Economic Analysis of the Northeast/Mid-Atlantic Low Carbon Fuel Standard: Draft Data and Assumptions, Parts I and II

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LCFS Stakeholder Webinar

August 12, 2010

Outline of Presentation

I. Background: Economic Analysis of the Northeast/Mid-Atlantic Low Carbon Fuel Standard (NE/MA LCFS)
- Objectives
- Key steps
- Data and Methods

II. Reference Case Scenarios
- Definition of Reference Cases A and B
- Data and Assumptions for Reference Cases

III. NE/MA LCFS Policy Scenarios
- Definition of LCFS Policy Scenarios
- Key Assumptions for LCFS Policy Scenarios

IV. NE/MA LCFS Benefits Analysis

V. Estimating NE/MA Production of Low Carbon Fuels

VI. Analysis of NE/MA Regional Economic Impacts

VII. Next Steps

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Objectives of the Northeast/Mid-Atlantic LCFS Economic Analysis

Key objectives for the economic analysis of the Northeast/Mid-Atlantic LCFS (NE/MA LCFS) include the following:

- Estimate relative magnitude of potential costs and benefits resulting from LCFS implementation
- Understand which variables and parameters have the most influence on the costs, benefits, and overall impacts of the program
- Identify key issues and tradeoffs of policy options for LCFS decision-makers
- Provide stakeholders with opportunities for review and input
- Adhere to "best practices" in regulatory economic analysis

The LCFS Economic Analysis is:

- Not intended to be a forecast of future economic conditions or the likelihood of any policy outcome;
- Not intended to limit possible policy options available to decision-makers.

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Key Steps in the NE/MA LCFS Economic Analysis

Key steps and revised schedule for the NE/MA LCFS Economic Analysis:

1. Characterize Reference Cases and NE/MA LCFS Policy Scenarios (April)
2. Release and Solicit Public Comments: Draft Data and Assumptions, Part I (April-May)
3. Generate NE/MA LCFS Compliance Scenarios (May-June)
4. Release and Solicit Public Comments: Draft Data and Assumptions, Part II (Aug.)
5. Calculate Aggregate Cost and Benefit Results (Sep.-Oct.)
6. Estimate Regional Economic Impacts (Oct.)

Data

Our analysis relies primarily upon reports and databases which have undergone peer-review and/or public review process wherever possible.

- Costs and timing of deployment of emerging fuels and technologies
  - Highly uncertain, not reflected in literature and public domain yet

- We have sought additional information from stakeholders on the following data needs:
  - Production costs of emerging low-carbon fuels (especially MSW-derived fuels);
  - Estimates of baseline rates of technology deployment
  - Costs of related infrastructure (especially EV infrastructure)

- Key data sources include:
  - US EPA's *Regulatory Impact Analysis* of the Renewable Fuel Standard 2
  - California Air Resources Board (CARB)'s *Initial Statement of Reasons* for CA LCFS
  - Energy Information Administration's *Annual Energy Outlook 2010*
  - National Renewable Energy Lab estimates
  - Industry and state estimates
  - Peer-reviewed journal articles

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1. Characterizing the Reference Case(s). The "reference case" is an estimate of what the future might look like in the absence of a regional LCFS, to be used as a basis of comparison for the results of scenarios that characterize the low carbon fuel policy;

- Not a "prediction" of the future, but rather a plausible expectation based on recent trends.
- Includes existing policies, as well as those judged to be "reasonably certain or expected." Relevant policies defined to include federal, regional, and state programs that likely to affect the volume and characteristics of transportation fuels, related infrastructure, and/or vehicles.
- An alternative reference case (Ref Case B) is used to depict a future with higher rate of economic growth and consequently, higher fuel demand and prices.

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2. Characterizing the NE/MA LCFS Policy Scenarios.

The proposed NE/MA LCFS policy scenarios are designed to depict the incremental impacts of the program relative to the reference cases, or "world without the regional LCFS."

- Goal of LCFS: spur faster development of highly uncertain emerging technologies;
- Scenarios are not forecasts; rather "what if" depictions designed to meet the following objectives:
  - Meet a 10% reduction in carbon intensity of transportation fuels over 10 years
  - Capture a broad range of possibilities and uncertainties about the future:
    - Rates of innovation and commercialization of low carbon fuels & technologies
    - Costs of future low carbon fuels and infrastructure
    - Consumer preferences and market penetration
    - General economic conditions
- Recognize the technology-forcing role of LCFS as a performance standard;
- Address interests of multiple stakeholders with diverse concerns; and
- Provide policy insights within given resources and schedule.

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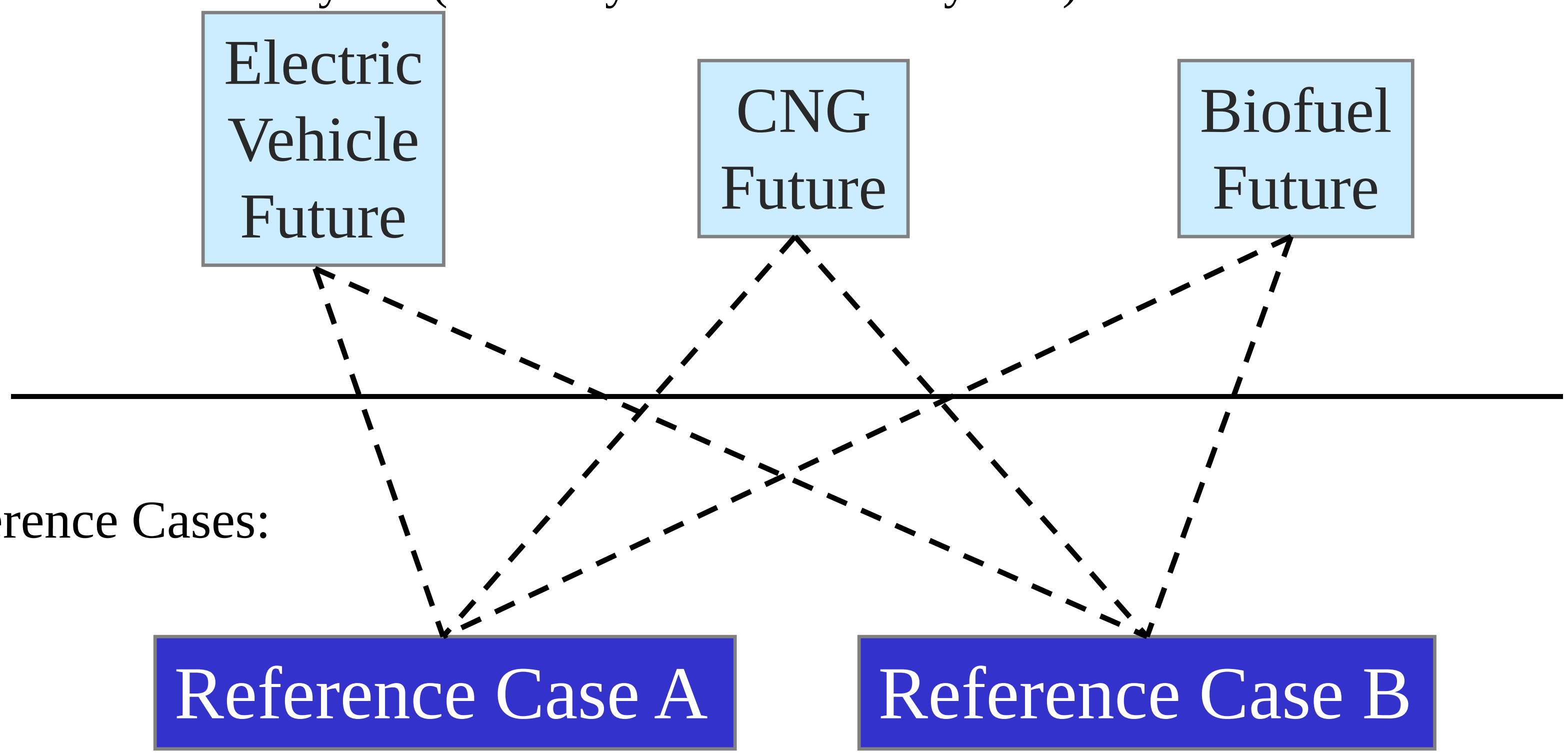
Results from the 3 core policy scenarios will be compared to each reference case to understand the incremental impacts of the program.

Policy Scenarios: Start date for all 3 Policy Cases is 2013. Timeframe is 10 years (with 15 years as sensitivity case).



Reference Cases:

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3. Assessing LCFS Costs.

- First: Calculate incremental costs associated with regional LCFS by calculating volumes of different low carbon fuels required to meet a 10% LCFS target over 10 years.
  - NE-GREET used to determine various fuels contribution to reductions in carbon intensity (CI) below baseline
  - NE-VISION used to determine fuel volumes required at different CI levels
- Second: Calculate the cost of incremental fuels needed to meet the 10% standard using a range (i.e., low- and high-end) of projected unit costs (i.e., per gallon gasoline equivalent) for low carbon fuels;
- Third: Calculate infrastructure and program costs using reasonable formulas (e.g., driven by volume of fuels, other cost drivers).

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3. Assessing LCFS Costs. Categories of costs that will be addressed in the analysis include:

- Costs of Low Carbon Fuel Production:
  - Advanced ethanol and biodiesel
  - Electricity for PHEV/EVs
  - CNG
- Costs of Related Fuel Infrastructure:
  - Blending infrastructure
  - Delivery infrastructure (e.g., E85 delivery, CNG stations)
  - PHEV/EV infrastructure (e.g., charging stations)
- Costs of Program Implementation and Enforcement:
  - Reporting costs (to industry)
  - Program implementation and enforcement costs (to states)
- Costs of Vehicles Using Low Carbon Fuel:
  - Incremental vehicle costs

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4. Assessing LCFS Benefits.

- The LCFS benefits assessment will estimate and quantify GHG reductions anticipated from a 10% reduction in carbon intensity in transportation fuels.
  - Range of values from published GHG literature used to evaluate GHG reductions.

- Benefit categories quantified and monetized, using appropriate values from published literature, when possible:
  - Net reductions in criteria pollutants
  - Economic impacts of regional production of low carbon fuels

- Other benefit categories addressed qualitatively
  - Increase in rate of innovation
  - Potential reduction in fuel price volatility

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5. Accounting for uncertainties through sensitivity analysis.

Goal: Not to forecast a specific set of outcomes, but to capture a range of uncertainties about the future and generate useful insights for policymaking;

- Costs and timing of deployment of emerging fuels and technologies highly uncertain, not reflected in literature yet;
- Sensitivity analyses focus on variables expected to have the most significant influence on results:
  - Costs and available volumes of baseline fuels
  - Costs and rate of innovation/market penetration of low carbon fuels
  - Carbon intensity (g CO_2e/MJ) of low carbon fuels

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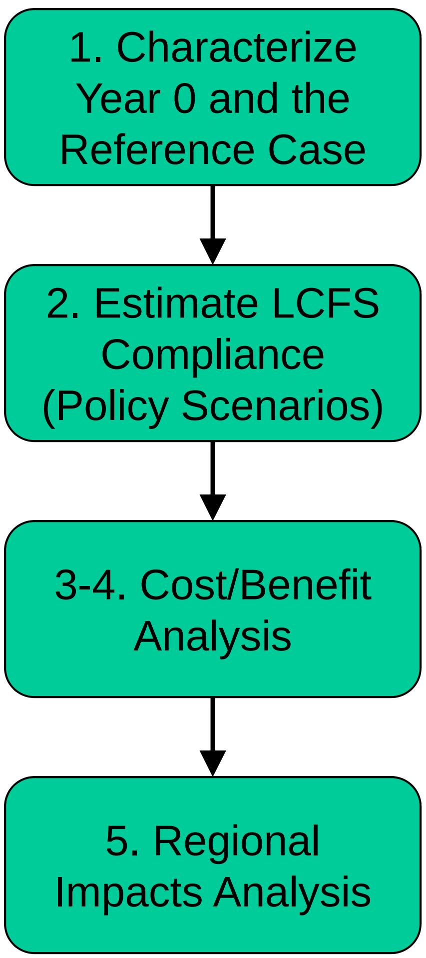
6. Transparency. An analysis that strives for maximum clarity and transparency will have greater credibility.

