilly, Henry D. Jacoby, Richard 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.

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

[36] "E85 – A Market Performance and Forecast, Fuels Institute," 2014.

[37] "E85 – A Market Performance and Forecast, Fuels Institute," p. 34, 2014.

Figure 6: Fuels Institute's Top Quartile and EIA's E85 Sales Forecasts (Billion Gallons)

	2015	2016	2017	2018	2019	2020	2021	2022
Fuels Institute	0.40	0.51	0.65	0.83	1.06	1.35	1.72	2.20
EIA	0.34	0.37	0.22	0.22	0.27	0.29	0.39	0.64

Source: EIA's AEO 2015, Fuels Institute.

5. Upper Bounds on Supply of Various Biofuels

The model incorporates production or consumption limits on the following biofuels: Cellulosic Biofuel, Sugar Ethanol, Biogas, Biodiesel, and Renewable Diesel. The maximum supply of biofuels is shown in Figure 7, and the logic and sources upon which these levels were derived is described below.

Figure 7: Maximum level of biofuels (Billion Gallons)

	Ethanol			Diesel	
	Cellulosic	Sugar	Biogas	Bio	Renewable
2015	0.04	0.68	0.13	1.90	0.30
2016	0.10	0.75	0.31	2.03	0.30
2017	0.14	0.82	0.49	2.16	0.30
2018	0.16	0.91	0.49	2.29	0.30
2019	0.17	1.00	0.49	2.47	0.33
2020	0.17	1.10	0.49	2.67	0.43
2021	0.17	1.20	0.49	2.87	0.54
2022	0.17	1.33	0.49	3.07	0.68

As discussed earlier, the EPA can waive the RFS2 requirement, in whole or in part, if there is an inadequate domestic supply. With respect to the cellulosic biofuels mandate, there is an established track record by the 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, the 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, we concluded that it was unlikely that cellulosic biofuels will be used in any appreciable quantities during our forecast horizon.

The maximum supply of cellulosic ethanol was set equal to the maximum of the consumption of cellulosic ethanol in the AEO's 2015 Reference and High Oil Price case. The maximum supply of cellulosic ethanol is 0.03, 0.12, and 0.14 Billion gallons for 2015, 2016, and 2017, respectively. AEO 2015 High Oil Price case forecasts these volumes for these years.

The maximum amount of sugar ethanol was set to 680 million gallons, the quantity that the U.S. imported in 2006. This is the highest volume of Brazilian ethanol that the U.S. ever imported, and imports in recent years have been considerably lower. In 2014, imports were only 64 million gallons. Production of sugarcane ethanol in Brazil has increased in recent years, but demand for ethanol in Brazil has also increased. This maximum is increased by 10% for each year from 2016 to 2022.

In the NPRM, the EPA provides values for CNG/LNG production in new facilities and in existing facilities in 2015 and 2016. We set the maximum limits on biogas to the sum of the EPA's high end estimates for production of CNG/LNG in new and existing facilities for each year. We use the annual growth rate of biogas production that the EPA determines for 2015 to 2016 to calculate biogas production limits in 2017 and then maintain the upper limit of biogas at the 2017 level through 2022.

The NPRM estimates the consumption of 1.69 billion gallons of total biomass-based diesel in 2014. The model's maximum allowable amount of biomass-based diesel consumption from 2015 to 2022 is computed by adding 0.2 billion gallons per year to the 2014 value. Renewable diesel capacity is set equal to the maximum of the EIA's AEO 2015 Reference Case[38] consumption of renewable diesel and the amount of renewable diesel supplied to the market in 2014 according to the EPA's NPRM. For 2015, the level of renewable diesel consumption in the AEO 2015 Reference Case exceeds the corresponding value in the High Oil Price Case. The maximum biodiesel capacity is assumed to be 10% greater than the difference between maximum capacities of the total biomass-based diesel and renewable diesel. This forecast for maximum potential production exceeds the EIA's AEO 2015 High Oil Price Case consumption level.

6. Other Fuel Constraints and Assumptions

The Statute Scenario 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 May 2015 showed that E0 reached a low of about 2.5% in the spring/summer of 2012. The more gasoline that is used to produce E0 means that there is less to be 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 assumed the share of the E0

[38] The EIA's 2015 AEO Reference case forecasts greater amounts of renewable diesel than its High Oil Price case.

and E10 gasoline pool that is E0 can drop no lower than 2.5%. This is consistent with data generated by EIA.[39]

We assume E15 sales to be zero because the EPA forecasts them to be quite small:

> Efforts to increase the use of ethanol beyond the blend wall are primarily a function of the volume of E85 that is consumed, since volumes of E15 are likely to continue to be small in 2016. Over the last several years, EPA has taken a series of regulatory steps to enable E15 to be sold in the U.S. In 2010 and 2011, EPA issued partial waivers to enable use of E15 in model year 2001 and newer motor vehicles, and in June of 2011, EPA finalized regulations to prevent misfueling of vehicles, engines, and equipment not covered by the partial waiver decisions. However, growth in the number of retail stations offering E15 has been slow – currently there are only about 100 stations offering it. Even if this number grows more quickly in 2015 and 2016 than it did previously, such increases would probably not increase total ethanol consumption by more than 5 - 10 million gallons in comparison to the use of ethanol in E10. [40]

[39] EIA Weekly Refiner and Blender Net Production data available at: http://www.eia.gov/dnav/pet/pet_pnp_wprodrb_dcu_nus_w.htm.

[40] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA–HQ–OAR–2015–0111; FRL–9927–28–OAR, p. 33126, June, 2015.

