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# Rhode Island State Energy Plan Scenario Modeling Executive Summary & Results

**Prepared for:**

RIEDC Rhode Island Economic Development Corporation

Rhode Island, Working Again.

REF Renewable Energy Fund

A Program of the Rhode Island Economic Development Corporation

STATE OF RHODE ISLAND OFFICE OF ENERGY RESOURCES

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September 24, 2013

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# Executive Summary

## *Background*

To help inform an update of the Rhode Island State Energy Plan (RISEP), Navigant prepared a scenario analysis of three alternative energy futures for the state of Rhode Island. Each of the scenarios presented is comprised of changes to resources spanning the electric, thermal, and transportation sectors; and together they are intended to bracket the range of credible future outcomes - they are not predictive. To examine the trade-offs between scenarios, each is crafted around prioritizing one of the following three high-level directional objectives: energy security, economics, and sustainability.

With input from the RISEP Project team, Navigant developed a set of metrics for each directional objective, see Table 5: Directional Objectives and Metrics. Using these metrics, the quantitative results in this report are presented in contrast to a business as usual case (BAU) as prepared by ENE. In instances where the BAU did not explicitly forecast specific resources and metrics, Navigant supplemented this forecast with input from the RISEP Project Team, Advisory Council, and other expert opinion. For each scenario, deviation from the BAU is the composite effect of changes to each resource modeled.

To determine the potential of each resource included in the model, Navigant used technical documentation, publicly available information, and other expert opinion, see Appendices: Resource Targets for the complete list of resources considered. Following this, Navigant solicited feedback from the RISEP Advisory Council on the potential for each resource. Their intimate knowledge and understanding of the current and potential state of Rhode Island's energy economy proved invaluable in developing an analysis that most accurately frames the state's alternative energy futures. The parameterized resources and targets were then loaded into Navigant's Portfolio Optimization Model (POM) to analyze Rhode Island's electric sector and a modular-flow model built to analyze the thermal and transportation sectors. Where interactions between these sectors exist, outputs from one model were used to feed into the other.

With the parameterized resources in place, objective functions and resource target set-points were defined for each scenario to align it with a key directional objective (security, economics, and sustainability). The objective functions included changes to renewable portfolio standards, in-state procurement requirements, fuel-diversity targets, employment minimums, and other resource specific targets. The resource target set-points were manually selected to bring the results of each scenario in line with its prioritized directional objective.

Each scenario was then modeled and the results tabulated. What follows are tables summarizing the results in each scenario as well as those in the BAU for the electric, thermal, and transportation sectors. Additional information, including key metrics reported on an annual basis (also organized by sector) is included in the results section of this report.

## *Scenario Modeling Results Summaries*

### Table 1: Electric Sector Summary of Results

| | Metric | Units | BAU | Scenario 1: Prioritize Security | Scenario 2: Prioritize Economics | Scenario 3: Prioritize Sustainability |
|---|---|---|---|---|---|---|
| Security | Diversity of Fuels Used to Meet In-State Demand[1] | Dominant fuel source in 2035 (%) | 87% | 50% | 87% | 85% |
| | Grid Tied Storage | MW in 2035 | 0 | 200 | 0 | 150 |
| | Stability, Reliability, Resiliency | +/- | N/A | +++ | + | + |
| Economics | Average Annual Electric Energy Expenditures[2] | $2012 Millions | 902 | 1,119 | 934 | 1,090 |
| | Average Cost of Electricity[3] | $2012/MWh (Wholesale) | $59.76 | $59.81 | $59.74 | $59.43 |
| | Average Price Volatility of LMPs[4] | Index in 2035 (Relative to BAU) | 1 | 0.926 | 0.999 | 0.961 |
| | Economic Activity (Total In-State Expenditures 2013 - 2035[5]) | $2012 Millions | 21,959 | 22,365 | 22,296 | 23,383 |
| | In-State Employment Impact[6] (Relative to BAU) | Job Years | N/A | 3,444 | 20 | 1,170 |
| Sustainability | GHG Reductions (RI Load Served)[7] | % below 2013 levels in 2035 | 23% | 35% | 23% | 56% |
| | NOx & SOx (RI) | % below 2013 levels in 2035 | 14% | 57% | 14% | 14% |
| | Land Use Conversion | Acres | 408 | 2,072 | 426 | 651 |

[1] Fuel used to meet in-state demand is assumed to be in-state generation plus electricity imports with the sources attributed to imports prorated by each source's share in overall ISO-NE fuel mix.

[2] Average annual electric expenditures counts total expenditures in the POM model including the capital cost of new generation, variable generation cost, and transmission cost. This includes both in-state and out of state expenditures.

[3] Average cost of electricity is solely the wholesale electricity cost and only includes the variable cost of generating power for Rhode Island.

[4] Average price volatility is calculated as the monthly variance of locational marginal prices.

[5] Total in-state expenditures are the total variable and fixed costs that are spend on power generation in Rhode Island between 2013 and 2035. All additional construction and generation in the rest of ISO-NE is excluded.

[6] In-State Employment only considers the first order impacts of the policies. It does not include potential second order economic impacts as changes in spending and investment ripples through the economy.

[7] GHG reductions include the reduction in system GHGs due to Rhode Island policy. Thus out-of-state renewables financed by the state are included here even though that construction does not impact the in-state fuel mix significantly.

**Table 2: Thermal Sector Summary of Results**

| | Metric | Units | BAU | Scenario 1: Prioritize Security | Scenario 2: Prioritize Economics | Scenario 3: Prioritize Sustainability |
|---|---|---|---|---|---|---|
| Security | Diversity of Fuels Used to Meet In-State Demand | Dominant fuel source in 2035 (%) | 60% | 53% | 74% | 53% |
| | Thermal Storage (ETS) | MW in 2035 | 0 | 1067 | 0 | 217 |
| | Stability, Reliability, Resiliency | +/- | n/a | +++ | + | ++ |
| Economics | Average Annual Thermal Energy Expenditures[8] | $2012 Millions | $1,075 | $1,038 | $788 | $968 |
| | Average Cost of Energy[9] | $2012/MMBTU | $19.23 | $19.33 | $17.99 | $18.61 |
| | Average Price Volatility of Fuels | Index in 2035 (Relative to BAU) | 1.000 | 0.945 | 0.976 | 0.962 |
| | Economic Activity (Total In-State Capital Expenditures 2013 - 2035[10]) | $2012 Millions | $0 | $679 | $1,837 | $1,638 |
| | In-State Employment Impact[11] (Relative to BAU) | Job Years | 0 | 6,707 | 21,153 | 16,129 |
| Sustainability | GHG Reductions (RI Load Served) | % below 2013 levels in 2035 | 20% | 40% | 34% | 44% |
| | NOx & SOx (RI) | % below 2013 levels in 2035 | 13% | 25% | 40% | 36% |

[8] Average annual thermal energy expenditure is the average total fuel expenditures in the thermal sector between 2013 and 2035. Sources of thermal energy with no variable costs (such as solar thermal and geothermal) do not contribute to this figure, but do contribute to total in-state expenditures.

[9] Average cost of energy is the consumption weighted average fuel cost on a $/MMBTU basis

[10] Economic activity is the total in-state capital investment required to make the changes to the thermal sector energy infrastructure between 2013 and 2035. It does not include any effects on economic activity associated with reduced fuel consumption.

[11] In-state employment impacts reflect the changes in employment only associated with capital expenditures. It does not include any reductions in direct employment associated with reduced fuel consumption, or secondary employment effects in Rhode Island's economy.

### Table 3: Transportation Sector Summary of Results

| | Metric | Units | BAU | Scenario 1: Prioritize Security | Scenario 2: Prioritize Economics | Scenario 3: Prioritize Sustainability |
|---|---|---|---|---|---|---|
| Security | Diversity of Fuels Used to Meet In-State Demand | Dominant fuel source in 2035 (%) | 56% | 39% | 42% | 47% |
| | Grid Tied Storage (EV Battery) | MW in 2035 | 137 | 1277 | 1277 | 6292 |
| | Stability, Reliability, Resiliency | +/- | n/a | +++ | + | +++ |
| Economics | Average Annual Transportation Fuel Expenditures[12] | $2012 Millions | $1,696 | $1,382 | $1,308 | $1,511 |
| | Average Cost of Fuels[13] | $2012/MMBTU | $29.87 | $29.14 | $29.05 | $30.44 |
| | Average Price Volatility of Transportation Fuels[14] | Index in 2035 (Relative to BAU) | 1.000 | 1.124 | 1.128 | 1.095 |
| | Economic Activity[15] (Total In-State Expenditures 2013 - 2035) | $2012 Millions | $0 | $4,127 | $5,138 | $3,040 |
| | In-State Employment Impact[16] (Relative to BAU) | Job Years | 10,346 | 12,895 | 8,027 | 10,346 |
| Sustainability | GHG Reductions (RI Load Served) | % below 2013 levels in 2035 | 12% | 34% | 36% | 40% |
| | NOx & SOx (RI) | % below 2013 levels in 2035 | 27% | 63% | 68% | 44% |

[12] Average annual transportation energy expenditure is the average total fuel expenditures in the transportation sector between 2013 and 2035.

[13] Average cost of energy is the consumption weighted average fuel cost on a $/MMBTU basis.

[14] Average Price Volatility of Transportation Fuels is calculated as the weighted average ratio of historic fuel prices standard deviation to the historical mean. In the transportation sector, gasoline has the lowest historic volatility, and as such, and scenario that reduces dependence on gasoline also brings with it greater price volatility.

[15] Economic activity is the total in-state capital investment required to make the changes to the transportation sector energy infrastructure between 2013 and 2035. It does not include any effects on economic activity associated with reduced fuel consumption.

[16] In-state employment impacts reflect only the changes in employment associated with capital expenditures. It does not include any reductions in direct employment associated with reduced fuel consumption, or secondary employment effects in Rhode Island's economy.

### *Summary of Key Findings*

Making tradeoffs between security, economics, and sustainability is inevitable in selecting any set of strategies to elicit change in Rhode Island's energy economy. This summary seeks to bring these tradeoffs to light, and explain some of the underlying mechanisms driving the change in each scenario modeled. To reiterate, the results of any given scenario are not a forecast, nor are they predictive, but instead are intended to bracket the range of credible future outcomes and inform the RISEP Project Team's policy recommendations and strategies for the state energy plan update.

#### Scenario 1: Security

**Electric Sector**

- By 2035, average system costs are 24% higher than in the BAU.
- In-state renewable build includes 70 MW on-shore wind, 302 MW solar, 7.5 MW biomass, and 180 MW off-shore wind. Additionally, 228 MW of out-of-state wind is financed to meet the RPS.
- The most cost-effective solution to reducing reliance on natural gas is to increase imports into Rhode Island.
- Once the 50% import limit is reached, Rhode Island builds renewable resource in-state to reach the required fuel diversity metric.
- This scenario exhibits significantly less volatile wholesale energy prices relative to the BAU.

**Thermal Sector**

- Scenario 1 sees substantial build out of ETS to shift load creating a more stable grid and renewable thermal resources to diversify away from fossil fuel powered heating.

**Transportation Sector**

- Natural Gas powered transportation triples in market share from the BAU and with moderate gains in fleet average efficiency and public transit ridership overtakes gasoline as the dominant fuel source.

**Figure 1: Key Findings in Scenario 1: Security**

Across all three sectors, Scenario 1, Security, is defined by two key characteristics: fuel diversity and energy storage. While promoting diversity in the choice and availability of fuels used to provide electricity, thermal energy, and transportation services helps reduce risk associated with supply disruptions and price shocks, it alone typically stands as a costly proposition.

As over 90 percent of the power generation used to meet Rhode Island demand is currently fueled by natural gas, diversifying away from that with the constraint that half of power generation move in-state causes a significant jump in annual energy expenditures. Similarly, were it not for the moderate gains in commercial and industrial thermal efficiency modeled in Scenario 1, the total annual fuel expenditures in the thermal sector would certainly surpass that of the BAU. In contrast, there exist opportunities to simultaneously promote fuel diversity and reduce average fuel prices in the transportation sector as fuels including CNG and electricity offer lower cost alternatives to gasoline. The higher cost in this instance is the upfront investment in supply infrastructure, which in turn presents a positive outcome for employment.

In both the electric and thermal sector, diversification also brings with it lower fuel price volatility as it promotes deployment of power generation and thermal energy technologies with low or no historic fuel price volatility. While counterintuitive, diversifying away from gasoline in the transportation sector leads to greater price volatility as each alternative fuel considered has greater historic price volatility. However, it is important to remember that volatility is not tied to forecast fuel prices as it implies no specific direction. In the transportation sector, it simply conveys that fluctuations in gasoline prices fall within a narrower band than do prices for alternative fuels. This is true in all three scenarios.

Similar to fuel diversity, energy storage offers many benefits to the security of Rhode Island's energy economy. It stands as a readily deployable resource in times of peak demand, enables grid operators to shift loads, provides ancillary services like frequency regulation, and helps address intermittency issues associated with high renewables penetration. However, while the exact dollar benefit associated with storage is often difficult to quantify, its cost is not. Energy security achieved through fuel-diversification and energy storage leads to cost increases almost by definition as it requires a shift from the current state, which often favors the least expensive options and imparts redundancy, in turn adding cost.

#### Scenario 2: Economics

**Electric Sector**

- Total expenditures are the lowest of any scenario, however they remain slightly higher than the BAU case due to the imposition of a higher RPS mandate and increased electrification of other sectors.
- The In-state renewable build includes 16 MW on-shore wind, 66 MW solar, and 180 MW off-shore wind. Additionally, 11 MW of out-of-state wind is financed to meet the RPS.
- The primary deviations from the BAU case include a higher RPS mandate and higher load in the residential and transportation sectors.

**Thermal Sector**

- Extensive deployment of CHP and industrial efficiency measures drive down aggregate expenditures in the thermal sector, resulting in lower average costs of energy with less capital investment than alternatives.

**Transportation Sector**

- Annual fuel expenditures drop by 38% by 2035 owing to drastic increases in average fleet MPG and moderate vehicle electrification.

**Figure 2: Key Findings in Scenario 2: Economics**

Unlike in Scenario 1, the most cost-effective solutions depicted in Scenario 2, Economics, often favor demand reduction and fuel concentration around the least cost option. In the electric sector, the power generation portfolio build-out looks much as it does in the BAU, with the added constraint of marginally higher RPS. While the average cost of electricity actually decreases, the total expenditures increase to accommodate additional demand from electric vehicles.

In the thermal sector, the emphasis of Scenario 2 is on maximizing access to natural gas for both conventional heating needs and combined heat and power applications in the industrial sector. Additional gains in both residential and commercial efficiency were also observed to most effectively control costs in this sector. It was also observed that the capital investment associated with these deep thermal efficiency retrofits and fuel conversions elicited the greatest positive impact on thermal sector employment of the three scenarios, likely due to the ubiquity of projects.

In contrast, the in-state economic activity does not translate directly into jobs in the transportation sector as much of the gains in demand management come from an aggressive increase in average fuel economy of passenger cars. Where there is a substantial increase in the underlying capital investment (higher efficiency cars) in this Scenario, the in-state labor contribution to this change in marginal. Similarly, the moderate efforts towards vehicle electrification can leverage existing in-home charging infrastructure and thus lacks the large scale capital conversion required to contribute many jobs in this scenario.

### Scenario 3: Sustainability

#### Electric Sector

- There is a 56% decrease in $CO_2$ emissions by 2035 from 2013 levels. To some extent, increased carbon efficiency in the electric sector is offset by significantly increased electrification of other sectors.
- In-state renewable build is 70 MW on-shore wind, 66 MW solar, and 180 MW off-shore wind. Additionally, 1,111 MW of out-of-state wind is financed to meet the RPS.
- Due to high EE penetration, load can be met with existing generating resources, reducing the incentive to meet the RPS requirement through in-state development.
- The results show 21% increase in total system expenditure vs. the BAU.

#### Thermal Sector

- Emissions from this sector drop to 44% below those in the BAU by 2035 resulting from a high penetration of solar and geothermal heating (combined 3,500 BBTU/year in 2035).

#### Transportation Sector

- Emissions are cut dramatically (40% below the BAU 2035 level) through an expansive roll out of public transit options and city planning which discourages single occupancy vehicles combined with widespread electrification and switching to biofuels.

**Figure 3: Key Findings in Scenario 3: Sustainability**

The objective functions used to define Scenario 3, Sustainability, in the POM set challenging RPS mandates of 25 percent renewables by 2023 and 75 percent by 2035. However, these targets result in less change to in-state power generation infrastructure than those in Scenario 1, as regional procurement of RECs satisfy this requirement. In turn, Rhode Island meets its RPS targets and contributes to a substantial reduction in greenhouse gas emissions, but without substantively changing the source of electricity used to meet demand.

In the thermal sector, GHG free sources of thermal energy, CHP, and other industrial efficiency measures are pursued aggressively leading to a 44 percent drop in GHG emissions over 2013 levels. However, this drop in emissions is not substantially larger than that achieved in Scenario 2, and does not offer the same level of benefit to employment associated with capital investments. Interestingly, these combined strategies also offer the same level of fuel diversification as modeled in Scenario 1, but offer less capacity for load shifting due to a lower penetration of ETS.

In the transportation sector, aggressive vehicle electrification and mandates for biofuels help reduce emissions from the existing fleet, while the number of vehicle miles traveled is reduced dramatically from an uptick in public transit ridership and complete streets initiatives. These capital intensive projects have a higher labor contribution than do vehicles manufactured out of state and as a result the capital efficiency of job creation is greater than in Scenario 2 and on par with Scenario 1.

## Model Overview

### *POM Overview*

Navigant's proprietary Portfolio Optimization Model (POM) is a capacity expansion model that emphasizes impacts of environmental policies and focus on renewable generation, while being suitable for risk analysis. It is linked with Navigant's PROMOD input dataset and incorporates the same generation base, demand forecasts, fuel prices, other operating costs, and plant parameters which are utilized in PROMOD. POM's algorithmic structure and solution methods are also compatible with Navigant's models for forecasting fuel prices, capacity market prices, and emissions prices. POM is a linear program that dynamically solves for the multi-decade planning horizon simultaneously to simulate economic investment decisions and power plant dispatch on a zonal basis subject to capital costs, reserve margin planning requirements, renewable portfolio standards, fuel costs, fixed and variable O&M costs, emissions allowance costs, and zonal transmission interface limits. It includes a multi-regional representation of the North American electrical system with constraints on inter-zonal transmission, and adopts a load duration curve representation to speed computational times. POM has every individual generating unit specified allowing for state-by-state reporting of generation data. Optionally POM can perform multivariate optimization, which considers other value propositions than just cost minimization, such as sustainability, technological innovation, or spurring economic development. This makes it especially suitable for modeling future renewable generation expansion.

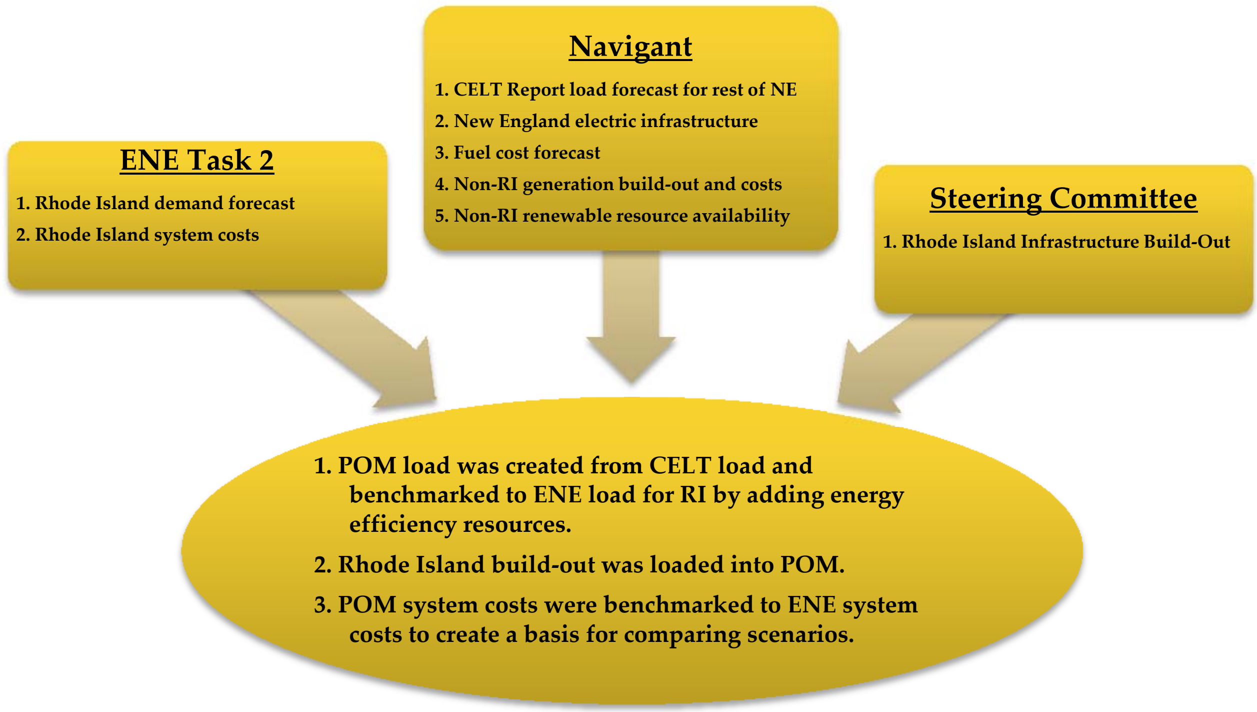
For this project, POM was set up to model the ISO-NE system in a standalone set-up. The entire region had to be represented, as ISO-NE is an integrated system for which the Rhode Island electrical system is only a component. Imports into and exports from New England were assumed to have a fixed hourly dispatch matching Navigant's most recent Eastern Interconnect PROMOD run. The purpose of this simplifying assumption is to focus the analysis on the details of the ISO-NE system and sensitivities on the results. Broadening the scope of POM would have limited the detail that could be addressed in the ISO-NE system.

