MEMORANDUM

Date: April 22, 2016

To: EC4 GHG Study Project Team

From: The NESCAUM Project Team

Subject: Preliminary List of Technology Pathways and Policy Sets for Rhode Island GHG Emissions Reduction Study

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1.1 Background

In support of the development of the *Rhode Island Greenhouse Gas (GHG) Emissions Reduction Study* (the Study) on behalf of the Rhode Island Executive Climate Change Coordinating Council (EC4), the EC4 GHG Study Project Team tasked the NESCAUM Project Team with developing an initial list of possible GHG mitigation pathways and policy sets that can help Rhode Island meet its GHG reduction targets. Under the Resilient Rhode Island Act of 2014,[1] EC4 is responsible for preparing and submitting a plan by December 2016 that can achieve reductions in Rhode Island's GHG emissions to the following levels:

- 10% below 1990 levels by 2020;
- 45% below 1990 levels by 2035;
- 80% below 1990 levels by 2050;

At the first meeting of EC4's public process for the Study (December 15, 2015), the NESCAUM Team presented an overview of the long-term transformations in energy use necessary for achieving deep, long-term reductions in GHG emissions by 2050.[2] Analyses and modeling efforts conducted by other jurisdictions (e.g., California) to identify pathways that achieve a very low-carbon future consistently demonstrate that, at minimum, three major transformations in energy production and use are required:[3]

- Efficiency: deep and broad improvements in efficiency of energy in buildings, transportation, and industry. These can include changes in practices by consumer and businesses, such as reducing travel by single-passenger vehicles, as well as technological improvements that increase efficiency (e.g., energy-efficient appliances, "smart grid" technologies).

- De-carbonization of electricity and electrification: Decarbonizing electric power can be accomplished by increasing the role of renewables, nuclear power, and carbon capture and storage. The GHG benefits of 'electrification,' i.e., switching from the use of a fossil fuel such as gasoline to electricity, will be limited by the degree to which the electricity grid is decarbonized.

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[1] http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-6.2/INDEX.HTM

[2] http://www.planning.ri.gov/documents/climate/2015/Meeting_1_Presentation.pdf

[3] http://deepdecarbonization.org/wp-content/uploads/2015/11/US_Deep_Decarbonization_Policy_Report.pdf For example, a study of decarbonization pathways for California is available at: https://ethree.com/public_projects/energy_principals_study.php.

- De-carbonization of other fuels: In addition to electricity, other fuels need to be replaced by lower-carbon alternatives to the extent feasible (e.g., conventional natural gas by biogas; gasoline replaced by cellulosic ethanol).[4]

In this memorandum, we provide an initial list of specific technologies and practices[5] that can result in significant GHG reductions, by sector. While this list of technologies and practices is not exhaustive, it does span the majority of common and well-known technologies and practices currently available or expected to be commercially viable for Rhode Island within the next 10 to 15 years. As we describe later in this memo, we also recommend specific criteria for evaluating which technologies and practices are most appropriate for consideration in the Rhode Island Greenhouse Gas Emissions Reduction Study. The final set of technologies and practices chosen through this process will be explicitly characterized and modeled in the Long-range Energy Alternatives Planning (LEAP) tool chosen for use this analysis, also described later in this memo.

In addition, we provide a list of the public policies, regulatory approaches, and other programs that could be deployed to enable greater penetration of GHG-reducing technologies and measures. This list is also relatively comprehensive[6]—many if not all of these policy approaches are currently being deployed in one or more developed economies at the sub-national (e.g., California) or national (e.g., United Kingdom) level. The final set of policies will be independently analyzed based on results of a literature review of similar policies in other jurisdictions to determine relative cost-effectiveness of different policy approaches as well as other considerations such as co-benefits, political feasibility, etc.

Finally, understanding the relative contributions of different sectors to Rhode Island's GHG emissions portfolio provides a helpful context to the current process of identifying technologies and policies for consideration by the EC4 GHG Study Project Team. These numbers will be established in a separate task under this project, i.e., establishing the Baseline Case. Since the Baseline Case is not yet available, in this memorandum we cite emissions estimates from a 2010 GHG inventory NESCAUM prepared for DEM in 2013 as illustrative of the relative contributions of different GHG-emitting sectors. Based on the 2010 inventory, an 80 percent reduction below 1990 emissions levels translates to 2.75 million metric tons of CO_2-equivalent ($MMTCO_2e$) by 2050, which represents an average emissions reduction of 2.5 percent each year from 2010 to 2050.[7]

[4] Many of these transitions from higher to lower carbon fuels are also commonly referred to as 'fuel-switching," and they need not always involve advanced fuels or technologies. For example, fuel-switching from coal to natural gas for electricity generation results in significant GHG emission reductions due to the lower carbon intensity of natural gas.