V. RESULTS

A. Study Results

As shown in Figure 8, when the required volume of total renewable fuel is equal to the EISA '07 statute requirement,the Statute Scenario exhibits a decrease in gasoline and diesel demand vs. EIA and outrageously high consumer costs that are evident immediately, i.e, in 2015. The 2015 statutory requirement would require about 30%[41] more RINs to be generated than were generated in 2014. In order to achieve the associated required blending percentage for obligated parties with the supply of available RINs requires about a 30% reduction in gasoline and diesel volumes from expected demand in 2015. To achieve this reduction in gasoline and diesel demand requires that costs increase by roughly $90 and $100 per gallon more than today's costs, respectively.

Figure 8: 2015 Gasoline and Diesel Results in Statute Scenario

	Fuel Demand (Billion Gallons)	Cost to Consumer ($/Gallon)
Gasoline	93	$92
Diesel	40	$103

Source: NERA analysis.

The price increases in gasoline and diesel are accompanied by a reduction in demand for the transportation fuels. Since the transportation sector is interconnected with other sectors in a way that the transportation services are consumed by other sectors, the fuel cost increase creates the spillover effects that ripple through the economy. Higher diesel fuel costs increase the cost to move raw materials and finished goods around the country, thus eventually making everything that directly or indirectly depends on transportation services more costly. Likewise the higher gasoline prices leave consumers with less disposable income. As a result of these impacts, consumption of goods and services declines. All of these impacts lead to severe economic harm.

B. The Dilemma with RFS2

There is a fundamental problem with the RFS2 mandate: the blending percentage standard for total renewable fuel, at statutory volumes exceeds 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. For 2015, this percentage is calculated at 11.6%.[42] This results in a market disruption as it is impossible to achieve the RFS2 biofuel

[41] EPA proposes 15.9 billion RINs for 2014. The statute requires 20.5 billion RINs in 2015.

[42] Source: NERA assumptions and analysis. The ratio of the RIN gallons to the sum of gallons in the diesel and gasoline pools including E85 less the statute level RIN gallons for total renewable fuels.

volume targets because E10 has a percentage value of 11.1% and B5 has a percentage value of 8.1%.

This issue of exceeding the maximum feasible level will only be exacerbated by the forecasted declining consumption of gasoline because of the tighter CAFE standards, which will lead to improved fuel economy and less gasoline consumption.

C. Macroeconomic Impacts

The price increases in gasoline and diesel are accompanied by a reduction in demand for the transportation fuels. Since the transportation sector is interconnected with other sectors in a way that the transportation services are consumed by other sectors, the fuel cost increase creates the spillover effects that ripple through the economy. Higher diesel fuel costs increase the cost to move raw materials and finished goods around the country, thus eventually making everything that directly or indirectly depends on transportation services more costly. As a result, consumption of goods and services declines.

During the model horizon, labor earnings decrease. This decline results from two competing effects on the production side – a substitution and an output effect. The substitution effect occurs as the increase in the cost of transportation services leads other sectors to substitute away from transportation services toward value added inputs like labor and capital to help reduce the total cost of production. The effect on output occurs where the cost increase in transportation service pushes up the output price which leads to a reduction in the level of production and lower demand for all inputs. When the output effect outweighs the substitution effect, the demand for labor falls, leading to a lower wage rate and lower labor earnings.

Consumption falls by an even greater amount. In addition to the negative impact of higher costs for finished goods and services caused by rising diesel and gasoline costs, 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 purchased in the absence of RFS2.

The combined effect of less disposable income and the higher cost for finished goods and services means that consumption declines even further.

VI. CONCLUSIONS

Based upon NERA's modeling of the transportation sector and the overall economy for implementing the RFS2 biofuel volume requirements, NERA concludes:

- In 2015 and beyond, it is not feasible to achieve the statute volumes of total renewable fuel required under EISA '07. The current level of gasoline demand, the blend wall limiting the share of ethanol that can be blended into the gasoline pool, and the lack of non-ethanol biofuels limit the market potential for total renewable biofuels. Similarly the current market potential for higher ethanol content gasoline like E85 and E15 is too small to have an immediate impact on the amount of ethanol that the gasoline market can absorb.

- Only by the EPA invoking its two different waiver authorities[43] to issue a waiver for cellulosic ethanol and the same deduction for the total renewable biofuels and advanced biofuel volumes requirements as well as a general waiver for both advanced biofuels and total renewable fuels would allow the RFS2 to be feasible.

- NERA's conclusion that it is infeasible to achieve the statute volumes for total renewable fuels in 2015 and beyond is consistent with NERA's findings from its 2012 study, which also found that if the EPA retained the EISA '07 statute volumes, severe economic harm would result in the 2015 to 2016 time frame. Infeasibility has not occurred yet because EPA has recognized the blend wall and is proposing volumes below the statute levels.

Economic harm: When the required biofuel volume standards are too severe, as with the statute scenario, the market becomes disrupted because there are an insufficient number of RINs to allow compliance. "Forcing" additional volumes of biofuels into the market beyond those that would be "absorbed" by the market based on economics alone at the levels required by the statute scenario will result in severe economic harm.

[43] The cellulosic ethanol waiver allows EPA to reduce applicable volumes for cellulosic biofuels and apply the same reduction to the total renewable biofuels and advanced biofuel volumes requirements. The general waiver allows EPA to reduce volumes for any renewable fuel if there is inadequate supply.

APPENDIX A. 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 policy 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. 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.