- In accordance with best practices in economic analysis, the analysis will:
  - Provide sufficient opportunities for stakeholder review
  - Present full range of uncertainties evaluated and their influence on results
  - Avoid overly technical language
  - Provide detailed documentation of methods, assumptions, and data

- Detailed documentation provided to describe the analysis:
  - This presentation (key assumptions)
  - Supporting spreadsheets (detailed data)

Flowchart of Economic Analysis

Steps in Analysis:



Key Data and Assumptions for Steps:

Table 1A-B: Reference case liquid fuels consumption
Table 1C: Reference case electricity price and demand
Table 2: Existing low carbon fuel infrastructure
Table 3A: State biodiesel mandates
Table 3B: State renewable portfolio standards
Table 4A-B: Reference case EVs and CNG

Table 5: Northeast/Mid-Atlantic biomass availability
Table 6: Northeast/Mid-Atlantic bioenergy calculator
Table 9: VISION transportation energy demand model
Table 10: Carbon intensity values

Table 5: Northeast/Mid-Atlantic biomass availability
Table 6: Northeast/Mid-Atlantic bioenergy calculator
Table 7A-B: Low-carbon fuel production costs
Table 9: VISION-NE

Table 5: Northeast/Mid-Atlantic biomass availability
Table 6: Northeast/Mid-Atlantic bioenergy calculator
Table 8: Capital costs for low carbon fuel production
Table 15: REMI reference case summary data
Table 16: Gasoline and diesel tax rates

II. NE/MA LCFS Reference Cases: Draft Data and Assumptions

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Summary of Changes to Part I, Data and Assumptions

- We received 15 public comments on our Part I, draft data and assumptions, released in April;
- Comments were submitted by 26 different stakeholders, and are available at: www.nescaum.org;
- Key changes and additions based on public comments include:
  - Updated Reference Case with AEO 2010 fuel price and demand data;
  - Added costs and scaling factors for fuel delivery infrastructure;
  - Added Reference Case estimates of advanced fuel and technology deployment;
  - Added detailed assumptions for core policy scenarios;
  - Added CI values for advanced fuels and Ref Case electricity; simplified CI values for natural gas;
  - Changed start of compliance period from 2012 to 2013;
  - Added methods for regional biomass and biofuel production; and
  - Added methods and approach for REMI analysis.

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Definition of Reference Case A

- The reference case represents "the world without the NE/MA LCFS," and form the basis for comparison with the results of the scenarios depicting the policy's impacts;
- Reference Case A, (or Ref Case A) uses the Energy Information Administration's *Annual Energy Outlook 2010* reference case price projections for baseline fuels, and corresponding energy demand/fuel volumes and levels of economic growth;
- Also assumes full compliance with existing state, regional, and federal policies (e.g., RGGI, RPS, CAFE);
- Assumes some proportion of low carbon advanced biofuels resulting from RFS2 will be used for compliance with CA LCFS.

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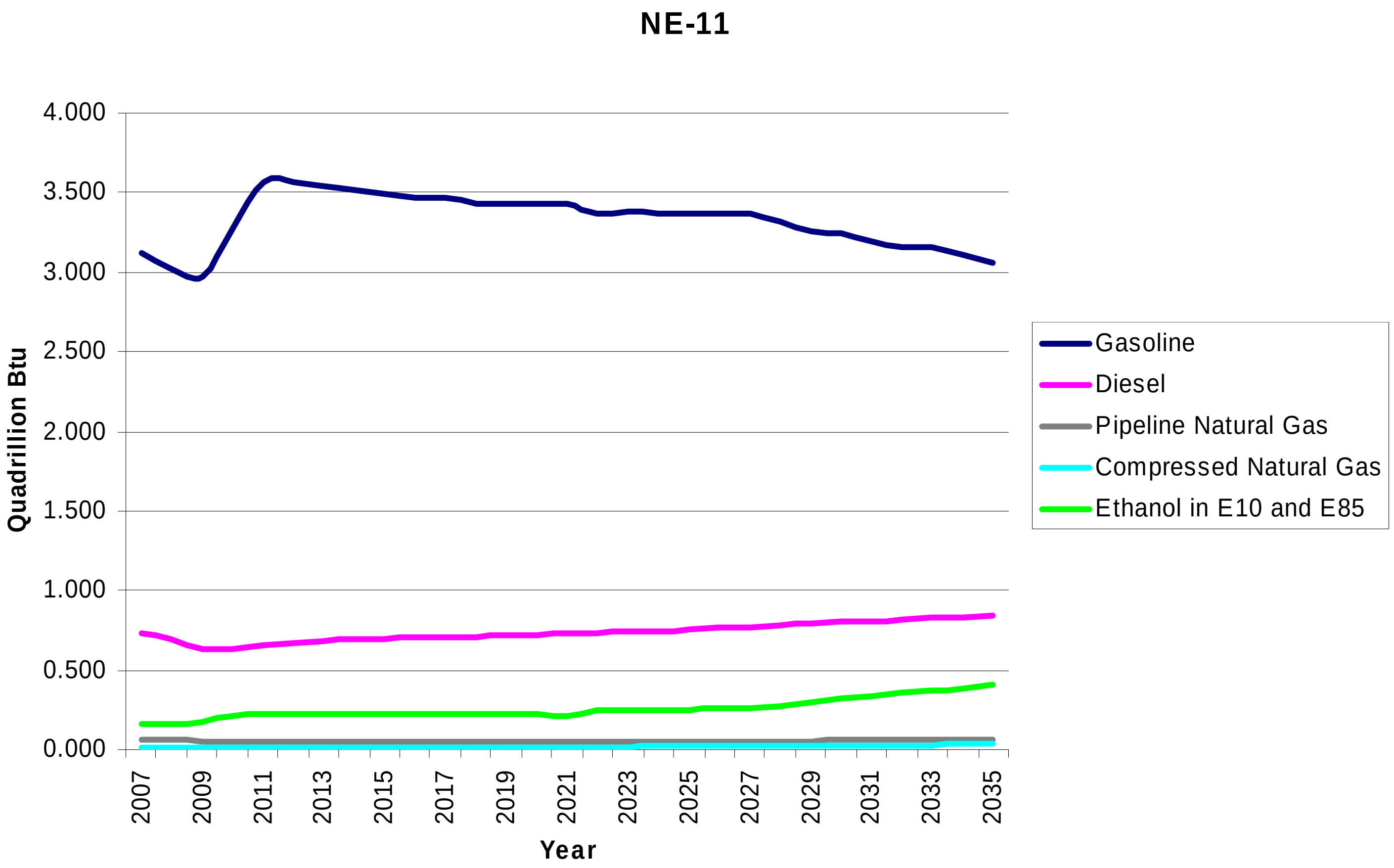
Ref Case A: Demand for Transportation Fuels



Source: Energy Information Administration, Annual Energy Outlook 2010.

•For full detail, see supporting spreadsheets: Table 1A,1C - Reference A Fuels

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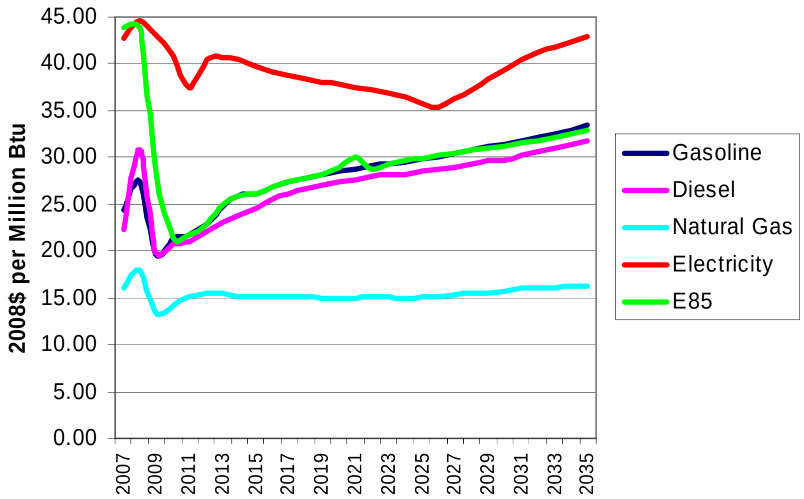
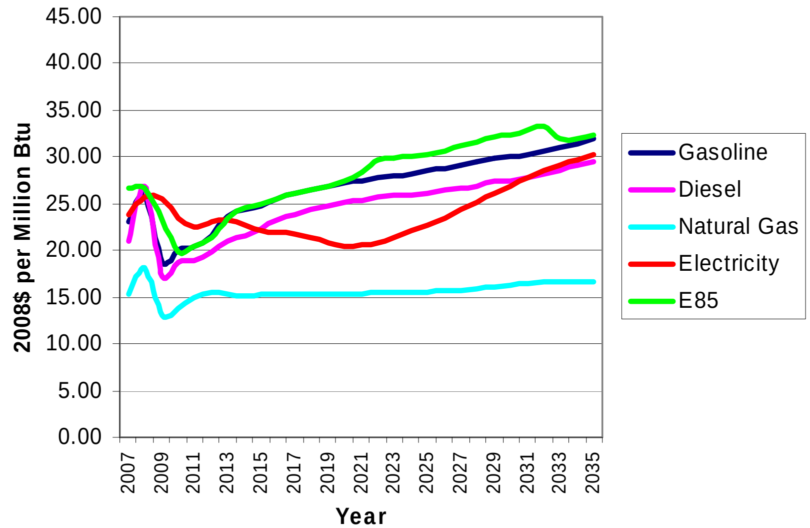
Ref Case A: Baseline Fuel Prices

