NESCAUM

Final Report

Economic Analysis of a Program to Promote Clean Transportation Fuels in the Northeast/Mid-Atlantic Region

Prepared By
Northeast States for Coordinated Air Use Management

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ECONOMIC ANALYSIS OF A PROGRAM TO PROMOTE CLEAN TRANSPORTATION FUELS IN THE NORTHEAST/MID-ATLANTIC REGION

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Rutgers University provided permission to NESCAUM to modify the NJAES Bioenergy Calculator©. The modification was limited to substitution of county data with state level data for the northeast region. Permission must be requested for additional modifications. NESCAUM has the right to distribute the final database. NESCAUM does not have authorization to assign rights to other entities.

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Any errors, omissions, or interpretations expressed in this report are the responsibility of NESCAUM alone.

List of Acronyms:

ACP: Alternative Compliance Payments
AEO: Annual Energy Outlook
AFCI: Average Fuel Carbon Intensity
ANR: Agency of Natural Resources
BAU: Business-As-Usual
BEV: Battery Electric Vehicle
Bgal: Billion gallons
Bgge: Billion gasoline gallon equivalent
Btu: British thermal unit
CAFE: Corporate Average Fuel Economy
CARB: California Air Resources Board
CFS: Clean Fuels Standard
CI: Carbon Intensity
CNG: Compressed Natural Gas
CNGV: Compressed Natural Gas Vehicle
DEC: Department of Environmental Conservation
DEM: Department of Environmental Management
DEP: Department of Environmental Protection
DES: Department of Environmental Services
DNREC: Department of Natural Resources and Environmental Control
DOER: Department of Energy Resources
E85: 85% Ethanol Blend
EER: Energy Economy Ratio
EIA: Energy Information Administration
EOEEA: Executive Office of Energy and Environmental Affairs
EPA: Environmental Protection Agency
EV: Electric Vehicle
FFV: Flex-Fuel Vehicle
FTE: Full-Time Employee
gCO2e/MJ: Grams carbon dioxide equivalent per megajoule
GGE: Gasoline gallon equivalent
GHG: Greenhouse Gas
GREET: Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model
GRP: Gross Regional Product
GWh: Gigawatt Hour
ICE: Internal Combustion Engine
ILUC: Indirect Land Use Change
INRS: Innovative Natural Resource Solutions
ISO: Independent Service Operator
ISOR: Initial Statement of Reasons
LCF: Low Carbon Fuel
LEV: Low Emission Vehicle
MJ: Megajoule
MSW: Municipal Solid Waste
MMT: Million Metric Tons
NAICS: North American Industry Classification System
NE/MA: Northeast/Mid-Atlantic
NE-MARKAL: Northeast-Market Allocation model
NESCAUM: Northeast States for Coordinated Air Use Management
NGV: Natural Gas Vehicle
NJAES: New Jersey Agricultural Experiment Station
NREL: National Renewable Energy Laboratory
NYSERDA: New York State Energy Research and Development Authority
PDI: Personal Disposable Income
PHEV: Plug-in Hybrid Electric Vehicle
PJM: Pennsylvania-New Jersey-Maryland Interconnection
Quad: Quadrillion Btu
REMI: Regional Economic Models, Inc.
RFS: Renewable Fuel Standard
RGGI: Regional Greenhouse Gas Initiative
SEDS: State Energy Data System
SCC: Social Cost of Carbon
TCI: Transportation Climate Initiative
VISION-NE: VISION-Northeast
VMT: Vehicle Miles Traveled
WWTF: Wastewater Treatment Facility
ZEV: Zero-Emissions Vehicle

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Executive Summary

Introduction

This report summarizes the results of an analysis of potential economic impacts of reducing carbon emissions from transportation fuels in the eleven state northeast and mid-Atlantic region.[1] On a regional basis, the transportation sector accounts for about one-third of all greenhouse gas (GHG) emissions. Nearly 100 percent of the transportation fuel used in the region is imported from outside the eleven states.

The results of the analysis suggest that the transition to lower carbon fuels could provide important energy security, climate change, and economic benefits in the region. For example, electricity, advanced biofuels, and natural gas are low carbon fuels not yet widely used in the region for transportation. A gradual transition to one or more of these fuels would reduce carbon emissions and those of other harmful pollutants, enhance energy independence and reduce vulnerability to price swings in imported petroleum, and create jobs in the region. The primary purpose of this report is to assist states as they evaluate the potential for implementing a regional clean fuels program that could reap these benefits.

One of the policy tools under evaluation is a regional low carbon fuel standard or clean fuels standard (CFS), which is a fuel-neutral, market-based program that would require a reduction in the overall carbon intensity (CI) of the region's transportation fuels over time. Carbon intensity is a measure of GHGs released throughout a fuel's full lifecycle, including extraction, production, transport, combustion and indirect effects, per unit of energy produced. In simple terms, the program would work by assigning a CI score for all fuel pathways, calculating the average CI for the applicable pool of fuels at the beginning of the program, and establishing a target average CI value to be achieved by a specified date.

This program would allow all fuels to compete based on their greenhouse gas impacts and costs. It would create incentives for advances in biofuels and promote broader deployment of other low carbon transportation fuels such as electricity and natural gas. By establishing a standard of performance for fuels, such a program could create competition among producers leading to technological innovation, and would provide industry with flexibility to employ the most cost-effective approaches for meeting program requirements.

This analysis of the costs and benefits of a regional clean fuels standard is *not designed as a forecast* of future economic conditions, fuel prices, CI values, or rates of innovation and market penetration for low carbon fuels. Rather, the study's design recognizes the significant uncertainties surrounding future values for important factors, and constructs

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[1] The eleven participating states are Connecticut, Delaware, Maine, Massachusetts, Maryland, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont.

several “what if?” scenarios with assumptions designed to explicitly address key uncertainties.

The results include modeled impacts on: (1) gasoline and diesel demand; (2) GHG emissions; (3) fuel expenditures, delivery infrastructure, and the vehicle mix; and (4) macroeconomic factors such as employment, gross regional product, real disposable personal income, and value-added changes by industry sector. Notably, the analysis did not attempt to identify and quantify other likely effects of the transition to cleaner fuels, such as improved public health and reduced health care costs.

Although this economic analysis focused on the evaluation of a generic CFS that achieves a specified CI reduction in given time period, the data and tools used in this assessment may help in the evaluation of other programs that achieve similar reductions in the carbon intensity of fuels.

Key Findings

This analysis found that the program analyzed could:

- reduce GHG emissions by introducing more low carbon fuels into the transportation sector;
- reduce gasoline and diesel use by 12 to 29 percent (4.0 to 8.7 billion gallons annually) once the program is fully implemented;
- enhance energy security by diversifying transportation fuels away from those produced from imported oil and toward domestic alternatives such as advanced biofuels, electricity and natural gas with more stable prices;
- achieve overall net savings on transportation costs when oil prices are high and near parity at low oil prices; and
- achieve these goals with a small but positive impact on jobs, gross regional product, and disposable personal income within the region.

Other important findings based on this analysis include:

- gasoline and diesel would continue as the dominant transportation fuels in the region for the next decade (providing from 80 to 87 percent of fuel energy use under low oil prices, and 73 to 81 percent of energy use under high oil prices);
- among the low carbon fuels evaluated, electricity provides the largest reductions in petroleum energy use; and
- greater volumes of low carbon fuels are needed when CI values are high; this results in higher overall costs (for fuels, infrastructure, and vehicles) to meet a given target compared to using fuels with low CI values, but also greater reductions in gasoline and diesel use and more significant benefits associated with those reductions.

The most important variables driving the results of the analysis include:

- the price of petroleum;
- the price of low carbon alternatives (fuel, infrastructure and vehicles); and
- the carbon intensity of petroleum and low carbon fuels.

A range of values were used to capture the underlying uncertainties in these variables to the extent feasible.

Methods and Data

NESCAUM analyzed a regional CFS that would achieve a 10 percent reduction in the carbon intensity of transportation fuels over a 10-year period. The participating states and interested stakeholders provided considerable insight on the appropriate design for this study. Key data sources used in this analysis included peer-reviewed studies, government sources, industry sources, reports, and databases. To capture the range of uncertainty for important variables, sources were surveyed for values that could be used as reasonable representations of lower- and upper-end values. In cases where empirical studies were limited, a range of estimates representing "optimistic" and "pessimistic" boundary values were developed by extrapolating related data.

The analysis evaluated the program's effect on a number of metrics including:

- gasoline and diesel demand;
- GHG emissions;
- changes in fuel expenditures, delivery infrastructure, and the number of advanced vehicles in the fleet; and
- macroeconomic factors such as employment, gross regional product, disposable personal income, and industry value-added.

Table ES-1 presents the design features of three main carbon reduction scenarios and two sensitivity scenarios that were analyzed in this study. The three core policy scenarios each demonstrate a 10 percent CI reduction over 10 years (assumed to be 2013 to 2022). In this analysis, it was assumed that the largest reductions are made in the latter part of the 10-year period. For the purposes of this study, NESCAUM focused on three types of potential low carbon fuel alternatives: advanced biofuels, electricity and natural gas. Each scenario depicts one fuel type more favorably and assumes that fuel will achieve 60 percent of the CI reduction required in the scenario being analyzed. The low-end range of CI scores and cost are applied to the preferred fuel in each scenario. The other two low carbon fuel types are each assumed to achieve 20 percent of the reduction and are assigned high-end CI and cost values.

NESCAUM also evaluated other possible reduction scenarios—5 percent over 10 years and 15 percent over 15 years—to explore the impact of key variables such as program stringency, implementation schedule, and the availability of low cost, low CI fuels on results. The 5 percent scenario assumes the high-end of the CI and cost range for all three fuel types. The 15 percent scenario assumes the low-end of the CI and cost ranges for all three. Together, these scenarios are intended to provide decision-makers with information about the impacts of a regional clean fuels standard under a wide range of potential market responses to the program's requirements.

All policy scenarios were compared to two business-as-usual (BAU) reference cases. The BAU is intended to represent the transportation fuel market absent policy intervention and provides a baseline against which to compare the impacts of a clean fuels program.

This analysis employed two BAU cases, reflecting low and high oil price forecasts based on the U.S. Energy Information Administration's *Annual Energy Outlook* (AEO) 2010. These low and high oil price forecasts predict 2022 retail gasoline prices at $3.79 and $5.50 per gallon, in nominal terms, respectively.[2] Another assumption that varies across the BAU cases is the carbon intensity of gasoline and diesel. These are assumed to stay constant in the low oil price BAU case and increase annually under high oil prices. The Low and High Oil Price BAU cases also reflect different rates of compliance with existing regulations, including the federal Renewable Fuel Standard and state Zero Emission Vehicle programs.

Table ES-1. Policy Scenarios Evaluated

10% Policy Scenarios	**Design Features and Key Assumptions**			
	Contribution to 10% CI Target	**Average Fuel Carbon Intensity**	**Fuel, Infrastructure, and Vehicle Costs**	**Availability of Regional Biomass**
Biofuels Future				
Biofuels	60%	Low	Low	High
Electricity	20%	High	High	n/a
Natural gas	20%	High	High	n/a
Natural Gas Future				
Natural gas	60%	Low	Low	High
Biofuels	20%	High	High	Low
Electricity	20%	High	High	n/a
Electricity Future				
Electricity	60%	Low	Low	n/a
Biofuels	20%	High	High	Low
Natural gas	20%	High	High	Low
5% Scenario	**Contribution to 5% CI Target**			
Biofuels	33%	High	High	Low
Electricity	33%	High	High	n/a
Natural gas	33%	High	High	Low
15%/ 15 Yr. Scenario	**Contribution to 15% CI Target**			
Biofuels	33%	Low	Low	High
Electricity	33%	Low	Low	n/a
Natural gas	33%	Low	Low	High

Note: "n/a" is not applicable, and refers to the fact that no biomass was used for the production of that fuel in the given scenario.

The *REMI Policy Insight* model, a multi-state economic policy analysis tool, was used to assess the macroeconomic impacts of these scenarios. The version of the model used in

[2] These prices, as well as other costs and benefits represented throughout this analysis, were adjusted to real 2010 dollars using an implicit price deflator.

this analysis covers the six New England states, New Jersey, New York, Delaware, Maryland, Pennsylvania, and the District of Columbia.

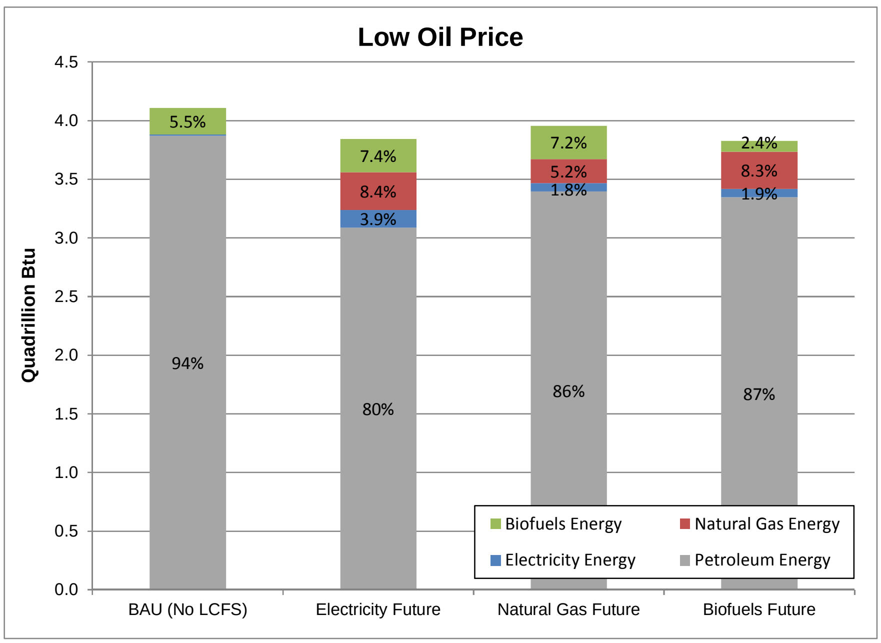
Results

Impact on Transportation Fuel Diversity and Demand

This analysis suggests that a clean fuels program could shift the composition of the region's transportation fuels from one totally dominated by gasoline (blended with 10 percent conventional ethanol) and diesel to a more diverse mix that includes new advanced liquid biofuels, electricity and natural gas. **Figures ES-1** and **ES-2** show how the fuel mix might change under the three core policy scenarios with high and low oil price assumptions. The program would have a significantly greater impact on fuel diversity with high oil prices.

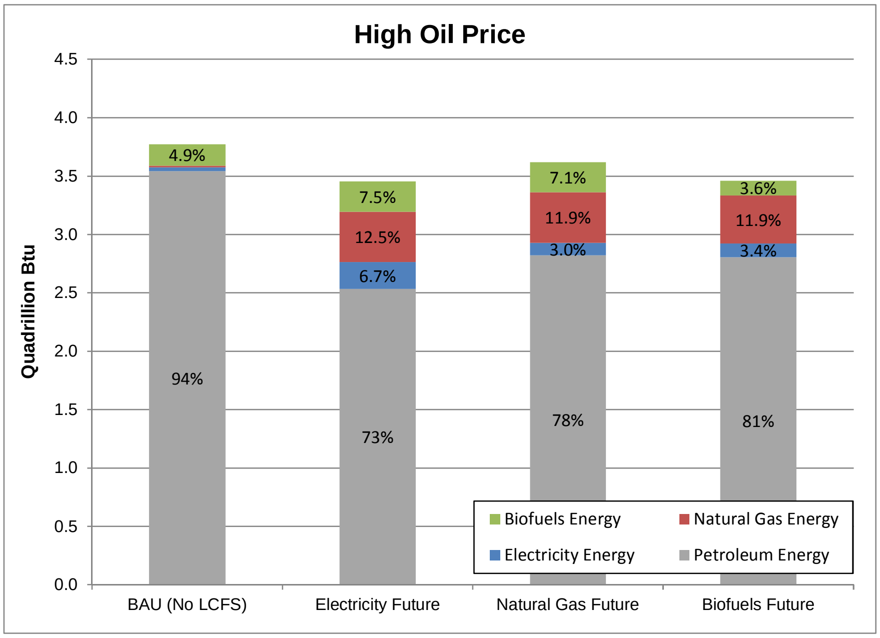
It is important to note that under a 10 percent CI target, gasoline and diesel would remain the dominant transportation fuels. Under low oil prices, at least 80 percent of fuel energy still comes from petroleum fuels. Under high prices, at least 73 percent of fuel energy is modeled to come from petroleum fuels when the 10 percent target is achieved. Based on this result, a more stringent CI target could further enhance fuel diversity and price stability goals.

Figure ES-1. Impact on Regional Transportation Fuel Diversity (Year 10)



These figures illustrate the inverse relationship between the carbon intensity of a fuel and the volumes of that fuel needed to achieve a given CI reduction target. For example, in the Biofuels Future, biofuels actually account for a smaller fraction of overall fuel energy than in the other scenarios, but provide greater carbon reductions due to a much lower CI value. Significantly fewer gallons of low CI biofuels, such as cellulosic ethanol, are needed to achieve the same carbon reduction as conventional corn ethanol. Because the magnitude of many categories of costs and benefits correlate with fuel volumes, this relationship significantly impacts many of the results in the analysis.

Figure ES-2. Impact on Regional Transportation Fuel Diversity (Year 10)



As shown in **Table ES-2**, this analysis suggests that a regional CFS could result in significant reductions in gasoline and diesel consumption compared to BAU over the 10-year period. Combined gasoline and diesel use under the Low Oil Price case is modeled to decrease by 4 to 7 percent (14 to 23 billion gallons) in the region relative to the BAU forecast. Under the High Oil Price case, demand could decrease by 8 to 13 percent (25 to 40 billion gallons).

Table ES-2. Gasoline and Diesel Demand under 10 Percent Reduction Scenarios (10-Yr. Totals)

Combined Gas and Diesel Demand	**Scenario**					
	Electricity Future		**Natural Gas Future**		**Biofuels Future**	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BAU Gasoline and Diesel Demand (Bgal)	337	315	337	315	337	315
Scenario Gasoline and Diesel Demand (Bgal)	314	275	323	290	323	286
Change in Gasoline and Diesel Demand (Bgal)	-23	-40	-14	-25	-14	-29
Percentage Change from BAU	*-7%*	*-13%*	*-4%*	*-8%*	*-4%*	*-9%*

Since nearly all of the alternatives to gasoline and diesel are assumed to be domestically produced, a clean fuels program could provide important energy security benefits in the northeast and mid-Atlantic region. Further, if the cost of alternatives to gasoline and diesel are, as expected, more stable over time, the program would help protect consumers of low carbon fuels from price volatility, which characterizes the current transportation fuel market.

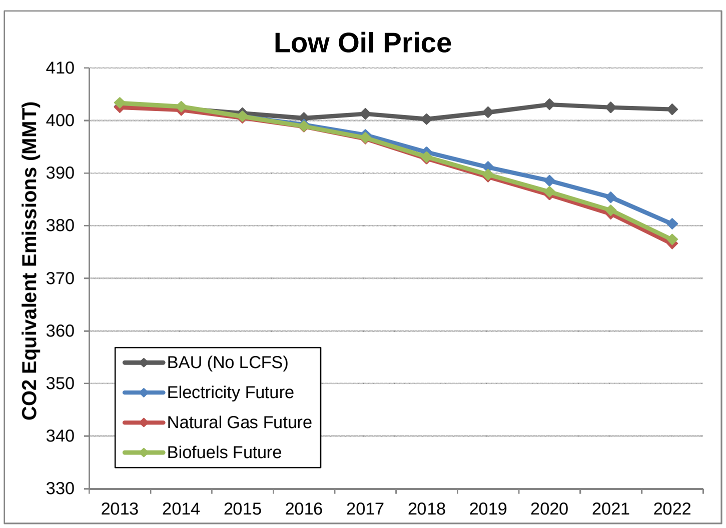
Table ES-3. Gasoline and Diesel Demand under 10 Percent Reduction Scenarios (Year 10)

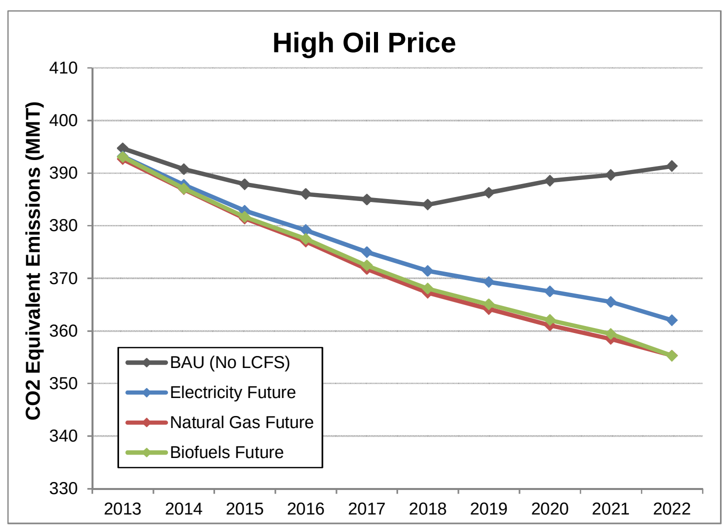
Combined Gas and Diesel Demand	Scenario					
	Electricity Future		Natural Gas Future		Biofuels Future	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BAU Gasoline and Diesel Demand (Bgal)	33.1	30.3	33.1	30.3	33.1	30.3
Scenario Gasoline and Diesel Demand (Bgal)	26.4	21.6	29.1	24.1	28.7	24.0
Change in Gasoline and Diesel Demand (Bgal)	-6.7	-8.7	-4.0	-6.1	-4.4	-6.2
Percentage Change from BAU	*-20%*	*-29%*	*-12%*	*-20%*	*-13%*	*-20%*

GHG Emissions Reductions and Values

The transportation sector is the single largest source of GHG emissions in the region, accounting for 33 percent of the total GHG inventory. This analysis suggests that the CFS could achieve significant GHG emission reductions from this sector. **Figures ES-3** and **ES-4** compares total lifecycle GHG emissions from transportation fuels under BAU and the three policy scenarios over the initial 10 year program period, under both High and Low Oil Price cases. In 2022, when the 10 percent reduction target is achieved, estimated GHG reductions range from 5 to 6 percent under the Low Oil Price case and 7 to 9 percent under the High Oil Price case. A similar level of annual GHG reductions would be expected in subsequent years, assuming the 10 percent CI reduction target is in place. These reductions would help participating states meet existing GHG emissions reduction obligations.

Figures ES-3 and ES-4. Reductions in GHG Emissions





The economic value of reducing (or avoiding future) GHG emissions is a subject of active debate, due to the uncertainties about the possible magnitude and type of climate impacts and also differing viewpoints on how to evaluate emissions reductions occurring at different points in time. In this analysis, values used for the "social cost of carbon," (SCC) range from nearly $24 per ton of carbon-equivalent in 2013 on the low-end (increasing to $29 per ton in 2022) to approximately $107 per ton at the high-end (2013 through 2022).[3]

Based on these SCC values, the value of cumulative GHG emissions reductions for the 10 percent CI reduction at year 10 range from $2.1 to $2.5 billion under low SCC and low oil prices. The range is $14 to $17 billion using high SCC and oil price assumptions. The SCC values vary within these ranges depending on the scenario.

Net Program Costs and Benefits

Tables ES-4 and **ES-5** show the modeled cumulative change in expenditures on transportation fuels, infrastructure, vehicles, and program administration resulting from implementation of the various carbon reduction scenarios under the Low and High Oil Price cases. For all scenarios, the costs of low carbon fuels are less than the cost of the gasoline and diesel they replace. However, the introduction of these low carbon alternatives requires investments in fuel delivery infrastructure and alternative fuel vehicle, which are also factored into the estimates of total cost.

The program costs shown for a given scenario reflect the total for all three fuels, not just the dominant fuel. Because of the inverse relationship between fuel CI and required volumes, the infrastructure and vehicle costs for a given policy “future” may in fact be dominated by a fuel other than the featured fuel for that scenario. For example, under the Biofuels Future, a significant share of the infrastructure and vehicle cost shown in the tables are for electricity and natural gas, which are assumed to have high CI values and high vehicle/infrastructure costs under this scenario. Consequently more vehicles and refueling infrastructure will be needed to achieve the CI reduction target, and the cost for a unit of carbon reduction is higher.

Net program benefits (or costs) are determined by comparing the total cost for low carbon alternatives to the benefits from reductions in both gasoline and diesel purchases and GHG emissions. This analysis suggests that the clean fuels program analyzed would result in net benefits under all scenarios, even excluding the value of GHG reductions, when oil prices are high. Depending on the scenario, the cumulative savings over 10 years range from around $18 billion to $52 billion, without GHG reductions, compared to the High Oil Price BAU case. When the value of GHG reductions is included in the net benefit calculation, cumulative savings increase to $26 billion to $55 billion under high oil prices.

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[3] The low-end value for social cost of carbon is from: Interagency Working Group on Social Cost of Carbon, United States Government (2010). *Social Cost of Carbon (SCC) for Regulatory Impact Analysis Under Executive Order 12866*. The discount rate for the low-end value is 3 percent. The high-end SCC value is from the Stern Review (2006), and uses a 0 percent discount rate.

Table ES-4. Net Costs and Benefits,
Low Oil Price Case - 10 Year Totals (in Billions of 2010$)

	Electricity Future	**Natural Gas Future**	**Biofuels Future**	**5%, 10 Yr.**	**15%, 15 Yr.**
Program Benefits:					
Value of Reductions in Gas & Diesel	$50.6	$30.7	$30.3	$13.2	$30.0
Program Costs:					
Low Carbon Fuel Costs	$29.4	$19.6	$18.9	$8.70	$19.8
Infrastructure Investments	$8.88	$4.94	$6.76	$1.9	$5.9
Incremental Vehicle Costs	$13.4	$4.05	$17.4	$5.2	$3.0
Program Admin. Costs	$0.243	$0.243	$0.243	$0.243	$0.316
Total Costs	$52.0	$28.9	$43.3	$16.1	$29.0
Net Program Benefits (Costs) w/o GHG Reductions	**($1.4)**	**$1.8**	**($13.0)**	**($2.9)**	**$1.0**
Net Program Benefits (Costs) WITH GHG Reductions	**$0.7 - $6.7**	**$3.3 - $11.4**	**$(10.6 - $3.9)**	**--**	**--**

Note: All estimates expressed in 2013 present values based on a 7 percent rate of discount. Range of net benefits with GHG reductions are based on low- and high-end social cost of carbon values. GHG values are not calculated for the 5 percent and 15 percent scenarios.

Table ES-5. Net Costs and Benefits,
High Oil Price Case - 10 Year Totals (in Billions of 2010$)

	Electricity Future	**Natural Gas Future**	**Biofuels Future**	**5%, 10 Yr.**	**15%, 15 Yr.**
Program Benefits:					
Value of Reductions in Gas & Diesel	$137	$87.2	$100	$104	$120
Program Costs:					
Low Carbon Fuel Costs	$62.3	$43.9	$42.8	$52.7	$49.0
Infrastructure Investments	$14.1	$8.26	$9.8	$8.2	$9.9
Incremental Vehicle Costs	$19.5	$5.75	$25.0	$24.8	$9.4
Program Admin. Costs	$0.243	$0.243	$0.243	$0.243	$0.316
Total Costs	$96.0	$58.2	$77.9	$85.9	$68.6
Net Program Benefits (Costs) w/o GHG Reductions	**$41**	**$29**	**$22**	**$17**	**$52**
Net Program Benefits (Costs) WITH GHG Reductions	**$43 - $55**	**$34 - $49**	**$26 - $39**	**--**	**--**

Note: All estimates expressed in 2013 present values based on a 7 percent rate of discount. Range of net benefits with GHG reductions are based on low- and high-end social cost of carbon values. GHG values are not calculated for the 5 percent and 15 percent scenarios.

Under the Low Oil Price case, the scenarios show either small net benefits or small net costs relative to BAU, even when the value of GHG reductions is excluded. The exception is the Biofuels Future, which shows $13 billion in net costs under low oil prices, which falls to $4 to $11 billion in net costs when the SCC of GHG reductions are included. These results suggest the price of oil is a more important determinant of the net impact of a clean fuels program than the low carbon fuel mix that might emerge to comply with the program's CI reduction target. The less optimistic 5 percent scenario is predicted to deliver lower net benefits, and the more optimistic 15 percent scenario higher net benefits than the three 10 percent reduction scenarios.

Net reductions in transportation fuel expenditures relative to BAU would accrue jointly to consumers of low carbon fuels, in the form of fuel savings, and to low carbon fuel producers, in the form of sales revenues. Consumers would accrue savings from purchases of the low carbon fuels that are projected to be lower in cost, on average, than gasoline and diesel, especially if oil prices are high. Actual consumer savings would depend on the retail prices set by producers for low carbon fuels.

Producers of low carbon fuels would increase revenues through sales of these products, and could increase profits depending on market demand and their ability to pass through costs. Since producers of different fuel types would compete to bring the most cost-effective CI reductions to the market, the retail prices of low carbon fuels would be strongly influenced by the lowest-cost producer of CI reductions.

Regulated companies would incur compliance and administration costs. They would seek strategies to achieve the lowest possible cost of compliance with the requirements of a clean fuels standard including: (1) direct purchases or production of advanced biofuels, and/or (2) purchases of credits generated by the introduction of electricity, natural gas or other alternative transportation fuels. Some low carbon fuels would provide CI reductions at a lower cost than others. The cost of a credit would be determined by the incremental marginal cost of producing fuel that provides a unit of CI reduction. Infrastructure investments and the incremental cost of advanced vehicles could also be bundled into the value of program credits. Since the underlying economics of the market for low carbon credits are so uncertain at this stage, this analysis does not provide a quantitative estimate of cost impacts on petroleum producers, or how those might translate into impacts on retail gasoline and diesel prices.

Macroeconomic Impacts

Table ES-6 summarizes the REMI modeling estimates of the program's impacts on employment, gross regional product, and real disposable personal income in the region for the three policy scenarios under low and high oil price projections for year 10, when the CI reduction target is fully achieved. The table also displays the cumulative totals for the 10-year program period, and results for the 5 and 15 percent scenarios. These impacts are relative to what would be expected without the program in place.

Table ES-6. Regional Macroeconomic Impacts

	Year 10		10 Year Total	
Type of Economic Impact	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**
Jobs Retained or Generated (Total)				
Electricity Future (10% CI reduction)	26,600	43,800	N/A	
Natural Gas Future (10% CI reduction)	9,490	21,700		
Biofuels Future (10% CI reduction)	41,300	50,700		
Biofuels, No In-Region Production (10%)	1,270	3,650		
5% CI Reduction Scenario (10 Yr.)	24,300	76,000		
15% CI Reduction Scenario (15 Yr.)	25,400	56,600		
Gross Regional Product (Million 2010 $s)				
Electricity Future (10% CI reduction)	3,080	4,920	12,400	28,700
Natural Gas Future(10% CI reduction)	2,120	3,930	7,310	17,100
Biofuels Future (10% CI reduction)	4,290	4,640	20,200	27,700
Biofuels, No In-Region Production (10%)	2,220	2,280	8,370	11,300
5% CI Reduction Scenario (10 Yrs.)	1,570	4,500	4,830	24,800
15% CI Reduction Scenario (15 Yrs.)	3,800	6,620	14,700	33,700
Disposable Personal Income (Million 2010 $s)				
Electricity Future (10% CI reduction)	1,400	3,230	3,660	14,700
Natural Gas Future (10% CI reduction)	950	1,620	2,200	7,240
Biofuels Future (10% CI reduction)	2,350	3,330	9,600	15,200
Biofuels, No In-Region Production (10%)	-53.9	891	-2,580	1,340
5% CI Reduction Scenario (10 Yr.)	1,040	4,130	2,180	16,100
15% CI Reduction Scenario (15 Yr.)	2,240	5,650	11,800	27,600

Source: NESCAUM analysis using REMI, 2011.

Employment

According to this analysis, the clean fuels program analyzed would add jobs in the region compared to BAU for all modeled scenarios. More jobs are projected under the High Oil Price case. In year 10, when the clean fuels achieves a 10 percent CI reduction target, results of the REMI model show approximately 10,000 to 40,000 incremental jobs annually under the Low Oil Price case and 20,000 to 50,000 under the High Oil Price case, compared to BAU. The jobs calculated by the REMI model include both part-time and full-time jobs and simply reflect the number of people employed beyond BAU for a given year. The annual values cannot be added to project a cumulative change in the number of jobs.

Gross Regional Product

Gross regional product (GRP), a measure of the states' economic output, increases under all of the policy cases evaluated in this analysis compared to BAU. Over the ten year period analyzed, cumulative GRP in the region is estimated to increase by $7.3 billion to $20.2 billion under the Low Oil Price case and by $17.1 to $28.7 billion under the High Oil Price case.

Disposable Personal Income

Real disposable personal income (DPI), the amount of income that households have available for spending and saving, is modeled to increase as a result of transportation fuel cost savings under the program analyzed. Household income in the region would grow by $2.2 billion to $9.6 billion under low oil prices and by $7.2 to $15.2 billion under high oil prices over the 10 years analyzed.

Impact on Industry Sectors

The REMI modeling suggests that a CFS would have both direct and indirect economic impacts on a range of industries within the region. Direct impacts are those associated with industries involved in the development, manufacture and deployment of low carbon fuels and infrastructure. Indirect affects accrue in those industry sectors that attract increased investment from disposable income that becomes available through savings on purchases of transportation fuels.

The utilities sector experiences the highest level of positive impacts, in terms of value-added, across all three scenarios. This reflects not only increased levels of electricity and natural gas sales for transportation purposes, but also production and installation of infrastructure for fueling and charging. The construction and manufacturing sectors also realize strong positive direct impacts, for both value-added and jobs, across all policy scenarios. These industries would experience positive value-added and job impacts related to installing fuel delivery infrastructure, building and operating biofuel and biogas production plants, and installing home charging and fueling systems.

Health care and finance/insurance are the two sectors generally found to experience the most positive indirect impacts from the program analyzed. While no spending was initially allocated to these industries in the analysis as a direct result of the program, indirect benefits take place as households and businesses retain more income or profit from reduced expenditure on transportation and invest those dollars elsewhere in the economy. Because health care spending accounts for a large portion of total spending in the U.S. economy, REMI predicts that dollars made available by a clean fuels program will spur additional spending in that sector.

According to this analysis, some sectors would experience negative impacts as a result of the clean fuels program analyzed. Retail and wholesale trade are estimated to experience net negative value-added and employment impacts. This sector includes fuel wholesalers as well as retail gasoline stations, which would both likely experience decreases in sales. However, the negative impacts experienced by the wholesale and retail trade industries would not be limited to directly affected businesses such as gas stations, because indirect effects of the program associated with commodity price changes would affect other types of retail and wholesale sales.

Although net impacts on the chemical manufacturing sector are estimated to be net positive as a result of the program analyzed, within that broad industry classification, the petroleum and coal products manufacturing sub-sector is expected to lose value-added and jobs as well. For example, in 2022 (Year 10), job losses in petroleum manufacturing will range from 150 jobs under low oil prices to 560 jobs under high oil prices. Reference case levels of jobs in petroleum manufacturing are estimated at 11,000, so these losses represent under one-tenth to one-half of one percent, respectively, relative to current employment levels in that sub-sector.

It is important to note that value-added and employment impacts shown in **Table ES-6** for the region already include these negative impacts on the wholesale and retail trade industries. In other words, despite the negative impacts on these two industry sectors, the net employment, industry value-added, and income impacts of the program would still be positive overall for the region.

Conclusion

This analysis suggests that an eleven-state regional clean fuels program could achieve the climate and energy goals articulated by the region's Governors in their 2009 Memorandum Of Understanding, with positive impacts on key macro-economic indicators.[4]

Such a program would increase fuel security and reduce the region's reliance on imported oil by encouraging a broader range of fuels to compete in the transportation market. It would reward cleaner and less expensive technologies and create competition among producers that could stimulate investment, innovation and broader deployment of low carbon fuels. This would help protect consumers from the price volatility of the global oil market, and increase production of domestically-produced lower-carbon alternative fuels, some of whose costs are expected to be lower and more stable over time than petroleum. The results of this study indicate that the higher the price of gasoline and diesel, the greater the savings would be for consumers.

This analysis suggests that a clean fuels standard could effectively reduce GHG emissions from the transportation sector across the region and stimulate economic growth. While the economic growth and jobs stimulated by the program are projected to be relatively small within an economy projected to total $4.9 trillion in 2022, they are positive under a wide range of possible market responses to the program's carbon intensity reduction requirements.

[4] The governors' Memorandum of Understanding can be accessed at www.nescaum.org/topics/low-carbon-fuels

1. INTRODUCTION TO THE NORTHEAST/MID-ATLANTIC STATES' CLEAN FUELS STANDARD

1.1. Background on Climate and Energy Policies in the Northeast/Mid-Atlantic States

The regional clean fuels standard (CFS) is a transportation initiative being evaluated by a coalition of 11 northeast and mid-Atlantic (NE/MA) states.[5] The objectives of the CFS include: (1) assisting states in meeting existing statutory obligations or other commitments to reduce greenhouse gas (GHG) emissions; (2) enabling greater fuel security and reliability; (3) driving innovation in clean energy technologies; (4) fostering economic growth; and (5) providing opportunities to consumers to reduce fuel costs. The CFS is a fuel neutral, market-based program that requires substituting lower carbon fuels for gasoline and diesel to reduce the overall carbon intensity of the region's transportation fuels over time. Other jurisdictions in North America that are currently developing and/or implementing similar fuel standards include British Columbia, California, Oregon, and Washington State. The European Union is also developing renewable fuel programs with specific GHG requirements.