The ISO-NE representation of POM used Navigant's summer base case build-out with the exception of Rhode Island generation capacity which was allowed to vary between scenarios. A fundamental assumption of the analysis is that Rhode Island policies can impact Rhode Island generation procurement and system dispatch but will not impact the broader policies of the rest of the New England states. This assumption allows the differences between the scenarios to be understood solely as impacts from Rhode Island policies.

### *Benchmarking to the BAU*

The electric sector modeling for this project consisted of analyzed scenarios with respect to the BAU case. The BAU did not include other parameters that are necessary for POM to be set up. The POM BAU was created by combining information from three sources, as shown in Figure 4. The ENE BAU gave Rhode Island load and total cost, and the steering committee provided assumptions on new Rhode Island renewable capacity that should be included in all scenarios. Navigant's summer base case was the source for the rest of the model parameters.

**Figure 4: Building up the Electric Sector BAU**




The POM model only considers incremental system costs and does not include legacy costs that a utility would pay. Therefore the POM output costs are unlikely to be near the BAU costs in the early years of the forecast and there is a need to benchmark the two. POM's system costs in the BAU were benchmarked to the ENE BAU costs by adding the difference between the two streams of numbers to the POM values. These adders were then applied to each of the scenarios so that the relative costs of each scenario could be calculated properly. Table 4 shows the calculation of the benchmark adder in 5 year increments. For example, in 2025, POM Rhode Island costs were outputted as $597 Million while the BAU Rhode Island costs were $830 Million. To match these values, the benchmark of $233 Million must be added to the POM results in 2025 for every scenario in the analysis. Note that the benchmark declines through the forecast period suggesting that the interpretation of the benchmark as representing legacy system costs not considered by POM is reasonable.

**Table 4: POM to BAU Benchmark**

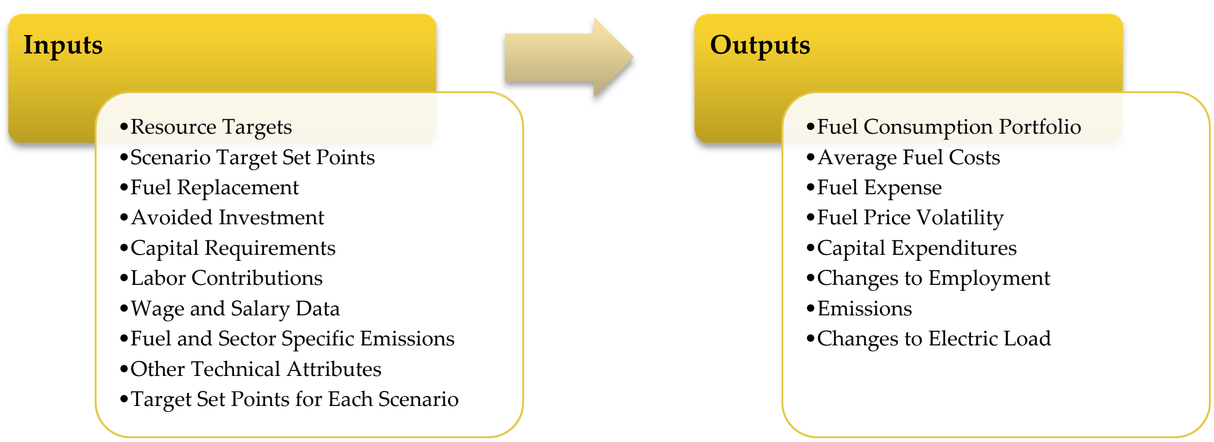
| Case | 2015 | 2020 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|
| **Raw POM Costs (MM $2012)** | 390 | 530 | 597 | 679 | 779 |
| **ENE BAU Costs (MM $2012)** | 1,008 | 897 | 830 | 873 | 837 |
| **Benchmark Cost Adder (MM $2012)** | 618 | 367 | 233 | 194 | 58 |

### *Thermal and Transportation Model Overview*

Navigant developed a spreadsheet-based modular-flow model to analyze changes in Rhode Island's thermal and transportation sectors. This model converts the effects of 15 resources to a common basis of energy demand (MMBTU) and accounts for annual changes in each resource required to meet the user specified targets. The model incorporates technical and economic attributes of each resource and fuel type to calculate the aggregate first order effects on key directional objectives.

Inputs to the model include the resource targets themselves; the mix of fuel replaced and future investment avoided by a given resource; resource allocation to the residential, thermal, and industrial sectors (thermal model); capital requirements; the labor contribution associated with both capital investments and fuel related expenses; state-average wage and salary data; the emissions profiles associated with each fuel in each sector; and several other technical attributes specific to each resource. Outputs from the model include the resulting fuel consumption portfolio; average fuel costs; fuel related expenses; capital investments; changes to employment (stemming from changes to both capital investments and fuel expenditures); aggregate fuel price volatility; and emissions by sector. For resources that interact with the electric sector (including CHP, ETS, and electric vehicles), outputs from the thermal and transportation model serve as inputs to the electric sector model. Additional information about the assumptions and inputs used in the thermal and transportation model is available in Appendices: Thermal Sector Assumptions and Supplemental Information and Transportation Sector Assumptions and Supplemental Information.

**Figure 5: Thermal and Transportation Model Inputs and Outputs**



## Scenario Development

### *Directional Objective Metrics*

With input from the Advisory Council, the RISEP Project Team established a set of 12 directional objectives related to the security, economics, and sustainability of Rhode Island's energy economy in Task 1 of the RISEP Project. In collaboration with the RISEP Project Team, Navigant developed quantitative and qualitative metrics for each directional objective to facilitate a comparison between each scenario modeled, and the business as usual case as developed by ENE in Task 2 of the RISEP Project.

**Table 5: Directional Objectives and Metrics**

| PLAN CRITERIA | INTENDED OUTCOMES: | DIRECTIONAL OBJECTIVES | RISEP PROPOSED METRICS | MODEL METRICS |
|---|---|---|---|---|
| **SECURITY** | …Occurs in every sector of Rhode Island's economy | **ADEQUACY** | Supply=Forecasted Demand | Fundamental Condition |
| | …Ensures a full range of lighting, comfort, convenience, productivity, and mobility for Rhode Island consumers | **SAFETY** | Risk, frequency, and length of supply disruptions; Fuel diversity; Capacity and # of storage or backup power systems | Fuel Diversity (Max %) |
| | …Continues under both ordinary and extraordinary conditions | **RELIABILITY** | | MWh of Storage |
| | | **RESILIENCY** | | Qualitative Assessment |
| **ECONOMICS** | …Provides opportunities for affordable energy bills for all Rhode Island consumers | **AFFORDABILITY** | Annual expenditure (total, by sector, and per capita) | Annual Expenditures, Average Fuel Prices |
| | …Promotes the regional and global competitiveness of Rhode Island business and industry | **STABILITY** | Derivative of price, energy cost variance | Price Volatility Index |
| | | **ECONOMIC GROWTH** | Gross State Product, annual in-state energy expenditure | Capital Investments |
| | | **EMPLOYMENT** | Job-years | Job-years |
| **SUSTAINABILITY** | …Promotes lifecycle benefits to human and environmental health | **CLIMATE** | $CO_2$, $CH_4$, $N_2O$ emissions | GHG Emissions |
| | | **AIR QUALITY** | $SO_2$, $NO_x$, particulate matter emissions | $SO_2$, $NO_x$ Emissions |
| | | **WATER USE & QUALITY** | Water use & quality indicators | |
| | | **LAND & HABITAT** | Area of land use conversion | Acres Converted |

### *Scenario 1: Security*

Scenario 1 prioritizes the security of Rhode Island's energy economy through fuel diversification and grid modernization efforts that increase storage for demand response, load shifting, and frequency regulation. Within the electric sector, this scenario targets a diverse power generation portfolio that does not rely on any one fuel source for more than fifty percent of generation by 2035. Additionally, this scenario mandates a build-out of grid tied storage at the maximum rate identified in the target setting exercise. For the thermal sector, this scenario promotes the adoption of a diverse set of options for both space conditioning and water heating across the residential, commercial, and industrial sectors; as well as provides load shifting capabilities through aggressive deployment of electric thermal storage (ETS). In the transportation sector, this scenario calls for expanded fuel choice for consumers with increases in adoption of PEVs, CNG vehicles, and a biofuels mandate.

### *Scenario 2: Economics*

Scenario 2 prioritizes the cost effectiveness of Rhode Island's energy economy and in-state economic development while hitting key targets for GHG reduction. In the electric sector, reducing energy expenditures is accomplished largely through demand side management, including gains in efficiency. Additionally, marginally higher RPS standards (25 percent by 2035) are addressed through development of large scale offshore wind projects and procurement from elsewhere in ISO-NE. For the thermal sector, switching to lower cost fuel options and additional efficiency gains in the industrial sector provide opportunities to reduce expenditures. In the transportation sector, this scenario aims to cut transportation related fuel expenditures through programs that dramatically increase vehicle average efficiency and provides for moderate expansion of cost effective public transit options.

### *Scenario 3: Sustainability*

Scenario 3 prioritizes the sustainability of Rhode Island's energy economy through the widespread deployment of renewables, thermal alternatives, and vehicle electrification. Changes in the electric sector hinge on aggressive renewable portfolio standards targeting 25 percent by 2023, and 75 percent by 2035. To help provide grid stability in light of the widespread deployment of renewables, grid tied storage is added at pace with renewables to facilitate frequency regulation. In the thermal sector, this scenario targets an aggressive rollout of zero emissions thermal energy alternatives including solar thermal and geothermal, as well as lower emission alternatives like biofuels. Similarly, in the transportation sector, Scenario 3 aims to aggressively reduce transportation related pollution through substantial increases in alternative fuel vehicles and public transit ridership, as well as reductions in vehicle miles traveled from non-public transit alternatives such as walking, biking, and telecommuting.

### *Electric Sector: POM Objective Functions*

POM relies on a set of objective functions and constraints to develop an optimized build out of the power generation infrastructure. Table 6 depicts the constraints imposed on POM in each of the three scenarios. The requirement that POM meets all objective functions subject to the constraints in the most cost effective manner is a fundamental function of the model.

**Table 6: POM Objective Functions**

| | Scenario 1: Security | Scenario 2: Economics | Scenario 3: Sustainability |
|---|---|---|---|
| **SECURITY** | • Minimize contributions of the dominant fuel source<br>• Target a balance of 50% in-state and 50% out of state generation by 2035<br>• Maximize build out of energy storage technologies and DR capabilities | • Net increase in diversity of fuels used to meet demand | • Build out energy storage technology at pace with renewables |
| **ECONOMICS** | • Change in 'Job Years' is positive<br>• **Meet all other criteria in the most cost effective manner** | • Minimize expenditures across all sectors<br>• Change in 'Job Years' is positive<br>• **Meet all other criteria in the most cost effective manner** | • Change in 'Job Years' is positive<br>• **Meet all other criteria in the most cost effective manner** |
| **SUSTAINABILITY** | • 40% renewables by 2035 (25% in-state) | • 25% renewables by 2035 | • 25% renewables by 2023<br>• 75% renewables by 2035 |

### *Thermal and Transportation Targets*

In contrast to POM, the thermal and transportation model requires the user to specify set-points (Low, Moderate, and High) for each resource considered. In the instance that a particular resource is explicitly forecast in the BAU case, a low set-point corresponds to no-change from the business as usual case. Where a particular resource was not explicitly projected, a low-set point implies no incremental change above what was independently forecast to happen in the resource target setting exercise. For additional information on the values associated with each resource target, please see Appendices: Resources & Assumptions.

**Table 7: Thermal Sector Resource Targets**

| Resource | Units | BAU | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|---|
| **Solar Thermal** | BBTU/year | Low | Moderate | Low | Aggressive |
| **Geothermal** | BBTU/year | Low | Aggressive | Low | Aggressive |
| **Biofuels** | BBTU/year | Low | Moderate | Low | Aggressive |
| **ETS** | MW | Low | Aggressive | Low | Moderate |
| **CHP** | BBTU/year | Low | Aggressive | Aggressive | Aggressive |
| **Natural Gas** | % of Demand | Low | Low | Aggressive | Low |
| **Residential Efficiency** | TBTU/year | Low | Low | Moderate | Low |
| **Commercial Efficiency** | TBTU/year | Low | Moderate | Moderate | Low |
| **Industrial Efficiency** | TBTU/year | Low | Moderate | Aggressive | Aggressive |

**Table 8: Transportation Sector Resource Targets**

| Resource | Units | BAU | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|---|
| **Fleet Efficiency** | MPG | Low | Moderate | Aggressive | Low |
| **Vehicle Electrification** | % Transport Sector | Low | Moderate | Moderate | Aggressive |
| **Biofuels** | % Transport Sector | Low | Moderate | Low | Aggressive |
| **Natural Gas Use** | BCF/year | Low | Moderate | Moderate | Low |
| **VMT Reduction** | VMT | Low | Low | Low | Moderate |
| **Public Transit Ridership** | Million Riders | Low | Moderate | Moderate | Aggressive |

# Results

## *Electric Sector Results*

For this section, please consider the definitions presented in Table 9: Electric Sector Metric Definitions.

**Table 9: Electric Sector Metric Definitions**

| Metric | Definition |
|---|---|
| **Power Generated In-State** | GWh of electricity generated by in-state resources |
| **In-State Capacity Additions** | GW of power generation capacity added in-state |
| **Total Demand** | Total in-state electric demand |
| **Dependence on Dominant Fuel Source** | The maximum portion of demand that is addressed by a single fuel source. Fuel used to meet in-state demand is assumed to be in-state generation plus electricity imports with the sources attributed to imports prorated by each source's share in overall ISO-NE fuel mix. |
| **Demand Addressed by Generation Type** | The portion of demand addressed by each type of power generation (regardless of location of power generation) |
| **Power Expenditures** | Power expenditures are the portion of annual expenditures attributed to each source, defined as follows. Benchmark, Other Capital, and Energy Costs are the capital and operating costs of the system without any additional constraints or objectives included in the scenarios. Fuel Diversity is the impact of the constraint added to limit reliance on natural gas. The in-state requirement is the cost impact of requiring that at certain fraction of power is generated in the state of Rhode Island. New RPS Costs are the capital and operating costs of renewable construction due to increases in the RPS mandates. |
| **Average Cost of Electricity** | Average cost of electricity is solely the wholesale electricity cost and only includes the variable cost of generating power for Rhode Island. |
| **Job Years Created** | In-State Employment only considers the first order impacts of the policies. It does not include potential second order economic impacts as changes in spending and investment ripples through the economy. |
| **GHG Emissions** | Metric tonnes of CO2 emitted. GHG reductions include the reduction in system GHGs due to Rhode Island policy. Thus out-of-state renewables financed by the state are included here even though that construction does not impact the in-state fuel mix significantly. |
| **NOX and SO2 Emissions** | Metric tonnes of NOX and SO2 emitted. Similar to GHG, this includes the reduction in system NOX and SO2 due to Rhode Island policy. |
| **Land Use Conversion** | Acres of land converted for changes to power generation infrastructure |

