Rhode Island Greenhouse Gas Emissions Reduction Plan

December 2016

RIEC4

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ACKNOWLEDGEMENTS

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LETTER FROM THE CHAIR

To: The Honorable Gina M. Raimondo, Governor
The Honorable M. Teresa Paiva Weed, President of the Rhode Island Senate
The Honorable Nicholas A. Mattiello, Speaker of the Rhode Island House of Representatives

In accordance with the provisions of Rhode Island General Laws §42-6.2-2(2), I am pleased to provide you with the following "EC4 Greenhouse Gas Emissions Reduction Plan," which includes strategies, programs, and actions to meet the targets for greenhouse gas (GHG) emissions reductions as established in the Resilient Rhode Island Act.

As a coastal state vulnerable to the impacts of climate change, the need for Rhode Island to take bold action to reduce greenhouse gas emissions is clear. Although climate change presents us with formidable challenges, we also face an unprecedented opportunity to capitalize on technology advances, industry growth opportunities, and innovation as we work to lower our carbon footprint. In transforming our energy systems, we can achieve climate change goals, while unlocking economic opportunity and improving the environmental and public health of our citizens and communities. For example, the quantitative modeling underpinning our State Energy Plan indicates that it is feasible to achieve mid-term GHG reduction targets while diversifying our energy portfolio and creating net benefits to our economy as a whole.

The Resilient Rhode Island Act charged the Executive Climate Change Coordinating Council (EC4) with developing a Plan to meet the GHG reduction targets laid out in the law. This Plan, based on the best available data and grounded in quantitative analysis and modeling, demonstrates that viable pathways exist for Rhode Island to achieve the Act's targets. In fact, thanks to the leadership of the Administration and General Assembly, Rhode Island is already poised to meet and exceed the Act's near-term GHG reduction target of 10% below 1990 levels by 2020. This achievement is due in no small part to your steadfast support for Rhode Island's nationally-recognized programs in energy efficiency (the Least-Cost Procurement mandate) and renewable energy (including the nation's first offshore wind project).

This Plan demonstrates that viable pathways exist for Rhode Island to achieve the Act's targets. In fact, thanks to the leadership of the Administration and General Assembly, Rhode Island is already poised to meet and exceed the Act's near-term GHG reduction target of 10% below 1990 levels

As illustrated in the Plan's findings, Rhode Island is well-positioned to leverage near-term successes into a sustained, long-term effort to transform our energy economy. Although our existing suite of policies enable us to meet the 2020 GHG reduction target, achieving the 2035 and 2050 GHG reduction targets will entail major, economy-wide energy transformations, both at a state and regional level. The Plan demonstrates that widespread adoption of clean energy technologies and practices would be necessary to meet these long-term targets, including significant electrification of heating and transportation energy use, powered by a nearly-completely clean energy-supplied electric grid. Additional key mitigation strategies, including sustained commitment to least-cost energy efficiency, increased focus on the reduction of vehicle-miles-traveled (VMT), growth in biofuel use, and land use strategies to preserve forests will play a critical role as well. The good news is that Rhode Island can draw on our state's unique strengths and accomplishments to date to advance our long-term progress in GHG mitigation.

The Plan recommends three areas of opportunity for decision-makers to consider:

- **Build on State Success**: Rhode Island has existing policies and proven models to address nearly all mitigation options, creating a strong foundation the State can build upon to reach our goals.
- **Enable Markets and Communities**: Rhode Island's best resources are our people and communities – with the right support, we can remove barriers to clean energy market growth, consumer education and engagement, partnership of utilities, and public sector leadership.
- **Leverage Regional Collaboration**: Rhode Island has a fruitful history of working cooperatively with neighbors to seek scalable, cost-effective solutions to mutual challenges; climate change mitigation is one such area that is ripe for strong regional partnerships.

As we move on to the next step of Plan implementation, the EC4 would like to highlight three major considerations. First, the following Plan responds to the charge of the Act to evaluate the technical feasibility of mitigation pathways toward GHG targets; however, policymakers must also consider ways to achieve goals that optimize the economic, environmental, and health benefits to Rhode Island. The EC4 notes that such impacts could significantly vary depending on the timing, magnitude, and types of mitigation options prioritized by policymakers. To that end, the EC4 emphasizes the need to further evaluate costs and benefits, including macroeconomic, environmental, and health impacts, in 2017 to help shed light on where the best opportunities lie to optimize outcomes based on the best available current market data and projections.

Second, the EC4 would like to emphasize that this document is the beginning, not the end, of an ongoing conversation to advance Rhode Island's GHG mitigation priorities, policies and actions. As per the Act, this document is intended to be used as a high-level reference for policymakers in the Administration and the General Assembly, not as a detailed implementation guide or work plan. Therefore, EC4 has crafted a Plan that frames the discussion, but intentionally defers detailed program and implementation discussion to appropriate working groups, agency initiatives, and stakeholder collaborations.

Finally, the EC4 acknowledges that planning is an exercise in uncertainty. Just as clean energy markets and technologies have evolved in unforeseen ways in past years, new solutions and options for GHG mitigation will emerge in the future. The EC4 recognizes that the tools at our disposal will change over time, and new technology and innovation will be a key ingredient to meeting our goals. We must plan and act now with today's knowledge, but understand that future opportunities will aid our long-term efforts to reach our objectives.

Climate change is one of the central challenges confronting our state. Fortunately, Rhode Island is ready to rise to the occasion and lead. We have the tools and strengths to succeed, a proven track record, and momentum to carry us forward. Indeed, the change in the political climate at the federal level reinforces the importance and power of work and progress at the state and regional levels.

We look forward with enthusiasm to working with you as we chart our path forward to implementing solutions and achieving Rhode Island's GHG goals.

Sincerely,

Janet Coit

Department of Environmental Management, Director
Executive Climate Change Coordinating Council, Chair

ABOUT THIS PLAN

This Plan is organized according to five sections, and two appendices:

- **GHG Sources and Projections**: This section describes Rhode Island's current GHG emissions profile, including major sources, and expected changes under "business-as-usual" (BAU) future conditions.
- **GHG Mitigation Pathways**: This section describes the major findings of EC4's modeling to determine technically-viable pathways towards meeting the Resilient Rhode Island GHG reduction targets.
- **Policy and Implementation**: This section describes policy and implementation options that could be pursued to achieve the Resilient Rhode Island targets.
- **Monitoring Progress**: This section describes procedures Rhode Island will take to monitor progress toward achieving the GHG targets.
- **The Path Forward**: This section describes the EC4's vision for GHG mitigation implementation and next steps to move from planning to action.
- **Appendix 1: Reference Case Assumptions and Results**: This appendix provides technical documentation for the "business-as-usual" reference case developed for use in this Plan's GHG mitigation modeling.
- **Appendix 2: Scenario Modeling Assumption and Results**: This appendix provides technical documentation for the scenario modeling used to inform the development of this Plan.

PROCESS AND METHODOLOGY

The EC4 commissioned a Rhode Island Greenhouse Gas Emissions Reduction Study (the Study) to inform the development of this Plan. The EC4 retained Northeast States for Coordinated Air Use Management (NESCAUM) to develop the Study. The EC4 established a Project Team to oversee management of the Study development composed of staff from the Rhode Island Department of Environmental Management (DEM), the Rhode Island Office of Energy Resources (OER), the Rhode Island Department of Transportation (DOT) and the Rhode Island Division of Planning (DOP). Finally, the EC4 established a Technical Committee to participate in the development of the Study and provide feedback on key draft work products and deliverables. The Technical Committee consisted of a targeted group of climate and energy stakeholders with subject matter expertise and experience in their respective areas. The Technical Committee met six times over the course of 2016 to provide ongoing input into the Study development.

Major components of the Study included:

1) Development of a baseline projection of GHG emissions out to 2050, assuming continuation of "business-as-usual" market and policy conditions;
2) Identification of "major mitigation options" that could substantially reduce GHG emissions if widely adopted, and upper bound estimates of mitigation option implementation rates over time, designed to represent deployment of technologies at their economic or technical potential; and
3) Scenario modeling of technically-viable GHG mitigation pathways that could achieve the Resilient Rhode Island GHG reduction targets, conducted using LEAP: the Long-range Energy Alternatives Planning System, a widely-used software tool for energy policy analysis and climate change mitigation assessment.[1]

[1] For details on LEAP, please see: www.energycommunity.org/LEAP/.

Results of the Study, including supporting analysis and sources of information, are included in appendices to this Plan. Wherever appropriate, footnotes and references direct the reader to supplemental information contained in these appendices.

EC4 AND THE RESILIENT RHODE ISLAND ACT

The 2014 Resilient Rhode Island Act established the EC4, and furthermore directed it to develop a plan to meet targets for greenhouse gas emissions reductions. Specifically, the statute charged the EC4 with the following duty:

> "No later than December 31, 2016, submit to the governor and general assembly a plan that includes strategies, programs, and actions to meet targets for greenhouse gas emissions reductions as follows:
>
> (i) Ten percent (10%) below 1990 levels by 2020;
> (ii) Forty-five percent (45%) below 1990 levels by 2035;
> (iii) Eighty percent (80%) below 1990 levels by 2050;
> (iv) The plan shall also include procedures and metrics for periodic measurement, not less frequently than once every five (5) years, of progress necessary to meet these targets and for evaluating the possibility of meeting higher targets through cost-effective measures."

Table 1 displays the GHG reduction targets for 2020, 2035, and 2050 based on Rhode Island's 1990 economy-wide emissions.[2]

Table 1. Resilient Rhode Island Act GHG Emissions Reduction Targets

Year	GHG Reduction Target	GHG Emissions Target (Million Metric Tons CO_2 equivalent / year)
1990	N/A	12.48 (historical)[3]
2020	10% below 1990 levels	11.23
2035	45% below 1990 levels	6.86
2050	80% below 1990 levels	2.50

[2] Rhode Island's economy-wide GHG inventory covers emissions from all major sources and sinks, including (in order from largest contribution to smallest contribution): transportation, electric power consumption, residential, commercial, and industrial. Notably, there are two options for accounting for GHG emissions from the electric power sector: a "generation-based" or "consumption-based" methodology. "Generation-based" accounting considers all GHG emissions emitted by fossil fuel electricity generation occurring within the state. "Consumption-based" accounting considers GHG emissions associated with electricity used within the state. Because electricity in New England is provided through a regional transmission grid, the cross-border export and import of electricity is common. Therefore, an individual state's "generation-based" GHG emissions are often different from that same state's "consumption-based" emissions. The EC4 formally adopted the use of a consumption-based emission accounting because this method more realistically comports with the regional nature of New England's electric grid and is consistent with the approaches taken by neighboring states. It can also be a more informative metric for state-level policymaking because many policy instruments available to states have more influence on electricity consumption than electricity generation.

[3] See Appendix 1 for more information on the development of Rhode Island's 1990 GHG baseline.

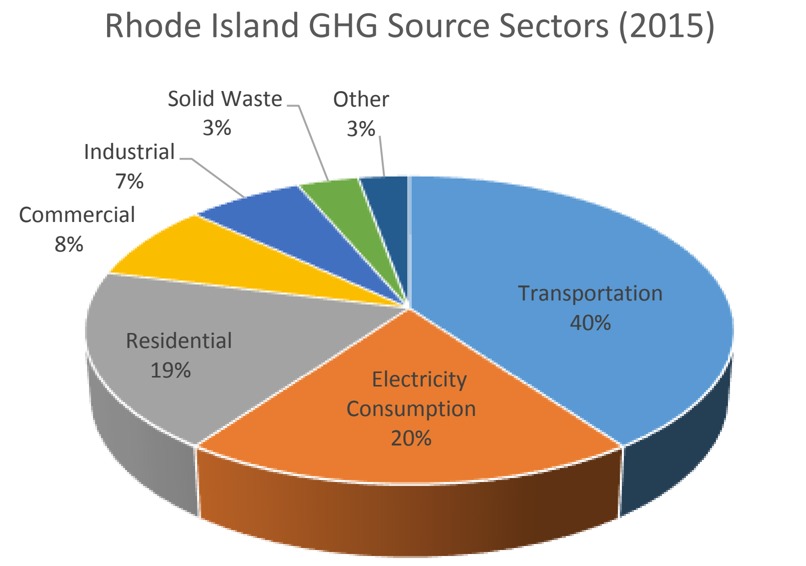
GHG SOURCES AND PROJECTIONS

This section provides background on Rhode Island's current GHG emissions profile, including major sources, and expected changes under "business-as-usual" future conditions.

CURRENT GHG PROFILE

What are the major sources of greenhouse gas emissions today in Rhode Island?[4] As shown in Figure 1, Rhode Island's most significant GHG source sectors are, in order: transportation, electric power consumption, residential, commercial, and industrial.[5] Transportation-related GHG emissions are caused by fuel consumption in on-road vehicles (e.g., light-duty cars and trucks, short- and long-haul trucking, and buses) and off-road sources (e.g., marine vessels, aircraft, construction and agricultural equipment, and rail). Electric consumption-related emissions are caused by electricity usage in all sectors, for applications such as lighting, air conditioning, appliances and devices, and space/water heating.[6] Residential, commercial, and industrial GHG emissions are caused by fuel consumption in buildings, primarily for space and water heating (as well as cooking), and for process heat generation and mechanical assembly in industrial applications. In 2015, Rhode Island's greenhouse gas emissions are estimated at 11.33 million metric tons CO_2e.[7]

Figure 1. Rhode Island GHG Source Sectors (2015)



*Other includes transmission/distribution, wastewater, agricultural, and land use/land use change/forestry

[4] The scope of this Plan is limited to direct GHG emissions associated with: 1) the consumption of fossil fuels or electricity in equipment, devices, and processes (e.g., appliances, heating systems, vehicles, and industrial uses) and 2) non-energy sources such as direct emissions from solid waste (i.e., landfill methane emissions), changes in land use (e.g., deforestation), and industrial uses (e.g., from the use of hydrofluorocarbons). It should be noted that there are additional GHG emissions beyond these direct emissions. These include emissions associated with upstream impacts of energy resource extraction, processing, and transport (e.g., methane leaks in natural gas production), as well as emissions associated with "embodied energy" in everyday products. Embodied energy is the sum of all energy inputs to produce goods and services on a full "lifecycle" basis. This includes emissions associated with the mining and processing of raw materials, and product manufacturing, transport, storage, use and disposal. With the exception of lifecycle GHG reductions for biofuels, this Plan does not consider emissions associated with upstream impacts of energy resources or embodied energy.

[5] See Appendix 1 for details on Rhode Island's major GHG source sectors. Figure 1 displays projected emissions from the LEAP model for 2015; the last year of available historical emissions data for Rhode Island is 2013.

[6] See Footnote 2 for explanation of consumption-based GHG emissions accounting for the electricity sector.

[7] Carbon dioxide equivalent (CO_2e) is a measure used to express the global warming potential of different greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide) in a common unit.

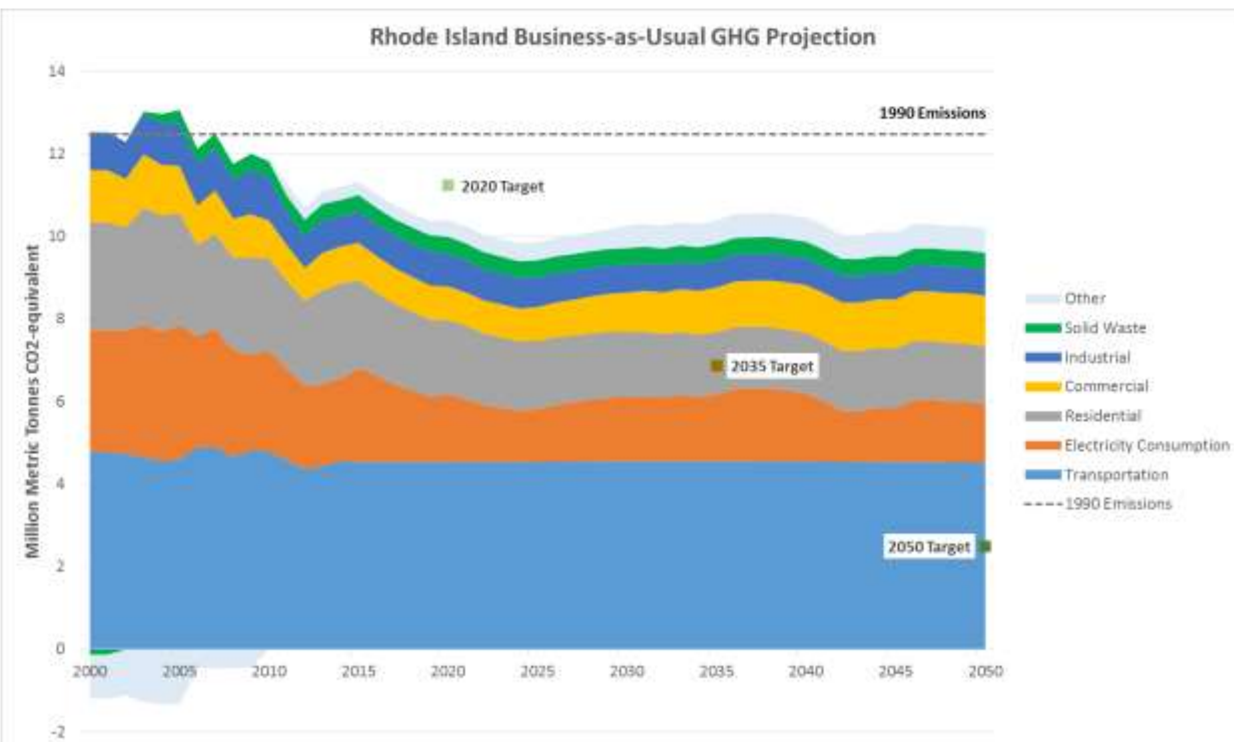
BUSINESS-AS-USUAL GHG PROJECTIONS

How is Rhode Island's GHG profile anticipated to change over time, absent the introduction of new federal, state, or local GHG mitigation policies? Forecast results show that Rhode Island's "business-as-usual" economy-wide GHG emissions are anticipated to decline in the near term from 11.33 million metric tons CO_2e in 2015 to 9.83 million metric tons in 2024, and subsequently rise steadily, reaching 10.19 million metric tons by 2050 (Figure 2).[8] Under BAU conditions, Rhode Island is anticipated to meet the Resilient Rhode Island 2020 target for GHG reductions, but not meet the 2035 or 2050 targets.

Major policy and market drivers of the BAU trend include:

- Energy Efficiency: Rhode Island Least-Cost Procurement energy efficiency programs in effect until 2024
- Regional Electric Power: Market- and policy-driven shifts in the New England market from oil and coal to natural gas and renewable energy for power generation
- Residential Energy Consumption: Slight decrease in demand due to combination of factors
- Commercial Energy Consumption: Steady growth in demand due to combination of factors
- Transportation Energy Consumption: Steady demand due to federal passenger vehicle GHG emissions standards offset by projected modest VMT growth across all vehicle types
- Other Emissions: Slight increase in GHGs due to combination of factors affecting land use change and waste; these sectors transition from a net emissions sink to a net emissions source

Figure 2. Rhode Island Business-As-Usual GHG Emissions Projection



[8] See Appendix 1 for more information on the "business-as-usual" reference case forecast.

GHG MITIGATION PATHWAYS

The EC4 evaluated scenario pathways for achieving the Resilient Rhode Island GHG emissions reduction targets. The scenarios considered the impact of aggressive deployment of GHG mitigation options (e.g., clean energy technologies) on the state's future GHG emissions profile. The modeling results indicate that achieving the Resilient Rhode Island targets will require major changes to Rhode Island's energy economy. Meeting the 2050 reduction target – an 80% reduction in GHGs below 1990 levels – would entail a wholesale transformation of energy production and use on both a state and regional level. At a high level, Rhode Island would need to address the following four categories of mitigation in order to transition to the very low-carbon future envisioned under the 2050 target (Table 2):

Table 2. Categories for Deep GHG Mitigation

Category	Description	Applicable Sectors
Energy Efficiency	Significant improvements in energy efficiency (using less energy to provide the same outputs or services) are critical in the buildings, transportation, and industrial sectors. These can include changes in practices by consumers or businesses, such as reducing travel by single-passenger vehicles, as well as technological improvements that increase efficiency, such as energy efficient appliances or lighting.	Buildings Transportation
Electrification	Electrifying energy end uses (converting from fossil fuels to electricity, such as with efficient electric heat pump systems or electric vehicles) maximizes the mitigation benefit of clean electricity.	Buildings Transportation
Decarbonization of Electricity	The GHG intensity of electric power can be reduced by increasing the role of renewables, no-to-low carbon energy resources (such as large hydropower), nuclear power, and carbon capture and storage.	Electricity
Decarbonization of Other Fuels	In addition to electricity, other fuels must be replaced by low-carbon alternatives to the extent feasible, such as substituting biogas for conventional natural gas or cellulosic ethanol for gasoline.	Buildings Transportation

MAJOR GHG MITIGATION OPTIONS

To explore potential pathways to meeting the Resilient Rhode Island targets, the EC4 identified a set of ten major mitigation options within the categories identified above that could each reduce GHG emissions. The mitigation options address all major GHG source sectors in the state and each relies on commercially available technologies. For each mitigation option, assumptions for a "high penetration" deployment scenario were developed, in order to represent the maximum feasible implementation potential that can reasonably be imagined for each option. Table 3 displays the mitigation options considered, and the penetration levels modeled to reach 2035 and 2050 reduction targets.

It should be noted that the following options represent GHG mitigation strategies available to us today. Additional technology innovation in future years is unknown at present, but will likely supply further solution sets that markets and policymakers can deploy to achieve the deep cuts in emissions necessary to meet aggressive long-term targets.

Table 3. Major GHG Mitigation Option Scenario Penetration Levels[a]

Major Mitigation Option	2035	2050
1. Energy Efficiency	Newly added savings of electricity, natural gas and heating oil (respectively) reach 1.5%, 1.5% and 0.5% of 2009 sales	Newly added savings of electricity, natural gas and heating oil (respectively) reach 2.7%, 2.3% and 0.9% of 2009 sales
2. VMT Reductions[b]	2% reduction in passenger car and truck VMT	10% reduction in passenger car and truck VMT
3. Utility-Scale Renewable Energy[c]	67% renewable installed capacity 72% carbon-free generation	98% renewable installed capacity 99% carbon-free generation
4. Distributed Generation[d]	*No change from reference case*	*No change from reference case*
5. Clean Energy Imports	Two new 1090 MW interconnections with Canada	Unchanged from 2035
6. Nuclear Re-Licensing	*No change from reference case*	Millstone 2 and 3 are not retired in 2036
7. Electric Heat	33% of residential and 30% of commercial main heating load met with electric heat pump systems	81% of residential and 67% of commercial main heating load met with electric heat pump systems
8. Biodiesel / Biomass Heat[e]	*No change from reference case*	*No change from reference case*
9. Electric Vehicles	34% of on-road VMT electrified 62% of rail transport electrified	76% of on-road VMT electrified 97% of rail transport electrified
10. Transport Biofuels	10% biodiesel in diesel 28% cellulosic ethanol in ethanol 10% ethanol and cellulosic ethanol in gasoline	31% biodiesel in diesel 78% cellulosic ethanol in gasoline

[a] Table reflects results from Scenario 2. See Appendix 2 for details.

[b] Relative to 2014.

[c] Percentage of carbon-free generation excludes imports and demand resources.

[d] The Distributed Generation mitigation option is mutually exclusive with "Utility-Scale Renewable Energy." Deployment of this option is explored in an alternate scenario. See Appendix 2 for details.

[e] The "Biodiesel/Biomass Heat" mitigation option is mutually exclusive with "Transport Biofuels." Deployment of this option is explored in an alternate scenario. See Appendix 2 for details.