All NE/MA states have statutory obligations or other commitments to achieve significant reductions in GHG emissions and are taking steps to reduce these pollutants by implementing energy efficiency, renewable energy, and other measures. The CFS is one of many policies under consideration throughout the region to meet climate action and clean energy goals. By and large, these policies and programs target those sectors of the economy that generate the majority of GHG emissions, including electricity generation, transportation, and buildings.

The participating states have a long history of cooperative action on environmental and energy issues. For example, in 2008, 10 of the participating CFS states launched the Regional Greenhouse Gas Initiative (RGGI), the first cap-and-trade program in the U.S. designed to reduce GHG emissions from large power plants. States are using revenues from the sale of RGGI allowances to invest in effective energy efficiency and renewable energy programs. In addition, the majority of states in the region have standards with binding requirements for increasing levels of renewable energy for electricity generation. The NE/MA states are also exploring new approaches to reducing GHG emissions and energy use in the transportation sector.

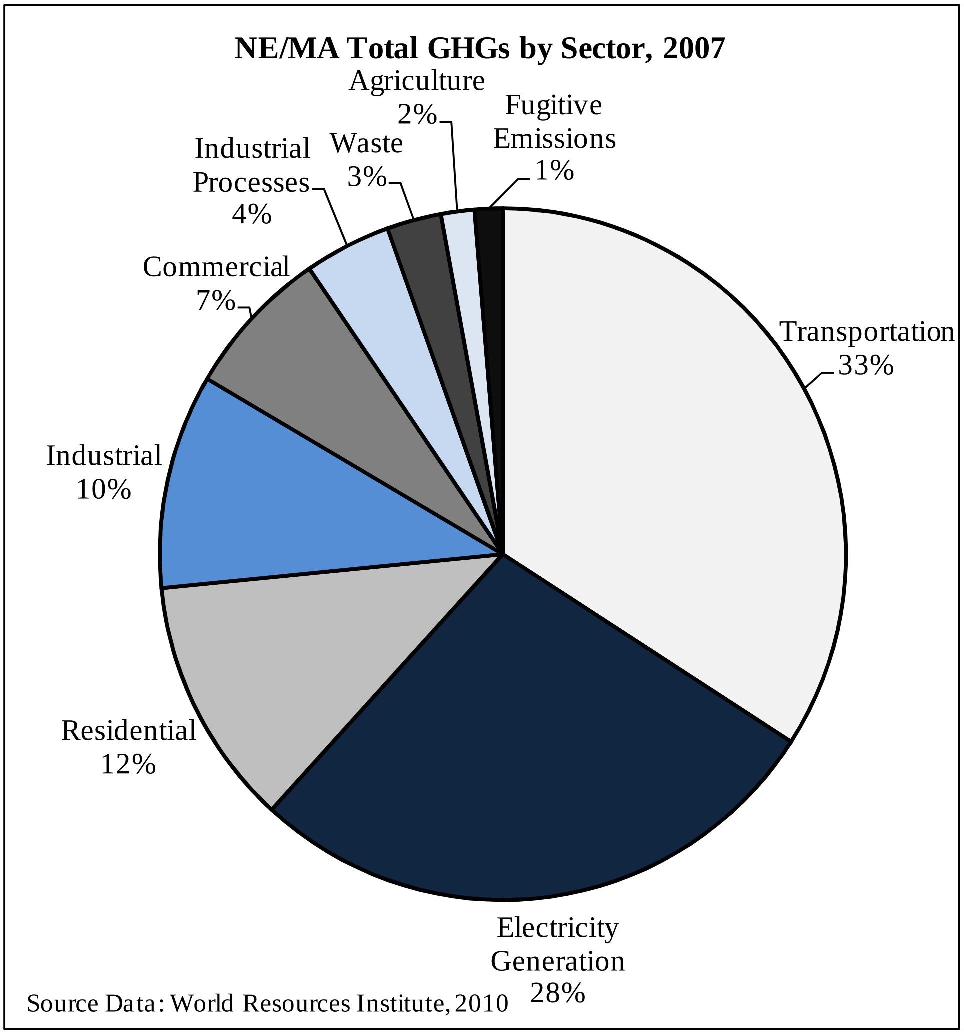
1.2. Strategies for Reducing NE/MA Transportation GHG Emissions

The transportation sector is the single largest source of GHG emissions in the NE/MA region. **Figure 1.1** below shows that in 2007, transportation accounted for 33 percent of the total GHG inventory in the region, roughly comparable to the combined emissions of

[5] The eleven states in the NE/MA region include: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

the residential, industrial, and commercial sectors (29 percent of total), or to emissions from electricity generation (28 percent).

Figure 1-1. Greenhouse Gas Emissions (GHGs) by Sector in NE/MA States, 2007



There are three primary ways to reduce GHG emissions from automobiles and trucks: (1) vehicle emissions and efficiency standards; (2) reductions in vehicle miles traveled (VMT); and (3) low carbon transportation fuels. The NE/MA states are pursuing options on all three fronts to reduce GHG emissions, increase energy security, spur economic development, and provide savings to consumers. Nine of the participating CFS states[6] have opted into California's Clean Cars program, which includes the nation's first GHG standards for automobiles and Zero Emission Vehicle requirements. These programs are spurring the development of a host of low GHG technologies, such as hybrid-electric and battery electric vehicles. These technologies are projected to provide consumers with significant fuel savings.

[6] The nine states that have opted in to California's Clean Cars program are: Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

A second set of strategies aimed at transportation GHG emissions are measures designed to reduce VMT by providing effective alternatives such as expanded use of public transportation, modal shifts in freight movement, and “smarter growth” strategies. The Transportation Climate Initiative (TCI) – launched in June 2010 by the environmental, energy, and transportation agency heads from the 11 NE/MA states plus the District of Columbia – is exploring policies and programs to improve the efficiency of the region’s transportation system.[7]

The CFS is a third major regional strategy, focused on reducing GHG emissions from transportation fuel use. The CFS requires reductions in the average carbon intensity (CI) of the regional transportation fuel mix through the use of low carbon alternatives to gasoline and diesel. CI is a measure of GHG emissions released throughout a fuel’s full lifecycle – including extraction, production, transport, combustion, and indirect effects such as emissions from land use change – per unit of energy produced. This program allows diverse fuels to compete based on their GHG characteristics and relative costs.

The CFS is a performance standard that would create incentives for advances in biofuels and promote broader deployment of other low carbon transportation fuels such as electricity and natural gas. The program would require transportation fuel providers to meet a carbon intensity reduction target, either by blending liquid low carbon fuels or purchasing low carbon credits generated by alternative fuels. Sales of fuel with carbon intensity higher than the reduction target would generate deficits; producers and distributors of low carbon fuels could generate credits by dispensing transportation fuels with lower carbon intensity. Low carbon fuel producers and distributors could sell credits to gasoline and diesel fuel suppliers to achieve the program’s CI reduction requirements.

The low carbon fuel market could create competition among producers, driving technological innovation, lower prices, and a more diverse mix of transportation fuels. This policy would provide the regulated industry with flexibility to determine which compliance options meet program requirements most cost-effectively.

1.3. Organization of the Report

The remainder of this report is organized into five sections (including supporting documentation). Section 2 describes the purpose of the analysis as well as the data, methods, and assumptions used to generate results.[8] Section 3 presents the cost and benefit results for the core CFS policy scenarios and sensitivity cases. Section 4 presents and describes the results of the macroeconomic modeling at the regional level. Section 5 includes references and appendices containing supporting documentation.

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[7] For more information on the Transportation Climate Initiative, see: http://www.georgetownclimate.org/state/files/TCI-declaration.pdf

[8] A full list of assumptions and detailed descriptions of the modeling tools used for the analysis are included in the appendices to the report.

2. DESCRIPTION OF THE NE/MA CFS ECONOMIC ANALYSIS

In April 2010, NESCAUM staff and the NE/MA states initiated an economic analysis to gain insights about the potential GHG reductions, changes in fuel use, costs, benefits, and other impacts of a region-wide CFS. In the initial phases of the analysis, NESCAUM and state staff compiled state-specific data, reports, databases, and other relevant information. Subsequent phases of the analysis included: (1) developing region-specific tools for estimating changes in energy use, conventional transportation fuels (i.e., gasoline and diesel), low carbon fuels, and alternative vehicles and related infrastructure; (2) creating calculators to estimate the value of costs and benefits associated with changes in fuel use and other changes; and (3) preparing inputs for and running a regional macroeconomic model.

Throughout 2010, the NE/MA states and NESCAUM held a series of meetings, webinars, and conference calls with stakeholders to discuss the design of the economic analysis and to brief stakeholders on potential data sources, draft assumptions, and methodologies. In addition, stakeholder input was solicited through two formal requests for written comment and in numerous discussions with individual stakeholder groups.

This section provides an overview of data, assumptions, methodologies, and modeling tools used in the analysis. Detailed descriptions of the data, methods, modeling tools, and key assumptions can be found in the Appendices and spreadsheets that accompany this report.

2.1. Purpose of the Analysis

This analysis is intended to provide decision-makers and stakeholders in the NE/MA states with information and insights about the possible economic impacts associated with implementing a regional CFS. It is critical to note that this analysis is *not intended to be a forecast* of future economic conditions, fuel prices, rates of innovation, or market penetration for low carbon fuels and alternative vehicles. Rather, the study's design recognizes the significant uncertainties surrounding the values of important variables, and constructs several "what if?" scenarios for achieving a 10 percent carbon intensity reduction in a specified timeframe with features that address key uncertainties.

This analysis provides quantitative or qualitative estimates of the potential incremental changes resulting from the CFS policy scenarios, including:

1. *Demand for conventional and low carbon transportation fuels,* including gasoline, diesel, and conventional biofuels, plus low carbon fuels such as advanced biofuels, electricity, and compressed natural gas (CNG).
2. *Fuel diversification,* the shift in the composition of the region's transportation fuels from one dominated by gasoline (blended with 10 percent conventional ethanol) and diesel to a broader mix that is likely to include liquid biofuels, electricity, and natural gas.
3. *Fuel delivery infrastructure* for charging and fueling electric and natural gas vehicles, and storing, blending, distributing, and fueling liquid biofuels.

4. *Numbers and market penetration rates of alternative vehicles*, including battery-electric (BEVs) and plug-in hybrid electric vehicles (PHEVs), light-, medium-, and heavy-duty natural gas vehicles (NGVs), and flex-fuel vehicles (FFVs).
5. *Changes in GHG emissions* based on total life-cycle analysis.
6. *Distributive impacts on affected groups*, including regulated companies, fuel consumers, producers of low carbon fuels (and related industries), and state governments.
7. *Macro-economic impacts*, including annual changes in regional employment levels, gross regional product, disposable personal income, and industry value-added.

2.2. Limitations of the Analysis

Due to the high level of uncertainty associated with key factors determining CFS impacts, some economic impacts remain outside the scope of this initial study. First, this analysis does not provide an estimate of a least-cost pathway (or pathways) for CFS program compliance. The possible range of fuel volumes needed, the relative cost-competitiveness of different fuel types, innovation rates, infrastructure needs, and the actions of market participants are too uncertain at this stage to conduct a meaningful least-cost estimation or a simulation of a potential CFS credit market. As such, the cost estimates provided in this report reflect estimates of possible expenditures and investments rather than precise estimates of industry compliance costs. However, the study provides a discussion of possible compliance strategies and how the costs of these strategies might be estimated in the future as better information becomes available.

Second, because this analysis does not project how a potential low carbon fuel market will develop or the costs or profits realized by all possible market participants, it also does not attempt to translate these market effects into a quantitative estimate of the possible effect of the program on the retail gasoline and diesel prices. Section 3, however, provides qualitative discussion of the possible impacts of this program on consumers, based on the cost assumptions used in the analysis.

Finally, an evaluation of the potential changes in air quality that might result from implementing a CFS is beyond the scope of this study. Many results of this analysis, however, would be appropriate inputs to subsequent analyses of air quality changes and resultant public health effects, such as changes in criteria and hazardous air pollutant emissions due to the program’s effects on the transportation fuel mix.

2.3. Data

This analysis relies on published data and estimates from a variety of recent studies, reports, and databases. Wherever possible, selected data were based on peer-reviewed journal articles and other sources that have been subject to public review and comment, such as government reports. Sources were surveyed for values that could best the capture the current range of uncertainty for key variables. While any number of alternative values could be used for many of the variables in this analysis, the intent was to choose values that represent reasonable boundaries.

The key data sources used in this analysis included (but were not limited to):

- Energy Information Administration *Annual Energy Outlook 2010* (AEO 2010);
- U.S. Environmental Protection Agency (EPA) *Regulatory Impact Analysis of the Renewable Fuel Standard (*2010*)*;
- California Air Resources Board (CARB) *Initial Statement of Reasons* (ISOR) for the Proposed Low Carbon Fuel Standard (2009);
- CARB *Initial Statement of Reasons* (ISOR) for the Proposed Zero Emission Vehicle (ZEV) Program (2008);
- National Renewable Energy Lab (NREL) estimates;
- U.S. Department of Energy (DOE) sources, including the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) and VISION models;
- Regional Economic Models, Inc. (REMI) Policy Insight™ database;
- Innovative Natural Resource Solutions' *Biomass Availability and Utilization In the Northeastern United States* (2008);
- U.S. EPA solid waste data;
- ISO-New England, New York ISO, and PJM Interconnect databases;
- Cornell University energy crop estimates;
- U.S. Department of Agriculture agricultural data;
- Rutgers University/New Jersey Agricultural Extension Service (NJAES) Bioenergy calculator©; and
- industry estimates.

In some cases, published data, studies and/or empirical evidence were very limited for certain variables due to the nascent state of many of the fuels and technologies included in this analysis. For these variables, a range of estimates representing "optimistic" and "pessimistic" boundary values were developed by extrapolating related data. For example, given the lack of empirical evidence on the infrastructure needed to support wide-scale charging of electric vehicles (EVs), an estimate of the number of public charging stations needed to support a given number of EVs was derived based on the number of existing gasoline fueling stations. That estimate was then adjusted upwards to account for the fact that EVs have a more limited driving range than internal combustion (ICE) vehicles and take longer to refuel, and therefore require additional charging opportunities.

Carbon intensity values for traditional (e.g., corn ethanol) and advanced biofuels (e.g., cellulosic ethanol) were drawn primarily from modeling estimates developed by U.S. EPA and CARB. Carbon intensity scores for natural gas were developed using DOE's GREET model, along with data from CARB and Lifecycle Associates, a consulting firm that evaluates lifecycle carbon intensity of various fuel pathways. Electricity CI values were based on published data from U.S. EPA, the three grids that supply electricity to the participating states (PJM Interconnect, ISO New England, and New York ISO), and analysis using the NE-MARKAL model.[9]

This analysis also relied heavily upon a modified version of the VISION model, developed by Argonne National Laboratory, to project transportation-sector energy demand under each selected scenario.[10] VISION-Northeast (VISION-NE) characterizes the fleet mix in future years by simulating the evolution of the fleet over time, as older vehicles are retired and new vehicles enter the fleet. The model calculates total energy demand for specific fuel types based on fleet and fuel data for a start year, and AEO projections for fuel economy and fuel price. VISION-NE then applies user-provided CI values for each fuel to generate results for a given scenario, including fuel quantities, vehicle numbers, GHG emissions, and the average carbon intensity of transportation fuels used in the region.

Price projections for conventional transportation fuels (gasoline and diesel) came from EIA's *Annual Energy Outlook 2010* (AEO 2010).[11] Estimates of the costs of producing advanced biofuels, including feedstock, production, and distribution costs, came primarily from U.S. EPA, CARB, and NREL. Biogas production costs were modifications of estimates provided by industry. Natural gas and electricity price projections were from the AEO 2010.

A number of data sources on biomass availability and energy content were used to develop a bioenergy database, the NE/MA Bioenergy Calculator, which generated low- and high-end estimates of potential biofuel and biogas production in the region.[12] These data sources included: Integrated Natural Resource Solutions, Rutgers University/New Jersey Agricultural Extension Services, U.S. Department of Agriculture, U.S. EPA, and Cornell University.

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[9] NE-MARKAL is the Northeast version of the Market Allocation model (MARKAL), an energy model. NESCAUM developed NE-MARKAL by scaling down a national version of MARKAL that was developed by U.S. EPA's Office of Research and Development (http://www.nescaum.org/topics/ne-markal-model) For information on the MARKAL model, *see* Loulou, R., G. Goldstein, and K. Noble, The MARKAL Family of Models, Energy Technology Systems Analysis Programme (ETSAP), October 2004 (www.etsap.org.)

[10] A detailed description of the additional features created in VISION for purposes of the LCFS analysis and the modeling methodology is included in *Appendix B*.

[11] The Annual Energy Outlook 2011 *Early Release* projects higher supply and lower prices for natural gas than AEO 2010, due to a higher estimate of the development of domestic shale gas resources. As such, many of the cost estimates for natural gas as a low carbon fuel would be lower if AEO 2011 values were used (they were not available in the timeframe of this analysis). However, any estimates of future commodity supplies and prices are subject to substantial uncertainty.

[12] A detailed description of the NE/MA Bioenergy Calculator is in *Appendix A*.

2.4. Methods and Key Assumptions

This section provides an overview of the methodologies and analytic concepts used in the analysis. More detailed descriptions of methods, modeling tools, and key assumptions are provided in the Appendices to this report.

Economic impact estimates for the regional CFS were generated by comparing policy scenarios to reference cases that depict the "business-as-usual (BAU)" situation, i.e., "the world without the CFS," under low and high oil price projections.

Each of the three main policy scenarios represents a future outcome in which low carbon fuels, infrastructure, and alternative vehicles are commercially available in quantities sufficient to meet a 10 percent reduction in CI, compared to the BAU cases. Rather than forecasting a single probable version of the future, this analysis addressed the uncertainties about future fuel availability and costs, infrastructure and vehicle needs, consumer preferences, and broader economic conditions by evaluating multiple scenarios with different boundary conditions (i.e., low- or high-end estimates) built into each scenario.

In addition to three core policy scenarios that achieve a 10 percent reduction in CI of transportation fuels, the analysis evaluated three sensitivity cases:

- a scenario that is less optimistic about fuel technology and costs, and achieves a five percent CI reduction over 10 years;
- a scenario that is more optimistic about fuel technology and costs, and achieves a 15 percent CI reduction over 15 years, and;
- a sensitivity case on the Biofuels Future, where the majority of advanced biofuels are produced outside of, rather than within, the NE/MA region.

The design of the three main CFS policy scenarios and the sensitivity cases are described in more detail later in this section. While more extreme future outcomes than those represented in these scenarios are possible, these scenarios and sensitivity cases were specifically designed to capture the range of uncertainties on the most important variables, using the best information currently available.

2.4.1. Treatment of Key Variables

Each policy scenario included in this analysis simulates compliance with a given carbon intensity reduction target, achieved through a combination of different low carbon fuels, fuel infrastructure, and alternative vehicles. To formally address the uncertainty that characterizes the key variables used in this analysis, each policy scenario includes low- and high-end estimates for key variables. The low- and high-end values are intended as reasonable outer boundaries for variables expected to have the most significant influence on results. These variables include:

- **CI values for conventional and low carbon fuels:** The CI values of low carbon fuels determine the quantities of fuels needed to reach a given CI reduction target. Because the CFS target is intensity-based, a low carbon fuel with relatively higher CI will be needed in greater quantities, compared to a low carbon fuel with a lower CI value, in order to reach a given target. Because CI values determine the quantities of low carbon fuels needed to reach a given target, they are the most influential variable in determining the benefits and costs associated with the fuels themselves, as well as the costs of fuel delivery infrastructure and the number of alternative vehicles needed.

One of the key sources of uncertainty about what is needed for compliance with a CFS is how the carbon intensity of the reference case fuels — i.e., gasoline and diesel — might change over time. The prevalence of higher-carbon intensity crude oil (HCICO) in the NE/MA marketplace and indeed, throughout the US, is increasing as new, non-traditional sources of crude, such as oil sands, come online. As described later in this section, this analysis incorporates a wide range of values for the carbon intensity of gasoline and diesel over time.

Another source of uncertainty of the lifecycle GHG emissions, for biofuels in particular, is the concept of *indirect land use change* (iLUC). The issue of iLUC refers to the risk that increased demand for biofuels causes market-induced changes to land use, such as clearing of forests, which could in turn cause an increase in carbon emissions net of any GHG reductions achieved by reducing the use of fossil fuels. The potential contribution of iLUC to a lifecycle CI score for biofuels is the current subject of extensive research and debate by the research community and policymakers at the state, national and international levels. In 2010, for example, CARB assembled an Expert Workgroup to evaluate methods and assumptions for modeling iLUC values and possible improvements to these estimates in the future.[13] The U.S. EPA and European Union have also devoted significant resources to the analysis of iLUC.

- **Costs of conventional and low carbon transportation fuels:** The relative costs of conventional transportation fuels (i.e., gasoline and diesel) and low carbon substitutes are important for determining overall and relative expenditures on transportation fuel under the CFS. If the cost of lower carbon fuels is less than that of conventional fuels on an energy equivalent basis, overall expenditures on transportation fuels would decline. Conversely, if low carbon fuels are higher in cost than conventional fuels, overall fuel expenditures would increase under a CFS. This analysis considers a range of possible costs for both conventional and low carbon fuels to address this uncertainty.

- **Effects of other energy and transportation policies**: The federal Renewable Fuel Standard rule (RFS2) includes a provision under which the U.S. EPA may lower the volume requirements for advanced biofuels in a given year. This provision has been invoked to substantially reduce the required volumes in each of the first two years of the federal program. Because of the reasonable likelihood that the volume requirements could be adjusted again in future years, it is difficult

[13] More information on the findings and recommendations of the CARB Expert Workgroup can be found at: http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/expertworkgroup.htm

to predict with certainty what effect this program will have on total national production of advanced biofuels volumes in a given scenario year. This analysis attempts to capture the range of possible outcomes by assuming that all RFS volume requirements are met in the High Oil Price case, and using a more conservative AEO estimate for total national RFS production volumes for the Low Oil Price case. Moreover, because RFS2 specifies only national production requirements, it is difficult to determine where in the U.S. any RFS2 fuels will actually be sold. The methodology by which sales of RFS2 advanced biofuels were apportioned geographically (i.e., to the NE/MA region, California, and the rest of the U.S.) in this analysis is described in detail later in this section.

The California Zero Emission Vehicle (ZEV) rule assigns credits to carmakers on a sliding scale based on specified vehicle performance targets (i.e., driving range and refueling time). For example, in the early years of the program, a battery-electric vehicle with a range of over 100 miles would earn three times as many credits as a vehicle with a range of less than 50 miles. Some manufacturers may choose to deliver a relatively large number of lower-range vehicles, while some may choose to supply fewer of the high-range vehicles. This flexibility in compliance options makes it difficult to predict with certainty exactly how many and what type of electric vehicles will be placed on the road in response to the ZEV rule. This analysis assumes that all manufacturers comply using a "middle-of-the-road" strategy consistent with analysis conducted by CARB in its ZEV report.[14]

- **Rate of expansion and cost of low carbon fuel storage and delivery infrastructure:** An increase in the sale, distribution, and use of low carbon fuels will require additional fuel storage and delivery infrastructure capacity. In the case of biofuels, substantial infrastructure for the storage, blending, and delivery of ethanol and biodiesel is already in place in the NE/MA states, and will require expansion under the RFS2. However, greater infrastructure expansion may be needed if the CFS requires greater volumes of either or both fuel types than what would be expected under the RFS2. This is especially true if ethanol blends greater than 15 percent are required for CFS compliance.[15] Any 85 percent ethanol (E85) blends that enter the NE/MA fuel market would require a dedicated refueling infrastructure. To support a large fleet of electric vehicles, improvements to delivery infrastructure such as transformers and charging stations may be required. Additionally, smart meter technology may be helpful for managing electric load from increased home charging. Expanded use of natural gas would require upgrading current CNG fueling stations, and building new stations to accommodate the fleet. By varying assumed rates of infrastructure

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[14] California Air Resources Board. *Initial Statement of Reasons*, Proposed Zero Emission Vehicle Program, 2008.

[15] In separate rulings in 2010 and 2011, U.S. EPA waived the current 10 percent volume blend limit for ethanol (E10) and replaced it with a blend limit of no more than 15 volume percent ethanol (E15) for all model years 2001 and later.

additions, this analysis addresses, to some degree, the relatively high uncertainty as to how the fuel infrastructure might vary with respect to the volumes of biofuels, electricity, and natural gas used, as well as the number of alternative vehicles needed.

- **Market penetration rates and costs of alternative vehicles**: While compliance with the CFS only requires changes in characteristics of transportation fuels, these changes in turn imply a certain number of alternative vehicles entering the marketplace to enable the deployment of various levels of low carbon transportation fuels. For example, electricity can only be used as a low carbon transportation fuel if EVs are sold into the marketplace in numbers consistent with a given volume of electricity. This also holds true for NGVs. Consumer preferences, the costs and attributes of alternative vehicles, fuel prices, and charging/fueling station availability are all factors that contribute to the uncertainty surrounding the market penetration of alternative vehicles. This analysis explicitly addresses part of this uncertainty, by considering variability in the types and incremental costs of these vehicles, compared to conventional vehicles.

- **Social cost of carbon used to value estimated changes in GHG emissions:** The economic value of reducing (or avoiding future) GHG emissions is a subject of active debate, due to the uncertainties about the possible magnitude and type of climate impacts and also differing viewpoints on how to evaluate emissions reductions occurring at different points in time. In this analysis, values used for the "social cost of carbon," (SCC) range from nearly $24 per ton of carbon-equivalent in 2013 on the low-end (increasing to $29 per ton in 2022) to approximately $107 per ton at the high-end (2013 through 2022).[16]

2.4.2. Modeling Tools Used in the Analysis

This analysis relied on a variety of established and new analytic tools and models. The flowchart in **Figure 2-1** shows the modeling tools used at each step in the analytic process, and the relationship between the inputs and outputs from each analytic step.

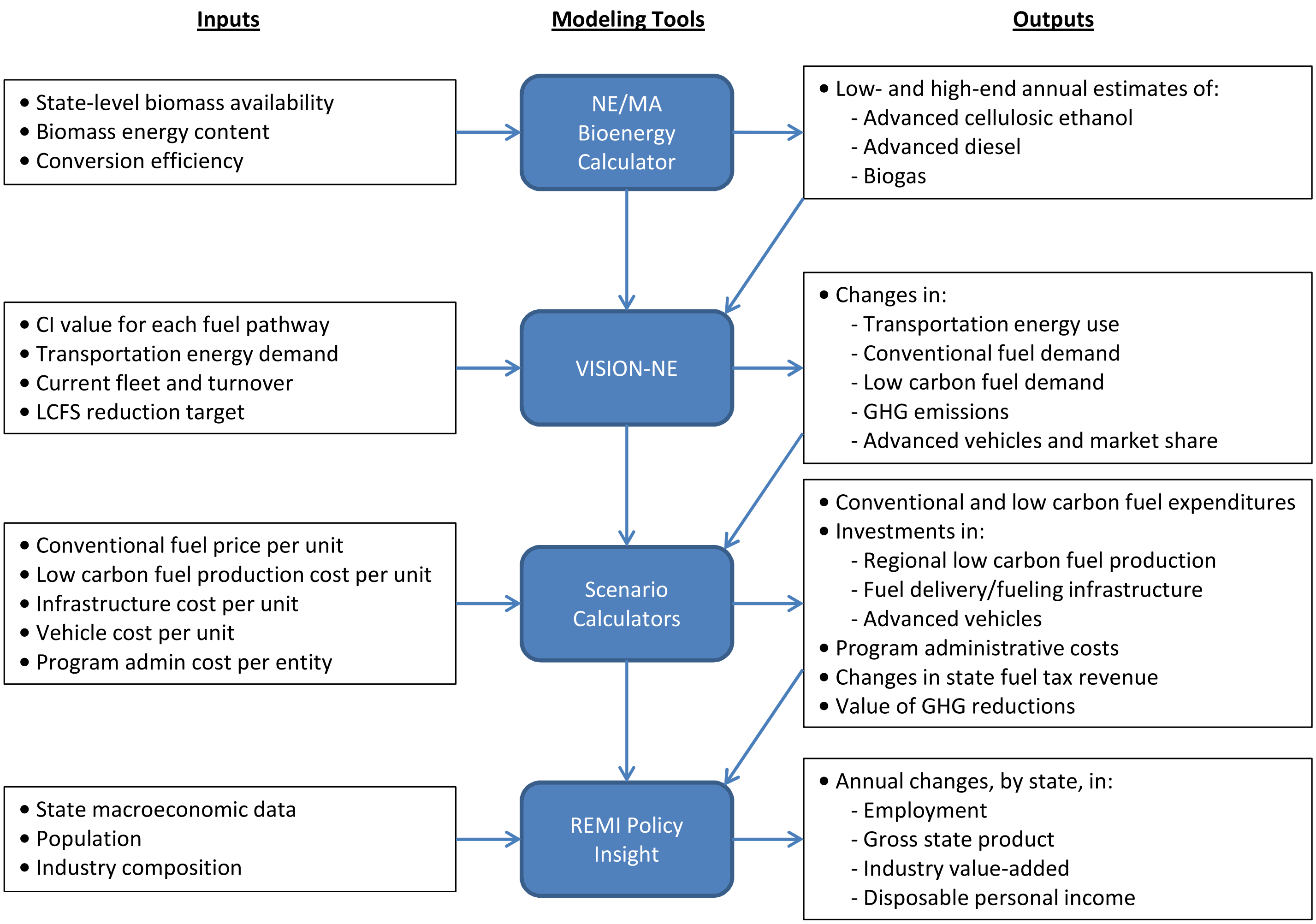
In the first step in the analysis, the *NE/MA Bioenergy Calculator* was used to convert state-level data describing the availability of different types of biomass (e.g., woody biomass, solid waste), energy content, and technology conversion efficiencies into low- and high-end estimates of the potential production of biofuel and biogas using regional resources.[17]

[16] The low-end value for social cost of carbon is from: Interagency Working Group on Social Cost of Carbon, United States Government (2010). *Social Cost of Carbon (SCC) for Regulatory Impact Analysis Under Executive Order 12866*. The discount rate for the low-end value is 3 percent. The high-end SCC value is from the Stern Review (2006), and uses a 0 percent discount rate.

[17] The NE/MA Bioenergy Calculator is described in more detail in *Appendix A*.

These low- and high-end estimates of in-region fuel production, along with CI values, transportation energy demand, and fleet characteristics were key inputs to the *VISION-NE* model, used in the next step in the analysis. VISION-NE – a modification of the national VISION model created by Argonne National Lab – was adapted to better characterize unique aspects of transportation fuel demand, vehicle miles traveled, and vehicle fleet characteristics in the NE/MA states.[18]

Figure 2-1. Modeling Tools Used in the CFS Economic Analysis



New features were added to VISION-NE to perform calculations of CFS compliance with a given CI reduction target. VISION-NE calculates changes in carbon intensity, energy demand, alternative vehicle penetration, fuel use, and associated GHG emissions based on the CI values provided for each reference case and policy scenario. Results from these calculations, comparing both reference cases to each policy scenario over the time period 2013 to 2022, become key inputs to the *CFS Scenario Calculators*.

[18] VISION-NE and supporting data and assumptions are described in *Appendix B*.

The CFS Scenario Calculators are spreadsheets that, for each policy scenario and sensitivity case, calculate the following results for the incremental impacts of the CFS: (1) total quantities of, and expenditures on, conventional and low carbon fuels, infrastructure, alternative vehicles, and program administration; (2) GHG emissions; and (3) potential state fuel tax revenue changes. All calculations were done on an annual basis. Net present values for streams of investments and expenditures were discounted at three and seven percent. Based on the outputs of the NE/MA Bioenergy Calculator, the Scenario Calculators estimated the volume of low carbon fuel produced in the region as well as the investments in feedstocks, production, and distribution of low carbon fuels.

The final step in the analysis involved evaluating macroeconomic impacts of a CFS on the regional economy, using the *REMI Policy Insight* (REMI) model. Key inputs to REMI include the levels of investment in low carbon fuels, infrastructure, and vehicles calculated by the scenario calculators, as well as indicators of which industries or sectors would be directly impacted by these changes. For example, investments in building new electric vehicle charging stations will directly impact the electric utilities and other providers of vehicle charging services that might install those systems. REMI, in turn, generates estimates of how such changes in investments and expenditure levels would reverberate through the regional economy and affect levels of employment, gross regional product, industry output, and disposable personal income.

2.4.3. Design of Reference Cases

To arrive at the estimates of the incremental impacts of the CFS, analytic results for the policy scenarios and sensitivity cases were compared to two reference cases representing BAU (i.e., without the CFS).

The two references cases, the “Low Oil Price” and “High Oil Price,” share key similarities. Specifically, both reference cases assume full compliance with many relevant policies that will be in effect during some or all of the program period evaluated. These policies include:

- **Regional Greenhouse Gas Initiative (RGGI) and state renewable energy standards:** These programs require reductions in carbon emissions and increases in renewable forms of generation in the electricity sector, respectively.[19] Together, these programs have the effect of reducing the average CI of electricity over time.
- **State biofuel requirements:** Pennsylvania and Massachusetts have passed requirements for minimum levels of biodiesel sales in their states.[20]
- **Other Fuel Standards:** Other jurisdictions are developing transportation fuel GHG standards that will likely affect how much low carbon fuel is available in the market for the NE/MA states. Specifically, California is currently

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[19] Regional Greenhouse Gas Initiative (RGGI) (2008). *Regional Greenhouse Gas Initiative Model Rule.*
[20] (1) General Assembly of Pennsylvania (2008). *House Bill No. 1202, Session of 2007.* and (2) Massachusetts Department of Energy Resources (DOER) (2009). “Massachusetts Biofuels Mandate: Program Design Decisions and Implementation Plan.” As of this writing, Massachusetts has not yet implemented its mandate.

implementing a low carbon fuel standard, which requires a 10 percent reduction in CI in transportation fuels sold and used in California over 10 years, beginning in 2012.[21]

There are also key differences in assumptions among the reference cases. Important exceptions to the assumption of full compliance with existing regulations are the federal RFS2 and ZEV programs. Compliance with the RFS2 and ZEV programs is assumed to vary between the two reference cases, reflecting potentially higher investment in and development of biofuel and vehicle technologies in the High Oil Price case that will result from higher petroleum prices.

RFS and ZEV Assumptions

Advanced biofuels mandated by the federal RFS2 were assumed to contribute to the CI reductions required under the CFS program. The RFS separates advanced ethanol into two categories, "cellulosic ethanol" and "other advanced ethanol," which must be 60 and 50 percent less carbon intensive than gasoline, respectively. Additionally, the analysis included "advanced diesel," which must be 50 percent less carbon intensive than conventional diesel fuel.

For the Low Oil Price reference case, projected volumes of cellulosic and advanced ethanol were taken from EIA's AEO. The High Oil Price case assumed full compliance with the EPA's RFS High Ethanol case. The RFS projections for national volumes of advanced diesel, which are more conservative than those projected in the AEO, were used for both the Low and High Oil Price cases.

For both reference cases, sufficient volumes of RFS biofuels were assumed to be sold in California to meet the CI reduction requirements of the California LCFS. The remaining fuel was assumed to be distributed to the remaining states in volumes proportional to each state's sales share of gasoline and diesel in comparison to the national total.

The CI reductions resulting from advanced biofuels mandated by the RFS, together with the effects of any high-carbon crude oil (HCICO) and vehicles sold under the ZEV mandate, were used to estimate the BAU CI of the NE/MA region's transportation fuel mix. Importantly, for the purpose of this analysis, the CFS reduction targets were defined relative to the baseline fuel, defined as gasoline or diesel produced from non-HCICO sources, not relative to the BAU fuel mix. **Figures 2-2** and **2-3** show CI for gasoline, BAU fuel mix, and the 10 percent target over the 10-year program period. The difference between the BAU CI and the 10 percent reduction target represents the effective CI reductions attributable to the CFS program.

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[21] California Air Resources Board (CARB) (2009). Proposed Regulation to Implement the Low Carbon Fuel Standard – Vols. I and II (Staff Report: Initial Statement of Reasons (ISOR)). Retrieved April 23, 2010, from http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf.