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 fuels consumed and price of fuel, respectively, in the AEO high oil price and reference cases. 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 and 1.2 for biodiesel. The elasticity for petroleum fuels was is 0.8.[44] Because sugar ethanol for the U.S. is a small percentage of the total sugar ethanol produced, we assume a high supply elasticity of 4 for this fuel. To account for the ability of the market to respond more over time, the supply elasticities increase by 5% per year.

2. 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. The E10 and diesel demand curves' initial elasticity equals that of Dahl's estimate for short-term elasticity of -0.1.[45] To allow for the trade-off between E10 and E0 for conventional vehicles and E10 and E85 for FFVs, we assume a demand elasticity of -0.5 for E0 and E85. To account for the ability of the market to respond more over time, the supply elasticities increase by 10% per year.

[44] Paltsev, Sergey, John M. Reilly, Henry D. Jacoby, Richard 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.

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

These curves are calibrated to the demand data. The EIA's AEO 2015 Reference Case provides the gasoline and diesel prices to which the demand curves' initial prices are calibrated (Figure 9).

Figure 9: AEO 2015 Reference Case Fuel Prices (2013$/Gallon)

	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	2.31	2.63	2.70	2.70	2.70	2.74	2.78	2.82
Diesel	2.66	2.96	3.00	3.02	3.06	3.11	3.16	3.24

Source: AEO 2015 Reference Case Table C5.

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 2015. 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, biodiesel, renewable diesel, and biogas.

Biogas is assumed to be consumed by CNG vehicles. The model combines the remaining fuel components into the four end-use fuels, which can be consumed by specific vehicle types:

- Minimum E0 cannot drop below 2.5% of the sum of E0 and E10. The amount of E0 represents the 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), where the denominator includes petroleum, bio-, and renewable diesel.

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 assume the EPA grants nearly a full waiver on cellulosic ethanol. The RFS2 constraint for cellulosic ethanol in each year is set equal to the maximum amount that the model assumes can be produced in that year. This assumption avoids the debate about the economic and technical feasibility of producing cellulosic biofuel[46] and is likely optimistic given the current difficulty procuring cellulosic biofuel supplies. Since this analysis assumes ample supplies of corn ethanol, sugar ethanol, and biomass based diesel 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 (see Figure 10).

Figure 10: EPA's Formulas for the RFS2 Percentage Mandates[47]

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

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

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

[46] 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.

[47] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA–HQ–OAR–2015–0111; FRL–9927–28–OAR, p. 33146, June, 2015.

The EPA's proposed standards for 2015 and 2016 are provided below in Figure 11.

Figure 11: EPA's Proposed Rule for RFS standards for 2015 and 2016[48]

	2015	2016
Cellulosic Biofuel	0.059%	0.114%
Biomass-Based Diesel	1.41%	1.49%
Advanced Biofuel	1.61%	1.88%
Renewable Fuel	9.04%	9.63%

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 limit constraint for diesel not to exceed 5% biodiesel
Limit on E85 sales based on Fuels Institute Top Quartile Case
Lower bound on E0 sales as a fraction of E0 and E10 sales
Upper bound on biofuel production for cellulosic ethanol, sugar ethanol, biogas, biodiesel, renewable diesel and total biomass based diesel
RIN bank(t) = RIN bank(t-1) + RIN Deposit(t) – RIN withdrawal(t) t = 2015, …, 2022
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*.)
Producer Surplus = the area under the supply curve for each fuel component (*e.g.*, corn ethanol, biodiesel, *etc*.)

The starting level of carryover D6 RINs at the beginning of 2015 equals 1.8 Billion RINs.

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 to the Statutory Scenario. The limits for biofuels and E85 sales are reported in billions of gallons.

[48] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, Office of Transportation and Air Quality, EPA–HQ–OAR–2015–0111; FRL–9927–28–OAR, p. 33148, June, 2015.

B. N_{ew}ERA Macroeconomic Model

1. Overview of the N_{ew}ERA Macroeconomic Model

The N_{ew}ERA macro 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[49] 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 2014* produced by the Energy Information Administration (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.

2. Model Data (IMPLAN and EIA)

The economic data is taken from the IMPLAN 2008 database, which includes balanced Social Accounting Matrices for all states in 2008. These inter-industry matrices provide a snapshot of the economy. Since the IMPLAN database contains only economic values, we benchmark energy supply, demand, trade, and prices to EIA historical statistics to capture the physical energy flows. The integration of the EIA energy quantities and prices into the IMPLAN economic database results in a balanced energy-economy dataset.

Future economic growth is calibrated to macroeconomic GDP, energy supply, energy demand, and energy price forecasts from the EIA *AEO 2014*. Labor productivity, labor growth, and population forecasts from the U.S. Census Bureau are used to project labor endowments along the baseline and ultimately employment by industry.