Figure 3 shows the cumulative impact of deploying all ten major mitigation options, demonstrating that all options are needed to achieve the 2050 GHG target.[9]

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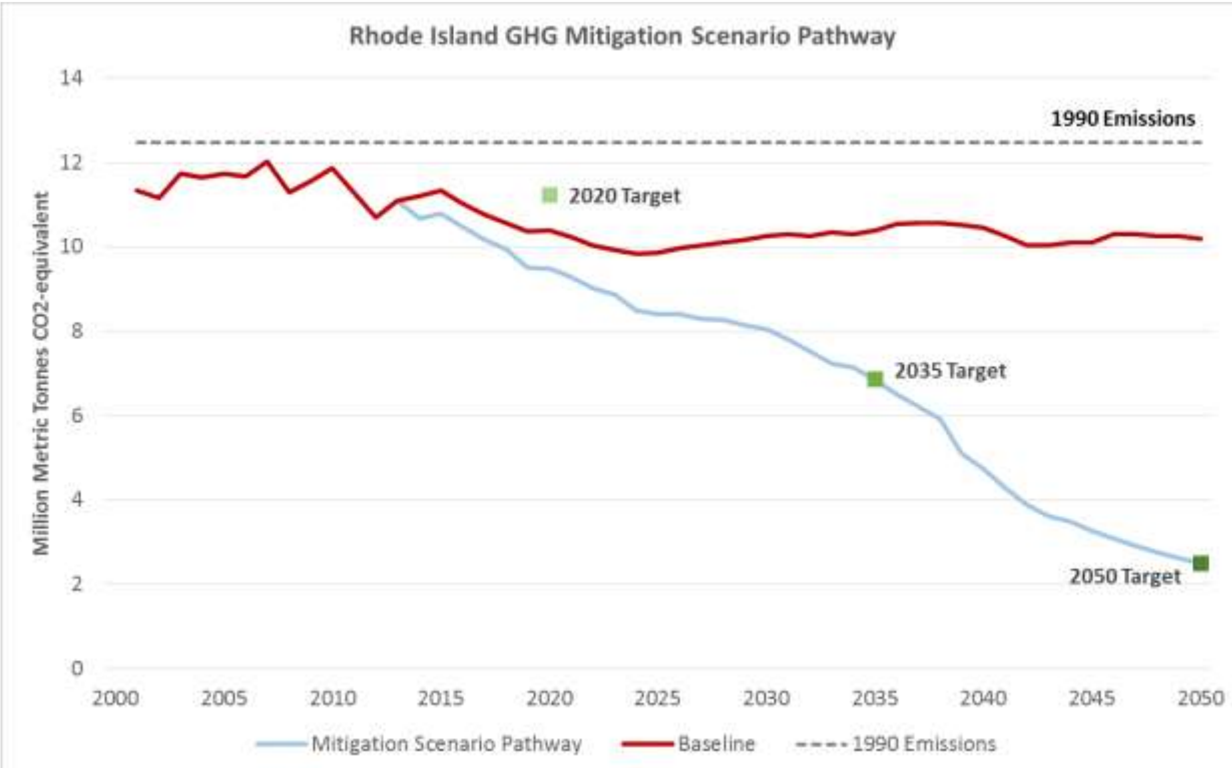
[9] See Appendix 2 for details on modeling results and additional scenarios that were analyzed for this Plan.

Figure 3. Rhode Island GHG Mitigation Scenario Pathway



SCENARIO MODELING FINDINGS

Scenario modeling of GHG mitigation pathways demonstrates that achieving the Resilient Rhode Island GHG reduction targets would likely require deployment of all major mitigation options.[10]

- **An 80% GHG reduction by 2050 would likely require a near-zero carbon grid coupled with significant electrification of residential/commercial space heating and on-road vehicles.**
  - Scenario modeling results indicate that the long-term GHG reduction target contemplated by the Resilient Rhode Island Act would allow for only a very limited budget of GHG emissions across the economy in 2050.
  - Therefore, extensive GHG mitigation would be required in all major GHG source sectors to achieve GHG reduction targets.
  - As displayed in Table 3 above, scenario modeling results show that achieving the 2050 target would likely require 99% carbon-free regional power generation; 81% of residential and 67% of commercial main heating load met with electric heat pumps; and 76% of on-road VMT electrified and 97% of rail transport electrified.
  - In addition to significant penetration of clean energy and heating/transportation electrification, model results suggest that implementation of additional strategies including deep energy efficiency, VMT reduction, biofuel deployment, and land use conservation would likely be need to achieve GHG reduction targets.

[10] Summary of major findings reflect results from Scenario 2. See Appendix 2 for details on modeling results and additional scenarios that were analyzed for this Plan.

- **Achieving GHG reduction targets has implications for stock turnover of fossil fuel-consuming equipment and infrastructure.**
    - Reaching the levels of GHG reduction in 2050 implied by the Act would require existing stocks of conventional technologies (e.g., fossil fuel generating resources, heating equipment, and vehicles) to be largely replaced with alternative, carbon-free technologies by 2050.
    - Decarbonization of the electric grid could be achieved system-wide through strategies such as regional market pricing mechanisms in order to gradually phase out more carbon-intensive resources and increase clean resources, whereas achieving substantial electrification of heating and transportation would require strategies to incentivize individual purchase decisions.
    - Scenario modeling suggests that even with substantial increases in adoption rates of alternatives, some proportion of conventional heating systems and vehicles could need to be replaced before the end of their useful lives in the years leading up to 2050 in order to achieve the necessary 2050 penetration levels of heating and vehicle electrification.

- **Advanced biofuels may be a resource-limited option and could be prioritized for use in the heating or the transportation sector.**
    - The future availability of advanced biofuels is uncertain and will ultimately be largely determined by federal policies and regional and national market conditions.
    - Scenario modeling for Rhode Island GHG mitigation pathways adopted an assumption that future advanced biofuels will have net zero-carbon lifecycle emissions, which has not yet been demonstrated in practice.
    - Advanced biofuel supplies could be used for GHG mitigation in the heating or the transportation sector.
    - Scenario modeling for Rhode Island directed biofuel resources to the transportation sector because fewer other viable technologies are commercially available at present to reduce heavy duty long-haul trucking fleet GHG emissions.

- **New technologies are likely to play an important role in meeting the long-term target of 80% GHG reduction by 2050.**
    - Scenario modeling only considered existing, commercially-available technologies.
    - Certain sectors such as the heavy duty long-haul trucking fleet do not have clear, viable existing mitigation alternatives to fossil fuels at scale.
    - New technologies and innovation in the upcoming years are likely to increase the suite of available, viable, and cost-effective solutions to meet long-term, deep emissions reductions.

POLICY AND IMPLEMENTATION

Thanks to the leadership of State policymakers, Rhode Island is already poised to meet and exceed the 2020 Resilient Rhode Island GHG reduction target. Achieving the 2035 and 2050 targets, however, will require much deeper cuts in emissions throughout all major GHG source sectors. The EC4 recommends that Rhode Island policymakers consider the following mix of strategies, programs, and actions to meet targets for greenhouse gas emissions reductions in Rhode Island:

1) Build on State Success
2) Enable Markets and Communities
3) Leverage Regional Collaboration

Per the Resilient Rhode Island statute, this Plan is intended to be used as a high-level reference for policymakers in the Administration and the General Assembly. Therefore, the actions presented below are described in terms of a broad framework to achieve the Resilient Rhode Island GHG reduction targets. Detailed aspects of program design and implementation are not discussed here; such conversations are intended to be delegated to appropriate working groups, agency initiatives, and stakeholder collaborations.

Furthermore, the EC4 notes that GHG mitigation planning is by nature an iterative exercise. No crystal ball can predict the future; new technologies and solutions are expected to emerge in decades to come. The policies and actions proposed below are based on our current knowledge, and as markets evolve and conditions change, planners will adapt policy tools accordingly.

1) BUILD ON STATE SUCCESS

Rhode Island has already enacted a suite of effective policies to increase adoption of technologies and practices that reduce GHG emissions. For example, Rhode Island's nationally-recognized electric and natural gas energy efficiency programs have been ranked as the top in the country.[11] Although the existing policies have demonstrated success, they are not sufficient on their own to drive Rhode Island to the Resilient Rhode Island targets. They do, however, provide a robust foundation on which the State can build to promote further progress toward the GHG goals. In practice, this means policymakers should support these programs and focus on filling gaps where needed to address as-of-yet untapped emissions abatement in key sectors such as transportation, and in the long-term, extending or expanding existing policies to reach the 2035 and 2050 targets. Below is a list of major GHG mitigation options Rhode Island would need to pursue to achieve the Resilient Rhode Island GHG targets, associated major existing state policies, and changes to policy that would likely be required to meet the GHG targets (Table 4).

[11] http://aceee.org/sites/default/files/pdf/state-sheet/2016/rhode-island.pdf

Table 4. Summary of Major Existing State Policies for GHG Mitigation

GHG Mitigation Option	Applicable Major Existing Rhode Island Policies	Legislative Sunset
1. Energy Efficiency	- Least-Cost Procurement - Energy Efficiency Codes and Standards	2024 N/A
2. VMT Reductions	- Transit Programs (bus, rail, ferry) - Land Use 2025 - Long-Range Transportation Plan	N/A N/A N/A
3. Clean Energy (utility-scale renewable energy, distributed generation, clean energy imports)	- Renewable Energy Standard - Long-Term Contracting Standard for Renewable Energy - Affordable Clean Energy Security Act - Renewable Energy Growth Program - Net Metering	2035 N/A N/A 2019 N/A
4. Electric Heat	- Least-Cost Procurement	2024
5. Biofuel Heat	- Biodiesel Heating Oil Act of 2013	2017
6. Electric Vehicles	- Zero Emission Vehicle Memorandum of Understanding - Drive Rhode Island to Vehicle Electrification - State Rail Plan	N/A N/A N/A
7. Transportation Biofuels	- None	N/A
8. Land Use Conservation	- Funding for open space protection - Forest Legacy Program, Forest Stewardship Program, Urban and Community Forestry	N/A N/A

ENERGY EFFICIENCY

Description of Mitigation Option: Energy efficiency means using less energy (e.g., electricity, natural gas, heating oil, propane) to provide the same or greater level of energy services. Energy efficiency in the context of this mitigation option refers to energy use reduction or management in buildings (i.e., residential dwellings as well as commercial and industrial facilities). Examples of energy-efficient technologies include weatherization, and high-efficiency lighting, appliances, and HVAC equipment. Energy efficiency gains can also be achieved through changes in consumer or business behavior (i.e., conservation). Finally, energy efficiency as a mitigation option can be considered to include advanced technologies and strategies such as load management/demand response and Volt/VAR optimization (VVO).[12]

Current Status and Existing Policies: Least-Cost Procurement (LCP), enacted in 2006, requires electric and natural gas utilities (i.e., National Grid) to invest in all cost-effective energy efficiency that costs less than conventional energy supply resources. Under Least-Cost Procurement, Rhode Island has achieved nation-leading levels of electricity and natural gas savings in recent years.[13] A statutorily-authorized consumer stakeholder board – the Energy Efficiency and Resource Management Council (EERMC) – oversees National Grid's development and implementation of programs, all with public input. The EERMC sets annual energy savings targets for investing in all cost-effective electricity and natural gas energy efficiency. LCP is currently scheduled to sunset in 2024.

[12] For background on VVO, please see: http://www.electricenergyonline.com/show_article.php?article=466.

[13] For details on Rhode Island's nationally-recognized energy efficiency programs, please see the Energy Efficiency and Resource Management Council's Annual Reports: http://www.rieermc.ri.gov/annualreport/.

Existing statutes in Rhode Island set minimum energy efficiency standards for appliances and buildings.[14] As of December 2016, Rhode Island had adopted the 2012 International Energy Conservation Code (IECC) with Rhode Island-specific amendments for both residential and commercial buildings.[15] A 2016 white paper commissioned by National Grid recommended aspirational goals of establishing a Zero Energy Building (ZEB) residential and commercial building energy code by 2035 (either mandatory or through voluntary stretch codes), with 100% of new construction to be ZEB after 2035, and 10% of existing buildings to be retrofitted to ZEB by 2035.[16] For appliance standards, Rhode Island is allowed under federal law to set standards for products not covered by federal standards.

SPOTLIGHT ON ENERGY EFFICIENCY

Rhode Island is a nationally-recognized leader in energy efficiency and was ranked the fourth most energy efficient state in the country in 2016. (The state has ranked in the top ten for nine years in a row.) The State's commitment to energy efficiency not only saves customers money, but also drives significant job growth—in 2015, 1,009 companies were involved with delivering energy efficiency services, with 79% of those companies located in Rhode Island. Since 2008, Rhode Island has invested $489 million in energy efficiency and consumers have realized $2.67 billion in economic benefits; since 2006, our energy efficiency programs will avoid seven million metric tons of CO_2.

The Town of North Providence celebrates participation in National Grid's Rhode Island Energy Challenge. (Photo Credit: National Grid)

Mitigation Policy Considerations: Scenario modeling results indicate that continued investments in all cost-effective energy efficiency represent an important component to achieving the Resilient Rhode Island GHG targets. To ensure maximized investment in this least-cost resource, policymakers could extend the LCP policy beyond 2024. Additionally, policymakers could address a critical gap in existing programs – limited energy efficiency services for delivered fuels (heating oil and propane) customers, a group comprising over one-third of all heating customers. A sustainable funding and/or financing solution is needed for these users to enjoy full and equal access to energy efficiency programs.[17]

For appliance standards, policymakers could continually screen additional technologies for inclusion under the state appliance efficiency standards. For building codes, policymakers could ensure that Rhode Island stays current with the latest IECC standards, at a minimum, and could also formally adopt the recommendations of the ZEB whitepaper. Furthermore, policymakers could ensure that

[14] For details on energy policy considerations relative to appliance standards and building codes, please see Energy 2035: Rhode Island State Energy Plan: http://www.energy.ri.gov/energyplan (Page 100).

[15] The 2015 IECC with Rhode Island-specific amendments is currently being evaluated for adoption by the State.

[16] https://www.nationalgridus.com/Trade/Rhode-Island-Zero-Energy-Building-Task-Force

[17] For details on market and policy issues related to delivered fuels energy efficiency in Rhode Island, please see the Thermal Working Group Report: http://www.energy.ri.gov/efficiency/thermal/.

energy efficiency is made visible to the marketplace – through strategies such as building and appliance labeling, and energy education – so energy costs become a common variable in all customers' decision-making processes.

VMT REDUCTIONS

Description of Mitigation Option: Reducing VMT is the transportation equivalent of energy conservation. Potential strategies to reduce VMT include: (1) decreasing the absolute number of single-occupancy vehicle trips by promoting and investing in alternative modes of transportation (e.g., rail, bus, ridesharing, biking, walking), and (2) reducing the absolute length of single-occupancy vehicle trips by encouraging higher-density patterns of development or changes in behavior.

Current Status and Existing Policies: The Rhode Island Division of Planning currently maintains the State Guide Plan (SGP), which directs the long-term growth and development of the state. A component of the SGP, Land Use 2025, guides land use decisions and directs growth and development to areas within the Urban Services Boundary. Transportation 2035, another component of the State Guide Plan, guides investment of federal transportation dollars at the local level. Strategies in this plan include reducing VMT through use of alternative travel modes, ride-sharing, and integration of bicycle and pedestrian facilities. The plan includes targets to reduce single occupancy vehicle commuting and increase transit mode share of work trips from 2.5% in 2000 to 2.8% in 2010, 3.0% in 2020 and 3.2% in 2030. Existing transit programs administered through RIPTA (bus), the MBTA (commuter rail), and RIDOT (ferry) encourage transit ridership. Finally, Rhode Island General Laws §36-6-21.1 establishes the State Employee Transportation Guide Plan and sets VMT reduction goals for State employees.

Mitigation Policy Considerations: Scenario modeling results indicate that a ~10% reduction in passenger vehicle and truck VMT by 2050 relative to 2014 would contribute to meeting the Resilient Rhode Island GHG targets. Use of public transit in Rhode Island today falls below the national average rate of 5.9% transit mode share. A 10% reduction in VMT would bring Rhode Island above the national average by 2050. The State will update its Long Range Transportation Plan starting in 2017 and should consider setting more aggressive mode share targets than in the current plan to aid in reducing GHG emissions through VMT reductions. Integrated land use and transportation decisions to bolster the effectiveness of transportation policy and investments (e.g., development or redevelopment of transit stations) as identified through the Long Range Transportation Plan could be considered. Investing in alternatives to solo driving, such as public transit, biking, walking and carpooling, and using pricing incentives to manage traffic and parking are also potential policy solutions for VMT reduction. Finally, implementation of VMT reduction strategies will result in a decline in Rhode Island gas tax revenues; the replacement of these lost revenues for transportation infrastructure improvements needs to be an important policy consideration for decision makers to address in coming years.

CLEAN ENERGY

Description of Mitigation Option: No-to-low carbon electricity sources (such as wind, solar, and hydropower) offer GHG reductions in the electricity sector by displacing higher-emitting generating resources reliant on fossil fuels, including coal, oil, and less efficient natural gas plants. Because Rhode Island is part of a larger integrated regional power grid, electricity flows across state borders, and power generated in one state may be consumed in another. Rhode Island is using a consumption-based accounting method for electric sector power emissions, which means that this mitigation option is defined by the regional adoption of clean energy, not just deployment within state borders.[18]

Current Status and Existing Policies: Rhode Island has a number of existing policies in place to promote the use of renewable and clean energy:

- The Renewable Energy Standard (RES) requires electricity providers to supply an increasing percentage of their retail electric sales from renewable resources. Rhode Island's RES is currently set at 38.5% by 2035.
- The Long-Term Contracting Standard for Renewable Energy (LTC) requires National Grid to solicit proposals from renewable energy developers and enter into long-term contracts with terms of up to 15 years. The LTC provides for 90 megawatts (MW) of contracts and for up to 150 MW of a utility-scale offshore wind farm.
- The Affordable Clean Energy Security Act (ACES) authorizes National Grid to participate in multi-state or regional efforts to procure large hydropower and/or renewable energy resources.
- The Renewable Energy Growth Program (REG) requires National Grid to enroll a total of 200 MW[19] of local renewable energy projects by 2019.
- Net Metering requires National Grid to credit power supplied by renewable energy projects onto the grid. Net metered projects must be located on-site, with certain exceptions for public sector projects, farms, affordable housing, and residential projects.

Mitigation Policy Considerations: Scenario modeling results indicate that achieving the Resilient Rhode Island GHG targets could likely require a ~99% clean regional grid by 2050. Due to Rhode Island's consumption-based accounting for electric power emissions, achieving GHG reductions in this sector

SPOTLIGHT ON OFFSHORE WIND

The five-turbine, 30 megawatt Block Island Wind Farm became the first offshore wind farm in the U.S. this year. The wind farm became a national model for successful coordination between state and federal agencies, including the development and implementation of the Ocean Special Area Management Plan (SAMP). The Ocean SAMP was completed by the University of Rhode Island and Coastal Resources Management Council, and evaluates siting for offshore wind in both state and federal waters. Additionally, more than 300 local workers were involved in building the wind farm, and four Rhode Island ports were used to complete construction and staging of the turbines. The project became commercially operational in December 2016. The island's decades-old diesel generators were recently shut down with the offshore wind project now producing and delivering power to the island and mainland. The Block Island Wind Farm will be operational for the next 20 years and will help Rhode Island meet its renewable energy goals, which include a 38.5% Renewable Energy Standard by 2035.

Construction on the Block Island Wind Farm finished this year. (Photo Credit: Deepwater Wind)

[18] See Footnote 2. In other words, the calculation of GHG reductions from the electricity sector is: (Rhode Island electric consumption) * (GHG emissions factor of the New England-wide power grid).

[19] Includes 40 MW from the Distributed Generation Standard Contracts Program (2011-2014).

requires action outside of the State's direct control (i.e., deployment of clean energy throughout the New England grid). Rhode Island can, however, work over the long-term to align in-state renewable energy policy and deployment targets to be consistent with the broader goal of a 99% clean regional grid by 2050. As part of this consideration, policymakers would need to weigh the comparative costs and benefits of different pathways (e.g., local versus regional renewables, the role of different technologies, and the need for incremental distribution or transmission investments).

ELECTRIC HEAT

Description of Mitigation Option: High-efficient electric cold climate heating systems (i.e., air source heat pumps (ductless mini-split or central systems) or ground-source heat pumps) offer GHG reductions in the thermal sector by displacing emissions from fossil fuel heating systems (i.e., natural gas furnaces and oil boilers). Electric heat pump systems produce a GHG reduction benefit due to the inherent efficiency of the heating technology as well as the relatively cleaner emissions profile of New England's power grid supply compared to that of natural gas or oil heating systems. This GHG reduction benefit increases over time as the electricity supply shifts toward a more decarbonized resource mix.

Current Status and Existing Policies: Recent years have seen rapidly growing market adoption of electric heat pump systems, which are valued by customers for their highly efficient cooling and – increasingly – heating features. Under Least-Cost Procurement, energy efficiency programs have incentivized the installation of higher-efficient heat pumps systems, especially those that can heat at cold winter temperatures, where they are replacing older, inefficient heat pumps or electric resistance systems.

Mitigation Policy Considerations: Scenario modeling results indicate that achieving the Resilient Rhode Island GHG targets could likely require electrification of ~70-80% of residential and commercial heating.[20] At present, Least-Cost Procurement energy efficiency programs do not incentivize heat pumps in situations where they would replace a fossil fuel heating system. Although this would result in a decrease of fossil fuel usage and therefore could result in net carbon reductions, it would also result in an *increase* in electric usage, which runs contrary to the current structure of energy efficiency programs. Further policy guidance is needed to allow electrification of heating to fully qualify as an activity under the State's energy efficiency program or another energy program.[21]

BIOFUEL HEAT

Description of Mitigation Option: Biofuels are liquid fuels derived from renewable organic substances (e.g., recycled cooking grease, plant residues, animal fats, and other renewable feedstocks). Biofuel can offer GHG reductions in the thermal sector by displacing lifecycle emissions[22] from fossil fuel heating systems using heating oil.

Current Status and Existing Policies: The 2013 Biodiesel Heating Oil Act established a 5% bioblend requirement for all heating oil sold in the state by July 1, 2017.

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[20] Implemented concurrently with aggressive decarbonization of the power grid.

[21] For details on policy issues related to electrification of heating, please see the Systems Integration Rhode Island (SIRI) Vision Document: http://www.energy.ri.gov/siri (Page 54).

[22] EPA requires that biomass-based biodiesel eligible under the federal Renewable Fuel Standard must achieve a 50% reduction in lifecycle GHG emissions: https://www.epa.gov/renewable-fuel-standard-program/proposed-renewable-fuel-standards-2017-and-biomass-based-diesel.

Mitigation Policy Considerations: Rhode Island's ability to replace existing heating fuels with biofuels will be constrained by supply, which will be largely determined by federal policies and regional and national market conditions. In Rhode Island, available biodiesel supplies could be used in the heating sector (i.e., to displace #2 home heating oil), the transportation sector (i.e., to displace transportation diesel fuel), or both. In the heating sector, Rhode Island could increase the existing statewide bioblend standard in a manner consistent with mitigating any potential equipment performance issues associated with higher biodiesel content.

ELECTRIC VEHICLES

Description of Mitigation Option: Battery electric or plug-in hybrid electric vehicles offer GHG reductions in the transportation sector by displacing emissions from conventional gasoline- and diesel-powered vehicles. Electric vehicles produce a GHG reduction benefit due to the inherent efficiency of the motor and drivetrain as well as the relatively cleaner emissions profile of New England's power grid supply compared to that of traditional transportation fuels (i.e., gasoline and diesel). This GHG reduction benefit increases over time as the electricity supply shifts toward higher clean energy penetration.

Current Status and Existing Policies: Rhode Island is a signatory to the multi-state Zero Emission Vehicle Memorandum of Understanding (ZEV MOU), with a goal of deploying 43,000 ZEVs on Rhode Island roadways by 2025. To advance progress toward this goal, Rhode Island has invested in a statewide network of publicly-accessible electric vehicle charging stations, initiated an electric vehicle rebate incentive program (Driving Rhode Island to Vehicle Electrification, or DRIVE), and established a ZEV Working Group.[23] The Rhode Island State Rail Plan contains goals, objectives, policies, and implementation actions for Rhode Island's passenger and freight rail transportation system.[24] RIPTA provides 9.6 million miles of fixed route bus service annually, with a fleet comprised of 27% hybrid-electric vehicles.