Figure 2-2. Business-as-Usual Carbon Intensity, Low Oil Price, and 10 Percent Reduction Target for Gasoline

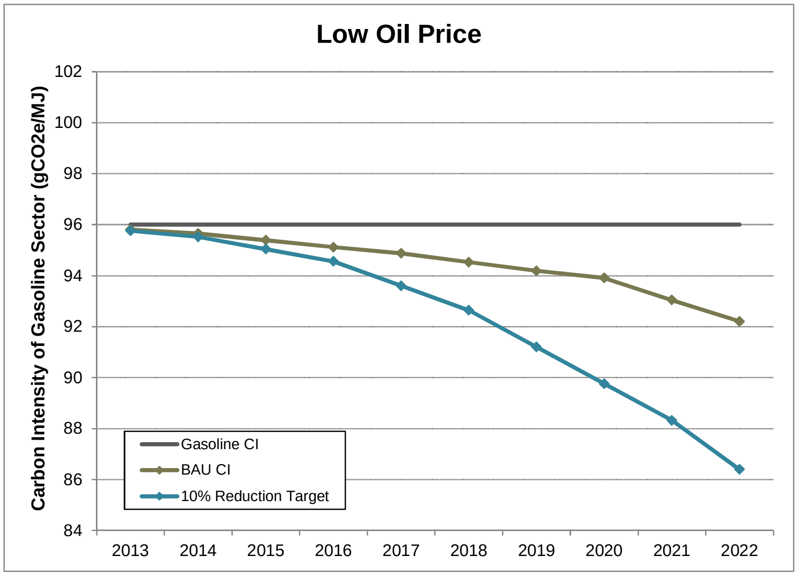
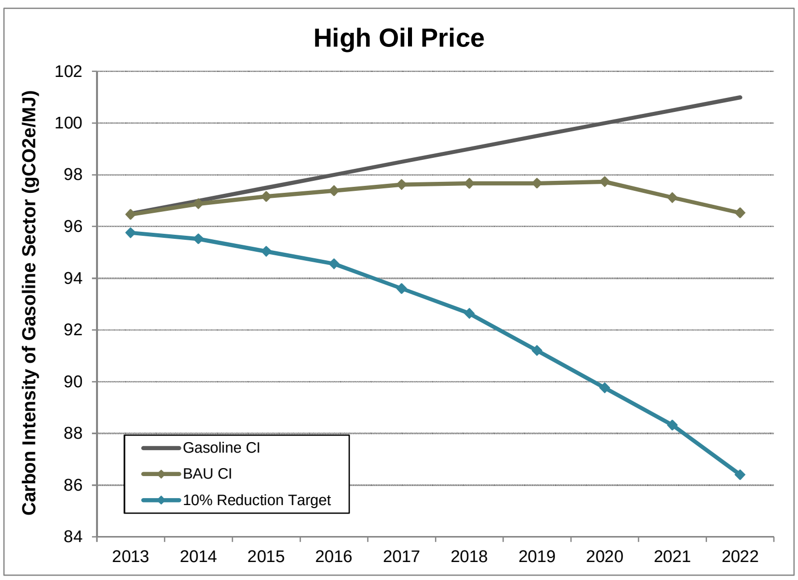


Figure 2-3. Business-as-Usual Carbon Intensity, High Oil Price, and 10 Percent Reduction Target for Gasoline



The above assumptions that describe compliance with the RFS in turn influence the policy scenario results. Specifically, the quantities of liquid biofuels shown for each of the CFS policy scenarios represent volumes of biofuels over and above those that would be expected for RFS compliance alone and are additional fuels needed to meet the requirements of the CFS CI reduction targets.

There are also differences in the assumptions of how the RFS plays out within the three 10 percent CI reduction scenarios. In the Electricity and Natural Gas Futures, the BAU volumes of advanced biofuels are assumed to remain part of the regional fuel mix under the CFS program, and any biofuels produced in the region are assumed to supplement these volumes. However, in the Biofuels Future, biofuels produced in the NE/MA are assumed to replace these BAU biofuels in order to capture the effects of a developing regional biofuels industry on local fuel markets.

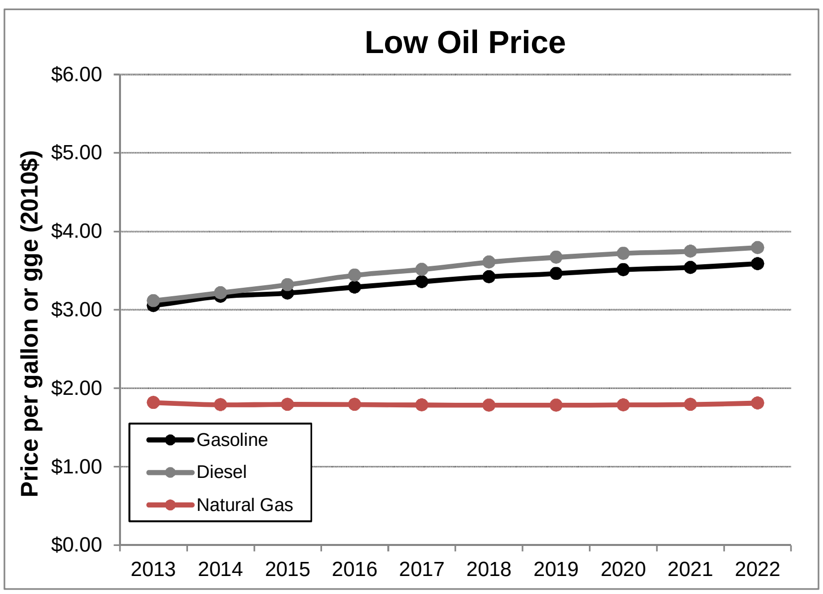
It is important to note that because CFS is an intensity-based standard, the volume of low-carbon fuels required will be inversely proportional to the CI value of those fuels. Thus, if fuels with very low CI values are available, it will require relatively smaller volume of these fuels to produce a given reduction in average CI. In contrast, higher CI values require larger volumes of low carbon fuels to achieve a given reduction in average CI.

Other differences in this analysis between the Low and High Oil Price reference cases include: (1) price projections for conventional transportation fuels (gasoline, diesel, and natural gas); and (2) CI values for gasoline and diesel. Both of these variables are described in more detail below.

Low Oil Price Case

Under the Low Oil Price case, price projections for each fuel type are consistent with the AEO 2010 "Reference" scenario. **Figure 2-4** shows projected fuel prices for 2013 to 2022. Gasoline and diesel prices are projected to grow at a relatively low rate from slightly over $3 per gallon for gasoline and diesel in 2013 to $3.59 for gasoline and $3.79 for diesel by 2022. In contrast, AEO's price for compressed natural gas is projected to remain level, at approximately $1.79 per gallon gas-equivalent throughout the period.

Figure 2-4. Projected Gasoline, Diesel, and Natural Gas Prices



Source: AEO 2010. Note: Gas and diesel prices include state and federal taxes.

As shown in **Table 2-1** below, under low oil prices the CI values are assumed to be 96.0 grams per per megajoule (g/MJ) and 94.0g/MJ for gasoline and diesel fuel, respectively.

Because higher-carbon sources of petroleum such as oil sands or shale oil are more expensive to develop than lower-carbon traditional petroleum supplies, under low oil prices, it was assumed that these high-CI sources had little effect on CI in the NE/MA market throughout the program period.

Table 2-1. Carbon Intensity Values (g/MJ) for Conventional Gasoline and Diesel, Low Oil Prices (2013 and 2022)

Fuel Type	Low Oil Price	
	2013	2022
Gasoline	96.0	96.0
Diesel	94.0	94.0

For gasoline and diesel substitutes in this reference case under RFS2, national renewable fuel sales projections from AEO2010 were used. Low-carbon fuels sold under the RFS2 requirements were assumed to be sold in sufficient volumes in California to meet their LCFS, and remaining low carbon RFS2 fuel volumes were distributed in proportion to gasoline sales in the other 49 states.

High Oil Price Case

Price projections for gasoline, diesel, and natural gas under this case were consistent with the AEO 2010 "High Oil Price" scenario. **Figure 2-5** shows that the AEO projects gasoline and diesel prices to increase at a much higher rate for this case than under the Low Oil Price case, primarily due to stronger economic conditions and higher global demand. Gasoline prices are projected to increase from \$3.66 per gallon to \$5.49 per gallon by 2022, while diesel prices are projected to rise from \$3.93 per gallon to \$5.91 by 2022. AEO projections for natural gas prices are at a relatively stable price of approximately \$1.84 per gallon gas-equivalent over the 10 years, due to a projected increase in supply of natural gas from shale gas reserves throughout the U.S.

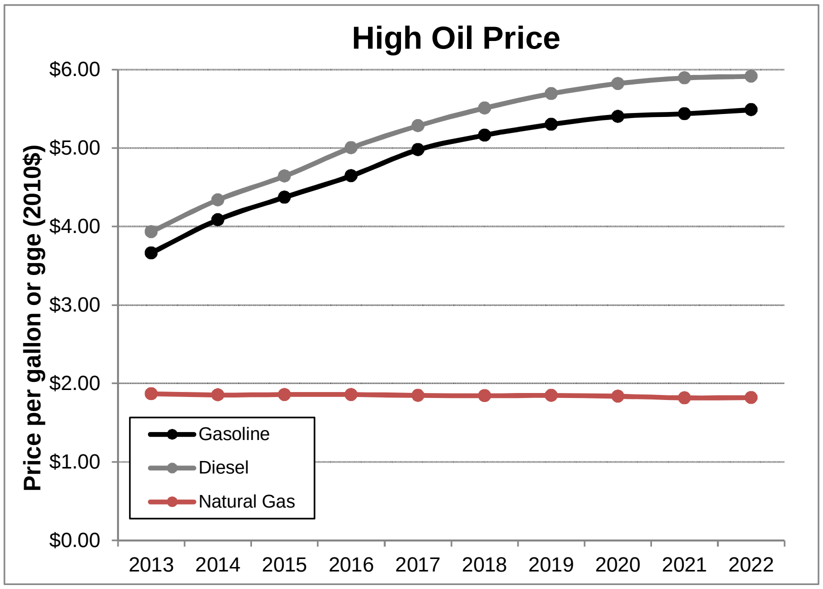
As **Table 2-2** shows, under high oil prices, the average CI values in the regional fuel pool are assumed to increase from 96.5 to 101 g/MJ for gasoline and from 94.5 to 99.0 g/MJ for diesel fuel from 2013 to 2022, reflecting an increase in the economic viability and market share of products derived from higher carbon intensity feedstocks. These estimates reflect an assumption that the carbon intensity of petroleum increases 0.5 g/MJ per year over the 2013 to 2022 timeframe.

For gasoline and diesel substitutes under RFS2, national renewable fuel sales consistent with the volume requirements specified by U.S. EPA under their RFS "High-Ethanol" scenario were used in this reference case.[22] Low carbon fuels sold under the RFS2 requirements were assumed to be sold in sufficient volumes in California to meet their

[22] The "high-ethanol" scenario was one of two possible compliance scenarios that EPA evaluated in its 2010 Regulatory Impact Analysis of the Renewable Fuel Standard. The other "low-ethanol" compliance scenario featured lower quantities of advanced ethanol. U.S. EPA (2010). *Regulatory Impact Analysis: Renewable Fuel Standard Program.* Retrieved April 23, 2010, from http://www.epa.gov/otaq/renewablefuels/420r07004.pdf.

LCFS. Remaining low carbon RFS2 fuel volumes were distributed in proportion to gasoline sales in the other 49 states.

Figure 2-5. Projected Gasoline, Diesel, and Natural Gas Prices



Source: AEO 2010. Note: Gas and diesel prices include state and federal taxes.

Table 2-2. Carbon Intensity Values (g/MJ) for Conventional Gasoline and Diesel, High Oil Prices (2013 and 2022)

Fuel Type	High Oil Price	
	2013	**2022**
Gasoline	96.5	101
Diesel	94.5	99.0

2.4.4. Description of Key Assumptions

This economic analysis relies upon the use of three main policy scenarios depicting a CFS program, each of which reflects a 10 percent CI reduction in transportation fuels relative to BAU over a 10-year time period. In addition to the three policy scenarios featuring a 10 percent CI reduction, this analysis includes three sensitivity cases that vary either the CI reduction target and/or other key assumptions.

As stated earlier in this section, the policy scenarios and sensitivity cases portrayed in this analysis are not intended as forecasts or predictions of likely outcomes. Rather, each scenario depicts a unique “what if?” trajectory of fuel technologies, infrastructure, and consumer choices that illustrate how a given CFS target could theoretically be met within a specified timeframe. In addition, in each policy scenario, the factors most likely to influence economic impacts vary, to account for the uncertainties in these variables as well as understand how sensitive results are to changes in these variables.

As described in Section 2.3.2.1 (Treatment of Uncertainty), the key factors that vary across CFS policy scenarios and sensitivity runs include:

- carbon intensity values;
- biomass availability for in-region production;
- prices for conventional and low carbon fuels;
- fuel infrastructure penetration rates and costs;
- alternative vehicle market penetration rates and costs; and
- CI reduction targets and timeframes.

This section generally describes the data sources and assumptions used for these variables. The following section provides more detail on how specific assumptions were used in the policy scenarios and sensitivity cases.

Carbon Intensity

Carbon intensity values are the single most important variable in determining the economic impacts of the CFS because they determine the volumes of low carbon fuels needed to meet the reduction target. **Table 2-3** shows the range of carbon intensity values assigned to low carbon fuels in the various policy scenarios and sensitivities analyzed in this study. For most of these fuels, the analysis employed a low-end and high-end CI estimate whenever possible to reflect current differences among published estimates of fuels' lifecycle GHG emissions.

U.S. EPA estimates were used for the low-end CI values for the advanced biofuels, including cellulosic ethanol and Fischer-Tropsch diesel. These low-end CI values generally reflect U.S. EPA's estimates of best possible CI attainable for these fuels by 2022, accounting for potential improvements in production efficiencies and technologies by industry.

The negative CI values for cellulosic ethanol indicate that U.S. EPA expects electricity generation to be a by-product of the ethanol production process, and that because this electricity is renewable it would, in turn, reduce the average carbon intensity of electricity. This shows up as a credit in the lifecycle CI value for cellulosic ethanol. Waste-based fuels in liquid and gaseous form have lower CI values than those made from virgin feedstocks, due to lower associated land-use GHG emissions.

The high-end CI values for cellulosic ethanol were based on U.S. EPA's minimum threshold GHG value for RFS eligibility, or 37.2 g/MJ.[23] CARB's estimate of the CI for conventional biodiesel is used as the high-end CI value for this fuel. High-end CI values for other fuels are "not applicable," because they are not needed based on the design of the scenarios (as explained further below).

[23] U.S. EPA requires that cellulosic ethanol must reduce lifecycle GHG emissions from gasoline by 60 percent to be eligible under the RFS. Based on U.S. EPA's assumed CI for conventional gasoline of 93 g/MJ, NESCAUM used a CI value for cellulosic ethanol of 37.2 g/MJ.

Table 2-3. Carbon Intensity Values for Low Carbon Fuels (g/MJ), 2013 to 2022

Fuel Type	Low-End	High-End
Ethanol:		
Cellulosic, Waste Feedstock	-27.0	37.2
Cellulosic, Virgin Feedstock	-9.0	37.2
Cellulosic Ethanol, Out-of-Region[24]	-18.0	37.2
Conventional Biodiesel[25]	40.0	70.0
Advanced Diesel:		
Fischer-Tropsch, Waste Feedstock	8.0	n/a
Fischer-Tropsch, Virgin Feedstock	27.0	n/a
Natural Gas:		
Conventional Natural Gas	68.0	78.0
Biogas, Waste Feedstock	11.0	n/a
Biogas, Virgin Feedstock	18.0	n/a
Electricity:[26]		
High-end (2013 to 2022)	n/a	80.5 decreasing to 75.0
Low-end (2013 to 2022)	57.0 decreasing to 55.0	n/a

Sources: U.S. EPA, CARB, Lifecycle Associates, and NESCAUM analysis, 2010.

The CI value for natural gas varies considerably depending on whether it is biogas, which has a very low CI of between 11.0 and 18.0 g per MJ on a full lifecycle basis, or conventional natural gas, which has a much higher CI relative to biogas, but is still a viable low carbon transportation fuel in comparison to gasoline or diesel. The assumptions for the low- and high-end values for carbon intensity of conventional natural gas used in this analysis — 68.0 and 78.0 g/MJ, respectively — reflect traditional natural gas extraction and distribution methods, and not the recent development of shale gas resources.[27]

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[24] This refers to cellulosic ethanol produced outside the NE/MA region to meet RFS requirements; the low-end CI value of -18 reflects an even distribution between waste- and virgin-based feedstocks, which approximates U.S. EPA's estimates of the composition of biomass resources available in the rest of the U.S.

[25] Conventional biodiesel represented in this analysis is primarily soy-based biodiesel. While waste-based biodiesel is generally considered to have a low CI value, estimates of the quantity of waste oils available in the NE/MA region for *additional* waste-based biodiesel production are very low.

[26] Electricity CI ranges shown above reflect 2013 value and 2022 values, respectively, and an adjustment for an energy-economy ratio (EER) of 3.0. The number of significant digits in the electricity CI values reflects greater significant digits in the underlying EER estimate.

[27] As of this writing, there is little new publicly available empirical data on the full lifecycle GHG impacts of natural gas derived from shale resources. The recently published Howarth *et al.* (2011) study on natural

Electricity CI values were based on average carbon emission rates across the 11-state NE/MA region, which spans two full power grids, ISO New England and the New York ISO, and part of a third power grid, the PJM Interconnect.[28] These average emission rates were adjusted to account for compliance with existing policies that reduce power sector GHG emissions, including RGGI and state renewable energy requirements.[29] The CI value for electricity also reflects an "energy-economy ratio" (EER) of 3.0 for electric vehicles, to account for the relative efficiency with which these vehicles use a unit of delivered energy in comparison to an internal combustion engine.[30]

NE-MARKAL, a 12-state energy optimization model covering the northeast and mid-Atlantic region, was used to generate the estimates of low-end electricity CI. The low-end electricity CI value reflects constraints built into NE-MARKAL that represent full compliance with RGGI and renewable energy requirements and limit additions of new carbon-intensive generation. The low-end estimate of 57.0 g/MJ represents a starting CI value in 2013 that gradually declines to 55.0 g/MJ by 2022, due to the effects of RGGI and renewable energy requirements.

The high-end CI value for electricity of 80.5 g/MJ in 2013 decreases to 75.0 g/MJ by 2022, and was based on a simplifying assumption of a 35 to 40 percent increase in average carbon intensity above the low-end CI range. This is a likely to be a conservative estimate that would likely result only if carbon-intensive generation resources (i.e., new coal plants) were added to the regional mix, and/or EVs were charged primarily at times of peak and intermediate demand, when less efficient generation units are dispatched and carbon intensity is higher.[31] While this analysis did not rely upon an electricity dispatch model to estimate these values, other studies using dispatch models have shown that relying heavily upon marginal dispatch to meet EV demand could significantly increase GHG emissions.[32]

Low Carbon Fuel Prices

Table 2-4 below lists the price assumptions used in this analysis for conventional transportation fuels — gasoline and diesel — and low carbon fuel alternatives in 2013

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gas GHG lifecycle emissions, for example, evaluates lifecycle emissions using alternative GHG accounting methodologies but does not rely upon new empirical data.

[28]The mid-Atlantic portion of the PJM grid consists of the states of New Jersey, Delaware, Maryland, and most of Pennsylvania. On balance, the average CI of electricity for this sub-section of PJM is slightly lower than the PJM-wide average, due to a relatively higher percentage in these states of lower CI generation resources such as natural gas and nuclear, compared with a relatively higher percentage of coal-based generation in other areas within the PJM grid.

[29] The influence of RGGI and state renewable energy requirements on CI is temporal—these programs are assumed to reduce the CI value of electricity over time.

[30] Adjusting for an EER of 3.0 requires dividing the average electricity CI value by 3.0.

[31] In the northeastern U.S., units that serve marginal load during peak demand generally include single-cycle natural gas turbines or back-up diesel generators.

[32] See, for example: McCarthy and Yang (2009). Determining marginal electricity for near-term plug-in and fuel cell vehicle demands in California: Impacts on vehicle greenhouse gas emissions. *Journal of Power Sources* 195 (7): 2099-2109.

and 2022.[33] Gasoline and diesel prices under the Low Oil Price case reflect the AEO 2010 reference case forecast, whereas the gas and diesel prices used in the High Oil Price case reflect AEO's 2010 High Oil Price forecast, which anticipates increasing demand from developing countries and a decrease in petroleum supplies from traditional producers.[34] No subsidies are included in these prices.

Table 2-4. Prices (and Costs) for Conventional and Low Carbon Fuels, 2013 and 2022 (per unit basis)

Fuel Prices	Low Oil Price		High Oil Price	
	2013	2022	2013	2022
Conventional Fuels:				
Gasoline ($/gal)	$3.05	$3.59	$3.66	$5.49
Diesel ($/gal)	$3.12	$3.79	$3.93	$5.91
Low Carbon Fuels:				
Natural gas ($/gge)	$1.82	$1.81	$1.87	$1.82
Electricity, high-end ($/kWh)	$0.18	$0.18	$0.18	$0.18
Electricity, low-end ($/kWh)	$0.14	$0.14	$0.14	$0.15
Cellulosic ethanol, high-end ($/gal)	$2.35	$2.35	$2.95	$2.95
Cellulosic ethanol, low-end, waste feedstock ($/gal)	$0.62	$0.62	$0.65	$0.65
Cellulosic ethanol, low-end, virgin feedstock ($/gal)	$1.35	$1.35	$1.70	$1.70
Fischer-Tropsch diesel ($/gal)	$3.42	$3.42	$3.92	$3.92
Soy biodiesel ($/gal)	$2.28	$2.28	$3.15	$3.15

Notes: Gasoline and diesel prices reflect federal and state taxes. Biofuel prices do not include federal production tax credits.

Natural gas price assumptions for the Low and High Oil Price cases were also taken from the AEO 2010. AEO's estimates reflect the fact that increased supplies of natural gas, the price of which has historically tracked closely with that of petroleum, have essentially resulted in many published forecasts of natural gas prices to reflect a "decoupling" from petroleum prices for the foreseeable future. AEO therefore projects natural gas prices to be relatively low in both the Low and High Oil Price cases (in comparison to historical prices) and fairly constant except for a slight decline projected by 2022.

The low-end assumption for average retail electricity prices in the NE/MA states came from AEO 2010, and is projected to be relatively level over the timeframe of this analysis, with prices at $0.14 per kWh in 2013, and increasing to $0.15 per kWh in 2022. The high-end assumption for electricity prices, i.e., $0.18 per kilowatt-hour (kWh)

[33] While the comparison of conventional and low carbon fuels within the VISION model is done on an energy equivalent basis (e.g., in MJ), the calculators used to generate estimates of low carbon fuel costs use prices expressed in the units typically used in the marketplace for a given fuel type. Electricity expenditures, for example, are calculated on a dollar per kWh basis.
[34] *Annual Energy Outlook*, 2010.

throughout this same period, is a simplifying assumption that is intended to represent an increase of roughly 20 to 30 percent over the low-end price. Similar to the high-end electricity CI value, this is not a modeled estimate generated by a formal electricity dispatch analysis, but an approximation of higher electricity prices associated with a growing contribution by renewable and low-carbon resources and/or higher electricity prices associated with charging vehicles during periods of peak demand.

Biofuels prices used in this analysis, shown in **Table 2-4**, represent average production costs rather than retail prices.[35] The low-end costs, derived from U.S. EPA's regulatory impact analysis of the RFS, reflect an optimistic estimate of the costs of various inputs to biofuel production — including feedstock and enzyme costs (in the case of cellulosic ethanol), as well as the costs of production, transport, and distribution activities — when the industry is producing at full commercial scale. Differences between production costs and market prices will be determined by producers' profits over and above the marginal cost of production (if any), plus any taxes and/or tax credits.

The high-end estimates for biofuel production costs range from $2.95 per gallon for cellulosic ethanol in 2022 to $3.92 per gallon for advanced diesel in 2022. These estimates reflect similar distribution costs as the low-end costs, but significantly higher estimates for feedstock, transport, and production costs in comparison to the low-end case. These estimates, derived from CARB values, were adjusted upwards by 30 percent to account for the effect of higher petroleum costs on the costs of feedstocks, production, and transport.

Table 2-5 provides a comparison of the prices of low carbon fuels and conventional fuel prices on an energy-equivalent basis. As seen from this comparison, low carbon fuel prices are assumed to be lower than the most comparable conventional fuel, with the exception of high-end cellulosic ethanol and Fischer-Tropsch diesel costs in 2013, under the Low and High Oil Price cases.

As noted earlier, values for biofuels represent production costs and not final retail market prices; final prices seen in the market will be determined by the willingness-to-pay of biofuel consumers.

[35] With the exception of soy biodiesel, low carbon biofuels included in this analysis are not yet produced and sold at commercial volumes; prices reflecting actual market supply and demand are not yet available.

Table 2-5. Prices (or Costs) for Low Carbon Fuels, 2013 and 2022 (gallon gas-equivalent basis)

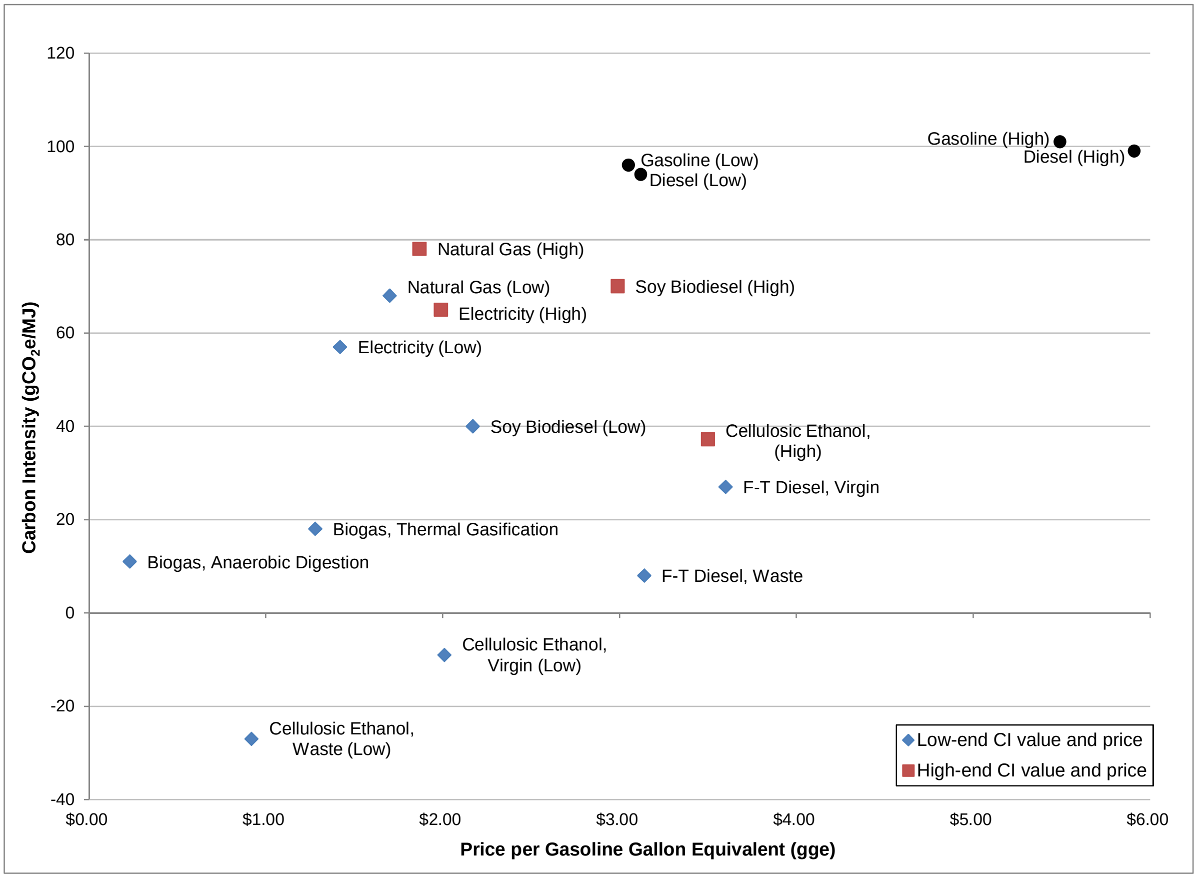
Fuel Prices ($/gge)	Low Oil Price		High Oil Price	
	2013	2022	2013	2022
Conventional Fuels:				
Gasoline ($/gal)	$3.05	$3.59	$3.66	$5.49
Diesel ($/gge)	$2.74	$3.33	$3.45	$5.18
Low Carbon Fuels:				
Natural gas ($/gge)	$1.82	$1.81	$1.87	$1.82
Electricity, high-end ($/gge)	$2.00	$2.00	$2.00	$2.00
Electricity, low-end ($/gge)	$1.52	$1.59	$1.52	$1.64
Cellulosic ethanol, high-end ($/gge)	$3.50	$3.50	$4.39	$4.39
Cellulosic ethanol, low-end, waste feedstock ($/gge)	$0.92	$0.92	$0.97	$0.97
Cellulosic ethanol, low-end, virgin feedstock ($/gge)	$2.01	$2.01	$2.53	$2.53
Fischer-Tropsch (F-T) diesel ($/gge)	$3.14	$3.14	$3.60	$3.60
Soy biodiesel ($/gge)	$2.17	$2.17	$2.99	$2.99

Notes: Assumptions values used in these calculations include: (1) An EER of 3.0 for electric vehicles and 1.0 for natural gas vehicles; and (2) energy content of 0.67 for ethanol and 0.96 for F-T diesel in comparison to conventional gasoline and diesel, respectively.

Figure 2-6 graphs the cost per gallon of gas-equivalent for clean low-carbon fuels against relative fuel CI values**.** This comparison of cost and CI values of fuels provides a measure of the relative cost-effectiveness of the clean fuels evaluated, i.e., the effectiveness with which a fuel type provides reductions in CI relative to its cost.

The fuels that provide the most cost-effective reductions in carbon intensity are found in the lower-left hand corner of the chart. These fuels, such as waste-based cellulosic ethanol, would be purchased in the greatest volumes first to generate the lowest cost reductions in carbon intensity. Then, the next most cost-effective fuels, such as soy biodiesel, cellulosic fuels from virgin feedstocks, and electricity, would be purchased. While other factors besides cost-effectiveness would influence the pattern of purchases of low carbon fuels, the availability of cost-effective low carbon fuels would provide opportunities for lowering the cost of CFS compliance.

Figure 2-6: Relative Cost-Effectiveness of Low Carbon Fuels



Fuel Infrastructure Needs and Costs

In addition to expenditures on low carbon fuels, this analysis considers the incremental costs of new infrastructure required to distribute those fuels. **Table 2-6** below displays the assumptions for new infrastructure additions required to deliver the low carbon fuels needed to meet the CFS reduction targets under the various scenarios. The general approach used in these assumptions is to scale infrastructure needs according to a specified volume of low carbon fuels or a number of alternative vehicles (which themselves are scaled to a specified volume of low carbon fuel).

As of yet, there is little empirical experience of having high levels of light-duty electric and natural gas vehicles in the marketplace, so the degree of uncertainty surrounding the level of infrastructure needed to accommodate the charging/fueling needs of these vehicles is quite high. Moreover, published estimates for the costs of individual infrastructure elements, such as home charging units, are somewhat limited, reflecting the fact that there is not yet broad consumer demand for or many manufacturers of these components in the marketplace.

Given the lack of empirical data for electricity and gas fueling needs, estimates of electricity and natural gas fueling stations used in this analysis were derived using the number of fueling stations for internal combustion engine (ICE) vehicles as a starting assumption. Currently in the US, there are 0.65 retail gasoline stations per 1,000 ICE vehicles.[36] Because electric vehicles have a more limited range than ICEs, electric vehicles are assumed to need a combination of home and public charging options. This analysis assumes that virtually all BEVs will use a home charger, and that 25 percent (on the low-end) to 33 percent (on the high-end) of owners of plug-in electric vehicles will also have a home charger. Public charging stations are assumed to be available initially at the same ratio as ICE vehicles to gasoline stations, with this ratio increasing by a small rate each year (and at a greater rate in the high-end case than in the low-end case).

Another assumption for the low-end estimate of electricity infrastructure was that "smart meters" will be used to help optimize BEV charging, i.e., 90 percent of charging is done at times when unused capacity is available. In this case, because of the assumption that vehicle charging will be managed so as to avoid overextending ground-level electricity distribution infrastructure, no new transformers are assumed to be needed.

In contrast, in the high-end estimate for electricity infrastructure, the assumption was that the time profile of vehicle charging is more mixed than in the low-end —i.e., 50 percent of charging occurs during times of peak or intermediate demand, and 50 percent occurring during times of available capacity.[37] In this case, it was assumed that smart meters are not used to manage charging, and as a result, upgrades of ground-level transformers are needed to accommodate home charging of vehicles.[38]

Natural gas fueling assumptions were also derived using the ratio of ICE fueling stations to ICE vehicles as a starting point. While the average range of a natural gas vehicle is closer to that of an ICE vehicle than that of an EV, it was assumed that at least twice the ratio of conventional gasoline stations, plus home fueling kits for one-third of NGV owners, are needed to adequately fuel NGVs. These assumptions for natural gas fueling infrastructure did not vary across scenarios, i.e., they were applied to all the policy scenarios and sensitivity cases. The number of incremental NGVs varies considerably across scenarios, however, so the total costs of infrastructure for natural gas fueling also vary accordingly.

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[36] U.S. DOE, *Transportation Energy Data Book* (2010). Available at: http://cta.ornl.gov/data/download29.shtml

[37] These assumptions for the low-end and high-end of the range of possible charging profiles are intended to be consistent with the low-end and high-end CI values for electricity. The low-end assumption of optimal charging corresponds to the lower electricity CI value, and the mixed charging profile corresponds to the high-end of the electricity CI range, when less efficient, more carbon-intensive units are dispatched to meet charging demand.

[38] According to several utilities, many of the existing 25 kVa transformers are upgraded to 50 kVa as part of utilities' typical maintenance schedule, but this analysis assumes that transformer upgrades would be additional to the baseline level of replacement and maintenance.

This analysis assumed that the requirements of the RFS will result in significant additions to biofuel blending and distribution infrastructure in the region even without the CFS. The estimates of new biofuel infrastructure and associated costs used in this analysis therefore represent infrastructure needs only for biofuels volumes that are incremental to the RFS fuel volumes. Based on an assumption that the ethanol "blendwall" is 15 percent, all volumes of ethanol in excess of that limit were assumed to be E85. These volumes were used to scale the number of new E85 fueling systems required to deliver that fuel.

Table 2-6. Low Carbon Fuel Infrastructure Assumptions

Type of Low Carbon Fuel	Assumption	Low-end of Range	High-end of Range
Electricity	Infrastructure additions	-Optimal charging profile: (90% off-peak; 10% peak)/intermediate); -100% BEVs and 25% PHEVs w/Level II chargers; -Level III chargers at 0.65 per 1,000 BEVs, increasing by 0.05/yr.; -1 smart meter per 3 BEVs; -No new transformers	Mixed charging profile (50% off-peak; 50% peak/intermediate); -100% BEVs and 33% of PHEVs w/Level II chargers; -Level III chargers at 0.65 per 1,000 BEVs, increasing by 0.5/yr.; -No new smart meters; -1 new transformer for every 10 BEVs
	Infrastructure costs	-\$2,200 per Level II charger (installed); -\$92,000 per Level III charger(installed); -\$400 per smart meter in 2013, \$200 by 2022; -\$5,000 per 50 kVa transformer upgrade	
Natural gas	Infrastructure additions	-1.3 NGV fueling stations per 1,000 NGVs; -33% of NGV owners w/home fueling kits -180 existing fueling stations upgraded	
	Infrastructure costs	-\$370,000 to upgrade fueling station; -\$1 million per new fueling station; -\$5,300 per home fueling kit (installed)	
Biofuels	Infrastructure additions	-New E85 stations based on E85 volumes incremental to RFS fuels sold in the region	
	Infrastructure costs	-\$0.19 per gal. ethanol -\$0.15 per gal. biodiesel -\$170,000 per E85 station (450,000 gal.)	-\$0.24 per gal. ethanol -\$0.15 per gal diesel -\$170,000 per E85 station (450,000 gal.)

Source(s): Various U.S. EPA, CARB, U.S. DOE/Clean Cities, and industry publications (2008-2011).

Alternative Fuel Vehicle Market Penetration Rates and Costs

While the CFS program itself only requires changes in the GHG properties of fuels, certain low carbon fuel options such as electricity and natural gas can be deployed only if there are sufficient alternative fuel vehicles in the marketplace to create demand for those fuels. It is therefore reasonable to expect that, at minimum, some of the incremental costs of these vehicles could be bundled into the costs of compliance with the CFS program.

Table 2-7 shows the incremental cost assumptions for alternative fuel vehicles. For electric vehicles, this analysis used an incremental cost assumption of $0 per BEV on the low-end and $5,000 per BEV on the high-end. These values apply over the full timeframe of the analysis. The low-end value is intended as a boundary that represents the highest likely rate of innovation in battery technology, thereby implying a rapid decrease in the primary driver of the incremental purchase price of EVs over that for comparable ICE vehicles. Another factor with the potential to significantly mitigate incremental costs of EVs are financing structures (e.g., battery leasing), which fully amortize battery costs such that consumers effectively pay for them as part of vehicle operating costs.[39]

The high-end value of $5,000 per BEV was used as an average over the timeframe to represent a slower rate of innovation in battery technology than represented by the low-end, but one that nonetheless brings down the incremental costs from a level of $15,000 in 2013 to $3,000 by 2020, for an effective weighted average of $5,000 over the full timeframe.[40]

The high-end value also assumes that the current federal incentives of $7,500 per EV purchase expire as scheduled in 2011, whereas the low-end of the range depicts a continuation of federal incentives.