Power Generation

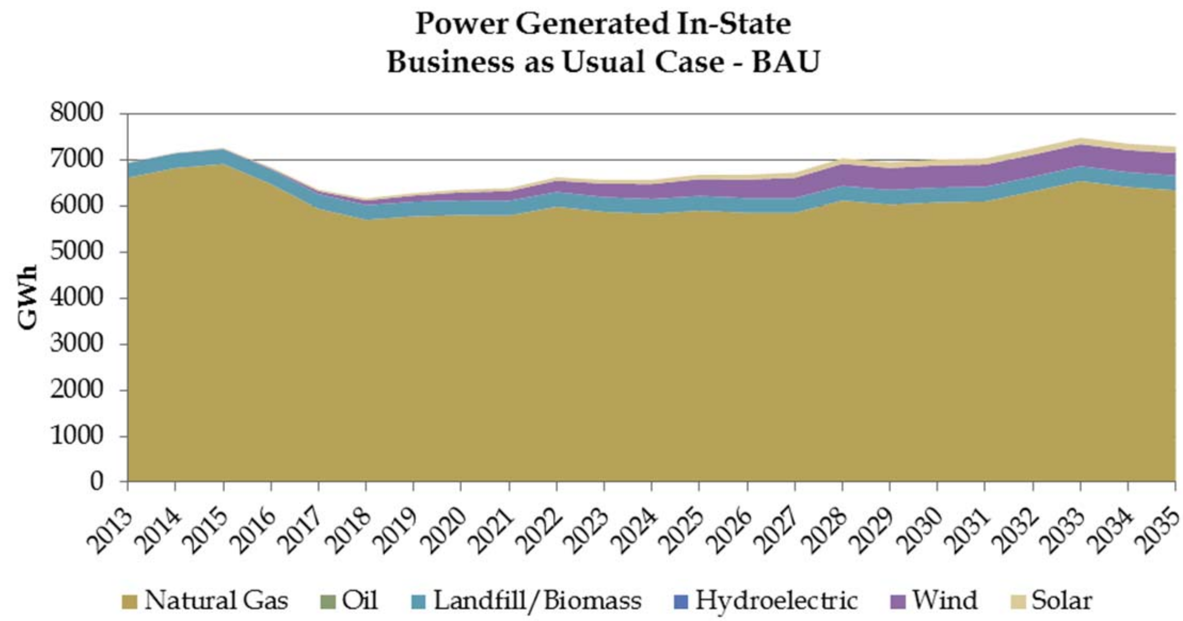



**Figure 6: Electric Sector In-State Power Generation Capacity: BAU**

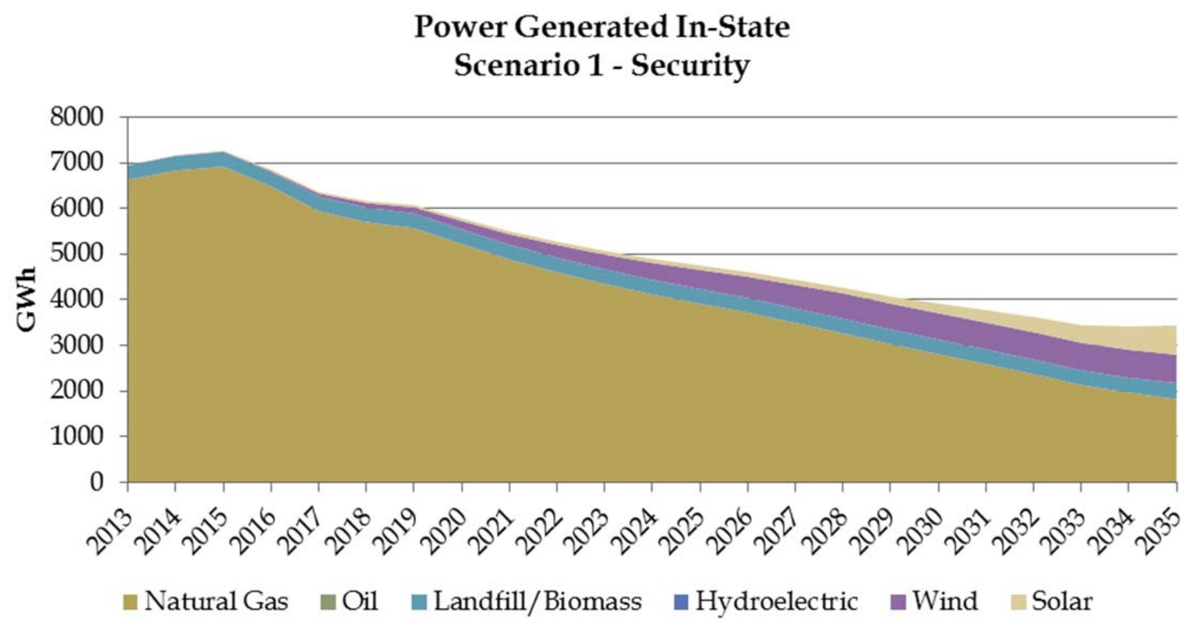



**Figure 7: Electric Sector In-State Power Generation Capacity: Scenario 1 – Security**

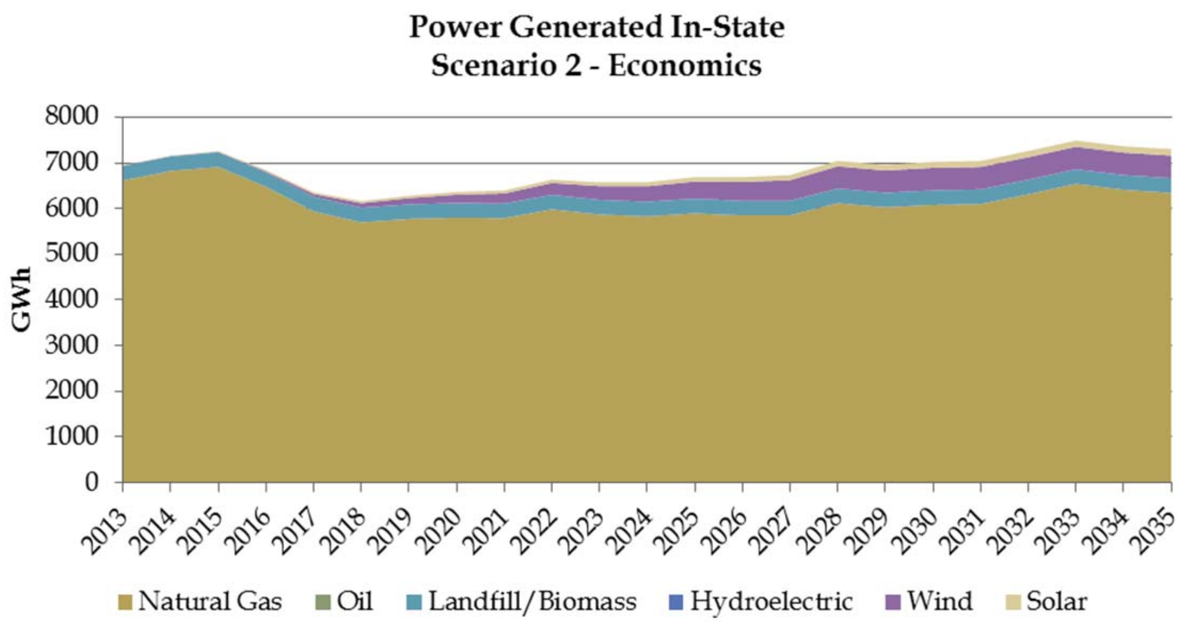



**Figure 8: Electric Sector In-State Power Generation Capacity: Scenario 2 – Economics**

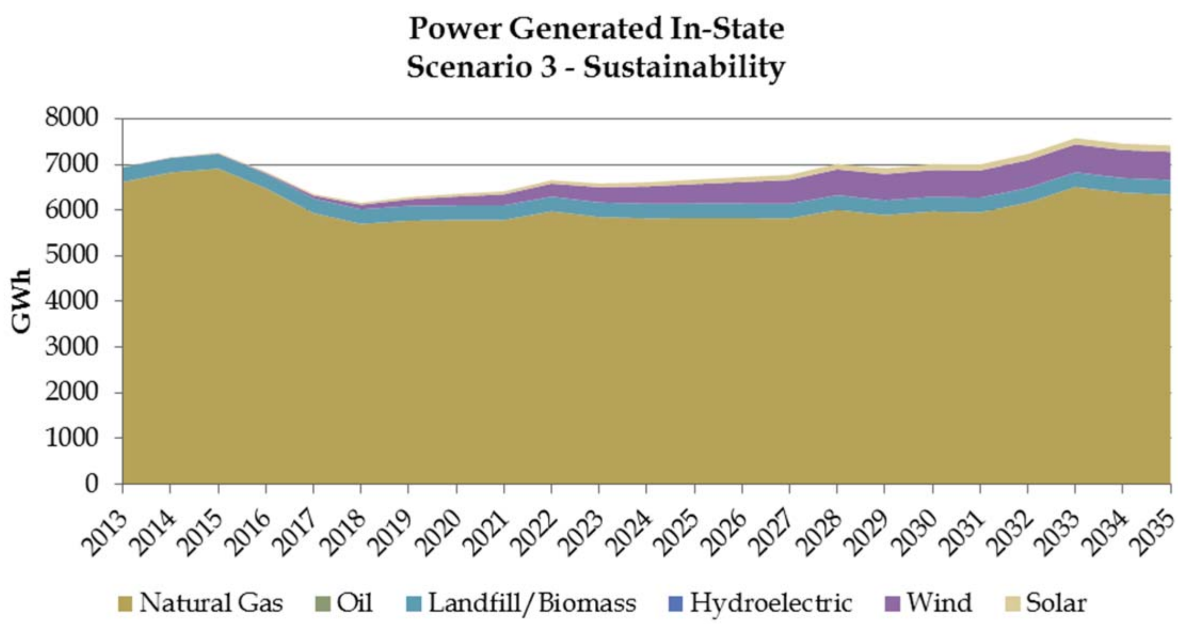



**Figure 9: Electric Sector In-State Power Generation Capacity: Scenario 3 – Sustainability**

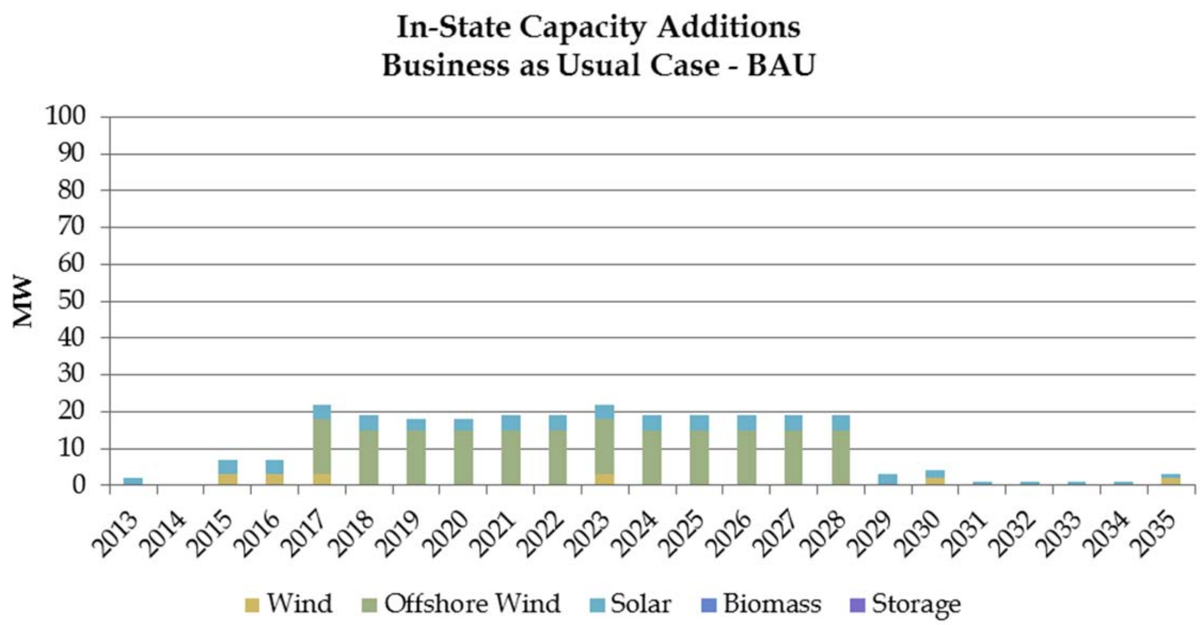



**Figure 10: Electric Sector In-State Capacity Additions: BAU[17]**

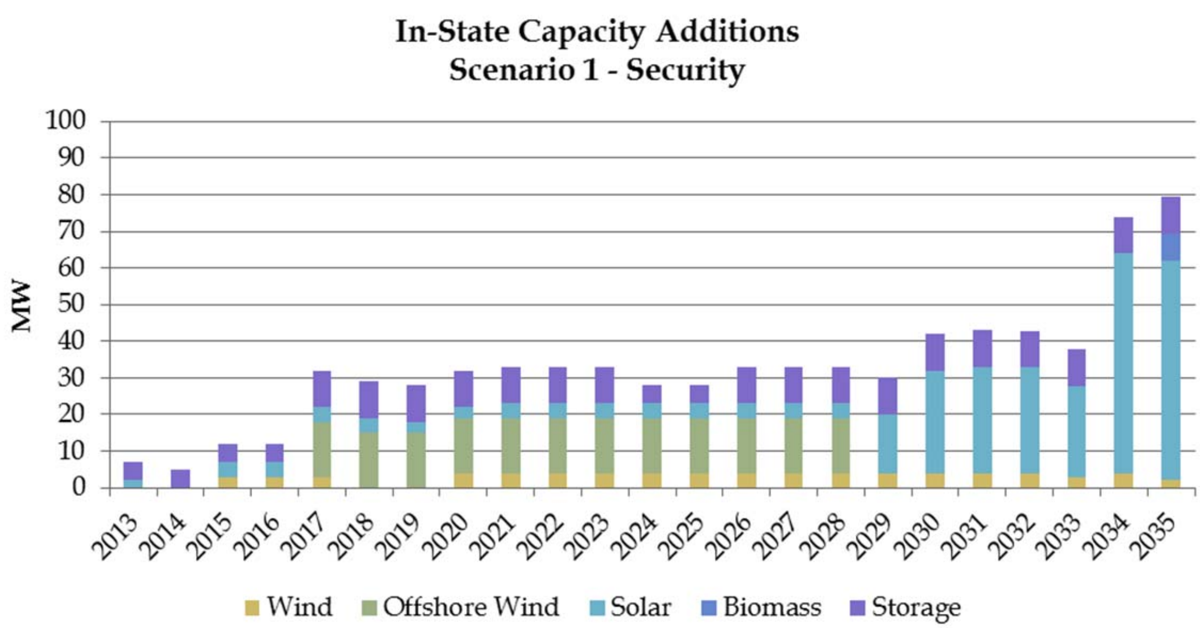



**Figure 11: Electric Sector In-State Capacity Additions: Scenario 1 – Security**

[17] 180 MW of offshore wind are assumed to come online in the BAU case per existing Rhode Island statutes that give the PUC the right to negotiate contracts for this amount. However, there is high uncertainty about when and if this construction would occur. The statute does not require the construction and no required date is given.

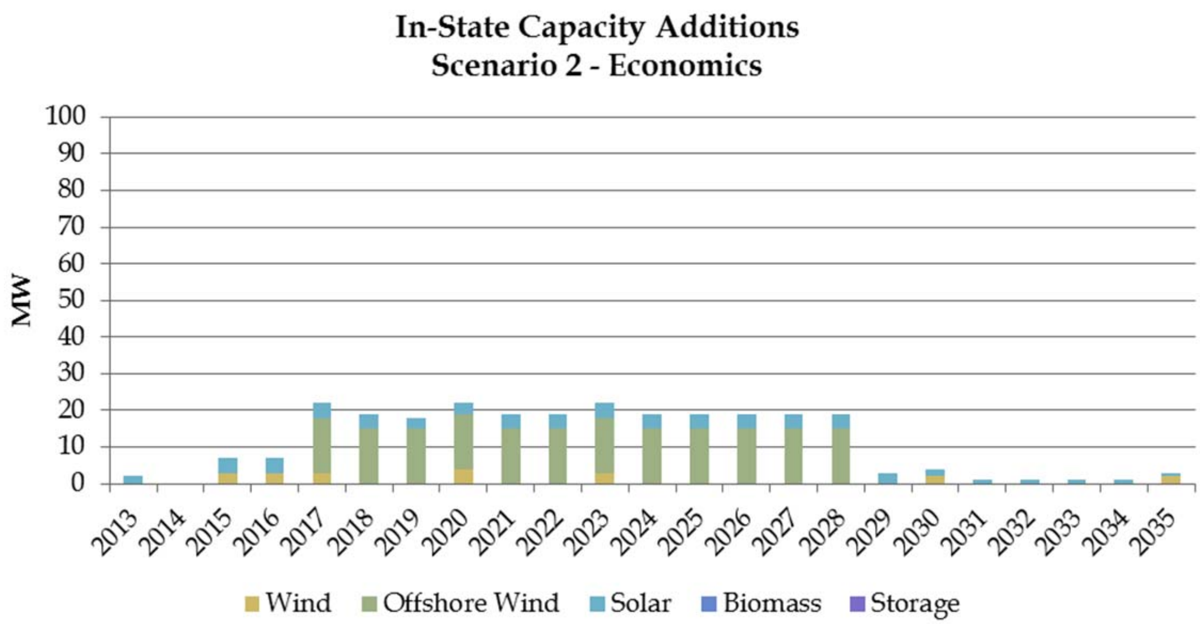



**Figure 12: Electric Sector In-State Capacity Additions: Scenario 2 – Economics**

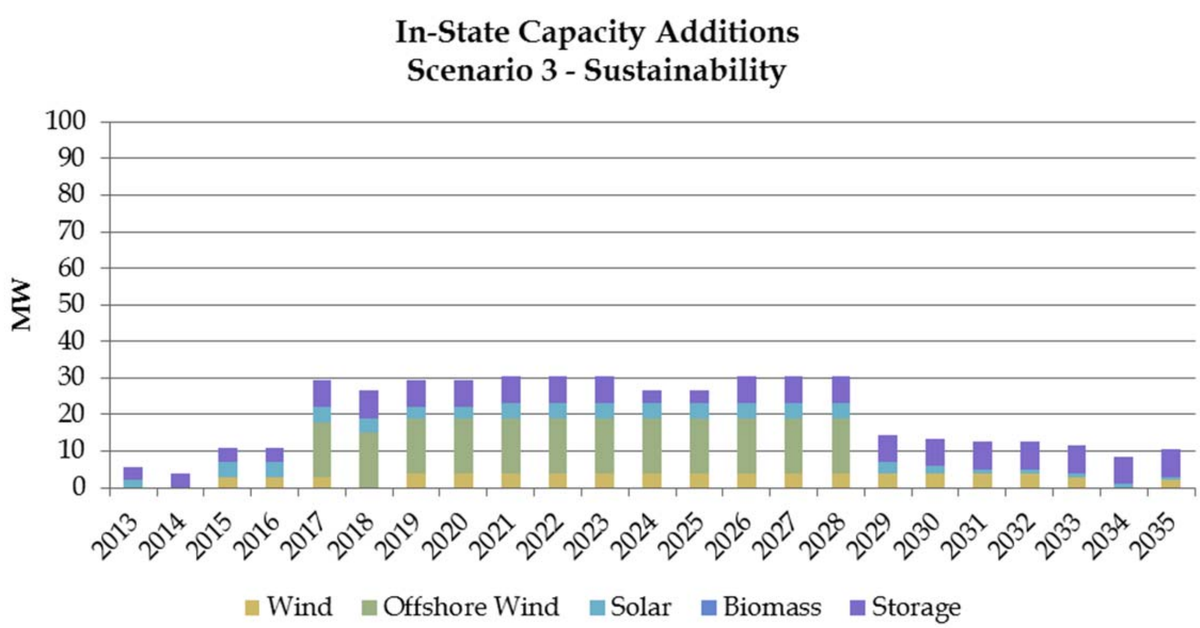



**Figure 13: Electric Sector In-State Capacity Additions: Scenario 3 – Sustainability**

### Demand

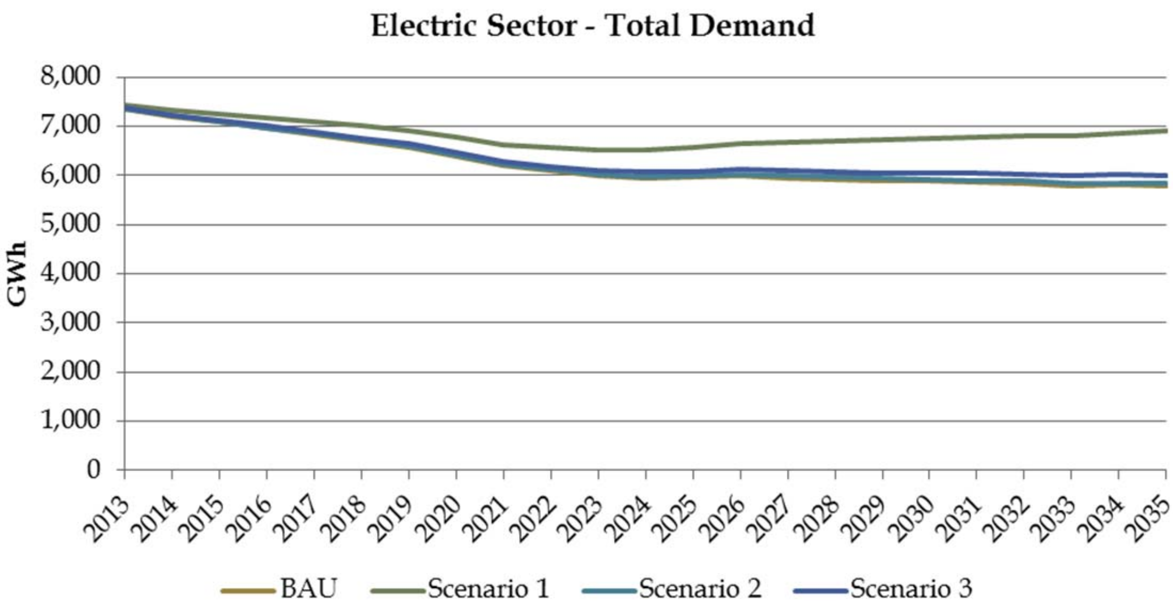



**Figure 14: Electric Sector Total Demand**[18]

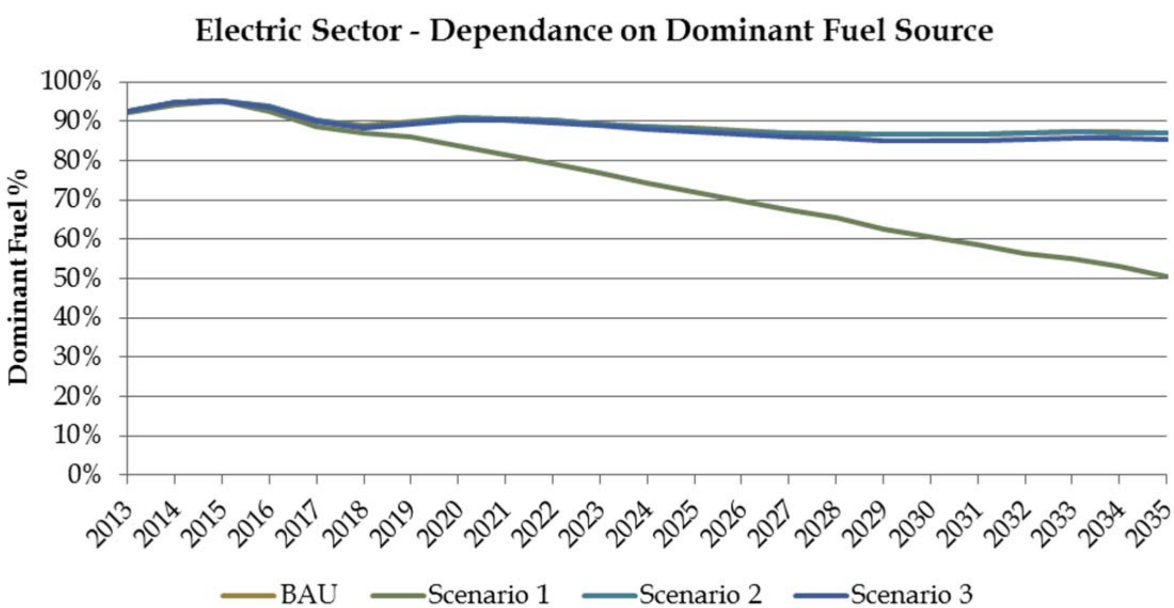



**Figure 15: Electric Sector Dominant Fuel Source**

[18] Note that total demand goes up in these scenarios from the BAU as other sectors electrify