Mitigation Policy Considerations: Scenario modeling results indicate that achieving the Resilient Rhode Island GHG targets could likely require ~75% of on-road VMT to be served by electric vehicles by 2050, along with ~97% of rail transport.[25] As of December 31, 2015, there were 538 electric vehicles registered in Rhode Island, out of a total of approximately 670,000 light duty vehicles in the state. Further initiatives to incentivize the adoption of electric vehicles and charging infrastructure would be needed to achieve the aggressive market penetration levels necessary to meet long-term GHG reduction targets. Future planning for the state's passenger and freight rail transportation system could also evaluate electrification as a strategy aligned with long-term GHG reduction targets. RIPTA could be encouraged to reflect the Resilient Rhode Island GHG reduction goals in its fleet planning efforts and transition to a zero-emissions fleet by 2050. Finally, increased adoption of electric vehicles will result in a decline in Rhode Island gas tax revenues; the replacement of these lost revenues for transportation infrastructure improvements needs to be an important policy consideration for decision makers to address in the coming years.

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[23] For more details on ZEV policies and programs in Rhode Island, please see the Rhode Island ZEV Action Plan: http://www.energy.ri.gov/Transportation/drive/index.php.

[24] For more details on the Rhode Island State Rail Plan, please see: http://www.planning.ri.gov/documents/trans/Rail_Plan_12_18_13.pdf.

[25] Implemented concurrently with aggressive decarbonization of the power grid.

TRANSPORTATION BIOFUELS

Description of Mitigation Option: Biofuels are liquid fuels derived from renewable organic substances (e.g., recycled cooking grease, plant residues, animal fats, and other renewable feedstocks). Biofuel can offer GHG reductions in the transportation sector by displacing lifecycle emissions[26] from motor vehicles using conventional petroleum fuels (i.e., biodiesel can displace diesel fuel and cellulosic ethanol can displace corn ethanol and petroleum-based gasoline).

Current Status and Existing Policies: There are no current policies in Rhode Island promoting the use of transportation biofuels.

Mitigation Policy Considerations: As mentioned above, Rhode Island's ability to replace existing heating fuels with biofuels will likely be constrained by supply, which will be largely determined by federal policies and regional and national market conditions. In Rhode Island, available biodiesel supplies could be used in the heating sector (i.e., to displace #2 home heating oil), the transportation sector (i.e., to displace transportation diesel fuel), or both. In the transportation sector, Rhode Island could explore the feasibility of establishing a statewide bioblend standard similar to the requirement that exists for #2 home heating oil.

LAND USE CONSERVATION

Description of Mitigation Option: Land use conservation strategies preserve natural systems and environments that provide carbon dioxide "sinks," helping to reduce the state's net GHG footprint. Strategies include protecting existing forest acreage, reforestation, conservation of riparian buffers, enhanced forest management programs (on both private and public lands), reductions in soil erosion to minimize losses in soil carbon storage, coastal wetland protection (e.g., blue carbon), and enhanced urban tree canopies.

Current Status and Existing Policies: Approximately 22% of Rhode Island is in permanent conservation status, and 55% of Rhode Island is forested; however, our forest resource is being lost and fragmented by a wide variety of development pressures. Existing programs like the Forest Legacy Program, the Forest Stewardship Program, and Urban and Community Forestry help reduce those pressures and allow forest land to be preserved and utilized as a carbon sink. Continued public support for funding open space protection continues to be a critical component of the State's land protection efforts.[27] Additionally, the State can minimize loss of existing forest acreage by prioritizing investments to support new growth within the existing Urban Services Boundary (as delineated in Land Use 2025) and in State-approved growth centers.

The Rhode Island Coastal Resources Management Council (CRMC) and its partners have developed Sea Level Affecting Marshes Model (SLAMM) maps for the coastal wetlands in all 21 Rhode Island coastal communities. The SLAMM maps demonstrate how coastal wetlands – which serve as important carbon sinks – will be impacted by different sea level rise scenarios.[28] State and local community planning efforts are beginning to incorporate SLAMM maps into decision making processes about coastal wetland conservation and migration. Ensuring the survival of Rhode Island's wetlands is an important component of GHG and resiliency/adaptation priorities.

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[26] See Footnote 21.

[27] Rhode Island voters approved the 2012 Environmental Management Bond, the 2014 Clean Water, Open Space and Healthy Communities Bond, and the 2016 Green Economy Bond by 69.8%, 71.2%, and 67.6%, respectively.

[28] For more details on SLAMM and projected salt marsh losses, see the SLAMM project summary report: http://www.crmc.ri.gov/maps/maps_slamm.html.

Mitigation Policy Considerations: Scenario modeling results indicate that achieving the Resilient Rhode Island GHG targets could likely require no net future loss of forest or cropland. Policymakers could aim to align future local and state conservation policies with this broader goal, and adoption of a "no net-loss of forests" policy, which other states in the region have endorsed, could be explored.

OTHER MITIGATION OPTIONS

The above list comprises the most significant mitigation options available to Rhode Island to address major GHG source sectors based on currently available technology. Other strategies may likely be required to meet the Resilient Rhode Island GHG targets, including, but not limited to:

- Natural Gas Leaks: Continuation of National Grid's gas infrastructure repair and replacement program to address fugitive methane leaks in the state's gas distribution system.[29]
- Energy Storage: Pursuit of policies to promote energy storage, which can provide many types of system benefits, including integrating clean energy resources in a more cost-effective manner.
- Solid Waste: Strategies to reduce methane emissions from the Central Landfill.

2) ENABLE MARKETS AND COMMUNITIES

In addition to the technology-specific incentive programs and mandates considered above, a series of complementary focus areas to address key barriers to technology deployment would help spur progress toward achieving the Resilient Rhode Island GHG targets. Establishing strong markets for clean energy requires a trained workforce, robust consumer demand, a more dynamic and flexible utility regulatory model, and public sector leadership. Rhode Island policymakers should prioritize the following actions to ensure that the state facilitates as well as reaps the benefits of a smooth and efficient transition to a low-carbon economy.

GROW CLEAN ECONOMY JOBS

The transition to a clean energy economy offers significant opportunities for economic development and job creation in Rhode Island.[30] The vast majority of current expenditure on fossil fuels exits our state because no natural gas or petroleum is produced or refined in the region. With a shift to a greater use of local and regional clean energy resources, however, Rhode Island can keep more energy dollars and jobs in-state. State policymakers should continue to place a priority on fostering nascent local clean energy industries, supporting innovation in clean energy, providing workforce training, and assisting incumbent fossil fuel industries (e.g., the delivered fuels industry) and disadvantaged communities with resources to excel in the burgeoning clean energy marketplace.

EMPOWER CITIZENS AND COMMUNITIES

Many of the GHG mitigation options necessary to meet the Resilient Rhode Island GHG targets rely on individual purchase decisions by consumers and communities to adopt new technologies (e.g., heating systems, personal vehicles). The State must continue to work with industry, local governments, and NGOs to build on progress to date to remove barriers to adoption including, but not limited to: low customer awareness and confidence in previously unfamiliar products; access to and availability of financing solutions; soft costs related to permitting and regulatory hurdles; technical assistance for municipalities to implement solutions. Such efforts can bolster the

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[29] For details on addressing natural gas leaks, please see Energy 2035: Rhode Island State Energy Plan: http://www.energy.ri.gov/energyplan (Page 135).

[30] For details on Rhode Island's growing clean energy economy, please see: http://www.energy.ri.gov/cleanjobs/.

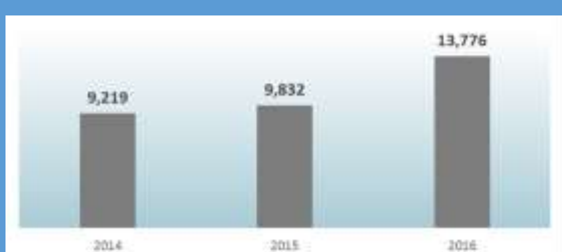
market for clean energy services and stimulate consumer demand. Policymakers should give particular attention to engaging with low-income and vulnerable communities to ensure that all citizens have opportunities to participate in and benefit from the new clean energy economy. In the long-term, by educating and empowering citizens and communities to take energy decisions into their own hands, Rhode Island could help spur a grassroots trend toward meeting the Resilient Rhode Island GHG targets.

FOSTER A MORE DYNAMIC UTILITY REGULATORY MODEL

Achieving the levels of GHG reduction targeted through the Resilient Rhode Island Act would necessitate much higher levels of renewable energy, as well as substantial electrification of the heating and transportation sectors. These trends hold significant implications for the way utilities plan, operate, and invest in the electric grid.[31] State policymakers and utility regulators will continue initial efforts already underway to consider thoughtful changes to utility planning, business models, performance incentives, and rate design in order to enable a transition to the future grid that values, integrates, and plans for growth in clean energy and carbon-free resources, while maintaining a safe and reliable electric system.

SPOTLIGHT ON CLEAN ENERGY JOBS

Rhode Island’s clean energy economy is becoming a powerful engine for job creation and business development. Strong State support for energy efficiency and renewable energy policies have stimulated a robust market for clean energy goods and services, making Rhode Island home to a new, growing clean energy industry. Rhode Island's 2016 Clean Energy Jobs Report found that employment in Rhode Island’s clean economy increased by a staggering 40% over 2015, far exceeding the projected growth of 17%. Clean energy jobs now support about 14,000 workers across the state, representing 3% of statewide employment.



Clean energy jobs grew 40% in Rhode Island over 2015. (Source: 2016 Clean Energy Jobs Report)

LEAD BY EXAMPLE

Under Executive Order 15-17, Governor Raimondo ordered state agencies to Lead by Example in energy efficiency and clean energy by setting the following goals: reducing energy costs by 10% by FY19; shifting the State’s energy supply portfolio to 100% renewables by 2025; ensuring a minimum of 25% of new light-duty State fleet purchases and leases are zero-emission vehicles by 2025; and developing a voluntary building stretch code.[32] Over the medium- and long-term, State policymakers could consider building on this commitment by state government to serve as an early adopter to demonstrate the benefits of GHG mitigation and clean energy solutions. At the local level, cities and towns can play an important role in achieving state GHG targets by integrating mitigation into community planning efforts, setting their own reduction goals, investing in clean energy projects, and directly engaging with diverse community voices. For example, Mayor Jorge Elorza recently committed the City of Providence to becoming a carbon neutral city by 2050 and

[31] For details on policy issues related to the future utility system, please see the Systems Integration Rhode Island (SIRI) Vision Document: http://www.energy.ri.gov/siri.

[32] For details on the Lead by Example initiative, please see: http://www.energy.ri.gov/leadbyexample/.

conducted its first GHG inventory with support from the Compact of Mayors, a growing coalition of cities and towns across the world that are committed to reducing GHG emissions.

3) LEVERAGE REGIONAL COLLABORATION

Because Rhode Island's energy system is closely integrated with that of New England as a whole, the State must continue to work in close collaboration with regional partners to advance clean energy and GHG mitigation solutions. For example, Rhode Island's participation in the Regional Greenhouse Gas Initiative (RGGI), the first market-based cap and trade program in the United States, offers an efficient regional mechanism to price electric sector GHGs and generate auction proceeds for the State to invest in energy efficiency and clean energy projects. The importance of regional collaboration is underscored by Rhode Island's consumption-based approach to electric sector GHG accounting, where emissions reductions depend on progress decarbonizing resources across the New England grid, not just in Rhode Island. In the near, medium, and long-term, Rhode Island should continue to prioritize collaborative action with neighboring states, where the power to leverage regional markets has the potential to yield larger and potentially more cost-effective emissions reductions.

REGIONAL GREENHOUSE GAS INITIATIVE

The Regional Greenhouse Gas Initiative (RGGI) is the first market-based cap and trade program in the United States designed to reduce electric power sector greenhouse gas emissions.[33] The program, which began in 2009, establishes a declining regional emissions cap, and requires electric generators greater than 25 MW to purchase emissions allowances through quarterly auctions. Participating states invest the auction proceeds in energy efficiency and clean energy programs that reduce GHG emissions and deliver economic benefits to consumers throughout the region. By 2020, the RGGI program will have reduced power sector CO_2 emissions in the region by 52% from 2005 levels. Rhode Island policymakers should continue participating in RGGI

SPOTLIGHT ON LEAD BY EXAMPLE

On December 8, 2015, Governor Raimondo signed Executive Order 15-17: State Agencies to Lead by Example in Energy Efficiency and Clean Energy. The Lead by Example Executive Order (LBE EO) sets robust energy reduction targets and clean energy goals for state agencies consistent with the Governor's broader policy goals that include clean energy industry and job growth; reducing public sector energy costs; diversifying the State's energy mix; and reducing public sector GHG emissions, including:

- Reducing energy costs by 10% by FY19;
- Shifting the State's energy supply portfolio to 100% renewables by 2025;
- Ensuring a minimum of 25% of new light-duty State fleet purchases and leases are zero-emission vehicles by 2025; and
- Developing a voluntary building stretch code.

Streetlights on I-295 replaced with LED technology (on the left). Rhode Island is poised to become the first state in the nation to convert all State-owned streetlights to LEDs with control technology, with projected annual savings over $1 million. (Photo Credit: RIDOT)

[33] For details on RGGI, please see: https://www.rggi.org/.

and advocate for long-term reductions in the regional cap consistent with achieving the Resilient Rhode Island GHG targets.

TRANSPORTATION AND CLIMATE INITIATIVE

The Transportation and Climate Initiative (TCI) is a regional collaboration of 11 Northeast and Mid-Atlantic states and the District of Columbia that seeks to develop the clean energy economy and reduce oil dependence and GHG emissions from the transportation sector.[34] Recognizing that nearly one-third of all GHG emissions come from the transportation sector, participating states have started taking action in four core areas: clean vehicles and fuels, sustainable communities, freight efficiency, and information and communication technologies. Rhode Island policymakers should continue to seek regional solutions for addressing transportation GHG emissions consistent with the Resilient Rhode Island GHG targets through TCI.

SPOTLIGHT ON RGGI

The Regional Greenhouse Gas Initiative (RGGI), the nation's first market-based cap and trade program to reduce electric-sector carbon dioxide emissions, is demonstrating concrete results. An independent report by the Analysis Group found that in its first three years, RGGI generated macroeconomic benefits to the regional economy, including the creation of over 16,000 jobs and $1.6 billion in total economic growth.[a] Between 2008 and 2014, the program avoided 1.7 million tons of CO_2 (the equivalent of taking 319,000 cars off the road), while generating $618.1 million in energy bill savings for customers across the region.[b] By 2020, the RGGI program will have reduced power sector CO_2 emissions in the nine participating states by 52% from 2005 levels.

[a] http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/economic_impact_rggi_fact_sheet.pdf

[b] https://www.rggi.org/docs/ProceedsReport/RGGI_Proceeds_Report_2014.pdf

NEW ENGLAND GOVERNORS/EASTERN CANADIAN PREMIERS

In accordance with Resolution 39-1 (A Resolution Concerning Climate Change) adopted by the New England Governors and Eastern Canadian Premiers (NEG/ECP) in August 2015, the Governors and Premiers are currently conducting an inclusive, collaborative process among the NEG/ECP jurisdictions, to be completed by August 2017.[35] The goal is to identify environmental, transportation, and energy strategies, policies, and measures whose implementation at the regional level will make possible the economy-wide GHG reductions needed for the NEG/ECP region to achieve the 2030 GHG emissions reduction marker range of 35 to 45% below 1990 levels as well as the 2050 target (75 to 85% below 2001 levels). This work will result in a Regional Climate Change Action Plan to be presented to the NEG/ECP in August of 2017.

OTHER REGIONAL WORK

Additional areas of opportunity exist to muster scale and unite adjacent markets through coordinated regional action. Such potential areas include clean energy procurement and carbon pricing. For example, Rhode Island recently worked in collaboration with National Grid, Connecticut and Massachusetts state agencies, and other regional utilities to develop a Request for Proposals that could identify clean energy and/or clean energy transmission projects that offer the potential for the

[34] For details on TCI, please see: http://www.transportationandclimate.org/.

[35] For details on NEG/ECP, please see: http://www.coneg.org/negecp. Resolution 39-1 is accessible at: http://coneg.org/Data/Sites/1/media/39-1-climate-change.pdf.

procuring states to meet their shared clean energy goals in a cost-effective manner consistent with individual, state-specific procurement statutes.[36] Carbon pricing is another strategy that might be considered by policymakers for application on a coordinated, regional – or national – basis. Carbon pricing is aimed at accounting for the broader environmental and societal impacts of GHG pollution (i.e., externalities), and is currently being explored by a broad stakeholder group in Rhode Island and other jurisdictions in the region.

MONITORING PROGRESS

The Resilient Rhode Island Act requires the EC4 to recommend "procedures and metrics for periodic measurement, not less frequently than once every five (5) years, of progress necessary to meet [GHG reduction] targets and for evaluating the possibility of meeting higher targets through cost-effective measures." Per the statute, the EC4 provides the following recommendation for state agencies to monitor progress toward the Resilient Rhode Island targets on an ongoing basis:

1. **Monitor progress using a triennial schedule of GHG reductions based on the Resilient Rhode Island GHG targets.**
   Table 5 provides triennial targets for GHG emissions, derived by interpolating between the 2020, 2035, and 2050 reduction targets.

2. **DEM will develop a triennial GHG emissions inventory for Rhode Island and report on progress towards meeting Resilient Rhode Island GHG targets.**
   DEM will develop a triennial GHG emissions inventory, consistent with the methodology used in this Plan.[37] The GHG emissions inventory will be compared on a triennial basis to the emissions reduction schedule presented here, with a triennial report of the results presented to the EC4 and posted on the DEM website.

3. **DEM will evaluate the possibility of meeting higher targets through cost-effective measures in the triennial report.**
   In the triennial report assessing progress toward the Resilient Rhode Island GHG targets, DEM will evaluate the possibility of meeting higher targets through cost-effective measures after consulting with the EC4.

Table 5. Resilient Rhode Island Act GHG Emissions Reduction Schedule

Year	Million Metric Tons CO2e*
2017	11.29
2020	11.23
2023	10.36
2026	9.48
2029	8.61
2032	7.73
2035	6.86
2038	5.99
2041	5.12
2044	4.24
2047	3.37
2050	2.50

*2015 GHG emissions are estimated at 11.33 million metric tons CO2e

[36] For details on the Multi-State Clean Energy RFP, please see: https://cleanenergyrfp.com/.

[37] See Appendix 1 for details on GHG inventory methodology.

THE PATH FORWARD

The EC4 is energized to move forward from planning to action. Confronting and mitigating the effects of climate change is critical to ensuring a healthy future for Rhode Island, and will require coordinated action on multiple fronts. As this Plan demonstrates, the magnitude of our task is daunting, but the opportunities to our state are clear. Responding to this challenge demands our focused attention and is achievable with sustained leadership, strategic investment, and smart policies. In the near-term, we can spur progress toward our goals by leveraging a suite of successful existing policy tools; mobilizing the innovation and participation of businesses, utilities, communities, and citizens; and partnering with our neighboring states to advance key policy priorities. Over the long-term, new, enhanced technologies and market shifts are anticipated to open additional paths forward to the goals. As stated, EC4 believes this is the beginning – not the end – of a critical ongoing conversation in which Rhode Island decision-makers and stakeholders will continue to engage during the coming months, years, and decades.

The EC4 envisions initiating a discussion in 2017 around near-term opportunities for leadership in GHG mitigation consistent with the framework established in this Plan. These may include opportunities for immediate state and local action, areas requiring further study, or strategies requiring regional cooperation. They also may include identification of existing regulations, policies, or other obstacles that pose barriers to implementing GHG mitigation solutions and reaching goals. The following implementation actions and focus areas represent a launching point for this conversation, which EC4 intends to vet and improve through stakeholder input and feedback:

- Support further evaluation of the costs and benefits of GHG mitigation pathways, including macroeconomic, environmental, and health impact analyses.
- Develop a state-of-the-art 2018-2020 Three-Year Energy Efficiency Procurement Plan, with special focus on expanded access to delivered fuels (oil and propane) heating customers, opportunities to drive toward new demand response strategies, and expanded financing mechanisms to leverage capital toward the achievement of robust savings goals.
- Initiate an effort to escalate clean energy adoption in Rhode Island, elevating our state's position as an emerging leader in renewable energy and building off of recent momentum from the nation's first offshore wind farm.
- Explore state and regional mechanisms for promoting clean transportation solutions consistent with addressing the state's largest GHG source sector.
- Craft a framework for addressing utility, rate, and regulatory modernization to position Rhode Island on the cutting-edge of power sector transformation activities and demonstrate our state as a proof-of-concept testbed for integrating clean energy, empowering customers, and improving the resiliency of our electric grid.
- Pursue regional approaches where they promise to enhance progress toward GHG goals, either through existing collaborations such as RGGI or through newly emerging ones.

The EC4 looks forward to the opportunity to collaborate with the Governor and General Assembly and advance these priorities as a part of a "no-regrets" strategy to drive Rhode Island toward our GHG reduction goals. Our current path supports green jobs and a healthier Rhode Island; more work is needed to realize our long-term goals. As time progresses and new opportunities and technologies emerge, the EC4 stands ready to work with stakeholders and policymakers to continually adapt our state's GHG mitigation strategy to achieve Rhode Island GHG reduction targets at maximum benefit to our communities and citizens.

APPENDIX 1 – REFERENCE CASE ASSUMPTIONS AND RESULTS

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Rhode Island Greenhouse Gas (GHG) Emissions Reduction Study

Developing the Reference Case in the Long-range Energy Alternatives Planning (LEAP) Framework

December 30, 2016

This memorandum describes how the reference case scenario is developed for the Rhode Island GHG Emissions Reduction Study. The reference case incorporates historical and projected energy supply and demand data as well as data on non-energy GHG emissions to create a baseline against which GHG mitigation scenarios can be evaluated. The reference case modeling is implemented using the Long-range Energy Alternatives Planning system, or LEAP (Heaps 2016), which is developed by the Stockholm Environment Institute. LEAP is a flexible, widely-used integrated modeling tool that can track energy consumption, production and resource extraction in all sectors of an economy and account for the dependencies between energy demand and supply.

1 Final Energy Demand

1.1 Historical Energy Consumption

Historical energy consumption for all fuels consumed in Rhode Island's residential, commercial, industrial, and transportation sectors is taken from the U.S. Energy Information Administration's (EIA's) State Energy Data System (SEDS) (U.S. Energy Information Administration 2015c). Covering the period 2000 – 2013, these data present a "top-down" view of energy consumption for each fuel with no technological detail. They are used for calibration purposes and to establish historical energy intensities for comparison with projected intensities, as necessary.

1.2 Projected Energy Consumption

Projections of energy consumption for all fuels in the residential, commercial and industrial sectors are based on EIA's Annual Energy Outlook (AEO) 2015 "Reference Case" and incorporate the technological and subsectoral detail[1] provided in the National Energy System Model (or NEMS, which underlies the AEO) (U.S. Energy Information Administration 2015g). NEMS provides a highly detailed technology-based ("bottom-up") characterization of energy service requirements, together with a description of the technologies which are used to satisfy these service demands. The AEO Reference Case prescribes a "business-as-usual trend estimate, given known technology and technological and demographic trends" (ibid) through the year 2040.

The primary drivers of Rhode Island's energy use trends are Rhode Island's Least-Cost Procurement mandate for electricity and natural gas, continued dependence on natural gas (and fuel-switching to natural gas), federal motor vehicle fuel economy standards, renewable energy

[1] There are many technologies satisfying many end-uses in a variety of subsectors. Examples of (heating, for example) technologies include natural gas furnaces, oil boilers, etc. Examples of (industrial, for example) subsectors include cement and lime, metal fabrication, etc.

policy mandates, and participation in the Regional Greenhouse Gas Initiative (RGGI) (Rhode Island Division of Planning 2015a). In the electric generation sector, energy reductions reflect investments from Rhode Island's Least-Cost Procurement mandate in electric energy efficiency, while overall supply continues to remain heavily reliant on natural gas. Increased renewable generation, including offshore wind, continue to provide only a relatively small portion of the generation supply. Participation in RGGI provides funding for increased energy efficiency and renewable energy resources. In the thermal sector, natural gas efficiency investments from the Least-Cost Procurement mandate help reduce future projected energy demand for heating in homes and buildings. For the transportation sector, federal Corporate Average Fuel Economy (CAFE) standards are the most significant driver of future fuel demand.