Natural gas vehicle incremental costs are $0 on the low-end, representing a case where market demand for NGVs increases such that manufacturers realize economies of scale production.[41]

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[39] Better Place is one example of a company operating EV pilot programs with a business model based on leasing EV batteries to consumers.
[40] The proposed range for incremental battery costs of $0 to $5,000 is lower than current prices of $15,000 per EV to reflect the fact that the majority of sales occur later in the timeframe, allowing for economies of scale, learning curves, and advances in battery architecture.
[41]Currently, the incremental cost of natural gas vehicles reflects limited production of these vehicles rather than more expensive vehicle components or labor costs; in countries with more developed natural gas vehicle markets, costs are significantly lower. (*Agee et al, 2010.)*

Table 2-7. Alternative Vehicle Assumptions

Type of Alternative Vehicle	Assumption	Low-end of Range	High-end of Range
Electric Vehicles (EVs)	Incremental cost	$0 per BEV and PHEV	$0 per PHEV; $5,000 per BEV
	Market penetration	50% PHEVs; 50% BEVs	90% BEVs; 10% PHEVs
Natural Gas Vehicles (NGVs)	Incremental costs	$0 per light-duty NGV; $0 per medium and heavy-duty NGV	$7,000 per light-duty NGV; $30,000 per medium and heavy-duty NGV
	Market penetration	1.0 NGV per ICE vehicle	1.0 NGV per ICE vehicle
Flex-fuel Vehicles (FFVs)	Incremental costs	$0 per FFV	$100 per FFV
	Market penetration	1.1 million FFVs per billion gallons E85	

Biomass Availability for In-Region Low Carbon Fuel Production

An important objective of the CFS is to reduce the region's reliance on imported fuels for transportation and simultaneously encourage production of low carbon fuels using resources from within the NE/MA states. The region has significant biomass resources from forest and agricultural residues, municipal solid waste, wastewater treatment facilities, and landfills, which could be used as feedstocks for producing biofuels, natural gas, and/or electricity. In addition, new market opportunities for low carbon fuels could encourage the development of an energy crop market in the region on lands that are not likely to support agricultural production.

NESCAUM developed the NE/MA Bioenergy Calculator to estimate biomass resources on an annual basis and potential low carbon fuel production in the region.[42] The calculator produces estimates of biomass availability aggregated at the regional level based on annual state-by-state biomass availability estimates. It translates these biomass levels into quantities of low carbon fuel, including cellulosic ethanol, biogas, and diesel. Because of the presence of many other programs and incentives for renewable electricity generation from biomass (e.g., renewable energy requirements), electricity from biomass combustion or new waste-to-energy facilities was <u>not</u> included as one of the fuel types likely to expand directly as a result of incentives provided the CFS.

[42]The NE/MA Bioenergy Calculator is based on a modification of the Rutgers/New Jersey Agricultural Extension Service (NJAES)Bioenergy Calculator©. The primary modification performed was to replace the county-level biomass estimates for New Jersey with state-level annual biomass estimates for all of the NE/MA states. Additional detail on the assumptions of the NE/MA Bioenergy Calculator can be found in *Appendix A*, including estimated quantities of biomass availability on an annual basis for individual states and the NE/MA region.

The fuel conversion technologies modeled in the calculator to generate these estimates included: enzymatic hydrolysis (cellulosic ethanol), transesterification (soy biodiesel), gasification (biogas), and Fischer-Tropsch (diesel).

Table 2-8 displays a snapshot of values from the Bioenergy Calculator. These values for low- and high-end annual biomass availability in 2013, 2022, and 2027 were applied in the various policy scenarios and sensitivity analyses to estimate low carbon fuel production in the region. The low-end of the range represents a conservative view of biomass availability, where economic, policy, and/or biophysical factors constrain the annual biomass supply to relatively low levels in comparison to the region's physical endowment levels. The high-end of the range represents a more optimistic depiction of actual biomass supply relative to physical endowment levels, where stronger price signals would promote more significant development of potential resources.

It is important to note that in the low- and high-end cases, estimates account only for biomass supplies that would be potentially available *additional to* biomass currently being supplied to existing markets (e.g., pulp, paper and pellet production, existing landfill gas operations). In other words, these quantities could be theoretically available without significantly affecting other markets for biomass (assuming the current level of demand from these other markets does not expand).

Depending on the type of biomass evaluated, annual availability was assumed to change over time. Lignocellulosic biomass includes energy crops and new forest growth, both of which were assumed to grow in availability as stronger incentives for renewable energy and fuels take hold. Municipal solid waste resources, on the other hand, were assumed to decline in availability as various states' solid waste reduction initiatives further decrease waste quantities. The availability of livestock and wastewater treatment solids and wastewater gas were assumed to remain relatively constant over the timeframe of the analysis.

Table 2-8. Annual Biomass Availability for Low Carbon Fuel Production

Biomass Type	**Annual Biomass Availability**						**Fuel Conversion Options**
	2013		**2022**		**2027**		
	Low	High	Low	High	Low	High	
Lignocellulosic Biomass (million dry tons)	3.4	9.1	13	27	13	27	Cellulosic ethanol F-T diesel Biogas
Municipal Solid Waste (million dry tons)	1.9	4.5	1.5	3.7	1.5	3.7	Cellulosic ethanol F-T diesel Biogas
Livestock/Wastewater treatments solids (million dry tons)	1.3	2.6	1.3	2.6	1.3	2.6	Biogas
Landfill gas and wastewater treatment gas (billion scf)	36	71	36	71	36	71	Biogas

Note: Waste grease and other bio-oils are excluded from this table because less than 20,000 dry ton-equivalents are produced annually.

Other Key Assumptions

This section describes other assumptions used in the analysis that have a significant influence on results.

Discount rates

The majority of public policies and private investments generate costs and benefits that occur at different periods in time. *Discounting* refers to the method applied to express these values occurring at different periods in terms of what they are worth today, known as *present value*. Discounting is accomplished by multiplying the value of costs, benefits, and impacts in future periods by a discount factor. After applying the discount factor, future values can be expressed as present values.

In accordance with U.S. EPA's guidance on best practices for economic analysis, this analysis applied two alternative discount rates, i.e., 3 and 7 percent.[43] A three percent rate is considered to be more reflective of the rate at which the public sector borrows, which some economists consider to be the best representation of society's preferences for valuing resources over time. The seven percent rate is a closer approximation of returns to private capital. Because there is considerable debate about which rate best reflects the way that society values consumption over time, this analysis applies both rates and shows results for each. The calculations for each of the scenarios show the values of all costs and benefits *before* discounting, as well as in present value terms after discounting.

While varying the discount rate between 3 and 7 percent in this analysis does substantially change the absolute values of estimated costs and benefits occurring at different points in time, many of the relative relationships between aggregate costs and benefits and patterns across scenario results remain constant regardless of the discount rate.

Program Administration

Implementation and enforcement of a CFS program would require staff resources on the part of the NE/MA states. This analysis assumed that individual states will require from one-half to two full-time employees (FTE) to administer the CFS, varying according to each state's fuel use, and that an average state FTE cost will be $150,000 (loaded).[44] In addition, it is assumed that some administrative activities would be regional in nature, and would require an additional three FTEs, increasing to four FTEs by 2018.

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[43]U.S. EPA. *Guidelines for Preparing Economic Analyses,* Office of the Administrator. December 2010. For a much more detailed discussion of alternative discount rates and their application in economic analysis of environmental regulations, see Chapter 6 of U.S. EPA's guidance document.

[44]A loaded annual cost for a full-time employee includes annual salary plus the costs of overhead and benefits.

Regulated companies will also incur administrative costs to demonstrate compliance with the program. These costs were assumed to include at least one full-time employee (FTE) per regulated company, at a loaded cost of $200,000 per FTE, for the duration of the program. For analytical purposes, this study assumed approximately 150 regulated companies in the region.

Social Cost of GHG Emissions

The economic value of reducing (or avoiding future) GHG emissions is a subject of substantial uncertainty and debate. In this analysis, values used for the "social cost of carbon" (SCC) ranged from nearly $24 per ton of carbon-equivalent in 2013 on the low-end (increasing to $29 per ton in 2022) to $107 per ton at the high-end (2013 through 2022).[45] These low- and high-end values for the social cost of carbon were applied to the range of cumulative reductions in GHG emissions estimated for each of the scenarios and sensitivity cases.

2.4.5. Design of CFS Policy Scenarios and Sensitivity Cases

This section provides more detail on the distinguishing features of the three main policy scenarios: the "Electricity Future," "Biofuels Future," and "Natural Gas Future." These scenarios share key commonalities. Each assumes compliance with a 10 percent CI reduction target over 10 years, 2013 to 2022, and contributions toward CFS compliance from three low carbon fuels: electricity, biofuels, and natural gas.

The CFS is expected to spur more rapid innovation and development in fuels and vehicle technologies than what would otherwise occur. However, this analysis does not attempt to forecast which fuel pathways and technologies might develop first. The policy scenarios were designed to show multiple possible pathways to CFS compliance, and equal probability was placed on each major fuel type playing a significant role in meeting the program goals.

The analytic design used to characterize each scenario depicts one of the three types of low carbon fuels undergoing a more rapid rate of development in technology (and an accordingly lower range for the costs of that fuel, its infrastructure, and vehicles).

Table 2-9 displays this analytic design, and maps the assumptions described in the previous section to the appropriate scenarios. For each CFS policy scenario, the featured fuel was assumed to provide a greater percentage of the total reductions in CI, and be available at the low-end of the CI and cost ranges. For instance, in the "Biofuels Future," biofuels provide 60 percent of the reduction required to meet the CFS target, and the CI values for biofuels and their costs are at the low-ends of their respective ranges. Natural gas and electricity provide 20 percent each of the needed reduction under the Biofuels Future, and values for their CI and cost are at the high-end of their ranges. In addition, the high-end of the availability range for in-region biomass production was used.

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[45] The low-end range of values for social cost of carbon is from: Interagency Working Group on Social Cost of Carbon, United States Government (2010). *Social Cost of Carbon (SCC) for Regulatory Impact Analysis Under Executive Order 12866*. The high-end SCC value is from the Stern Review (2006).

Similarly, the “Electricity Future” assumes that 60 percent of the reductions come from electricity, using the low-end of the CI range for electricity. Natural gas and biofuels each contribute 20 percent of the required reduction, and the fuels CI values are from the high-end of the range. This scenario also assumes the optimistic end of the ranges for electricity prices, optimized consumer charging behavior that takes advantage of existing electric generation capacity, and lower infrastructure needs and electric vehicle costs.

The “Natural Gas Future” assumes 60 percent of compliance comes from natural gas, and that the high-end of regional biomass and waste resources is available for gasification into biogas (which is commercially viable only in this scenario).This scenario also assumes that the low-end of the natural gas fuel cost, infrastructure, and vehicle cost ranges all apply. The high-end of the CI and cost ranges are applied to electricity and biofuels in this scenario.

As with the Natural Gas Future, the Biofuels Future assumes that the high-end of biomass and waste resources are available for low carbon fuel production. In this scenario, however, most of these resources are converted into low-CI cellulosic ethanol or diesel fuel, rather than biogas. Additionally, costs of advanced fuels and flex-fuel vehicles are at the low-end of their estimated ranges. Electricity and natural gas each provide 20 percent of the reductions needed for compliance, and are modeled at the high-end of their respective CI and cost ranges.

Table 2-9. Design of CFS Policy Scenarios, 10 Percent CI Reduction in 10 Years

10 Percent Policy Scenarios	Design Features and Key Assumptions			
	Contribution to 10 Percent CI Target	Average Fuel Carbon Intensity	Fuel, Infrastructure, and Vehicle Costs	Availability of Biomass/Primary Types of Low C Fuel Produced
Electricity Future				
Electricity	60%	Low-end of range	Low-end of range	n/a
Natural gas	20%	High-end of range	High-end of range	n/a
Biofuels	20%	High-end of range	High-end of range	Low-end of range; cellulosic ethanol and soy biodiesel
Natural Gas Future				
Electricity	20%	High-end of range	High-end of range	n/a
Natural gas	60%	Low-end of range	Low-end of range	High-end of range; Biogas
Biofuels	20%	High-end of range	High-end of range	Low-end of range; Cellulosic ethanol
Biofuels Future				
Electricity	20%	High-end of range	High-end of range	n/a
Natural gas	20%	High-end of range	High-end of range	n/a
Biofuels	60%	Low-end of range	Low-end of range	High-end of range: Cellulosic ethanol, F-T diesel, and soy biodiesel

As described, each the three policy scenarios for the 10 percent CI target blend together a variety of low- and high-end assumptions about CI values, costs, and other variables; thus, each of these scenarios is a "hybrid" that achieves the desired target through an optimistic portrayal of one fuel technology combined with less optimistic portrayals of the other two fuel technologies.

Table 2-10 displays the assumptions used for two cases that were developed to test the sensitivity of the results to the possibility that all three fuel technologies develop together in tandem, either quickly or slowly, rather than on different trajectories. The design of these sensitivity cases is as follows:

- **Five Percent, 10 Year scenario:** All three low carbon fuel technologies contribute equally to reductions but develop at a slower pace of innovation. CI values are at the high-end, and costs remain at the high-end of their estimated ranges throughout the study period. The achievable target reduction level is set at five rather than 10 percent, over the same 10-year timeframe.

- **15 Percent, 15 Year scenario:** All three low carbon fuel technologies contribute equally, develop together at a rapid rate of innovation, and have low CI values. Their accompanying costs are at the low-end of their possible ranges. A few low carbon fuel technologies, such as gasification, experience “learning effects,” so that investments in these technologies can be fully amortized within 10 years. The achievable target reduction level is set at 15 percent rather than 10 percent, and the timeframe is 15 rather than 10 years.

Table 2-10. Design of Sensitivity Cases, 5 and 15 Percent Reductions

Sensitivity Cases	Design Features and Key Assumptions			
	Contribution to CI Target	**Average Fuel Carbon Intensity**	**Fuel, Infrastructure, and Vehicle Costs**	**Availability of Biomass/Primary Types of Low C Fuel Produced**
5%, 10 Year Timeframe (2013-2022)	33% from each fuel	High-end of range for all 3 fuels	High-end of range for all costs	n/a
15%, 15 Year (2013 to 2027)	33% from each fuel	Low-end of range for all 3 fuels	Low-end of range for all costs	High-end of range; 50% of resources for biogas and 50% for cellulosic ethanol

3. RESULTS FROM CFS POLICY SCENARIOS AND SENSITIVITY CASES

This section presents the results from the analysis of the CFS policy scenarios and sensitivity cases described in Section 2, including: (1) changes in gasoline and diesel demand; (2) shifts in the composition of transportation fuels; (3) changes in fuel expenditures for conventional and low carbon fuels; (4) infrastructure additions and associated costs; (5) number and cost of alternative fuel vehicles; (6) changes in GHG emissions and their estimated value; and (7) possible impacts on industry, consumers, low carbon fuel producers, and state government. All results reported are for the 11-state NE/MA region.

Section 3.1 provides results for each of the three main policy scenarios that model a 10 percent reduction by 2022: the Electricity Future, the Biofuels Future, and the Natural Gas Future. Section 3.2 provides results of the sensitivity analyses, including scenarios for 5 and 15 percent CI target levels, as well as a variation on the Biofuels Future that assumes no new production of biofuels in the region. As stated earlier in this report, these scenarios are intended to bound a wide range of possible outcomes and should not be viewed as forecasts of likely or expected outcomes.

3.1. Results for 10 Percent CFS Policy Scenarios

CFS implementation results in a shift in the composition of regional transportation fuels from one composed almost exclusively of gasoline (blended with 10 percent conventional ethanol) and diesel to one that includes a greater proportion of low carbon fuels, such as advanced liquid biofuels, electricity, and natural gas. The next section describes changes in gasoline and diesel demand under the BAU reference cases and the three 10 percent CFS policy scenarios.

All changes in fuel use due to the CFS program are presented as incremental to the Low and High Oil Price reference cases, showing additional quantities of low carbon fuels beyond those resulting from the RFS and ZEV programs that would be required to meet the CI reduction target. Similarly, changes in fuel expenditures, vehicle costs, and infrastructure investments represent the incremental impacts of the program beyond those which would occur due to existing state and federal policies included in the reference case assumptions.

3.1.1. Changes in Demand for Gasoline and Diesel

As described in Section 2.0 of this report, before calculating the incremental effects of the CFS, this analysis first estimated the BAU changes in demand for gasoline and diesel, which include changes likely to occur in response to federal RFS and ZEV programs.

Compliance with the federal RFS2 program, the ZEV program for light-duty vehicles, and other existing policies is projected to result in decreases in gasoline demand in the Low Oil Price reference case. Projected fuel use falls even more significantly under the High Oil Price reference case due to the RFS and ZEV, but also as a response to higher fuel prices and increased use of alternative vehicles as they become more cost competitive. While the RFS2 provides some volumes of biodiesel that are used as diesel replacement, existing policies do less overall to promote use of alternative fuels in heavy-duty vehicles. As a result, diesel demand is projected to increase somewhat under the BAU over the 10-year program period, with a greater increase occurring under the Low Oil Price case.

As shown in **Figures 3-1** through **3-4**, implementing the CFS policy scenarios is projected to result in significant reductions in gasoline and diesel consumption compared to BAU over the 10-year period analyzed (2013 to 2022). As summarized in **Table 3-1**, combined gasoline and diesel use under the Low Oil Price case is estimated to decrease by 4 to 7 percent relative to BAU, which equates to 14 to 23 billion gallons of fuel in the region. Relative to the High Oil Price case, fuel use would decrease by 8 to 13 percent, the equivalent of 25 to 40 billion gallons of gasoline and diesel, over 10 years.

Table 3-1. Gasoline and Diesel Demand under 10% Reduction Scenarios (10 Yr. Totals)

Changes in Fuel Demand	**Scenario**					
	Electricity Future		**Natural Gas Future**		**Biofuels Future**	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BAU Gas and Diesel Demand (Bgal)	337	315	337	315	337	315
Gas and Diesel Demand under CFS (Bgal)	314	275	323	290	323	286
Change in Gas and Diesel Demand under CFS (Bgal)	-23	-40	-14	-25	-14	-29
Percentage Change from BAU	*-7%*	*-13%*	*-4%*	*-8%*	*-4%*	*-9%*
Low Carbon Fuel Demand:						
Electricity (GWh)	139,000	263,000	60,100	100,000	61,600	113,000
CNG (Billion gge)	9.8	16.9	6.2	13.4	9.7	16.4
Biofuels (Bgal)	4.6	8.9	4.6	8.8	0.3	8.9

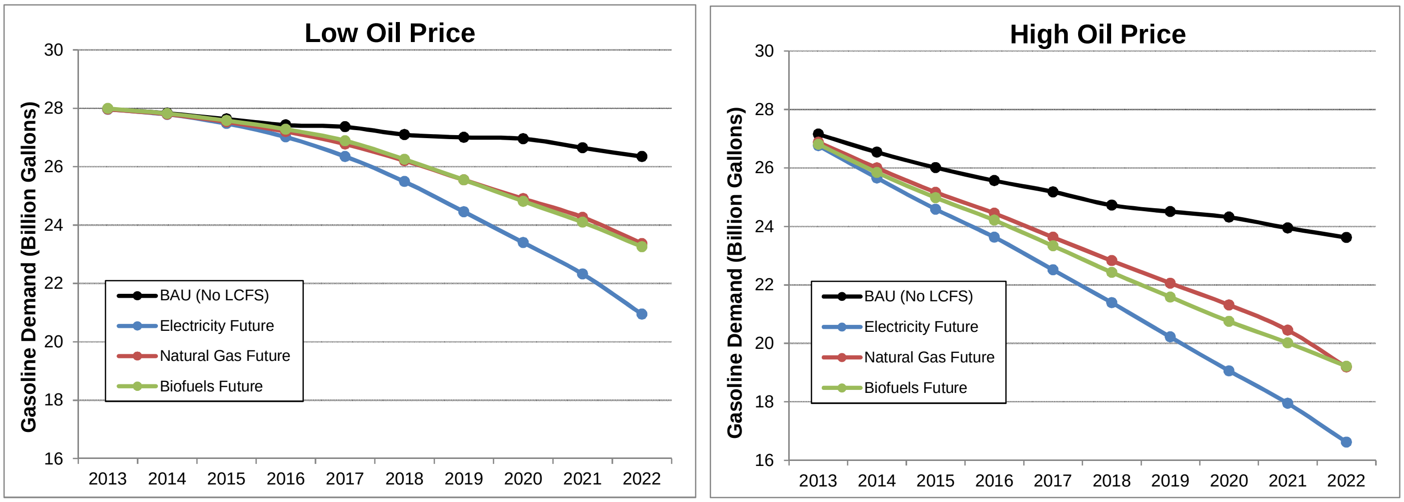
Table 3-2 presents the results for 2022, when the program would meet the 10 percent CI reduction target. Gasoline and diesel use in the region are projected to decrease by 4.0 to 6.7 billion gallons under the Low Oil Price case and by 6.1 to 8.7 billion gallons under the High Oil Price case in the final program year. This represents a 12 to 20 percent reduction in total gasoline and diesel demand relative to the BAU case under low oil prices and a 20 to 29 percent reduction under high oil prices. Similar annual reductions in transportation fuel use would be expected in subsequent years, assuming the 10 percent reduction target remains in place.

Table 3-2. Gasoline and Diesel Demand under 10% Reduction Scenarios (Year 10)

Changes in Fuel Demand	**Scenario**					
	Electricity Future		**Natural Gas Future**		**Biofuels Future**	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BAU Gas and Diesel Demand (Bgal)	33.1	30.3	33.1	30.3	33.1	30.3
Gas and Diesel Demand under CFS (Bgal)	26.4	21.6	29.1	24.1	28.7	24.0
Change in Gas and Diesel Demand under CFS (Bgal)	-6.7	-8.7	-4.0	-6.1	-4.4	-6.2
Percentage Change from BAU	*-20%*	*-29%*	*-12%*	*-20%*	*-13%*	*-21%*
Low Carbon Fuel Demand:						
Electricity (GWh)	40,800	58,200	17,500	21,800	17,600	24,300
CNG (Billion gge)	2.8	3.7	1.8	3.7	2.8	3.5
Biofuels (Bgal)	1.3	1.9	1.3	1.9	0.6	1.9

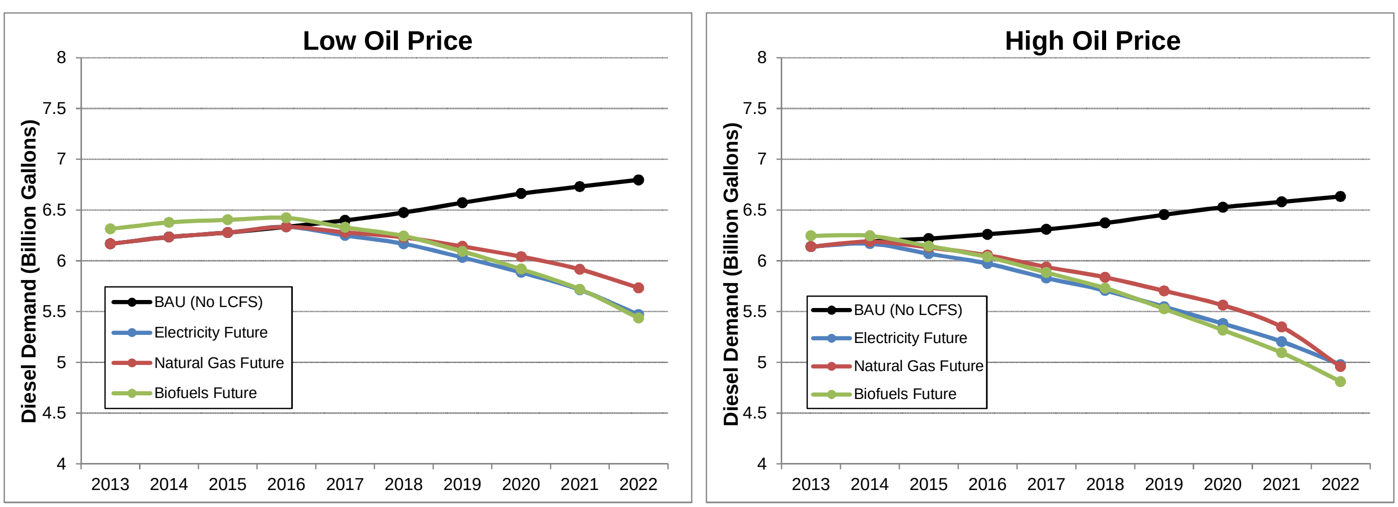
The results displayed in **Figures 3-1** and **3-2** suggest that a significantly greater volume of gasoline is displaced under the Electricity Future, relative to the Low and High Oil Price cases, than under the Biofuels and Natural Gas Futures. This results from the fact that electricity is assumed to have a relatively high CI value compared to those for biofuels and natural gas. A higher assumed CI means that more electricity must be used to meet the carbon intensity target, which displaces more gasoline demand compared to scenarios where fuels with lower assumed CI values are deployed in greater quantities.

Figures 3-1 and 3-2. Changes in Gasoline Demand under 10 Percent CFS, 2013-2022



Figures 3-3 and **3-4** show a reduction in diesel demand over the 10-year CFS compliance period for all three policy scenarios. In comparison to gasoline, there is a less pronounced difference for projected diesel demand among the three policy scenarios, due to a modeling assumption that many types of medium- and heavy-duty vehicles are unsuitable for electrification, given assumed technology development. As a result, displacement of conventional fuels due to use of electric vehicles is largely projected to occur in the gasoline sector.

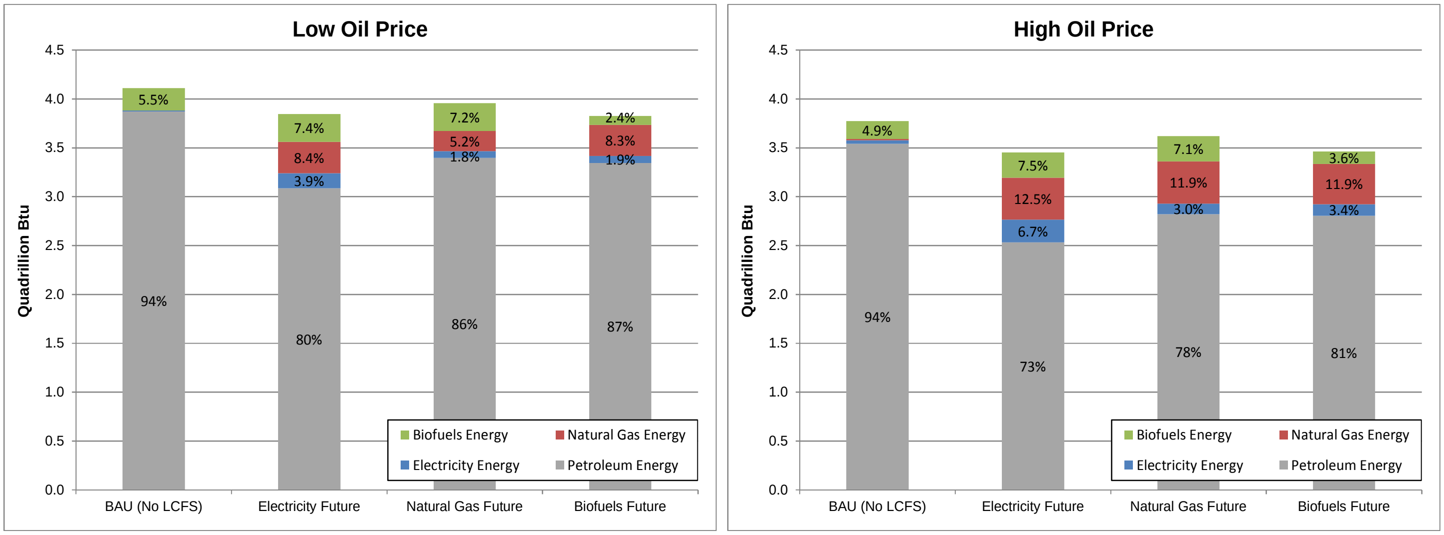
Figures 3-3 and 3-4. Changes in Diesel Demand under 10 Percent CFS, 2013-2022



3.1.2. Changes in Fuel Diversity and Transportation Energy Use

Fuel diversity refers to the range and availability of fuel types that serve a given energy need. By inducing broader variety and greater quantities of low carbon fuels, the CFS would increase the diversity of transportation fuel sources in the region. **Figures 3-5** and **3-6** illustrate projections of total energy consumption for gasoline and diesel, converted based on energy content into common units of quadrillion Btu.

Figures 3-5 and 3-6. Changes in Transportation Fuel Diversity under 10 Percent CFS, 2022



Under BAU, the region is still likely to be heavily dependent upon petroleum-based fuels in 2022, with about 94 percent of total energy from petroleum fuels, about five to six percent from biofuels, and very small contributions from natural gas and electricity (i.e., less than one percent of energy).

In all CFS policy scenarios evaluated, total energy demand is estimated to decrease, volumes of conventional transportation fuel is estimated to decline, and fuel diversity are projected to increase relative to BAU. All of these effects are greater under the High Oil Price case. Fuel diversity in 2022 is estimated to be greatest under the Electricity Future, with petroleum energy use ranging from 73 to 80 percent, and low carbon fuel use relatively well-distributed across electricity, biofuels, and natural gas. In the Biofuels and Natural Gas Futures, low carbon fuel use includes a higher percentage of natural gas. While the region would still be largely reliant upon petroleum fuels in 2022 with the CFS in place, these results suggest that the CFS could encourage a market transformation that would enable broader consumer choices and further increase fuel diversity after 2022.

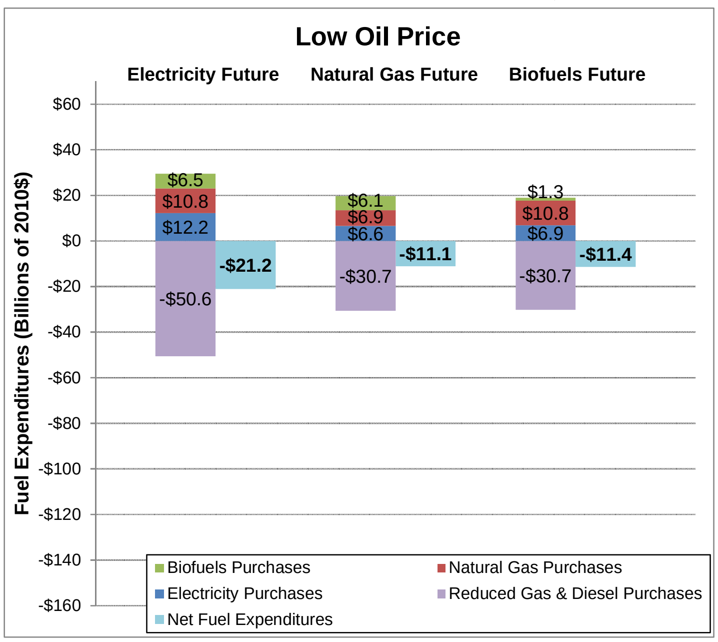
This figure also illustrates the inverse relationship between CI values and the quantity of low carbon fuels needed to meet a given reduction target for CI. If a fuel has a low CI value, smaller quantities of that fuel are needed to meet a given CI reduction goal relative to a fuel with higher CI value. For example, as seen in the Biofuels Future scenario, only very small volumes of biofuels with low CI values, such as cellulosic ethanol and F-T diesel, are needed to meet the CI reduction target. In comparison, larger quantities of biofuels are used in the Electricity and Natural Gas Future scenarios, because these biofuels are assigned higher CI values in these scenarios and thus provide lesser reductions in carbon intensity.

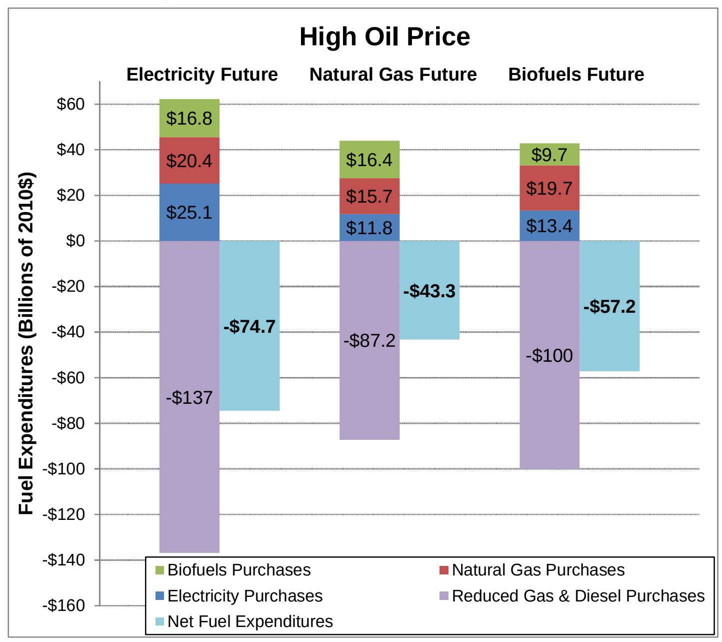
3.1.3. Changes in Expenditures on Transportation Fuels

The estimated changes in expenditures on transportation fuels resulting from implementing a 10 percent CFS target over 10 years are similar to the trends in gasoline and diesel demands in the three CFS policy scenarios described above.

Figures 3-7 and **3-8** (7 percent discount rate) and **Figures 3-9** and **3-10** (3 percent discount rate) present modeled results for the effects of the CFS on: (1) new expenditures on low carbon fuels; (2) expenditures on gasoline and diesel; and (3) the *net* change in total expenditures on transportation fuels (i.e., difference between BAU expenditures and total fuel expenditures under the CFS). These estimates are cumulative over the 10-year period, 2013 to 2022.

Figures 3-7 and 3-8. Net Expenditures on Transportation Fuels (10-Yr. Totals) (7 Percent Discount Rate)



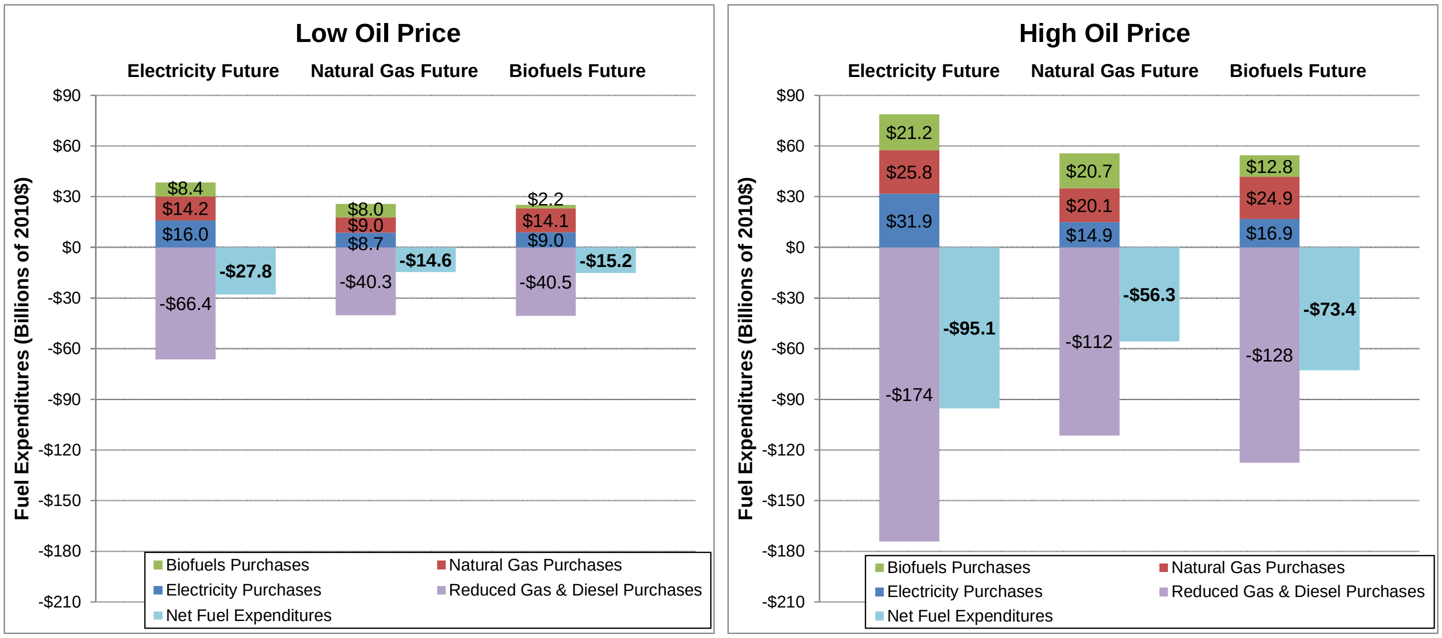


This analysis suggests that for each of the policy scenarios, the value of the reductions in gasoline and diesel purchases would exceed the value of new expenditures on low carbon alternatives. Therefore, cumulative net expenditures on transportation fuels would be lower under the CFS than BAU over the 10-year period. While this is true for both the Low and High Oil Price cases, reductions in net fuel expenditures increase with higher gasoline and diesel prices.