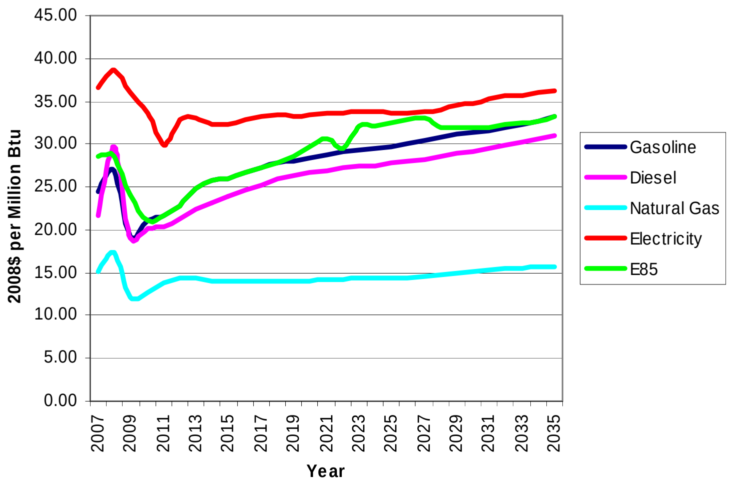
New England



South Atlantic



Mid-Atlantic



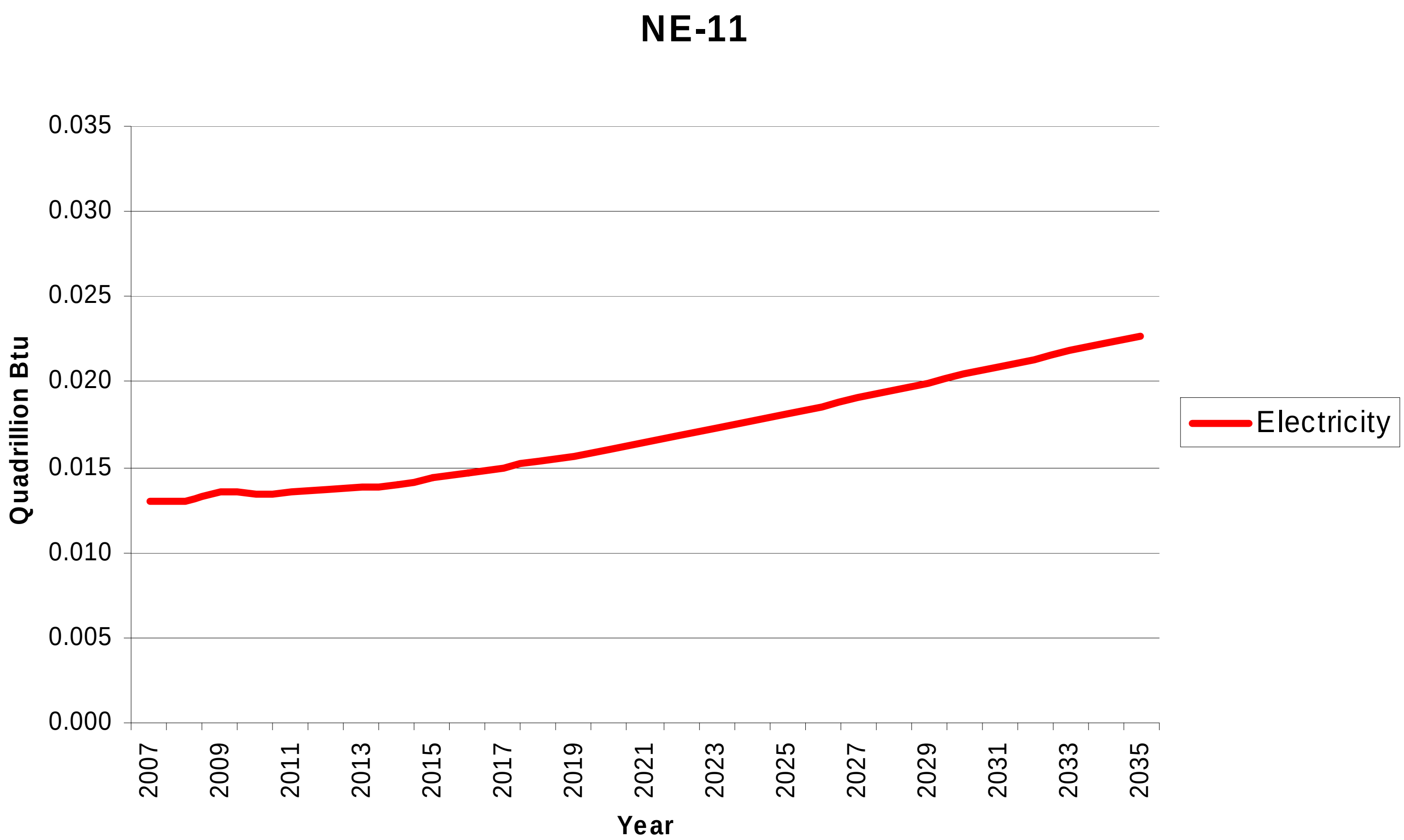
Key AEO Assumptions for Ref Case A:

- Near to mid-term prices are due to current practices, politics, and availability;
- Long term prices largely due to economic forces;
- Higher price levels will come from future, higher exploration and production costs from non-OPEC producers.

Source: Energy Information Administration, Annual Energy Outlook 2010.

•For full detail, see supporting spreadsheets: Table 1A - Reference A Fuels

Ref Case A: Baseline Electricity Demand



For full detail, see supporting spreadsheet: Table 1C – Reference A/B Electricity

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Definition of Reference Case B

- We add a second reference case, Ref Case B, to account for uncertainties in future economic conditions, fuel prices, etc.

- Key Assumptions of Ref Case B include:
  - *Annual Energy Outlook 2010* high price projections for baseline fuels, and corresponding higher energy demand/fuel volumes and levels of economic growth;
  - Higher fuel prices will result in greater development of higher carbon petroleum resources than REF A;
  - Full compliance with existing state, regional, and federal policies (e.g., RGGI, RPS, CAFE);
  - Higher proportion of low CI fuels resulting from RFS2 will be used to meet CA LCFS than in REF A.

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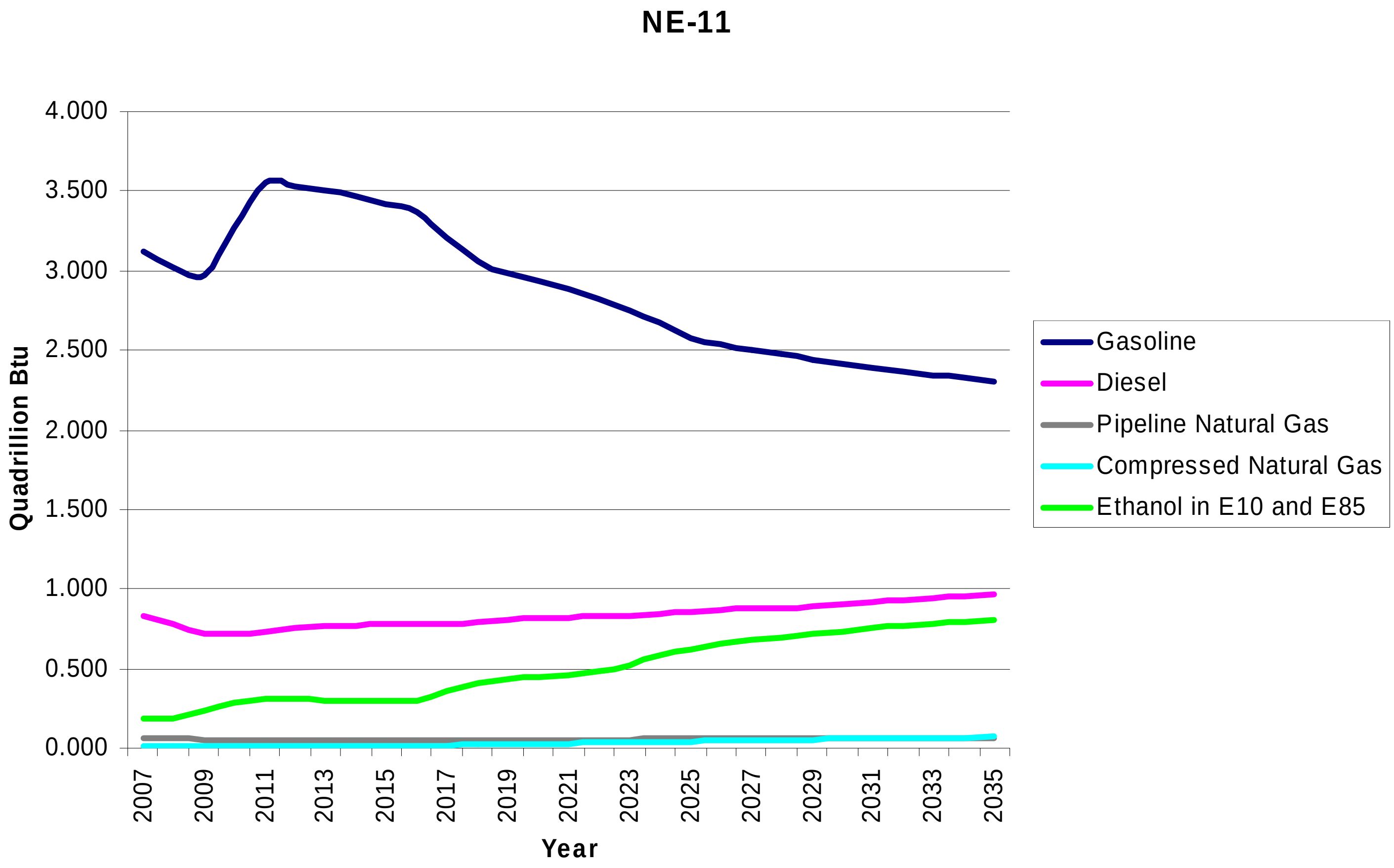
Reference Case B: Baseline Fuel Demand



Source: Energy Information Administration, Annual Energy Outlook 2010.

•For full detail, see supporting spreadsheets: Table 1B—Reference B Fuels

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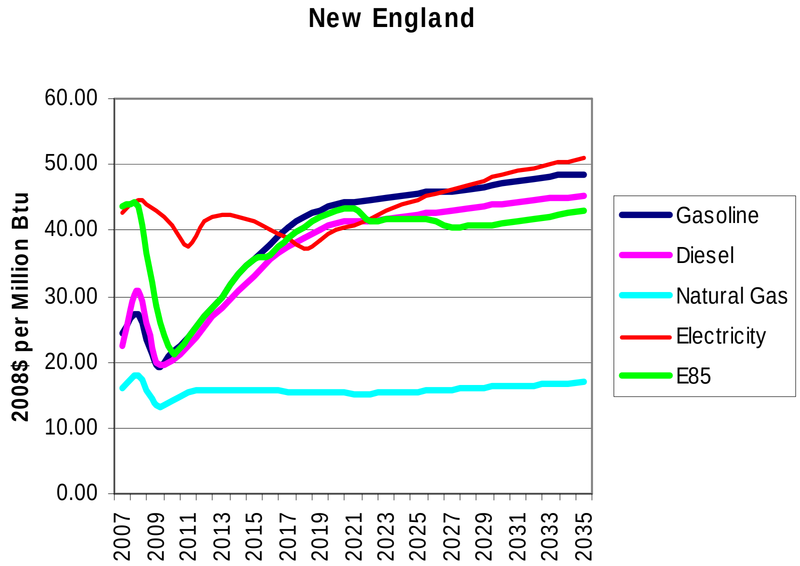
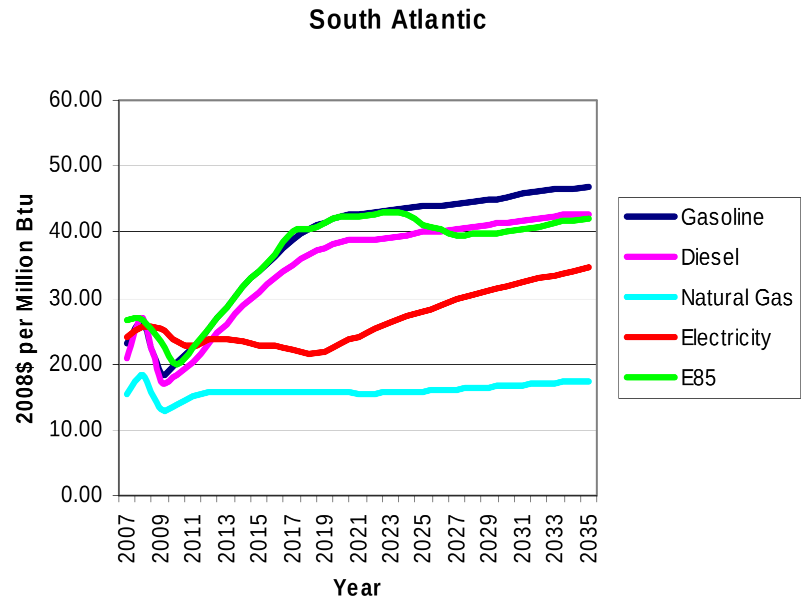
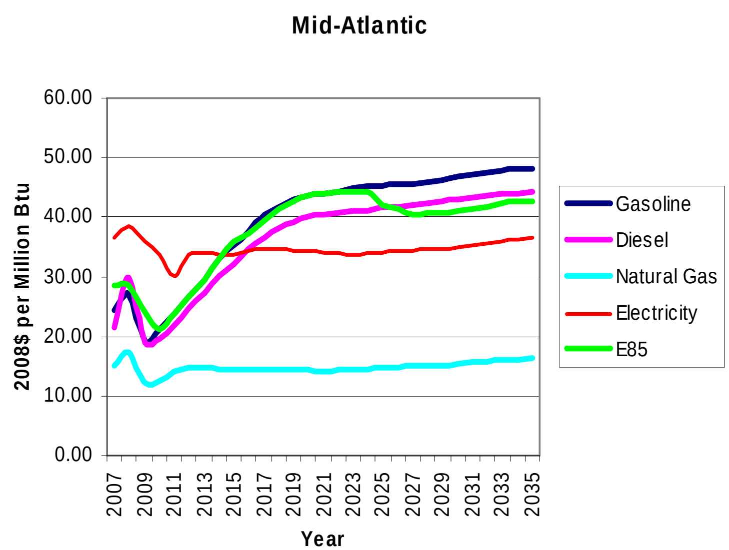
DRAFT: Preliminary assumptions for economic analysis 8/12/2010