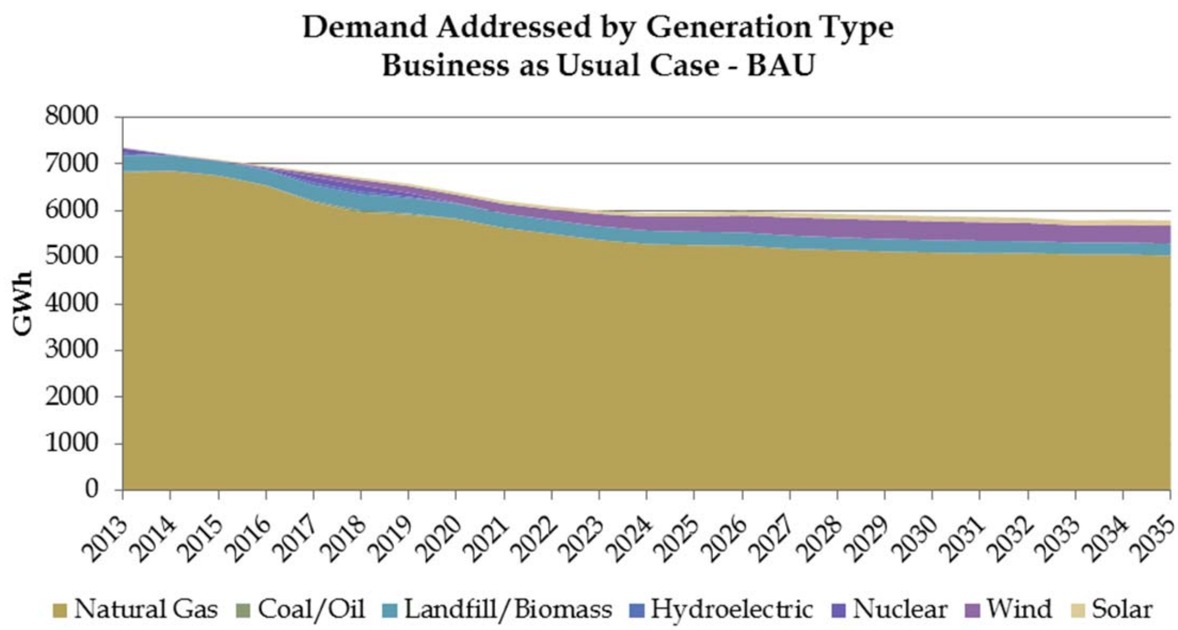



**Figure 16: Electric Sector Demand by Generation Type: BAU**

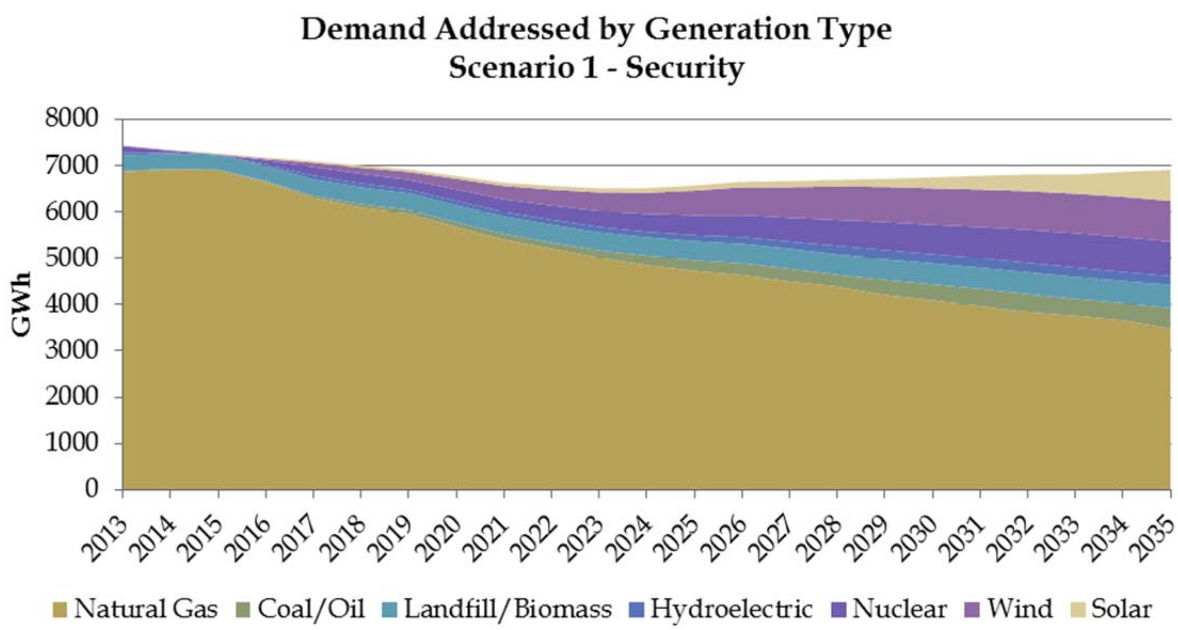



**Figure 17: Electric Sector Demand by Generation Type: Scenario 1 - Security**

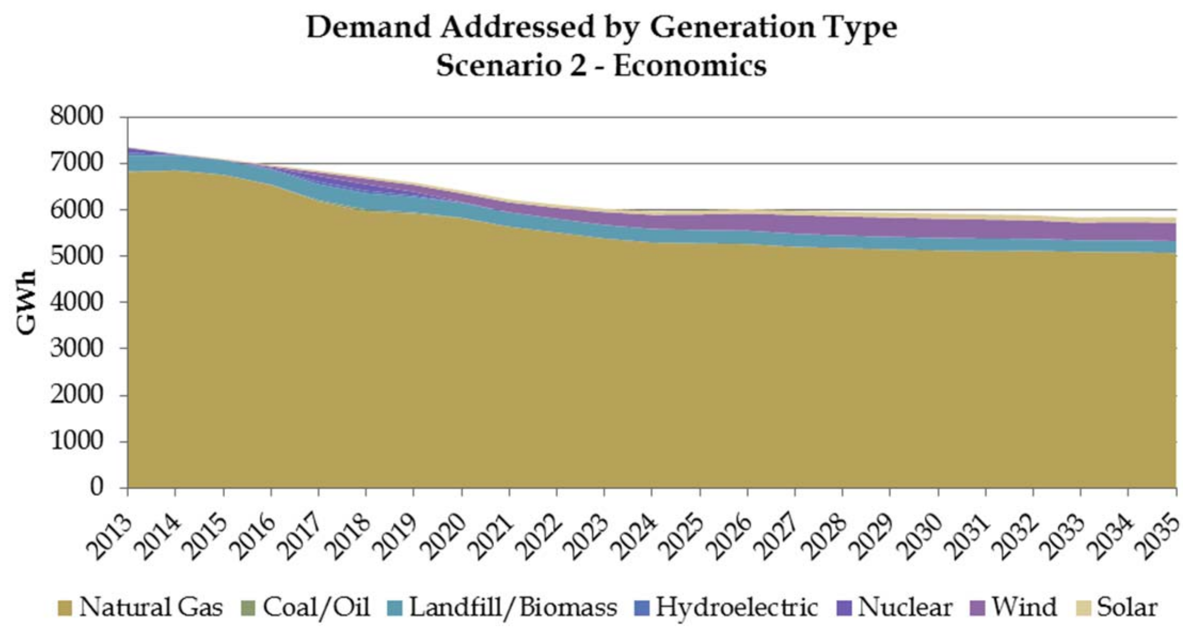



**Figure 18: Electric Sector Demand by Generation Type: Scenario 2 – Economics**

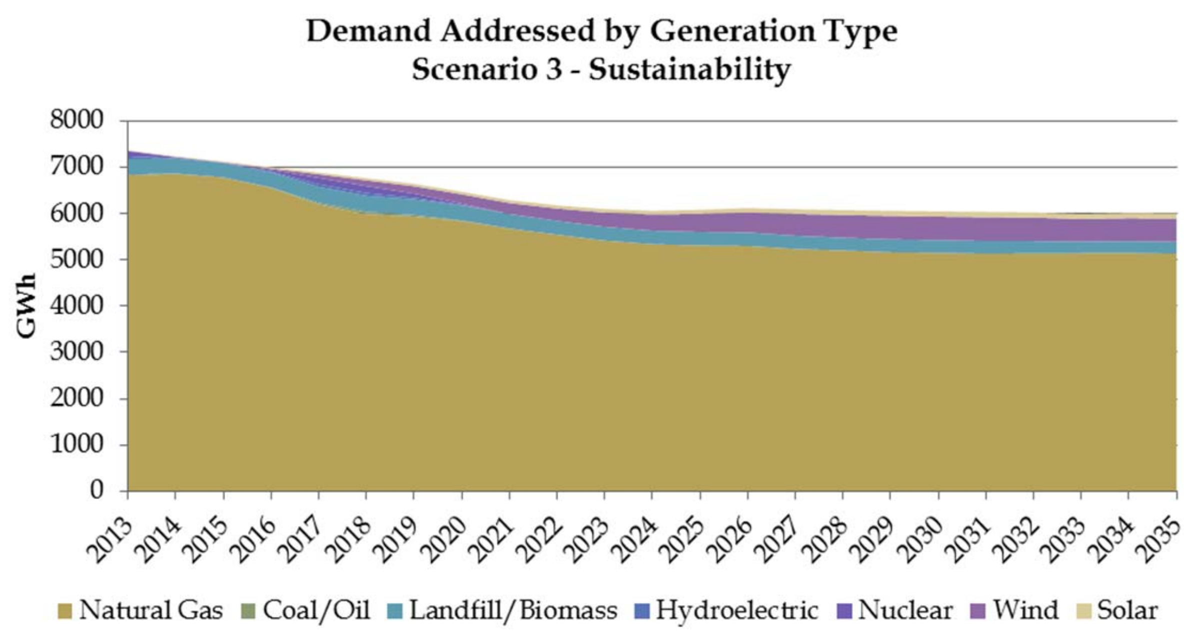



**Figure 19: Electric Sector Demand by Generation Type: Scenario 3 – Sustainability**

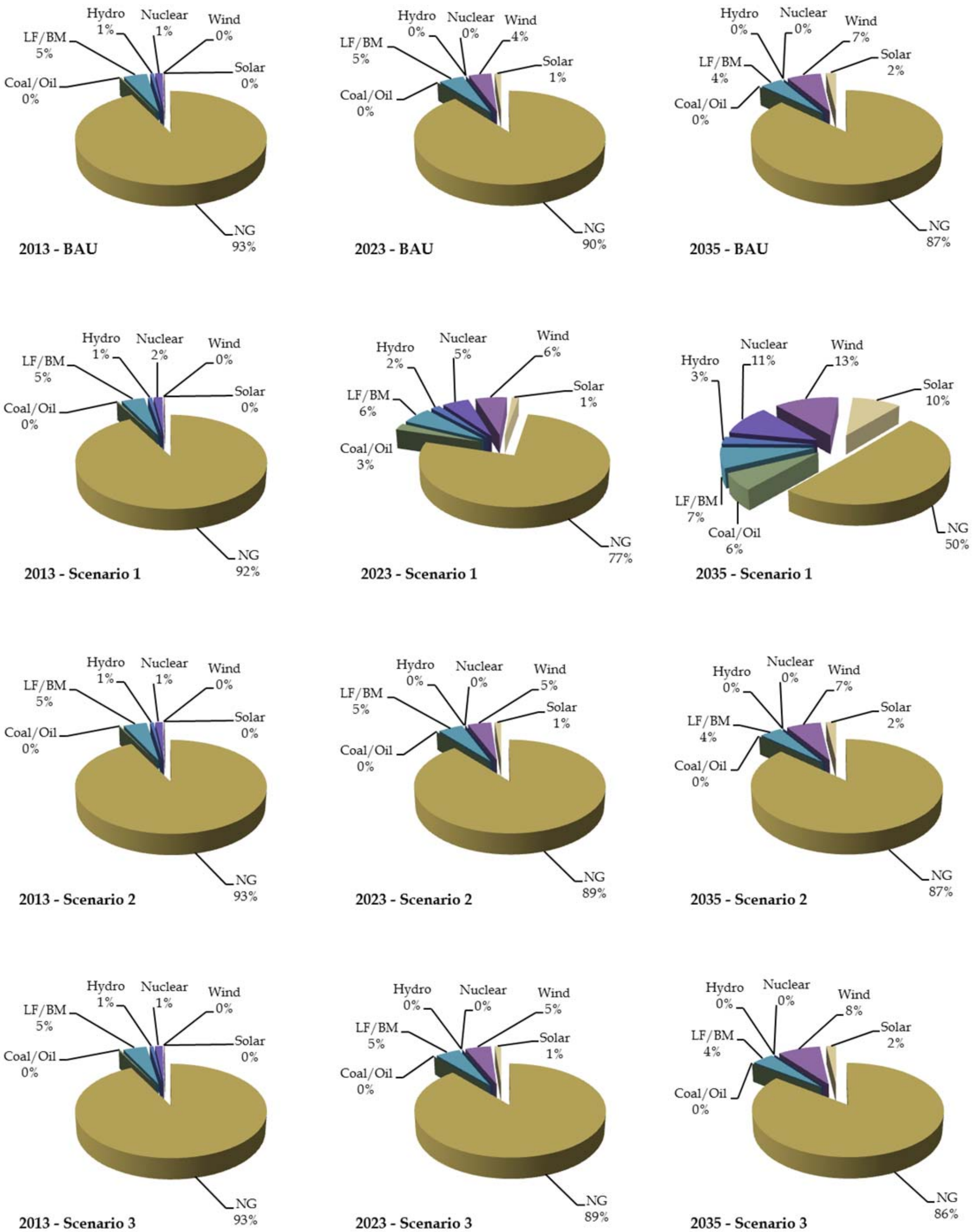



**Figure 20: Electric Sector Demand (2013, 2023, 2035)**

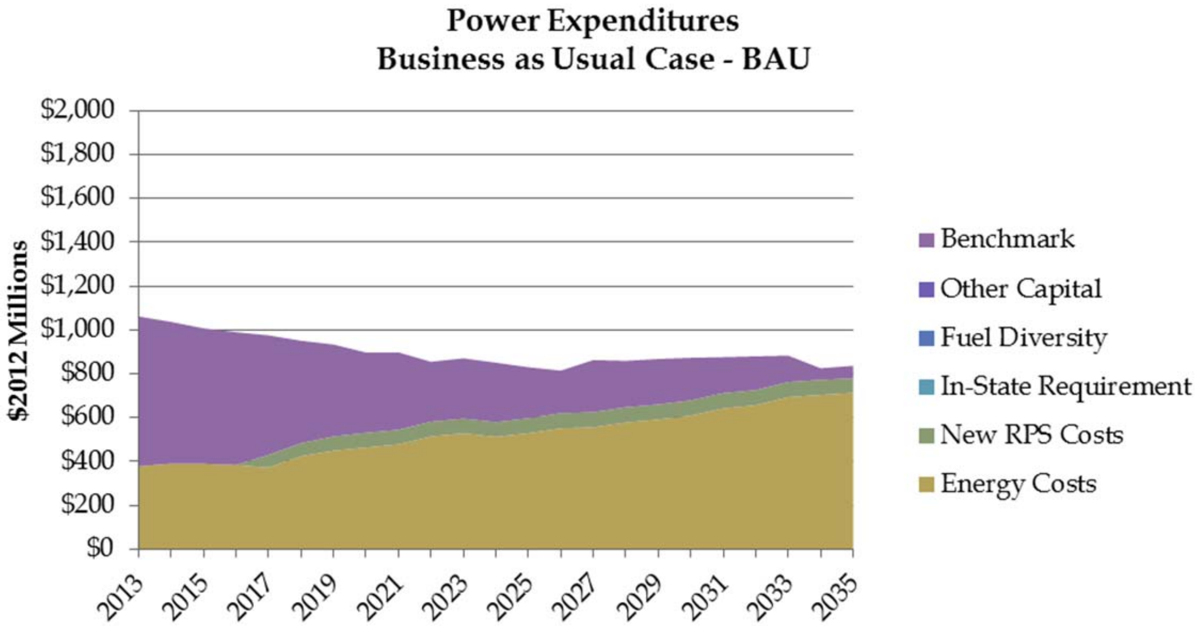



**Figure 21: Electric Sector Power Expenditures: BAU**

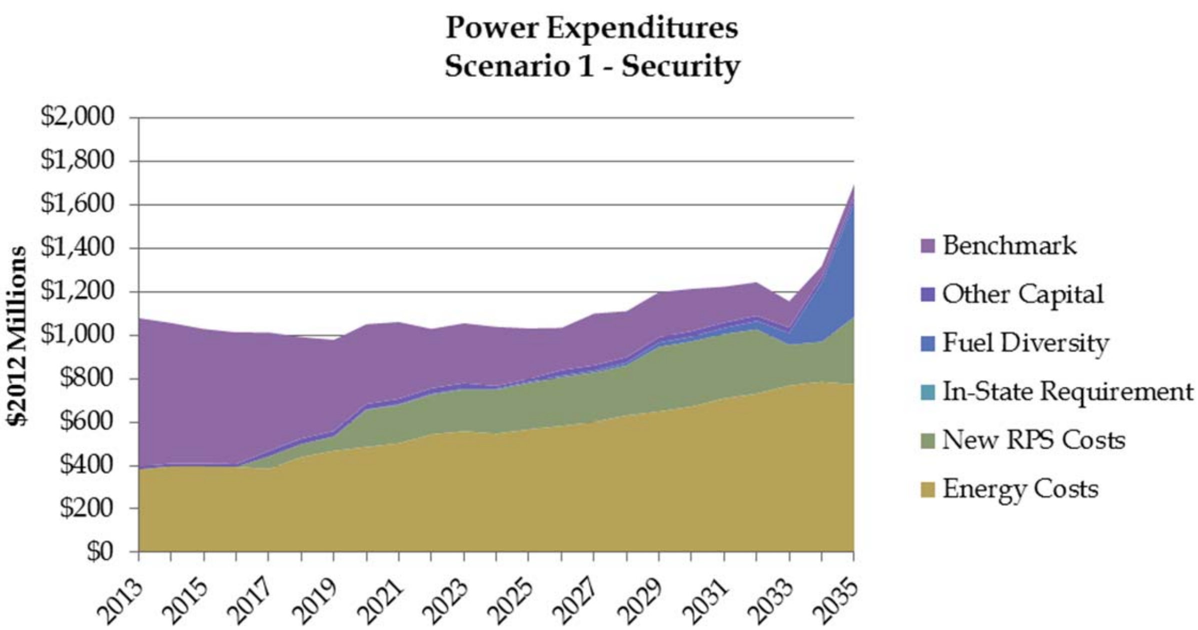



**Figure 22: Electric Sector Power Expenditures: Scenario 1 - Security**

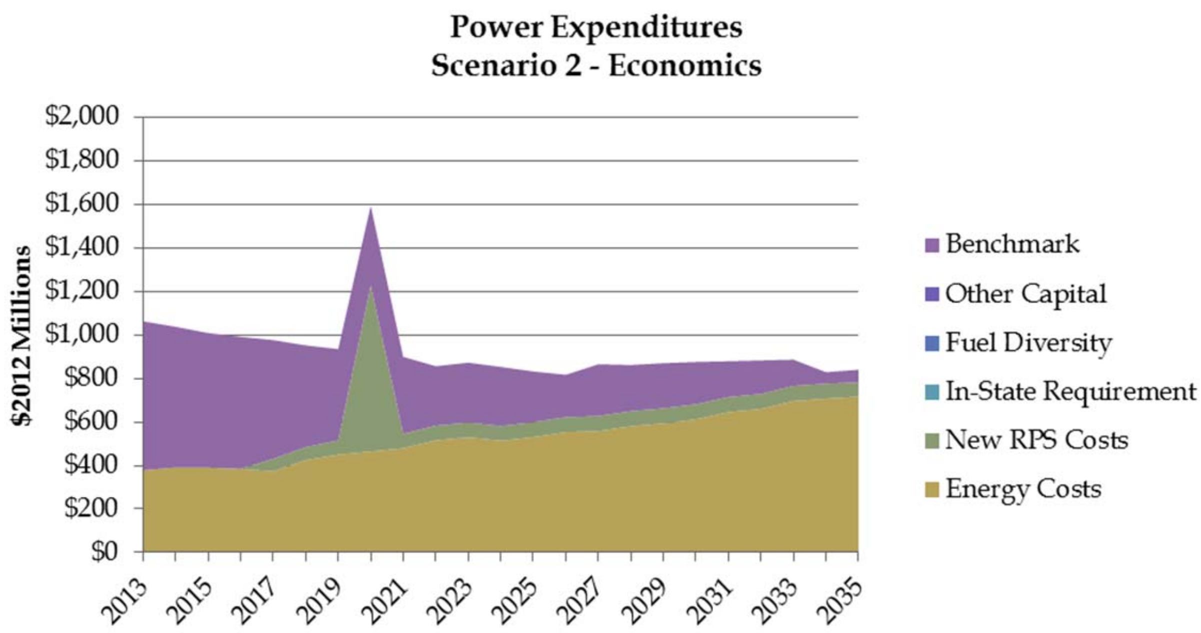



**Figure 23: Electric Sector Power Expenditures: Scenario 2 – Economics**[19]

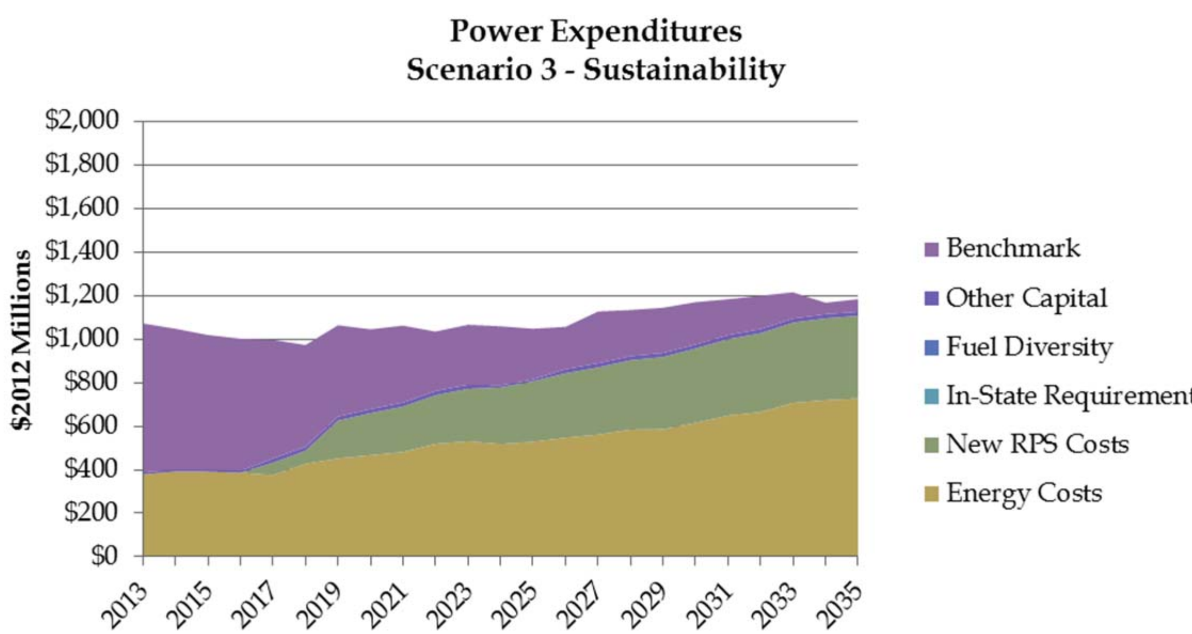



**Figure 24: Electric Sector Power Expenditures: Scenario 3 - Sustainability**

[19] The spike in 2020 is due to how POM accounts for the capital costs of new construction. POM outputs the costs in a single year rather than spread out over the life of the project. This spike should be interpreted as a cost that would actually be borne by consumers over a number of years.

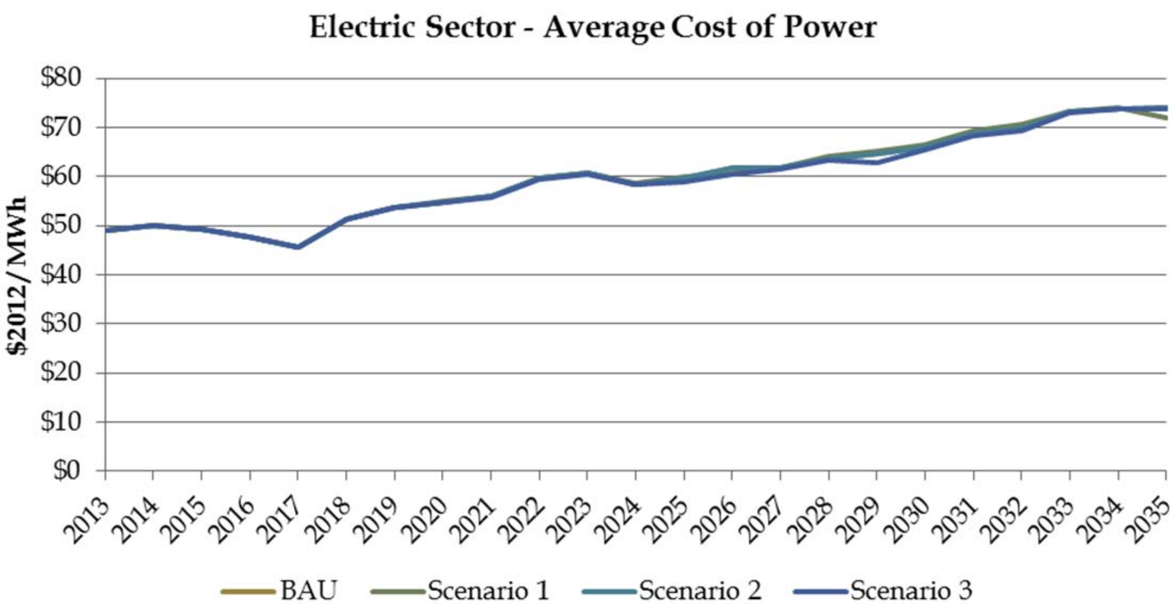



**Figure 25: Electric Sector Average Cost of Wholesale Electricity**[20]

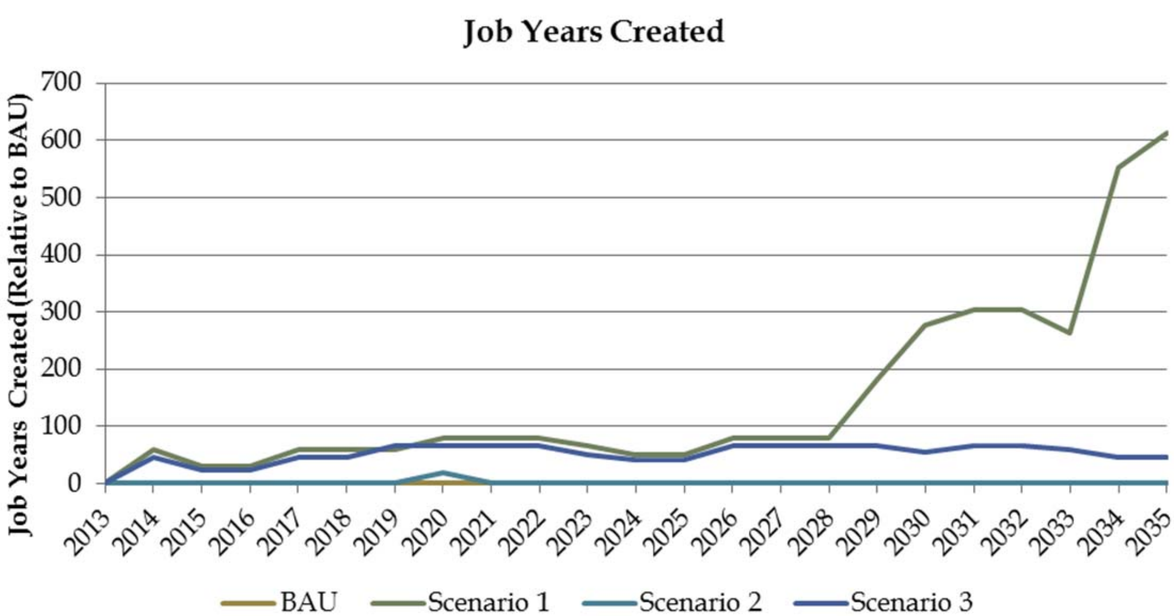