Using a 7 percent discount rate, the cumulative net savings on fuel expenditures range from a low of $11.1 billion under the Natural Gas and Biofuels Futures (Low Oil Price case) to a high of $74.7 billion under the Electricity Future (High Oil Price case). This result for the Electricity Future is consistent with the earlier finding that overall reductions of gasoline and diesel fuel use are greater in this scenario, so the value of reduced expenditures on gasoline and diesel are also greater.

Figures 3-9 and **3-10** show a similar set of relationships among the value of low carbon fuel purchases, the value of reductions in gasoline and diesel purchases, and net fuel expenditures using a three percent discount rate. However, the present value of net fuel expenditures is greater when calculating at a lower discount rate of 3 percent. Using a 3 percent discount rate, the projected values for net fuel savings range from a low of $14.6 billion under the Natural Gas and Biofuels Futures (Low Oil Price case), to a high of $95.1 billion under the Electricity Future (High Oil Price case).

Figures 3-9 and 3-10. Net Expenditures on Transportation Fuels (10-Yr. Totals) (3 Percent Discount Rate)



3.1.4. Low Carbon Fuel Infrastructure

New infrastructure would be needed to accommodate storage, blending, and distribution of the low carbon fuel volumes, and vehicle fueling estimated for compliance with a CFS target. In the case of electricity, infrastructure needs consist of new public charging stations and home chargers for EVs, smart meters to manage vehicle charging at home, and in some cases, improvements to the electricity grid's distribution infrastructure (i.e., ground-level transformers).

For natural gas, CNG fueling stations throughout the region would require upgrading and new CNG stations and home refueling systems would need to be built or installed.

Significant biofuel blending and delivery infrastructure already exists in the region, but to the extent that the CFS requires greater volumes of ethanol and biodiesel relative to BAU, new biofuel storage and blending infrastructure would be needed. In addition, if ethanol volumes in any scenario are estimated to exceed U.S. EPA's current blending limit of 15 percent, this would require additional investments in fueling stations that could accommodate E85 blends.

Table 3-3 below shows the quantities of low carbon fuels estimated for each policy scenario and the corresponding level of infrastructure investment this analysis suggests would be needed to deliver these fuel volumes (discounted at 7 percent).

Table 3-3. Low Carbon Fuel Volumes and Infrastructure Investments (10-Yr. Totals) (7 Percent Discount Rate)

	Electricity Future		**Natural Gas Future**		**Biofuels Future**	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Electricity Quantities (GWh):	139,000	263,000	60,100	100,000	61,600	113,000
Electric Infrastructure (2010$):						
Vehicle Chargers	$6.0 B	$9.4 B	$2.7 B	$3.7 B	$2.7 B	$4.1 B
Smart Meters	$0.3 B	$0.5 B	$0.0 B	$0.0 B	$0.0 B	$0.0 B
Grid Improvements	$0.0 B	$0.0 B	$0.6 B	$0.7 B	$0.6 B	$0.8 B
Total Electric Infrastructure (2010$):	**$6.3 B**	**$9.9 B**	**$3.2 B**	**$4.5 B**	**$3.3 B**	**$4.9 B**
Natural Gas Quantities (Bgge):	9.8	16.9	6.2	13.4	9.7	16.4
NG Fueling Infrastructure (2010$):	$2.1 B	$3.1 B	$1.3 B	$2.9 B	$2.1 B	$2.9 B
Total NG Infrastructure (2010$):	**$2.1 B**	**$3.1 B**	**$1.3 B**	**$2.9 B**	**$2.1 B**	**$2.9 B**
Biofuel Volumes (Bgal):	4.6	8.9	4.6	8.8	0.3	8.9
Biofuel Infrastructure (2010$):						
Blending and Distribution	$0.5 B	$1.1 B	$0.4 B	$0.9 B	$1.4 B	$2.0 B
E85 Fueling	$0.0 B	$0.1 B	$0.0 B	$0.0 B	$0.0 B	$0.0 B
Total Biofuel Infrastructure (2010$):	**$0.5 B**	**$1.1 B**	**$0.4 B**	**$0.9 B**	**$1.4 B**	**$2.0 B**
Total Infrastructure (2010$):	**$8.9 B**	**$14.1 B**	**$4.9 B**	**$8.3 B**	**$6.8 B**	**$9.8 B**

Note: Totals may not equal sum due to rounding conventions.

As previously described, the greatest volumes of gasoline and diesel are estimated to be displaced in the Electricity Future. Logically, the value of the infrastructure investment required increases proportionally with the size of the market's transition away from petroleum fuels and towards new, low carbon alternatives. Consequently, the cost of infrastructure investments would be highest in the Electricity Future, where the greatest quantities of alternative fuel (electricity), as well as the largest amount of infrastructure improvements are required.

In the Electricity Future, a nearly two-fold increase in required transportation-related electricity exists between the Low Oil Price (nearly 140,000 GWh) and High Oil Price cases (over 260,000 GWh). Estimated electricity use in the Natural Gas and Biofuels Futures is markedly lower, ranging from approximately 60,000 GWh for both scenarios in the Low Oil Price case to between 100,000 GWh (Natural Gas Future) and 113,000 GWh (Biofuels Future) in the High Oil Price case.

Of the three primary electricity infrastructure system components– vehicle chargers, smart meters, and distribution grid enhancements – this analysis estimates that costs for vehicle chargers would constitute the largest portion of the overall investments needed for delivering electricity to EVs. Using a 7 percent discount rate, cumulative investments over 10 years for vehicle chargers range from a low of approximately $2.7 billion for the Natural Gas and Biofuels Futures (under the Low Oil Price case) to $9.4 billion for the Electricity Future (under the High Oil Price case). In all cases, vehicle charger investments account for at least 80 percent of total electricity infrastructure investments; in some instances, they account for as much as 95 percent of the estimated electricity infrastructure needs.

Electricity infrastructure investments constitute the single largest component of fuel infrastructure needs under all of the CFS policy scenarios evaluated in this analysis. In the Electricity Future, electricity infrastructure investments are estimated to account for 71 percent of the cumulative $8.9 billion costs under the Low Oil Price case, and 70 percent of the cumulative, 10-year $14.1 billion costs under the High Oil Price case. In the Natural Gas and Biofuels Futures, investments in electricity infrastructure are estimated at between 50 and 65 percent of the total infrastructure investments. As a point of comparison for this level of investment in electricity infrastructure, the system operators of the three power grids serving the CFS states spend roughly $5.6 billion annually on capacity and transmission improvements, with some of these investments being directed towards development of smart grid technology and low-carbon renewables such as wind power.[46]

Required investments in natural gas fueling infrastructure would also be significant. Under the Low Oil Price case, natural gas investments are estimated to range from $1.3 billion in the Natural Gas Future to $2.1 billion in the Electricity and Biofuels Futures, or roughly one-fifth of total infrastructure investment. Under the High Oil Price case, investments in natural gas fueling are modeled as a slightly larger piece of total infrastructure investments in the Natural Gas and Biofuels Futures, at 35 and 30 percent, respectively.

Natural gas infrastructure needs in the Natural Gas Future, ranging from $1.3 billion (Low Oil Price case) to $2.9 billion (High Oil Price case), are no higher, and in some cases lower, than in the other scenarios. This is due to the fact that the primary source of natural gas assumed in this scenario is biogas, a natural gas substitute with a very low assumed CI (11.0 to 18.0g CO_2e/MJ). As a result, less natural gas would be needed to meet that fuel's share of the target CI reduction than in the other scenarios, and the required infrastructure to support those volumes is accordingly lower.

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[46]See annual reports from ISO-New England (2010 Regional Electricity Outlook), NY ISO (2009 Annual Report) and PJM Interconnect (Regional Transmission Expansion Plan 2010). Additional low-carbon power generation beyond the levels required to meet RGGI and renewable energy standards could potentially decrease the average CI of electricity to levels below the low-end CI value for electricity used in this analysis.

Investments in new biofuels infrastructure are estimated to be the lowest of the three infrastructure systems, ranging from a low of $0.4 billion for the Natural Gas Future to a high of $2.0 billion for the Biofuels Future (under the High Oil Price case). This range accounts for only 10 to 20 percent of total infrastructure investments needed across the three policy scenarios. This result is consistent with the assumption that a CFS is more likely to affect the composition of advanced biofuels in the region, but not drive significant new biofuel volumes above and beyond those projected for meeting the federal RFS and other existing policies. Consequently, the CFS is not likely to create incremental demand for expansive additions to existing biofuel delivery and blending infrastructure.

In 2010, U.S. EPA raised the limit on the ethanol "blendwall" (the maximum volume of ethanol allowed to be blended into gasoline) from 10 to 15 percent. The volumes of ethanol estimated for most scenarios do not exceed the higher blendwall, with the exception of the Electricity Future under high oil prices. In this case, the analysis suggests a small volume of E85 would be used to meet the CI target in that scenario. However, because the incremental cost of FFVs is quite low ($100 per vehicle on the high-end), the costs of accommodating the incremental E85 volumes has little impact on the total cost of the scenario.

Table 3-4 shows modeled fuel volumes and associated infrastructure investments using a 3 percent discount rate. Quantities of low carbon fuels for each scenario are the same as in the 7 percent case, but estimated infrastructure investment levels are larger in magnitude, reflecting the effect of discounting at a lower rate. Total infrastructure investments range from $6.3 to $17.1 billion using a 3 percent discount rate, compared to a range of $4.9 to $14.1 billion with a 7 percent discount rate.

Table 3-4. Low Carbon Fuel Volumes and Infrastructure Investments (10-Yr. Totals) (3 Percent Discount Rate)

	Electricity Future		Natural Gas Future		Biofuels Future	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Electricity Quantities (GWh):	139,000	263,000	60,100	100,000	61,600	113,000
Electric Infrastructure (2010$):						
Vehicle Chargers	$7.6 B	$11.4 B	$3.4 B	$4.5 B	$3.4 B	$5.0 B
Smart Meters	$0.4 B	$0.6 B	$0.0 B	$0.0 B	$0.0 B	$0.0 B
Grid Improvements	$0.0 B	$0.0 B	$0.7 B	$0.9 B	$0.7 B	$1.0 B
Total Electric Infrastructure (2010$):	**$8.0 B**	**$12.0 B**	**$4.1 B**	**$5.4 B**	**$4.2 B**	**$6.0 B**
Natural Gas Quantities (Bgge):	9.8	16.9	6.2	13.4	9.7	16.4
Fueling Infrastructure (2010$):	$2.6 B	$3.7 B	$1.7 B	$3.7 B	$2.6 B	$3.5 B
Total NG Infrastructure (2010$):	**$2.6 B**	**$3.7 B**	**$1.7 B**	**$3.7 B**	**$2.6 B**	**$3.5 B**
Biofuel Volumes (Bgal):	4.6	8.9	4.6	8.8	0.3	8.9
Biofuel Infrastructure (2010$):						
Blending and Distribution	$0.7 B	$1.3 B	$0.5 B	$1.1 B	$1.8 B	$2.5 B
E85 Fueling	$0.0 B	$0.1 B	$0.0 B	$0.0 B	$0.0 B	$0.0 B
Total Biofuel Infrastructure (2010$):	**$0.7 B**	**$1.4 B**	**$0.5 B**	**$1.1 B**	**$1.8 B**	**$2.5 B**
Total Infrastructure (2010$):	**$11.3 B**	**$17.1 B**	**$6.3 B**	**$10.2 B**	**$8.6 B**	**$12.1 B**

Note: Totals may not equal sum due to rounding error.

3.1.5. Changes in Alternative Vehicle Markets

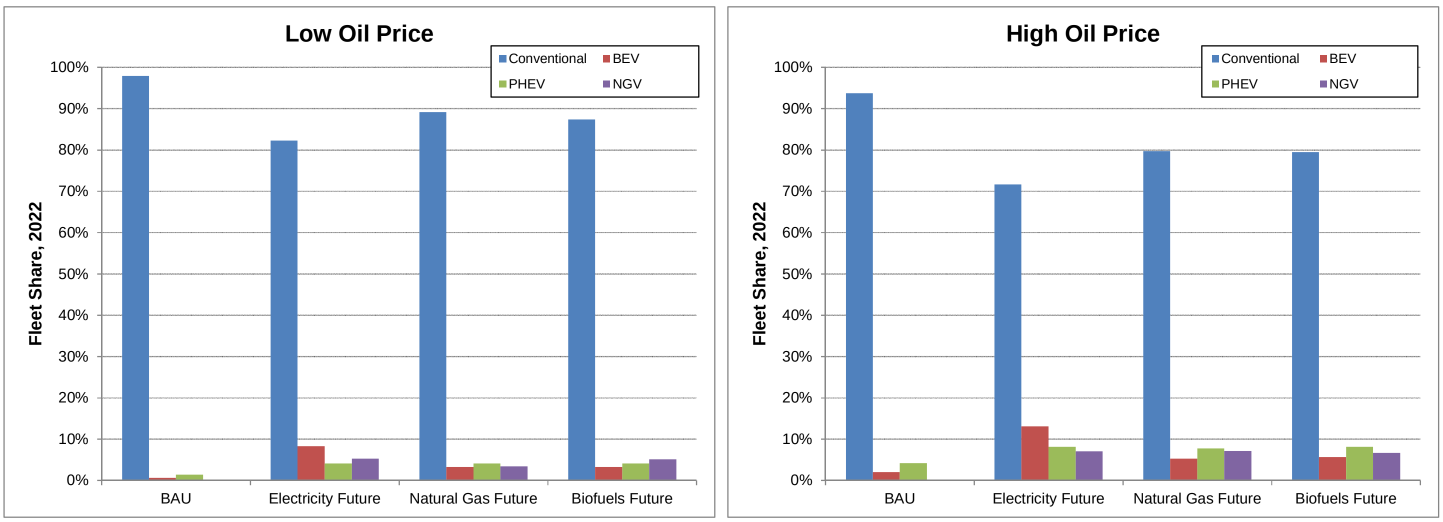
As noted earlier, although the CFS does not directly require purchases of alternative vehicles, demand for low carbon fuels may be limited to levels below those needed for compliance with the CFS unless there are sufficient alternative vehicles in the marketplace. This analysis considers three types of low carbon fuels, two of which – electricity and natural gas – imply greater market share for alternative vehicles. Biofuels, on the other hand, are already in the fuel marketplace at meaningful levels and generally will not require alternative vehicle technologies. Other types of advanced low carbon fuels may enter the marketplace, such as "drop-in" hydrocarbon biofuels, which can also be used in existing vehicles. However, modifications to vehicles may be needed if and when ethanol blends exceed certain levels to meet a given CFS target. For example, ethanol volumes exceeding the current U.S. EPA blend limit of 15 percent would require FFVs that can accommodate E85 or other high ethanol blends.

A number of factors will determine the extent to which electric and natural gas vehicles make inroads to the marketplace currently dominated by ICE vehicles, including: (1) consumer preferences; (2) the incremental costs of alternative vehicles relative to comparable vehicles powered by ICEs; (3) vehicle performance; (4) fuel prices; and (5) the availability of charging/fueling infrastructure.

In this analysis, the shares of conventional, electric, natural gas, and FFVs in the marketplace by 2022 is determined by calculating the number of alternative vehicles of the appropriate type needed to use the given energy content associated with a corresponding volume of low carbon fuel.[47]

Figures 3-11 and **3-12** show the estimated fleet shares, as a percentage of all vehicles on the road, for each type of alternative vehicle in both BAU cases, as well as under the CFS policy scenarios. In the BAU cases, the analysis shows that alternative vehicles would achieve at least a small percentage of overall fleet share even without CFS requirements, especially when oil prices are high.

Figures 3-11 and 3-12. Fleet Shares of Conventional and Alternative Vehicles (Year 10)



As would be expected, the shares of alternative fuel vehicles change significantly under the CFS policy scenarios. Logically, fleet share for EVs is highest in the Electricity Future scenario. By 2022, BEVs are estimated to make up 13 percent and plug-in hybrid electric vehicles (PHEVs) 8 percent of the total light-duty vehicle fleet in the High Oil Price case.

Fleet share for NGVs is actually highest in the Biofuels Future (High Oil Price case), which is also the scenario with the highest use of natural gas (16.4 billion gallons of gge). In all scenarios, including the BAU cases, the number of additional FFVs required in the marketplace is very small.

In general, fleet shares of alternative vehicles are estimated as higher across the BAU and all policy scenarios in the High Oil Price case, as consumers seek substitutes for gasoline-fueled vehicles. It is notable, however, that regardless of the CFS policy scenario, conventional vehicles continue to dominate overall fleet composition throughout the

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[47] For additional information on the VISION modeling of the vehicle fleet, see *Appendix B.*

study period. Except for the Electricity Future, when oil prices are assumed to be high, the market share of conventional vehicles in 2022 does not fall below 80 percent.

Table 3-5 provides the cumulative number of incremental alternative vehicles and the costs of purchasing vehicles under the CFS policy scenarios by 2022, under a 7 percent discount rate.[48] These alternative vehicle numbers are incremental to the alternative vehicles that would be purchased anyway, without the CFS, under the BAU reference cases.

As expected, the number of incremental EVs (i.e., BEVs and PHEVs combined) is highest under the Electricity Future scenario. Both the 5 million EVs under the Low Oil Price and the 7.3 million EVs under the High Oil Price case are higher than the analogous vehicle levels for either the Natural Gas or Biofuels Future scenarios. As described in Section 2.0, the incremental cost of EVs in this scenario is assumed to be zero, so total incremental vehicle costs in the Electricity Future are driven primarily by the cost of NGVs, equaling $13.4 billion in the Low Oil Price case, and $19.5 billion in the High Oil Price case.

Table 3-5. Incremental Alternative Vehicles and Costs (Year 10) (7 Percent Discount Rate)

	Electricity Future		**Natural Gas Future**		**Biofuels Future**	
Numbers of Alternative Vehicles and Incremental Costs	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BEVs (Thousands):	3,690	5,390	1,250	1,620	1,250	1,800
PHEVs (Thousands):	1,300	1,900	1,310	1,700	1,320	1,890
Total No. of EVs (Thousands):	**5,000**	**7,290**	**2,550**	**3,320**	**2,570**	**3,680**
BEV Incremental Cost (Billion 2010$):	$0.0 B	$0.0 B	$4.0 B	$5.8 B	$4.1 B	$6.4 B
PHEV Incremental Cost (Billion 2010$):	$0.0 B	$0.0 B	$0.0 B	$0.0 B	$0.0 B	$0.0 B
Total EV Incremental Cost (Billion 2010$):	**$0.0 B**	**$0.0 B**	**$4.0 B**	**$5.8 B**	**$4.1 B**	**$6.4 B**
LD NG Vehicles (Thousands):	2,390	3,240	1,550	3,260	2,350	3,060
M/HD NG Vehicles (Thousands):	129	155	80	166	129	155
Total No. of NGVs (Thousands):	**2,520**	**3,400**	**1,630**	**3,430**	**2,500**	**3,300**
LD NG Vehicle Incremental Cost (Billion 2010$):	$11.4 B	$16.3 B	$0.0 B	$0.0 B	$10.9 B	$15.5 B
M/HD NGVs Incremental Cost (Billion 2010$):	$2.4 B	$3.1 B	$0.0 B	$0.0 B	$2.4 B	$3.1 B
Total NGV Incremental Cost (Billion 2010$):	**$13.4 B**	**$19.4 B**	**$0.0 B**	**$0.0 B**	**$13.3 B**	**$18.6 B**
Total No. of Alternative vehicles (Thousands)	**7,500**	**11,000**	**4,100**	**6,800**	**5,100**	**7,000**
Total Incremental Cost (Billion 2010$):	**$13.4 B**	**$19.5 B**	**$4.0 B**	**$5.8 B**	**$17.4 B**	**$25.0 B**

[48] The numbers of incremental alternative vehicles under the policy scenarios differ from total fleet share of alternative vehicles, because some vehicles are purchased in the absence of the LCFS. In addition, total fleet share figures reflect vehicle retirements.

In the Natural Gas Future, the number of incremental EVs is estimated at roughly one-half of those under the Electricity Future, at 2.6 million under the Low Oil Price case, and 3.3 million under the High Oil Price case. The number of NGVs in this scenario is also lower than under the Electricity Future, at 1.6 million and 3.4 million NGVs, respectively, under the Low and High Oil Price cases. This results from the assumption that biogas with very low CI values dominates the natural gas quantities estimated for this scenario. Consequently, less natural gas and fewer NGVs are projected to be needed than in the Electricity Future, which depicts the use of more conventional natural gas with a substantially higher assumed CI value.

In the Biofuels Future, although the numbers of both EVs and NGVs are roughly comparable to those under the Natural Gas Future, the total incremental cost of alternative vehicles is the highest of all three scenarios, ranging from $17.4 billion (Low Oil Price case) to $25.0 billion (High Oil Price case). This result stems from the assumption that the incremental cost of both EVs and NGVs are at the high-end of their respective cost ranges in this scenario.

Due to the low penetration of E85 in all scenarios, the number of FFVs is zero in all scenarios, except for the Electricity Future under the High Oil Price case. Due to the assumption that even the high-end incremental cost of these vehicles is low ($100 per vehicle), these costs add up to just over $40 million, which is a negligible percentage of the total incremental vehicle costs of $19.5 billion in that scenario.

3.1.6. Changes in GHG Emissions

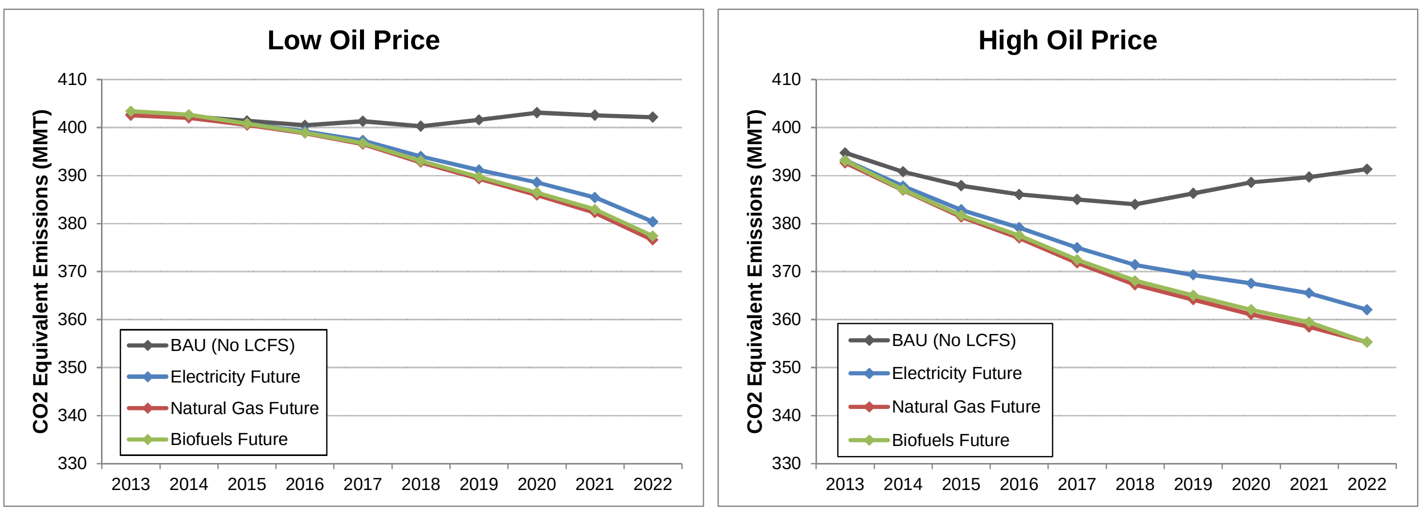
A key objective of the CFS is to reduce transportation-related GHG emissions by lowering the carbon intensity of transportation fuel used, relative to the BAU. Because the CFS is an intensity-based standard, not a cap on emissions, in theory, total GHG emissions could increase under a CFS if increases in fuel quantities used outweigh the per unit improvements in GHG intensity achieved under a CFS. However, as noted in the introduction, the CFS is intended as one of three primary strategies to address GHG emissions from the transportation sector. With effective vehicle efficiency measures and VMT strategies in place, a CFS would result in absolute reductions in GHG emissions as well as intensity reductions.

Figures 3-13 and **3-14** show the magnitude of modeled reductions in GHG emissions, in million metric tons of CO_2-equivalent (MMT CO_2e), for BAU and the three policy scenarios under the Low and High Oil Price cases, respectively.

Under BAU, GHG emissions in the Low Oil Price case start at approximately 403 MMT in 2013 and are estimated to remain relatively stable throughout the 10-year period. Under the Natural Gas and Biofuels Futures, GHG emissions are estimated to decline by seven percent relative to BAU (Low Oil Price case), to 376 MMT in 2022. The Electricity Future provides slightly lower reductions, to 380 MMT in 2022, or 6 percent from BAU in the Low Oil Price case. This scenario’s smaller impact on GHG reductions stems from fuel price effects calculated in the VISION model, based on historical trends of consumer driving behavior relative to fuel price.[49] Due to the high efficiency and low cost of electricity as a transportation fuel, consumers are actually projected to drive further on average when using this technology relative to more expensive fuels, slightly increasing energy demand and emissions.

Under BAU in the High Oil Price case, GHG emissions start at 395 MMT in 2013, and are expected to decline slightly in the middle years of the program before ending at 391 MMT in 2022. This dynamic is attributable to the assumption, described in Section 2.0, that the average CI of petroleum is higher in this scenario. Due to the assumption of rising carbon intensity for petroleum fuels in the High Oil Price case, all three scenarios project greater GHG reductions relative to BAU than in the Low Oil Price case. The Biofuels and Natural Gas Futures indicate a nine percent reduction from BAU GHG emissions in 2022, to 355 MMT. Again, the Electricity Future would provide slightly smaller emission reductions than the other two scenarios, with an estimated 362 MMT of GHG emissions in 2022.

Figures 3-13 and 3-14. Changes in GHG Emissions under 10 Percent CFS, 2013-2022



As discussed earlier in this report, the economic value of reducing (or avoiding future) GHG emissions is a subject of substantial uncertainty. A range of values are used for the social cost of carbon in this analysis. On the low-end, a value of nearly $24 per ton of carbon-equivalent in 2013 (increasing to $29 per ton in 2022) is used. On the high-end, the SCC value is $107 per ton, which applies to the full time period of 2013 through 2022.[50] These low- and high-end values for the social cost of carbon were applied to the range of cumulative reductions in GHG emissions estimated for the 10-year period.

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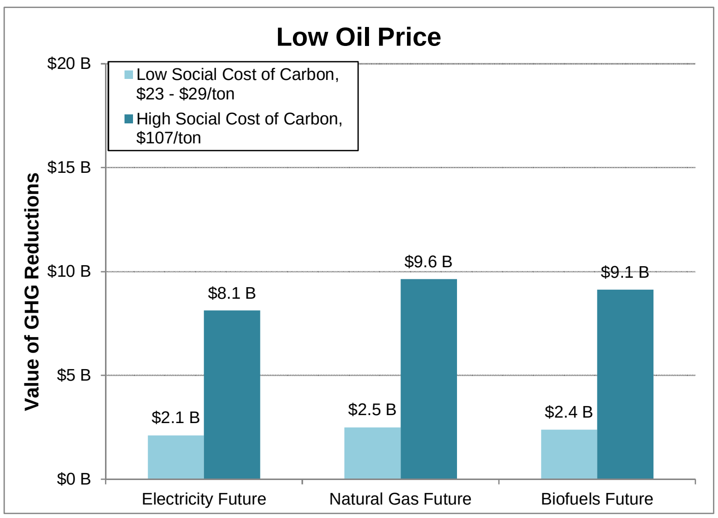
[49] Argonne National Laboratory cites the historical relationship of these effects as a two percent increase in VMT for a 10 percent reduction in fuel cost/mile.

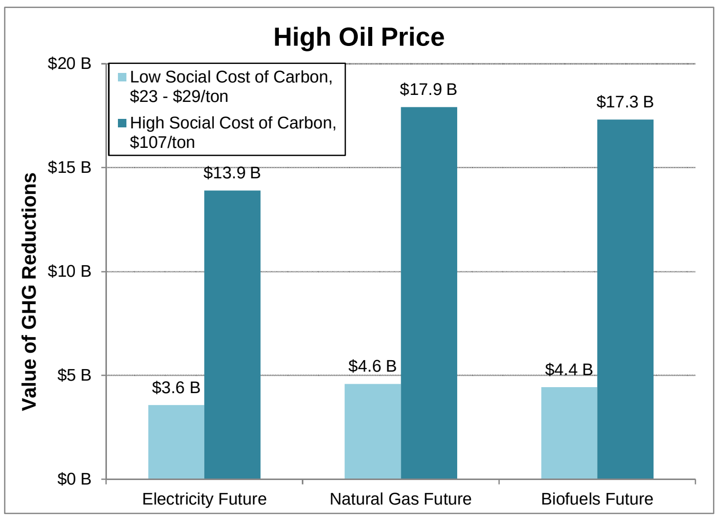
[50] The low-end value for social cost of carbon is from *Social Cost of Carbon (SCC) for Regulatory Impact Analysis Under Executive Order 12866*, by the Interagency Working Group on Social Cost of Carbon, U.S.

Figures 3-15 and **3-16** show the estimated value of the cumulative GHG reductions for the Low and High Oil Price cases, respectively. The highest values of GHG reductions in the Low and High Oil Price cases correspond to the Biofuels and Natural Gas Futures, which are modeled to provide the largest overall GHG emissions reductions. In the Biofuels and Natural Gas Futures, the cumulative value of GHG reductions using the low-end SCC value is about $2.5 billion in the Low Oil Price case. Given the nearly four-fold difference in the low- and high-end estimates for the SCC, the high-end value is significantly higher, at $9.1 billion for the Biofuels Future and $9.6 billion for the Natural Gas Future under the Low Oil Price case. In the High Oil Price case, the low- and high-end values of carbon emissions reductions for the Biofuels Future are $4.4 billion and $17 billion, respectively; for the Natural Gas Future, the low- and high- end values are $4.6 billion and $18 billion, respectively.

Because the Electricity Future would provide smaller overall GHG emissions reductions, this scenario correspondingly shows a lower value of reduced carbon emissions. In the Low Oil Price case, the low- and high-end values for GHG reductions are $2.1 billion and $8.1 billion, respectively; in the High Oil Price case, the low- and high-end values are $3.6 billion and $14 billion, respectively.

Figures 3-15 and 3-16. Value of GHG Emission Reductions under 10 Percent CFS (10-Yr. Total)





3.1.7. Net Program Costs and Benefits

This section provides a summary of the net benefits and costs of the three 10 percent policy scenarios. **Tables 3-6** and **3-7** show the cumulative change in expenditures on transportation fuels, infrastructure, vehicles, and program administration resulting from implementing the various CFS scenarios under the Low and High Oil Price cases. For all

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Government (2010). The low-end value is discounted at three percent. The high-end SCC value is from the Stern Review (2006), and is discounted at zero percent.

scenarios, the costs of low carbon fuels are estimated to be less than expenditures on the gasoline and diesel they replace. However, the introduction of these low carbon alternatives requires investments in fuel delivery infrastructure and alternative fuel vehicles, which are also factored into the estimates of total cost.

Table 3-6. Net Costs and Benefits for CFS Scenarios, Low Oil Price Case (10 Yr. Total) (in Billions of 2010$)

	Electricity Future	**Natural Gas Future**	**Biofuels Future**
Program Benefits:			
Value of Reductions in Gas & Diesel	$50.6	$30.7	$30.3
Program Costs:			
Low Carbon Fuel Costs	$29.4	$19.6	$18.9
Infrastructure Investments	$8.88	$4.94	$6.76
Incremental Vehicle Costs	$13.4	$4.05	$17.4
Program Admin. Costs	$0.243	$0.243	$0.243
Total Costs	$52.0	$28.9	$43.3
Net Program Benefits (Costs) w/o value of GHG Reductions	**($1.4)**	**$1.8**	**($13.0)**
Net Program Benefits (Costs) WITH value of GHG Reductions	**$0.7 - $6.7**	**$3.3 - $11.4**	**$(10.6 – $3.9)**

Note: All estimates expressed in 2013 present values based on a 7 percent rate of discount.

Table 3-7. Net Costs and Benefits for CFS Scenarios, High Oil Price Case (10 Yr. Total) (in Billions of 2010$)

	Electricity Future	**Natural Gas Future**	**Biofuels Future**
Program Benefits:			
Value of Reductions in Gas & Diesel	$137	$87.2	$100
Program Costs:			
Low Carbon Fuel Costs	$62.3	$43.9	$42.8
Infrastructure Investments	$14.1	$8.26	$9.8
Incremental Vehicle Costs	$19.5	$5.75	$25.0
Program Admin. Costs	$0.243	$0.243	$0.243
Total Costs	$96.0	$58.2	$77.9
Net Program Benefits (Costs) w/o value of GHG Reductions	**$41**	**$29**	**$22**
Net Program Benefits (Costs) WITH value of GHG Reductions	**$43 - $55**	**$34 - $49**	**$26 - $39**

Note: All estimates expressed in 2013 present values based on a 7 percent rate of discount.

The program costs shown for a given scenario reflect the total for all three low carbon fuels, not just the prevalent low carbon fuel. Because of the inverse relationship between fuel CI values and required fuel volumes, the infrastructure and vehicle costs for a given policy "future" may in fact be dominated by a fuel other than the featured fuel for that scenario. For example, under the Biofuels Future, a significant share of the infrastructure and vehicle cost shown in the table are for electricity and natural gas, which are assumed to have high CI values and high vehicle/infrastructure costs under this scenario. Consequently more vehicles and refueling infrastructure will be needed to achieve the CI reduction target, and the cost for a unit of carbon reduction is higher.

Net program benefits (or costs) are determined by comparing the total cost for low carbon alternatives to the benefits from reductions in both gasoline and diesel purchases and GHG emissions. This analysis suggests that the CFS would result in net benefits under all scenarios, even excluding the value of GHG reductions, when oil prices are high. Depending on the scenario, the cumulative savings over 10 years range from around $18 billion to $52 billion, without GHG reductions, compared to the High Oil Price case. When the value of GHG reductions is included in the net benefit calculation, cumulative savings are estimated to increase to $26 billion to $55 billion under high oil prices.

Under the Low Oil Price case, the scenarios show either small net benefits or small net costs relative to BAU, even when the value of GHG reductions is excluded. The exception is the Biofuels Future, which shows $13 billion in net costs under low oil prices, which falls to $4 to $11 billion in net costs when GHG reductions are included. These results suggest the price of oil is a more important determinant of the net impact of CFS than the low carbon fuel mix that might emerge to comply with the program's CI reduction target.

3.1.8. Impacts on Affected Entities

As described in the *Methods* sections, the first step in an economic analysis of potential regulations is to account for impacts, i.e., net costs and benefits resulting from a policy relative to what would have happened in the absence of the policy. Next, the analysis determines distributive impacts, i.e., how net costs and benefits are distributed among affected groups such as industries, consumers, and government. In addition, the analysis should generally distinguish true economic costs and benefits from what economists refer to as "transfer payments," which represent direct payments from one entity to another, but do not usually change net economic welfare.[51] The next section provides a quantitative and qualitative discussion of the distribution of costs and benefits among affected groups, i.e., industry, consumers, fuel producers, and state governments.

[51]For example, taxes are generally considered to be a simple transfer payment from taxpayers to the government sector, rather than a cost or benefit. However, if changes in taxes also create distortionary impacts that affect the level of investment or spending in an economy, then they can also result in costs or benefits that change overall economic activity.

Industry

For petroleum producers and distributors that could be regulated under the CFS, the cost of compliance is expected to be the sum of: (1) producing or purchasing new low carbon biofuels and blending these biofuels into existing fuel products, and/or (2) purchasing credits that represent reductions in carbon intensity from non-liquid fuels sold into the market by other producers (i.e., natural gas or electric utilities).

Many petroleum companies have substantial experience in purchasing and blending biofuels into existing fuel products. Some are currently developing advanced biofuels (or own substantial investments in other companies doing so). While this analysis provides estimates of the cost of new low carbon liquid biofuels, as well as the accompanying fuel infrastructure needed to deliver those fuels, it does not attempt to estimate whether or to what degree regulated companies will rely upon purchasing and blending biofuels as a strategy for CFS compliance, versus purchasing credits from other low carbon fuel producers, such as electric or gas utilities.

Petroleum companies are expected to pursue whichever compliance strategy, or combination of strategies, results in the lowest possible cost of complying with CFS requirements. However, given the significant uncertainties associated with important determinants of the supply and cost of low carbon fuels, such as the CI values assigned to biofuels and other low carbon fuels, the timing of commercial viability of key fuel and vehicle technologies, consumer preferences, and market conditions, a least-cost optimization assessment of possible compliance options would not provide meaningful insights at this stage.