The following tables show how the various subsectors, end-uses, technologies and/or fuels which are found in NEMS have been included in the Rhode Island LEAP model. Each table may be read from left to right, with macroscopic subsectors or categories on the left, and specific fuel consumption or technologies on the right. Detail is provided for key end-uses only - other end-uses terminate only in *fuels* (italicized, understood to be a list of fuels consumed within the category) or *technologies* (understood to be a list of technologies which consume fuel within the category).

Table 1: Structure of Household Demand

<table>
<tr><th colspan="5">Residential</th></tr>
<tr><td rowspan="20">Single Family, Multi-Family or Mobile Homes</td><td rowspan="15" colspan="2">HVAC</td><td rowspan="13">Heating</td><td>Air Source Heat Pump</td></tr>
<tr><td>Electric Furnace</td></tr>
<tr><td>Fuel Oil Boiler</td></tr>
<tr><td>Fuel Oil Furnace</td></tr>
<tr><td>Ground Source Heat Pump</td></tr>
<tr><td>Kerosene Furnace</td></tr>
<tr><td>LPG Furnace</td></tr>
<tr><td>Natural Gas Boiler</td></tr>
<tr><td>Natural Gas Furnace</td></tr>
<tr><td>Natural Gas Heat Pump</td></tr>
<tr><td>Wood Stove</td></tr>
<tr><td>Biodiesel Boiler</td></tr>
<tr><td>Biodiesel Furnace</td></tr>
<tr><td>Secondary Heating</td><td>Fuels</td></tr>
<tr><td>Cooling</td><td>Technologies</td></tr>
<tr><td rowspan="5">All Other</td><td>Lighting</td><td>Various End-Uses</td><td>Technologies</td></tr>
<tr><td colspan="2">Computing and Networking</td><td rowspan="4">Fuels</td></tr>
<tr><td colspan="2">Cooking</td></tr>
<tr><td colspan="2">Clothes Washing and Drying</td></tr>
<tr><td colspan="2">Dish Washing</td></tr>
</table>

		Other Appliances	
		Refrigeration and Freezing	
		Television and Video	
		Water Heating	

Table 2: Structure of Commercial and Service Sector Demand

Commercial			
Assembly, Education, Food Sale, Food Service, Health Care, Lodging, Large Office, Small Office, Mercantile and Service, Warehouse, Other	HVAC	Heating	Rooftop Air-Source Heat Pump
			Commercial Ground-Source Heat Pump
			Electric Boiler
			Electric Residential Heat
			Gas Boiler
			Gas Furnace
			Residential-type Gas Heat Pump
			Oil Boiler
			Oil Furnace
			Wood Boiler
			Biodiesel Boiler
			Biodiesel Furnace
		Cooling	*Technologies*
		Ventilation	
	All Other	Lighting	
		Water Heating	
		Cooking	
		Refrigeration	
		Non-PC Office Equipment	*Fuels*
		PC Office Equipment	
		Other	
		Unspecified	
Non-Building (i.e. cell towers, street lighting)			*Fuels*

Table 3: Structure of Industrial Demand

Industrial			
Manufacturing (Food Products, Paper and Allied Products, Bulk Chemicals, Glass and Glass Products, Cement and Lime, Iron and Steel, Aluminum, Metal Fabrication, Machinery, Computer and Electronics, Transport Equipment, Electrical Equipment and Appliances, Wood Products, Plastics and Rubber, Balance of Manufacturing)	Process and Assembly	*Various End-Uses*	*Fuels*

	Buildings	*Fuels*
Non-Manufacturing (Crop Agriculture, Other Agriculture, Coal Mining, Oil and Gas Mining, Metallic and Non Mineral Mining, Construction)	Process and Assembly	*Fuels*

Projections of energy consumption for all fuels in the transportation sector are based on the MOtor Vehicle Emission Simulator (MOVES) model (U.S. Environmental Protection Agency 2016a). MOVES is the U.S. Environmental Protection Agency (EPA) accepted mobile source emission model for state air quality planning and emissions inventory development under the Clean Air Act. The MOVES runs for the Rhode Island LEAP reference case were developed using input data specific to Rhode Island for projecting state vehicle-miles traveled (VMT) and energy consumption by vehicle type, out to 2050. VMT growth rates were obtained from the Rhode Island Statewide Model Update (Rhode Island Division of Planning 2016). All key vehicle classes and transport modes are represented, and are listed in Table 4. Total VMT across on-road vehicle types in the reference case were projected to grow about 0.2% annually from 2015 through 2050. Again, italicized items denote detailed lists of end-uses, fuels or technologies which have been excluded from the table for brevity.

Table 4: Structure of Transport Demand

Transportation		
On-Road	Motorcycle	*Fuels*
	Passenger Car	
	Passenger Truck	
	Light Commercial Truck	
	Intercity Bus	
	Transit Bus	
	School Bus	
	Refuse Truck	
	Single Unit Short-Haul	
	Single Unit Long-Haul	
	Motor Home	
	Combination Short-Haul	
	Combination Long-Haul	
Off Road	Construction	
	Commercial	
	Industrial	
	Rail Support	
	Air Support	
	Agriculture	
	Recreational	

	Pleasure Craft		
	Logging		
	Lawn		
	Air Travel		
	Rail	Passenger	*Fuels*
		Freight	
	Navigation	International Shipping	*Fuels*
		Domestic Shipping	

Final energy consumption is calculated using an "activity analysis" in the Rhode Island LEAP model. This is a simple technique which represents final energy demands (for each fuel or technology within a particular subsector or end-use) as the product of two numbers: the *activity level*, or number of units which require energy services, and the *energy intensity*, the amount of energy consumed per unit of activity. The activity level and energy intensity for each major demand sector are taken from high-level demographic and economic projections, which are listed below in Table 5. Energy intensities may further be specified in two variants: as a *final* energy intensity, providing the total quantity of energy required for each activity unit, or as a *useful* energy intensity, from which total energy requirements for each activity unit can be calculated from the desired energy service requirement and the efficiency of devices which provide the service. The selection of modeling methodology in LEAP is directly related to the nature of results which are found in NEMS outputs. Useful energy requirements are given for heating and cooling end-uses, while final energy requirements are provided for other categories of energy demand.

Table 5: Major Data Input Sources for Demand Sectors

Sector	Primary Data Sources	Unit of Activity	Characterization[2] of End-Uses and Technologies/Fuel Consumption for each Unit of Activity
Residential	AEO 2015 outputs (U.S. Energy Information Administration 2015f) and (U.S. Census Bureau 2015)	Number of households by housing type (single family, multi-family, mobile) and Square footage per household for heating and cooling end-uses	(U.S. Energy Information Administration 2014c)
Commercial	AEO 2015 outputs (U.S. Energy Information Administration 2015d)	Commercial square footage by business type	(U.S. Energy Information Administration 2014a)
Industrial	AEO 2015 outputs (U.S. Energy Information Administration 2015e)	Dollars of output by industrial sector or Physical commodity production (paper and allied products, glass and glass products, cement, iron and steel, aluminum only)	(U.S. Energy Information Administration 2014b)
On Road Transportation & Off Road Equipment	RI-specific MOVES run and Rhode Island Statewide Model Update	Vehicle-miles traveled, Number of devices	(U.S. Environmental Protection Agency 2016a) (Rhode Island Division of Planning 2016)
Rail, Aviation & Shipping	AEO 2015 outputs (U.S. Energy Information Administration 2015f)	Total energy consumption (MMBTU)	(U.S. Energy Information Administration 2015)

Since NEMS generates only regionally-aggregated results for New England (and other groups of states), data and outputs from AEO must be downscaled appropriately before they can be entered into the Rhode Island LEAP model. In particular, activity data which are projected in NEMS are reduced using proportionality factors appropriate for Rhode Island, while energy intensities are left intact. The activity downscaling approach is briefly described for each major demand sector in Table 6.

Following the downscaling procedure, two additional modifications are performed.

[2] Documents cited in this column are for the 2014 AEO, as the U.S. Energy Information Administration had not yet updated NEMS documentation for the 2015 AEO at the time of the Reference Case development. However, having carefully reviewed the updated AEO 2015 assumptions as of September 2015 (U.S. Energy Information Administration 2015i), the authors concluded that little of the methodology had changed, therefore the 2014 documentation remained current.

1) Useful service demands for household and commercial building heating are reduced to account for the shorter heating season in Rhode Island when compared with the New England average. An analysis of the average number of heating degree days in Rhode Island implies an 11% reduction in useful heat requirements per square foot, relative to the service demand described by AEO 2015.
2) The mix of residential heating fuels and technologies is adjusted using the state's heating market segmentation analysis (Meister Consultants Group, n.d.), relative to the average regional mix seen in AEO 2015 projections.

AEO generates projections through 2040 only. These projections must therefore be extrapolated through 2050 for key variables to cover the full planning horizon for the Rhode Island LEAP model, using annual average growth rates (AAGR) established through 2040. An overview of techniques and variables which are extrapolated is given in Table 6. All other activity level and energy intensity data which are not mentioned explicitly in this table are held constant through 2050 at AEO-projected 2040 levels.

Table 6: Modifications to Annual Energy Outlook for Rhode Island LEAP Demands

Sector	Unit of Activity	Activity Downscaling Methodology	2040 - 2050 Extrapolation Methodology
Residential	Number of households by housing type (single family, multi-family, mobile) and Square footage per household for heating and cooling end-uses	Number of households by housing type provided for RI from US Census Bureau Heating service demands and technology/fuel mix adjusted for RI as described above	Total households extrapolated using 2009 – 2040 AAGR. Useful heating and cooling requirements extrapolated using 2025 – 2040 AAGR. Energy intensity for all other devices extrapolated using 2025 – 2040 AAGR.
Commercial	Commercial square footage by business type	Total RI square footage = (Total New England square footage) * (Commercial GDP in RI / Commercial GDP in New England)	Useful heating, cooling, water-heating, cooking and refrigeration requirements extrapolated using 2025 – 2040 AAGR. Energy intensity for all other devices extrapolated using 2025 – 2040 AAGR.
Industrial	Dollars of output by industrial sector or Physical commodity production (paper and allied products, glass and glass products, cement, iron and steel, aluminum only)	RI output = (New England output) * (Sector GDP in RI / Sector GDP in New England)	Energy intensity for all fuels extrapolated using 2025 – 2040 AAGR.
Transportation	Vehicle miles traveled	MOVES outputs are already RI specific – no need to downscale	No extrapolation required.

When using two different sources of data for different time periods (historical 2001 – 2013 consumption from SEDS, AEO-projected consumption from 2014 onwards), it becomes necessary to calibrate the two sources of data to ensure a continuous transition in the first projected year. Calibration is performed by adjusting the average efficiency or energy intensity for all technologies which consume the same fuel within each sector, to recover the sector's total consumption of that fuel observed in 2013 from SEDS.

2 Energy Supply

The reference case modeling of energy supply for Rhode Island covers the electric power sector, indigenous production of primary renewable energy, and imports of other primary and secondary fuels. The LEAP representation of the power sector is a downscaled model of the ISO New England (ISO-NE) power system from which Rhode Island draws electricity. This permits a consumption-based accounting approach to be used, where each megawatt-hour of electricity consumed in Rhode Island is served by the average mix of resources projected for ISO-NE as a whole. Several types of resources are represented in the electric power model, including:

a) Currently existing generating capacity in Rhode Island. Plants with a total capacity of at least 1 MW are represented individually, while other capacity is aggregated by technology. Behind-the-meter (BTM) solar and wind capacities (comprised of all net-metered capacity as well as capacity which is both less than 25 kW and installed under the state's Renewable Energy Growth program) are distinguished from front-of-the-meter (FTM) capacities.
b) Existing generating capacity within the ISO-NE control area, but outside Rhode Island. Each plant is grouped with other like technologies, in one of 24 distinct classifications.
c) Potential future generating capacity in ISO-NE (represented by 16 generation technologies).
d) ISO-NE demand resources inside and outside Rhode Island, including on-peak and seasonal peak passive demand resources, real-time demand response, and real-time emergency generation.
e) Imports from adjoining control areas (New Brunswick, New York, and Québec).

2.1 Current or Historical Capacity and Electricity Generation

Existing generating capacity is derived from EIA Form 860 (U.S. Energy Information Administration 2015a), Rhode Island Office of Energy Resources (2016), and ISO-NE (2015b). Generators labeled industrial or commercial according to EIA-860 are excluded from the power model because they are assumed to be implicitly contained in the AEO 2015 demand projections[3]. The same argument is applied to a fraction of BTM capacity, which is assumed to be embedded in the AEO-based total demand projections and in load duration curves taken from ISO-NE (ISO New England 2015b). Finally, any capacity which was decommissioned before

[3] Industrial and commercial distributed generation capacity that qualifies as an ISO-NE demand resource is excepted from this exclusion for the sake of consistency with how other demand resources are modeled. The amount of capacity in question is small (approximately 61 MW in 2015).

2014 is also excluded because it is not required by the LEAP software in order to recreate historical electricity generation. The effective capacity from demand resources and imports is taken from ISO-NE documentation (ISO New England 2016b; ISO New England 2016a; ISO New England 2015b; ISO New England 2015a).

Historical generation of electricity and associated consumption of various feedstock fuels for 2001-2014 is calculated using EIA's 900-series forms (U.S. Energy Information Administration 2015b). Historical imports are from ISO-NE (2016e).

Table 7: Summary of each technology or resource represented in LEAP for 2014, the most recent historical year available from EIA sources

Existing Resources in 2014		
Location	**Plant, Technology or Resource**	**Capacity (MW)**
Rhode Island	Blackstone Tupperware	1.6
	Block Island	7.7
	Entergy Gas	596.0
	Forbes Street Solar	3.0
	Johnston Landfill Gas	34.0
	Manchester Street NGCC*	515.0
	Ocean State Power I	254.2
	Ocean State Power II	254.2
	Pawtucket	68.8
	Pawtucket Blackstone	1.6
	Providence Solar	1.7
	Ridgewood	6.4
	Thundermist	1.2
	Tiverton NGCC*	272.5
	WED North Kingstown Green	1.5
	West Davisville Solar	2.0
	West Greenwich Solar	1.9
	BTM Onshore Wind	8.3
	BTM Solar PV**	2.3
	Other FTM Onshore Wind	0.01
	Other FTM Solar PV**	5.6
	Other Run of River Hydro	1.8
	Real Time Demand Response	85.1
	On Peak Energy Efficiency	87.5
	On Peak Distributed Generation	4.6
Outside Rhode Island	Reservoir Hydro	654.9
	Run of River Hydro	1,112.4

	BTM Solar PV**	505.3
	FTM Solar PV**	198.3
	Conventional Steam Coal	2,083.8
	Conventional Steam Coal CHP***	102.6
	Landfill Gas	52.1
	Municipal Solid Waste	532.1
	Natural Gas Combined Cycle	10,863.8
	Natural Gas Combined Cycle CHP***	839.2
	Natural Gas Combustion Turbine	760.4
	Natural Gas Fuel Cell	16.0
	Natural Gas ICE****	8.5
	Natural Gas ICE**** CHP***	7.6
	Natural Gas Steam	730.6
	Pilgrim and Seabrook	1,912.0
	Millstone 2	909.9
	Millstone 3	1,253.0
	Onshore Wind	665.7
	Oil Combined Cycle	478.0
	Oil Combustion Turbine	2,192.5
	Oil Combustion Turbine CHP***	20.0
	Oil ICE****	158.0
	Oil Steam	4,646.6
	Other	31.3
	Wood and Wood Waste	513.8
	Imports New Brunswick	1,000.0
	Imports New York	1,730.0
	Imports Québec	2,217.0
	Real Time Demand Response	1,425.7
	On Peak Energy Efficiency	1,010.5
	On Peak Distributed Generation	53.2
	Seasonal Peak Energy Efficiency	298.8
	Seasonal Peak Load Management	52.7
ISO-NE	Real Time Emergency Generation	915.4
	Imports New Brunswick	1,000.0
	Imports New York	1,730.0
	Imports Québec	2,217.0

*Natural gas combined cycle.
**Photovoltaic.
***Combined heat and power.
****Internal combustion engine.

Consumption-based electricity modeling

Since the geographic scope of the analysis covers only electricity demand which arises within territorial Rhode Island, implementing a consumption-based modeling approach in the power sector means that each megawatt of capacity and megawatt-hour of electricity generated in the ISO-NE control area must be downscaled to a miniaturized representation of the New England grid. This "fictitious" electrical grid must be sized appropriately to meet Rhode Island's electrical requirements (and a pro-rated share of exports to outside the ISO-NE area). The technique ensures that the set of generating technologies represented in the LEAP model will be dispatched in the same way that they would be dispatched if meeting electricity demand for all New England. A multiplicative downscaling factor c, loosely defined as the ratio of Rhode Island's electrical demand to that of the whole ISO-NE control area, is applied to the capacity and historical electricity production of each process. The downscaling factor can be defined for every historical year using the following ratio:

$$\boldsymbol{c} = \frac{\boldsymbol{d} - \boldsymbol{V}(\mathbf{1} - \boldsymbol{l})}{\boldsymbol{G}(\mathbf{1} - \boldsymbol{l}) - \boldsymbol{E} + \mathbf{8760}(\mathbf{1} - \boldsymbol{l})\boldsymbol{\Sigma}_{\boldsymbol{i}}^{\boldsymbol{BTM}} \boldsymbol{C}_{\boldsymbol{i}} \boldsymbol{CF}_{\boldsymbol{i}}}$$

In the numerator, in-state electricity demand d is reduced using the Rhode Island demand resource "on-peak energy efficiency,"[4] which is quantified as the megawatt-hours of demand reduction V (ISO New England 2014a), adjusted to account for transmission losses. The parameter l is the electrical loss incurred from production to consumption, expressed as a fraction of power generated. The average transmission and distribution loss factor is held at 8% in all years (ISO New England 2014b). The expression's denominator includes on-grid generation and imports from outside ISO-NE (collectively represented by G) and total export requirements from ISO-NE E. It also includes electricity produced by behind-the-meter (BTM) processes as well as the ISO-NE demand resource "on-peak distributed generation," each with capacity C and average capacity factor CF (ibid). For all projected years, the downscaling factor c is held at its most recently calculated 2014 historical value of 7.23%.

Various other technical characteristics of power resources, such as heat rates and capacity factors, are derived from the previously cited sources and AEO documentation.

2.2 Projected Capacity Expansion and Electrical Dispatch

Reference case projections in the electric power sector are driven by Rhode Island's requirements for electricity. To represent the electric power sector through the year 2050, two processes must be modeled: the expansion of generating capacity including power plants, technologies and other resources (such as electricity imports and demand resources), as well as the operation (or *dispatch*) of these resources to meet electric load.

[4] The ISO-NE on-peak energy efficiency demand resource is assumed to be distinct from efficiency which is achieved under the current least-cost procurement statute.

Capacity Expansion

Capacity expansion includes all necessary capacity growth to maintain the reliability of the grid as aging power plants retire, as demand increases, or as grid characteristics change. Expansion plans that are explicitly described in ISO-NE's current Interconnection Request Queue (ISO New England 2016c) are included in the reference case using the downscaling method described in the preceding section, after applying a multiplicative attrition rate to all planned capacity increases. For wind, the attrition rate is 82% of planned capacity[5] additions while other projects are assigned at attrition rate of 85%. Both attrition rates were calculated from historical data in the Interconnection Queue. Retirements of existing plants are assumed to occur after each plant's useful lifetime, using commissioning dates given in EIA-860 (U.S. Energy Information Administration 2015a) and lifetimes taken from a variety of sources (Tidball et al. 2010; Schlömer et al. 2014; International Energy Agency 2012).[6]

Additional capacity may also be added in order to maintain the planned system reserve margin of 16.1%, dropping to 14.4% by 2020 (calculated from ISO-NE's installed capacity requirements, ISO New England 2015c). Each unit or resource contributes its Seasonal Claimed Capability (SCC, ISO New England 2016d) towards meeting this reserve target. These types of capacity additions do not explicitly appear in ISO-NE documents – instead they are constructed whenever they are needed from a list of pre-selected "endogenous" technologies. Endogenous technology options are chosen so that new capacity maintains the same ratio as newly added technologies observed in the Interconnection Queue since 2008, factoring in historical attrition rates.

[5] A lower attrition rate for wind of 41% is used initially, reaching 82% by 2025. This was found to be necessary to ensure that the required renewable portfolio standard was being met during the first ten years of the scenario (refer to Section 4 for a description of how various renewable portfolio standards are handled in the model).

[6] In cases where aging power plants were seen to continue operating in 2014 already beyond their expected lifetimes, their expected decommissioning dates were pushed back.

Table 8 shows the list of plants or technologies which may be added endogenously in the reference case, as well as those existing plants or resources whose capacities are projected using explicit expansion or retirement plans.

Table 8: Summary of capacity projections for each technology or resource represented in LEAP

Future Resources		
Location	**Plant, Technology or Resource**	**New Capacity**
Rhode Island	Johnston Solar	1 MW in 2015
	WED Coventry	15 MW in 2015
	Block Island Wind	30 MW in 2016
	Burrillville Clear River	1030 MW in 2019
	BTM Solar PV	Variable+
	All Existing Plants and Resources	Explicit additions or retirements
Outside Rhode Island	All Existing Technologies and Resources	Explicit additions or retirements
	BTM Solar PV	Variable+
ISO-NE	FTM Solar PV	Endogenous
	Landfill Gas	Endogenous
	Natural Gas Combined Cycle	Endogenous
	Natural Gas Fuel Cell	Endogenous
	Natural Gas Combustion Turbine	Endogenous
	Natural Gas Steam	Endogenous
	Oil Combined Cycle	Endogenous
	Oil Combustion Turbine	Endogenous
	Onshore Wind	Endogenous
	Offshore Wind	Endogenous
	Reservoir Hydro	Endogenous
	Run of River Hydro	Endogenous
	Wood and Wood Waste	Endogenous

+Projected behind-the-meter solar photovoltaic capacity is taken from the latest ISO-NE CELT report (ISO New England 2015b), adjusted by the amount of BTM solar which is already assumed in AEO's reference case electricity demand projection.

Capacity Dispatch

The electricity generation mix is projected by dispatching available downscaled capacity both inside and outside Rhode Island. Annual electricity requirements are comprised of in-state demand, plus a share[7] of electricity which is exported outside the ISO-NE control area, plus transmission and distribution losses. These energy requirements are subdivided into separate dispatch periods within the year, using real and projected load duration curves from ISO New England (2015b). Each dispatch period contains a group of representative hours for each separate hour of each day of the week within each season. In all there are 673 dispatch periods which

[7] The scaling factor which is used to downscale ISO-NE-wide capacities and historical electricity production is also applied to export requirements to adjacent control areas. The most recently available historical export, taken from ISO New England (2016e), is held constant in all future years.

make up each year, including one period for those hours during which the top 1% of system load occurs. The electricity generation mix is then projected by dispatching each power plant, technology option or resource to meet electricity requirements within each separate dispatch period and within each year of the scenario. Each dispatchable resource is assigned a priority order (also called *merit order*, summarized in Table 9) that determines when it is used to meet load. Must-run resources such as intermittent renewable generation are dispatched at their full available capacity at all times, regardless of load.

Table 9: Electrical Dispatch Priorities for Generation Technologies, Imports and Demand Resources (DR)

Technology	Merit Order
Run-of-River Hydro	Must-run
Distributed and Utility Solar	Must-run
Onshore and Offshore Wind	Must-run
On Peak Distributed Generation (DR)	Must-run
Rhode Island-only+ On Peak Energy Efficiency (DR)	Must-run
Reservoir Hydro	1
Fuel Cell	1
Nuclear	1
Landfill Gas	2
Natural Gas Steam	2
Biomass	2
Québec Imports	2
Steam Coal (CHP and non-CHP)	3
Natural Gas Combined Cycle and ICE CHP	3
Other	3
New York/New Brunswick Imports	3
Municipal Solid Waste	4
Natural Gas Combined Cycle CHP and Combustion Turbine	4
Oil Combined Cycle and Oil Steam	4
Natural Gas ICE	5
Oil ICE	5
Oil Combustion Turbine (CHP and non-CHP)	6
Rhode Island-only+ Real Time Demand Response (DR)	6

All Other Demand Resources	Not dispatched

⁺Generally, ISO-NE demand resources contribute capacity towards the system reserve margin but are not dispatched in the model. Two exceptions are permitted for On Peak Energy Efficiency and Real Time Demand Response resources which are physically located in Rhode Island, and which may be used to meet the state's electricity requirements.