**Figure 26: Electric Sector Job Years Created Relative to BAU**

[20] The rise in wholesale electric prices after 2017 is due to rising natural gas prices assumed in the Navigant base case

Environmental Indicators

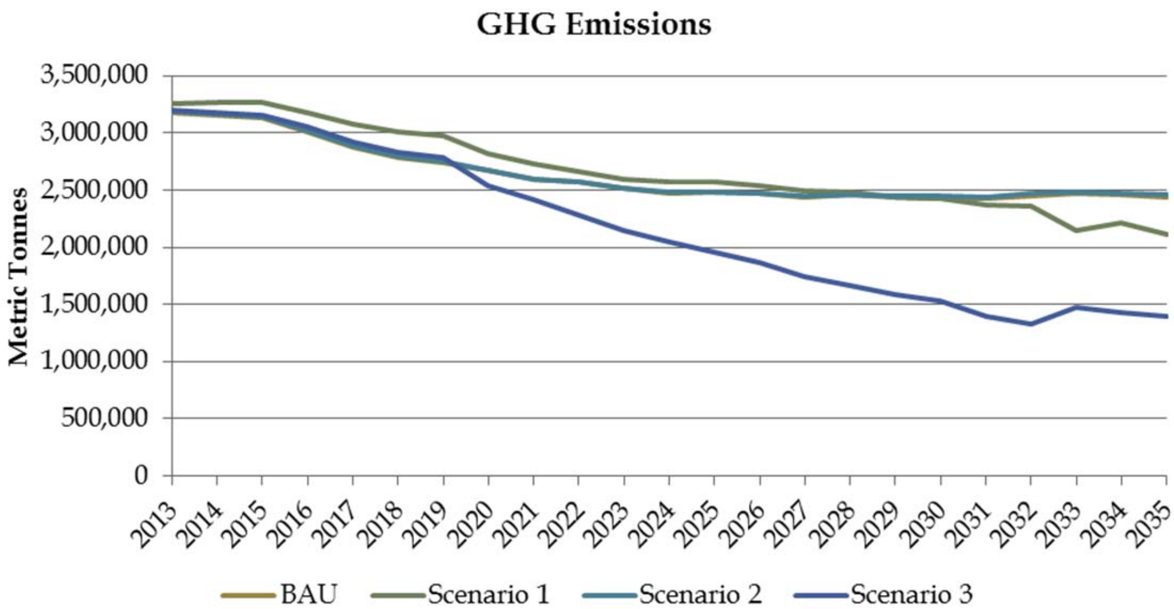



**Figure 27: Electric Sector GHG Emissions**

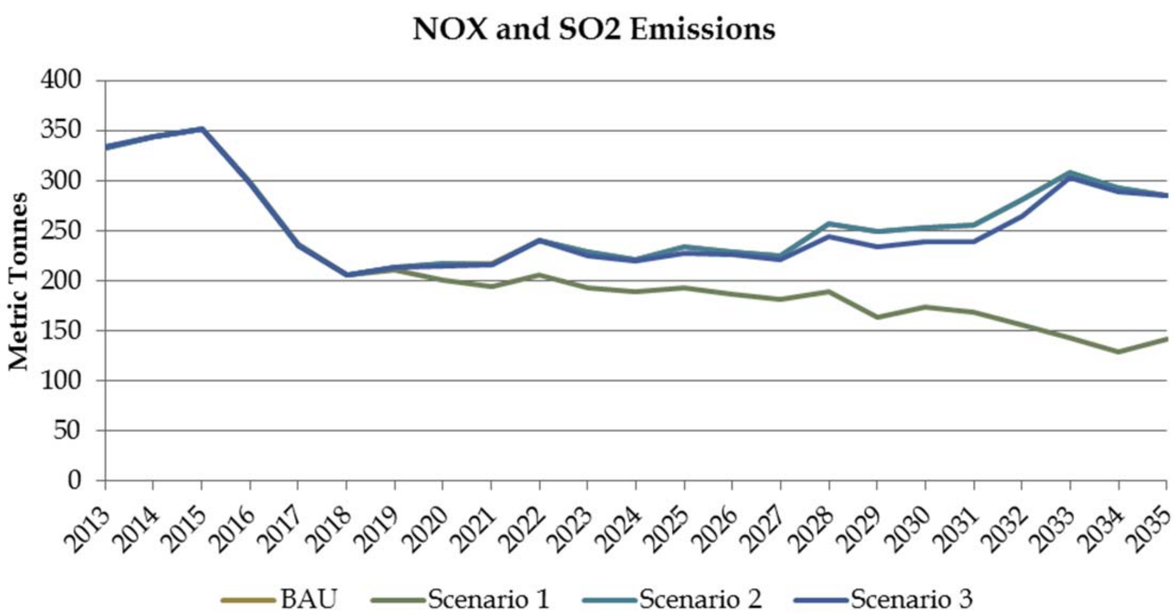



**Figure 28: Electric Sector NOX and SO2 Emissions**

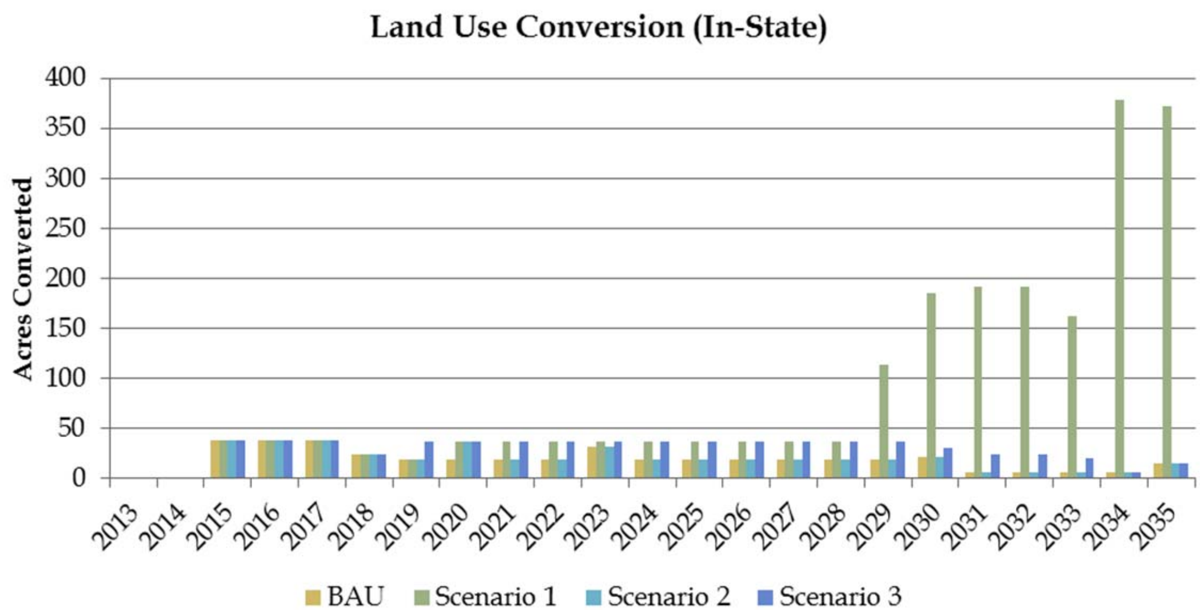



**Figure 29: Electric Sector Land Use Conversion**

### *Thermal Sector Results*

For this section, please consider the definitions presented in Table 10: Thermal Sector Metric Definitions.

**Table 10: Thermal Sector Metric Definitions**

| Metric | Definition |
|---|---|
| Total Demand | Total in-state thermal demand |
| Dependence on Dominant Fuel Source | The maximum portion of demand that is addressed by a single fuel source |
| Demand Profile by Fuel | The portion of demand addressed by each fuel type |
| Fuel Expenditures | The portion of annual expenditures attributed to each fuel type |
| Average Cost of Fuel | The annual consumption weighted average cost of fuels |
| Capital Expenditures | Annual capital investments in thermal energy infrastructure (non-fuel expenditures) |
| Job Years Created | In-state job years resulting from capital changes to thermal energy infrastructure |
| GHG Emissions | Metric tonnes of CO2 emitted |
| NOX and SO2 Emissions | Metric tonnes of NOX and SO2 emitted |