3. Brief Discussion of Model Structure

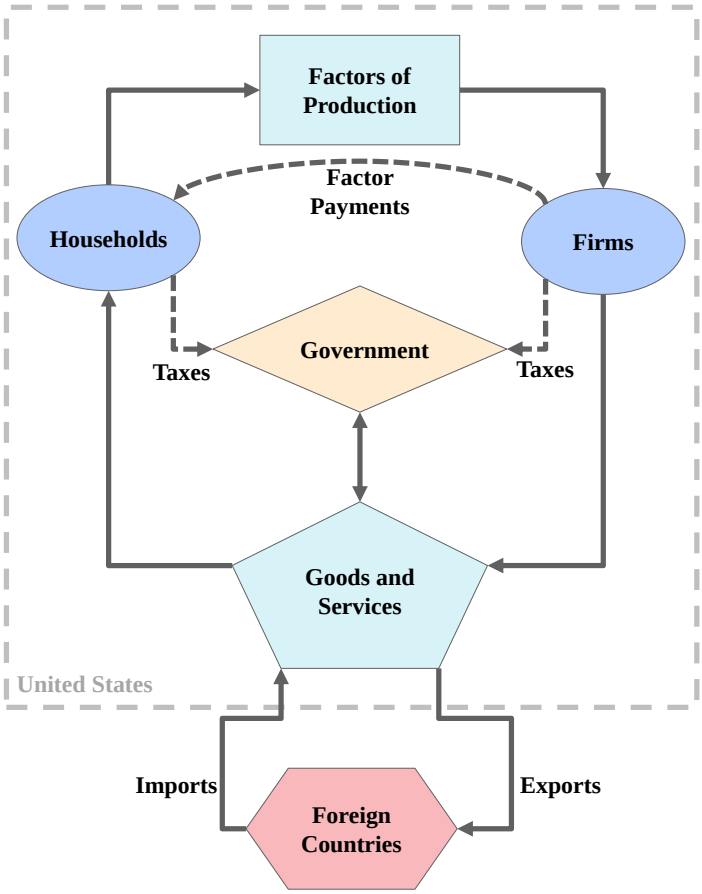
The theoretical construct behind the N_{ew}ERA model is based on the circular flow of goods, services, and payments in the economy (every economic transaction has a buyer and a seller whereby goods/service go from a seller to a buyer and payment goes from the seller to the buyer). As shown in Figure 12, the model includes households, businesses, government, financial markets, and the rest of the world economy as they interact economically in the global economy. Households provide labor and capital to businesses, taxes to the government, and savings to financial markets, while also consuming goods and services and receiving government subsidies. Businesses produce goods and services, pay taxes to the government and use labor and capital. Businesses are both consumers and producers of capital for investment in the rest of the economy. Within the circular flow, equilibrium is found whereby goods and services

[49] IMPLAN produces unique set of national structural matrices. The structural matrices form the basis for the inter-industry flows which we use to characterize the production, household, and government transactions, see www.implan.com.

consumed is equal to those produced and investments are optimized for the long term. Thus, supply is equal to demand in all markets.

The model assumes a perfect foresight, zero profit condition in production of goods and services, no changes in monetary policy, and full employment within the U.S. economy.

Figure 12: Circular Flow of Income



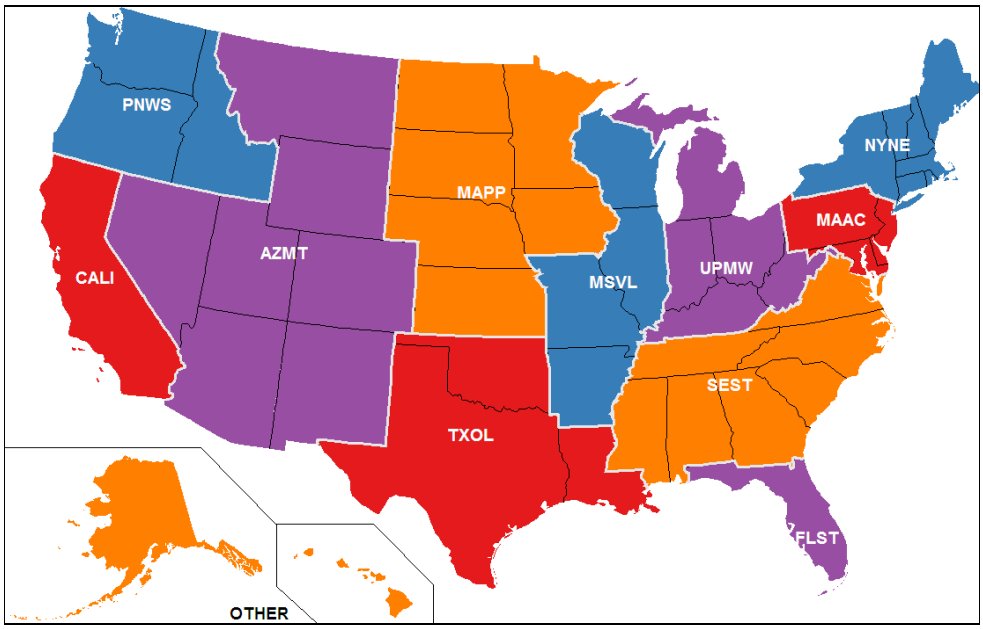
a. Regional Aggregation

The standard N_{ew}ERA macro model includes 11 regions: NYNE-New York and New England; MAAC-Mid-Atlantic Coast; UPMW-Upper Mid-West; SEST-South East; FLST-Florida; MSVL-Mississippi Valley; MAPP-Mid America; TXOL-Texas, Oklahoma, and Louisiana; AZMT-Arizona and Mountain states; CALI-California; and PNWS-Pacific Northwest.[50] The aggregate model regions are built up from the 50 U.S. states' and the District of Columbia's economic data. The model is flexible enough to create other regional specifications. The 11 N_{ew}ERA regions and the States within each N_{ew}ERA region are shown in the following figure.

[50] Hawaii and Alaska are included in the PNWS region.

For this Study we aggregate the 50 states into two regions: For this Study we aggregate the 50 states into one region: USA.