Resource Requirements and Constraints

The supply of primary renewable energy available in Rhode Island is represented in the reference case by modeling the annual sustainable yield of renewable resources: onshore wind and biomass (Lopez et al. 2012), offshore wind (Applied Technology & Management et al. 2007), utility and distributed solar, hydro, geothermal (Brown et al. 2015), landfill gas (National Grid 2010) and municipal solid waste (Rhode Island Division of Planning 2014). These amounts serve as constraints on total production in any one year. Other primary fossil fuels and secondary fuels besides electricity are assumed to be imported into Rhode Island as necessary to satisfy the state's requirements[8].

3 Emissions of Greenhouse Gases and Local Air Pollutants

To calculate emissions of GHGs and other air pollutants from the energy system, emission factors—defined as the mass of pollutant per unit of energy consumed or produced—are assigned to each activity or process that consumes or produces energy in the LEAP model. The factors are then multiplied by projected energy consumption or production to determine total emissions.[9] Factors are specified for all GHGs emitted from the energy system (including carbon dioxide, nitrous oxide, and methane) as well as NOx, NMVOC, sulfur dioxide, carbon monoxide, and particulate matter less than 10 and 2.5 microns in diameter.

For consistency with Rhode Island's most recent GHG inventory, state-specific emission factors for major energy demand sectors are taken from EPA's State Inventory Tool (SIT) where possible (U.S. Environmental Protection Agency 2015b). Gaps for fuel, demand sector or pollutant combinations that are not provided in SIT are filled from a variety of publicly available sources, particularly EPA's WebFIRE system (U.S. Environmental Protection Agency 2016b) and the Intergovernmental Panel on Climate Change's (IPCC's) Database on Greenhouse Gas Emission Factors (Intergovernmental Panel on Climate Change 2016), with smaller data gaps filled by a mixture of other source and the modeling team's own assumptions (Bond et al. 2004; European Environment Agency 2013; Argonne National Lab 2015).

Emission factors for energy transformation processes are also incorporated. The model includes fugitive emissions associated with the transmission and distribution of natural gas, and with the

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[8] In-state requirements for natural gas by end-users (excluding power plants) are increased by 1.5% to account for estimated pipelines losses incurred in its transmission and distribution.

[9] There are two exceptions to this methodology: nitrogen oxides and sulfur dioxide emitted from the on-road transport sector. Emissions of these pollutants are specified using on a *per vehicle-mile traveled* basis.

transmission of electricity (for example, sulfur hexafluoride emissions from capacitor banks). Pollution arising from electricity generation is tracked for all power plants and technologies in the power sector model, consistent with a consumption-based accounting approach. Emission factors for each major technology are taken first from EPA's eGRID database (U.S. Environmental Protection Agency 2015a), the from the WebFIRE system and IPCC as needed (U.S. Environmental Protection Agency 2016; Intergovernmental Panel on Climate Change 2016). These data are supplemented by emissions factors from a variety of other sources. Average GHG emissions per kilowatt-hour from adjacent control areas - Québec, New Brunswick, New York - are also included (U.S. Environmental Protection Agency 2015a; Environment and Climate Change Canada 2016).

The land-use, land-use change, and forestry (LULUCF) sink was added to 1990 based on available land cover datasets (downloaded from the Rhode Island Geographic Information System (RIGIS) website http://www.rigis.org/), estimates of carbon stocks for each land cover type (Abt Associates 2015), and trends in carbon dynamics from the EPA State Inventory Tool (U.S. Environmental Protection Agency 2015b). RIGIS land cover datasets were available for the years 1988, 1995, 2003/2004, and 2011. These were used to identify historical changes in acreage of multiple land cover classes, including three types of forest. These historical changes were interpolated across the dataset years to derive an estimate for the 1990 Rhode Island GHG inventory.

The reference case projection of LULUCF GHG fluxes to 2035 was based on (1) estimates of future residential, commercial, and industrial land needs and (2) the assumption that future land needs will be met according to historical land conversion trends (i.e., most new residential developments will be developed from forested lands). Estimates of future land needs were based on population projections (Rhode Island Division of Planning 2013), employment projections (Rhode Island Department of Labor and Training 2014), and Land Use 2025 (Rhode Island Division of Planning 2006). We estimated future forest carbon dynamics using regional modeling in the U.S. Forest Carbon Budget Model (U.S. Forest Service 2010) and used estimates of carbon stocks for each land cover type developed in similar analysis for Massachusetts (Abt Associates 2015).

4 Current Policies

The reference case projection accounts for existing federal, regional, and state policies expected to shape future energy use and GHG emissions in Rhode Island. It does not include proposed policies or rules that are not yet adopted as requirements. Table 10 summarizes how major existing policies are addressed in the reference case.

Table 10: Handling of Major Existing Policies in Reference Case

Policy	Description	How Addressed in Reference Case Model
Transportation		
Corporate	Fuel economy standards for existing light-	Included in MOVES Rhode Island assumptions

Policy	Description	How Addressed in Reference Case Model
Average Fuel Economy (CAFE) Standards	duty vehicles, through 2011 model year.	(MOVES outputs imported into LEAP model).
EPA/NHTSA Emissions and Fuel Efficiency Standards	Standards for cars and light trucks, model years 2012-2016 and 2017-2025. Also includes Phase 1 Standards for medium- and heavy-duty engines and vehicles with 2014-2016 model years.	Included in MOVES Rhode Island assumptions (MOVES outputs imported into LEAP model).
EPA Emissions Standards	Tier 1 and 2 light-duty vehicle standards for nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOC) through 2016 model year. Tier 3 light-duty vehicle NOx and NMVOC standards and low-sulfur gasoline for model year 2017.	Included in MOVES Rhode Island assumptions (MOVES outputs imported into LEAP model).
California's LEV Regulations	Low emission vehicle standards for NOx and NMVOC in light-duty vehicles.	Included in MOVES Rhode Island assumptions (MOVES outputs imported into LEAP model).
EPA On-Road Emission Standards	On-road standards are also applied to construction equipment, small gasoline engines, off-road recreational vehicles, etc.	Included in MOVES Rhode Island assumptions (MOVES outputs imported into LEAP model).
Driving Rhode Island to Vehicle Electrification (DRIVE)	Rhode Island consumer rebate for electric vehicles.	Not included in modeling assumptions. Reference scenario is compliant with CAFE standards for automakers, which is a fleet-average requirement. Therefore DRIVE does not impact GHG projections.
International Civil Aviation Organization (ICAO) CO_2 Standard for New Aircraft	Proposed international performance standard for new commercial and business aircraft delivered after January 1, 2028.[10]	Included in reference case as a projected fuel demand decrease.
Other Energy		
Regional Greenhouse Gas Initiative (RGGI)	Cap and trade market for 25+ MW power stations in the following states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (RGGI Inc. 2016a).	Baseline capacity expansion plans through 2020 (ISO New England 2016c) are assumed to be in alignment with declining RGGI targets given market signals. As noted previously, the reference case

[10] While the ICAO aircraft measure is a proposal, it reflects the current industry trend in which the introduction of new jet designs in the next five years will meet or exceed the proposed standard in advance of the standard actually going into effect (ICCT 2016). Therefore, we include it in the reference case as a conservative reflection of projected business-as-usual energy demand in the commercial and business aircraft sector.

Policy	Description	How Addressed in Reference Case Model
	Adjusted[11] regional carbon dioxide allowances in each year are the following: • 2014: 82,792,336 tonnes CO_2 • 2015: 66,833,592 tonnes CO_2 • 2016: 64,615,467 tonnes CO_2 • 2017: 62,452,795 tonnes CO_2 • 2018: 60,344,190 tonnes CO_2 • 2019: 58,288,301 tonnes CO_2 • 2020: 56,283,807 tonnes CO_2 In 2015, Rhode Island was allocated 2.8% of regional allowance (RGGI Inc. 2016b).	model uses a consumption-based approach to determine GHG emissions from electricity supply, so reference case emissions are not directly comparable to the RGGI allocation. By adjusting emission factors, the model could be used to estimate generation-based emissions that would be comparable to the allowances, but this is outside the scope of this study.[12]
Renewable Energy Standard (RES)	Renewable energy must make up the following shares of retail electricity sales in Rhode Island, interpolating linearly between each (State of Rhode Island 2016, sec. R.I.G.L § 39-26-4): • 3% in 2007 • 5.5% in 2011 • 8.5% in 2014 and 2015[13] • 38.5% in 2035 Permitted under the standard: renewable electricity produced anywhere in the ISO-NE control area, electricity produced by consumer-owned distributed generators located in Rhode Island. Eligible renewable resources include solar, wind, geothermal, tidal/ocean, small hydro (plant size not exceeding 30 MW), wood/wood waste, and landfill gas. Exclusions under the standard: renewable electricity purchased voluntarily by consumers; renewable capacity that entered into service before December 31	Renewable portfolio standards from all ISO-NE states and adjacent control areas — including Rhode Island's RES — are combined to determine the expected renewable electricity requirements for the entire ISO-NE system through 2035 (the final year under Rhode Island's current policy). Priorities for dispatching supply resources and constructing new resources are adjusted as necessary (final dispatch priorities are given in Table 9) to align the reference case power mix with the combined requirements. Voluntary purchases of renewable power are not considered.

[11] From the "First and Second Control Period Interim Adjustment for Banked Allowances" (RGGI Inc. 2014). Simply, these adjustments account for historical emissions which have been less than the historical emissions cap – i.e., if the cap is larger than is shown to be necessary to induce change, it will have little impact and should therefore be reduced.

[12] Such a comparison would not include purchased offsets outside the power sector, which may meet up to 10% of compliance obligations under RGGI but are not represented in the LEAP model.

[13] Table 1 of Rhode Island Public Utilities Commission (2016) describes a delayed increase in the RES mandate in the year 2015. The RES in 2015 is thus 8.5% instead of 10%, as it would be following the schedule of increases since 2007.

Policy	Description	How Addressed in Reference Case Model
	1997 may provide only 2% of retail sales used to meet the standard.	
Various Renewable Capacity Targets	Long-Term Contracting Standard for Renewable Energy (90 MW 2009-2014) (Rhode Island Division of Planning 2015a) Distributed Generation Standard Contracts Program (40 MW 2011-2014) (ibid) 160 MW Renewable Energy Growth Program (160 MW 2014-2019) (ibid)	Capacity for the Long-Term Contracting Standard and Distributed Generation Program is represented as existing generation capacity in the model, as is capacity installed to date under the Renewable Energy Growth Program. New capacity is assumed to be developed to meet the Renewable Energy Growth (REG) Program's 160 MW target in 2019. New capacity under the REG program is expected to be 85% solar PV, 13% onshore wind and the remainder for hydropower and anaerobic digestion of waste (Musher 2016).
Least-Cost Energy Efficiency Procurement Law	"Least-cost procurement, which shall include procurement of energy efficiency and energy conservation measures that are prudent and reliable and when such measures are lower cost than acquisition of additional supply, including supply for periods of high demand." (State of Rhode Island 2006, sec. R.I.G.L § 39-1-27.7). *Newly-added*[14] electric energy savings from the least-cost procurement (LCP) program are projected to be, in each year (National Grid 2016): • 268,468 MWh in 2014 • 222,822 MWh in 2015 • 199,760 MWh in 2016 (estimated) • 201,347 MWh in 2017 (estimated) From 2018 – 2021 and 2022 - 2024, new electricity savings are estimated at 2.7% and 2.0% of 2009 sales, respectively (ENE 2013). Similarly, newly-added natural gas savings are (National Grid 2016): • 409,029 MMBTU in 2014 • 419,778 MMBTU in 2015 • 395,760 MMBTU in 2016 (estimated)	Projected energy demand from AEO 2015 already accounts for efficiency mandates in the following federal laws: • American Recovery and Reinvestment Act of 2009 • Energy Independence and Security Act of 2007 • Energy Policy Acts of 1992 and 2005 • Energy Improvement and Extension Act of 2008 • National Appliance Energy Conservation Act of 1987 • Clean Air Act Amendments of 1990 Additional details are provided in Appendix A of the AEO 2015 assumptions (U.S. Energy Information Administration 2015h). Notwithstanding, the LEAP reference case projection assumes that the least-cost procurement law enables *additional* efficiency beyond what is already contained in AEO 2015. Electricity and natural gas savings from the law are represented by subtracting the expected energy fuel savings from calculated energy consumption for residential and commercial sectors, separately. In addition, distillate heating oil

[14] Newly-added efficiency refers to any efficiency measure which did not exist the previous year. However, the total energy savings expected in any one year is the result of surviving efficient devices introduced in all previous years. Only post-2014 savings from the LCP program are included, since the model relies upon real historical consumption data from SEDS through 2013.

Policy	Description	How Addressed in Reference Case Model
	• 414,606 MMBTU in 2017 (estimated) From 2018 – 2020 and 2021 - 2024, new natural gas savings are estimated at 1.0% and 0.5% of 2009 sales, respectively (ENE 2013). Heating oil savings are not explicitly covered by the LCP program.	savings are expected to arise alongside electric savings, and they are subtracted from total fuel consumption in the same way. Like gas savings, newly-added heating oil savings are estimated as 1.0% of 2009 sales from 2014 – 2020 and 0.5% of 2009 sales from 2021 – 2024. After the expiry of the LCP statute in 2024, no additional efficient technologies or projects are introduced and those already implemented will gradually retire.[15] In addition to the *electricity*-saving impact of the LCP, ISO-NE recognizes energy efficiency as a passive demand resource and assigns an appropriate capacity credit. The contribution of efficiency resources to ISO-NE system reserve capacity is included on the supply-side of the model. Peak MW of capacity and capacity factors are derived from ISO-NE (2016b), ISO-NE (2016a), and ISO-NE (2015b). To be consistent with the consumption-based approach, capacity from all efficiency resources in the ISO-NE control area are counted, however, only those energy savings from efficiency in Rhode Island are explicitly included in the model.
Net Metering	Net metering may be offered to consumers generating electricity in an amount that does not exceed their average annual consumption over the previous three years (State of Rhode Island 2011, sec. R.I.G.L § 39-26.4-2). 'Virtual' net metering, where a customer can receive net metering credits for a project located off-site, is now allowed in Rhode Island in certain instances for public sector projects, farms, affordable housing, and residential projects. Excepting biomass (but including biogas from anaerobic digestion), all generation resources that qualify for the RES are eligible.	A fraction of behind-the-meter generation capacity (determined from ISO-NE (2015b)) does not need to be represented explicitly in the model because it is assumed to be embedded in the AEO-derived demand projections and therefore embedded in the load curves used in the model. Other behind-the-meter capacity is included in the electricity supply model, where its production contributes to meeting demand and load. Projected growth in behind-the-meter capacity is taken from ISO-NE's Distributed Generation Forecast, which accounts for the incentives provided by net metering in Rhode Island and other New England states (ISO New England 2015b).

[15] A full description of annual energy savings arising from the LCP, as well as the retirement schedule for these savings, is included in the memo *LEAP Analysis of Rhode Island GHG Mitigation Scenarios: Summary of Results*.

Policy	Description	How Addressed in Reference Case Model
Biodiesel Heating Oil Act of 2013	Distillate heating oil supplied to residential, commercial, and industrial consumers must contain the following volumetric share of biodiesel (State of Rhode Island 2013, sec. R.I.G.L § 23-23.7-4): • 2% in 2014 • 3% in 2015 • 4% in 2016 • 5% in 2017	Appropriate fraction of distillate consumption for heating is shifted to biodiesel. Target in 2017 is assumed to persist in all following years.
Clean Power Plan	Pollution reduction for existing power plants. Stayed by Supreme Court in 2016.	Not represented explicitly in the reference case.
Solarize Rhode Island	Education and financial incentives for homeowner and business adoption of solar photovoltaics.	Not represented explicitly in the reference case—not expected to be additional to other policies.
Renewable Energy Fund	Grants for residential, commercial, and public renewable energy installations.	Not expected to have an additional effect on the reference case.
Low Income Home Energy Assistance Program (LIHEAP) Enhancement	Small subsidies for residential electricity and natural gas consumers on their bill.	Not expected to have an additional effect on the reference case.
Rhode Island Property Assessed Clean Energy (PACE) Program	Small loans to homeowners and commercial properties for energy efficiency and renewable energy improvements.	Not expected to have an additional effect on the reference case.
Non-Energy		
Land Use 2025 – Rhode Island State Land Use Policies and Plan	Assumptions about future land needs.	Calculated future land needed for residential, commercial, and industrial development based on methods in land use plan and more current data and projections.
Solid Waste 2038: Rhode Island Comprehensive Solid Waste Management Plan	This report makes recommendations for reducing the waste stream entering the Central Landfill in order to extend its life beyond 2038 (Rhode Island Division of Planning 2015b).	While the report makes several recommendations, they have not currently been implemented as policies. Therefore, the effects of the recommendations have not been included in the reference case, which was estimated using default data from the EPA State Inventory Tool.
Kigali Amendment to Montreal Protocol	International agreement to reduce production and use of ozone-depleting substitutes (hydrofluorocarbons), which are also potent GHGs, over next 30 years.	Estimated emissions from ozone-depleting substances based on current levels of emissions and the schedule of reductions specified in the Kigali Amendment: 10% reduction below 2010-2012 levels by 2019, 40% by 2024, 70% by 2029, 80% by 2034, and 85% by 2036. Emissions from ozone-depleting substances are held constant in the reference case after 2036.

5 Historical and Reference Case Validation

The Rhode Island LEAP model was validated by comparing results to other recent analyses of Rhode Island's GHG emissions. Notably, it is important to compare LEAP-estimated emissions with the state's 1990 and 2010 GHG inventories (Northeast States for Coordinated Air Use Management 2013) to ensure that the model accurately reproduces historical emissions, and to ensure that each inventory sector is correctly represented in LEAP (i.e., an "apples-to-apples" comparison). Table 11 summarizes annual CO_2-equivalent emissions from various sectors under these two analyses. It is useful for highlighting any methodological differences that exist between the inventories and LEAP assessment, and also for providing a consistent basis from which emissions reduction targets may be calculated, which refer to a 1990 base year. In particular, key differences among the analyses include the treatment of fugitive emissions from electricity transmission and of non-energy emissions from land-use, land-use change and forestry (LULUCF), both of which are absent in 1990 and 2010 inventories (shaded grey in the table).

These methodological discrepancies must be rectified using a set of adjustments in order to compare electric sector emissions using a common basis. Fugitive emissions from electricity transmission must be removed from the LEAP reference case, and the LULUCF sink retroactively added to the 1990 inventory.

Further differences persist in the way that consumption-based emissions from the electric generation sector were calculated for the 1990 and 2010 inventories when compared to the ISO-NE downscaling method used in developing the LEAP Reference Case. In the previous 1990 and 2010 inventories by the Northeast States for Coordinated Air Use Management (2013), it was assumed that in-state generation first went to meet Rhode Island's in-state electricity demand. In both the 1990 and 2010 inventories, in-state generation was less than in-state demand, therefore all in-state generation emissions were counted in the Rhode Island GHG inventories. The electric generation sector emissions associated with the remaining in-state demand were assumed to be met using the grid-average electrical mix from Connecticut, Massachusetts, Vermont, New Hampshire, and Maine.

For comparison with the LEAP Reference Case, the previous 1990 and 2010 Rhode Island GHG consumption-based electric sector emissions had to be re-calculated. This was done using New England-wide (i.e., all New England states including Rhode Island) electric generation sector GHG emissions and state-level electricity consumption data obtained from EIA (U.S. Energy Information Administration 2016a & 2016b). This established a New England-wide GHG emission factor for the electric generation sector, which was multiplied by Rhode Island's electricity consumption in 1990 and 2010 to arrive at new estimates for consumption-based GHG emissions in the same manner as done in the LEAP Reference Case.

Table 11: Comparison of Annual GHG Emissions by Sector, for Rhode Island's State Inventory and LEAP Model*

Category	Sector	Annual Megatonnes of CO_2e		
		1990 Inventory	2010 Inventory	2010 LEAP Modeling
Energy	Transportation	4.97	4.33	4.79[16]
	Residential	2.37	2.28	2.24
	Commercial	1.15	0.93	0.92
	Industrial	0.71	0.64	0.61
	Natural Gas Distribution	0.3	0.15	0.15
	Electricity Distribution			0.03
	Electricity Consumption	3.81	3.39	2.29
Non-Energy	Agriculture	0.04	0.02	0.02
	Industrial Processes	0.09	0.43	0.43
	Solid Waste	0.23	0.22	0.39
	Wastewater	0.08	0.08	0.08
	LULUCF			-0.21
Subtotal		*13.76*	*12.47*	*11.74*
Adjustments	Electricity Distribution Fugitives			-0.03
	Electricity Consumption Methodology[17]	-0.99		0.15
	LULUCF Addition	-0.29		
TOTAL		**12.48**	**n/a**	**11.86**

*Brown-shaded cells indicate where an adjustment is either not necessary or is not performed.

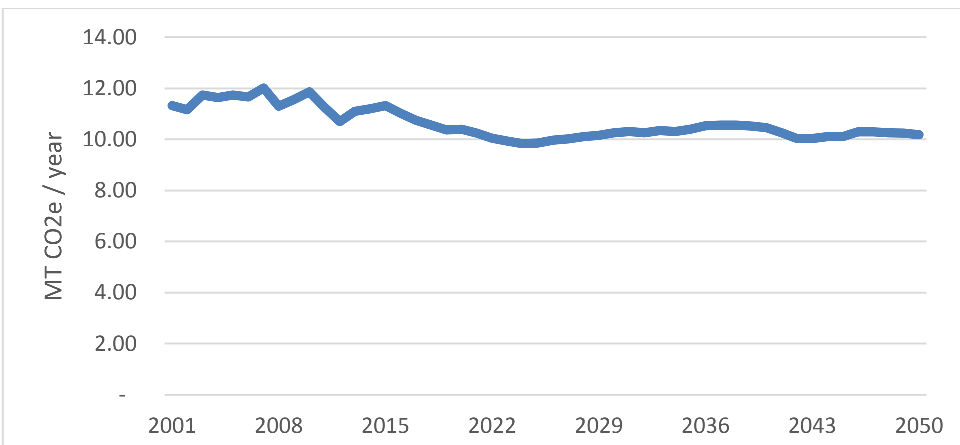
The LEAP reference case was also compared to the business-as-usual forecast in the recent Rhode Island State Energy Plan (Rhode Island Division of Planning 2015a). The LEAP reference

[16] Differences in historical energy consumption are observed between SEDS as accessed in 2016 (and used for LEAP modeling) and the same database as accessed in 2013 (used for 2010 inventory calculations). These differences are most pronounced in the transport sector: The 2013 SEDS data used for the 2010 inventory showed less gasoline consumption than the updated 2016 SEDS data used in the Rhode Island LEAP model, and zero ethanol. These "missing" fuels substantially reduce the 2010 inventory's emissions estimate for transport.

[17] Two changes are required to bring into line the electricity sector emissions in the 1990 inventory and the Rhode Island LEAP analysis. While the 1990 inventory was developed using a consumption-based accounting approach, the approach first assumed that in-state generation was given first priority to meet Rhode Island's electricity requirements. Only the remaining requirements were assumed to be met using the grid-average electrical mix from CT, MA, VT, NH and ME. The first adjustment (subtracting 0.99 MT CO_2e from the 1990 inventory) rectifies this, instead making the assumption that all electricity used to satisfy Rhode Island's requirements comes from the grid average mix, as it does in the LEAP analysis. The second change adjusts for the inclusion of "exported emissions" in the Rhode Island LEAP analysis. A true consumption-based emission accounting methodology must also reduce the emissions estimates by an amount which would be associated with electricity exported outside of the ISO-NE control area (0.15 MT CO_2e in 2010). However, not knowing the quantity of exported electricity in 1990, this adjustment cannot be made retroactively to the 1990 inventory. It must therefore be removed (0.15 MT CO_2e added) from the LEAP analysis in all years.

case and the Rhode Island State Energy Plan (RISEP) have similar declining emissions trends for each of the major sectors (Transportation, Thermal, and Electricity Supply) between 2013 and 2035 (2035 is the last year in the RISEP projection). While these energy sector trends are similar, the RISEP trend does not include non-energy GHG source sectors, such as solid waste and LULUCF. In addition, the methodologies differ between the LEAP reference case and the RISEP in assigning electricity sector emissions. The LEAP approach is based on the power plant fuel mix, dispatch order, and emissions throughout the entire ISO-NE grid (and from outside imports to ISO-NE), and emissions are prorated to Rhode Island based on in-state demand relative to total ISO-NE demand. The RISEP approach assumes all in-state generation is used to meet in-state demand, with their associated power plant emissions from Rhode Island fossil fuel power plants, and the remaining Rhode Island demand and emissions are prorated from the rest of the ISO-NE grid and outside imports. As a result, the electric sector emissions between the LEAP reference case and the RISEP projection through 2035 generally track in parallel, with an offset in emissions due to the differences in how GHGs are assigned to in-state demand between the two approaches.