Reference Case B: Baseline Fuel Prices







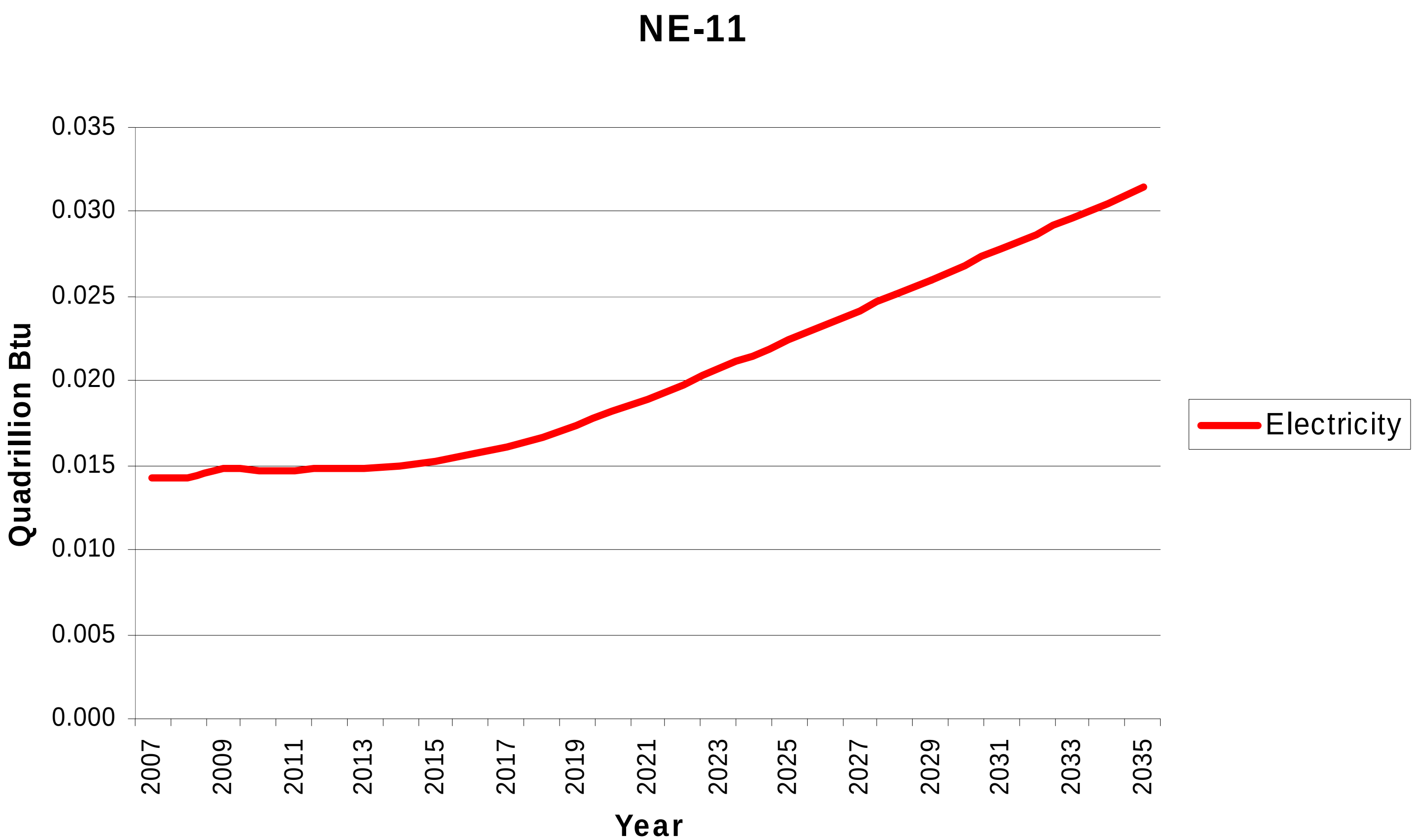
Key AEO Assumptions for Ref Case B:

- Economy recovers post-2010 but an escalation of oil prices ensues due to restrictions on conventional production;
- More domestic production of higher cost unconventional liquid fuels; and
- OPEC fuel production share falls to 35 percent.

Source: Energy Information Administration, Annual Energy Outlook 2010.

•For full detail, see supporting spreadsheets: Table 1B—Reference B Fuels

Reference Case B: Electricity Demand



For full detail, see supporting spreadsheet: Table 1C – Reference A/B Electricity

Base Year: 2006

- The NE/MA LCFS will set a carbon intensity reduction target for fuels relative to emissions intensity in a given Base Year;

- 2006 is the most recent year for which complete datasets are available from all states;

- Simplifying assumptions made for baseline fuel blends in Base Year:
  - Assume all gasoline is reformulated gas (RFG)
  - Assume all distillate fuels are ultra-low sulfur diesel (ULSD)

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Carbon Intensity (CI) of Baseline Fuels

Carbon Intensity of baseline fuels will set the reference point for the reductions in carbon intensity required by the LCFS:

- Gasoline CI = 96g/MJ
- Diesel CI = 94g/MJ
- Baseline Ethanol CI = 96g/MJ
- Assume all other baseline fuel volumes negligible.

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Carbon Intensity (CI) of Electricity (1)

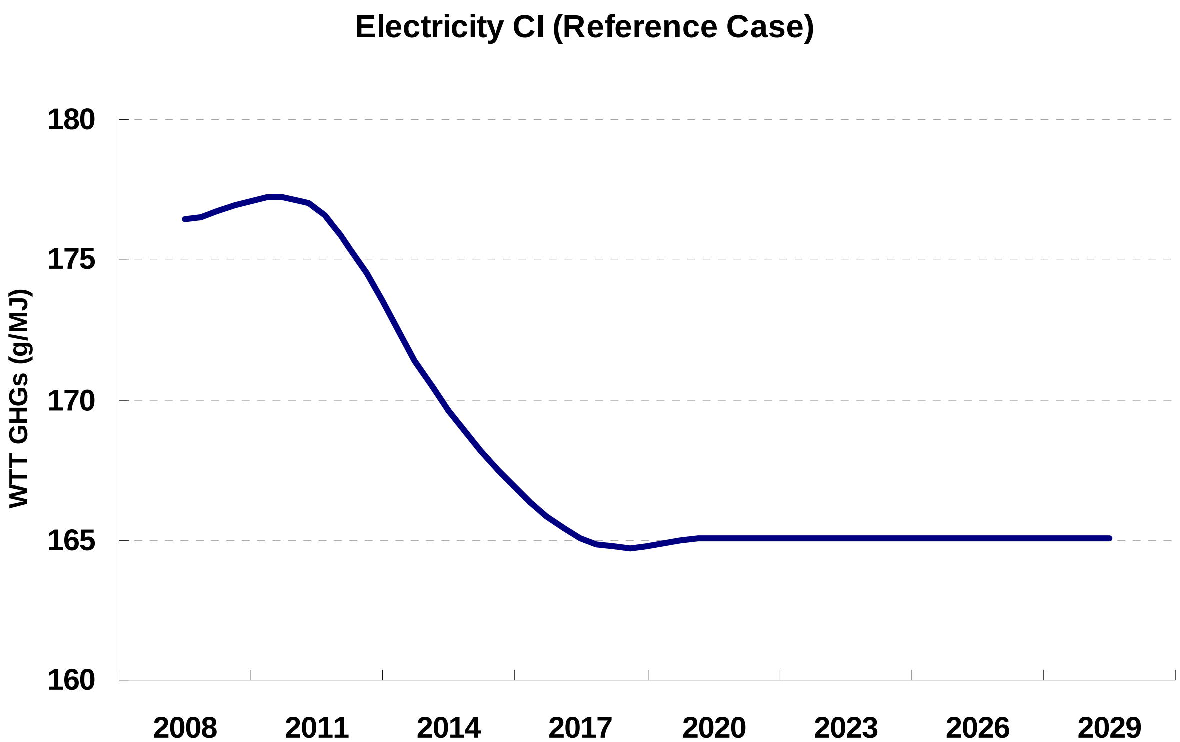
- Electricity's carbon intensity (CI) is based on average CO_2 emissions rates from ISO-New England, NY-ISO, and Mid-Atlantic portion of PJM grids, calculated using NE-MARKAL energy model.

- Electricity CI declines from 2008 to 2018, due to the influence of existing energy and climate policies (described in next section).

- Reference case, Electricity CI:
  - 2008: 176.4 g/MJ (unadjusted for EER) = 58.8 (adjusted for EER);
  - 2014: 169.6 g/MJ (unadjusted for EER) = 56.5 (adjusted for EER);
  - 2017 through 2029: 165 g/MJ (unadjusted for EER) = 55.0(adjusted for EER);

- Net carbon intensity of electricity imports is assumed to be approximately the same as in-region electricity grid CI.

Carbon Intensity of Electricity (2)



Methodology:

The NE-MARKAL energy model was used to provide a forecast of the mix of electrical generation for the NE/MA region. The modeling assumes the RGGI GHG cap and all existing state renewable portfolio standards. This grid mix was used as an input to the GREET lifecycle analysis tool to provide a NE/MA specific electricity carbon intensity. NE-MARKAL documentation can be downloaded at: http://www.nescaum.org/topics/ne-markal-model/ne-markal-model-documents.

For full detail, see supporting spreadsheet: Table 10B – Electricity CI

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Role of Existing Policies

- To account for the incremental effects of the NE/MA LCFS, we first need to isolate and calculate the effects of existing policies that are also likely to affect the development, production, and use of low carbon fuels;
- The analysis assumes: full compliance with existing GHG and energy regulations, programs, and incentives at state, regional, and federal level.
- For existing policies scheduled to expire during the period of analysis, we assume their goals are maintained over time (e.g., RGGI maintains 2018 levels of CO_2).
- An exception to this are tax credits/rebates, which we assume either *expire* or *are continued*, depending on the policy scenario.

Role of Existing Policies

- Relevant existing policies include:
  - Federal:
    - *Renewable Fuel Standard* (RFS2)
    - Corporate Average Fuel Economy (CAFÉ)/GHG emissions
    - Federal blenders' credits, tax credits, and technology rebates
  - Regional:
    - Regional Greenhouse Gas Initiative (RGGI)
    - Zero Emission Vehicle (ZEV) program
  - State:
    - Renewable energy standards (i.e., RPS)
    - Biofuel mandates
    - Waste policies

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Renewable Fuel Standard2 (RFS2)

- Reference cases assume advanced biofuels required by RFS2 go to CA, remainder of required volumes are proportionally distributed throughout US;

- Reference case B assumes CA demand for low-carbon fuels increases to offset increase in high-carbon feedstocks:
  - Draft boundary assumption:
    - 70% HCICO share in 10 years at 7g/MJ CI penalty
    - → 0.5% annual increase in AFCI
    - → 5% total AFCI increase by 2022

- Assume 10% blend limit for gasoline;

- Assume EPA projections for flex-fuel vehicle penetration and E85 infrastructure, apportioned to region based on total fuel use.

RFS2 Key Assumptions: Biofuels Future

- Liquid biofuels industry advances quickly to commercialization;
- NE/MA LCFS creates incentives for producers to create fuels which go beyond EPA's GHG thresholds, e.g. ultra-low carbon fuels at the lower end of CI range (<20g/MJ), as compared to 37g/MJ for cellulosic under RFS2;
- LCFS will not influence the volumes of biofuels produced for RFS2 compliance, or the timing of their availability;
- LCFS *will* result in favorable changes to the lifecycle GHG attributes of a subset of the total volume of RFS2 biofuels produced; and
- The low-C fuels that are produced as a direct result of the LCFS incentives are likely to be produced in the NE/MA region.