Figure 13: Standard N_{ew}ERA Model's Macroeconomic Regions



b. Sectoral Aggregation

The N_{ew}ERA model includes 12 sectors: six energy sectors (coal, natural gas, crude oil, electricity, and refined petroleum products) and seven non-energy sectors (services, manufacturing, energy-intensive, agriculture, motor vehicle production, trucking, and commercial transportation excluding trucking). We represent a single type of crude oil and multiple refined petroleum products where oil use by sector is differentiated. These sectors are aggregated up from the 440 IMPLAN sectors to 28 sectors, defined as the *AEO 2014* sector in Figure 14. These 28 sectors' economic and energy data are consistent with IMPLAN and EIA, respectively. For this study, we further aggregate these 28 production sectors into 12 production sectors. The mapping of the sectors is shown below in Figure 14. The model has the flexibility to represent sectors at any level of aggregation.

Figure 14: N_{ew}ERA Sectoral Representation in Core Scenarios[51]

	N_{ew}ERA	AEO	
Final Demand	C	C	Household consumption
	G	G	Government consumption
	I	I	Investment demand
Energy Sectors	COL	COL	Coal
	GAS	GAS	Natural gas
	OIL	OIL	Refined Petroleum Products
	CRU	CRU	Crude oil
	ELE	ELE	Electricity
Non-Energy Sectors	AGR	AGR	Agriculture
	TRN	TRN	Transportation
	TRK	TRK	Trucking
	M_V	M_V	Motor vehicle
	SRV	SRV	Services
	SRV	DWE	Dwellings
	EIS	PAP	Paper and Pulp
	EIS	CHM	Chemicals
	EIS	GLS	Glass Industry
	EIS	CMT	Cement Industry
	EIS	I_S	Primary Metals
	EIS	ALU	Alumina and Aluminum
	MAN	CNS	Construction
	MAN	MIN	Mining
	MAN	FOO	Food, Beverage and Tobacco Products
	MAN	FAB	Fabricated Metal Products
	MAN	MAC	Machinery
	MAN	CMP	Computer and Electronic Products
	MAN	TRQ	Transportation Equipment
	MAN	ELQ	Electrical Equip., Appliances, and Components
	MAN	WOO	Wood and furniture
	MAN	PLA	Plastics
	MAN	OMA	Other Manufacturing sectors

c. Production and Consumption Characterization

Behavior of households, industries, investment, and government is characterized by nested CES production or utility functions. Under such a CES structure, inputs substitute against each other in a nested form. The ease of substitutability is determined by the value of the elasticity of substitution between the inputs. The greater the value of the substitution elasticity between the inputs; the greater the possibility of tradeoffs.

The CES nesting structure defines how inputs to a production activity compete with each other. In the generic production structure, intermediate inputs are aggregated in fixed proportion with a composite of energy and value-added inputs. The energy input aggregates fossil and non-fossil energy sources, and the value-added input combine capital and labor. Sectors with distinctive

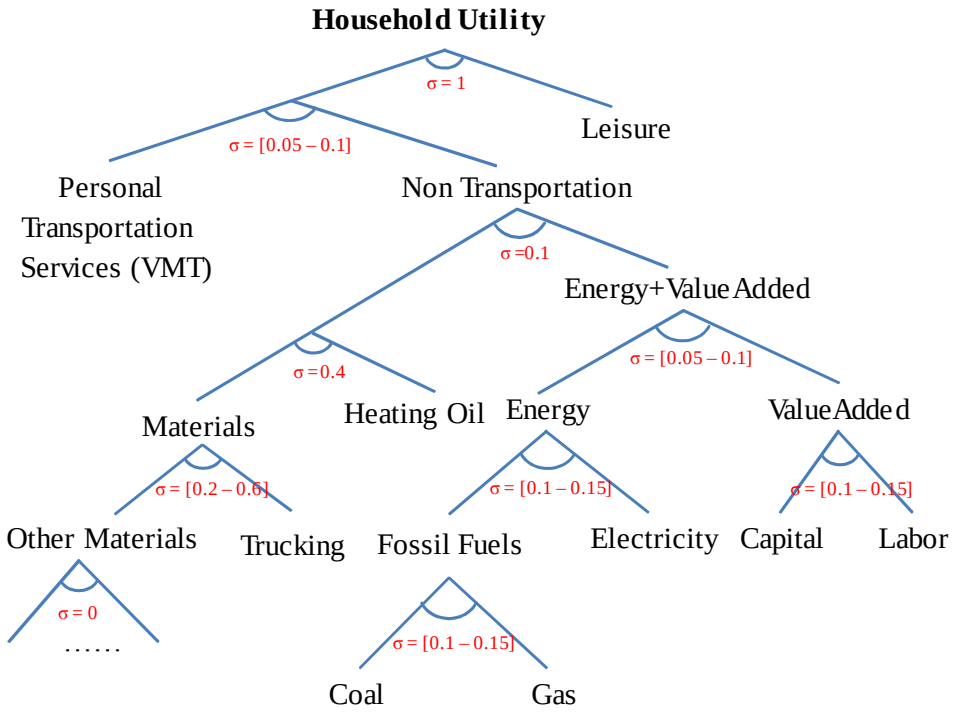
[51] We expand our default sectoral definition for the chemicals analysis to include ethane as an additional commodity and three additional sectors representing chemicals subsectors. We describe these additions in detail in Chapter VIII.

production characteristics are represented with structures different from the generic form. For alternative transportation fuels, such as ethanol and bio-diesel, inputs are demanded in fixed proportion. The characterization of nonrenewable resource supply adds a fixed resource that is calibrated to a declining resource base over time, so that it implies decreasing returns to scale. This also implies rising marginal costs of production over time for exhaustible resources. The detailed nesting structure of the households and production sectors, with assumed elasticity of substitution parameters, is shown in figures below.

i. Households

Consumers are represented by a single representative household. The representative household derives utility from both consumption of goods and services, transportation services, and leisure. The utility is represented by a nested CES utility function. The elasticity of substitution parameters between goods are shown in Figure 15.