For these reasons, this analysis does not estimate the cost of industry compliance or its potential impacts on retail gasoline and diesel prices. While both are beyond the scope of this analysis, the assumptions for petroleum price trends and possible low carbon fuel prices and costs described in Section 2 highlight the expectation that many low carbon fuels could be lower in price or comparable in price to petroleum-based fuels. Regardless of petroleum companies' ability to pass through any compliance costs to customers for liquid fuels, based on this analysis, at minimum, those consumers who switch to natural gas and electric vehicles have an opportunity to save substantially on transportation fuel expenditures.

In addition to the costs of producing or purchasing low carbon fuels and/or credits, regulated companies will incur administration costs to demonstrate compliance with the program. These costs are assumed to include paying at least one full-time employee (FTE) per regulated company, at a loaded cost of $200,000 per FTE, for the duration of the program. Based on the assumption of 150 regulated companies in the region, the total costs to industry for program administration are estimated at $30 million per year (undiscounted). The net present value of these costs over 10 years ranges from $225 million to $264 million, under seven and three percent discount rates, respectively. These costs could certainly vary across individual companies, however, depending on the level of compliance needed.

Consumers

The net reductions in transportation fuel expenditures relative to BAU will accrue to certain groups of consumers, in the form of fuel savings. Based on the price estimates for low carbon fuels used in this analysis, consumers who switch to natural gas and electric vehicles would likely accrue substantial savings on fuel costs and experience less price volatility than those who continue to use petroleum-based fuels blended with biofuels.

The effects of the program on retail gasoline and diesel prices are indeterminate at this point. Ultimately, these impacts will depend on the cost structure of participants in the market for low carbon fuels, their ability to pass on any costs into credit prices, and the ability of petroleum producers to pass through any compliance costs.[52] It is also expected that overall demand for petroleum products would decline with BAU price increases in the absence the CFS program, and the ability of petroleum producers to pass through costs may decline as demand falls.

Low Carbon Fuel Producers

Producers of low carbon fuels will increase revenues through sales of low carbon fuels, and could capture increased profits as well, depending on market demand and their ability to pass through costs. Because it is expected that producers of different fuel types will compete to supply the most cost-effective CI reductions, the market for low carbon fuels will be strongly influenced by the lowest-cost producers of CI reductions, as well as the market price for petroleum-based fuels.

State Governments

There are two categories of possible fiscal impacts on state governments associated with implementing the CFS: (1) states would incur costs for administering and enforcing the CFS program; and (2) in the absence of adjustments to current fuel tax schedules to incorporate low carbon fuels, some states could lose revenues from fuel taxes on gasoline and diesel fuels, as sales of these products decline.

The costs to states for program administration and enforcement could be deferred by raising revenue through the program, such as through a surcharge of credit value. An initial estimate of total costs to states for administering the regional CFS is $18 million (seven percent discount) to $21 million (three percent discount) over the 10-year period, or $1.8 to $2.1 million per year. These estimates are based on the assumption that individual states will require from one-half to two full-time employees (FTE), varying according to each state's fuel use, and that an average state FTE cost will be $150,000 (loaded).[53] In addition, some administrative activities would be regional in nature, and would require an additional three FTEs, increasing to four FTEs by 2018.

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[52] The price elasticity of demand for gasoline, which reflects the sensitivity of demand from consumers in response to a change in gasoline prices, will decline if substitutes for gasoline become available, all else being equal.

[53] A loaded annual cost for a full-time employee includes annual salary plus the costs of overhead and benefits.

Losses in state tax revenue could occur if states do not make adjustments to current tax schedules to account for the shift in fuel use towards new fuel types. Many states already have tax rates in place for alternative liquid fuels, but only a few have tax rates set for natural gas when used as a transportation fuel. Of all the NE/MA states, only Pennsylvania has a full schedule of tax rates for all of the low carbon fuels, including electricity, evaluated in this report.

As shown in **Table 3-8**, with a 7 percent discount rate, BAU state fuel tax revenues range from nearly $81 billion to just over $85 billion over 10 years, depending on the High or Low Oil Price case. Assuming no change to existing state fuel tax structures, potential losses in state tax revenues vary with the policy scenario, in accordance with the underlying changes in gasoline and diesel demand (as shown in Section 3.1.1). Because the volume of gasoline and diesel displaced is highest under the Electricity Future, the corresponding potential tax revenue losses are also highest, ranging from $3.4 to $6.3 billion, or 4 percent and 7 percent of BAU revenues over the 10-year period, respectively. Under the other scenarios, the reductions in gas and diesel use are lower, thus possible tax revenue losses are also lower, ranging from 2 percent to 4 percent of BAU revenues. The potential loss of revenue shown in Table 3-6 would apply only if those states currently without a tax structure for alternative or low carbon fuels choose not to implement one.

Table 3-8. Potential Changes in State Fuel Tax Revenues (10-Yr. Totals) (7 Percent Discount Rate)

	Scenario					
	Electricity Future		**Natural Gas Future**		**Biofuels Future**	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BAU Fuel Tax Revenue (2010$)	$85.1 B	$80.9 B	$85.1 B	$80.9 B	$85.1 B	$80.9 B
Scenario Fuel Tax Revenue (2010$):	$81.7 B	$74.6 B	$83.4 B	$77.6 B	$82.7 B	$77.0 B
Change in Fuel Tax Revenue (2010$):	-$3.4 B	-$6.3 B	-$1.7 B	-$3.3 B	-$2.4 B	-$3.9 B
Percentage Change from BAU:	-4%	-7%	-2%	-4%	-2%	-5%

Applying a 3 percent discount rate, as in **Table 3-9**, results in a higher estimate of potential reductions in fuel tax revenues over 10 years, ranging from $2.3 billion on the low-end to $7.9 billion at the high-end, or 2 percent and 8 percent of BAU, respectively.

Table 3-9. Potential Changes in State Fuel Tax Revenues (10-Yr. Totals) (3 Percent Discount Rate)

	Scenario					
	Electricity Future		Natural Gas Future		Biofuels Future	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
BAU Fuel Tax Revenue (2010$)	$99.7 B	$94.5 B	$99.7 B	$94.5 B	$99.7 B	$94.5 B
Scenario Fuel Tax Revenue (2010$):	$95.1 B	$86.6 B	$97.4 B	$90.4 B	$96.5 B	$89.6 B
Change in Fuel Tax Revenue (2010$):	-$4.6 B	-$7.9 B	-$2.3 B	-$4.1 B	-$3.2 B	-$4.9 B
Percentage Change from BAU:	-5%	-8%	-2%	-4%	-3%	-5%

3.2. Results for Five Percent and 15 Percent Sensitivity Analyses

In order to understand the sensitivity of the CFS economic impacts to the CI reduction target and the timeframe for compliance, this analysis included sensitivity cases designed to test the influence of those variables. In addition to the two scenarios presented below, the analysis included a sensitivity case in which all biofuels volumes are produced outside the region. Fuel quantities and vehicle numbers for this sensitivity are identical to those in the Biofuels Future listed above; however, the macroeconomic impacts associated with locating all production facilities outside the region differ from those associated with the Biofuels Future, and are presented in Section 4.

3.2.1. Five Percent Target, 10-Year Scenario

As described in Section 2.2.2, the 5 percent, 10-year scenario is a sensitivity case intended to represent a less optimistic view of fuel availability and technology innovation in comparison to the 10 percent scenarios. As such, in this scenario, the high end of the range for fuel CI values, fuel costs, and incremental vehicle costs are assumed. The program’s CI reduction target is less ambitious than the 10 percent target, requiring only a 5 percent reduction for transportation fuels over the same timeframe (2013 to 2022). Another difference is that this scenario reflects relatively even contributions of the three low carbon fuel types, rather than having a single fuel provide the majority of the contributions to the CI reductions.

Table 3-10. Comparison of 10 Percent and 5 Percent Scenarios (10-Yr. Totals) (7 Percent Discount Rate)

	10 Percent						5 Percent, 10-Year Scenario	
	Electricity Future		Natural Gas Future		Biofuels Future			
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Total Gas and Diesel Demand (Bgal)	314	275	323	290	323	286	331	285
Reductions from BAU (Bgal)	23	40	14	25	14	29	6	30
Percentage Reduction from BAU	*-7%*	*-13%*	*-4%*	*-8%*	*-4%*	*-9%*	*-2%*	*-10%*
Value of Reductions from BAU (Billions of 2010$)	-$50.6	-$137	-$30.7	-$87.2	-$30.3	-$100	-$13.2	-$104
Electricity Demand (GWh)	139,000	263,000	60,100	100,000	61,600	113,000	21,900	116,000
Cost of Electricity (Billions of 2010$)	$12.2	$25.1	$6.6	$11.8	$6.9	$13.4	$2.3	$13.8
CNG Demand (Billion gge)	9.8	16.9	6.2	13.4	9.7	16.4	3.5	17.1
Cost of CNG (Billions of 2010$)	$10.8	$20.4	$6.9	$15.7	$10.8	$19.7	$3.7	$20.9
Biofuels Demand (Bgal)	4.6	8.9	4.6	8.8	0.3	8.9	1.7	9.0
Cost of Biofuels (Billions of 2010$)	$6.5	$16.8	$6.1	$16.4	$1.3	$9.7	$2.7	$18.1
Net Fuel Expenditures (Billions of 2010$)	**-$21.2**	**-$74.5**	**-$11.1**	**-$43.3**	**-$11.4**	**-$57.2**	**-$4.5**	**-$51.1**

As shown in **Table 3-10** above, an outcome of the use of the higher-end CI range for low carbon fuels is that relatively more low carbon fuel is needed in the 5 percent, 10-year scenario, in comparison to the 10 percent policy scenarios, even to reach a less stringent CI reduction target. This effect is especially evident in the High Oil Price case, where volumes of biofuels and natural gas, respectively, exceed those needed in any of the 10 percent scenarios. Similarly, the electricity needed in the 5 percent, 10-year scenario exceeds the electricity demand in all of the core policy scenarios except for the Electricity Future.

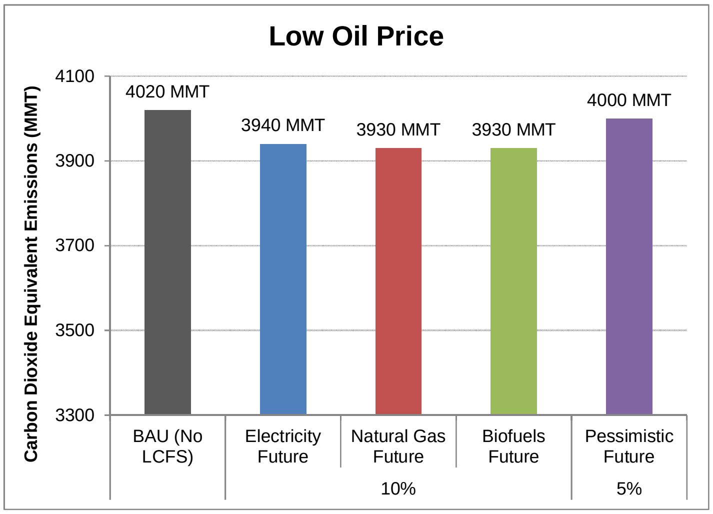
A beneficial outcome of the need for larger quantities of low carbon fuels in this case is that higher volumes of gasoline and diesel are displaced, which in turn reduces gasoline and diesel expenditures and partially offsets the higher costs incurred for low carbon fuels, vehicles, and infrastructure.

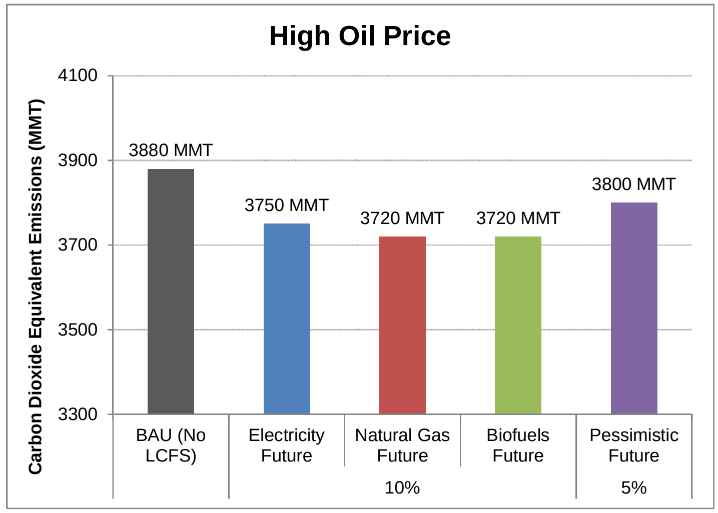
As would be expected, fewer GHG reductions would accrue under a CFS with a 5 percent reduction target. **Figures 3-17** and **3-18** show that, under the 5 percent, 10-year scenario, GHG emissions would still decrease from BAU levels by 17.3 to 86.2 million metric tons, under the Low and High Oil Price cases, respectively. In comparison, however, the 10 percent scenarios would achieve reductions from the BAU GHG levels of roughly 85 to 153 million metric tons, under the Low and High Oil Price cases, respectively.[54] These

[54] Based on an average of the GHG reductions across the three 10 percent scenarios.

reductions are greater than in the five percent, 10-year scenario by a factor of five under the Low Oil Price case and nearly a factor of two under the High Oil Price case.

Figures 3-17 and 3-18. Transportation GHG Emissions for 5 Percent and 10 Percent CFS Targets (10-Yr. Totals)





3.2.2. 15 Percent Target, 15-Year Scenario

As also described in Section 2.2.2, the 15 percent, 15-year scenario is a sensitivity case intended to represent a more optimistic outcome in comparison to the 10 percent scenarios. As such, this case is designed around more optimistic assumptions for technology innovation rates and fuel and (related infrastructure and vehicle) costs than under the 10 percent scenarios. In accordance with this scenario representing an optimistic view of low carbon fuel development and availability, the low end of the range for fuel CI values, fuel costs, and incremental vehicle costs all apply.

In this scenario, the program's CI reduction target is more ambitious than the 10 percent target, requiring a 15 percent reduction for transportation fuels. However, this scenario also reflects a timeframe that is five years longer to achieve the deeper reduction requirements, i.e., 2013 to 2027. And as is the case in the 5 percent, 10-year scenario, another difference is that this scenario reflects relatively even contributions toward the CI reduction from the three low carbon fuel types, rather than a situation where a single low carbon fuel dominates.

Because the 15 percent scenario is designed to show compliance over a 15-years rather than 10 years, some of the differences between the 10 and 15 percent results simply reflect the effects of this longer timeframe. For example, as seen in **Table 3-11** below, under the 15 percent, 15-year scenario, total gas and diesel demand is estimated at over 487 billion gallons under the Low Oil Price case, and 426 billion gallons under the High

Oil Price case. Both of these demand levels are about 50 percent higher than under the 10 percent scenarios.

Table 3-11. Comparison of 10 Percent and 15 Percent CFS Scenarios (7 Percent Discount Rate)

	10 Percent						15 Percent, 15-Year	
	Electricity Future		Natural Gas Future		Biofuels Future			
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Total Gas and Diesel Demand (Bgal)	314	275	323	290	323	286	487	426
Reductions from BAU	23	40	14	25	14	29	19	43
Percentage Reduction from BAU	-7%	-13%	-4%	-8%	-4%	-9%	-4%	-9%
Value of Reductions from BAU (Billions of 2010$)	-$50.6	-$137	-$30.7	-$87.2	-$30.3	-$100	-$30.0	-$120
Electricity Demand (GWh)	139,000	263,000	60,100	100,000	61,600	113,000	149,000	247,000
Cost of Electricity (Billions of 2010$)	$12.2	$25.1	$6.6	$11.8	$6.9	$13.4	$12.3	$22.9
CNG Demand (Billion gge)	9.8	16.9	6.2	13.4	9.7	16.4	8.8	20.1
Cost of CNG (Billions of 2010$)	$10.8	$20.4	$6.9	$15.7	$10.8	$19.7	$7.2	$17.5
Biofuels Demand (Bgal)	4.6	8.9	4.6	8.8	0.3	8.9	-2.5	8.6
Cost of Biofuels (Billions of 2010$)	$6.5	$16.8	$6.1	$16.4	$1.3	$9.7	-$0.3	$8.7
Net Fuel Expenditures (Billions of 2010$)	**-$21.2**	**-$74.5**	**-$11.1**	**-$43.3**	**-$11.4**	**-$57.2**	**-$10.9**	**-$71.3**

The most notable outcome of the 15 percent, 15-year scenario is that quantities of low carbon fuels needed to meet the 15 percent target are only somewhat higher than in the 10 percent scenarios, and not 50 percent higher. This outcome results from the fact that the low-end of the CI values is assumed for <u>all</u> low carbon fuels represented in this scenario; thus, fewer low carbon fuels are needed, in relative terms, to meet the higher CI reduction target.

Total fuel costs in the 15 percent scenario are also relatively in line with the fuel expenditure levels for the 10 percent scenarios, despite the longer implementation timeframe, as the costs for low carbon fuels in this scenario are assumed at the low-end of their range.

In the case of biofuels, expenditures in the 15 percent scenario under low oil prices are actually negative at $0.3 billion. This is because, in this scenario, advanced biofuel volumes are negative, at 2.5 billion gallons *less* than what would is estimated for the BAU Low Oil Price case. This is because in this scenario, there is assumed to be greater availability of biofuels with very low CI values, which in the volumes projected under the RFS are more than sufficient to meet the carbon intensity reduction targets of the program. Therefore, the carbon intensity reduction goals can be met using only modest volumes of advanced biofuels.

While total net expenditures on low carbon fuels remain negative (i.e., represent savings relative to BAU) under the 15 percent, 15-year scenario as they are for the 10 percent scenarios, the savings on low carbon fuels under this scenario are also proportionally lower. This reflects not only the influence of the low-end CI values, but also the longer timeframe — the present value of expenditures on low carbon fuels reflects that these investments are discounted over 15 years instead of 10 years.

4. REGIONAL ECONOMIC IMPACTS

This section presents the key findings of the macroeconomic impact analyses for each of the policy scenarios examined, the Electricity, Natural Gas and Biofuels Futures. Results for the sensitivity case on the Biofuel Futures scenario are also presented. The results in this section are aggregation of state-level macroeconomic results, and as such, can be interpreted as a snapshot of how the CFS could impact the regional economy as a whole.

4.1. The REMI Model

The *REMI Policy Insight* model, a multi-state economic policy analysis tool, was used to assess the macroeconomic impacts of the CFS. The version of REMI used in this analysis covers the six New England states, New Jersey, New York, Delaware, Maryland, Pennsylvania, and the District of Columbia. REMI's underlying methodology captures how direct changes resulting from a policy (such as changes in income or expenditures by households, businesses, and institutions) affect economic growth and create further feedbacks throughout the economy.

4.2. Methodology

In the macroeconomic modeling phase of the CFS analysis, the categories of direct changes resulting from the CFS relative to the BAU (discussed in Sections 3.1.1 through 3.1.5) include: (1) net expenditures on fuel; (2) new demand for low carbon fuel production and infrastructure; (3) new demand for installation of low carbon infrastructure; and (4) investor-owned utility revenues.

The economic impact of each low carbon policy scenario on the region is described in terms of annual changes compared to BAU for the following economic measures:

- *Employment* – the number of jobs, by industry;
- *Gross Regional Product* – the total value of goods and services produced by all industry in the region;
- *Personal Disposable Income* – total real after-tax income available for spending or saving; and
- *Industry Value-added* – a specific industry's contribution to the gross regional product.

4.3. Results for the 10 Percent CFS Reduction Target

4.3.1. CFS Employment Impacts

This section presents and evaluates the estimated employment impacts of the CFS policy scenarios relative to the Low and High Oil Price BAU scenarios. In each year evaluated, REMI was used to estimate the number of jobs created or retained for the BAU reference cases and the CFS policy cases.[55] The values in **Table 4-1** represent the differences between the BAU and the CFS scenario annual employment forecasts in year 1 (2013), year 5 (2017) and year 10 (2022) of the program. Since the REMI model's concept of employment does not distinguish between full- and part-time employment, or account for the duration of a job, the results do not reflect cumulative changes over the 10-year period (known as "job-years").[56] It is also important to note that these estimates represent *net* employment impacts, so a positive value may reflect job losses in some industries that are outweighed by gains in other industries (and vice versa).

Table 4-1 presents two measures of employment, the absolute difference from the BAU and the percentage change. The results include jobs directly created or retained by the program (i.e., plant engineers, construction workers and electrical component manufacturing jobs) and indirect or induced employment. Indirect employment impacts occur in industries that supply or otherwise support the directly impacted industries and all subsequent business-to-business activity. Induced employment results from changes in consumer demand as the effects of wage increases in industries that supply low carbon fuels and related needs are realized. These wage increases in turn support new employment in other industries not necessarily related to the direct requirements of the program.

Under the High Oil Price case, there are larger positive employment impacts estimated across all policy scenarios and years than under the Low Oil Price case. This relates to the fact that the CI of gasoline is increasing in the High Oil Price case, which requires larger reductions and greater quantities of low carbon fuels and infrastructure across all policy futures. Job creation is shown to increase especially in the latter years of the program, reflecting that, as the CFS CI reduction target begins to have greater effect over time, the program creates more demand for goods and services. All of the policy scenarios show positive net employment impacts by year 5 of the program.

The Biofuels Future stimulates the highest numbers of jobs in year 10, followed by the Electricity and Natural Gas Futures. The Biofuels Future depicts the highest level of low carbon fuel production occurring within the region, which accounts for the high level of jobs in years 5 and 10, at which time new production plants and supporting industries would be fully ramped up.

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[55] REMI does not distinguish between jobs that currently exist and would otherwise end (such as short-term construction), but are retained as a result of the program, versus new jobs.

[56] Annual job levels can be converted into estimates of full-time equivalent workers using data from the National Income and Product Accounts published by the US Bureau of Economic Analysis; however, that analysis was not conducted as part of this study.

Table 4-1. Yearly Employment Impacts by CFS Policy Scenario

	2013 (Year 1)		**2017 (Year 5)**		**2022 (Year 10)**	
Type of Economic Impact	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**
Jobs Retained and Generated (Total)						
Electricity Future	-456	11,400	14,500	43,400	26,600	43,800
% Change from BAU	-0.001%	0.031%	0.036%	0.113%	0.064%	0.106%
Natural Gas Future	14	187	1,110	6,590	9,490	21,700
% Change from BAU	0.000%	0.001%	0.003%	0.017%	0.023%	0.053%
Biofuels Future	948	565	23,600	43,900	41,300	50,700
% Change from BAU	0.003%	0.002%	0.059%	0.114%	0.099%	0.123%
Biofuels Future, Out-of-Region	-2,040	-8,410	-274	-80	1,270	3,650
% Change from BAU	-0.005%	-0.023%	-0.001%	-0.000%	0.003%	0.009%

It is worth noting that, by year 5, the Electricity Future produces nearly as many job impacts as the Biofuels Future under the High Oil Price case. This is a result of the assumption that, under the Electricity Future, the costs of producing fuels in-region are significantly higher than in the other scenarios. This impacts the economy in two ways: (1) biofuel producers are spending more on each unit of fuel they produce; and (2) labor-intensive industries involved with fuel production increase their revenues.

The Natural Gas Future has very modest jobs impacts in comparison to the other two policy scenarios. For example, in year 5, jobs created in the Natural Gas Future are only about 16 percent of those created under the Electricity and Biofuels Future in the High Oil Price case. Although jobs in the Natural Gas Future are much higher by year 10, at nearly 9,500 under the Low Oil Price and almost 22,000 under the High Oil Price case, these are still less than half of those under the other scenarios. These results stem from the fact that the Natural Gas Future includes significant quantities of biogas, which is a fuel with a very low CI value. Consequently, the overall volumes of low carbon fuels needed to meet the target are relatively low, as are corresponding investments in fuel purchases, production, and infrastructure.

The Biofuels Future, Out-of-Region sensitivity case models a future that relies heavily on biofuels, but assumes that the preponderance of those fuels are produced outside the region, rather than within the NE/MA states. As a result, this scenario shows significantly lower but still positive job impacts, falling from nearly 51,000 net new jobs under Biofuels Future (High Oil Price case), to less than a tenth of that, or nearly 3,700 jobs.

This depicts an outcome where jobs involved in building and operating biofuel production plants as well as many of the upstream jobs supporting the biofuel industry (e.g., biomass suppliers) would be located outside the region. **Table 4-1** illustrates that the overall employment impact of any of the CFS scenarios would be very small in magnitude relative to the BAU, which depicts a region with an average annual regional employment of roughly 40 million jobs. Consequently, the CFS is shown to have a positive but modest change in the overall labor market in the participating states, regardless of scenario.

4.3.2. CFS Impacts on Gross Regional Product

This section summarizes the estimated effects of the CFS on Gross Regional Product (GRP), a measure of the value of all goods and services produced in the regional economy. **Table 4-3** provides estimates of changes in the value of goods and services purchased directly to comply with the CFS and the value of other consumer goods and services that are purchased because of the availability of additional income realized from net fuel savings.[57] Because GRP is a monetary value and represents a flow of dollars over time, the 10-year cumulative value is relevant for this metric. **Table 4-2** presents two measures of GRP: the absolute differences from BAU, and the percentage change.

Table 4-2. Gross Regional Product Impacts by CFS Policy Scenario (Millions 2010$)

	2013 (Year 1)		2017 (Year 5)		2022 (Year 10)		10 Year Sum	
Type of Economic Impact	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**
Gross Regional Product (Million 2010 $s)								
Electricity Future	-35.7	443	945	2,940	3,080	4,920	12,900	28,700
% Change from BAU	-0.001%	0.013%	0.026%	0.074%	0.065%	0.105%	0.037%	0.089%
Natural Gas Future	8.4	187	396	1,350	2,120	3,930	7,310	17,100
% Change from BAU	0.000%	0.005%	0.010%	0.034%	0.045%	0.084%	0.007%	0.024%
Biofuels Future	-188	-336	1,570	2,910	4,290	4,640	20,200	27,700
% Change from BAU	-0.005%	-0.010%	0.038%	0.073%	0.09%	0.099%	0.063%	0.095%
Biofuels Future, Out-of-Region	-298	-630	559	1,120	2,220	2,280	8,370	11,300
% Change from BAU	-0.009%	-0.018%	0.013%	0.028%	0.047%	0.049%	0.007%	0.023%

Each of the policy scenarios realizes a positive impact on GRP by year 5 of the program. Small losses in GRP relative to the BAU are experienced in the first year of the program under the Biofuels and Electricity Futures due to the fact that in year 1, the benefits associated with reduced expenditures on gasoline and diesel do not yet outweigh the costs of low carbon fuel purchases and infrastructure investments. This effect is not observed in the Natural Gas Future because CNG is less expensive than the other fuels on an energy-equivalent basis, and thus generates net consumer savings from the outset.

These results suggest that the CFS could have a net positive overall effect on the region's economy. In the High Oil Price scenario, the cumulative GRP benefits for the three core scenarios range from $17.1 billion for the Natural Gas Future to $28.7 billion in the Electricity Future over the 10-year period analyzed. As with employment, the percentage change suggests that the potential impacts of a CFS are small relative to the magnitude of the regional economy. For example, the average annual impact across scenarios under High Oil Prices by 2022 is $2.6 billion, which is negligible relative to the BAU forecast of a $4.9 trillion regional economy in that year.

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[57] The latter category of purchases is often referred to as "induced" spending.

Similar to the impacts on jobs, the GRP results for the Biofuels Future, Out-of-Region sensitivity case show that producing low carbon fuels within the region is preferable for the regional economy compared to importing these fuels from other parts of the U.S. The GRP impacts of the Out-of-Region sensitivity case range from $8.4 to $11.3 billion, less than half the GRP benefits of the Biofuel Future.

4.3.3. CFS Impacts on Real Personal Disposable Income

This section evaluates the estimated impacts of the regional CFS on personal disposable income (PDI), a measure of the total after-tax income available for spending or saving by the region's residents. Real PDI is nominal personal income adjusted for inflation. As shown in **Table 4-3**, similar to the impacts of the program on other metrics like employment, the estimated effects of the CFS on regional PDI are extremely small in absolute terms.

Table 4-3. Real Personal Disposable Income Impacts by CFS Policy Scenario (Million 2010$)

	2013 (Year 1)		**2017 (Year 5)**		**2022 (Year 10)**		**10 Year Sum**	
Type of Economic Impact	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**
Disposable Personal Income (Million 2010 $s)								
Electricity Future	-62.6	-241	-80.9	1,400	1,400	3,230	3,660	14,700
% Change from BAU	-0.002%	-0.008%	-0.002%	0.039%	0.030%	0.069%	0.010%	0.039%
Natural Gas Future	-7.6	-56.3	-4.7	424	950	1,620	2,200	7,240
% Change from BAU	-0.000%	-0.002%	-0.000%	0.012%	0.020%	0.035%	0.006%	0.019%
Biofuels Future	-91.4	-643	493	1,360	2,350	3,330	9,560	15,200
% Change from BAU	-0.003%	-0.022%	0.013%	0.038%	0.049%	0.071%	0.025%	0.041%
Biofuels Future, Out-of-Region	-177	-658	-456	-21.1	-53.9	891	-2,580	1,340
% Change from BAU	-0.006%	-0.0233%	-0.012%	-0.001%	-0.001%	0.019%	-0.007%	0.004%

In some cases negative values occur in the early years of the program, reflecting the fact that despite nominal personal income gains, significant demand on labor and capital markets could bid up costs in the short-term as a result of the CFS. The quick injection of demand into these markets has the effect of raising prices across a broad range of consumer product categories. Consequently, while in nominal terms residents in the region experience higher incomes, in real terms the income is worth slightly less than under the BAU. Over time, the benefits accruing to households outweigh this price effect and residents realize gains on a nominal and real basis.

Under the Biofuels Future, the results show a decline in real PDI in year 1 of the program. As the stimulus increases under the High Oil Price case, the price effect is compounded, causing a more exaggerated decline in real PDI. By year 5, the net household expenditure benefits and increased demand for capital and labor begin to outweigh the price effect in the early years.

In the High Oil Price case, only the Biofuels Future, Out-of-Region sensitivity shows a PDI decline in real terms by year 5. The Biofuels Future scenario remains the most effective at stimulating real PDI, and on a cumulative basis, this scenario depicts increases in real PDI across the region by over $15 billion. These results suggest important economic opportunities associated with developing and maintaining biofuel production capacity within the region.

Again, effects on PDI for the Natural Gas Future are moderate in comparison to the other scenarios. The 10-year sum of $2 to 7 billion under the Low and High Oil Price cases, respectively are substantially less than for the Electricity and Biofuels Futures. This result is due to the fact that, with a lower level of investment in natural gas fuels needed to meet the reduction target, the savings on gasoline and diesel purchases occurring in this scenario are also lower, thus net benefits to PDI are less pronounced.

4.3.4. Impacts by Industry Group

The REMI model represents 70 distinct industry categories based on the North American Industry Classification System.[58] **Table 4-4** highlights the ten industry sectors estimated to benefit most significantly from a CFS, or a regional basis.[59] In each of the policy scenarios analyzed, impacts included industries directly affected by the CFS, such as manufacturing and construction, and those affected indirectly, such as health care. Industries that experience indirect impacts from the CFS reflect the typical areas where consumers and business would most likely spend new disposable income that becomes available through savings on transportation fuels.

The utilities sector was estimated to experience the highest level of positive impacts, in terms of value-added, across all three scenarios. This reflects not only increased levels of electricity and natural gas sales by utilities, but also the production and installation of infrastructure for fueling and charging.

Construction and manufacturing sectors were also shown to realize strong positive direct impacts, for value-added and jobs, across all policy scenarios. These industries would

[58] The NAICS is a system developed by the U.S. Department of Commerce to track industry data and economic performance.
[59] Industries were ranked according to value-added under the High Oil Price case.

Table 4-4. Top Ten Industry Sectors with Estimated Positive CFS Impacts (Year 10)

		Value Added, 2022 (Million 2010 $s)		Jobs, 2022 (Total)	
Scenario	**Industry**	**Low Oil Price**	**High Oil Price**	**Low Oil Price**	**High Oil Price**
Electricity Future	Utilities	2,695	3,743	4,709	6,548
	Construction	1,046	1,318	13,847	17,333
	Health Care	272	1,288	3,756	17,226
	Finance and Insurance	245	918	737	2,845
	Real Estate	154	736	496	2,493
	Manufacturing	592	528	3,825	4,069
	Information	157	429	367	1,012
	Technical Services	265	411	2,682	4,065
	Waste Services	140	300	1,178	2,438
	Forest and Agr. Services	146	182	18,696	22,942
Natural Gas Future	Utilities	1,586	2,643	2,773	4,627
	Construction	671	1,058	9,000	14,126
	Health Care	163	861	2,257	11,517
	Technical Services	426	671	4,630	7,187
	Finance and Insurance	169	661	509	2,029
	Manufacturing	454	630	2,935	4,839
	Real Estate	96	492	329	1,683
	Information	101	297	239	706
	Other Services	44.9	214	1,488	6,852
	Accommodation and Food Services	34.9	128	1,045	3,690
Biofuels Future	Utilities	27.7	36.0	74.1	96.3
	Construction	20.0	22.6	445	501
	Manufacturing	29.7	20.0	201	165
	Forestry and Agr. Services	5.90	7.32	958	1,179
	Technical Services	5.58	5.69	97.7	98.3
	Real Estate	1.02	3.82	3.72	21.0
	Waste Services	2.24	2.98	26.2	31.7
	Transportation and Warehousing	3.07	2.74	26.4	21.7
	Accommodation and Food Services	0.720	2.56	26.7	83.6
	Information	0.772	1.65	3.74	7.66
Biofuels Future, Out-of-Region	Utilities	2.05	2.66	3.58	4.66
	Health Care	0.063	0.932	0.951	12.5
	Construction	0.659	0.776	8.69	10.2
	Finance and Insurance	0.095	0.671	0.270	2.08
	Technical Services	0.314	0.357	3.28	3.69
	Manufacturing	0.991	0.333	4.24	1.89
	Information	0.087	0.277	0.200	0.664
	Accommodation and Food Services	0.022	0.126	0.689	3.61
	Waste Services	0.028	0.045	0.266	0.687
	Management of Companies	0.058	-0.018	0.161	-0.058

experience positive both value-added and job impacts related to installing fuel delivery infrastructure, building and operating biofuel and biogas production plants, and installing home charging and fueling systems.

The health care and finance/insurance sectors are the two industries generally found to experience the most positive indirect impacts from the CFS, though the ordering changes by scenario. While no direct spending associated with implementing the CFS was initially allocated to these industries in the analysis, indirect benefits take place as households and businesses retain more income (or profit) and invest those dollars elsewhere in the economy. Because health care spending accounts for a substantial proportion of total spending in the region's economy, dollars made available by the CFS will spur further spending in that sector.

The forestry and agricultural services sector has some of the highest job impact rankings, with an estimated range of nearly 19,000 to 23,000 jobs by year 10, as employees in this industry sector support the high level of low carbon fuel production in the region. However, this industry's value-added is not nearly as significantly affected by the CFS. This is likely because this sector involves many of the inputs to biofuel and biogas production, but is a labor-intensive commodity industry with low value-added associated with its products, such as waste biomass. The actual value-added associated with the manufacturing of biofuels and biogas is captured in the manufacturing sector, which ranks higher for value-added.

Estimates of the economic impacts on industries affected by the CFS are not universally positive, as some sectors would be likely to experience a decline in sales revenues. **Table 4-5** below shows the impacts in 2022 (Year 10) for the two industries — retail and wholesale trade — that are estimated to experience net negative value-added and employment impacts as a result of the CFS. The wholesale and retail trade industries directly affected by the program would include fuel wholesalers as well as retail gasoline stations; both would likely experience a decrease in sales as a result of the CFS. However, the negative impacts experienced by the wholesale and retail trade industries would not necessarily be limited to directly affected businesses, such as terminal operators or retail gasoline stations.

Table 4-5. Top Industry Sectors with Negative CFS Impacts (Year 10)

Scenario	Industry	Value Added, 2022 (Million 2010 $s)		Jobs, 2022 (Total)	
		Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Electricity Future	Wholesale Trade	-707	-1,380	-2,930	-5,690
	Retail Trade	-2,270	-4,341	-28,337	-54,077
Natural Gas Future	Wholesale Trade	-432.3	-993	-1,759	-4,050
	Retail Trade	-1,343	-3,045	-16,723	-37,938
Biofuels Future	Wholesale Trade	-399	-1,029	-1,687	-4,277
	Retail Trade	-1,584	-3,375	-19,819	-42,094

The negative impacts to the wholesale and retail trade industries also include indirect effects of the program associated with commodity price changes. The indirect effects begin with a general rise in commodity prices which decreases the purchasing power of households. In the REMI system, a significant part of the household budget is spent on goods and services provided by the retail sector. A part of the negative impacts in **Table 4-5** are accounted for by this decrease in household spending on a broad array of retail goods and services.[60]

In addition, although net impacts on the chemical manufacturing sector are estimated to be net positive as a result of the CFS, within that broad industry classification, the petroleum and coal products manufacturing sub-sector is projected to experience negative impacts on both value-added and jobs. For example, in 2022 (year 10), job losses in petroleum and coal manufacturing are estimated to range from 150 jobs under low oil prices to 560 jobs under high oil prices. In relative terms, however, these losses represent a very small fraction (i.e., one-tenth to one-half of one percent, respectively) relative to the current employment level of 11,000 jobs in the petroleum and coal manufacturing sub-sector.