[5] For purposes of this memorandum, we define "technologies" as devices and equipment which use energy more efficiently and/or reduce emissions relative to conventional devices and equipment, and "practices" to refer to changes in consumer and business practices and behaviors which result in lower energy use and emissions (e.g., reducing single-passenger vehicle trips, increasing levels of employee telecommuting).

[6] Some policies on this list may be described using different names or broader categories than other lists of climate mitigation policies. For example, "grid modernization policy" is high-level and broad category of policy that can be understood to include many different individual policies, such as use of advanced metering or time-of-use electricity rates.

[7] In 2013, NESCAUM estimated Rhode Island's total 2010 emissions at 12.47 $MMTCO_2e$, exclusive of GHG emissions or sequestration in the forestry and land use sector. This inventory used a 'consumption-based' approach in accounting for GHG emissions from the electric power sector. Under this accounting approach, GHG emissions associated with electricity used in Rhode Island are included.

1.2 List of GHG Reduction Policies and Technologies/Practices

In this section, we describe the kinds of policies and programs available to states (and regions) to increase the deployment of specific technologies and practices that reduce GHG emissions. Generally speaking, policies that create transformations in energy production and use, and thereby result in significant, long-term GHG reductions, fall into one of the following three categories:

1. **Limits on GHG emissions:** The first group of policy approaches spur changes in technology and practices by placing limits on GHG emissions, either through an implicit price on carbon (or GHG) emissions, an explicit cap or limit on carbon (or GHG) emissions, or a performance standard.

   A *cap on emissions* is a limit which encourages any entity subject to the limit to seek out least-cost methods for achieving emissions reductions. A cap is often combined with a trading system that enables regulated entities to benefit from opportunities for low-cost emission reductions available throughout the system. *Placing a price on carbon (or GHG) emissions*, via a tax, user fee, or surcharge, creates a financial incentive for emitters to reduce overall costs by reducing GHG emissions, either through investments in efficiency, cleaner production technologies, or both. A *performance standard* sets a minimum level of performance for emissions or energy use relative to a pre-defined measure, such as total electricity generated or unit of economic activity.[8]

2. **Direct incentives and investments:** These policies can include (but are not limited to) subsidies or tax credits provided directly to businesses and households that deploy clean technologies and/or implement changes in practices, and thereby reduce the cost of using these technologies relative to less expensive fossil fuel-based alternatives. Direct investments by federal, state, or local authorities or utilities in public infrastructure (e.g., public transit systems, electricity grid and natural gas distribution systems, electric vehicle charging or fueling stations)[9] also provide or enable lower-carbon options for businesses and consumers to meet their energy needs.

3. **Complementary policies and programs:** Because no single policy is sufficient to address all aspects of the market failures which result in greater GHG emissions than are optimal for society, other policies and programs are often needed to complement major policies like limits on GHG emissions or direct incentives. For example, net metering policies allow businesses and homeowners to sell extra renewable electricity generated on-site back to the electricity grid, and often complement renewable portfolio standards. Workforce training (e.g., training roofers to install residential solar), innovative financing programs, technical assistance, reforming regulatory and pricing structures for regulated utilities, and public outreach and education are examples of other policy approaches that states often find are necessary to maximize the effectiveness of higher-level GHG reduction policies such as cap-and-trade.

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[8] The final Clean Power Plan rule promulgated by US EPA provides states with flexibility to choose between a cap on GHG emissions from power plants (known as a mass-based standard), or a rate-based standard based on GHG emissions performance (i.e., lbs. of CO_2 per net MWh). Both mass- and rate-based emissions goals for Rhode Island under the Clean Power Plan can be found at: http://www3.epa.gov/airquality/cpptoolbox/rhode-island.pdf.

[9] The private sector also invests in electric charging and alternative fueling stations, often in collaborative partnerships with public sector agencies at the federal, state, and local level.