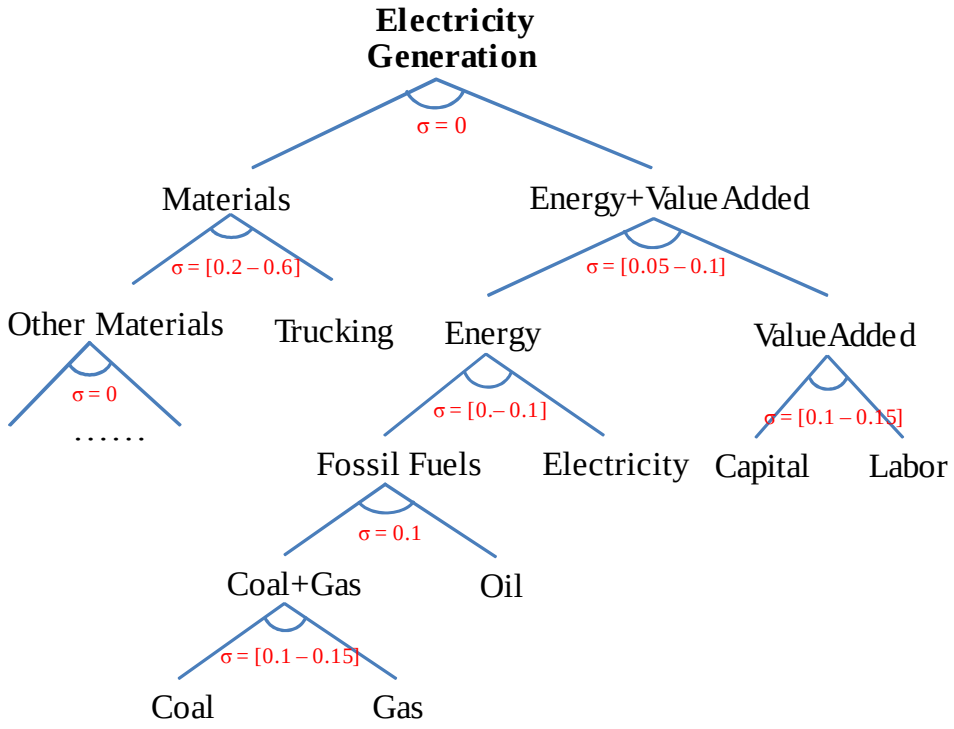
Figure 15: N_{ew}ERA Household Representation



ii. Electric Sector

We assume a simple representation of the electric sector. The electric sector models natural gas, coal, and oil-fired generation. The representation of the production is shown below.

Figure 16: N_{ew}ERA Electricity Sector Representation



iii. Other Sectors

The trucking and commercial transportation sector production structure is shown in Figure 17. The trucking sector uses diesel as transportation fuel. This sector has limited ability to substitute into other fossil fuels. The other industrial sectors (agriculture, manufacturing, energy-intensive, and motor vehicles production) and the services sector production structure, with assumed elasticity of substitution, are shown in Figure 18.

iv. Refinery Sector

In the model, each region has a single representative refinery sector that has a production structure similar to other industrial sector. We assume that the refined petroleum product is traded in the world refined petroleum markets – a homogenous good, and responds to a single world refined petroleum price. This means that the domestic price of refined petroleum product is set at the world price.

Figure 17: N_{ew}ERA Trucking and Commercial Transportation Sector Representation