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RFS2 Key Assumptions: "Other Futures"

- Natural Gas Future:
  - High-end of regional biomass availability
  - Majority of regional feedstocks used for NG substitute pathways first, as appropriate
  - Use low-end CI values for biomass-based NG pathways
  - Assume low-end of fuel production costs for NG pathways
- Electricity Future:
  - Low-end of regional biomass availability
  - Majority of regional feedstocks used for NG substitute pathways first, as appropriate
  - Use high-end CI values for biomass-based NG pathways
  - Assume high-end of fuel production costs for NG pathways

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Interactions between RFS2 and NE/MA LCFS Policy Scenarios

Policy Case	EISA Volume %	Reference Case	Fuel Type	Regional Fuels			RFS2 Fuels		Total AFCI Δ
				CI	Volume	AFCI Δ	CI	Volume	
Liquid Biofuels Future	100%	A	Liquid	Low	High		Low		-6%
			Gas	High	Low		High		-2%
		B	Liquid	Low	High		Low		-6%
			Gas	High	Low		High		-2%
Natural Gas Future	<100%	A	Liquid	High	Low		High		-2%
			Gas	Low	High		Low		-6%
		B	Liquid	High	Low		High		-2%
			Gas	Low	High		Low		-6%
Electricity Future	<100%	A	Liquid	High	Low		High		-2%
			Gas	High	Low		High		-2%
		B	Liquid	High	Low		High		-2%
			Gas	High	Low		High		-2%

Federal Policy: CAFE

- Assume new 2010 CAFE standards for all states through 2016
- Ref Case A assumes no additional mileage improvements for 2017 and later
- Ref Case B assumes CARB Pavley2 projections for 2017 and later
- Actual fleet average will be slightly lower (real-world) per EIA's *Annual Energy Outlook*

Light-Duty Model-Year Average Fuel Economy (mpg)		
	Ref Case A	**Ref Case B**
2011	27.8	27.8
2012	28.9	28.9
2013	29.8	29.8
2014	30.6	30.6
2015	32.1	32.1
2016	34.1	34.1
2017	34.1	37.7
2018	34.1	40.1
2019	34.1	41.6
2020+	34.1	42.5

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Federal Tax Credits and Subsidies (1)

Federal Biofuel Tax Credits and Subsidies:

- Federal ethanol credits:
  - $0.45 per gallon blended, including imported ethanol – Expiring December 31, 2010
  - $1.01 per gallon for cellulosic ethanol produced– Expiring December 31, 2012
- Federal biodiesel credits:
  - $1.00 per gallon for renewable biodiesel, excluding imported biodiesel
  - $0.50 per gallon if co-processed at petroleum refineries, excluding imported biodiesel
  - Scheduled expiration date: Currently expired
- Federal tariff on imported biofuels:
  - $0.54 per gallon
  - Scheduled expiration: December 31, 2011

For full detail, see supporting spreadsheet: Table 7A-Low Carbon Fuel Costs, Low

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Federal Tax Credits and Subsidies (2)

- Federal tax credit on electric vehicle charging infrastructure:
  - 50% of installation cost, up to $2,000;
  - Scheduled expiration: December 31, 2010
- Federal tax credit on electric vehicle purchases:
  - $2,500-$7,500 per vehicle, depending on battery capacity;
  - Scheduled expiration: December 31, 2012
- Federal tax credit on NG vehicle purchases:
  - Equals 50% of the incremental cost of the vehicle, plus an additional 30% of the incremental cost for vehicles with near-zero emissions. Limits apply depending on weight class.
  - Scheduled expiration: December 31, 2010.

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Regional Policy: Regional Greenhouse Gas Initiative (RGGI)

- Assume full compliance with regional cap-and-trade program limiting CO_2 emissions from large power plants (>25MW) in 10 LCFS states:
  - Cap limit equals 188.1M short tons of CO_2 from 2009 to 2014; 2.5% reduction in CO_2 emissions each year from 2015 to 2018;

- Assume maintenance of RGGI program after 2018 (i.e., 10% reduction achieved by 2018, no additional reductions required thereafter).

Source: Regional Model Rule: Regional Greenhouse Gas Initiative, 2008.

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Regional Policy: ZEV Requirements

- 8 states in region have adopted California's Zero-Emission Vehicle (ZEV) requirements: CT, MD, ME, MA, NJ, NY, RI, VT
  - Reference cases assume full ZEV implementation in these states
  - Limited volumes of PHEVs required beginning in 2012
  - "Pure" ZEV (battery-electric or fuel cell vehicles) required starting with model year 2018

	ZEV			PHEV		
	Credit requirement (% of fleet)	Credits per vehicle	Vehicle Requirement (% of fleet)	Credit requirement (% of fleet)	Credits per vehicle	Vehicle Requirement (% of fleet)
2012 - 2014	-	3	-	2.2%	1.5	1.5%
2015 - 2017	-	3	-	3.0%	1.5	2.0%
2018 +	5.0%	3	1.7%	2.5%	1.5	1.7%

  - ZEV program impacts in 2022:
    - Total CI reduction of 0.3 g/MJ
    - 18,000 BEVs, 54,000 PHEVs
    - Total electric demand = 1,900 GWh
- EV/PHEV Technology:
  - Assume energy economy ratio (EER) of 3.0 for BEV and PHEV
  - Assume 22-mi all-electric range (AER) for reference case PHEVs (per CARB ZEV ISOR Table 4.2); higher value or distribution of values for "Electric Future" scenarios
  - Use VISION default method (based on SAE J1711) to calculate electric VMT % based on AER

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State Policy: Renewable Energy Standards

- Assume full compliance with goals of mandatory state renewable portfolio standards (RPS);

- Assume no additional requirements for renewable generation beyond last year of any given state's RPS timeframe.

•For full detail, see supporting spreadsheet: Table 3B-State RPS

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State Policy: MA Biofuel Mandate

- Massachusetts requires 2% blend in biodiesel sold in the state, beginning in 2012, with a 50% lifecycle GHG improvement from baseline diesel fuel;
- MA Department of Energy Resources is proposing use of EPA's 2012 values for GHG lifecycle emissions of biodiesel;
- Volumes of biodiesel (B100) required to meet mandate:
  - 12M gallons for heating market +
  - 8M gallons for transportation market
  - 20M gallons total
- Annual growth in demand for on-road diesel is projected to be 1.94% per year, 2010-2035.

Source: MA DOER estimates, 2010; EIA AEO projections, 2010.

For full detail, see supporting spreadsheet: Table 3A-Mandated Biofuel Volumes

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State Policy: PA Biofuel Mandate

- Pennsylvania: "Act 78 of 2008 – The Biofuel Development and In-State Production Incentive Act" requires 2% biodiesel blend in all diesel sold in PA, starting in May 2010.
- PA's annual market for on-road diesel in 2010 is 1.8B gallons;
- ~36M gallons of biodiesel (B100) is required to meet PA's B2 blending standard in 2010.
- Annual growth in demand for on-road diesel is projected to be 1.94% per year, 2010-2035.

Source: PA DEP estimates, 2010.

For full detail, see supporting spreadsheet: Table 3A-Mandated Biofuel Volumes

State Waste Policies

- State policies addressing the treatment and management of municipal solid waste can affect the degree to which municipal solid waste (MSW) feedstocks can be used for low carbon fuel production;
- Two states (MA and DE) have policies that are effective moratoriums on the use of MSW for additional waste-to-energy (i.e., electricity);
- Quantities of MSW available for use in waste-to-energy facilities have been adjusted accordingly for MA and DE in our calculations of low carbon fuel production.

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Reference Case Low Carbon Fuels

- To accurately account for the incremental costs of low carbon fuels required for LCFS compliance, we first need to account for existing production and distribution of low carbon fuels and related infrastructure in the region;
- Key insights based on our assessment include:
  - In general, production of and delivery infrastructure for low carbon fuels are limited in the 11-state NE/MA region;
  - Current biofuel production includes corn ethanol and biodiesel production; no advanced biofuel production at commercial scale exists yet in the region;
  - Current use of electric and CNG vehicles in the region is very limited, as is charging and fueling infrastructure;
  - However, current policies (e.g., ZEV, state biodiesel mandates) will increase today's level of distribution, and production even without LCFS;
  - Firms conducting research & development (R&D) related to low carbon fuels are very well-represented in the NE/MA states;

Electricity Reference Case

Distribution:

- Current 13 Electric Vehicle charging stations in the NE/MA region.
  - Existing charging stations are evenly split between fleet and public charging
- Additional charging stations will be added to accommodate electric vehicles required under ZEV program:
  - 18,000 Battery-electric and 54,000 plug-in electric vehicles in 2022
- Additional distribution upgrades are also likely to take place to support ZEV vehicles, depending on location and consumers' charging patterns.

Biofuel Reference Case

Production:

- 3 corn ethanol plants in the region with a total operating capacity of 275 million gallons per year.
  - 2 plants in NY; 1 in PA
- 24 Biodiesel plants in the region with a total production capacity of 225 million gallons per year

Distribution:

- 101 E85 fueling stations in the 11-state NE/MA region
- 65 Biodiesel fueling stations in the region

For full detail, see supporting spreadsheet: Table 2 – Existing LCF Infrastructure

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CNG Reference Case

- Reference Case Demand for CNG from Transportation Sector based on AEO 2010

Distribution:

- 190 CNG fueling stations are located in the region;
- 140 of the CNG stations are exclusively used for fueling fleet vehicles;
- Most public CNG fueling stations are located in NY and MA.

- Single CNG fueling station delivers 130,000 gallons of gasoline-equivalent (gge) per year, enough to meet annual fuel demand from 75 heavy trucks or 220 passenger cars.

For full detail, see supporting spreadsheet: Table 2 – Existing LCF Infrastructure

Existing Low Carbon Fuel R&D Firms

- Firms specializing in research and development (R&D) low-C fuels and supporting technologies (e.g., EV batteries) are very well-represented in the NE/MA region;
- NE/MA LCFS should increase demand for these products and thereby push emerging technologies to reach commercial viability;

Company / Institute	State	Sector
Elcriton Inc.	DE	Organic chemical manufacturing
Center for Carbon Free Integration (University of Delaware)	DE	Basic low carbon fuel / technology research
Mascoma	NH	Cellulosic ethanol
DSM Innovation Inc	NJ	Cellulosic ethanol
Rutgers Biotechnology Center for Agg. & Env.	NJ	Basic low carbon fuel / technology research
Transmediair Inc.	NJ	Biomass gasification
New England Community Renewable Energies	MA	Biofuel / solar technology research

Source: NESCAUM communication with State energy and environmental agencies; New England Clean Energy Council; Biotechnology Industry Organization (BIO), 2010.

Note: This list is for illustration purposes and is not yet complete.

III. NE/MA LCFS Policy Scenarios: Draft Data and Assumptions

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Global Assumptions for NE/MA Economic Analysis

- Target level of NE/MA LCFS: 10% reduction in carbon intensity of NE/MA transportation fuels within 10 years;
- Program requirements begin in 2013 and continue through 2022;
- Timeframe of the analysis: 2013 to 2022 for 10-year program;
  - GHG and criteria pollutant reductions will be evaluated over a longer-time frame
- All values expressed in (or adjusted to) real 2008 dollars.

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Discount Rates

- Social discount rate: 0% and 3%
  - 0% reflects (Weitzman *et al.*, 2009) research that the risk of non-linear and irreversible impacts of climate change warrants consideration of a zero discount rate;
  - 3% reflects guidance for federal agencies in evaluating social (public) benefits of regulatory programs

Sources: 1) Weitzman, M. 2009. 2) Executive Order 12866, 2009.

- Private discount rate: 6% and 10%
  - 6% reflects low-end of current returns on private capital
  - 10% reflects higher rate of return on investments in emerging technologies and industries with greater risk

Carbon Intensity (CI) Values for NE/MA Economic Analysis

- Carbon intensity values were selected to show a broad range of uncertainty of the lifecycle GHG emissions of fuels;
  - Factors such as indirect land use change can have a large influence on CI values;

- For some fuel pathways, high-end CI values were not applicable because of the design of our scenarios:
  - E.g., CI value for cellulosic ethanol from virgin feedstocks not needed in our non-Biofuel Future scenarios;

- These CI values are for purposes of economic analysis only. CI values for the NE/MA LCFS program may differ substantially.

For full detail, see supporting spreadsheets: Table 10A/B – Carbon Intensities

Core NE/MA LCFS Policy Scenarios

The 3 core LCFS policy scenarios were designed to accomplish the following objectives:

- Meet a 10% reduction in carbon intensity (CI) of transportation fuels over 10 years, beginning in 2013
- Represent alternative "what if?" visions of the future that account for a broad range of uncertainties:
  - Rates of innovation and commercialization of low carbon fuels & technologies;
  - Costs of future low carbon fuels and infrastructure;
  - Consumer preferences and market penetration of new technologies; and
  - General economic conditions.
- Recognize the technology-forcing role of LCFS as a performance standard;
- Address interests of multiple stakeholders with diverse interests; and
- Provide policy insights within given resources and schedule.