It is important to note that policy approaches in these distinct groups are not mutually exclusive of one another, and in fact are often deployed in combination to complement one another or achieve joint public policy goals. For example, many of the states participating in the Regional Greenhouse Gas Initiative (RGGI) cap-and-trade program limiting CO_2 emissions from large power plants also have policies with explicit requirements for minimum levels of renewable energy and energy efficiency, and in some cases provide tax credits or direct incentives for clean technologies (e.g., electric vehicles).[10] In addition, many of these policies have the flexibility to be tailored specifically to an individual sector (e.g., buildings) or group of emitters (e.g., power plants), or they can be designed as cross-cutting policies that address emissions throughout multiple sectors of the economy. An economy-wide carbon tax and an emissions cap are both examples of cross-cutting policies; public procurement policies (e.g., requiring government purchases of low-carbon equipment) are another.

Below we provide tables showing the proposed set of technologies/practices that reduce GHG emissions and the corresponding policy approaches that create the incentives and improve market conditions for greater adoption and use of these technologies/practices, organized by sector. It is worth highlighting that the policy approaches shown in the tables are specific to each energy use sector, and therefore do not include broader policy instruments such as cap-and-trade or carbon pricing. Cap-and-trade[11] and placing a price on carbon (or GHG emissions) are flexible enough to be applied to a single sector, multiple sectors, or even economy-wide across all sectors.

1.2.1 Transportation and Land Use

According to the 2010 GHG inventory prepared for Rhode Island, transportation accounts for more than one-third of Rhode Island's 2010 emissions (4.33 MMT CO_2e), and is therefore a sector with significant potential for GHG emission reductions. Technologies and practices for reducing transportation sector emissions can be grouped as those which: 1) improve vehicle efficiency; 2) decarbonize transportation fuels; or 3) reduce vehicle travel.

Forest carbon sequestration acts as a net carbon sink in Rhode Island, and removed emissions equal to 1.34 MMT CO_2e in 2010.[12] While the land use sector is not expected to become a net source of emissions in Rhode Island in the future, shifts in land use that are characterized by low-density development (also known as sprawl) are important to consider because of their potential to foster growth in vehicle travel, especially by single passenger vehicles, and associated emissions.

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[10] Conversely, policies that are not closely coordinated across sectors or public policy goals can work at odds with one another. For example, incentives for renewable biomass technologies that do not deploy advanced combustion technology and/or effective emission controls can result in deterioration of air quality.

[11] A policy that places a cap on emissions does not necessarily require a trading system to accompany it, but both theoretical and empirical experience in applying caps to traditional air pollutants (e.g., nitrogen oxides and sulfur dioxide) as well as carbon emissions (e.g., Regional Greenhouse Gas Initiative) demonstrate that allowing trading among regulated entities can significantly reduce the overall cost of compliance with a cap. The majority of empirical examples of cap-and-trade policies to date involve caps on emissions from large stationary sources only, such as power plants and refineries. There are technical and administrative challenges to extending cap-and-trade systems beyond electric power plants and other stationary sources to include other sectors and sources (e.g., transportation), such as tracking and verifying emission reductions across many small sources of emissions (e.g., automobiles). Such challenges will need to be considered as part of the process of identifying policies with the greatest potential to achieve cost-effective GHG emission reductions.

[12] 2010 GHG Inventory submitted to Rhode Island DEM in 2013.

Table 1. Greenhouse Gas Reduction Technology/Policy Combinations for Transportation and Land Use

Technologies and Practices for Reducing GHGs	Policy Approaches
Reductions in VMT • Smart Growth practices - *Increased density of new development, closer proximity to transit, improved street connectivity* - *Improved infrastructure for multi-modal travel (i.e., bicycles, walking)* - *Increased telecommuting and ridesharing* • Ridesharing • Increased bike lanes and infrastructure • Increased public transit service levels and ridership • Expanding public transit - *Bus rapid transit, expansion of commuter rail* • Enhancing public transit infrastructure	• Investments in public transit (e.g., regional rail, subway, bus rapid transit) • Transit-oriented development • Infrastructure investments for multi-modal travel (bicycling, pedestrian) • Price or taxes on fuel, congestion, or parking • Planning zoning for increased density and mixed use development • Reductions in free parking • Incentives for ridesharing and telecommuting • Revise local, county, and state development review process
Vehicle efficiency • Improving fuel efficiency • Improving aerodynamics and weight reduction • Fuel economy improvements (light-duty, medium and heavy-duty/freight)	• Light-duty vehicle fuel economy standards[13] • Medium- and heavy-duty vehicle fuel economy standards • Trucking and freight strategy • Feebates
Zero and low emission vehicles • Advanced vehicles - *Battery Electric Vehicles, Plug-in Hybrid Electric Vehicles, Hydrogen Fuel Cells, E85 vehicles* • Biofuel buses • Electric buses • Electrify commuter rail • CNG for Medium/Heavy Duty (e.g., On-road Freight) • Diesel retrofits	• Multi-state Zero Emission Vehicle program • Direct purchase incentives • Support and incentives for charging/fueling infrastructure for advanced vehicles
Aviation/marine • Aircraft operational changes when landing, taxiing, and idling at gate • Electrification of airport ground equipment • Biofuels • Alternative marine power at port docks[14]	• Caps on airport and seaport emissions • GHG standards for aircraft and marine vessels
Low-carbon fuels • Cellulosic ethanol and diesel • Synthetic biofuels	• Fuel performance standard • Incentives for biofuel production • Support for distribution infrastructure