#### Demand

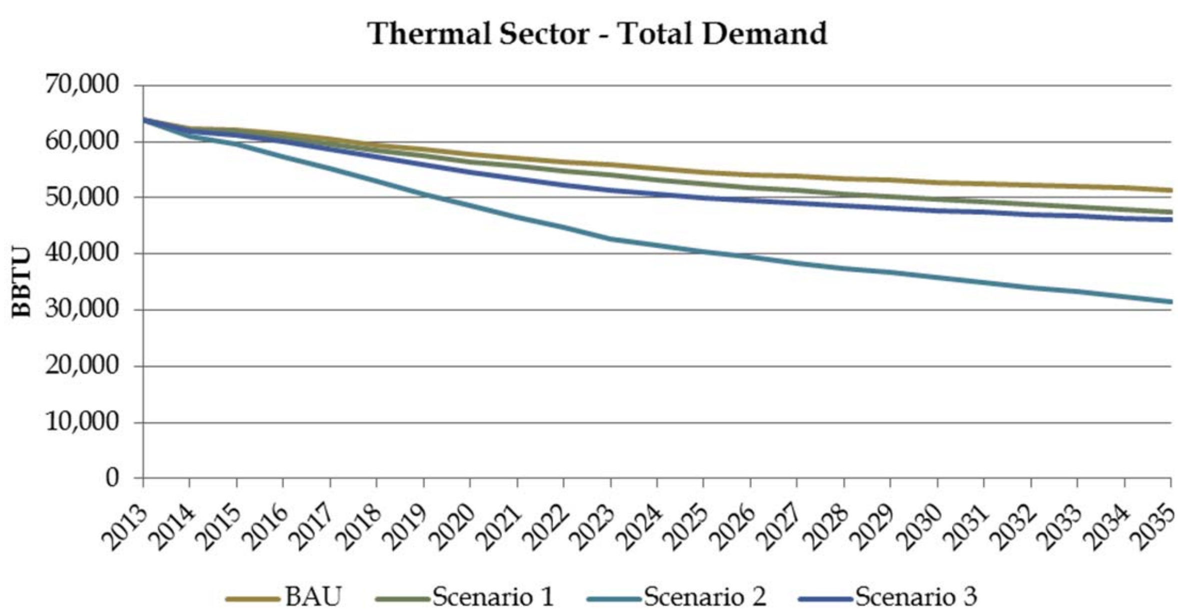



**Figure 30: Thermal Sector Total Demand**

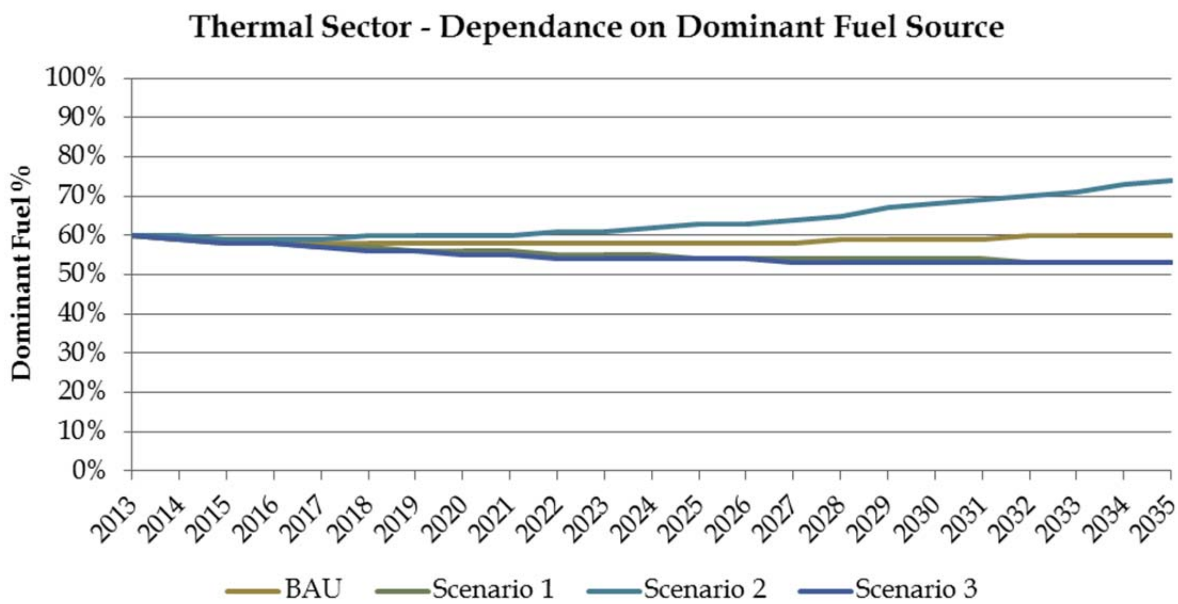



**Figure 31: Thermal Sector Dominant Fuel Source**

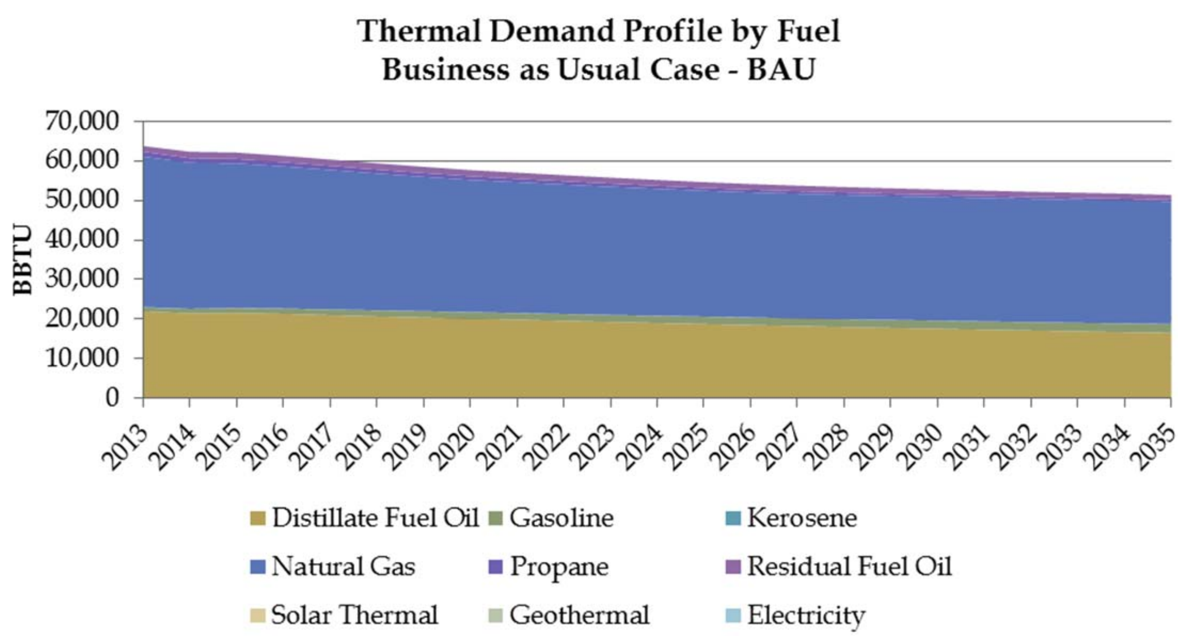



**Figure 32: Thermal Sector Demand by Fuel: BAU**

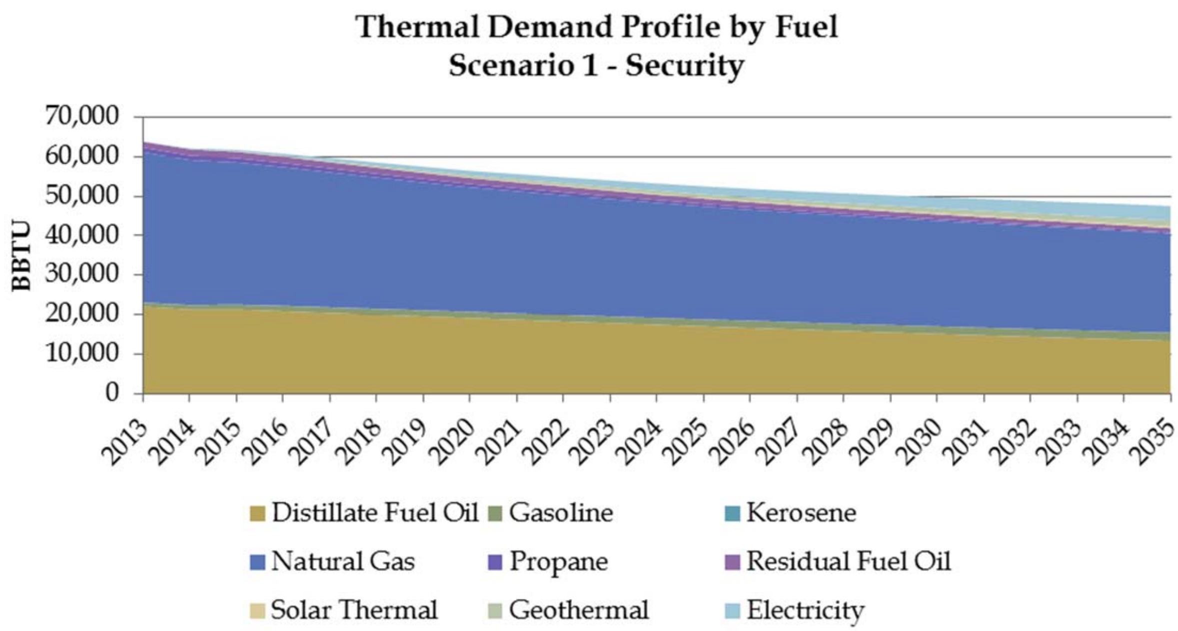



**Figure 33: Thermal Sector Demand by Fuel: Scenario 1 – Security**

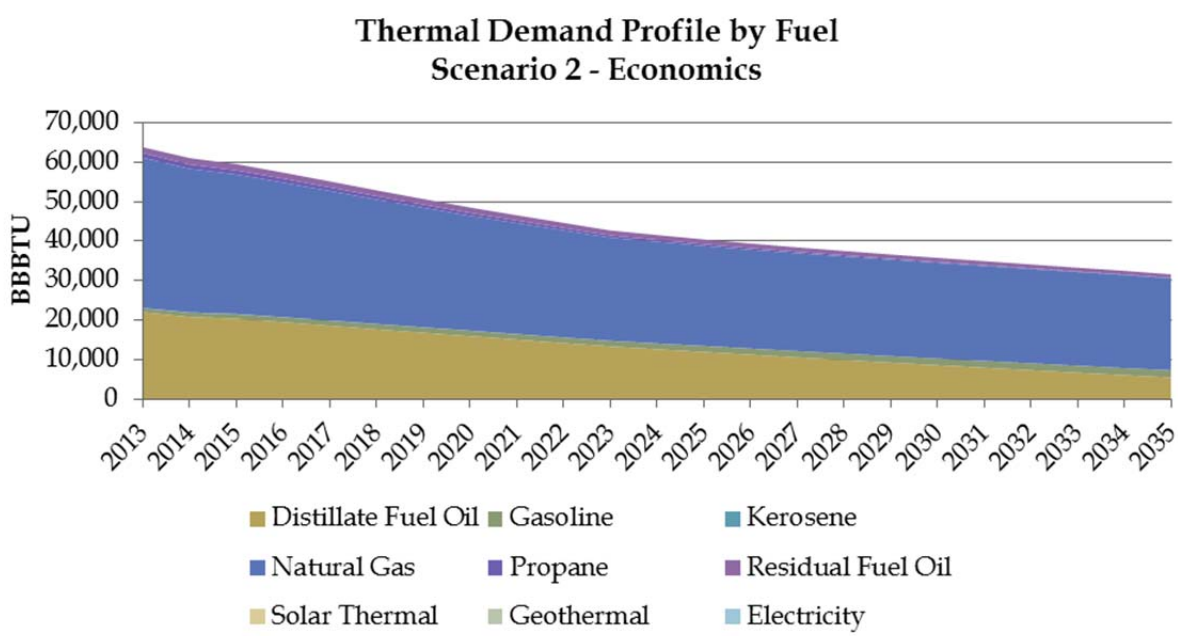



**Figure 34: Thermal Sector Demand by Fuel: Scenario 2 – Economics**

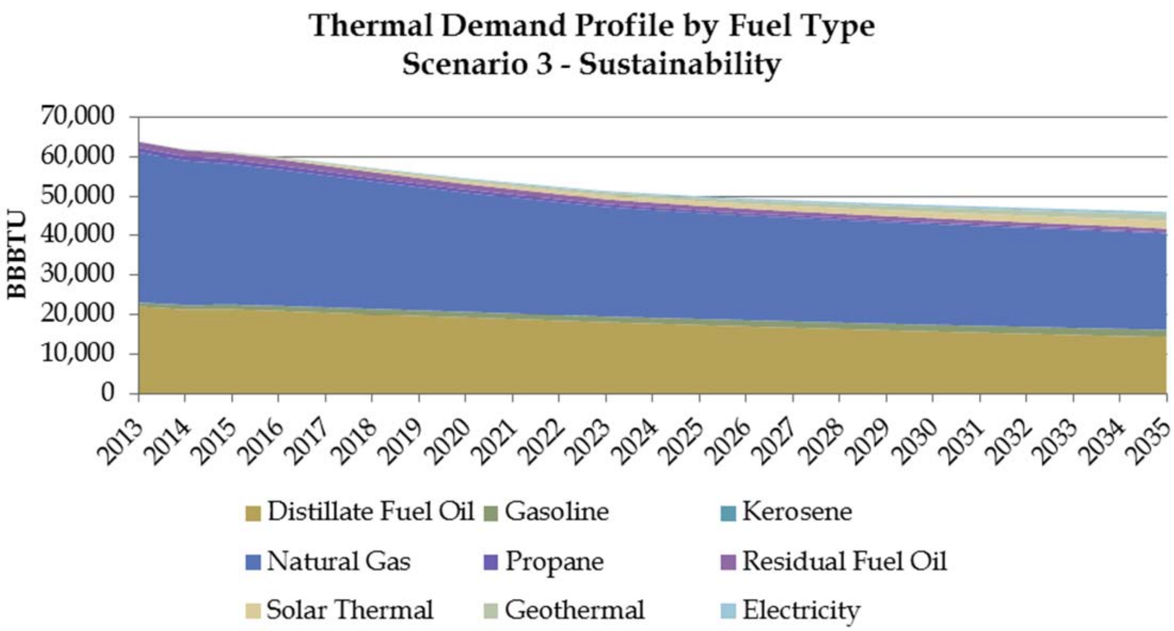



**Figure 35: Thermal Sector Demand by Fuel: Scenario 3 – Sustainability**

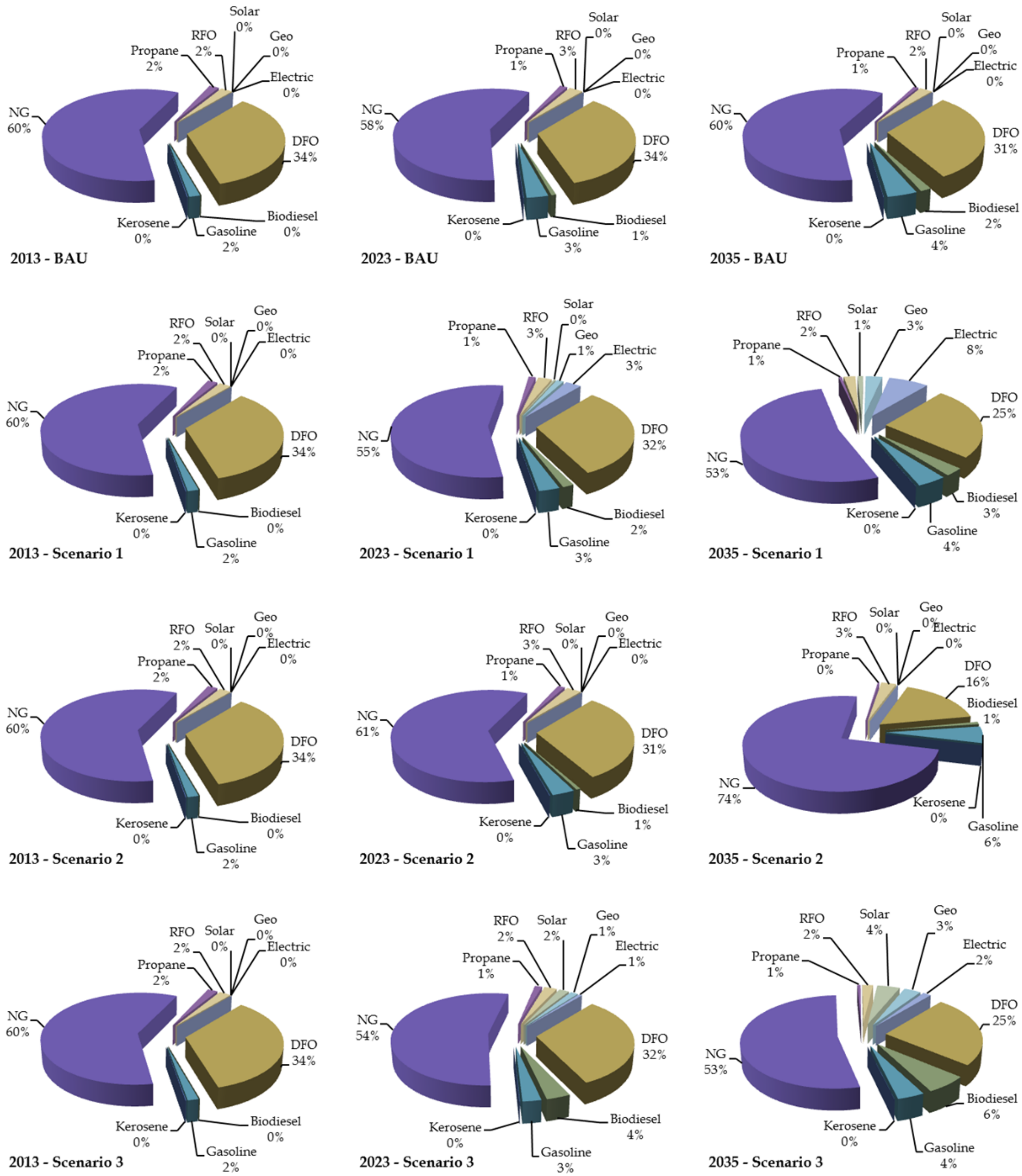



**Figure 36: Thermal Sector Demand (2013, 2023, 2035)**

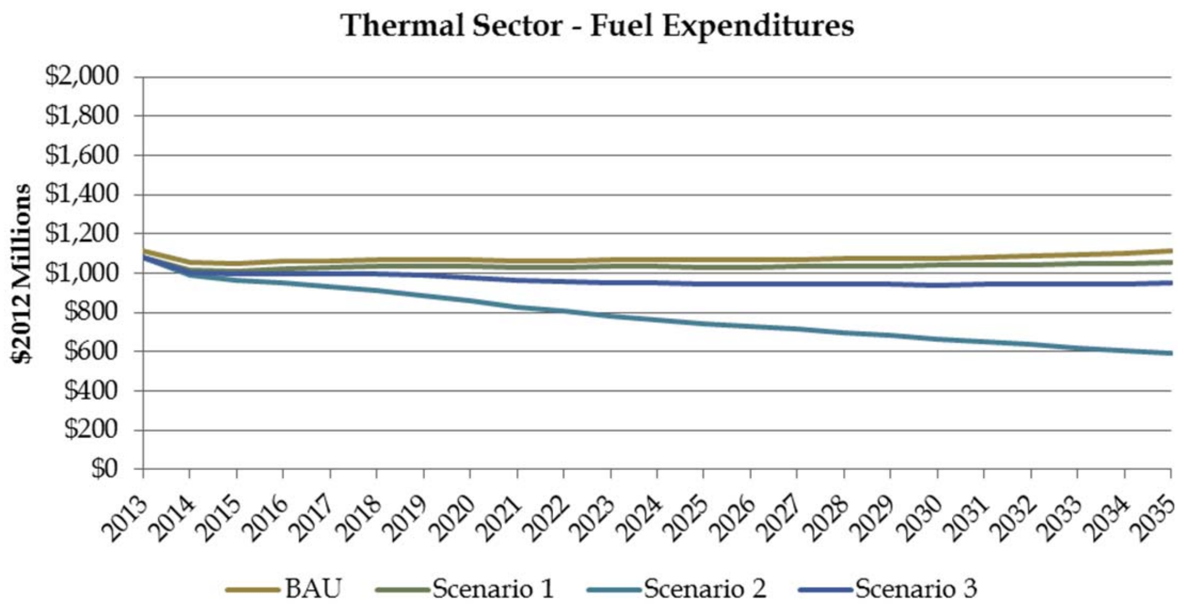



**Figure 37: Thermal Sector Total Fuel Expenditures**

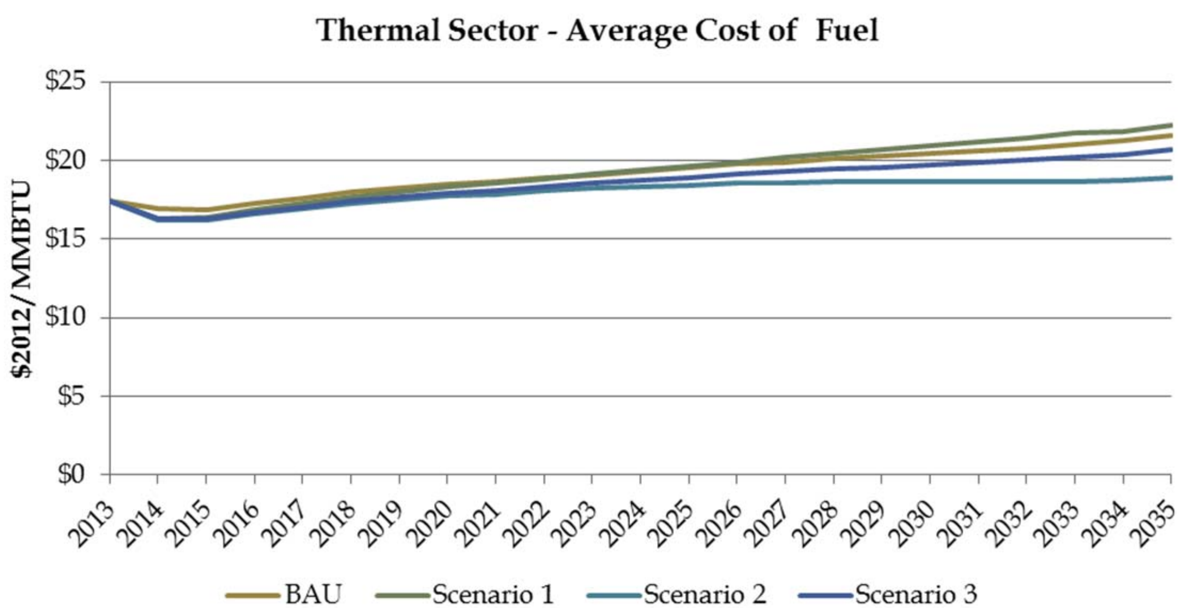



**Figure 38: Thermal Sector Average Cost of Fuel**

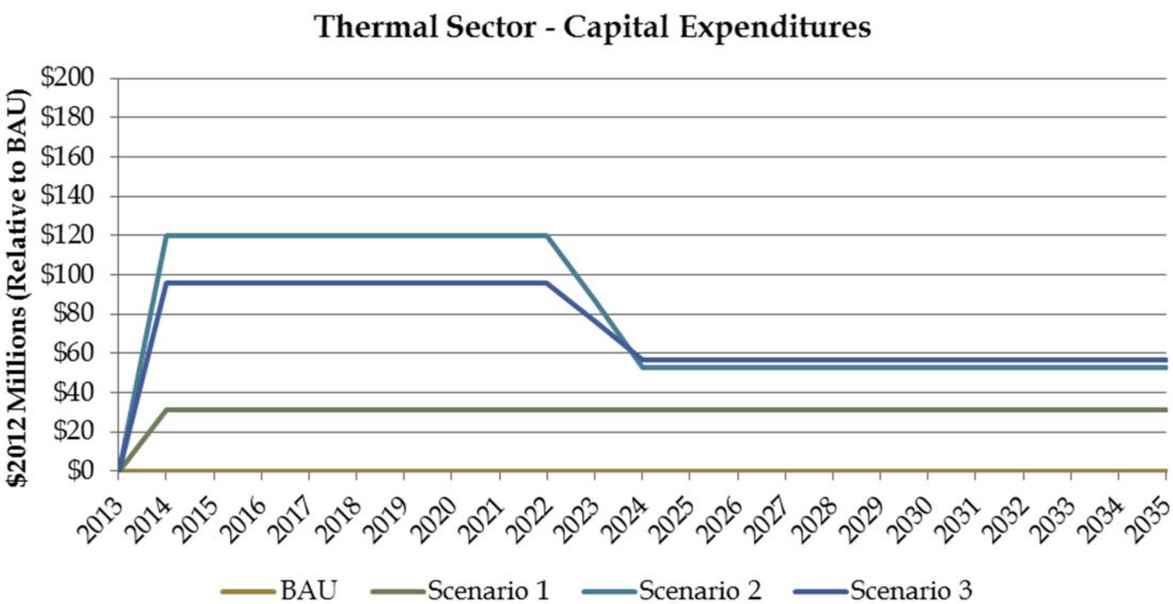



Figure 39: Thermal Sector Capital Expenditures

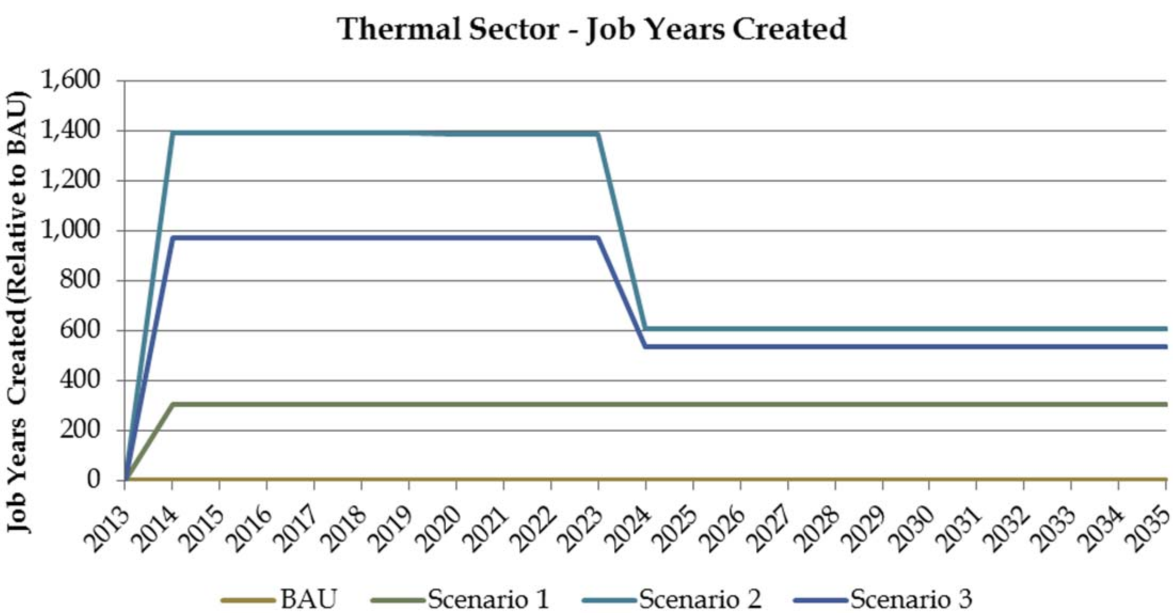



Figure 40: Thermal Sector Job Years Created

Environmental Indicators

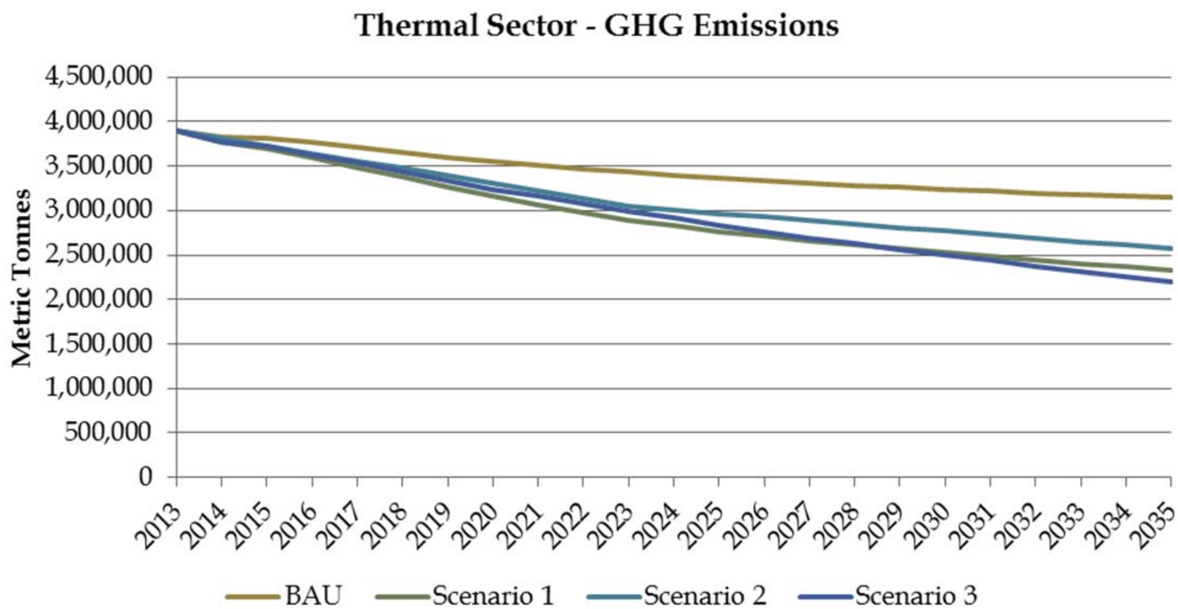