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Tools for Calculating Results of Policy Scenarios (1):VISION-NE

- NE-VISION is an LCFS policy scenario calculator;
- Based on Argonne National Laboratory's VISION transportation energy demand model;
- Customized for the NE/MA region's fleet;
- Expanded to include modules for electricity, renewable fuels, and other features;
- Enables user-input CI values and volumes for selected fuel pathways;
- Our analysis assumes VISION defaults except where noted.

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Tools for Calculating Results of Policy Scenarios (2): GREET

- GREET is an excel spreadsheet model developed and maintained by Argonne National Laboratory (US DOE);
- Calculates CO_2-equivalent GHG and criteria emission factors (g/mmBtu) for numerous fuel pathways;
- GREET is both a calculation methodology *and* a large set of input data;
  - Methodology is valid for any region
  - Many default inputs are national averages; user can substitute state- or region-specific data
- For this analysis, some CI values based on published estimates and some derived from GREET;
- GREET-derived CI values use all GREET default values except:
  - Electricity mix
  - Baseline crude mix

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Policy Scenario 1: "Electricity Future"

- Assumes that electricity and electric vehicles become the dominant fuel and technology, respectively, for meeting the NE/MA LCFS;
- Consistent with high EV penetration are: high consumer acceptance of EVs, low-end of electricity costs, low electric CI, optimal use of additional grid capacity;
- In this scenario, electricity contributes 6% while CNG and biofuels do not innovate and penetrate the market as quickly, contributing only 2% towards the 10% target;

Scenario	1
Key Variables:	**"Electric Vehicle Future"**
Technology penetration	Hi rate of EV penetration/grid innovation
% of LCFS compliance	EVs-6%; CNG and Biofuels-2% each
Prices of low C fuels	Elec low, others med to high
Prices of low C infrastructure	Elec low, others high
CI Values	Elec low, others high
Target Level	10%
Availability of in-region fuels	N/A for electricity; others low-end

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Key Assumptions for "Electricity Future" Scenario

- Under the "Electricity Future" policy scenario, the following assumptions apply:
  - All EV-related tax credits assumed to continue;
  - All non-EV tax credits assumed to expire as scheduled;
  - Costs of electricity will be at the low-end of its estimated range;
  - Costs of CNG and biofuels will be at the high-end of their estimated ranges, respectively;
  - Incremental costs of EVs is assumed to be zero in this scenario;
  - Incremental costs of CNG vehicles = $7K (LDV) to $40K (HDV) and flex-fuel vehicles =$100;
  - CI values for CNG and biofuels are at high-end of their respective ranges.

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Key Assumptions for "Electricity Future" Scenario (1)

- Electricity is a potential low carbon fuel for transportation but is also generated to meet many other needs, so the NE/MA LCFS will be only one of many factors influencing electricity generation, costs, carbon intensity, etc.
- Our method for calculating the incremental impacts of the NE/MA on electricity markets and grid capacity for this scenario assumes:
  - Calculating the energy demand associated with 6% reduction;
  - Equal market share for EVs and PHEVs;
  - Characteristics of Vehicle Technology:
    - Assume energy economy ratio (EER) of 3.0 for BEV and PHEV
    - Assume 22-mi all-electric range (AER) for all PHEVs (per CARB ZEV ISOR Table 4.2)
    - Use VISION default method (based on SAE J1711) to calculate electric VMT % based on AER
  - Charging: Load determined by maximum no. of vehicles plugged simultaneously and the proportion of Level 1, 2 and 3 chargers in use
    - Level 1, 2 and 3 charging at 1.4kW, 6kW and 50kW respectively
  - Electricity demand from EVs will be distributed across NE/MA region according to population.

Energy Economy Ratio (EER)

- Necessary to account for variation in tank-to-wheel efficiency (miles per MJ) for substitute fuels
- Enables “apples-to-apples” comparison of various fuels based on the utility each fuel provides

$$CI_{electricity} = CI_{grid} / EER$$

- Sensitivity to EER will be captured by varying total electricity CI
- Assume CARB Published EER values*:
  - Electricity: Gasoline = 3.0
  - Electricity: Diesel = 2.7
  - CNG: Diesel = 0.9
  - CNG: Gasoline = 1

Source: *CARB LCFS Final Regulation Order, Table 5

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Key Assumptions for "Electricity Future" Scenario (2)

- Assume use of existing capacity in 3 grids (ISO-NE, NY-ISO, and PJM) will be optimal in this scenario:
  - 90% charging will be off-peak
  - 10% of charging will occur on-peak
- Incremental load will be calculated accordingly, by comparing EV demand in MWh with available capacity during off-peak periods across 3 grids;
- Impact of incremental demand on electricity CI will be calculated assigning average grid CI to additional load.

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Key Assumptions for "Electricity Future" Scenario (3)

- Estimated range of EV charging infrastructure costs :
  - Home charging, Level 1: $0-$833
  - Home charging, Level 2: $2,000 to $3,700
  - Public charging stations: $4,500

Sources: Boston Consulting Group, US Dept. of Energy , Tesla, Nissan, California Energy Commission.

- Charging in this scenario will use Level 2 and Level 3 chargers.

- PEV charging will require some amount of upgrades to the distribution system based on estimated incremental peak demand, which will vary with policy scenario;

- Estimated range of incremental distribution costs:
  - Most of incremental need will be at level of low-voltage transformers
  - Assume existing 25kVa transformers will be replaced by 50kVA transformers
  - Range of expected costs for 50kVA transformers (installed):
    - $4,500 (low) to $6,000 (high)

Source: National Grid draft estimates, 2010.

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Key Assumptions for Electricity in CNG and Biofuels Future

- In the "CNG Future" and "Biofuels Future" scenarios, electricity will contribute only 2% toward the 10% compliance goal and will be subject to the following assumptions:
- Charging times will be less-than-optimal from a grid capacity perspective:
  - 50% charging will be off-peak;
  - 50% of charging will occur on-peak.
- Charging in this scenario will rely upon a mix of Level 1 and Level 2 chargers.
- Incremental load will be calculated accordingly, by comparing EV demand in MWh with available capacity during on- and off-peak periods across 3 grids;
- Impact of incremental demand on electricity CI will be calculated assuming additional load is served by typical marginal generation in PJM, (i.e., coal-fired generation).
- Impacts on electricity prices expected to be higher under this scenario; sources for calculating impacts on electricity prices are still needed.

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LCFS Policy Scenario 2: “Biofuels Future”

- Assumes biofuels and biofuel-capable vehicles become dominant fuel and technology, respectively, for meeting the NE/MA LCFS;

- Consistent with high biofuel penetration: relatively fast innovation in biofuels, relatively low feedstocks costs and lower fuel CI, adequate supply of feedstocks from the region;

- Other Low-C fuels, electricity and natural gas, do not reach the same level of innovation and market penetration in this scenario, contributing only 2% toward the 10% target.

Scenario	**2**	
Key Variables:	**"Biofuels Future"**	
Technology penetration	Hi rate of biofuel innovation (fuels & infrastructure)	
% of LCFS compliance	Biofuels-6%; CNG and EVs-2% each	
Prices of low C fuels	Biofuels low, others high	
Prices of low C infrastructure	Biofuels low, others high	
CI Values	Biofuels low, others high	
Target Level	10%	
Availability of in-region fuels	Feedstocks for liquid fuels high; others low	

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Key Assumptions for "Biofuels Future" Scenario

- Under the "Biofuels Future" policy scenario, the following assumptions apply:
  - All non-biofuel tax credits (e.g., EV charging) assumed to expire as scheduled;
  - Costs for biofuels will be at the low-end of their estimated range;
  - Costs of electricity and NG will be at the high-end of their estimated range;
  - Incremental costs of flex-fuel vehicles assumed to be zero;
  - Incremental costs of EVs =$5K; CNG vehicles = $7K (light-duty) to $40K (heavy dutu)
  - Carbon intensity values for biofuels at low-end of their range, high-end of range for electricity and CNG

For full detail, see supporting spreadsheet: Tables 7A/B Low Carbon Fuel Costs

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Key Assumptions for "Biofuels Future" Scenario

- Production costs of biofuels are included for fuel pathways most relevant for the NE/MA program at this time:
  - Cellulosic and sugarcane ethanol
  - Biodiesel, traditional and advanced
- Range of possible biofuel production costs are assembled using best available low- and high-end estimates, respectively, from EPA and CARB (i.e., feedstock costs, production, plant O&M, distribution)
- Estimated costs of waste-based fuels are generally lower, due to low costs of waste feedstocks in comparison to virgin feedstocks;
- Federal biofuel credits ranging from $0.45 to $1.01 per gallon (depending on type of fuel) assumed to continue for duration of program;
- Import tariffs of $0.54 per gallon apply to imported biofuels (i.e., sugarcane ethanol).

For full detail, see supporting spreadsheet: Tables 7A/B Low Carbon Fuel Costs

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Other Assumptions for "Biofuels Future" Scenario

- Costs of New Biofuel Infrastructure:
  - Ethanol/E85
    - Ethanol blending equipment: $310K per facility
    - Truck unloading equipment: $500K per facility
    - Retail fueling stations: $131K (1 dispenser) to $177K (3 dispensers) per new facility; $130K to upgrade existing pump from 1 to 3 dispensers
    - Ethanol storage tanks: $1.4M/each (1M gallon capacity)
  - Biodiesel infrastructure:
    - Biodiesel storage tanks: $70 per barrel of capacity for new tanks
    - Biodiesel blending equipment: $400K per terminal
    - Biodiesel piping: $60K per terminal

- Costs of infrastructure will be scaled using biofuel volume assumptions in EPA RFS RIA;
- E85 volumes will be calculated based on exceedances of current ethanol blendwall of 10%.

For full detail, see supporting spreadsheet: Table 8 – Capital Costs

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LCFS Policy Scenario 3: "CNG Future"

- Assumes that CNG and CNG vehicles become a dominant fuel and technology, respectively, for meeting the NE/MA LCFS;
- Consistent with high CNG penetration are: high consumer acceptance of CNG vehicles, relatively low NG costs and NG CI, adequate supply of NG from the region (including from production using in-region biomass);
- Other Low-C fuels, electricity and biofuels, do not reach the same level of innovation and market penetration in this scenario, contributing only 2% toward the 10% target.

Scenario	**3**
Key Variables:	**"CNG Future"**
Technology penetration	Hi rate of CNG penetration (vehicles & infrastructure)
% of LCFS compliance	CNG-6%; EV and Biofuels-2% each
Prices of low C fuels	CNG low, others high
Prices of low C infrastructure	CNG low, others high
CI Values	CNG low, others high
Target Level	10%
Availability of in-region fuels	Biomass for NG avail high; others low

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Key Assumptions for "CNG Future" Scenario

- In this scenario, production of NG from regional biomass, including expansion of existing biogas resources and gasification, will play a prominent role.

- New gasification facilities will be located proximate to existing NG delivery infrastructure.

- Estimated Costs of CNG Infrastructure:
  - CNG fueling stations: $370,000 (upgrade existing station) to $1M (new station)
  - No. of new fueling station required will be calculated based on 1 new station for the CNG demand associated with supporting 75-100 heavy-duty trucks

Sources: California Air Resources Board, *Initial Statement of Reasons* (Vol.1), 2009; Clean Energy 2010.

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Key Assumptions for "CNG Future" Scenario

- CNG Energy-economy ratio: Diesel = 0.9; Gasoline = 1.0
- CNG demand to meet 6% of 10% target is assumed to be from light-duty vehicle sector;
- Under the "CNG Future" policy scenario, the following assumptions apply:
  - All non-CNG tax credits assumed to expire as scheduled;
  - Costs for CNG will be at the low-end of its estimated range;
  - Costs of electricity and biofuels will be at the high-end of their estimated ranges, respectively;
  - Incremental costs of CNG vehicles assumed to be zero;
  - Incremental costs of EVs =$5K and flex-fuel vehicles =$100;
  - Carbon intensity values for NG is at low-end of its range; CI values electricity and biofuels are at high-end of their respective ranges.