[13] Fuel economy standards for both light- and medium/heavy-duty vehicles are generally implemented at the federal level in the US, but historically Rhode Island and other northeastern states have exercised their option under the federal Clean Air Act to adopt California's more stringent vehicle emissions standards that then create an impetus toward deeper vehicle efficiency requirements at the federal level.

[14] Also referred to as 'cold ironing,' alternative marine power is the practice of connecting ships at port to onsite electric power, which reduces GHG and other emissions from back-up diesel generators.

Technologies and Practices for Reducing GHGs	Policy Approaches
• Low-carbon biofuels (light-duty, medium and heavy-duty/freight) • Low-carbon fueling delivery and infrastructure - *Electric vehicle, CNG, E85, and hydrogen fueling infrastructure*	
Forestry and Agriculture • Forest Best Management Practices (BMPs) • Reforestation • Urban/suburban tree planting and tree retention strategies • Improved agricultural practices - *Organic farming, nutrient reductions, no-till and improved residue management* • Wetlands restoration for "blue" carbon • Conversion of marginal agriculture to forests	• Forest management practices • Grants or incentives for tree planting retention/programs • Technical assistance

1.2.2 Electric Power Sector

Because the electric power grid is managed and operated at a regional level (by the Independent System Operator (ISO) for six New England states, ISO New England), there are limits to Rhode Island's ability to enact policies unilaterally that would significantly impact GHG emissions from electric power generation.[15] As such, some of the policy approaches listed below could be pursued most effectively through a high level of coordination with neighboring states, or via implementation at the regional level rather than by Rhode Island alone.

Table 2. GHG Reduction Technology/Policy Combinations for Electric Power Sector

Technologies and Practices for Reducing GHGs	Policy Approaches

Renewable Energy[16]
• Utility-scale and distributed renewable technologies
  - *Rooftop solar PV*
  - *Onshore wind*
  - *Offshore wind*
  - *Hydroelectric*
  - *Geothermal*
  - *Tidal*
• Landfill gas
• Biomass
	• State energy procurement standards
	• Direct rebate programs
	• On-bill financing
	• Leveraging private financing
	• Renewable Portfolio Standards
	• Feed-in tariffs
	• Workforce training and development
	• Production tax credits
	• Net metering
	• Joint procurement/long-term contracts

[15] The New England electricity grid is managed through a wholesale market for electricity designed primarily to ensure grid reliability.

[16] The renewable energy category encompasses both small renewable resources in various locations (known as distributed generation) as well as large centralized renewable generation such as Canadian hydroelectric power or wind in northern New England. Large hydropower is included in the "other low or zero carbon generation" category because it is not an eligible Class I resource under Rhode Island's Renewable Energy Standard (RES) (http://www.ripuc.org/utilityinfo/RES_Rules.pdf.)