**Figure 41: Thermal Sector GHG Emissions**

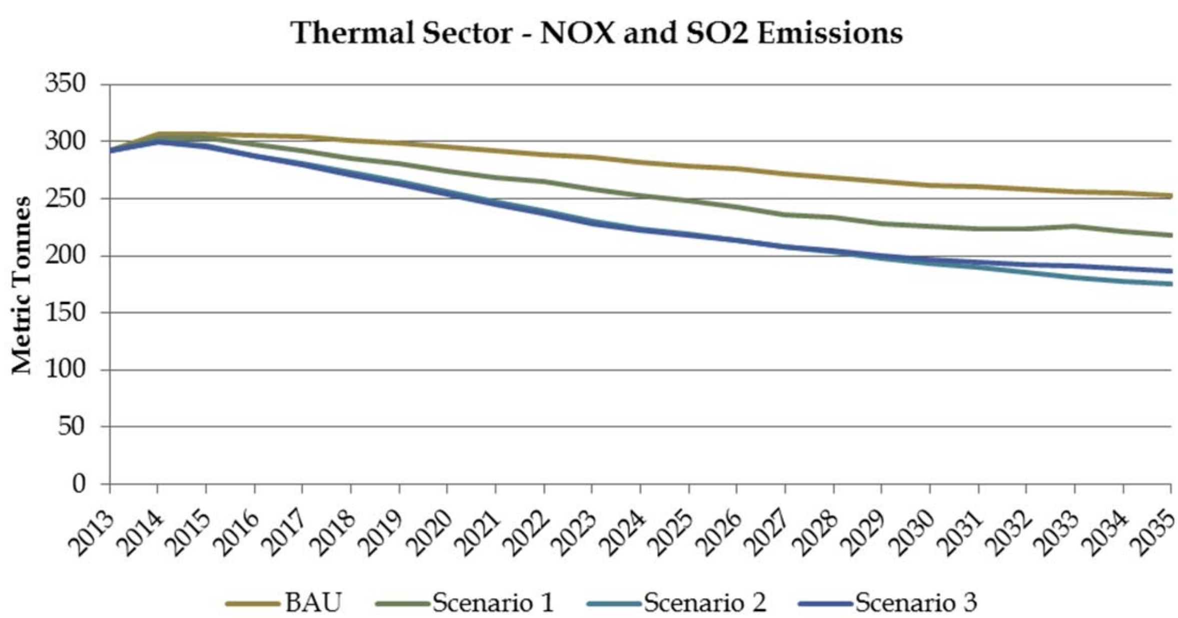



**Figure 42: Thermal Sector NOX and SO2 Emissions**

### *Transportation Sector Results*

For this section, please consider the definitions presented in Table 11: Transportation Sector Metric Definitions.

**Table 11: Transportation Sector Metric Definitions**

| Metric | Definition |
|---|---|
| **Total Demand** | Total in-state demand for energy in the transportation sector |
| **Dependence on Dominant Fuel Source** | The maximum portion of demand that is addressed by a single fuel source |
| **Demand Profile by Fuel** | The portion of demand addressed by each fuel type |
| **Fuel Expenditures** | The portion of annual expenditures attributed to each fuel type |
| **Average Cost of Fuel** | The annual consumption weighted average cost of fuels |
| **Capital Expenditures** | Annual capital investments in transportation infrastructure (non-fuel expenditures) |
| **Job Years Created** | In-state job years resulting from capital changes to transportation infrastructure |
| **GHG Emissions** | Metric tonnes of CO2 emitted |
| **NOX and SO2 Emissions** | Metric tonnes of NOX and SO2 emitted |