LCFS Program Costs

In addition to the costs of low carbon fuels associated with each policy scenario, we consider the costs of implementing the NE/MA LCFS:

- Costs of the program include:
  - Costs of reporting will be borne by regulated parties for reporting their regulated fuel volumes and compliance activities.
    - Assume 1 full-time employee (FTE) at jr. engineer level for each regulated entity;
    - $150K/yr for each FTE.
  - Administrative and enforcement costs will be borne by participating LCFS states to deal with records submitted by regulated parties and ensure compliance;
    - High-fuel throughput LCFS states (i.e., NJ, DE, PA, NY) require 2 to 3 FTEs at $100k/yr.
    - Low-fuel throughput LCFS states (i.e., all others) require 1 FTEs at $100k/yr.
    - NE/MA may establish a regional body for tracking credits similar to RGGI, Inc.
- Assume that program costs do not vary—will be the same for each policy scenario.

Sensitivity Analyses

In addition to 3 core policy scenarios, we will do sensitivity analyses of key assumptions:

- **Target level:** 5% and 15% targets will be calculated as linear extrapolation of results from policy scenarios based on 10% target

- **Compliance schedule and/or program duration:** we will either vary the "shape" of the compliance schedule, and/or analyze a longer time horizon (e.g., 15 or 20 yrs) for compliance with a 10% LCFS target

  - Either sensitivity approach will analyze the impact of allowing more time for commercialization of low carbon technologies and fuels

- **Heating oil:** as a sensitivity to the "Biofuel Future" scenario, the heating oil sector will face a 0% reduction target and will be assumed to generate credits that can be purchased for compliance by regulated entities

IV. Estimating Regional Production of Low Carbon Fuels

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Estimates of Regional Low Carbon Fuel Production

- The 11 NE/MA states have significant biomass resources that can be used in the production of low carbon fuels for LCFS compliance;

- Key biomass feedstocks available in the NE/MA region include:
  - Woody and agricultural biomass
  - Energy crops (e.g., willow, switchgrass)
  - Waste biomass (e.g, municipal solid waste, livestock waste)

- Our analysis is based on low- and high-end estimates of available biomass resources that reflect uncertainties in economic and environmental factors which determine actual feedstock availability;
  - High-end estimates generally reflect maximum technical potential;
  - Low-end estimates reflect conservative percentages of maximum potential, keeping existing markets intact.

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Estimates of Woody and Agricultural Biomass Availability

Woody biomass estimates:

- Woody biomass estimates based on regional analysis of USDA's *Forest Inventory Analysis* data for 11 NE/MA states;
- Categories include: forest residues, mill residues, urban wood, and new forest growth;
- Low-end residues assumed to be 50% of high-end estimate;
- Low-end harvest of new growth assumed to be 15% of high-end estimate;

Agricultural biomass estimates:

- Based on EPA estimates by state of agricultural residues for RFS2 analysis;
- Categories include: barley, corn, wheat, oats, rice, sorghum;
- Low-end assumed to be 50% of high-end estimate;

For full detail, see supporting spreadsheet: Table 5 – NE/MA Biomass Availability

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Estimates of Regional Energy Crop Potential

- Energy crop estimates (high-end) based on analysis by Dr. Peter Woodbury, Cornell (2010);

- Estimates of land available for growing energy crops assume that:
  - 50% of non-agricultural lands (e.g., pasture) are available;
  - Current agricultural production maintained; new lands made available by increasing crop yields;
  - No conversion of forests;

- Categories of energy crops include:
  - Fast-growing willow;
  - Warm-season grasses;
- Low-end estimate is 50% of high-end estimate.

For full detail, see supporting spreadsheet: Table 5 – NE/MA Biomass Availability

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Estimates of Regional Waste Availability

Low-end Availability:

- Only waste currently landfilled considered
- No cardboard or paper
- 75% of yard waste, food waste, and wood scraps
- 50% of biosolids from wastewater treatment facilities (WWTF)
- 50% of livestock waste

High-end Availability:

- Some diversion of waste currently designated for waste-to-energy for liquid fuel, gas, and electricity production
- 25% of corrugated cardboard and office paper
- 50% of newspaper and other paper waste
- 100% of biosolids from WWTF and livestock waste

For full detail, see supporting spreadsheet: Table 5 – NE/MA Biomass Availability

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Regional Low Carbon Fuel Calculator

- Estimates of low carbon fuel volumes will be generated using a modified version of the *New Jersey Bioenergy Calculator© and Biomass Resource Database.*
- *The NJ Bioenergy Calculator©*, created by the NJ Agricultural Experiment Station (NJAES) at Rutgers University (with support from Navigant Consulting), was designed to estimate potential quantities of electricity, advanced biofuels, and biogas produced from NJ biomass resources (estimated at the county level).
- Our modifications to the calculator for the NE/MA LCFS analysis will include:
  - Creating state-level biomass resource worksheets for each NE/MA state;
  - Adjusting assumptions for quantities of biomass available;

Any and all errors and omissions to the modified version of the NJAES Bioenergy Calculator© are the responsibility of NESCAUM. Any parties interested in modifying the calculator should contact NJAES for permission.

Supporting NE/MA bioenergy spreadsheet still under development. To review original NJAES calculator, see: ***njaes****.rutgers.edu/****bioenergy/njaes-bioenergy-calculator****.xls*

DRAFT: Preliminary assumptions for economic analysis 8/12/2010

Fuel Production Pathways

Fuel	Technology	Feedstocks
Gasoline Substitutes	Thermochemical processing of cellulose*	Energy Crops Agricultural and Forestry Residue Solid Waste (food, paper, wood scraps)
	Biochemical processing of cellulose	
	Dilute acid hydrolysis*	
	Gasification/ Liquefaction	
	Anaerobic Digestion/ Landfill*	Livestock Waste and WWTF Biosolids
Diesel Substitutes	Transesterification*	Bio-Oils Waste Oils
	Gasification - Fischer Tropsch*	Energy Crops Agricultural and Forestry Residue Solid Waste (food, paper, wood scraps)
Natural Gas Substitutes	Anaerobic Digestion/ Landfill	Energy Crops Agricultural and Forestry Residue Solid Waste (food, paper, wood scraps) Livestock Waste and WWTF Biosolids
	Thermal Gasification	
	WWTF Gas Processing	WWTF Gas

***Indicates that the NJAES Bioenergy Calculator© tool represents this pathway.**

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Translating NE/MA Biomass into Low Carbon Fuel Production (1)

- We will estimate a minimum and maximum potential supply of low carbon fuels produced using resources from the NE/MA region;
- Fuel pathways used to estimate low C fuel supply will include:
  - Liquid biofuels
  - NG from biomass
- Electricity production pathways will not be evaluated because:
  - Electricity can be generated in many ways that do not rely upon biomass resources;
  - Electricity market works independently of transportation fuel markets;
- Minimum low carbon fuel supply will be derived by combining the low-end available quantities with the high-end CI values for given feedstocks/pathways;
- Maximum low carbon fuel supply will be derived by combining the high-end available biomass quantities with the low-end CI values for given feedstocks/pathways;

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Translating NE/MA Biomass into Low Carbon Fuel Production (2)

- Maximum supply will be applied in the Biofuels and CNG Future cases:
  - Biofuels Future assumes that regional biomass resources are used primarily to produce liquid fuels, within appropriate technical limits and not to exceed 6%;
  - CNG Future assumes that the majority of regional biomass is used primarily to produce natural gas substitutes, within appropriate technical limits, and not to exceed 6%;

- Minimum supply of low carbon fuels will be applied in the Electricity Future case:
  - Electricity Future assumes that some regional biomass resources are used to produce a limited amount of low-carbon liquid fuels, but that these will not be available at commercial scale (in contrast to the Biofuels Future);
  - Biofuels will also be costed out at the higher-end of the cost range;
  - CNG in Electricity Future assumed to be sourced from most readily available sources of (e.g., LFG, anaerobic digesters), but at higher end of cost range.

Creating Fuel Production Inputs for REMI

- Based on the estimates of the volume of low C fuel production for the low- and high-end biomass ranges, we will estimate the no. of new production facilities required to support that production;
- Inputs to REMI to capture the economic impacts of new facilities will reflect:
  - Annual supply of biomass and associated services needed to supply new facilities
  - Construction and operation of new fuel production facilities
- Will not identify specific locations of new LCF production facilities, but will assume that impacts of new facilities are distributed proportionally across states according to their total biomass availability;
- Capital costs for new fuel production facilities based on NREL and EPA estimates.

For full detail, see supporting spreadsheet: Table 15 – REMI Reference Case

V. Analysis of NE/MA LCFS Benefits

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Key Assumptions for NE/MA LCFS Benefits Analysis

- GHG benefits of LCFS calculated by multiplying emissions reductions from each LCFS scenario by an estimate (or range of estimates) of the social cost of carbon for each year;
- In 2010, Federal interagency task force (EPA, Energy, Ag, Commerce, CEQ, others) developed estimates of the social cost of carbon to allow agencies to value reductions in CO_2 emissions;
- Proposed low-end social cost of carbon, 3% discount rate: $21.40 (2010 value prorated for 2012);
- Will also be calculated at 0% discount rate.

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LCFS Benefits: GHG Reductions (con't.)

- High end estimate of value of avoided GHG emissions:
  - Stern *et al.* estimate social cost of carbon at $85 per ton of CO_2 (2000$)
  - Represents the global cost today, assuming a BAU trajectory of a 3.9 degree C increase by 2100 relative to pre-industrial temperatures

- Proposed high-end social cost of carbon: $85/ton (will be adjusted for 2012 dollars)

Sources: 1) Federal Interagency Task Force. 2010. "Social Cost of Carbon (SCC) for Regulatory Impact Analysis Under Executive Order 12866." and 2) Stern, N. *et al.* (2006), *Stern Review: The Economics of Climate Change*, HM Treasury, London.

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LCFS Benefits: Air Quality Impacts

- NESCAUM will estimate calculate changes in criteria pollutant emissions using NE- GREET and apply estimates from the EPA RIA and CARB for each scenario to bound potential impacts on air quality

- RFS2 RIA calculates direct (tailpipe and evaporative) emissions relative to petroleum-based fuels and emissions from production and distribution of renewable fuels:
  - MOVES, Mobile6, and National Mobile Inventory Model (NMIM) used for direct emissions
  - Emission factors for upstream emissions from agriculture taken from GREET and NREL
  - Biofuel production and transportation emissions calculated in GREET
  - Reference case and controls calculated with National Emissions Inventory and other tools
  - 2005 CMAQ modeling platform used to assess air quality impacts

- CARB used data from existing facilities and feedstock production to produce a "tank to wheels" and lifecycle analysis based on data from siting and mitigation regulatory data

LCFS Benefits: Policy-Induced Innovation Effects

- Review of literature on the effects of policy shows significant impact of policy drivers on rate of innovation in energy technologies;
- Analysis will provide quantitative and qualitative review of potential innovation benefits of LCFS:
  - Basis for quantitative impacts on innovation will be the difference between the reference case levels of fuels and technologies, and levels of fuels and technologies represented in each policy scenario

Sources: Goulder, L. and Matthai, 2000. Optimal CO2 abatement in the presence of induced technological change, *Journal of Environmental Economics and Management*; Pew Center on Global Climate Change, *Induced technological change and climate policy*, Pew Center on Global Climate Change, 2004).

VI. Analysis of NE/MA LCFS Regional Economic Impacts

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Estimating Regional Economic Impacts (1)

- In addition to the broad assessment of NE/MA LCFS costs and benefits, we will also analyze how certain categories of LCFS costs and benefits will be realized by or accrue to specific industry and consumer groups (e.g., biofuel mfrs.) in the Northeast.

- Key outputs of the regional economic impact assessment include:
  - Changes in gross state (regional) product
  - Changes in employment, labor income
  - Changes in total economic production
  - Results address industry-specific and aggregate impacts state/region

- Our tool for the regional economic impact analysis will be the REMI© model, a 12-state economic and demographic forecasting model.

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About the REMI Model

- Began in 1986 Amherst, MA - MA Dept. of Revenue was first customer;
- REMI builds *regionally-calibrated* economic forecast/<u>simulation</u> software systems for clients in the U.S., and some overseas applications;
- It is a *dynamic CGE economic analysis system* with significant (though not infinite) internal logic to specify how an economy moves forward/adjusts to numerous (*labor/capital/other inputs*) market conditions;
- It has been used in *sequence* with other technical pre-processor analysis models (e.g. energy supply sector, GHG abatement solutions);
- The 12-state REMI model contains private-sector industry-detail equivalent to the 3-digit NAICS (industry) definitions.