Infrastructure & Operations • Renewable energy storage (e.g., advanced batteries, compression) • Utility-scale and distributed energy storage • Smart meters • Demand response programs • Advanced natural gas combined cycle turbines[17]	• Streamlined siting and permitting of new generation • Performance standards (emission or output-based) • Grid modernization • Incentives for energy storage R&D • Incentives for demand optimization (direct load control capability) • Rate design • Regional agreements on energy infrastructure (e.g., for transmission/delivery infrastructure) • Reforming regulatory model and incentives for regulated utilities
Other Low or Zero Carbon Generation • Large hydropower • Nuclear power • Carbon capture and storage • Advanced waste-to-energy	• Production tax credits • Support of research and development • Streamlining of siting and permitting • Support for related legal and regulatory requirements (e.g., waste disposal, liability issues) • Technical assistance

1.2.3 Buildings and Facilities Sector

The 2010 consumption-based GHG inventory conducted for Rhode Island shows that emissions from the Buildings and Facilities sector (3.85 MMT CO_2e) are collectively higher than the emissions from the electric power sector in Rhode Island (3.39 MMT CO_2e), and nearly as much as the transportation sector (4.33 MMT CO_2e). Within the Buildings and Facilities sector, residential heating demand is the single largest source of emissions, representing 18 percent of Rhode Island's overall GHG emissions in 2010. There are significant opportunities to reduce these emissions, through electrification of fossil-based thermal sources as well as through weatherization and other energy efficiency measures. For example, Rhode Island's Least-Cost Procurement policy,[18] which directs electric and natural gas utilities to invest in least-cost energy efficiency options before purchasing additional supply, currently applies only to customers using regulated fuels (i.e., electricity and natural gas). However, over one-third of homes in Rhode Island currently use unregulated fuels (e.g., heating oil and propane). Expanding the Least-Cost Procurement policy to include these homes could offer a significant opportunity for energy and emission reductions.

Table 3. GHG Reduction Technology/Policy Combinations for Buildings and Facilities Sector

Technologies and Practices for Reducing GHGs	Policy Approaches
Energy Efficiency • High efficiency lighting	• Expand Least-Cost Procurement mandate to unregulated fuels (e.g., heating oil and LPG)

[17] U.S. Energy Information Administration assumes that conventional natural gas combined cycle plants have an efficiency of 48.4 %, whereas natural gas units using advanced turbine technology will have an efficiency of 53.1%.

[18] Established under the "Comprehensive Energy Conservation, Efficiency, and Affordability Act of 2006." http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-1/39-1-27.7.HTM

• Deep envelope retrofits for existing buildings - *Insulation/windows/envelope improvements* • Expanded combined heat and power • High efficiency HVAC • High efficiency water heating • All cost-effective energy efficiency in residential/commercial (electricity, gas, oil) • Fuel-switching (e.g., oil to natural gas, diesel to biodiesel) • District heating/cooling • Advanced building codes for new construction • Advanced appliance standards • Compact footprints for new construction • Building and energy management systems	• Advanced building codes • Residential and commercial retrofits • Performance standards (e.g., appliance and lighting standards) • Incentives for demand response[19] • Combined heat & power incentives • Tax credits • Public/private financing, e.g., energy savings performance contracts, Property Assessed Clean Energy (PACE) programs • Workforce training and development
Renewable and Low-Carbon Thermal • Ground source heat pumps • Air source heat pumps • Solar thermal • Biomass pellet stoves • Biogas and biofuels	• Incentives for residential and commercial solar/renewable thermal • Technical support (e.g., training for HVAC installers) • Blending standards (e.g., biodiesel blending) • Production tax credits • Other requirements for utilities/regulated fuels (e.g., requiring electric utilities to promote reductions in use of fossil fuels for heating)

1.2.4 Industry, Waste, and Other

Relative to other sectors, there are fewer GHG emission reduction opportunities from waste, waste water, industrial processes, or other non-CO_2 emissions sources, largely because the current level of GHG emissions in Rhode Island from these sources is relatively low, and in some cases there are already mitigation plans in place.

Emissions from industrial processes made up 3 percent of the 2010 GHG emissions (0.43 MMT CO_2e), largely from the use of substitutes for ozone depleting substances (ODSs), such as hydroflourocarbons (HFCs).

Solid waste represents approximately 2 percent of Rhode Island's 2010 GHG emissions (0.22 MMT CO_2e). At the Central Landfill, the largest landfill in Rhode Island, methane is already being captured and used for electricity generation, and an anaerobic digester for managing food waste and other organics, was scheduled to open at end of 2015.[20]

While the current level of emissions from natural gas distribution leaks is relatively low, at 1 percent of 2010 GHG emissions (0.15 MMT CO_2e), National Grid is currently carrying out a multi-year program to

[19] Demand response could also be considered a strategy under the electric power sector, but is included in the Buildings sector because many of the same entities which deploy building energy efficiency at scale (i.e., energy service companies) also are involved in demand aggregation and management.