Reference Case Greenhouse Gas Emissions through 2050, after adjustments



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APPENDIX 2 – SCENARIO MODELING ASSUMPTIONS AND RESULTS

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Rhode Island Greenhouse Gas (GHG) Emissions Reduction Study

LEAP Analysis of Rhode Island GHG Mitigation Scenarios:

Summary of Results

December 30, 2016

This memorandum presents the summary results of the Rhode Island greenhouse gas (GHG) mitigation scenarios analyzed in the Long-range Energy Alternative Planning (LEAP) system. The memorandum is divided into the following sections: 1) Description of building block measures used in mitigation scenarios; 2) Descriptions of the selected scenarios, and 3) Scenario emission results.

Recognizing the scale of the transformations necessary to lower GHG emissions by 80% below 1990 levels by 2050, we followed a two-phase process to identify and analyze major GHG mitigation options as building blocks for five overall 80% GHG reduction pathway scenarios to be analyzed by LEAP. In Phase 1, we identified a set of initial core mitigation options with potential to reduce GHG emissions in the most important source sectors in Rhode Island. With input from the EC4 Technical Committee and State Team, we defined and modeled a high-investment/penetration approach and performed individual LEAP runs for each select mitigation option. These initial mitigation options were not intended to demonstrate attaining, individually or in combination, Rhode Island's 2050 target, but were to inform the EC4 Technical Committee, State Project Team, and stakeholders of the partial effects in and among this core set of mitigation options. This in turn helped inform decisions for Phase 2 in which we built five mitigation pathway scenarios aimed at meeting Rhode Island's 80% GHG reduction target.

The mitigation options identified in Phase 1 are the 10 measures listed below:

1. Electric, natural gas, and heating oil energy efficiency
2. Reduction of on-road vehicle miles traveled (VMT)
3. Utility-scale renewable electricity
4. Distributed renewable electricity (rooftop solar photovoltaics)
5. Additional imports of low-carbon electricity
6. Nuclear electricity (license renewal for existing plants)
7. Electric heat in buildings
8. Biofuels/biomass heat in buildings
9. Electric vehicles
10. Advanced biofuels for transportation

In the following sections, we describe these Phase 1 measures and how they were combined into the five mitigation scenarios of Phase 2 for the LEAP analysis. We show a graphical presentation of the GHG reduction trajectories out to 2050 for each scenario, including how the reduction trajectories vary between scenarios due to different assumed penetration levels of key measures.

The trajectories are also plotted against Rhode Island's mid-term 2020 and 2035 goals and 2050 long-term GHG reduction target, which are the reference points for tracking future progress.

I. Descriptions of Measures in LEAP Scenarios

1. Phase 1 building block measures in LEAP scenarios

A. Electric and natural gas efficiency

Description:
Savings of electricity, natural gas and distillate heating oil are added to the Rhode Island LEAP model in a "top-down" manner – this means that the savings are not attributed directly to a particular end-use or technological improvement, but are applied in aggregate to a sector or subsector as a whole. As a result, the representation of energy efficiency in the model adjusts final energy demands which would otherwise be calculated from a baseline built purely on the Annual Energy Outlook 2015 (AEO2015) (U.S. Energy Information Administration 2015b). The AEO2015 reference trajectory demonstrates very little autonomous improvement in energy efficiency.

Any fuel savings incurred under Rhode Island's least-cost procurement (LCP) law in 2013 or in prior years is necessarily captured in historical energy consumption data from the State Energy Data System (SEDS) (U.S. Energy Information Administration 2015a). However, since the final year of historical SEDS data, National Grid has continued to record actual fuel savings which can be attributed to in-state energy efficiency programs. The reference case must therefore be modified accordingly, to explicitly account[1] for any electricity and gas savings from 2014 and 2015. Energy savings are reported separately for each major efficiency program, and are summarized on an annual basis in National Grid's year-end reports (National Grid 2015; National Grid 2016). Year-end reports also provide updated short-term energy efficiency projections through the end of 2017.

Although year-end efficiency reports describe newly-added energy savings from one year to the next, they do not include an estimate for the *total* energy savings in a given year, which is the result of newly-added efficiency measures from previous years. Energy savings which are attributable to each National Grid efficiency program may be assigned an approximate number of years during which the measure is expected to persist, based on the average lifetime of efficient technologies deployed under the program. While National Grid does not publically maintain a bottom-up database of each efficient technology sold in each year (or the efficiency of the less-efficient device which it replaces), the names of each program may be used to estimate the end-use which it targets. Each National Grid efficiency program is grouped into one of six "aggregate programs," with average lifetimes given in Table 1 and Table 2.

Table 1: Aggregate program name, sector or end-use and average number of active years (lifetime) for electricity-saving measures deployed under major National Grid efficiency programs.

[1] As described in the Reference Case Memo, Rhode Island's LCP is not embedded in the Annual Energy Outlook's final demand projections.

Applicable Sector and End-Use in LEAP	Lifetime	Aggregate Program	National Grid Program
Single Family Residential Heating and Cooling	11	Single Family Weatherization or New Construction	Single Family - Income Eligible Services
			Residential New Construction
			EnergyWise
Multi-Family Residential Heating and Cooling	11	Multi-Family Weatherization	Income Eligible Multifamily
			EnergyWise Multifamily
All Residential	11	Residential Products	Energy Star HVAC
			Energy Star Lighting
			Energy Star Products
All Residential	1	Residential Behavior	Home Energy Reports
All Commercial	12	Commercial Weatherization of New Construction	Large Commercial New Construction
			Large Commercial Retrofit
All Commercial	12	Commercial Products	Small Business Direct Install

Table 2: Aggregate program name, sector or end-use and average number of active years (lifetime) for natural gas-saving measures deployed under major National Grid efficiency programs.

Applicable Sector and End-Use in LEAP	Lifetime	Aggregate Program	National Grid Program
Single Family Residential Heating and Cooling	21	Single Family Weatherization or New Construction	Single Family - Income Eligible Services
			Residential New Construction
			EnergyWise
Multi-Family Residential Heating and Cooling	16	Multi-Family Weatherization	Income Eligible Multifamily
			EnergyWise Multifamily
All Residential	17	Residential Products	Energy Star HVAC
All Residential	1	Residential Behavior	Home Energy Reports
All Commercial	11	Commercial Weatherization of New Construction	Large Commercial New Construction
			Large Commercial Retrofit
All Commercial	13	Commercial Products	Small Business Direct Install

Each new kilowatt-hour of electricity or BTU of natural gas which is saved under each program is assumed to persist for the number of years described in the tables above, before retiring completely. As described in the Reference Case memo (Northeast States for Coordinated Air Use Management, Stockholm Environment Institute US, and Abt Associates 2016), newly-added savings are taken from 2014/2015 real savings and 2016/2017 estimates (National Grid 2015; National Grid 2016). Beginning in 2018, these estimates are followed by projected savings through 2024 in the Business-as-Usual scenario of the Rhode Island State Energy Plan (RISEP) (ENE 2013), which are given as a percentage of 2009 sales of electricity and natural gas, respectively. Delivered distillate heating oil savings are not explicitly broken out in National Grid year-end reporting. Instead total annual heating oil savings under the Reference Case are established beginning in 2014 using the same newly-added percentage of 2009 sales that is assigned to natural gas.

<u>Technology/Measure Potential:</u>

Continuing the trend in newly-added energy efficiency established by the Reference Case, the electricity and natural gas efficiency measure includes additional newly-added savings from 2025 – 2050. These new savings are also expressed as a percentage of 2009 sales in electricity and natural gas (also heating oil) through 2035, taken from the RISEP (ENE 2013). Newly added savings in remaining years are also assumed, though identifying the mechanisms by which these savings can be achieved falls outside of this analysis. Table 3 summarizes the newly-added savings in each year. Total annual energy savings in each fuel are captured in the figures that follow, with energy savings from the Reference Case provided for context.

Table 3: Energy savings added in 2018 and beyond, under the electricity and natural gas efficiency scenario. Prior savings given by National Grid's short-term projections. Unless otherwise stated, 2025 – 2035 savings are taken from the RISEP Business-as-Usual (BAU) scenario.

Fuel	2009 Sales	Newly-added savings, (% of 2009 sales)					
		2018 - 2020	*2021 - 2024*	*2025 - 2030*	*2031 - 2035*	*2036-2040*	*2041 - 2050*
Electricity	7494594 MWh	2.7%	2.0%*	1.5%		2.5%	2.7%
Natural Gas	39001480 MMBTU	1.0%	0.5%		1.5%**	2.3%	
Distillate Fuel Oil	22532000 MMBTU	1.0%	0.5%			0.5-0.9%***	

**New electricity savings are 2.7% of 2009 sales in 2021.*
***New natural gas savings are increased from those expected under RISEP's BAU from 2031 – 2035.*
****Heating oil savings are linearly extrapolated to 0.9% of 2009 sales by 2050.*

Figure 1: Projected total electricity savings adjustments to AEO2015, under Reference Case (baseline) and efficiency scenario.

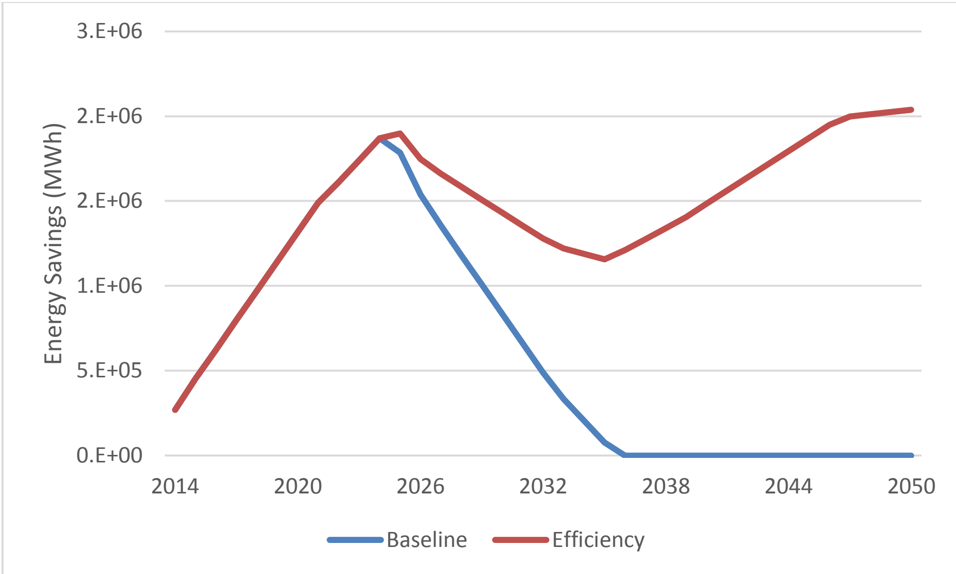


Figure 2: Projected total natural gas savings adjustments to AEO2015, under Reference Case (baseline) and efficiency scenario.

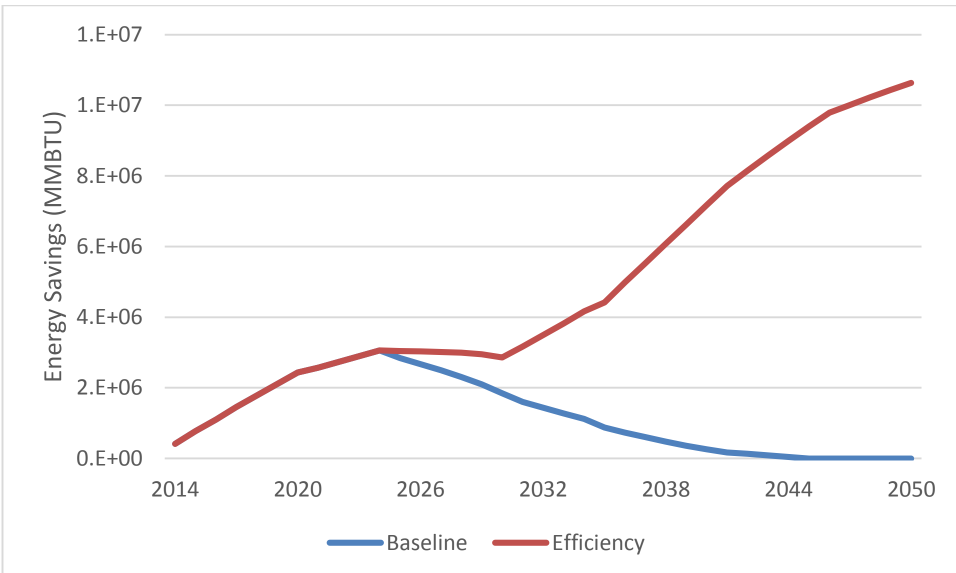
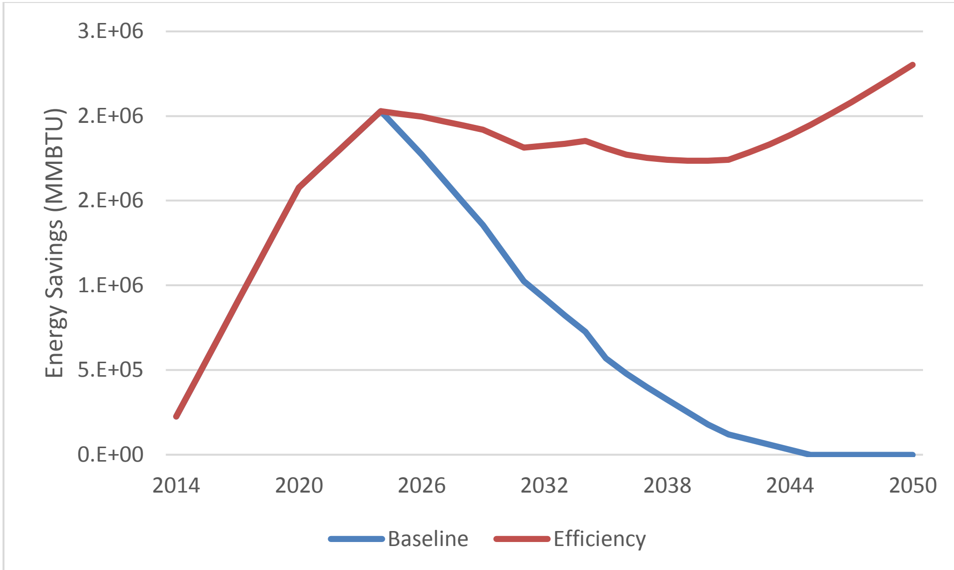


Figure 3: Projected total distillate fuel oil savings adjustments to AEO2015, under Reference Case (baseline) and efficiency scenario.



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3. *———. 2016. "2015 Energy Efficiency Year-End Report." RIPUC Docket No. 4527.*
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6. *———. 2015b. "Annual Energy Outlook 2015 with Projections to 2040." DOE/EIA-0383(2015). Washington, DC. http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf.*

B. VMT reductions

Description:

Estimated annual vehicle miles traveled (VMT) during 2015 in Rhode Island is 7,445 million, and is projected to grow to 7,810 million by 2030 and 7,899 million by 2040 (Rhode Island Statewide Planning Program 2016). VMT in light-duty passenger vehicles makes up the majority of total VMT in Rhode Island, and is the focus of VMT reduction strategies for this analysis.

Because the factors which drive VMT[2] are very specific to individual states (and locations within states), and the array of possible strategies to reduce VMT is also wide-ranging, it is difficult to estimate the potential reductions in VMT without bottom-up modeling of specific sites and strategies.

In the absence of existing studies of VMT reduction opportunities specific to Rhode Island, we collected information on existing and planned programs with the potential to reduce VMT from RI DOT, RIPTA, and the RI Division of Planning. In addition, we have also reviewed relevant studies for Rhode Island and others at the state and national level, described below:

1) Recent modeling of VMT reductions done by the State Smart Transportation Initiative (SSTI) for support of the 2015 update of the Massachusetts Clean Energy and Climate Plan. This analysis considered several different strategies to reduce VMT, including increasing density of new housing development, decreasing the distance between residences and retail, decreasing availability of free parking, and improving sidewalks and access to transit. SSTI's modeling approach used regression analysis to predict a change in VMT for each census block group, based on several explanatory variables: housing density, average distance to transit, average distance to retail, intersection density, sidewalk coverage, and number of managed parking facilities. SSTI's analysis used the regression equations with different combinations of VMT reduction strategies to estimate the percent VMT reduction compared to the baseline under various scenarios. Estimates of the impact of individual VMT reduction strategies relative to business-as-usual VMT growth range from approximately 0.9 percent by 2040 (for a decrease in the availability of free parking) to 6.7 percent by 2040 (for an increase in high-density mixed-use development). If all VMT reduction strategies were implemented together, the analysis estimates a 15 percent decrease in Massachusetts' VMT by 2040.
2) The Growing Cooler report (Smart Growth America, 2007) cited a meta-analysis of many studies of travel which found that people living in places with twice the density, diversity of uses, accessible destinations, and interconnected streets drive about one-third less than otherwise comparable residents of low-density sprawl.
3) A report on GHG reduction strategies by the University of California-Berkeley (2013) finds that under California's economy-wide climate mitigation program, the 17 metropolitan planning organizations in California estimated potential changes in GHG emissions from transportation ranging from a 15 percent decrease to a 1 percent increase by 2035.
4) Navigant Consulting, 2013. Rhode Island State Energy Plan: Scenario Modeling Executive Summary and Results. This study provided estimates of reductions in VMT and resultant energy savings associated with increasing annual ridership levels on Rhode Island buses and transit systems.
5) Rhode Island State Employee Transportation Guide Plan, 2013. Prepared by Department of Administration, Division of Planning, Statewide Planning Program on behalf of the State Employee Commuting Task Force. This plan indicates a goal to reduce weekly VMT from commuting by state employees in single-occupancy vehicles (SOV) by 15%

[2] Examples of these factors include: density of development, location of employment centers relative to housing, availability and accessibility of public transit and other modes of travel (bicycling, walking), and street interconnectedness.

by January 2012, 25% by January 2014, and by 35% by January 2016. While focused on strategies to reduce the commuting VMT of RI state employees, the plan describes options for VMT reductions which can be deployed at the state level, including: public transportation, bicycles, carpools, modified work schedules, and technology-based options such as telecommuting.

6) The consulting firm VHB has built a transportation demand model (TDM) for Rhode Island which can be used to run scenarios reflecting mode-shifting from vehicle travel to increased use of bus and transit. The RI Division of Planning used output from RI's TDM to model a scenario that increases transit ridership from the current 1.69% of all trips to 5.00% of all trips by 2040. This corresponded to a 3.4% reduction in VMT relative to the 2040 VMT "business-as-usual" baseline and a 0.5% reduction in VMT relative to 2015.

Technology/Measure potential:

VMT reductions that could be achieved by a suite of the following VMT reduction strategies are listed below, but we note that the percent VMT reduction achievable by each VMT reduction strategy is poorly quantified.

- **Infrastructure Development Strategies**
  - Expansion of bus route network
  - Development of new bikeway infrastructure
- **Pricing Strategies**
  - General parking fees
  - Mileage fees
  - Programs that require employee parking fees
  - Programs that incentivize employers pay employees to give up parking spaces
- **Demand Management Strategies**
  - Incentives to make work places bike friendly and transit friendly (e.g. installation of bike racks, employer subsidies for public transportations)
- **Transit Improvement Strategies**
  - Expansion of transit signal priority (TSP) systems
  - Development of transit stations and improvements in transit reliability
  - Expansion of van pooling program
- **Smart Growth Strategies**
  - Incentives or requirements supporting mixed-use development
  - Incentives that promote high density development
  - Improvement of sidewalk coverage in urban areas
  - Improvement of street network connectivity

Information sources:

1. *Costs for Pedestrian and Bicycle Infrastructure Improvements. Pedestrian and Bicycle Information Center (October 2013).*
2. *Massachusetts Clean Energy and Climate Plan for 2020, 2015 Update. Massachusetts Executive Office of Energy and Environmental Affairs (updated December 2015).*
3. *Growing Cooler: The Evidence on Urban Development and Climate Change. Smart Growth America (released September 2007).*

4. *Near-Term Transportation Energy and Climate Change Strategies: Interregional Transportation Related Greenhouse Gas Emissions Reduction Strategies. University of California, Berkeley, Transportation Sustainability Research Center (December 2013).*
5. *Smart Growth America, 2011. "Rhode Island Smart Transportation: Save Money and Grow the Economy." Available at: http://www.smartgrowthamerica.org/documents/smart-transportation-rhode-island.pdf*
6. *Rhode Island State Employee Transportation Guide Plan, 2013. Prepared by Department of Administration, Division of Planning, Statewide Planning Program on behalf of the State Employee Commuting Task Force.*
7. *Navigant Consulting, 2013. Rhode Island State Energy Plan: Scenario Modeling Executive Summary and Results.*
8. *US Federal Transit Administration (FTA), 2016. "Before and After Studies Of New Starts Projects Report to Congress." 2010 – 2015. https://www.transit.dot.gov/funding/grant-programs/capital-investments/and-after-studies-new-starts-projects*
9. *American Public Transportation Association (APTA), 2015. "U.S. Average New Vehicle Costs for 2014 and 2015 Vehicles by Type." http://www.apta.com/resources/statistics/Documents/Table23-VehCostTransitLength-2015-Vehicle.pdf*
10. *Rhode Island Statewide Planning Program, 2016. "Rhode Island Statewide Model Update." http://www.planning.ri.gov/documents/trans/travel/tp166.pdf*

C. Utility-scale renewable electricity

Description:
We follow the California PATHWAYS 2015 updated analysis as a guide to develop a high penetration scenario for utility-scale renewables in LEAP. As in this work for Rhode Island, the California PATHWAYS effort developed 80% GHG reduction scenarios by 2050 in California relative to the state's 1990 emissions. Renewable generation sources accounted for 75-86% of the capacity installed on the California grid in 2050 and over 80% of annual generation. Using this as a benchmark, we assumed renewable energy penetration levels consistent with the California PATHWAYS analysis.

We used an NREL 2012 assessment of technical potential in the ISO-NE region to develop a renewable energy future by resource type that provides about 85% of total electricity generation by 2050. In the Phase 1 measure, we assumed generation shares of about 35% from utility-scale solar, 23% from onshore wind, 20% from offshore wind, and 5% collectively from wood/waste biomass, small hydro, and landfill gas. The renewables generation largely displaced natural gas in the measure, with the remaining balance supplied largely by existing nuclear generation.

The renewable shares are illustrative as their technical generation potential (GWh/yr) given in the NREL 2012 assessment indicates some renewable generation sources (e.g., rural utility-scale PV and offshore wind) are well in excess of current electricity demand (see Table 4). Therefore, there is some room for varying the shares across renewable generation types. For this example, we assumed onshore wind as having a relatively greater share of generation due to its current lower cost relative to most other renewable options. These shares, however, could be varied in future analyses to reflect potential policy goals (see, for example, the separate discussion in the following section on distributed renewable electricity with a focus on rooftop solar PV).

Assumptions and data gaps:

Technical potential matched to meet demand does not consider system integration of a large amount of intermittent renewables into grid. Sensitivity analysis could be performed to probe alternative ways to address system reliability. One approach would be to over-build renewable capacity across a large region that would require lower levels of grid storage or generation backup (e.g., battery storage, residual natural gas combustion). A second approach is to build out renewables to match demand with greater levels of grid storage, such as batteries. These sensitivity scenarios could provide a relative comparison of costs from the two approaches, but are not the subject of this analysis.