It is important to note that value-added and employment impacts reported in Section 4.3.1 for the region are inclusive of the negative impacts on the wholesale and retail trade and petroleum and coal manufacturing industries. Despite the negative impacts on these two industry sectors, the net employment and value-added impacts of the CFS are positive overall for the region.

[60]In each of the scenarios, the industries responsible for building and operating new low carbon fuel infrastructure experience a significant increase in demand. Each of these industries, in turn, depends on the services of other industries to operate. When new demand is channeled to these secondary or indirectly impacted industries, as a consequence of supply and demand economics, the price of what the industry produces increases. Because the directly impacted industries are linked to a broad array of industries, when direct spending increases, there is a general increase in prices throughout the economy.

4.4. Results for Five Percent and 15 Percent CFS Reduction Targets

This section compares the macroeconomic impacts — changes in employment, gross regional product, and real disposable personal income — for the 5 percent, 10-year and 15 percent, 15-year scenarios.

The macroeconomic results for the sensitivity cases are generally reflective of the patterns seen in the scenario results described earlier in this report. For example, because of the high CI values for the fuels in the five percent, 10–year scenario, reaching this target requires very high levels of low carbon fuels, and correspondingly high expenditures on fuels and fuel production, infrastructure, and alternative vehicles in spite of its lower CI reduction target. For some macroeconomic metrics, this scenario has as significant or even larger impacts on the regional economy than the 10 and 15 percent scenarios, even though the latter scenarios are estimated to achieve greater GHG reductions.

Similarly, the volumes of low carbon fuels, related expenditures, and fuel production that take place in the NE/MA states are higher in the 15 percent, 15-year scenario. than in the three 10 percent scenarios. As a result, the positive impacts on the regional economy under the 15 percent scenario are, generally speaking, higher whenever fuel volumes are higher as well.

Table 4-6 below presents total jobs generated and retained under the five and 15 percent CI targets evaluated in this analysis during the final year of the program, when the impacts are peaking. Notably, the largest employment impacts in the final year of the program are 76,000 in the five percent scenario under the High Oil Price case, which requires the highest levels of low carbon fuels. This is partly attributable to the fact that this scenario displaces a high level of gasoline and diesel, thereby generating high levels of fuel savings to consumers. Consumers in turn spend these savings on goods and services from relatively labor-intensive industries, which in turn spurs an increase in employment levels.

Table 4-6. Comparison of Employment Impacts for 5 Percent and 15 Percent Scenarios

Scenario or Sensitivity Case	Final Year of Program (2022 or 2027)	
	Low Oil Price	High Oil Price
Jobs Retained and Generated (Total)		
5%, 10 Year Scenario	24,297	76,008
15%, 15 Year Scenario	25,379	56,641

The 15 percent scenario requires less low carbon fuel on an annual basis than the average of the 10 percent scenarios; however, this scenario takes place over a longer timeframe and relative to the 10 percent scenarios, the need for low carbon fuels in the last few years of the program was significantly greater. Higher fuel levels and a longer timeframe are the primary reasons the 15 percent scenario has higher employment impacts than the 10 percent scenarios in some cases.

Table 4-7 compares changes in GRP (summed across all NE/MA states) for all of the scenarios for year 10 of the program, as well as cumulative impacts over the full program time horizon. The 15 percent, 15-year scenario has the highest overall impact on GRP in the final year of the program and cumulatively, ranging from nearly $15 billion to $34 billion, under the Low and High Oil Price cases, respectively. Changes in cumulative GRP for the five percent, 10-year scenario are relatively low, at $4.8 billion to nearly $25 billion under the two reference cases, respectively. This somewhat muted effect on GRP, in spite of high low carbon fuel volumes estimated in this scenario, is probably attributable to the fact that production of fuels in the region is at the lower end of the range in this case, thus overall levels of production are relatively lower in comparison.

Table 4-7. Comparison of Gross Regional Product for 5 Percent and 15 Percent Scenarios

Scenario/Sensitivity Case	Final Year of Program (2022 or 2027)		10- or 15-Year Sum	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Gross State Product (Million 2010 $s)				
5%, 10-Year Scenario	1,567	4,495	4,833	24,764
15%, 15-Year Scenario	3,796	6,624	14,739	33,720

Table 4-8 compares changes in real DPI (summed across all NE/MA states) for all scenarios for year 10 of the program, as well as cumulative impacts over the full program time horizon. Again, the 15 percent scenario is associated with the highest cumulative DPI effects over the full timeframe, ranging from nearly $12 billion to $28 billion in comparison to the two reference cases. The 5 percent scenario shows the next highest cumulative income effect in the High Oil Price case, at $16.0 billion, which probably results from high levels of consumer fuel savings in this case. Under the Low Oil Price case, the average of the 10 percent scenarios has a higher income effect ($5.1 billion) than the 5 percent scenario, because consumer savings are higher.

Table 4-8. Comparison of Real Disposable Personal Income, 5 Percent and 15 Percent Scenarios

Scenario or Sensitivity Case	Final Year of Program (2022 or 2027)		10- or 15-Year Sum	
	Low Oil Price	High Oil Price	Low Oil Price	High Oil Price
Disposable Personal Income (Million 2010 $s)				
5%, 10-Year Scenario	1,041	4,125	2,182	16,069
15%, 15-Year Scenario	2,242	5,645	11,796	27,610

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Appendix A:

Description of the Northeast/Mid-Atlantic Bioenergy Calculator

Appendix A: Description of the Northeast/Mid-Atlantic Bioenergy Calculator

A key objective of the economic analysis of the NE/MA CFS was to assess the potential for biomass resources located in the region to be used in the production of low carbon fuels. In order to estimate low carbon fuel production in the region, NESCAUM developed the NE/MA Bioenergy Calculator.[61] This Appendix provides an overview of the calculator, describes the data and methods used to generate a range of estimates for low carbon fuel production in the region, and explains how these estimates were used in the economic analysis.

A.1. Overview of the NE/MA Bioenergy Calculator

NESCAUM developed the NE/MA Bioenergy Calculator to estimate the potential production of low carbon fuels from biomass resources located in the NE/MA states. The objectives of the calculator were to: (1) assess the types, quantity and distribution of biomass resources across the region; (2) make assumptions about the availability of these resources for the production of low carbon fuels; (3) determine likely conversion technologies for producing fuel and match these technologies to appropriate biomass types; and (4) calculate levels of low carbon fuel production from in-region resources to correspond with policy scenarios represented in the CFS economic analysis.

NESCAUM adapted the New Jersey Bioenergy Calculator created by Rutgers State University/New Jersey Agricultural Experiment Station to catalog the region's biomass endowment and calculate potential low carbon fuel production based on that endowment.[62] Changes to the New Jersey calculator for the purposes of this study included: replacing New Jersey-specific biomass data with those describing biomass resources for each NE/MA state; editing the categories and types of biomass; modifying the filters that screen out biomass type; revising the fuel conversion factors; and adding a new type of low carbon fuel (i.e., biogas, a natural gas substitute). Even with these modifications, however, the calculation methodologies and overall design of the calculators are similar to the Rutgers model.

Biomass feedstocks in the NE/MA calculator are divided into five categories. *Lignocellulosic biomass* includes energy crops, agricultural crop residues, woody biomass and yard waste. *Solid waste* refers to the organic portion of municipal solid waste (MSW), i.e. waste paper, food waste, and wood scraps. *Bio-oils* includes both oil crops (e.g., soybean) and waste grease. *Other waste* includes agricultural livestock waste and wastewater treatment facility (WWTF) biosolids and biogas, as well as methane gas produced from landfill wastes.

[61] Rutgers New Jersey Agricultural Experiment Station (NJAES) (2010). *Bioenergy Calculator.* http://bioenergy.rutgers.edu/biomass-energy-potential/njaes-bioenergy-calculator.xls.
[62] Ibid.

A.2. Data and Methods

Using a variety of data sources to quantify each category of biomass in every NE/MA state, NESCAUM generated low-end and high-end estimates that represent the likely boundaries of annual biomass availability in the region during the ten- to fifteen-year time period (i.e., 2013 to 2027) evaluated in the CFS economic analysis. NESCAUM developed a wide range to reflect the significant uncertainties that will determine actual biomass availability.

As described in Section 2 of this report, the low-end of the range represents a conservative view of biomass availability in the region, where economic, policy, and/or biophysical factors constrain the annual biomass supply to relatively low levels, in comparison to the region's physical endowment levels. The high-end of the range represents a more optimistic depiction of actual biomass supply relative to physical endowment levels. It is important to note that in both the low- and high-end cases, estimates account only for surplus biomass supplies that would be potentially available *in addition to* biomass currently supplied to existing markets (e.g., pulp, paper, and pellet production, existing landfill gas operations).

Annual biomass estimates can be found in each of the state worksheets of the NE/MA Bioenergy Calculator. The state estimates are aggregated in the "NE-11 Availability" worksheet of the calculator. Low-end and high-end annual availability are also calculated in this sheet.

Energy Crops

Energy crop estimates were provided by Dr. Peter Woodbury at Cornell University.[63] The estimates build off state-level estimates of energy crop potential from the U.S. EPA RFS2 Regulatory Impact Analysis.[64] Adjustments to U.S. EPA's estimates include the use of more recent land use and land cover data, and an analytical approach at a finer scale of detail. For example, in the Woodbury estimates, small parcels (less than 5 acres) were generally considered unsuitable for energy crop development. In addition, a regression analysis based on actual crop yields was used to estimate bioenergy feedstock yields. For New York, energy crop data from the New York State Renewable Fuels Roadmap were used.[65]

Because energy crops are currently not grown in significant quantities in the NE/MA region, it was assumed that energy crop production would be zero for the first two years

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[63] Woodbury, Peter (2010). Unpublished estimates of energy crop biomass by state. Cornell University.
[64] U.S. Environmental Protection Agency (EPA) (2010). Regulatory Impact Analysis: Renewable Fuel Standard Program. Retrieved April 23, 2010, from http://www.epa.gov/otaq/renewablefuels/420r07004.pdf.
[65] Pace Law School Energy and Climate Center. (2010). *Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York State.* New York State Energy Research and Development Authority (NYSERDA), the New York State Department of Environmental Conservation (NYSDEC), and the New York State Department of Agriculture and Markets. Retrieved April 4 from http://www.nyserda.org/publications/renewablefuelsroadmap/

of the CFS (i.e., 2013 and 2014) and would ramp-up over the life of the program as producers plant energy crops in response to program incentives.

For the low-end availability case, NESCAUM assumed that 50 percent of the energy crops are available annually for fuel production within the region. In the high-end case, 100 percent was considered to be available for fuel production on an annual basis.

Woody Biomass

Estimates of annual woody biomass availability were derived from a 2008 study conducted by Innovative Natural Resource Solutions, LLC (INRS), as well as other state studies and data.[66] NESCAUM applied initial filters to INRS estimates and assumed that 50 percent of forest residues, sawmill and secondary mill residues, and urban wood and 25 percent of new forest growth could be considered incremental to demand from existing markets. After applying the initial availability filters, for the low-end availability case, it was assumed that 50 percent of the remaining woody biomass resources would be available for fuel production; for the high-end availability case, 100 percent of remaining woody biomass resources were assumed to be available for fuel production.

Agricultural Crop Residues

Agricultural crop estimates were also based on data provided in the 2008 INRS study. It was assumed that 50 percent of agricultural crop residues would remain available after meeting demand in existing markets. In the low-end availability case, it was assumed that 50 percent of the remaining agricultural crop residues would be available for fuel production; for the high-end availability case, 100 percent of the remaining resources were assumed to be available for fuel production.

Municipal Solid Waste (MSW)

Estimates of total MSW destined for landfill by state were based on BioCycle's "The State of Garbage in America."[67] To determine the portion of the waste composed of biomass, U.S. EPA estimates of the average percentage of yard waste, waste paper, food waste, and wood scraps in a unit of MSW were applied to the total MSW quantities.[68] It was assumed that one-half of food waste and wood scraps and one-third of yard waste would be available after increases in composting and other recycling program levels. In the low-end availability case, 50 percent of these MSW resources were assumed to be available for fuel production; for the high-end availability case, 100 percent of resources were directed towards fuel production.

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[66] Innovative Natural Resources Solutions (INRS) LLC (2008). *Biomass Availability and Utilization in the Northeastern United States.* Northeast States for Coordinated Air Use Management.

[67] Simmons, Phil *et al.* (2008). The State Of Garbage In America. *BioCycle: Journal of Composting & Organics Recycling* 49: 22.

[68] U.S. Environmental Protection Agency (EPA) (2010). *Regulatory Impact Analysis: Renewable Fuel Standard Program*. Retrieved April 23, 2010, from http://www.epa.gov/otaq/renewablefuels/420r07004.pdf.

Waste paper recycling rates are assumed to increase over time, thus lowering waste paper availability. In the high-end availability case, recycling rates increase from 70 to 80 percent; in the low-end availability case they increase to 100 percent recycling, and waste paper is not assumed to be available for fuel production.

Waste Grease

Waste grease estimates are based on the Northeast Biomass Regional Program's "U.S. Biofuel Production Potential Calculator."[69] Because waste grease resources are already utilized for fuel production in the NE/MA region, it was assumed that these resources would continue to be available on an annual basis. In the low-end availability case, 50 percent of waste grease was assumed be available for fuel production; for the high-end availability case, 100 percent of resources are directed towards fuel production.

Livestock and Waste Water Treatment Facility (WWTF) Wastes

Livestock waste and bedding calculations were based on U.S. Census Bureau and U.S. Department of Agriculture data. Biosolid and gas quantities from WWTFs were estimated based on population figures from the U.S. Census Bureau. Fifty percent of these resources are assumed to be available after initiatives such as on-site gas capture for electricity production. In the low-end availability case, 50 percent of the remaining waste resources are assumed to be available for fuel production; for the high-end availability case, 100 percent of resources are directed towards fuel production.

Landfill Gas

Estimates of available methane gas from landfills were based on data from U.S. EPA's Landfill Methane Outreach Program.[70] Only 50 percent of the methane that would be produced from existing waste in landfills that U.S. EPA considers to be candidates for new methane capture systems was included in the analysis. It was assumed 25 percent of the methane gas from landfills would be available for fuel production in the low-end availability case and 50 percent would be available for fuel production in the high-end availability case.

A.3. Conversion of Biomass Resources to Low Carbon Fuel

Figure A-1 depicts a range of existing and developing technologies for converting biomass into low carbon fuels of different types. Only those biomass conversion pathways for transportation fuels that could substitute for gasoline and petroleum, and thus could directly benefit from a CFS program, were included in the analysis.[71] Therefore, for the purposes of the CFS economic analysis, available biomass resources were assumed to be used in the production of biofuels or as a substitute for natural gas.

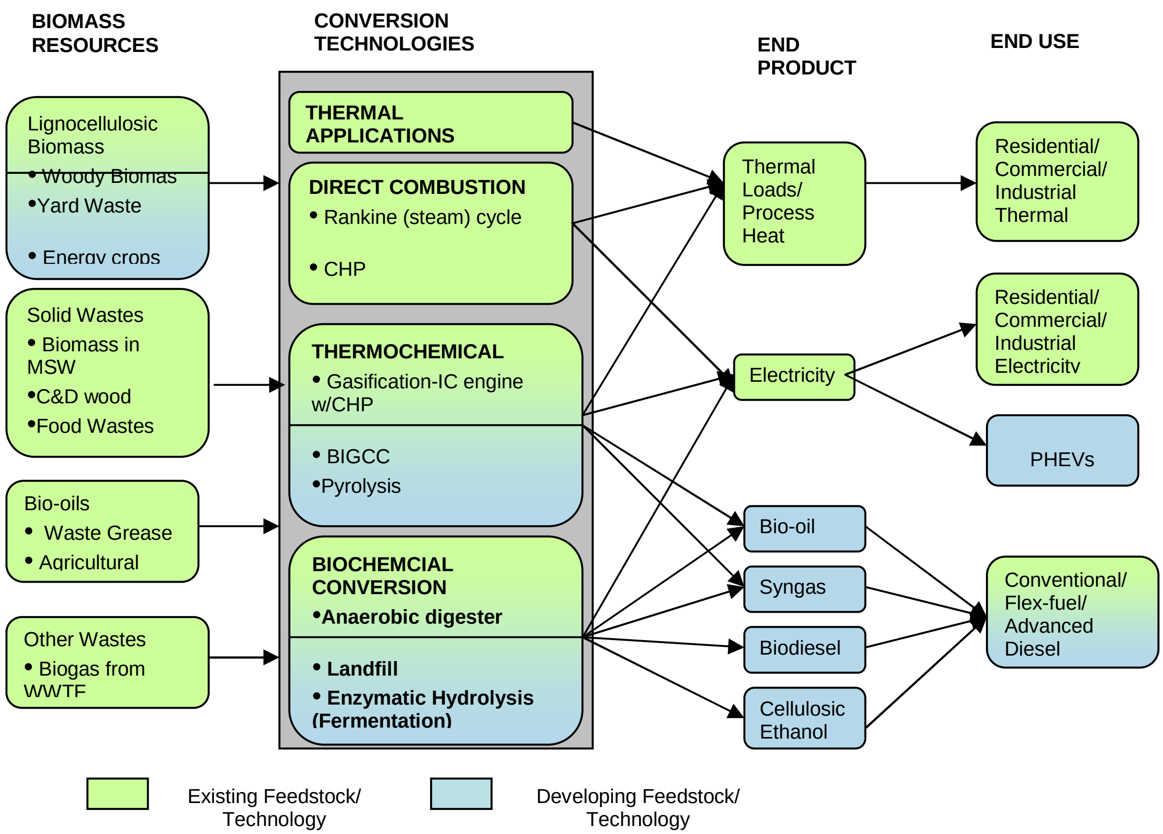
[69] Antares Group, Inc. (2007). *U.S. Biofuel Production Potential.* National Biomass Regional Program. Retrieved July 23, 2010 from http://www.nrbp.org/updates/2007-08/US_Biofuel_Production_Potential.xls.

[70] U.S. Environmental Protection Agency (EPA) (2010-2011). Landfill Methane Outreach Program Landfill and Project Database. Available at http://www.epa.gov/lmop/projects-candidates/index.html

[71] Electricity generation from biomass was not considered as a pathway in the NE/MA economic analysis of the LCFS. Due to numerous policies in the NE/MA states that incentivize electricity generation from biomass (e.g., RGGI, renewable portfolio standards), it is difficult to attribute electricity generation from biomass to an LCFS.

Conversion factors and methodologies used were taken from the New Jersey Bioenergy Calculator, and can be found in the "Conversion Tables" worksheet of the NE/MA Bioenergy Calculator. Conversions from biomass to low carbon fuel are made on each of the state worksheets and aggregated in the "NE-11 Availability" worksheet.

Figure A-1. Existing and Advanced Biomass Conversion Technologies



Source: Adapted from Rutgers New Jersey Agricultural Experiment Station, 2010.[72]

A.4. Role of NE/MA Bioenergy Calculator Results in CFS Economic Analysis

Biomass availability (low or high) for conversion to low carbon fuels was tailored to the three core CFS policy scenarios and to the sensitivity cases in accordance with the design and intent of the scenarios.

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[72] Rutgers New Jersey Agricultural Experiment Station (NJAES) (2007). *Assessment of Biomass Energy Potential in New Jersey*. Prepared for: The New Jersey Board of Public Utilities. Retrieved April 23, 2010 from http://bioenergy.rutgers.edu/biomass-energy-potential/njaes-biomass-assessment-finalreport.pdf

In the Biofuels Future, high biomass availability was assumed for all solid feedstocks for the production of either cellulosic ethanol or Fischer-Tropsch diesel. Biomass resources were allocated at a ratio of 4 to1 for the production of ethanol and diesel, respectively, based on the current ratio of gasoline to diesel sales in the region. Diesel was also assumed to be produced with the available waste grease using trans-esterification conversion technology.

In the Natural Gas Future, high biomass availability was assumed for all feedstocks appropriate for conversion to biogas. Solid wastes with moisture content greater than 50 percent were assumed to be converted to a natural gas substitute using anaerobic digestion. Solid wastes with moisture content less than 50 percent were assumed to be converted using thermal gasification.[73] In both cases, biogas and landfill gas were assumed to be converted into a substitute for natural gas.

In the Electricity Future, low biomass availability was assumed for the production of liquid and gaseous fuels. For the purposes of this analysis, regional biomass resources were not directed towards electricity generation. Due to numerous policies in the NE/MA states that already provide incentives for electricity generation from biomass (e.g., renewable portfolio standards), it would be difficult to credit new biomass-based electricity generation to a CFS.

Table A-1 below summarizes how the assumptions regarding the availability of biomass resources vary by scenario and sensitivity case in the CFS economic analysis.

Table A-1. Bioenergy Assumptions Used in CFS Policy Scenarios

Scenario	Biomass Availability for Biofuel Production	Biomass Availability for Biogas Production
Biofuels Future (10% CFS Target)	High-end for lignocellulosic biomass, solid waste, and waste grease	N/A
Natural Gas Future (10% CFS Target)	Low-end for waste grease	High-end for lignocellulosic, solid waste, and other waste
Electricity Future(10% CFS Target)	Low-end for all biomass categories	N/A
Pessimistic Future (5% CFS Target)	Low-end for lignocellulosic, solid waste, and waste grease	N/A
Optimistic Future (15% CFS Target)	High-end for lignocellulosic biomass, solid waste, and waste grease	High-end for WWTF and landfill gas

[73] The "Energy Content" worksheet in the NE/MA Bioenergy Calculator contains information on the moisture content of each biomass resource.

Appendix B:

Description of VISION-NE Model and Analysis

Appendix B: Description of VISION-NE Model and Analysis

NESCAUM's economic analysis of the NE/MA CFS evaluates three core policy scenarios, each of which depicts compliance with a specified target for the average carbon intensity (CI) of transportation fuels. NESCAUM developed a customized version of the VISION model to calculate the volumes of low carbon fuels and related technologies (e.g., alternative vehicles) needed to meet the target under each of these compliance scenarios. This appendix describes the VISION-NE model and how it was used to generate estimates of low carbon fuel volumes, numbers of alternative vehicles, and the overall change in energy use under each of the three policy scenarios.

B.1. Description of the VISION Model

The VISION model was developed by Argonne National Laboratory to estimate the potential energy use, oil consumption, and carbon emission impacts of advanced light-duty and heavy-duty vehicle technologies.[74] VISION starts with a base-year vehicle fleet, and enables the user to specify sales shares for different vehicle types (e.g., battery-electric vehicles) in subsequent years. The model maintains a detailed annual profile of the fleet as it retires aging vehicles while introducing new vehicles according to user inputs. The model calculates energy demand and projected fuel consumption for each vehicle and fuel type based on vehicle fleet size, vehicle efficiency, and vehicle miles traveled (VMT).

VISION's core methodology is well suited to the needs of the CFS economic analysis due to its ability to model the introduction of new vehicle technologies over time, and determine associated changes in energy use. Many of the alternative vehicle technologies considered in the CFS economic analysis, such as battery-electric and plug-in hybrid vehicles, are included in the original VISION model. Other parameters related to the use or impacts of these technologies, such as vehicle efficiency and fuel price, are highly customizable and able to accommodate the range of assumptions selected for this analysis. NESCAUM made a series of changes to VISION's default assumptions for the purposes of this analysis. In addition, the core capabilities of the VISION model were expanded by integrating a number of CFS-specific calculators. All changes and additions are highlighted and documented within the model's spreadsheet; the most significant of these are described below.

B.2. NESCAUM Modifications to VISION

To accommodate the specific needs of the CFS economic analysis, NESCAUM made numerous changes and additions to the core VISION model; the modified version is hereafter referred to as VISION-NE. VISION contains an approximation of the national vehicle fleet, which was scaled to the 11-state NE/MA region based on gasoline and diesel consumption data from the Energy Information Administration's State Energy Data System (SEDS). Scaling factors from SEDS data were also developed and applied

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[74] The basic VISION model and accompanying documentation are available on the Argonne National Laboratory website. http://www.transportation.anl.gov/modeling_simulation/VISION/

to off-road diesel and No. 2 distillate heating oil. Additional alternative fuel types were made available to certain medium-duty and heavy-duty vehicles, and the model was expanded to account for multiple types of biofuels.

A key addition to the core VISION model is a set of Average Fuel Carbon Intensity (AFCI) calculators which evaluate the overall CI of transportation fuels used in the region for each scenario year from 2013 to 2027. Each AFCI calculator uses CI and energy demand for each fuel type to determine the average CI of the entire regional fuel mix for a single year. To allow greater flexibility in modeling the effects of different vehicle combinations, the calculators were designed to make separate AFCI determinations for the gasoline and diesel sectors.

VISION-NE also includes an array of inputs enabling the user to specify CI for each fuel type. For convenience, input selectors were built to choose between low, default, and high CI values corresponding to reference case and policy scenario assumptions; however, the VISION-NE model can accept any user-specified CI values.

In addition to providing CI inputs for alternative fuels such as electricity and advanced biofuels, VISION-NE accepts alternative values for the CI of petroleum fuels, enabling the user to simulate scenarios where high carbon intensity crude oil plays an increasing role in the regional fuel mix.

B.3. Characterization of CFS Reference Cases

As a prerequisite to assessing the economic impacts that could result from the CFS, VISION-NE was used to determine average fuel CI and total energy use for two reference cases. Each reference case represents a world without the CFS, otherwise known as "business-as-usual," (BAU) and provides a point of comparison for the results of the policy analyses. NESCAUM's economic analysis considers two reference cases to account for key uncertainties about future fossil fuel prices, technology innovation, and other factors. Both reference cases used in the CFS economic analysis reflect the Energy Information Administration's Annual Energy Outlook (AEO) 2010 characterization of the base vehicle fleet, and assume compliance with other existing federal and state policies that affect transportation fuels and vehicles, with a few exceptions.[75]

The Low Oil Price case assumes that gasoline and diesel retain their initial carbon intensity values of 96g/MJ and 94g/MJ, respectively, while the High Oil Price case assumes that increased development of non-conventional petroleum resources causes carbon intensity to rise by 0.5g/MJ in each successive program year.

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[75] EPA's Renewable Fuel Standard (RFS2), California's Low Carbon Fuel Standard, the Regional Greenhouse Gas Initiative (RGGI), the California Zero-Emission Vehicle (ZEV) mandate as adopted in several NE/MA states, federal Corporate Average Fuel Economy (CAFE) standards, and state renewable energy and fuel requirements are included in the reference cases. Compliance with two of these policies varies by reference case; the High Oil Price reference case assumes less than full compliance with the volume requirements for advanced ethanol under EPA's Renewable Fuel Standard (RFS2), and that three times the minimum number of vehicles required under the ZEV standard are sold in the NE/MA region.

To determine the CI impacts of existing policies, calculators were added to project regional sales volumes of biofuels under EPA's Renewable Fuel Standard (RFS2) and electric vehicles under California's Zero Emission Vehicle (ZEV) program, especially as it applies to NE/MA states that have adopted this program under Section 177 of the Clean Air Act. The RFS2 fuel volume calculator assumes a higher demand for advanced biofuels in California due to that state's existing LCFS program, and apportions a throughput-weighted fraction of the remainder to the Northeast/Mid-Atlantic region. The ZEV calculator allows the user to simulate regional sales of battery electric and plug-in hybrid vehicles associated with individual states' adoption of the California ZEV rule.

Based on user inputs for volumes of RFS2 fuels, penetration of ZEV vehicles, and CI of petroleum fuels, VISION-NE calculates annual reference case estimates of: (1) new sales and total stock for each vehicle type; (2) total energy use for each fuel type; and (3) average CI for the gasoline and diesel sectors.

B.4. Characterization of CFS Policy Scenarios

Three policy scenarios were developed, each of which assumed compliance with a specified CI reduction target. Each policy scenario, described in detail in Appendix C, reflects a future in which one of three primary low carbon fuel types (electricity, natural gas, and liquid biofuels) provides a majority (60 percent) of compliance with the specified CFS target. In each scenario, "optimistic" (lower) CI and cost values were assumed for the featured fuel, and "pessimistic" (higher) values for the other two fuels.

To model these scenarios in VISION-NE, CI inputs were modified by assigning a lower value to the featured fuels and a higher value to the other fuels. VISION-NE was then used to calculate the volume of each fuel required to achieve the reduction target for each scenario.

For each program year and fuel sector, the reference case average CI value was compared to the reduction targets to determine the incremental reductions necessary for compliance with the CFS. Each of the three compliance technologies were assigned a share of those reductions, with 60 percent of the difference provided by the dominant low-carbon fuel type and 20 percent each provided by the other two low-carbon fuel types in each year. The VISION-NE fleet share inputs were modified such that the effective CI reduction for each fuel type would match the scenario target in each year.

In addition to the primary scenario characteristics, constraints on sales shares were introduced for specific vehicle types to reflect likely market behavior. Specifically, sales shares for electric vehicles, plug-in hybrids, and CNG vehicles were each constrained such that they could not fall below their proportion in the previous year. In addition, vehicle sales shares were not allowed to fall below their reference-case values. Given that many heavy-duty vehicle types, such as long-haul trucks, are expected to be less compatible with electrification or use of natural gas, the use of electricity as a replacement for diesel was limited to only certain classes of medium-duty vehicles.

Finally, the use of compressed natural gas was limited to medium-duty and select heavy-duty vehicles, such as city transit buses.

Results from VISION-NE are reported on an annual basis, and also aggregated over the duration of the program where appropriate. The process was repeated for each of the three policy scenarios and the results for each were compared to the two reference cases, applying the appropriate CI values for the low carbon fuels in each scenario. **Table B-1** summarizes the key inputs to and outputs from VISION-NE. The inputs listed represent all the modifications to VISION-NE defaults required to replicate the policy scenarios constructed for this analysis.

Table B-1. Key VISION-NE Inputs and Outputs

Inputs	Outputs
- Selected reference case and CFS policy scenario - Reduction target and schedule - Reference carbon intensity values for gasoline and diesel - Carbon intensity values for electricity, conventional natural gas, biogas, and liquid biofuels pathways - Sales share of battery-electric, plug-in hybrid, and CNG vehicles - Energy share of battery electric, plug-in hybrid, and CNG vehicles replacing diesel - Sales volume for each of the liquid biofuels pathways	- Total energy and volume demand for gasoline, diesel, biofuels, natural gas, biogas, and electricity - Vehicle stock and sales for conventional gasoline and diesel vehicles, BEVs, PHEVs, CNGVs - Average fuel carbon intensity and percentage reduction - Scenario carbon dioxide equivalent emissions - Change in gasoline and diesel usage, energy demand, carbon intensity, and carbon dioxide equivalent emissions relative to the reference case

Appendix C:

Summary of Key Assumptions

Table C-1. Electricity Future Scenario – 10% Target, 10 Yrs.		
Category	**Assumptions**	**Source(s)**
Reduction Target in Carbon Intensity (CI)	--10% by 2022	NESCAUM analysis, 2011.
Compliance Contribution by Fuel Type	--60% electricity; 20% natural gas; 20% biofuel	NESCAUM analysis, 2011
General Reference Case	--Interaction with EPA Renewable Fuel Standard 2 (RFS2): -California receives sufficient volumes of cellulosic ethanol to meet its LCFS target -Northeast/Mid-Atlantic (NE/MA) region receives a portion of the remainder based on size of NE/MA fuel market, relative to the US market minus California --Interaction with other reference case policies/programs: -Full compliance with Regional Greenhouse Gas Initiative (RGGI) and state renewable energy requirements; -Full compliance with state biofuel mandates; -Full compliance with California Low Carbon Fuel Standard (LCFS) --Reference Case Biofuels CI: (gCO_2e per megajoule (MJ)): -RFS-compliant cellulosic ethanol: 37.2 gCO_2e/MJ (2013 to 2022); -RFS-compliant advanced ethanol: 46.5 gCO_2e/MJ (2013 to 2022); -RFS biodiesel: 46.0 gCO_2e/MJ (2013 to 2022);	NESCAUM analysis, 2011. RGGI and various state mandates. NESCAUM analysis, 2011. CARB LCFS ISOR, 2009. EPA RFS2 RIA, 2010.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Oil Price Case (Reference Case A)	--Reference Case Fuels CI: (gCO_2e per megajoule (MJ)): -Gasoline: 96.0 gCO_2e/MJ (2013 to 2022); -Diesel: 94.0 gCO_2e/MJ (2013 to 2022)	NESCAUM analysis based on 2009 NESCCAF report, 2011.
	--Projections of energy demand (2013-2022): -Calculated in VISION-NE, based on the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2010	NESCAUM analysis based on EIA AEO and Argonne National Laboratory, 2011.
	--Interaction with other policies/programs: -Full compliance with zero-emission vehicle (ZEV) mandate	CARB ZEV ISOR, 2008.
	-Volumes of advanced ethanol reflect less than full compliance with RFS2 requirements;	EIA AEO, 2010.
	-Volumes of advanced biodiesel reflect full RFS2 compliance	EPA RFS2 RIA, 2010.
	--Prices for Reference Case Fuels (converted to 2010$): -Gasoline: Weighted-average price for all grades, including federal, state, and local taxes; $3.05/gal (2013) to $3.59/gal (2022); -Diesel: Diesel fuel for on-road use, including federal and state taxes; $2.77/gal (2013) to $3.37/gal (2022)	NESCAUM analysis, 2011; EIA AEO, 2010.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
High Oil Price Case (Reference Case B)	--Reference Case Fuels CI (gCO_2e per megajoule (MJ)): -Gasoline: 96.5 gCO_2e/MJ (2013) to 101 gCO_2e/MJ (2022); -Diesel: 94.5 gCO_2e/MJ (2013) to 99.0 gCO_2e/MJ (2022); -Conventional natural gas (natural gas is a Reference Case Fuel in the High Oil Price case for medium- and heavy-duty vehicles): 73.0 gCO_2e/MJ (2013-2022) --Projections of energy demand (2013-2022) -Calculated in VISION-NE based on EIA AEO 2010 High Oil Price Case --Interaction with other policies/programs: -Three times minimum compliance level of zero-emission vehicle (ZEV) mandate -Volumes of advanced ethanol reflect full compliance with RFS2 requirements; -Volumes of advanced biodiesel reflect full RFS2 compliance --Prices for Reference Case Fuels (converted to 2010$): -Gasoline: $3.66/gal (2013) to $5.49/gal (2022); -Diesel: $3.50/gal (2013) to $5.26/gal (2022); -Compressed natural gas: $1.87 (2013) to $1.82 per gallon of gasoline-equivalent (gge) (2022)	NESCAUM analysis, 2011. EIA AEO, 2010. NESCAUM analysis, 2011; EIA AEO, 2010. NESCAUM analysis 2011; CARB ZEV ISOR, 2008. EPA RFS2 RIA, 2010. NESCAUM analysis, 2011; EIA AEO, 2010.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Carbon Fuel Carbon Intensity (CI) Values	--High CI values are applied to all biofuels: -Gasoline substitutes: Waste-based cellulosic ethanol: 37.2 gCO_2e/MJ; Virgin cellulosic ethanol: 37.2 gCO_2e/MJ; RFS-compliant cellulosic ethanol: 37.2 gCO_2e/MJ -Diesel substitutes: Soy-based biodiesel: 70.0 gCO_2e/MJ; --Low CI values are applied to electricity and high CI values are applied to natural gas: -Electricity: 80.5 (2013) to 75.0 gCO_2e/MJ (2022) for 10% of electric vehicle (EV) charging load; 57.0 (2013) to 55.0 gCO_2e/MJ (2022) for 90% of EV charging load -Natural gas: Conventional: 78.0 gCO_2e/MJ (2013-2022)	NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. NESCAUM analysis based on NE-MARKAL, 2011. GREET, 2010. CARB LCFS ISOR, 2009. Lifecycle Associates, 2009.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
NE/MA Bioenergy Availability	--Low-end of biomass availability estimates for NE/MA region applied --Biomass is used exclusively for biofuel production, with production limited by biomass availability --No biogas is used; only conventional natural gas is used	Rutgers Univ./New Jersey Agricultural Extension Service, 2010; USDA 2010; state and other sources for biomass estimates. NESCAUM analysis, 2011. NESCAUM analysis, 2011.
Low Carbon Fuel Production Costs	-- No subsidies included in costs; High Oil Price case feedstock and production costs increased by 45% and 25% respectively above Low Oil Price levels; converted to 2010$ --High-end cost applied to biofuel (converted to 2010$): - Low Oil Price Case (Reference Case A): Waste-based cellulosic ethanol: $2.35/gal.; Virgin cellulosic ethanol: $2.35/gal.; Waste-based biodiesel: $3.42/gal.; Soy-based biodiesel: $2.28/gal.; Cellulosic biodiesel: $3.42/gal; -High Oil Price Case (Reference Case B): Waste-based cellulosic ethanol: $2.95/gal.; Virgin cellulosic ethanol: $2.95/gal.; Waste-based biodiesel: $3.92/gal.; Soy-based biodiesel: $3.15/gal.; Cellulosic biodiesel: $3.92/gal	NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2010. NESCAUM analysis based on EPA RFS2 and EIA AEO, 2011. NESCAUM analysis based on CARB LCFS and EIA AEO, 2011.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Carbon Fuel Production Costs [continued]	--High-end cost for natural gas and low-end cost for electricity: -Compressed natural gas (from thermal gasification or biogas): $1.87 (2013) to $1.82 per gallon of gas-equivalent (gge) (2022); -Electricity: $0.137/kWh (2013) to $0.143/kWh (2022)	EIA AEO, 2010. NESCAUM analysis based on EIA AEO, RTO, and other sources, 2011.
Biofuel Calculations	--Low carbon fuels replace RFS2 fuels when carbon intensity is lower than EPA threshold GHG requirement; lower total volumes of biofuel due to lower CI of CFS fuels --Ethanol blendwall: -Sufficient proportion of fleet can use E15 fuel by 2022; -All volumes greater than E15 blendwall are E85 for use in flex-fuel vehicles (FFV) --Biofuel infrastructure costs for storage, blending, and distribution: -Waste-based ethanol: $0.24/gal.; -Virgin ethanol: $0.24/gal.; -Biodiesel: $0.15/gal.; -E85: $172,000 per 450,000 gal. station --Biofuel vehicle market penetration and costs: -1.14 million FFVs per billion gallons of E85; -$100 incremental FFV cost	NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA E15 waivers, 2010-1. EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2009. NESCAUM analysis based on VISION-NE, 2011. EPA RFS2 RIA, 2010.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Electricity Calculations	--Carbon intensity of electricity for vehicle charging: -High electricity CI applies to 10% of EV charging load; -Low electricity CI applies to 90% of EV charging load	NESCAUM analysis based on industry and utility estimates, 2011.
	--Charging and grid infrastructure needs: -100% of battery electric vehicle (BEV) owners and 25% of plug-in hybrid electric vehicle (PHEV) owners have a Level II home charger; -0.65 Level III public chargers per 1,000 BEVs in 2013, increasing 0.05 per year; -Smart meters used to manage charging (1 for every 3 BEVs), but no new transformers needed	NESCAUM analysis, 2011. Transportation Energy Data Book, 2008. Various utility and industry estimates, 2010.
	--Charging and grid infrastructure costs: -$2,200 per Level II private charger (fully installed); -$92,000 per Level III public charger (fully installed); -$400 per smart meter in 2013; $200 in 2022	NESCAUM analysis based on AeroVironment, Nissan, and utility estimates, 2011.
	--EV attributes and costs: -Attributes: 50% BEVs, 50% PHEVs in the NE/MA region; Heavy-duty vehicles are not electrified; Medium-duty vehicle electrification penetration limited to 10% BEV, 50% PHEV; Gasoline replacement energy economy ratio (EER): 3.0; Diesel replacement EER: 2.7; Approximately 2.4 mi/kWh -Costs: $0 incremental cost per BEV (2013 to 2022); $0 incremental cost per PHEV (2013 to 2022)	NESCAUM analysis based on industry estimates, 2011. CARB LCFS ISOR, 2009. NESCAUM analysis, 2011.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Natural Gas Calculations	--Natural gas fueling infrastructure penetration and costs: -Infrastructure penetration: 1.3 public fueling stations per 1,000 natural gas vehicles (NGV); 180 existing fueling stations upgraded to accept NGV in NE/MA states; 1/3 of NGV owners have a home natural gas charger; -Costs: $373,000 to upgrade an existing CNG fueling station to accept NGV; $1,014,000 per new compressed natural gas (CNG) fueling station; Home natural gas charger: $400 installation and $4,900 capital cost --NGV attributes and costs: -Attributes: Gasoline replacement EER: 1.0; Diesel replacement EER: 0.9; -Costs: $7,000 incremental cost for light-duty NGVs; $30,000 incremental cost for medium-/heavy-duty NGVs	NESCAUM analysis, 2011; based on DOE Transportation Energy Data Book, 2008. NESCAUM analysis, 2011. CARB LCFS ISOR, 2009. “FuelMaker Phill” home charger, available through PlumbersStock.com, 2011. CARB LCFS ISOR, 2009. DOE Alt. Fuels Data Center, 2010. NREL, 2010.