[20] http://www.ecori.org/renewable-energy/2015/5/28/ris-first-anaerobic-digester-expected-by-end-of-year

address leaks, based on its Infrastructure Safety and Reliability Plan (ISR).[21] Rhode Island could continue to support these efforts.

Table 4. GHG Reduction Technology/Policy Combinations for Industry, Waste, and Other Sector

Technologies and Practices for Reducing GHGs	Examples of Policy Approaches
• Industry-specific or GHG-specific initiatives (e.g., reducing F-gas emissions - SF_6, HCFCs) • All cost-effective energy efficiency in industrial processes (e.g., high-efficiency motor drives) • Combined heat and power • Fuel-switching (e.g., oil to natural gas, diesel to biodiesel)	• Performance standards • Industrial process incentives
• Reductions in natural gas leaks	• Continue support for National Grid's leak-prone pipe replacement program
• Landfill gas-to-energy • Advanced waste-to-energy (i.e., gasification, pyrolysis)	• Tax incentives • Technical assistance
• Increasing recycling, reuse, and waste avoidance • Diversion of organics to composting and anaerobic digestion • Increased source reduction and recycling	• "Pay-as-you-Throw" program • Funding for local recycling programs • Technical assistance • Education and outreach
• Methane capture at Publicly-Owned Treatment Works (POTWs)	• Technical assistance

1.3 Criteria for Ranking Technology Pathways-Policy Approach Combinations

The key objective of this analytic effort is to develop a list of possible technology pathways, practices, and strategies for reducing GHG emissions, and a corresponding set of enabling policies and programs that will provide the highest likelihood of Rhode Island meeting its near-, mid-, and long-term goals for reductions in GHG emissions. These technologies/practices and policies will then be combined to create different unique scenarios. The purpose of the scenarios is evaluate the costs, benefits, and considerations of a range of different possible pathways for achieving Rhode Island's GHG emissions reduction targets. It is important to note that because these GHG emission reduction targets are so significant relative to current GHG emission levels, by definition, meeting emission reduction targets by the timeframes stipulated will require deployment of many if not all of the technologies and practices on the lists above. As such, the assumed *level of penetration* for specific technologies and practices will be the key variable which differentiates scenarios from one another.

In this section, we propose a set of criteria for use in the process of filtering, ranking, and prioritizing combinations of technologies/practices and policies. The purpose of applying these criteria to filter down the number of possible combinations is two-fold: First, defining criteria clearly and then applying them systematically and evenly to explore the merits and disadvantages of different combinations of technologies/practices and policies provides a fair and transparent "apples-to-apples" basis for comparison, and ultimately for recommending the inclusion of some options and exclusion of others. Second, going through the process of applying criteria will generate a public record of how

[21] http://www.ripuc.org/eventsactions/docket/4590page.html

technologies/practices and policy combinations perform against given criteria. Given that future economic, political, and social conditions, technologies, costs, and business and consumer preferences are subject to change, this public record will be valuable source of information for making future adjustments and changes as Rhode Island's GHG Emissions Reduction Plan is evaluated and revisited at various points in time.

Below is a list of criteria proposed by our team for filtering, ranking, and selecting possible combinations of technologies/practices and policies for inclusion in scenarios for further analysis. Based on input from the EC4 and stakeholders about which criteria are most (or least) important and should be given the highest (or lowest) weight, we will use these criteria to help define themes to use in creating distinct scenarios. For example, if feedback indicates that creating positive economic development impacts in Rhode Island is a high priority, then the levels of technologies and practices featuring local distributed generation and efficiency improvements could be set at their highest possible levels to create a scenario which achieves GHG reductions on schedule while maximizing economic development.