Technology or Measure Potential:

Technical potentials are taken from NREL (2012), and shown in the table below relative to ISO-New England annual demand circa 2014 (GWh/yr). The table shows there is a large technical potential for renewable generation in aggregate across the ISO-New England region relative to current demand (circa 2014). This indicates that there is the possibility of many differing combinations of renewable generation mixes for Rhode Island than could be assumed in the limited number of LEAP scenarios evaluated in this analysis.

Table 4: Technical potential (GWh/yr) for renewable generation in New England relative to ISO-NE demand, circa 2014.

Renewable Technology	Technical potential (GWh/yr)	% of ISO-NE demand, ~2014
Urban Utility-Scale PV	35613	29.5%
Rural Utility-Scale PV	3155627	2610.0%
Onshore Wind	45264	37.4%
Offshore Wind	1561442	1291.4%
Biopower-solid	7402	6.1%
Biopower-gaseous	2710	2.2%
Hydropower	9546	7.9%

Information sources:

1. *E3, California PATHWAYS: GHG Scenario Results (updated April 6, 2015).*
2. *Lazard's Levelized Cost of Energy Analysis—Version 9.0, (November 2015).*
3. *NREL. "U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis." NREL/TP-6A20-51946. Golden, CO: National Renewable Energy Laboratory (2012).*

D. Distributed renewable electricity

Description:

This measure is a variation to the utility-scale renewables measure. In this measure, some utility-scale renewable energy capacity is replaced with distributed renewables, which may have higher installation costs relative to utility-scale projects. We examine it separately, however, because while costs may be higher, it has the potential for more local economic benefits (e.g., jobs) as the resource is largely driven through local installations using local labor. Utility-scale renewables are typically located in more remote areas, which may also be often out-of-state.

Despite the northern latitude, rooftop solar PV has a relatively large technical potential across New England relative to electricity demand, based on a 2016 NREL report. The NREL report notes that even though solar is a below-average resource in New England compared to other U.S. regions, the amount of generation needed is offset by the New England states' below average per-capita electricity consumption. Within Rhode Island, NREL estimates a technical potential for rooftop solar PV generation in an amount greater than 55% of the state's total electricity sales in 2013. The New England states as a whole have the technical potential to generate electricity from rooftop solar PV in an amount greater than 50% of the region's 2013 electricity sales (NREL 2016).

For LEAP modeling, we replaced 35% of renewable generation assumed in the previous utility-scale renewables measure with rooftop solar PV generation by 2050. This amount of solar PV generation is about 25-30% of total generation from all electricity generation sources in 2050. We chose this level of penetration as an example of a reasonably aggressive goal that might be targeted through policy incentives as a local economic development strategy.

<u>Assumptions and data gaps:</u>
Technical potential is based on PV module performance of 16%. It would be higher/lower if module performance is assumed higher/lower.

Potential is based only on existing, suitable roof tops. It does not include ground-mounted PV. Technical potential would be greater if installing on less suitable roof area, mounting over open spaces like parking lots, or by integrating PVs into building facades.

The NREL report does not consider system integration of a large amount of solar PV into grid.

<u>Technology/Measure potential:</u>
Within New England, the 2016 NREL report estimates an annual generation technical potential across all buildings (residential and commercial) of 61,600 GWh from an installed capacity of 53.7 GW. Within Rhode Island, NREL estimated an in-state technical potential across all buildings of 4,400 GWh from an installed capacity of 3.8 GW. The 2016 NREL report ranked Rhode Island fourth highest among all states in rooftop PV's annual generation technical potential relative to 2013 electricity sales.

Information sources:

1. *E3, California PATHWAYS: GHG Scenario Results (updated April 6, 2015)*
2. *NREL, Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment, Tech. Report NREL/TP-6A20-65298 (January 2016) http://www.nrel.gov/docs/fy16osti/65298.pdf*
3. *U.S. DOE SunShot, Photovoltaic System Pricing Trends, 2015 Edition (August 25, 2015)*

E. Additional imports of low-carbon electricity

Description:

Currently, ISO-NE has two high voltage direct current (HVDC) lines to resources operated by Hydro Québec rated at 2000 MW and 217 MW of energy capacity. We currently are representing these in the RI LEAP model. We assume in the scenarios the addition of a hypothetical transmission line of 1090 MW energy capacity beginning in 2019, and the addition of a second hypothetical transmission line also of 1090 MW energy capacity in 2025. We set the capacity of the transmission lines to be equivalent to a recent Northern Pass proposal, but we note that the addition of transmission lines to bring low-carbon electricity into New England could include electricity generated by other renewables (wind, solar) across a broader geographical region, and not be exclusively limited to hydro imports.

Information sources:

1. *ISO-NE, Status of Proposed Plan Application (PPA) Applications as of July 27, 2016, http://www.iso-ne.com/system-planning/transmission-planning/proposed-plan-applications*
2. *Northern Pass forward nhplan, http://www.northernpass.us/project-overview.htm*

F. Nuclear re-licensing

Description:

The US Nuclear Regulatory Commission (NRC) permits license extensions for nuclear generating units in 20-year increments (U.S. Nuclear Regulatory Commission 2016a). License extensions have already been granted for Millstone Nuclear Power Station's Units 2 and 3 in Connecticut, so that they may continue operating until 2035 and 2045, respectively (U.S. Nuclear Regulatory Commission 2016b; U.S. Nuclear Regulatory Commission 2016c). This scenario examines the continued operation of these plants after a second license extension, enabling the generators to operate well beyond the final year covered by the analysis. New Hampshire's Seabrook, the other nuclear plant in the ISO-NE control area, remains operational through 2050 in the model's baseline. It is unaffected by this high-penetration scenario.

As part of the re-licensing application, NRC Regulation 10 CFR Part 54 (U.S. Nuclear Regulatory Commission 2015b) requires plant owners to conduct an aging management review for age-related degradation of structures, systems and components and to develop an aging management program to maintain plant safety during the period of extended operation. In addition to the safety review, NRC Regulation 10 CFR Part 51 (U.S. Nuclear Regulatory Commission 2015a) requires an environmental review for the license renewal application to assess potential environmental impacts during extended operation. In the aging management program, minor and major refurbishment activities are usually identified for the years prior to the license expiry date. These refurbishments incur expenses and force the unit into an outage period while the work is being completed.

Assumptions and Data Gaps:

Refurbishment work, which begins eight years before the current license expiry, is assumed to be required as part of the re-licensing process for this scenario. During this period, it is typical for four separate minor refurbishments called "Current Term Outages" to be conducted (consisting of electrical cable upgrades, minor structural upgrades, etc.), each lasting 3 – 4 months and during which time the unit will be unable to operate (U.S. Nuclear Regulatory Commission 1996). A final major refurbishment in the year preceding the issue of a new license will force the unit offline for up to 9 months, so that critical components such as steam generators or other vessel internal components may be upgraded.

During each of these outages, the availability of the generating units is reduced. This will reduce the dispatch of nuclear electricity, requiring other sources of generation to fill the gap. A summary of modeling assumptions for Millstone's re-licensing and assumed refurbishment are outlined in Table .

Table 5: Availability for refurbishment and relicensing of Millstone Nuclear Power Station, units 2 and 3.

Outage	Generating Unit Availability	Outage Years	
		Millstone 2	Millstone 3
Current Term Outage 1	67.5%†	2026 – 2027	2036 – 2037
Current Term Outage 2	67.5%†	2028 – 2029	2038 – 2039
Current Term Outage 3	67.5%†	2030 – 2031	2040 – 2041
Current Term Outage 4	67.5%†	2032 – 2033	2042 – 2043
Major Refurbishment	22.5%‡	2034	2044

† Based on a 25% reduction of the unit's normal availability of 90%.

‡ Based on a 75% reduction of the unit's normal availability of 90%.

<u>Technology or Measure Potential:</u>

The potential of this option is limited to the installed nuclear capacity in the ISO-NE control area, and which is scheduled to retire during the modeling horizon. Millstone units 2 and 3 are the only nuclear capacities to be covered by the measure.

Information sources:

1. *Canadian Manufacturers & Exporters. 2010. "The Economic Benefits of Refurbishing and Operating Ontario's Nuclear Reactors." https://cna.ca/wp-content/uploads/2014/05/Refurbishing-Ontario%E2%80%99s-Nuclear-Fleet-a-Major-Economic-Boost.pdf.*
2. *U.S. Nuclear Regulatory Commission. 1996. "Generic Aging Lessons Learned (GALL) Report — Final Report (NUREG-1801, Revision 2)." https://books.google.com/books?id=Tyw3AQAAMAAJ&pg=PR1#v=onepage&q&f=false*
3. *———. 2015a. "Part 51 - Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions." http://www.nrc.gov/reading-rm/doc-collections/cfr/part051/.*
4. *———. 2015b. "Part 54 - Requirements for Renewal of Operating Licenses for Nuclear Power Plants." http://www.nrc.gov/reading-rm/doc-collections/cfr/part054/.*

5. ———. 2016a. "Backgrounder on Reactor License Renewal." http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-reactor-license-renewal.html.
6. ———. 2016b. "Millstone Power Station, Unit 2." http://www.nrc.gov/info-finder/reactors/mill2.html.
7. ———. 2016c. "Millstone Power Station, Unit 3." http://www.nrc.gov/info-finder/reactors/mill3.html.

G. Electric heat in buildings

Description:

According to EIA data, only 7 percent of homes in New England use electricity as their main fuel for space heating. Another 24 percent of homes use electricity as a secondary space heating fuel. For commercial buildings, the EIA data show that while electric heating is commonly available (approximately 45 percent of square footage in New England uses electricity as a main or backup heating fuel), it is not used very often, as it supplies only 3 percent of the total heating load. The majority of homes and businesses in the region use fossil fuels (i.e., No. 2 heating oil, natural gas, and propane) for space heating. Most of Rhode Island's current electric heating is provided by electric resistance heating systems. In this this mitigation option, our focus is on high efficiency electric heat pump technologies.

Current heating and cooling demand for Rhode Island is approximately 30 million GJ for the residential sector and approximately 8 million GJ for commercial buildings. We estimate the current number of heat pumps, forced-air furnaces, and boilers in use in RI homes and businesses using EIA data and the projections by Meister Consulting Group for RI. According to data from NEMS, new heat pumps have a life expectancy ranging from 7 to 21 years, with an average life of approximately 14 years. Forced-air furnaces and boilers have average useful lives of approximately 17 and 25 years, respectively. We use these data on equipment lifetimes to estimate the number of units coming out of service in each year, which could be replaced with new air- or ground-source heat pumps or biomass systems. Initial estimates from Meister Consulting Group find that 18,700 single-family heating system replacements occur in Rhode Island each year, based on an average turnover time of 13 years.

Assumptions and data gaps:

The total amount of heat from fossil energy replaced by heat pumps is adjusted to account for the increased efficiency provided by heat pumps, using the following assumptions from EIA's NEMS:

- Air source heat pumps will have an average Coefficient of Performance of 3.
- Ground source heat pumps will have an average Coefficient of Performance of 5.
- The furnaces and boilers replaced by heat pumps will have an average Annual Fuel Utilization Efficiency of 80 percent, based on assumptions from NEMS.

Meister Consulting Group recently performed an analysis of renewable heating and cooling technologies for RI, which included scenarios of 2 percent, 5 percent, and 10 percent of replacement of total thermal load by heat pumps, biomass systems, and other renewable heating technologies by 2035. However, modeling results for other states indicate that a much more aggressive scenario than Meister's 10 percent replacement scenario will be needed to meet a target of an 80 percent reduction in GHG emissions by 2050.

Rather than use Meister's assumptions about a percent penetration rate for heat pumps, we model the installation of heat pumps based on the assumed retirement rate of existing fossil units (e.g., natural gas and oil boilers and furnaces) and assumptions about the percentage of retiring units that are replaced with heat pumps. The useful life of residential and commercial fossil units ranges from 17 to 25 years, based on assumptions from NEMS. It is assumed that the proportion of fossil units retiring in each year is (1 / useful life).[3] We make assumptions about the proportion of the retiring fossil units that must be replaced with heat pumps in each year to meet Rhode Island's emission reduction targets.

For residential units, we assume that 20 percent of retiring fossil units are replaced with heat pumps in 2017. That percentage rises to 80 percent by 2035. However, to meet a goal of approximately 80 percent penetration of heat pumps by 2050, the replacement rate must rise sharply after 2035 to 480 percent by 2050. A heat pump replacement rate greater than 100 percent means than some fossil units must be retired before the end of their useful life in order to achieve the heat pump penetration goals.

For commercial units, we assume that 30 percent of retiring fossil units are replaced with heat pumps between 2017 and 2035. After 2035, the heat pump replacement rate rises to 210 percent by 2050. As with the residential units, this means that some fossil units will have to be retired before the end of their useful life. However, because of relatively faster turnover of commercial heating units, the penetration rate does not have to rise as sharply as that for residential units.

Data are limited for forming projections of the proportion of installed heat pumps that will be air-source versus ground-source, but recent installations in other states suggest that air source heat pumps are being deployed at a higher rate than are ground source heat pumps. We used the ratio of ground-source and air-source heat pumps from Meister's scenarios (90 percent air-source and 10 percent ground-source).

Information sources:

1. *Energy Information Administration, Residential Energy Consumption Survey (RECS), Commercial Building Energy Consumption Survey (CBECS), Manufacturing Energy Consumption Survey (MECS)*
2. *Energy Information Administration, National Energy Modeling System (NEMS)*
3. *Oak Ridge National Lab, 2010. Assessment of National Benefits from Retrofitting Existing Single-Family Homes with Ground Source Heat Pump Systems: Final Report (August 2010), Prepared by X. Liu, Energy and Transportation Science Division.*
4. *Commonwealth Accelerated Renewable Thermal Strategy Final Report. Navigant Consulting and Meister Consultants Group, prepared for Massachusetts Department of Energy Resources. January 2014.*

[3] Note that we follow Meister's assumptions that 90 percent of heat pumps will have a fossil fuel-based backup unit that will provide approximately 20 percent of the heating load.

5. *Meister Consultants Group, draft Thermal Installation Scenarios for Rhode Island (2016).*

<u>*H. Biomass and biofuels for heat in buildings*</u>

<u>Description:</u>
Rhode Island's ability to replace existing heating fuels with biofuels could be constrained by supply, which will be determined by federal policies and regional and national market conditions. We calculate Rhode Island's proportional share of national biofuel volumes required under EPA's Renewable Fuel Standard (RFS), based on Rhode Island's current total demand for diesel across sectors. We assume that Rhode Island's proportional share of RFS biodiesel production will remain constant and estimate that future national biodiesel will meet RFS required levels up to 2018.[4] Beyond 2018, we assume additional quantities of biodiesel will become available in the marketplace, increasing by 5% per year, culminating in biofuels providing 31.3% of heating oil demand in Rhode Island by 2050.

We note that RI's biodiesel supply can be shared between the transportation and building heating sectors. In this variant, we project a hypothetical 100 percent allocation of available biodiesel to the building sector. Measure J below provides the counter hypothetical in which all biodiesel is used in the transportation sector. Buildings currently account for 63 percent of total demand for diesel/No. 2 heating oil in Rhode Island, and many oil furnaces and boilers can accommodate a biodiesel blend without additional retrofitting, so it is likely that some portion of available biodiesel will be used in buildings.

For use of solid biomass in heating, we use projections of technology penetration levels and technical characterizations for biomass pellet heating systems in the residential sector and biomass chip heating systems in the commercial sector, respectively, developed by Meister Consulting Group (MCG) in its analysis of renewable thermal strategies for Rhode Island. As discussed under Measure G above, air- and ground-source heat pumps will be the primary technology to meet heating demand in the buildings sector, but biomass-based systems will also play a small role.

<u>Assumptions:</u>
Total demand for diesel in RI constitutes 0.38 percent of national diesel demand. We assume that Rhode Island will have access to that proportion of national biodiesel supply.

We assume that future national biodiesel will meet RFS required levels up to 2018. Beyond 2018, we create a high-supply case that assumes additional quantities of biodiesel will become available in the marketplace, increasing by 5% per year. We assume that biodiesel cannot make up more than 20% of the diesel/biodiesel blend because biodiesel blends higher than 20% can present storage issues, affect warranties, and congeal in low temperatures for many heating oil systems unless they are modified.

[4] EPA's proposed RFS volume for biomass-based diesel for 2018 is 2.1 billion gallons. Available at: https://www.epa.gov/renewable-fuel-standard-program/proposed-renewable-fuel-standards-2017-and-biomass-based-diesel.

For this analysis, we assume that biofuels will provide GHG reductions on a lifecycle basis. We adopt the assumption from the California PATHWAYS analysis that future advanced biofuels will have net zero-carbon emissions, i.e., 100 percent reduction (E3, 2015). This, however, must be treated with caution, as the California PATHWAYS zero-carbon assumption has not been demonstrated in practice, and is an area of uncertain feasibility. This caution also applies in the application of advanced biofuels to transportation, as described below in Measure J. Policy makers will need to consider carefully how much weight to place on the future mitigation potential (or availability) of advanced biofuels in achieving Rhode Island's 80 percent reduction goal, such as considering hedging with relatively deeper GHG reductions elsewhere, should biofuel advances not occur to a greater extent.

For solid biomass, similar to the assumption for biodiesel, we assume net zero-carbon emissions. EPA's Scientific Advisory Board (SAB) on GHG emissions accounting for biogenic feedstocks used in stationary sources will publish its findings later this year, and these findings could provide the basis for a more refined set of assumptions about lifecycle GHG emissions associated with solid biomass fuels.[5]

Technology potential:
RI biodiesel supply in 2018 (proportional share of RFS required volume):

0.96 (LHV)[6] TBtu

Table 6 below describes the percent of projected demand for No. 2 heating fuel in buildings which could be met by RI's proportion of biodiesel supplied under the high supply case. Note that biodiesel's ability to meet the total diesel demand for the building sector is constrained by (1) the supply of biodiesel and (2) our assumption that the biodiesel and conventional diesel mix cannot exceed 20% biodiesel by volume (also 20% by energy content). From now to 2030, biodiesel's ability to meet the total diesel demand is constrained by supply. By 2040, biodiesel's ability to meet the total diesel demand is constrained by our assumption that the mix cannot exceed 20% biodiesel by volume.

[5] More information on EPA's SAB is available at:
https://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/3235DAC747C16FE985257DA90053F252/$File/Charge+and+cover+memo_Feb+25,+2015.pdf

[6] The lower heating value (LHV) assumes that liquid water in the fuel evaporates during combustion (vaporization takes additional energy).

Table 6: RI projected diesel demand for heating in building sector.

Year	Projected Diesel and No. 2 Heating Fuel Demand for Building Sector (TBtu)	Projected Biodiesel Supply for RI in High Supply Case (TBtu)	Percentage of projected diesel demand for building sector that can be met by RFS biodiesel (percentage by energy content)
2020	13.0	1.06	8.18%
2030	10.2	1.72	16.91%
2040	8.07	2.81	20.00%
2050	7.45	4.58	20.00%

Source: Abt Associates analysis of EIA projections.

Information sources:

1. *State Energy Data System (SEDS) 2014 for diesel/No. 2 fuel use nationally and in RI - http://www.eia.gov/state/seds/xxx*
2. *E3, California PATHWAYS: GHG Scenario Results (updated April 6, 2015).*
3. *EPA Renewable Fuel Standard website for biodiesel volumetric requirement in 2018 - https://www.epa.gov/renewable-fuel-standard-program/renewable-fuel-annual-standards*
4. *DOE Alternative Fuels Data Center for biodiesel (B100) energy content - www.afdc.energy.gov*
5. *United States Department of Agriculture, Economic Research Service, U.S. Bioenergy Statistics, Table 17 http://www.ers.usda.gov/data-products/us-bioenergy-statistics.aspx*
6. *U.S. Energy Information Administration (EIA), Independent Statistics & Analysis, U.S. Weekly No. 2 Heating Oil Residential Price, https://www.eia.gov/opendata/qb.cfm?sdid=PET.W_EPD2F_PRS_NUS_DPG.W*
7. *Meister Consultants Group, draft Thermal Installation Scenarios for Rhode Island (2016).*
8. *California Air Resources Board (CARB), 2009. Proposed Regulation to Implement the Low Carbon Fuel Standard, https://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf*

I. Electric vehicles

Description:

The Rhode Island LEAP scenarios adopt the penetration rates used in the California PATHWAYS analysis for light-duty electric vehicles. In the California PATHWAYS high battery electric vehicle (BEV) scenario, 80% of light-duty vehicles were battery electric or plug-in hybrids by 2050. In addition to electrification of the light-duty motor vehicle fleet, zero-carbon measures are included for larger vehicle classes. These include 80% zero-carbon buses, 95% zero-carbon refuse trucks, and 65% zero-carbon combination short-haul trucks.

Information sources:

1. *E3, California PATHWAYS: GHG Scenario Results (updated April 6, 2015).*
2. *EPAUS9R - An Energy Systems Database for use with the Market Allocation (MARKAL) Model, https://www.epa.gov/air-research/epaus9r-energy-systems-database-use-market-allocation-markal-model.*

J. Advanced biofuels for transportation

Description:

This measure is based on analysis of opportunities for fuel-switching from conventional transportation fuels to advanced biofuels in RI's transportation sector, as follows: (1) switching from conventional diesel to biodiesel and (2) expanding the percentage of cellulosic ethanol in the gas/ethanol mix.

As previously given in Measure H (Biofuels and biomass for heat in buildings), Rhode Island's ability to replace existing transportation fuels with biofuels could be constrained by the national supply of advanced biofuels, which will be determined to some degree by federal policies and market conditions. We calculate Rhode Island's proportional share of national volumes of advanced biofuels required under EPA's Renewable Fuel Standard (RFS), based on Rhode Island's current total demand for ethanol and diesel across sectors. We assume that Rhode Island's proportional share of national biofuel production will remain constant.

We assume that future national biodiesel supply will follow RFS required levels through 2022 and we create a high-supply case for future national biodiesel supply beyond 2018. As described under Measure H, we note that RI's biodiesel supply can be shared between the transportation and building heating sectors. Here, we illustrate a scenario where 100 percent of RI's biodiesel supply is allocated to replacing diesel use in the transportation sector. Specific applications are to larger vehicle classes where electric technologies are not currently available, such as long-haul trucks.

We estimate that national ethanol supply will follow RFS required levels through 2022 and we create a high-supply case for future national biodiesel supply beyond 2022.

Assumptions:

Total demand for diesel in RI constitutes 0.38 percent of national diesel demand. We assume Rhode Island will have access to that proportion of national biodiesel supply. We assume future national biodiesel supply will increase by 5% per year from 2018 – 2050.

Total demand for ethanol in RI constitutes 0.28 percent of national ethanol demand. We assume that Rhode Island will have access to that proportion of national cellulosic ethanol supply.

We assume future national cellulosic ethanol supply will follow the published RFS required volumes up to 2022. We create a high-supply case based on the Department of Energy's 2016 Billion Ton Report 3% yield, $60 farm price scenario, which projects cellulosic biomass supply increasing to about 930,000,000 tons of cellulosic biomass. We use the Billion Ton Report's conversion factor of 0.85 gallons ethanol/ton of biomass and linearly interpolate between years for which the report projected cellulosic biomass supply. There is some uncertainty associated with this approximation, because cellulosic ethanol is an emerging technology and production of cellulosic ethanol has failed to meet EPA's volumetric requirements under the RFS in recent years.

We assume that a gasoline and ethanol mix cannot exceed 85% ethanol by volume and that biodiesel will be used by a limited number of passenger cars and trucks, light commercial trucks, intercity buses, transit buses, school buses, refuse trucks, and motor homes, as well as in the short-haul, long-haul, and off-road transportation sectors.

We adopt the California PATHWAYS zero-carbon net emissions assumption, but repeat our earlier caution that this has not been demonstrated in practice, and is an area of uncertain feasibility. We recognize that due to current lack of zero-carbon technology options for some mobile source categories, such as long-distance heavy-duty trucks, GHG mitigation options are currently limited in this sector, but care must be taken to track the evolution of advanced biofuels in the future and monitor whether they will become capable of helping meeting Rhode Island's GHG reduction requirements.