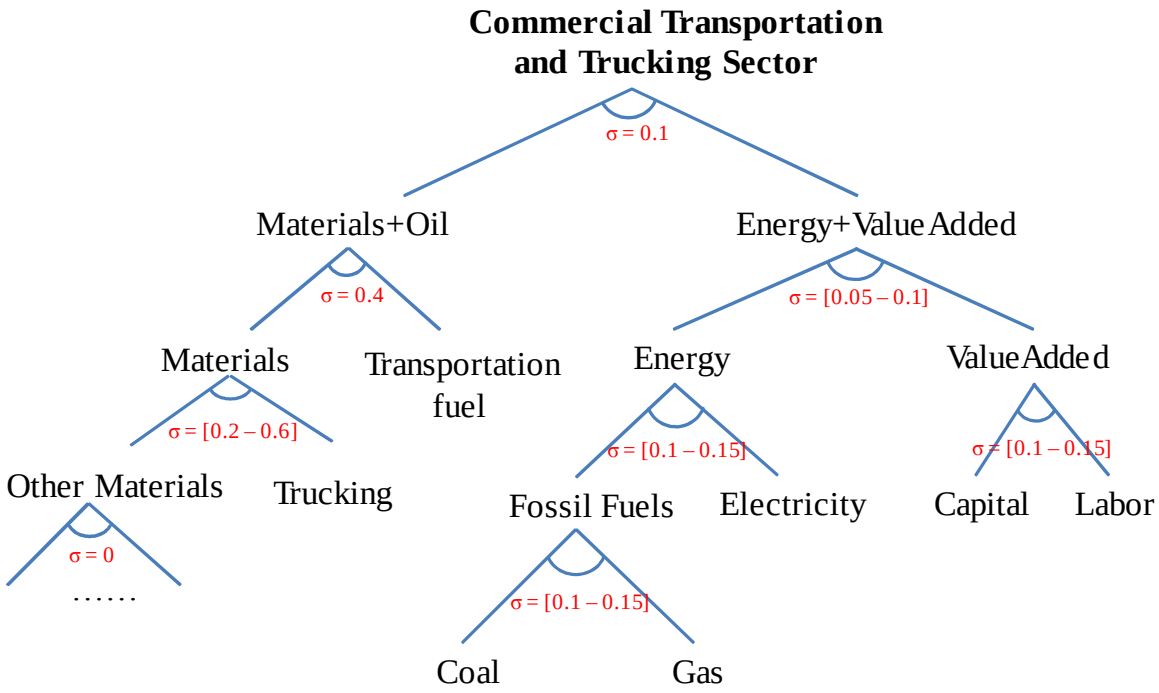
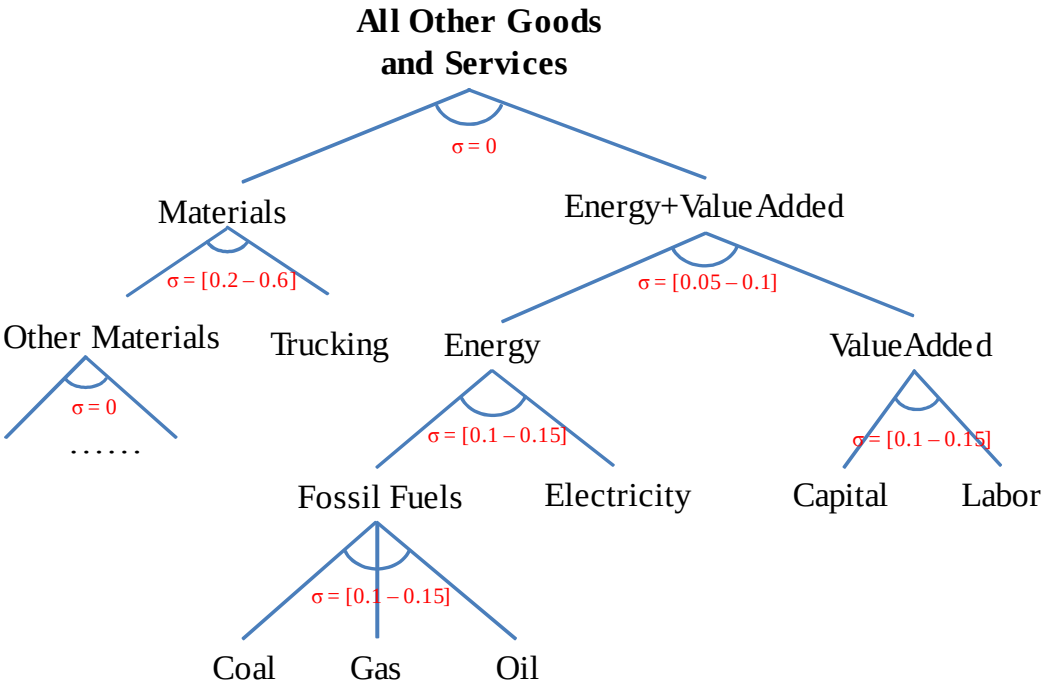


Figure 18: N_{ew}ERA Other Production Sector Representation

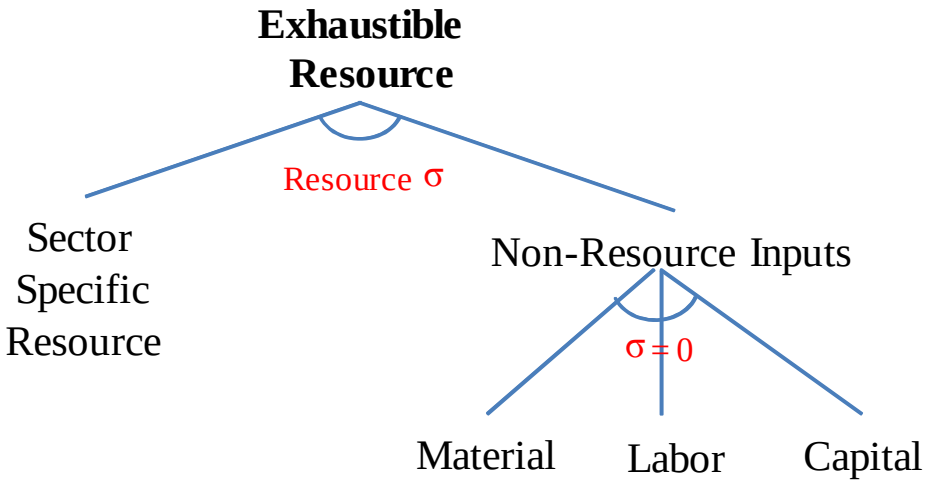


v. Exhaustible Resource Sector

The simplest characterization of non-renewable resource supply adds a fixed resource that is calibrated to decline over time, so that the decreasing returns to scale implied for the non-resource inputs lead to rising marginal costs of production over time. The top level elasticity of substitution parameter is calibrated to be consistent with resource supply elasticity. We assume the natural gas resource supply elasticity varies with the U.S. resource supply scenario. For the Ref Scenario, the elasticity of supply for natural gas begins at 0.3 and increases to 0.7 by 2038. Crude oil and coal supply elasticities are invariant across the different baselines. Crude oil supply elasticity is assumed to be 0.3 in 2013 and 1.0 in 2038. Coal supply elasticity is assumed to be 0.4 in 2010 and 1.5 in 2038. The production structure of natural gas, crude oil, and coal is shown below.