- *Potential magnitude of GHG emission reductions in Rhode Island* — In light of the large magnitude of GHG reductions needed to achieve an 80 percent reduction relative to Rhode Island's 1990 emissions by 2050, each major emitting sector will need, at minimum, to achieve significant levels of efficiency increases as well as de-carbonization of electricity and fossil fuels. By necessity, every technology/measure with high potential for significant GHG reductions will need to play a prominent role in scenarios that are designed to meet the long-term GHG reduction target.
- *Cost-effectiveness*— The cost of implementing clean technologies and changes in business and consumer practices over time, relative to their GHG reductions, is a measure of cost-effectiveness. While there are substantial uncertainties particularly about the costs and effectiveness of technologies far into the future, current cost and performance data are sufficient to support at least initial ordinal rankings of cost-effectiveness. In applying this criterion, we will incorporate best available estimates of future costs of clean energy technologies currently under commercial development that could play a large role in enabling GHG reductions. For example, energy storage technologies (e.g., batteries, air compression) could enable a much higher penetration of renewable power resources than is currently possible.
- *Co-benefits*— As noted earlier, policies to reduce GHG emissions should be aligned and coordinated as much as possible with Rhode Island's other public policy goals. We will consider the following types of co-benefits commonly associated with policies targeting energy use and GHG reductions:
    - Air quality and public health
    - Ecosystem services (e.g., habitat conservation, flood protection)
    - Economic development impacts (*described further below*)
    - Resiliency to impacts of climate change (e.g., improved grid reliability during storms)
- *Economic development impacts in Rhode Island*— Enacting policy changes that transform the ways Rhode Islanders produce and use energy can have positive or negative consequences for the state's economic output, gross state product, and employment. In general, technologies and practices that increase efficiency and/or reduce the use of imported fossil fuels can boost the

state's net productivity.[22] We will apply state- and region-specific economic variables (known as multipliers) to capture these type of macroeconomic impacts associated with scenarios. To the extent that appropriate information is available, the macroeconomic evaluation will address the impacts of changes in energy prices experienced by consumers and businesses due to higher deployment of GHG reduction strategies and practices.

- *Technical limitations and cost considerations*— The penetration of certain technologies and practices with significant potential to reduce GHG emissions may be constrained due to physical or technical limits (e.g., challenge of balancing intermittency of electricity supplied by renewable resources with electricity demand), administrative challenges, or cost considerations. As a result, strategies with high technical and cost barriers are often considered politically challenging as well.
- *Ease of implementation and administration*— While many policies have potential for substantial GHG reductions, they could also require a proportionally high level of resources for state agencies, regulatory bodies, and other affected entities to administer (and in the case of regulatory bodies, enforce them).
- *Requirements for coordination and complementary policies*— This criterion will evaluate whether Rhode Island can implement an option on its own, or will need to coordinate with other jurisdictions. It will also evaluate whether a strategy can achieve reductions alone, or whether it will require complementary policies to achieve GHG reduction goals. For example, renewable energy standards usually require other policies, such as net metering, to improve the economic viability of renewable energy projects.
- *Primary modeling approach*— We will need to determine the relative benefits and feasibility of modeling individual GHG reduction technologies and practices (and groups of technologies, practices, and policies) within LEAP or outside LEAP. Key considerations will be data availability, level of effort involved, and the analytic value of modeling at a higher versus lower level of detail.

1.4 Proposed Next Steps

As described in our team's scope of work for supporting EC4 in the development of the GHG Emissions Reduction Study, the next step in the analytic process is to filter, rank, and prioritize combinations of GHG reduction technologies/practices and enabling policy approaches and then make recommendations using combinations of technologies/practices and policies for building scenarios that will be evaluated using the LEAP tool. As mentioned above, we will be relying upon feedback from the EC4 and stakeholders on the list of proposed criteria to help us define the key features to vary across different scenarios.

To do this, we propose the following next steps for the NESCAUM Project Team to complete:

- Solicit input from EC4 stakeholders on the draft lists of sector-specific technologies/practices for reducing GHG reductions and policy options, as well as the criteria proposed for evaluating technology and policy combinations:
  - Are there other technologies/practices that will generate GHG reductions in Rhode Island which should be added to this list?

[22] Productivity refers to the value of a state's economic output, i.e., goods and services. Because the New England region imports all of its fossil fuels, activities that displace the use of fossil fuels will generally result in a net positive economic impact to the region and individual states.

    - Are there technologies/practices on this list which should be excluded from consideration, and if so, why?
    - Are there other criteria that should be considered in the process of evaluating technology/measure and policy combinations? What should be the relative weight or importance of individual criterion (e.g., each should have equal weight)?
- Incorporate input from the EC4 Project Team, Technical Committee, and stakeholders on: 1) the comprehensive list of technologies/practices and policy combinations, and 2) criteria for evaluation.
- Evaluate combinations of GHG reduction technologies/practices and policies against the list of criteria using best available qualitative and quantitative information.
- Based on the input and feedback received on technologies/practices and policies, the Project Team will provide recommendations for the design of different scenarios for meeting GHG reduction targets, and present them to EC4 Project Team.