<u>Technology potential:</u>

Switch from conventional diesel to biodiesel:

RI biodiesel supply in 2018 (proportional share of RFS required volume):

0.96 (LHV) TBtu

Table 7 below describes the percent of projected demand for diesel in transportation which could be met by RI's proportion of biodiesel supplied under the RFS requirements in a high-supply case.

Table 7: RI projected diesel demand for transportation sector.

Year	Projected Diesel Demand for Transportation Sector (TBtu)	Projected Biodiesel Supply for RI in High Supply Case (TBtu)	Percentage of projected diesel demand for transportation sector that can be met by RFS biodiesel (percentage by energy content)
2020	9.94	1.06	10.7%
2030	11.61	1.72	14.9%
2040	13.13	2.81	21.4%
2050	14.66	4.58	31.3%

Source: Abt Associates analysis of EIA projections.

Expansion of cellulosic ethanol's percentage of gas/ethanol mix:

RI cellulosic ethanol supply in 2017 (proportional share of RFS required volume):

0.38 (LHV) TBtu

Table 8 below describes the percent of projected demand for gas and ethanol in transportation which could be met by RI's cellulosic ethanol supply in a high-supply case. Note that cellulosic ethanol's ability to meet the total ethanol and gasoline demand for the transportation sector is constrained by (1) the supply of cellulosic ethanol and (2) our assumption that the gasoline and ethanol mix cannot exceed 85% ethanol by volume (79.08% by energy content). From now to 2040, cellulosic ethanol's ability to meet the total ethanol and gasoline demand is constrained by supply. By 2050, cellulosic ethanol supply is projected to exceed demand, but cellulosic ethanol still cannot meet all of the combined ethanol and gasoline demand because of the 85% blend wall.

Table 8: RI projected ethanol demand for transportation sector.

Year	Projected Total Ethanol and Gasoline Demand for Transportation Sector (TBtu)	Projected Cellulosic Ethanol Supply for RI in High Supply Case (TBtu)	Cellulosic ethanol percentage of total gas/ethanol mix (percentage by energy content)
2017	42.43	1.19	0.16%
2020	42.87	2.27	5.30%
2030	32.62	10.16	31.14%
2040	22.27	17.18	77.16%
2050	18.53	24.10	79.08%

Source: Abt Associates analysis of EIA projections.

Information sources:

1. *EPA Renewable Fuel Standards for biodiesel requirements, https://www.epa.gov/renewable-fuel-standard-program/proposed-renewable-fuel-standards-2017-and-biomass-based-diesel*
2. *EIA State Energy Data System (SEDS) 2014, http://www.eia.gov/state/seds/*
3. *2016 Billion Ton Report, Department of Energy, https://bioenergykdf.net/billionton2016/overview*
4. *United States Department of Agriculture, Economic Research Service, 2016, U.S. Bioenergy Statistics, http://www.ers.usda.gov/data-products/us-bioenergy-statistics.aspx*
5. *Oil Price Information Service, Ethanol and Biodiesel Information Service, July 2016, http://www.opisnet.com/images/productsamples/EBISnewsletter-sample.pdf*
6. *California Air Resources Board, 2011. Low Carbon Fuel Standard 2011 Program Review Report, http://www.arb.ca.gov/fuels/lcfs/workgroups/advisorypanel/20111208_LCFS%20program%20review%20report_final.pdf*
7. *California Air Resources Board (CARB), 2009. Proposed Regulation to Implement the Low Carbon Fuel Standard, https://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf*

2. Non-energy GHG reduction measures

A. Solid Waste

Description:

The Rhode Island LEAP scenarios assume that the Central Landfill is closed in 2038 as anticipated in the Rhode Island Comprehensive Solid Waste Management Plan. We further assume that after the landfill is closed, the waste stream in Rhode Island is significantly reduced through an increase in recycling and composting measures, and that any remaining waste is exported to other states. Even though the Central Landfill is assumed to be closed in 2038, it will continue to emit some GHGs as the waste in place decays. Based on simulations using EPA’s

State Inventory and Projection Tool, we determined that the landfill would continue to be a source of GHG emissions for approximately 10 years after closure, and that GHG emissions of the landfill will decline to 0 by 2048.

Information sources:

1. *Solid Waste 2038: Rhode Island Comprehensive Solid Waste Management Plan, 2015,* *http://www.planning.ri.gov/documents/LU/2015/SolidWaste2038_Approved_05142015_Final.pdf*
2. *U.S. Environmental Protection Agency, State Inventory and Projection Tool, 2016,* *https://www.epa.gov/statelocalclimate/state-inventory-and-projection-tool*

B. Land Use, Land-Use Change, and Forestry (LULUCF)

Description:

This mitigation strategy assumes no net loss of forest, wetlands, and pasture lands in RI from 2011[7] to 2035. The strategy represents a scenario where Rhode Island households shift to more dense residential developments, and where demand for new housing and commercial development is met by filling in already developed lands before developing natural lands. Conserving forests reduces GHG emissions relative to the reference case by (1) avoiding carbon emissions that would occur in the reference case due to loss of carbon storage in forests and (2) maintaining land area that can continue to sequester carbon each year.

Estimates of future land needs are based on population projections (Rhode Island Division of Planning 2013), employment projections (Rhode Island Department of Labor and Training, 2014), the 2025 Land Use Planning Report (Rhode Island Division of Planning 2006), and the assumption that new Rhode Island households will be accommodated in denser residential developments than the current trend.

We estimate future forest carbon dynamics using regional modeling in the U.S. Forest Service's Forest Carbon Budget model (USFS 2010) and used estimates of carbon stocks for each land cover type developed in similar analysis for Massachusetts (Abt Associates, 2015).

Our projections end at 2035 due to the high level of uncertainty regarding future land use change and the impacts of future climate change on forests' health and ability to sequester carbon. After 2035, our assumption in LEAP is that the carbon flux from LULUCF remains constant at projected 2035 levels through 2050.

[7] We began the mitigation calculation at 2011 because that is the most recent year for which Rhode Island Geographic Information System (RIGIS) land cover and land use data is available.

Figure 4: Changes in forest acreage and carbon storage under different scenarios.

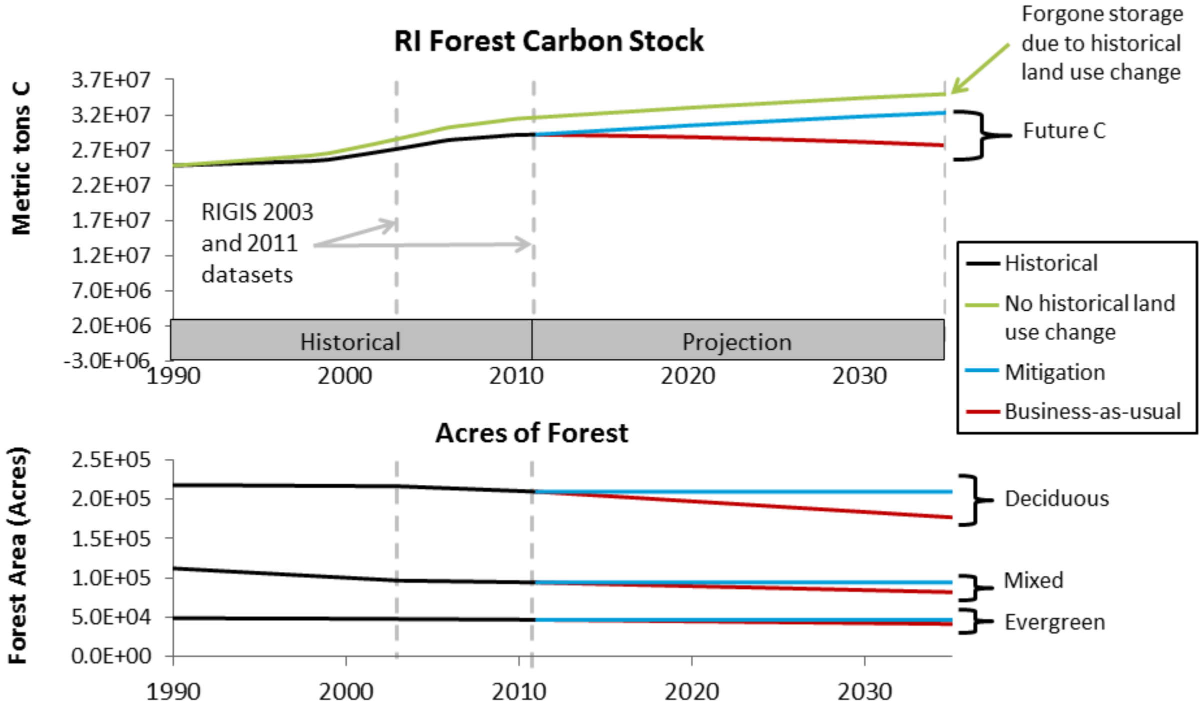
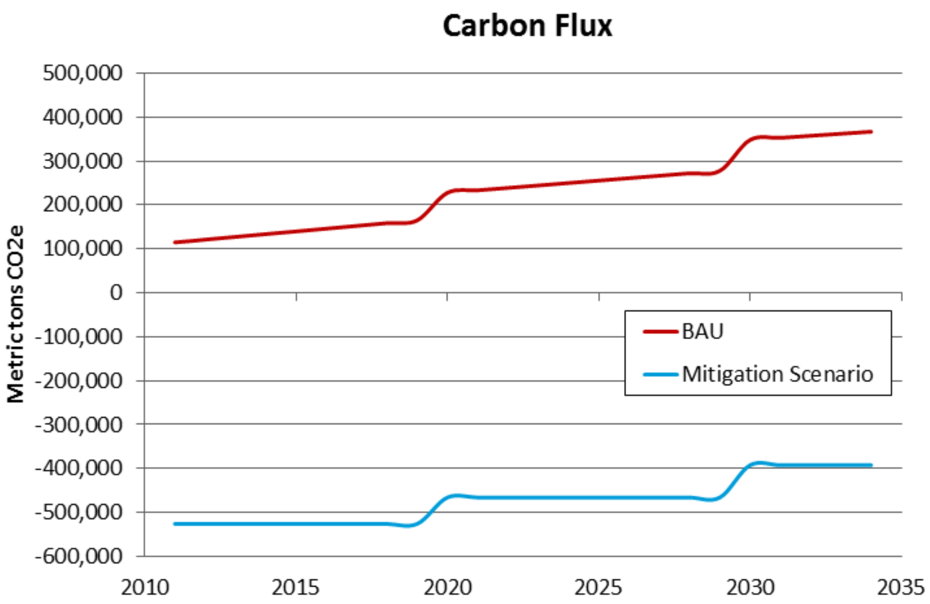


Figure 5: Changes in annual forest carbon fluxes under different scenarios.



Information sources:

1. *Abt Associates. 2015. "Research & Analysis Supporting Development of 2015 Massachusetts Clean Energy and Climate Plan."*
2. *Rhode Island Department of Labor and Training, Labor Market Information. 2014. "Rhode Island's Employment Projections by Major Industry Division."*

3. *Rhode Island Division of Planning. 2006. "Land Use 2025 – Rhode Island State Land Use Policies and Plan."*
4. *Rhode Island Division of Planning. 2013. "Rhode Island Population Projections 2010 – 2040."*
5. *U.S. Department of Agriculture, Forest Service (USFS). 2010. Heath, L., M. Nichols, J. Smith, and J. Mills. "FORCARB2: An updated version of the U.S. Forest Carbon Budget Model." http://www.nrs.fs.fed.us/pubs/35613.*
6. *Rhode Island Geographic Information System (RIGIS). 2015. "Land Cover & Land Use – 2011."*

II. LEAP Scenario Descriptions

The Resilient Rhode Island targets relative to the 1990 Rhode Island GHG inventory used in this analysis are summarized in Table 9.

Table 9: Resilient Rhode Island GHG emission targets.

Emissions Target Below 1990	Year	Allowed Emissions (MMtonnes CO_2e/year)
---	1990	12.48 (historical)
10%	2020	11.23
45%	2035	6.86
80%	2050	2.50

In this analysis, we developed with input from the Rhode Island State Team and the EC4 Technical Committee the following five scenarios aimed at achieving Rhode Island's 80% GHG reduction target by 2050. As described below, the scenarios differ in implementation rates of some measures and combinations of measures. In general, however, all scenarios share many common features that reflect relatively limited degrees of freedom in achieving the deep GHG reductions needed to achieve an 80% reduction by 2050. All scenarios require extensive electrification of the heating and transportation sectors as well as deep decarbonization of the electricity sector. All scenarios include the same solid waste and LULUCF mitigation measures, as well as 100% rail electrification.

1. *Scenario 1.0 "80% Below 1990 by 2050"*

Scenario 1.0 is referred to as "80% Below 1990 by 2050", and includes most of the Phase 1 building block measures at their maximum implementation rates as described in the previous section. These maximal implementation rates are referred to as "Phase 1 limits". Scenario 1.0 excludes two measures: distributed renewable electricity and biomass and biofuel heating in buildings. Distributed renewable electricity is included as a measure in Scenario 2.1 (described below), and its absence here does not reduce the overall amount of renewable generation. In excluding biomass and biofuel heating, Scenario 1.0 allocated all available biofuels entirely to the transportation sector. In Scenario 2.2 (also described below), a greater portion of available biofuels is allocated for heating in the buildings sector. A summary of Phase 1 measures and the extent to which they are included in Scenario 1.0 is given in the following table.

Table 10: Scenario 1.0 "80% Below 1990 by 2050."

Phase 1 Measure	Inclusion in Scenario 1.0
Electric, Natural Gas, and Heating Oil Efficiency	Fully included
VMT Reductions	Fully included
Utility-Scale Renewable Electricity	Fully included
Distributed Renewable Electricity	*Not included*
Additional Imports of Clean Electricity	Fully included
Nuclear Re-licensing	Fully included
Electric Heat in Buildings	85% of Phase 1 limit
Biomass and Biofuels Heating in Buildings	*Not included*
Electric Vehicles	85% of Phase 1 limit
Advanced Biofuels for Transportation	Fully included*

**This measure targets only the diesel and gasoline and ethanol consumption that remains after the majority of transport is electrified.*

2. *Scenario 2.0 "45% Below 1990 by 2035, 80% Below 1990 by 2050"*

With the implementation schedule described in the above table for Scenario 1.0, Rhode Island's GHG abatement is projected to exceed the Resilient Rhode Island Act GHG reduction target for 2035. As a consequence, Scenario 2.0, labeled "45% Below 1990 by 2035, 80% Below 1990 by 2050," reduces the initial rate of implementation of several measures through 2035 to provide a GHG reduction trajectory which meets (but does not significantly exceed) the 45% by 2035 interim GHG reduction target. After 2035, implementation rates then accelerate to achieve the same 80% GHG reduction goal in 2050 as in Scenario 1.0. Scenario 2.0 reduces biodiesel blend, ethanol blend, and cellulosic ethanol (in ethanol) blend targets through 2035, as well as the 2035 shares of electric heat pumps and electric vehicles relative to those observed in Scenario 1.0. In addition, renewable capacity) may be reduced until 2035, increasing afterwards.[8] The extent to which each Phase 1 measure is included in Scenario 2.0 is described below.

[8] In the Rhode Island LEAP model, neither capacity nor dispatch is controlled directly – instead, future capacity options may be specified, and these are added and dispatched as necessary. Therefore, in Scenario 2.0 and derivative scenarios, the relative additions of renewable and non-renewable generation capacity are adjusted. A more complete description is provided in the Reference Case memo.

Table 11: Scenario 2.0 “45% Below 1990 by 2035, 80% Below 1990 by 2050.”

Phase 1 Measure	Inclusion in Scenario 2.0
Electric, Natural Gas, and Heating Oil Efficiency	Fully included
VMT Reductions	Fully included
Utility-Scale Renewable Electricity	Additions of renewable capacity set to 60% of Phase 1 limit through 2035, 100% of Phase 1 limit thereafter
Distributed Renewable Electricity	*Not included*
Additional Imports of Clean Electricity	Fully included
Nuclear Re-licensing	Fully included
Electric Heat in Buildings	50% of Phase 1 limit in 2035, increasing to 85% by 2050
Biomass and Biofuels Heating in Buildings	*Not included*
Electric Vehicles	10% of Phase 1 limit in 2020, increasing to 50% in 2035 and 85% by 2050
Advanced Biofuels for Transportation	Biodiesel/diesel, cellulosic ethanol/ethanol and ethanol/gasoline blends reach only 2017 levels in Phase 1 limit by 2035, increasing to full implementation by 2050

Table 12 provides additional context on the extent of additional renewable energy resources projected for 2050 in Scenario 2.0. The table summarizes the shares of renewable energy generation and capacity by 2050 projected by LEAP at the ISO-NE regional level, rather than down-scaled to Rhode Island. This is illustrates what would be projected for the entire ISO-NE region in order to achieve Rhode Island’s down-scaled share of regional electricity generation sector GHG emissions needed to meet its 80% GHG reduction goal using the consumption-based approach in LEAP. The table also shows ISO-NE’s projected renewable capacity in 2020 (far right column), which provides additional context for the large increase in renewable capacity projected by LEAP for the ISO-NE region by 2050. The increased renewable energy generation and capacity by 2050 reflects not only meeting traditional demand (e.g., residential/commercial lighting and appliances), but also increased demand for electric vehicle recharging and other GHG mitigation measures in Scenario 2.0 requiring electricity. When combined with the nuclear re-licensing measure, Scenario 2.0 projects over 98% of generation in 2050 to be from zero-carbon sources.

Table 12: Mix of renewable energy generation shares by 2050 for ISO-NE region.

	% Share of Generation by 2050*	LEAP Projected Installed Capacity (MW) in ISO-NE by 2050	ISO-NE Projected Capacity (MW) by 2020
Utility-scale PV	34.1%	46,594	
Distributed PV**	0.05%	65	All Solar: 542
Offshore Wind	21.7%	8,610	
Onshore Wind	23.7%	12,369	All Wind: 4,228
Wood & Wood Waste (biopower-solid)	2.1%	918	40
Landfill Gas (biopower-gaseous)	0.5%	192	2
Hydropower	1.0%	193	31
Total	83.2%	68,942	4,843

**The "% Share of Generation in 2050" is calculated relative to generation excluding demand resources and imports.*
***Distributed PV is not explicitly included in this measure, but a small amount is projected to occur under the reference case, which is carried over into the LEAP results.*

3. *Scenario 2.1 "Distributed PV and Offshore Wind"*

Scenario 2.1 is called "Distributed PV and Offshore Wind", and is the first of three variants of Scenario 2.0. It explores a different mix of renewable electricity capacity options by increasing the additions of offshore wind while reducing additions of onshore wind, and by trading some additions of utility-scale solar PV for distributed solar PV. The following table lists the measures as combined in Scenario 2.1.

Table 13: Scenario 2.1 "Distributed PV and Offshore Wind."

Phase 1 Measure	Inclusion in Scenario 2.1
Electric, Natural Gas, and Heating Oil Efficiency	Fully included
VMT Reductions	Fully included
Utility-Scale Renewable Electricity	Partially included* – ratio of offshore to onshore wind capacity additions increases by 100% relative to Phase 1 limit by 2050
Distributed Renewable Electricity	Partially included* – ratio of BTM solar PV capacity additions relative to FTM solar PV additions increased by 76% in all years
Additional Imports of Clean Electricity	Fully included
Nuclear Re-licensing	Fully included
Electric Heat in Buildings	50% of Phase 1 limit in 2035, increasing to 85% by 2050
Biomass and Biofuels Heating in Buildings	*Not included*
Electric Vehicles	10% of Phase 1 limit in 2020, increasing to 50% in 2035 and 85% by 2050
Advanced Biofuels for Transportation	Biodiesel/diesel, cellulosic ethanol/ethanol and ethanol/gasoline blends reach only 2017 levels in Phase 1 limit by 2035, increasing to full implementation by 2050

**In addition to adjustments made to the type of renewable capacity additions, the total ratio of renewable capacity additions relative to non-renewable capacity additions increases from 60% of the Phase 1 limit through 2035 and 250% thereafter.*

4. *Scenario 2.2 "Biofuel Heating"*

Scenario 2.2 is the second variant of Scenario 2.0, and is called "Biofuel Heating". This variation adds the biomass and biofuels for heating in buildings measure into Scenario 2.0, while reducing the implementation of electric heat pumps. We continue to allocate some level of biofuels to the transportation sector, but at lower volumes than in Scenario 2.0. The following table lists the measures as implemented in Scenario 2.2.

Table 14: Scenario 2.2 "Biofuel Heating."

Phase 1 Measure	Inclusion in Scenario 2.2
Electric, Natural Gas, and Heating Oil Efficiency	Fully included
VMT Reductions	Fully included
Utility-Scale Renewable Electricity	Additions of renewable capacity set to 60% of Phase 1 limit through 2035, 100% of Phase 1 limit thereafter
Distributed Renewable Electricity	*Not included*
Additional Imports of Clean Electricity	Fully included
Nuclear Re-licensing	Fully included
Electric Heat in Buildings	30% of Phase 1 limit in 2035, increasing to 70% by 2050
Biomass and Biofuels Heating in Buildings	Fully included*
Electric Vehicles	10% of Phase 1 limit in 2020, increasing to 50% in 2035 and 85% by 2050
Advanced Biofuels for Transportation	Biodiesel/diesel, cellulosic ethanol/ethanol and ethanol/gasoline blends reach only 2017 levels in Phase 1 limit by 2035, increasing to full implementation by 2050

**Aside from biomass heating, biofuel targets described in this measure target only the distillate heating oil consumption that remains after the majority of space heating is electrified.*

5. *Scenario 2.3 "Fewer Heat Pumps and Electric Vehicles, More Renewables"*

Scenario 2.3, "Fewer Heat Pumps and Electric Vehicles, More Renewables", is the third variant of Scenario 2.0. It describes a pathway with less aggressive electrification of heating and transport end-uses, but more aggressive decarbonization of the power supply to compensate. The variations to the key measures are listed in the following table.

Table 4: Scenario 2.3 "Fewer Heat Pumps and Electric Vehicles, More Renewables."

Phase 1 Measure	Inclusion in Scenario 2.3
Electric, Natural Gas, and Heating Oil Efficiency	Fully included
VMT Reductions	Fully included
Utility-Scale Renewable Electricity	Additions of renewable capacity set to 100% of Phase 1 limit through 2035, 250% thereafter
Distributed Renewable Electricity	*Not included*
Additional Imports of Clean Electricity	Fully included
Nuclear Re-licensing	Fully included
Electric Heat in Buildings	45% of Phase 1 limit in 2035, increasing to 80% by 2050
Biomass and Biofuels Heating in Buildings	*Not included*
Electric Vehicles	10% of Phase 1 limit in 2020, increasing to 45% in 2035 and 80% by 2050
Advanced Biofuels for Transportation	Biodiesel/diesel, cellulosic ethanol/ethanol and ethanol/gasoline blends reach only 2017 levels in Phase 1 limit by 2035, increasing to full implementation by 2050

III. LEAP Scenario Emissions Results

Figure tracks the GHG reduction trajectories of Scenario 1.0, "80% Below 1990 by 2050" and Scenario 2.0, "45% Below 1990 by 2035, 80% Below 1990 by 2050". The horizontal dashed line delineates Rhode Island's 1990 GHG emissions inventory level of 12.48 MMtonnes CO_2e, while green squares indicate the 2020 (20% below 1990), 2035 (45% below 1990), and 2050 (80% below 1990) GHG reduction targets. As the trajectories show, both scenarios well exceed the 2020 Resilient Rhode Island reduction target and meet the 2050 target, while Scenario 1.0 exceeds the mid-term 2035 target by over 20%. The relaxed implementation rates of several measures in Scenario 2.0 brings the GHG reduction trajectory in line with the 2035 target of 45% below 1990 emissions, but this necessitates a ramp up in measure implementation rates for this scenario between 2035 and 2050. The variant Scenarios 2.1, 2.2 and 2.3 are omitted because they are qualitatively nearly identical to Scenario 2.0 in the chart.

Figure 6: Scenario 1.0 and Scenario 2.0 GHG (CO_2e) reduction trajectories relative to Reference Case (Baseline).