Electricity Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Program Administration	--State government program administration: -$150,000 per full-time state employee (FTE); -4 largest states by fuel consumption require 2 state-level FTEs each (NY, PA, NJ, MA); -2 medium-sized states require 1 state-level FTEs each (MD, CT); -5 smallest states require 0.5 state-level FTEs each (NH, ME, DE, RI, VT); -Regional-level administration requires 3 FTEs until 2017, increasing to 4 thereafter --Regulated entity program administration: -$200,000 per FTE -150 regulated entities; -1 FTE per regulated entity	NESCAUM analysis, 2011.
Value of GHG Emission Reductions	--Social cost of carbon dioxide emissions: -Low-end: $23.87/ton (2013) to $28.87/ton (2022); 3% discount rate -High-end: $106.52/ton (2013 to 2022); 0% discount rate	Interagency Working Group, 2010. Stern Review, 2006.

Table C-2. Natural Gas Future Scenario – 10% Target, 10 Yrs.		
Category	**Assumptions**	**Source(s)**
Reduction Target in Carbon Intensity (CI)	--10% by 2022	NESCAUM analysis, 2011.
Compliance Contribution by Fuel Type	--60% natural gas; 20% electricity; 20% biofuel	NESCAUM analysis, 2011.
General Reference Case	--Interaction with EPA Renewable Fuel Standard 2 (RFS2): -California receives sufficient volumes of cellulosic ethanol to meet its LCFS target -Northeast/Mid-Atlantic (NE/MA) region receives a portion of the remainder based on size of NE/MA fuel market, relative to the US market minus California --Interaction with other reference case policies/programs: -Full compliance with Regional Greenhouse Gas Initiative (RGGI) and state renewable energy requirements; -Full compliance with state biofuel mandates; -Full compliance with California Low Carbon Fuel Standard (LCFS) --Reference Case Biofuels CI: (gCO_2e per megajoule (MJ)): -RFS-compliant cellulosic ethanol: 37.2 gCO_2e/MJ (2013 to 2022); -RFS-compliant advanced ethanol: 46.5 gCO_2e/MJ (2013 to 2022); -RFS biodiesel: 46.0 gCO_2e/MJ (2013 to 2022);	NESCAUM analysis, 2011. RGGI and various state mandates. NESCAUM analysis, 2011. CARB LCFS ISOR, 2009. EPA RFS2 RIA, 2010.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Oil Price Case (Reference Case A)	--Reference Case Fuels CI: (gCO_2e per megajoule (MJ)): -Gasoline: 96.0 gCO_2e/MJ (2013 to 2022); -Diesel: 94.0 gCO_2e/MJ (2013 to 2022)	NESCAUM analysis based on 2009 NESCCAF report, 2011.
	--Projections of energy demand (2013-2022): -Calculated in VISION-NE, based on the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2010	NESCAUM analysis based on EIA AEO and Argonne National Laboratory, 2011.
	--Interaction with other policies/programs: -Full compliance with zero-emission vehicle (ZEV) mandate -Volumes of advanced ethanol reflect less than full compliance with RFS2 requirements; -Volumes of advanced biodiesel reflect full RFS2 compliance	CARB ZEV ISOR, 2008. EIA AEO, 2010. EPA RFS2 RIA, 2010.
	--Prices for Reference Case Fuels (converted to 2010$): -Gasoline: Weighted-average price for all grades, including federal, state, and local taxes; $3.05/gal (2013) to $3.59/gal (2022); -Diesel: Diesel fuel for on-road use, including federal and state taxes; $2.77/gal (2013) to $3.37/gal (2022)	NESCAUM analysis, 2011; EIA AEO, 2010.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
High Oil Price Case (Reference Case B)	--Reference Case Fuels CI (gCO_2e per megajoule (MJ)): -Gasoline: 96.5 gCO_2e/MJ (2013) to 101 gCO_2e/MJ (2022); -Diesel: 94.5 gCO_2e/MJ (2013) to 99.0 gCO_2e/MJ (2022); -Conventional natural gas (natural gas is a Reference Case Fuel in the High Oil Price case for medium- and heavy-duty vehicles): 73.0 gCO_2e/MJ (2013-2022) --Projections of energy demand (2013-2022) -Calculated in VISION-NE based on EIA AEO 2010 High Oil Price Case --Interaction with other policies/programs: -Three times minimum compliance level of zero-emission vehicle (ZEV) mandate -Volumes of advanced ethanol reflect full compliance with RFS2 requirements; -Volumes of advanced biodiesel reflect full RFS2 compliance --Prices for Reference Case Fuels (converted to 2010$): -Gasoline: $3.66/gal (2013) to $5.49/gal (2022); -Diesel: $3.50/gal (2013) to $5.26/gal (2022); -Compressed natural gas: $1.87 (2013) to $1.82 per gallon of gasoline-equivalent (gge) (2022)	NESCAUM analysis based on VISION-NE and other sources, 2011. EIA AEO, 2010. NESCAUM analysis, 2011. EIA AEO, 2010. NESCAUM analysis 2011; CARB ZEV ISOR, 2008. EPA RFS2 RIA, 2010. NESCAUM analysis, 2011; EIA AEO, 2010

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Carbon Fuel Carbon Intensity (CI) Values	--High CI values are applied to all biofuels: -Gasoline substitutes: Waste-based cellulosic ethanol: 37.2 gCO_2e/MJ; Virgin cellulosic ethanol: 37.2 gCO_2e/MJ; RFS-compliant: 37.2 gCO_2e/MJ -Diesel substitutes: Soy-based biodiesel: 70.0 gCO_2e/MJ;	NESCAUM analysis, 2011. EPA RFS2 RIA, 2010.
	--High CI values are applied to electricity and low CI values are applied to natural gas: -Electricity: 80.5 (2013) to 75.0 gCO_2e/MJ (2022) for 50% of electric vehicle (EV); charging load; 57.0 (2013) to 55.0 gCO_2e/MJ (2022) for 50% of EV charging load	NESCAUM analysis based on NE-MARKAL, 2011.
	-Natural gas: Conventional: 68.0 gCO_2e/MJ (2013-2022) Waste-based biogas: 11.0 gCO_2e/MJ (2013-2022) Virgin thermal gasification: 18.0 gCO_2e/MJ (2013-2022)	GREET, 2010. CARB LCFS ISOR, 2009. Lifecycle Associates, 2009.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
NE/MA Bioenergy Availability	--High-end of biomass availability estimates for NE/MA region applied --Biomass is used exclusively for biogas production --Additional reductions beyond biomass availability met with conventional natural gas --Lowest CI fuel available is assumed to be used first (e.g., waste-based biogas is used before biogas from thermal gasification	Rutgers Univ./New Jersey Agricultural Extension Service, 2010; USDA 2010; state and other sources for biomass estimates. NESCAUM analysis, 2011. NESCAUM analysis, 2011. NESCAUM analysis, 2011.
Low Carbon Fuel Production Costs	-- No subsidies included in costs; High Oil Price case feedstock and production costs increased by 45% and 25% respectively from Low Oil Price levels; converted to 2010$ --High-end cost applied to biofuel (converted to 2010$): -Low Oil Price Case (Reference Case A): Waste-based cellulosic ethanol: $2.35/gal.; Virgin cellulosic ethanol: $2.35/gal.; Waste-based biodiesel: $3.42/gal.; Soy-based biodiesel: $2.28/gal.; Cellulosic biodiesel: $3.42/gal; -High Oil Price Case (Reference Case B): Waste-based cellulosic ethanol: $2.95/gal.; Virgin cellulosic ethanol: $2.95/gal.; Waste-based biodiesel: $2.95/gal.; Soy-based biodiesel: $3.15/gal.; Cellulosic biodiesel: $3.92/gal.	NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2010. NESCAUM analysis based on EPA RFS2 and EIA AEO, 2011. NESCAUM analysis based on CARB LCFS and EIA AEO, 2011.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Carbon Fuel Production Costs [continued]	--Low-end cost for natural gas and high-end cost for electricity: -Compressed natural gas: $1.82 (2013) to $1.81 per gallon of gas-equivalent (gge) (2022); -Electricity: $0.18/kWh (2013 to 2022)	EIA AEO, 2010. NESCAUM analysis based on EIA AEO, RTO, and other sources, 2011.
Biofuel Calculations	--Low carbon fuels replace RFS2 fuels when carbon intensity is lower than EPA threshold GHG requirement; lower total volumes of biofuel due to lower CI of CFS fuels --Ethanol blendwall: -Sufficient proportion of fleet can use E15 fuel by 2022; -All volumes greater than E15 blendwall are E85 for use in flex-fuel vehicles (FFV) --Biofuel infrastructure costs for storage, blending, and distribution: -Waste-based ethanol: $0.24/gal.; -Virgin ethanol: $0.24/gal.; -Biodiesel: $0.15/gal.; -E85: $172,000 per 450,000 gal. station --Biofuel vehicle market penetration and costs: -1.14 million FFVs per billion gallons of E85; -$100 incremental FFV cost	NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA E15 waivers, 2010-1. EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2009. NESCAUM analysis based on VISION-NE, 2011. EPA RFS2 RIA, 2010.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Electricity Calculations	--Carbon intensity of electricity for vehicle charging: -High electricity CI applies to 50% of EV charging load; -Low electricity CI applies to 50% of EV charging load	NESCAUM analysis based on industry and utility estimates, 2011.
	--Charging and grid infrastructure needs: -100% of battery electric vehicle (BEV) owners and 1/3 of plug-in hybrid electric vehicle (PHEV) owners have a Level II home charger;	NESCAUM analysis, 2011.
	-0.65 Level III public chargers per 1,000 BEVs in 2013, increasing 0.5 per year;	Transportation Energy Data Book, 2008.
	-1 new 50 kVa ground-level transformer needed for every 10 BEVs	Various utility and industry estimates, 2010.
	--Charging and grid infrastructure costs: -$2,200 per Level II private charger (fully installed); -$92,000 per Level III public charger (fully installed); -$5,000 per 50 kVa transformer	NESCAUM analysis based on AeroVironment, Nissan, and utility estimates, 2011.
	--EV attributes and costs: -Attributes: 50% BEVs, 50% PHEVs in the NE/MA region; Heavy-duty vehicles are not electrified; Medium-duty vehicle electrification penetration limited to 10% BEV, 50% PHEV;	NESCAUM analysis based on industry estimates, 2011.
	Gasoline replacement energy economy ratio (EER): 3.0; Diesel replacement EER: 2.7 Approximately 2.4 mi/kWh	CARB LCFS ISOR, 2009.
	-Costs: $5,000 incremental cost per BEV (2013 to 2022) $0 incremental cost per PHEV (2013 to 2022)	NESCAUM analysis, 2011.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Natural Gas Calculations	--Natural gas fueling infrastructure penetration and costs: -Infrastructure penetration: 1.3 public fueling stations per 1,000 natural gas vehicles (NGV); 180 existing fueling stations upgraded to accept NGV in NE/MA states; 1/3 of NGV owners have a home natural gas charger; -Costs: $373,000 to upgrade an existing CNG fueling station to accept NGV; $1,014,000 per new compressed natural gas (CNG) fueling station; Home natural gas charger: $400 installation and $4,900 capital cost --NGV attributes and costs: -Attributes: Gasoline replacement EER: 1.0; Diesel replacement EER: 0.9; -Costs: $0 incremental cost for light-duty NGVs; $0 incremental cost for medium-/heavy-duty NGVs	NESCAUM analysis, 2011; based on DOE Transportation Energy Data Book, 2008. NESCAUM analysis, 2011. CARB LCFS ISOR, 2009. "FuelMaker Phill" home charger, available through PlumbersStock.com, 2011. . CARB LCFS ISOR, 2009. NESCAUM analysis, 2011.

Natural Gas Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Program Administration	--State government program administration: -$150,000 per full-time state employee (FTE); -4 largest states by fuel consumption require 2 state-level FTEs each (NY, PA, NJ, MA); -2 medium-sized states require 1 state-level FTEs each (MD, CT); -5 smallest states require 0.5 state-level FTEs each (NH, ME, DE, RI, VT); -Regional-level administration requires 3 FTEs until 2017, increasing to 4 thereafter --Regulated entity program administration: -$200,000 per FTE; -150 regulated entities; -1 FTE per regulated entity	NESCAUM analysis, 2011.
Value of GHG Emission Reductions	--Social cost of carbon dioxide emissions: -Low-end: $23.87/ton (2013) to $28.87/ton (2022); 3% discount rate -High-end: $106.52/ton (2013 to 2022); 0% discount rate	Interagency Working Group, 2010. Stern, *et al*, 2006.

Table C-3. Biofuel Future Scenario – 10% Target, 10 Yrs.		
Category	**Assumptions**	**Source(s)**
Reduction Target in Carbon Intensity (CI)	--10% by 2022	NESCAUM analysis, 2011.
Compliance Contribution by Fuel Type	--60% biofuel; 20% electricity; 20% natural gas	NESCAUM analysis, 2011.
General Reference Case	--Interaction with EPA Renewable Fuel Standard 2 (RFS2): -California receives sufficient volumes of cellulosic ethanol to meet its LCFS target -Northeast/Mid-Atlantic (NE/MA) region receives a portion of the remainder based on size of NE/MA fuel market, relative to the US market minus California --Interaction with other policies/programs: -Full compliance with Regional Greenhouse Gas Initiative (RGGI) and state renewable energy requirements; -Full compliance with state biofuel mandates; -Full compliance with California Low Carbon Fuel Standard (LCFS) --Reference Case Biofuels CI: (gCO_2e per megajoule (MJ)): -RFS-compliant cellulosic ethanol: 37.2 gCO_2e/MJ (2013 to 2022); -RFS-compliant advanced ethanol: 46.5 gCO_2e/MJ (2013 to 2022); -RFS biodiesel: 46.0 gCO_2e/MJ (2013 to 2022);	NESCAUM analysis, 2011. RGGI and various state mandates. NESCAUM analysis, 2011. CARB LCFS ISOR, 2009. EPA RFS2 RIA, 2010.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Oil Price Case (Reference Case A)	--Reference Case Fuels CI: (gCO_2e per megajoule (MJ)): -Gasoline: 96.0 gCO_2e/MJ (2013 to 2022); -Diesel: 94.0 gCO_2e/MJ (2013 to 2022)	NESCAUM analysis based on 2009 NESCCAF report, 2011.
	--Projections of energy demand (2013-2022): -Calculated in VISION-NE, based on the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2010	NESCAUM analysis based on EIA AEO and Argonne National Laboratory, 2011.
	--Interaction with other policies/programs: -Full compliance with zero-emission vehicle (ZEV) mandate	CARB ZEV ISOR, 2008.
	-Volumes of advanced ethanol reflect less than full compliance with RFS2 requirements;	EIA AEO, 2010.
	-Volumes of advanced biodiesel reflect full RFS2 compliance	EPA RFS2 RIA, 2010.
	--Prices for Reference Case Fuels (converted to 2010$): -Gasoline: Weighted-average price for all grades, including federal, state, and local taxes; $3.05/gal (2013) to $3.59/gal (2022); -Diesel: Diesel fuel for on-road use, including federal and state taxes; $2.77/gal (2013) to $3.37/gal (2022)	NESCAUM analysis, 2011; EIA AEO, 2010.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
High Oil Price Case (Reference Case B)	--Reference Case Fuels CI (gCO_2e per megajoule (MJ)): -Gasoline: 96.5 gCO_2e/MJ (2013) to 101 gCO_2e/MJ (2022); -Diesel: 94.5 gCO_2e/MJ (2013) to 99.0 gCO_2e/MJ (2022); -Conventional natural gas (natural gas is a Reference Case Fuel in the High Oil Price case for medium- and heavy-duty vehicles): 73.0 gCO_2e/MJ (2013-2022)	NESCAUM analysis, 2011. EIA AEO, 2010.
	--Projections of energy demand (2013-2022) -Calculated in VISION-NE based on EIA AEO 2010 High Oil Price Case	NESCAUM analysis, 2011; EIA AEO, 2010.
	--Interaction with other policies/programs: -Three times minimum compliance level of zero-emission vehicle (ZEV) mandate -Volumes of advanced ethanol reflect full compliance with RFS2 requirements; -Volumes of advanced biodiesel reflect full RFS2 compliance	NESCAUM analysis, 2011; CARB ZEV ISOR, 2008. EPA RFS2 RIA, 2010
	--Prices for Reference Case Fuels (converted to 2010$): -Gasoline: $3.66/gal (2013) to $5.49/gal (2022); -Diesel: $3.50/gal (2013) to $5.26/gal (2022); -Compressed natural gas: $1.87 (2013) to $1.82 per gallon of gasoline-equivalent (gge) (2022)	NESCAUM analysis, 2011; EIA AEO, 2010.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Carbon Fuel Carbon Intensity (CI) Values	--Low CI values are applied to all biofuels: -Gasoline substitutes: Waste-based cellulosic ethanol: -27.0 gCO_2e/MJ; Virgin cellulosic ethanol: -9.0 gCO_2e/MJ; RFS-compliant cellulosic ethanol: -18.0 gCO_2e/MJ -Diesel substitutes: Soy-based biodiesel: 40.0 gCO_2e/MJ; Waste-based cellulosic diesel: 8.0 gCO_2e/MJ; Virgin cellulosic diesel: 27.0 gCO_2e/MJ --High CI values are applied to electricity and natural gas: -Electricity: 80.5 (2013) to 75.0 gCO_2e/MJ (2022) for 50% of electric vehicle (EV) charging load; 57.0 (2013) to 55.0 gCO_2e/MJ (2022) for 50% of EV charging load -Natural gas: Conventional: 78.0 gCO_2e/MJ (2013-2022)	NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. NESCAUM analysis based on NE-MARKAL, 2011. GREET, 2010.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
NE/MA Bioenergy Availability	--High-end of biomass availability estimates for NE/MA region applied --Biomass is used exclusively for liquid biofuels --No biogas is used; only conventional natural gas is used to meet 20% natural gas contribution --Lowest CI fuel available produced in region is assumed to be used first (e.g., waste-based cellulosic ethanol is used before virgin cellulosic ethanol, before RFS ethanol)	Rutgers Univ./New Jersey Agricultural Extension Service, 2010; USDA 2010; state and other sources for biomass estimates. NESCAUM analysis, 2011. NESCAUM analysis, 2011. NESCAUM analysis, 2011.
Low Carbon Fuel Production Costs	--No subsidies included in costs; Reference Case B feedstock and production costs increased by 45% and 25% respectively; converted to 2010$ --Low-end cost applied to biofuel (converted to 2010$): -Low Oil Price Case (Reference Case A): Waste-based cellulosic ethanol: $0.62/gal.; Virgin cellulosic ethanol: $1.35/gal.; Waste-based biodiesel: $3.42/gal.; Soy-based biodiesel: $2.28/gal.; Cellulosic biodiesel: $3.42/gal; -High Oil Price Case (Reference Case B): Waste-based cellulosic ethanol: $0.65/gal.; Virgin cellulosic ethanol: $1.70/gal.; Waste-based biodiesel: $0.65/gal.; Soy-based biodiesel: $3.15/gal.; Cellulosic biodiesel: $3.92/gal.	NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2010. NESCAUM analysis based on EPA RFS2 and EIA AEO, 2011. NESCAUM analysis based on CARB LCFS and EIA AEO, 2011.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Low Carbon Fuel Production Costs [continued]	--High-end cost applied to natural gas and electricity: -Compressed natural gas (from thermal gasification or biogas): $1.87 (2013) to $1.82 per gallon of gas-equivalent (gge) (2022); -Electricity: $0.18/kWh (2013 to 2022)	EIA AEO, 2010. NESCAUM analysis based on EIA AEO, RTO, and other sources, 2011.
Biofuel Calculations	--Low carbon fuels replace RFS2 fuels when carbon intensity is lower than EPA threshold GHG requirement; lower total volumes of biofuel due to lower CI of CFS fuels --Ethanol blendwall: -Sufficient proportion of fleet can use E15 fuel by 2022; -All volumes greater than E15 blendwall are E85 for use in flex-fuel vehicles (FFV) --Biofuel infrastructure costs for storage, blending, and distribution: -Waste-based ethanol: $0.19/gal.; -Virgin ethanol: $0.19/gal.; -Biodiesel: $0.15/gal.; -E85: $172,000 per 450,000 gal. station --Biofuel vehicle market penetration and costs: -1.14 million FFVs per billion gallons of E85; -$0 incremental FFV cost	NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA E15 waivers, 2010-1. EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2009. NESCAUM analysis based on VISION-NE, 2011. NESCAUM analysis, 2011.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Electricity Calculations	--Carbon intensity of electricity for vehicle charging: -High electricity CI applies to 50% of EV charging load; -Low electricity CI applies to 50% of EV charging load	NESCAUM analysis based on industry and utility estimates, 2011.
	--Charging and grid infrastructure needs: -100% of battery electric vehicle (BEV) owners and 1/3 of plug-in hybrid electric vehicle (PHEV) owners have a Level II home charger;	NESCAUM analysis, 2011.
	-0.65 Level III public chargers per 1,000 BEVs in 2013, increasing 0.5 per year;	Transportation Energy Data Book, 2008.
	-1 new 50 kVa ground-level transformer needed for every 10 BEVs	Various utility and industry estimates, 2010.
	--Charging and grid infrastructure costs: -$2,200 per Level II private charger (fully installed); -$92,000 per Level III public charger (fully installed); -$5,000 per 50 kVa transformer	NESCAUM analysis based on AeroVironment, Nissan, and utility estimates, 2011.
	--EV attributes and costs: -Attributes: 50% BEVs, 50% PHEVs in the NE/MA region; Heavy-duty vehicles are not electrified; Medium-duty vehicle electrification penetration limited to 10% BEV, 50% PHEV;	NESCAUM analysis based on industry estimates, 2011.
	Gasoline replacement energy economy ratio (EER): 3.0; Diesel replacement EER: 2.7; Approximately 2.4 mi/kWh	CARB LCFS ISOR, 2009.
	-Costs: $5,000 incremental cost per BEV (2013 to 2022); $0 incremental cost per PHEV (2013 to 2022)	DOE, 2010. NESCAUM analysis, 2011.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Natural Gas Calculations	--Natural gas fueling infrastructure penetration and costs: -Infrastructure penetration: 1.3 public fueling stations per 1,000 natural gas vehicles (NGV); 180 existing fueling stations upgraded to accept NGV in NE/MA states; 1/3 of NGV owners have a home natural gas charger; -Costs: $373,000 to upgrade an existing CNG fueling station to accept NGV; $1,014,000 per new compressed natural gas (CNG) fueling station; Home natural gas charger: $400 installation and $4,900 capital cost --NGV attributes and costs: -Attributes: Gasoline replacement EER: 1.0; Diesel replacement EER: 0.9; -Costs: $7,000 incremental cost for light-duty NGVs; $30,000 incremental cost for medium-/heavy-duty NGVs	NESCAUM analysis, 2011; based on DOE Transportation Energy Data Book, 2008. NESCAUM analysis, 2011. CARB LCFS ISOR, 2009. “FuelMaker Phill” home charger, available through PlumbersStock.com, 2011. CARB LCFS ISOR, 2009. DOE Alt. Fuels Data Center, 2010. NREL, 2010.

Biofuel Future Scenario – 10% Target		
Category	**Assumptions**	**Source(s)**
Program Administration	--State government program administration: -$150,000 per full-time state employee (FTE); -4 largest states by fuel consumption require 2 state-level FTEs each (NY, PA, NJ, MA); -2 medium-sized states require 1 state-level FTEs each (MD, CT); -5 smallest states require 0.5 state-level FTEs each (NH, ME, DE, RI, VT); -Regional-level administration requires 3 FTEs until 2017, increasing to 4 thereafter --Regulated entity program administration: -$200,000 per FTE; -150 regulated entities; -1 FTE per regulated entity	NESCAUM analysis, 2011.
Value of GHG Emission Reductions	--Social cost of carbon dioxide emissions: -Low-end: $23.87/ton (2013) to $28.87/ton (2022); 3% discount rate -High-end: $106.52/ton (2013 to 2022); 0% discount rate	Interagency Working Group, 2010. Stern, *et al*, 2006.

Table C-4. 5% and 15% Target Sensitivity Cases

Sensitivity Case	Assumptions	Source(s)
5% Target; 10 Years (2013-2022);	--5% reduction target in carbon intensity: 33% biofuels; 33% electricity; 33% natural gas	NESCAUM analysis, 2011.
	--High CI values are applied to all biofuels: -Gasoline substitutes: Waste-based cellulosic ethanol: 37.2 gCO_2e/MJ; Virgin cellulosic ethanol: 37.2 gCO_2e/MJ; RFS compliant: 37.2 gCO_2e/MJ -Diesel substitutes: Soy-based biodiesel: 70.0 gCO_2e/MJ	NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. NESCAUM analysis, 2011.
	--High CI values are applied to electricity and natural gas: -Electricity: 80.5 (2013) to 75.0 gCO_2e/MJ (2022) for 50% of electric vehicle (EV) charging load; 57.0 (2013) to 55.0 gCO_2e/MJ (2022) for 50% of EV charging load -Natural gas: Conventional: 78.0 gCO_2e/MJ (2013-2022)	NESCAUM analysis, 2011. NESCAUM analysis based on NE-MARKAL, 2011. GREET, 2010.
	--Low-end of biomass availability estimates for NE/MA region applied	Rutgers University/New Jersey Agricultural Extension Service, 2010; USDA 2010; state and other sources for biomass estimates.
	--Biomass is used exclusively for biofuel production, up to 1/3 threshold	NESCAUM analysis, 2011.

Sensitivity Case	**Assumptions**	**Source(s)**
5% Target; 10 Years (2013-2022);	--No biogas is used; only conventional natural gas is used to meet natural gas contribution	NESCAUM analysis, 2011.
	--High-end cost applied to biofuel (converted to 2010$): -Reference Case A (Low Oil Price Case): Waste-based cellulosic ethanol: $2.35/gal.; Virgin cellulosic ethanol: $2.35/gal.; Waste-based biodiesel: $3.42/gal.;	EPA RFS RIA, 2010. CARB LCFS ISOR, 2009.
	-Reference Case B (High Oil Price Case): Waste-based cellulosic ethanol: $2.95/gal.; Virgin cellulosic ethanol: $2.95/gal.; Waste-based biodiesel: $2.95/gal.;	NESCAUM analysis based on EPA RFS2 and EIA AEO, 2011. NESCAUM analysis based on CARB LCFS and EIA AEO, 2011.
	--High-end cost for electricity: -Electricity: $0.18/kWh (2013 to 2022)	NESCAUM analysis based on EIA AEO, RTO, and other sources, 2011.
	--Biofuel infrastructure costs for storage, blending, and distribution: -Waste-based ethanol: $0.24/gal.; -Virgin ethanol: $0.24/gal.	EPA RFS2 RIA, 2010.
	--Biofuel vehicle market penetration and costs: -$100 incremental FFV cost	EPA RFS2 RIA, 2010.
	--Carbon intensity of electricity for vehicle charging: -High electricity CI applies to 50% of EV charging load; -Low electricity CI applies to 50% of EV charging load	NESCAUM analysis based on industry and utility estimates, 2011.

Sensitivity Case	Assumptions	Source(s)
5% Target; 10 Years (2013-2022);	--Charging and grid infrastructure needs: -100% of battery electric vehicle (BEV) owners and 1/3 of plug-in hybrid electric vehicle (PHEV) owners have a Level II home charger; -0.65 Level III public chargers per 1,000 BEVs in 2013, increased 0.5 per year; -1 new 50 kVa ground-level transformer needed for every 10 BEVs --EV attributes and costs: -Costs: $5,000 incremental cost per BEV (2013 to 2022); --NGV attributes and costs: -Costs: $7,000 incremental cost for lighty-duty NGVs; $30,000 incremental cost for medium-/heavy-duty NGVs	NESCAUM analysis, 2011. Transportation Energy Data Book, 2008. Various utility and industry estimates, 2010. NESCAUM analysis based on AeroVironment, Nissan, and utility estimates, 2011. DOE Alt. Fuels Data Center, 2010. NREL, 2010.
15% Target; 15 Years (2013-2027);	--15% reduction target in carbon intensity: 33% biofuel; 33% electricity; 33% natural gas --Prices for Reference Case A Fuels (converted to 2010$): -Gasoline: $3.05/gal (2013) to $3.74/gal (2027) -Diesel: $2.77/gal (2013) to $3.49/gal (2027) --Prices for Reference Case B Fuels (converted to 2010$): -Gasoline $3.66/gal (2013) to $5.63/gal (2027) -Diesel: $3.50/gal (2013) to $5.50/gal (2027)	NESCAUM analysis, 2011. NESCAUM analysis based on EIA AEO, 2011. NESCAUM analysis based on EIA AEO, 2011.

Sensitivity Case	Assumptions	Source(s)
15% Target; 15 Years (2013-2027); "Optimistic" Scenario	--Low CI values are applied to all biofuels: -Gasoline substitutes: Waste-based cellulosic ethanol: -27.0 gCO_2e/MJ; Virgin cellulosic ethanol: -9.0 gCO_2e/MJ; RFS compliant: 37.2 gCO_2e/MJ -Diesel substitutes: Soy-based biodiesel: 40.0 gCO_2e/MJ Waste-based cellulosic diesel: 8.0 gCO_2e/MJ Virgin cellulosic diesel: 27.0 gCO_2e/MJ --Low CI values are applied to electricity and natural gas: -Electricity: 80.5 (2013) to 75.0 gCO_2e/MJ (2018-2027) for 90% of electric vehicle (EV) charging load; 57.0 (2013) to 55.0 gCO_2e/MJ (2018-2027) for 10% of EV charging load -Natural gas: Conventional: 68.0 gCO_2e/MJ (2013-2027) Waste-based biogas: 11.0 gCO_2e/MJ (2013-2027) Virgin thermally gasified 18.0 gCO_2e/MJ (2013-2027) --High-end of biomass availability estimates for NE/MA region applied: -Biomass is used for biofuel and biogas production, split evenly and limited by 33% threshold or biomass availability	NESCAUM analysis, 2011. EPA RFS2 RIA, 2010. NESCAUM analysis based on NE-MARKAL, 2011. GREET, 2010. CARB LCFS ISOR, 2009. Lifecycle Associates, 2009. New Jersey Agricultural Extension Service, 2010; USDA 2010; state and other sources for biomass estimates. NESCAUM analysis, 2011.

Sensitivity Case	**Assumptions**	**Source(s)**
15% Target; 15 Years (2013-2027);	--Low-end cost applied to biofuel (converted to 2010$): -Low Oil Price Case (Reference Case A): Waste-based cellulosic ethanol: $0.62/gal.; Virgin cellulosic ethanol: $1.35/gal.; Waste-based biodiesel: $3.42/gal.; -High Oil Price Case (Reference Case B): Waste-based cellulosic ethanol: $0.65/gal.; Virgin cellulosic ethanol: $1.70/gal.; Waste-based biodiesel: $0.65/gal.; --Low-end cost for electricity: -Electricity: $0.137/kWh (2013) to $0.146/kWh (2027) --Biofuel infrastructure costs for storage, blending, and distribution: -Waste-based ethanol: $0.19/gal.; -Virgin ethanol: $0.19/gal. --Biofuel vehicle market penetration and costs: -$100 incremental FFV cost from 2013-2022; --Carbon intensity of electricity for vehicle charging: -High electricity CI applies to 10% of EV charging load; -Low electricity CI applies to 90% of EV charging load	EPA RFS2 RIA, 2010. CARB LCFS ISOR, 2009. NESCAUM analysis based on EPA RFS2 and EIA AEO, 2011. NESCAUM analysis based on CARB LCFS and EIA AEO, 2011. NESCAUM analysis based on EIA AEO, RTO, and other sources, 2011. EPA RFS2 RIA, 2010. NESCAUM analysis, 2010. NESCAUM analysis based on industry and utility estimates, 2011.

Sensitivity Case	Assumptions	Source(s)
15% Target; 15 Years (2013-2027); “Optimistic” Scenario	--Charging and grid infrastructure needs: -100% of battery electric vehicle (BEV) owners and 1/3 of plug-in hybrid electric vehicle (PHEV) owners have a Level II home charger; -0.65 Level III public chargers per 1,000 BEVs in 2013, increased 0.5 per year; -1 new 50 kVa ground-level transformer needed for every 10 BEVs --EV attributes and costs: -Costs: $5,0000 incremental cost per BEV (2013 to 2022); $0 incremental cost per BEV after 2022 --NGV attributes and costs: -Costs: $7,000 incremental cost for light-duty NGVs; $30,000 incremental cost for medium-/heavy-duty NGVs; $0 per NGV after 2022	NESCAUM analysis, 2011. Transportation Energy Data Book, 2008. Various utility and industry estimates, 2010. DOE, 2010. NESCAUM analysis, 2011. NESCAUM analysis, 2011. NESCAUM analysis, 2011.
10% Target; 10 Years (2013-2022); No biofuel production in NE/MA states	--10% reduction target in carbon intensity: 60% biofuel; 20% electricity; 20% natural gas -- 2/3 of biofuel distribution costs occur in NE/MA region --Biofuel Production Costs equal to those in biofuels future --50% of out-of-region biofuels are virgin, 50% waste-based --Out-of-region biofuels have same CI as biofuels future, -18 gCO_2e/MJ	NESCAUM analysis, 2011. NESCAUM analysis, 2011. NESCAUM analysis, 2011. EPA RFS2 RIA, 2010.