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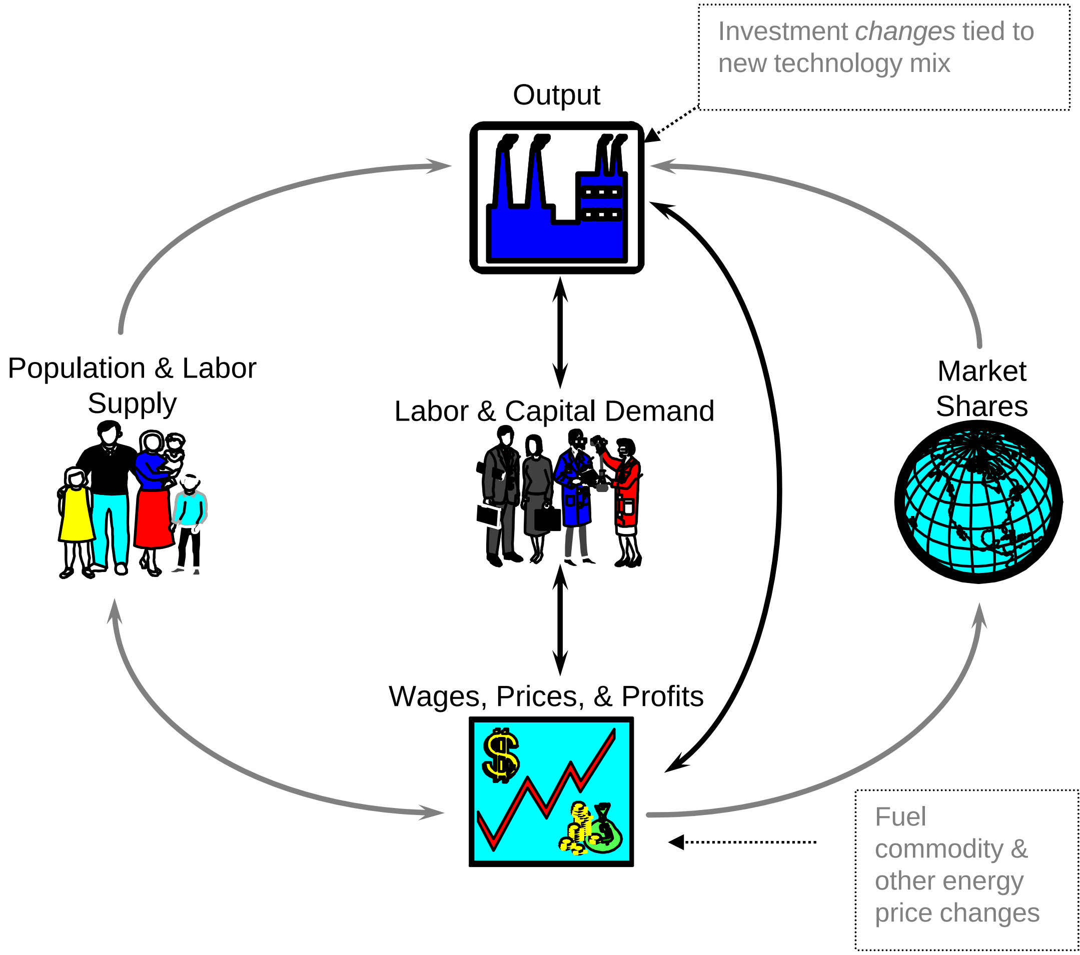
Depiction of REMI logic – *single economy*



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Best Practices in Economic Analysis (2)

- Analysis of other impacts—
  - Analysis should also provide insights on the distribution of aggregate costs and benefits across different groups (e.g., relevant industries)
- The *distributive effects* of the initial cost & benefits are decided *external* to the REMI model – as part of the scenario definitions for NE/MA's LCFS.
- The REMI analysis captures the scenario's subsequent "+" and "-" economic transactions in the state/region for its households and business community, with an underlying industry-specific allocation.

REMI Scenario Implementation

1. Economic levers will be developed for each participating State based on scenario data – the *direct effects*
2. The *direct effects* will have a set of stated assumptions around them as defined by NE/MA (e.g. the amount of new infrastructure needed to deploy *biofuels/EV's/CNG*)
3. Economic levers will convey to the model the annual "*deltas*" over the reference case
4. Economic levers are carefully selected to mimic (in the model) any expected *influence* a particular LCFS direct effect would exert on existing market conditions – provided that response is *internal* to the REMI model

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What are we mapping?

- Move from the LCFS *cost analysis* & *benefits analysis* into a set of information regarding economic transactions

- Those transactions may encompass the following:

1. *capital investment (demand) shifts,*
2. *changes in the cost to household sector and/or business sector related to changes in their operational spending (fuel purchases predominantly) or from*
3. *a ratepayer effect from any Utility component of the NE/MA LCFS definition*
4. *Changes in consumer and intermediate demand from the altered mix of operational spending*

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Categories of LCFS Economic Impacts

- ***Consumers' Cost differential of Low Carbon Fuel Purchases:***
  - cellulosic ethanol
  - low-C biodiesel
  - electricity for PHEV/EVs
  - CNG
- ***Capital Investment differential associated with Related Infrastructure:***
  - Blending infrastructure
  - Delivery infrastructure (e.g., E85 delivery, CNG stations)
  - PHEV/EV infrastructure
  - Who ultimately bears these infrastructure costs?
- ***Capital Investment differential associated with Related End-use Techology Purchases:***
  - Incremental costs of electric, CNG, and flex-fuel vehicle purchases
  - Who ultimately bears these incremental vehicle purchase costs?
- ***Program Administration differential Costs:***
  - Reporting costs
  - Program implementation and enforcement costs
  - Who ultimately bears these costs?

Categories of LCFS Benefits

- <u>Regional Economic Benefits</u> - Increase in energy security (fuel production calculated outside the REMI analysis)
  - Local fuel production (*dictated by NE/MA LCFS scenario assumptions*)

- <u>Avoided GHG emissions</u> - To the extent these can be restated as altering *net* HH energy rates or *net cost of doing business* for different industries, we can embed these into the lever set.

- <u>Co-reductions in criteria pollutants</u> – to the extent these can be monetized as effecting the *net cost of doing business* for different industries, we can embed these into the lever set. Otherwise, it will be addressed outside the model.

- <u>Technological Innovation</u> - To the extent this can be identified as a direct effect, we can embed these into the lever set. Otherwise, it will be addressed outside the model.

From Direct Effect to Total Effect

- The REMI multi-state model considers the magnitude and allocation of each state's *direct* effects and how that alters the overall cost of living, households' ability to consume and cost-of-doing business.

- This affects overall GSP (& employment) vis a vis *Consumption*, and the state's industries relative competitiveness to export domestically and overseas. The cost of living effect will influence working age migration which has labor market/utilization implication for area employers.

- The economic context is that 11 states will be differentially affected under a NE/MA LCFS scenario, there will be subsequent interactions between them as a result, as well as with the *rest of U.S.*

DRAFT: Preliminary assumptions for economic analysis 8/12/2010

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EV Scenario: Example REMI Map

(Example for Illustrative Purposes – Final Map May Differ)

Sector / REMI NAICS Code	Incremental Change	REMI Variable
Households	Decreased Gasoline Purchases (+)	Consumer Spending / Gasoline and Oil
Households	Cost of Home Charging Infrastructure (Capital and labor broken out) (-)	Decrease in consumer purchasing power
Households	Increased Electricity Purchases (-)	Consumer Spending / Electricity
State Government	Decreased Fuel Tax Revenue (-)	Government Spending
22 / Utilities	Increased Electricity Sales (+)	Industry Sales
22 / Utilities	Cost of Public Charging Infrastructure (Capital and labor broken out) (-)	Production Costs
22 / Utilities	Distribution System Upgrades (-)	Production Costs
335 / Electrical equipment and appliance manufacturing	Cost of home Charger (Capital) (+)	Exogenous Final Demand
detailed Construction -*Other mainten. & repair*	Cost of home Charger (Labor) (+)	Detailed INDUSTRY sales (approx. 45% will be payments to labor)
335 / Electrical equipment and appliance manufacturing	Cost of Public Charging Infrastructure (Capital_elec. Comp.) (+)	Exogenous Final Demand
332 / Fabricated metal prod. Manufacturing	Cost of Public Charging Infrastructure (Capital_other materials) (+)	Exogenous Final Demand
detailed Construction -*Other mainten. & repair*	Cost of Public Charging Infrastructure (Labor) (+)	Detailed INDUSTRY sales (approx. 45% will be payments to labor)
335 / Electrical equipment and appliance manufacturing	Transmission Upgrades (+)	Exogenous Final Demand

Biofuels Scenario: Example REMI Map

(Example for Illustrative Purposes – Final Map May Differ)

Sector / REMI NAICS Code	Incremental Change	REMI Variable
Households	Decreased Gasoline Purchases (+)	Consumer Spending / Gasoline and Oil
Households	Increased Bio-fuel Purchases (-)	Consumer Spending / Gasoline and Oil or Gas
Custom REMI Biofuel production industry	Increased Bio-fuel Sales (-)	Industry Sales
Custom REMI Biofuel production industry	Cost of Biofuel production facility (-) (Capital and labor broken out)	Production Costs
Custom REMI Biofuel production industry	Cost of Feedstock's used in biofuel production (-)	Production Costs
State Government	Decreased Fuel Tax Revenue (-)	Government Spending
333 / Industrial machinery manufacturing	Cost of Biofuel production facility (+) (Capital)	Exogenous Final Demand
541 / Professional, Scientific, and Technical Services	Cost of Biofuel production facility (+) (Labor)	Exogenous Final Demand
Custom REMI Aggricultural Industry	Cost of Feedstock's used in biofuel production (-)	Industry Sales

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CNG Scenario: Example REMI Map

(Example for Illustrative Purposes – Final Map May Differ)

Sector / REMI NAICS Code	Cost / Benefit	Comment
Households	Decreased Gasoline Purchases (+)	Consumer Spending / Gasoline and Oil
Households	Increased CNG Purchases (-)	Consumer Spending / Gasoline and Oil or Gas
22 / Gas Utility	Increased Natural Gas Sales (+)	Industry Sales
44-45 / Retail Trade (Fueling stations)	Cost of New Public Fueling Infrastructure On-Site Compression (Capital and labor broken out) (-)	Production Costs
State Government	Decreased Fuel Tax Revenue (-)	Government Spending
	Cost of **New** Public and Home Fueling Infrastructure On-Site Compression (Capital and labor broken out) (+)	
332 / Machinery Manufacturing	Compressor (Capital)	Exogenous Final Demand
333 / Machinery Manufacturing	Dispensor (Capital)	Exogenous Final Demand
334 / Machinery Manufacturing	Dryer (Capital)	Exogenous Final Demand
332 / Fabricated metal prod. Manufacturing	Storage (Capital)	Exogenous Final Demand
Detailed Construction -Other mainten. & repair	Total infrastructure installation cost (labor)	Detailed INDUSTRY sales (approx. 45% will be payments to labor)
	Cost of **Existing** Public Fueling Infrastructure Retrofits On-Site Compression (Capital and labor broken out) (+)	
332 / Machinery Manufacturing	Compressor	Exogenous Final Demand
333 / Machinery Manufacturing	Dispensor	Exogenous Final Demand
334 / Machinery Manufacturing	Dryer	Exogenous Final Demand
Detailed Construction -Other mainten. & repair	Total infrastructure installation cost (labor)	Detailed INDUSTRY sales (approx. 45% will be payments to labor)

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Next Steps

Next steps for completing the LCFS Economic Analysis:

- Deadline for public comments: August 27, 2010
- Send comments to: lcfs@nescaum.org

- States and NESCAUM review public comments on Parts I&II, Data and Assumptions and revise as appropriate (end-Aug.)
- Initiate modeling of aggregate costs/benefits for core policy scenarios (end-Aug.)
- Review draft aggregate costs and benefits, prepare inputs for REMI (Sep.-Oct.)
- Conduct analysis of regional economic impacts (Oct.)