Production from the crude oil, natural gas, and coal sector is either supplied to the domestic market or exported. Crude oil that is supplied to the domestic market is comingled with imported crude oil and is supplied to the domestic refinery. Natural gas and coal also follow a similar supply chain.

Figure 19: NewERA Resource Sector Representation



d. Trade Structure

All goods and services, except refined petroleum product, are treated as Armington goods, which assume that domestic and foreign goods are differentiated and thus, are imperfect substitutes. The level of imports depends upon the elasticity of substitution between the imported and domestic goods. The Armington elasticity among imported goods is assumed to be twice as large as the elasticity between domestic and aggregate imported goods, characterizing greater substitutability among imported goods.

We balance the international trade account in the N_{ew}ERA model by constraining changes in the current account deficit over the model horizon. The condition is that the net present value of the foreign indebtedness over the model horizon remains at the benchmark year level. This prevents distortions in economic effects that would result from perpetual increases in borrowing, but does not overly constrain the model by requiring current account balances in each year.

This treatment of the current account deficit does not mean that there cannot be trade benefits from crude oil exports. Although trade will be in balance over time, the terms of trade shift in favor of the U.S. because gains from lifting of the crude oil export ban. That is, by exporting goods of greater value, in this study it is the incremental crude oil exports, to overseas customers, the U.S. is able to import larger quantities of goods than it would be able to if the same domestic resources were devoted to producing exports of lesser value. Allowing high-value exports to proceed has a similar effect on terms of trade as would an increase in the world price of existing exports or an increase in productivity in export industries. In all these cases, the U.S. gains more imported goods in exchange for the same amount of effort being devoted to production of goods for export. The opposite is also possible, in that a fall in the world price of U.S. exports or a subsidy that promoted exports of lesser value would move the terms of trade against the U.S., in that with the same effort put into producing exports the U.S. would receive less imports in exchange and terms of trade would move against the U.S. The fact that crude oil export will only happen if there is sufficient market demand ensures that terms of trade will improve if crude oil exports occur. If the domestic price is favorable then the gains from trade would be even higher.

e. Investment Dynamics

The static model assumes no connection between the periods through investment. For each period, there is a fixed amount of capital supply. All investment goods are produced and consumed in the same year. The model optimizes consumption and investment in each period given the total income from factor of production (labor, capital, resources) earned in the same period.

f. Model Assumptions

The underlying assumptions of labor growth and initial capital stock drive the economy over time in the model. The model assumes full employment in the labor market. This assumption means total labor demand in a policy scenario would be the same as the baseline labor projection. The baseline labor projections are based on population growth and labor productivity forecasts over time. Hence, the labor projection can be thought to be a forecast of efficient labor units. The model assumes that labor is fungible across sectors. That is, labor can move freely out of one production sector into another without any adjustment costs or loss of productivity. Like labor, each region is endowed with its own capital stock and can move across sectors without any adjustment cost.

Energy intensities are calibrated to the EIA projections. The differentiated energy intensities across regions result in different responses in energy supply and demand as energy price changes.

The N_{ew}ERA macroeconomic model includes a simple tax representation. The model includes only two types of input taxes: marginal tax rates on capital and labor. The tax rates are based on the NBER TAXSIM model. Other indirect taxes such as excise and sales are included in the output values and not explicitly modeled.

g. Advantages of the Macro Model Framework

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 internally consistent energy benchmark data, as well as IMPLAN consistent economic values.

The macro model incorporates all production sectors and final demanders 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 modeling tool such as the N_{ew}ERA macro 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 and 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, the N_{ew}ERA macro model can consistently capture future policy changes that envisage having large effects.

The modeling tool is also helpful to analyze the effects of price control mechanism, such as, lifting of the crude oil export ban analyzed in this study. The model captures initial price distortion associated with imposing a ban along the baseline. By lifting the ban, and hence the price distortions, we are able to analyze efficiency gain and other benefits associated with terms of trade in a consistent manner within this framework.

The N_{ew}ERA macro 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 2015* Reference and High Oil Price cases). 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.

h. Model Outputs

The N_{ew}ERA model outputs include supply and demand of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include gross regional product, consumption, investment, disposable income, and changes in income from labor, capital, and resources.

APPENDIX B. DETAILED TRANSPORTATION MODEL RESULTS FOR THE STATUTE SCENARIO

Figure 20: Quantities in Statute Scenario (Billion Gallons, Unless Otherwise Noted)

	2015
%E0 in Gasoline	2.5%
%Ethanol in E10	10%
%Biodiesel in Diesel	4.7%
Cellulosic Ethanol	0.043
Corn Ethanol	8.5
Sugar Ethanol	0.68
BOB (Blendstock)	84.3
E0	2.3
E10	91.0
E85	0.13
Total Gasoline	93.4
Biodiesel	1.9
Petroleum Diesel	37.8
Renewable Diesel	0.3
Diesel	40.0
Biogas	0.125

Figure 21: Cost to Consumer in Statute Scenario (2013$/gallon)

	2015
Cellulosic Ethanol	$3.85
Corn Ethanol	$1.07
Sugar Ethanol	$4.98
BOB (Blendstock)	$1.40
E0	$23.49
E10	$93.64
E85	$20.11
Average Gasoline[52]	$91.79
Biodiesel	$8.19
Petroleum Diesel	$1.62
Renewable Diesel	$21.22
Diesel	$103.00

[52] The price for average gasoline is the weighted average price of E0, E10, and E85.

NERA
ECONOMIC CONSULTING

NERA Economic Consulting
1255 23rd Street NW
Washington, DC 20037
Tel: +1 202 466 3510
Fax: +1 202 466 3605
www.nera.com