#### Demand

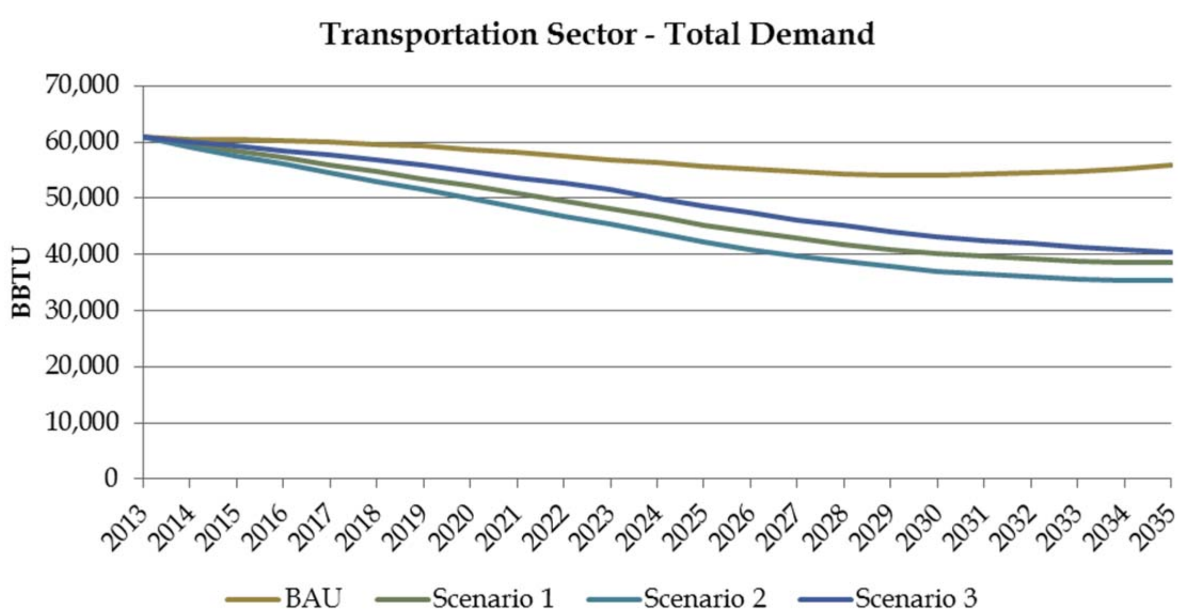



**Figure 43: Transportation Sector Total Demand**

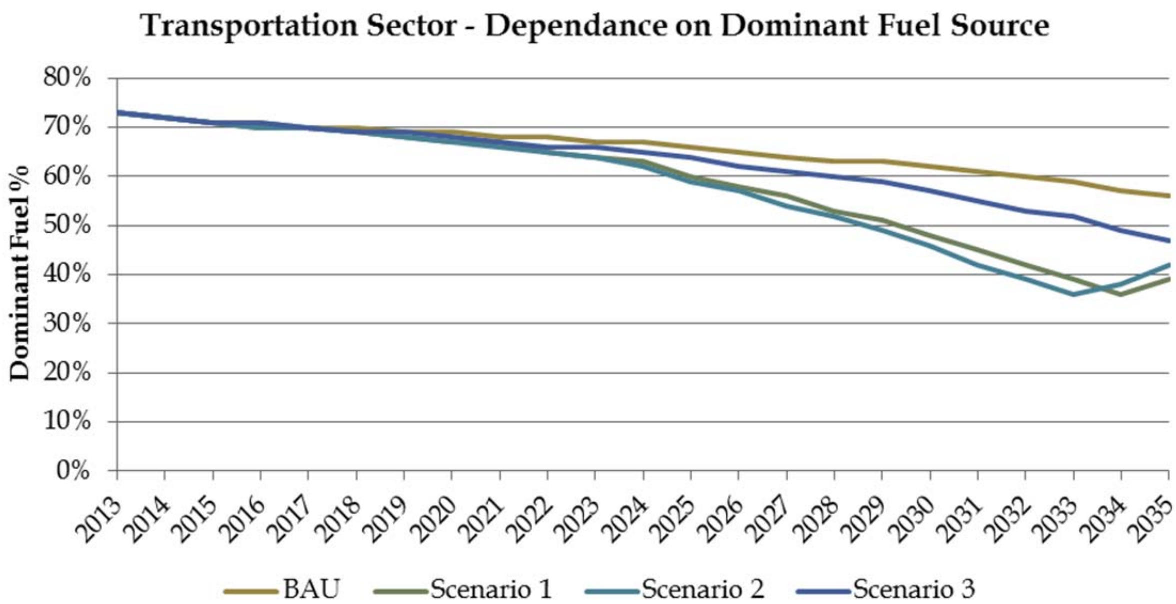



**Figure 44: Transportation Sector Dominant Fuel Source**

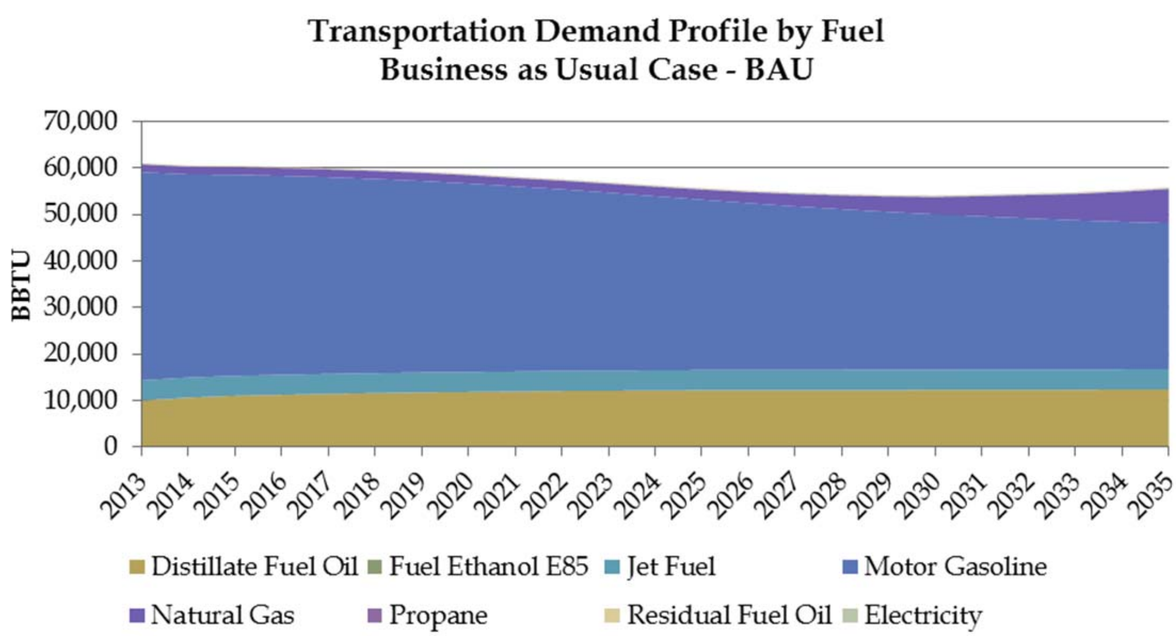



**Figure 45: Transportation Sector Demand by Fuel: BAU**

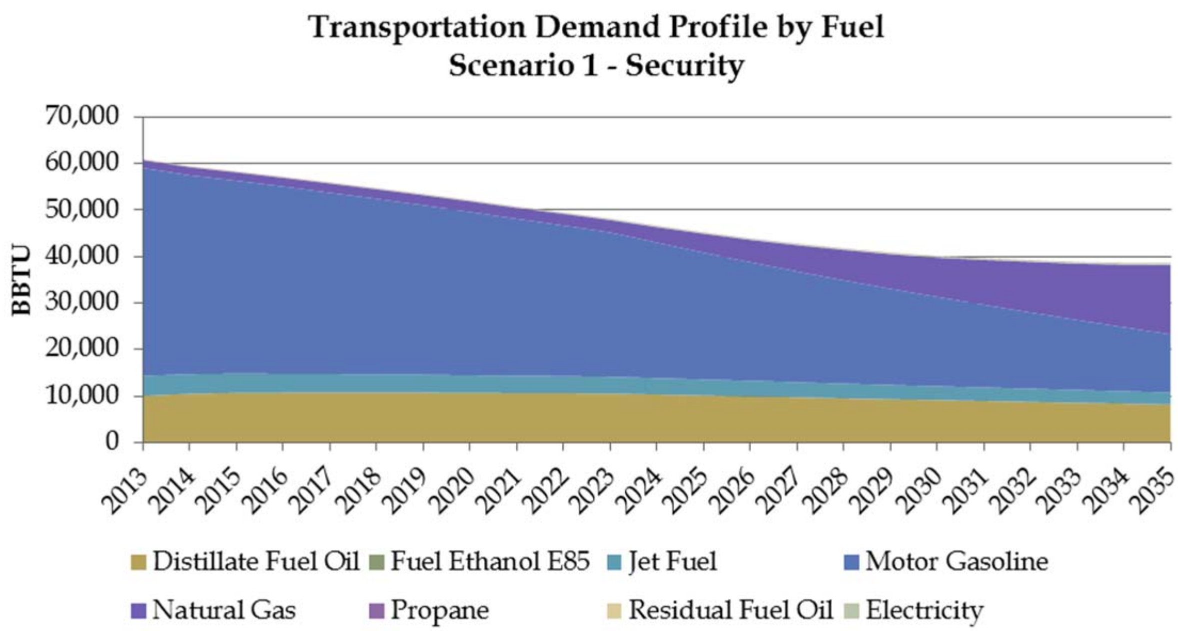



**Figure 46: Transportation Sector Demand by Fuel: Scenario 1 – Security**

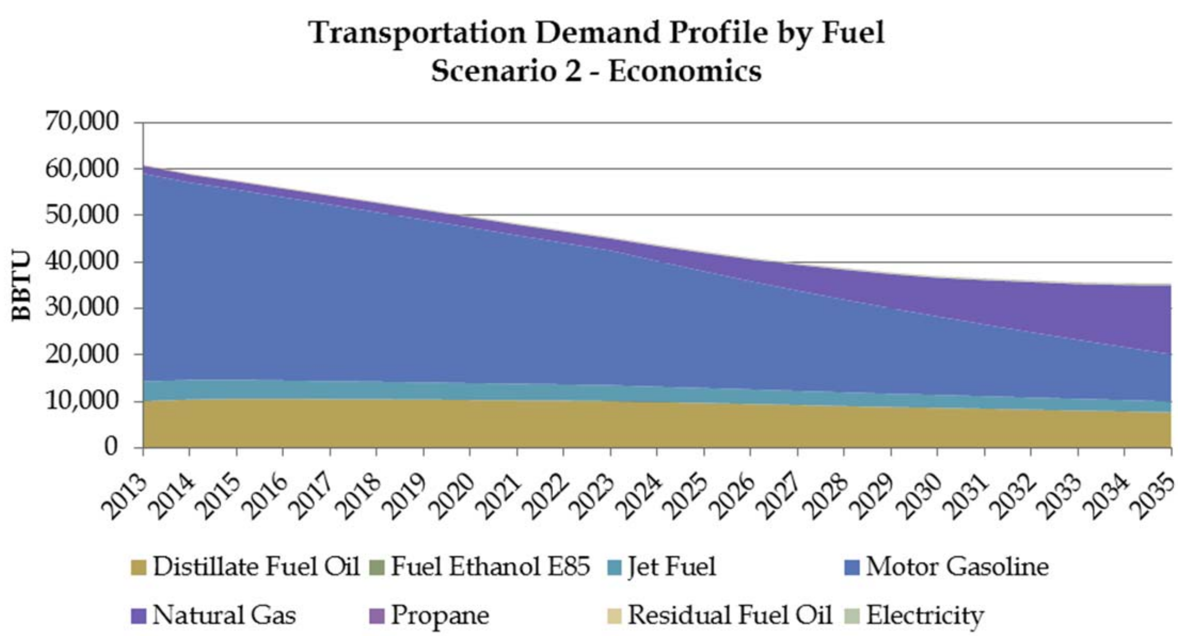



**Figure 47: Transportation Sector Demand by Fuel: Scenario 2 – Economics**

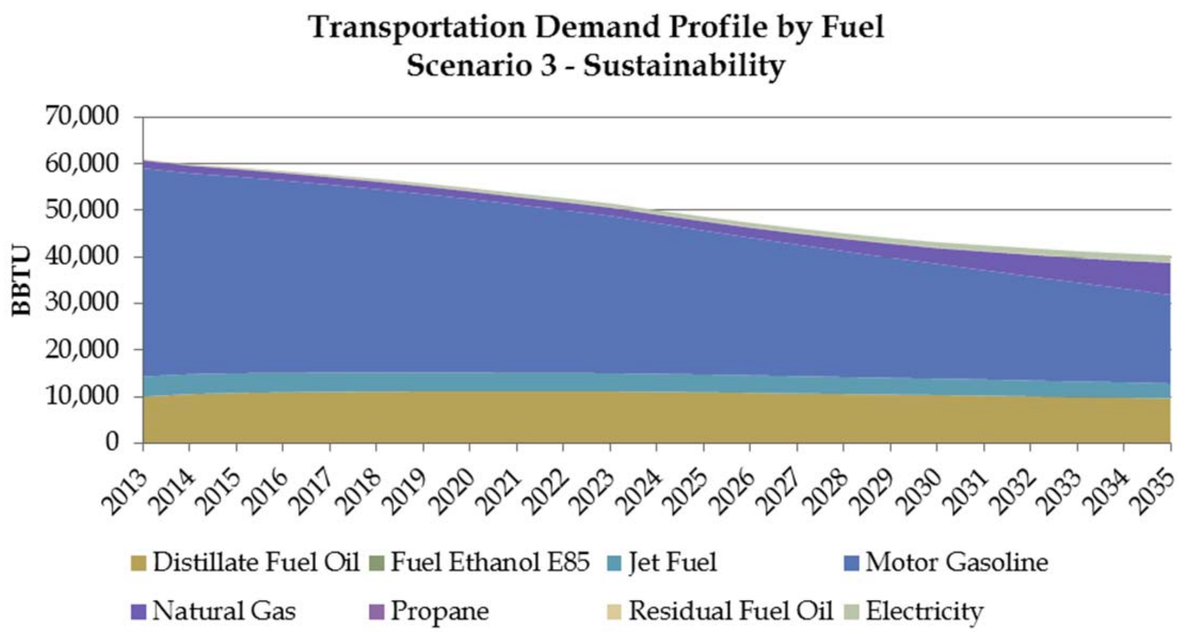



**Figure 48: Transportation Sector Demand by Fuel: Scenario 3 – Sustainability**

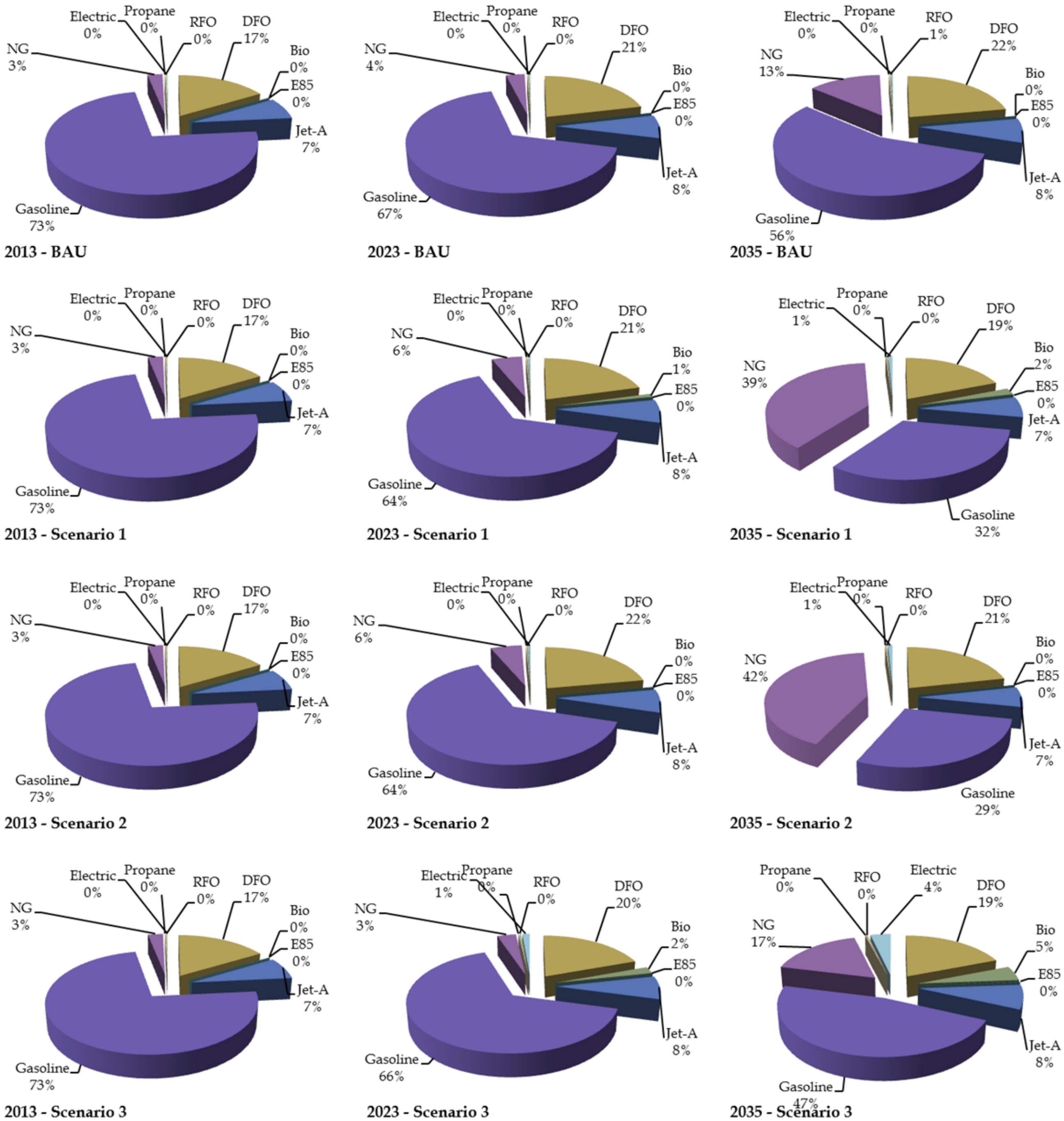



**Figure 49: Transportation Sector Demand (2013, 2023, 2035)**

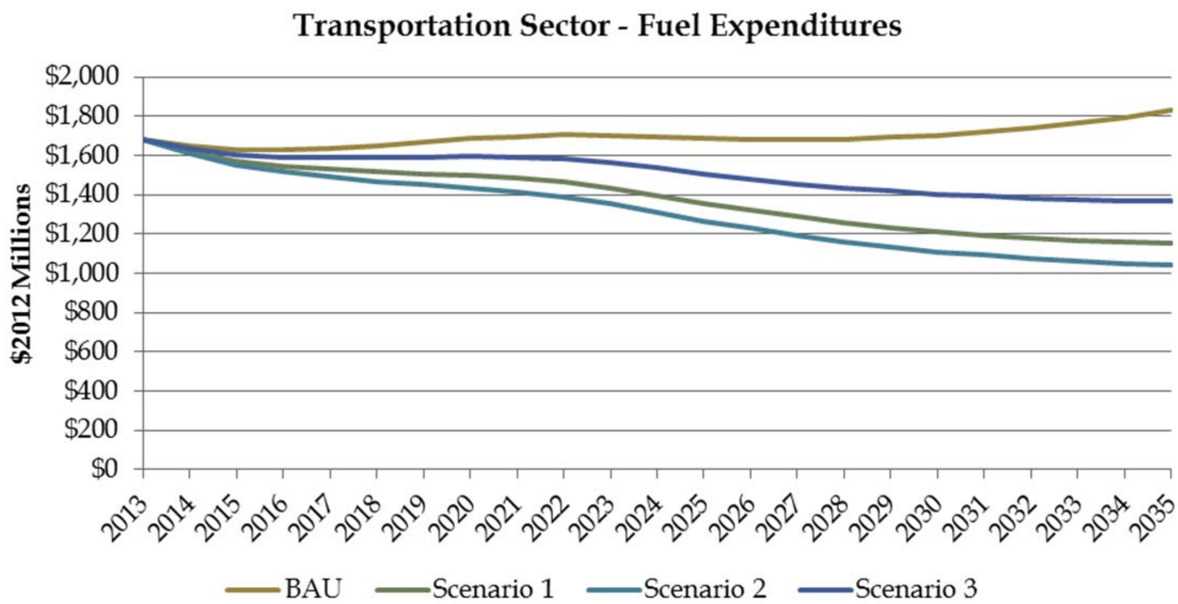



**Figure 50: Transportation Sector Total Fuel Expenditures**

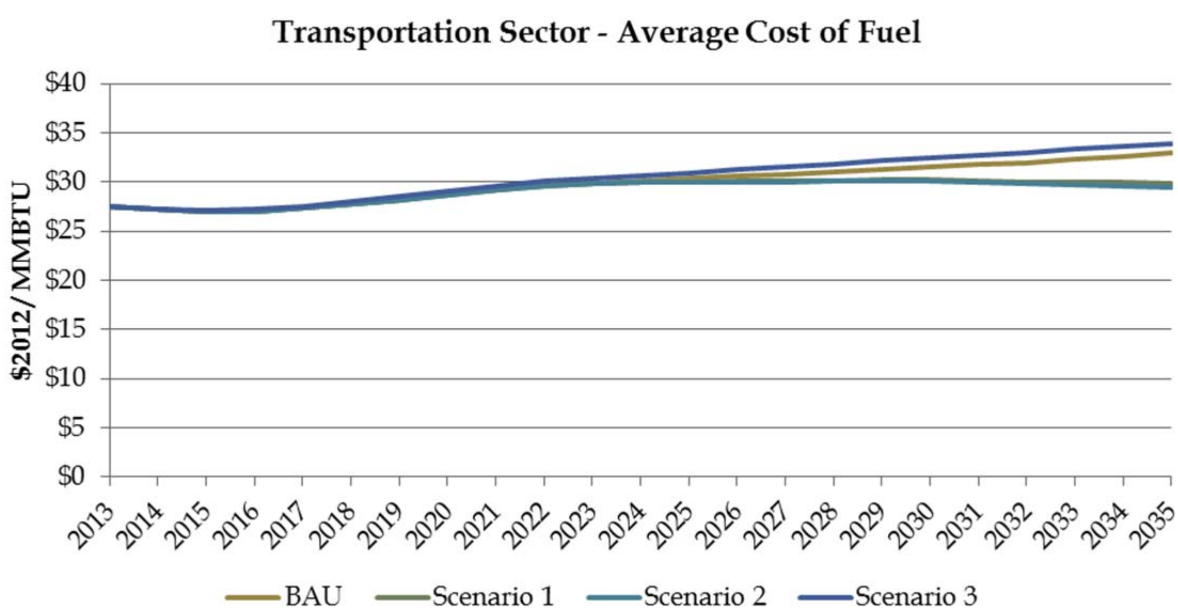



**Figure 51: Transportation Sector Average Cost of Fuel**

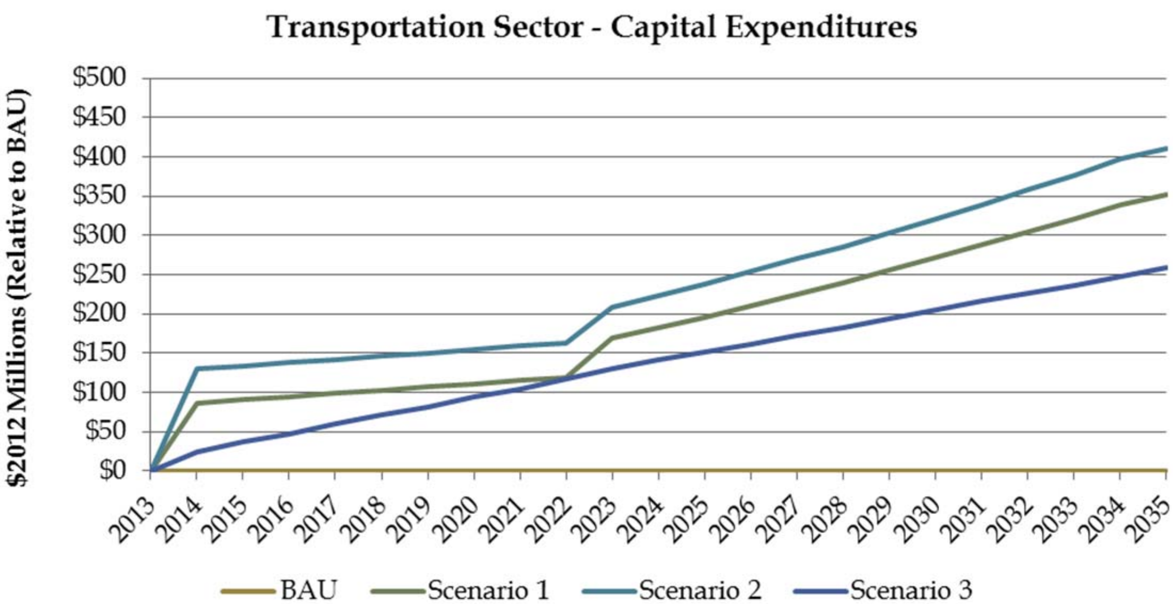



**Figure 52: Transportation Sector Capital Expenditures**

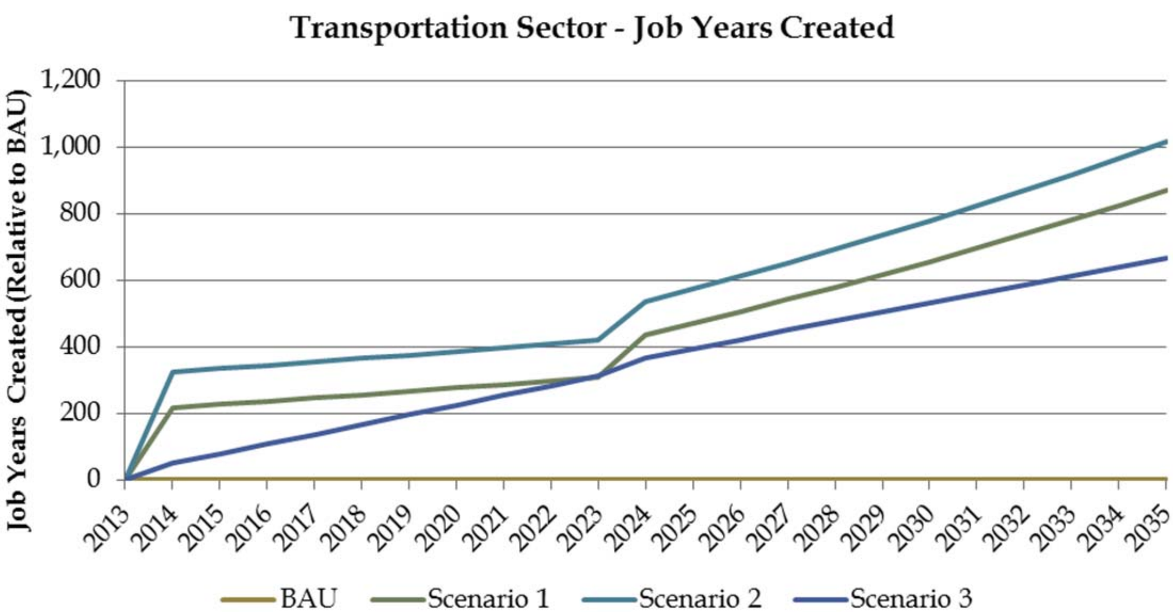



**Figure 53: Transportation Sector Job Years Created**

Environmental Indicators

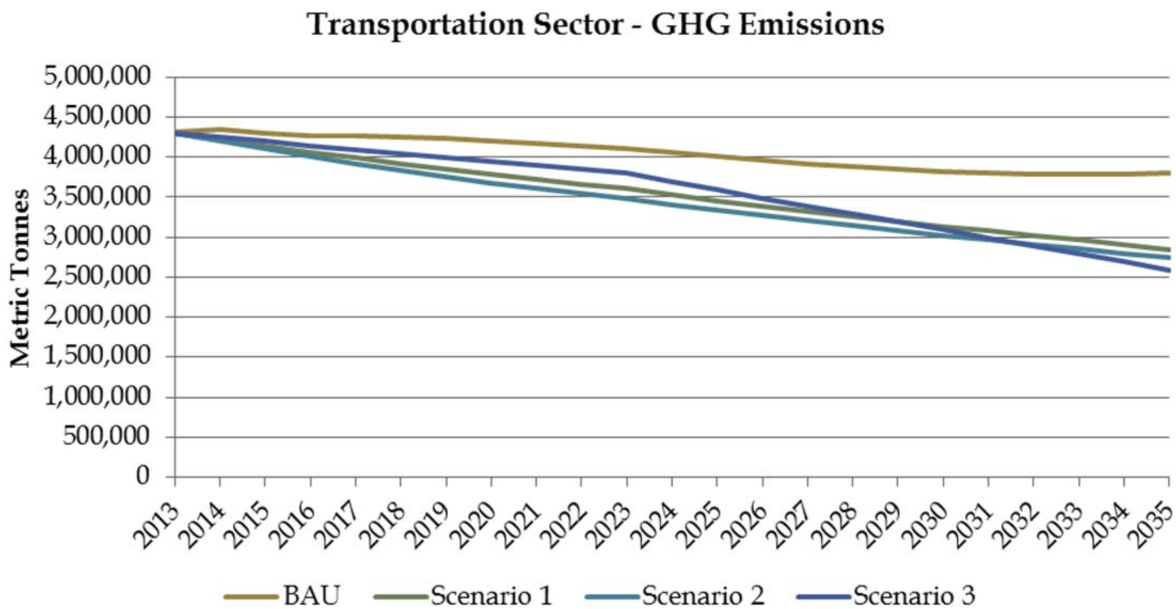



**Figure 54: Transportation Sector GHG Emissions**

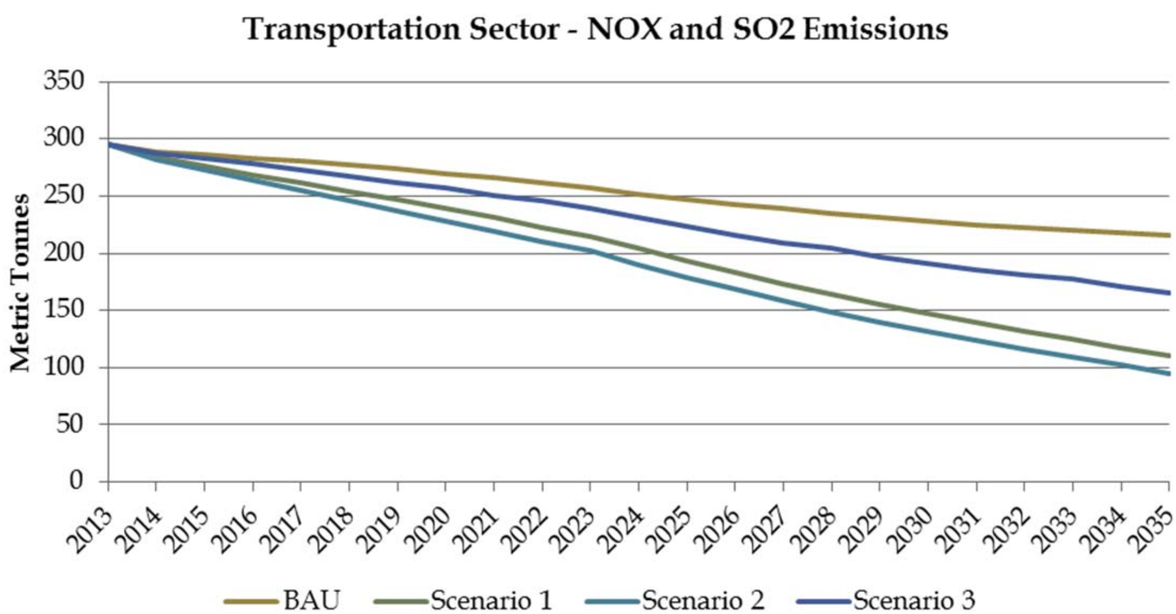



**Figure 55: Transportation Sector NOX and SO2 Emissions**

### *Aggregate Results*

#### Demand

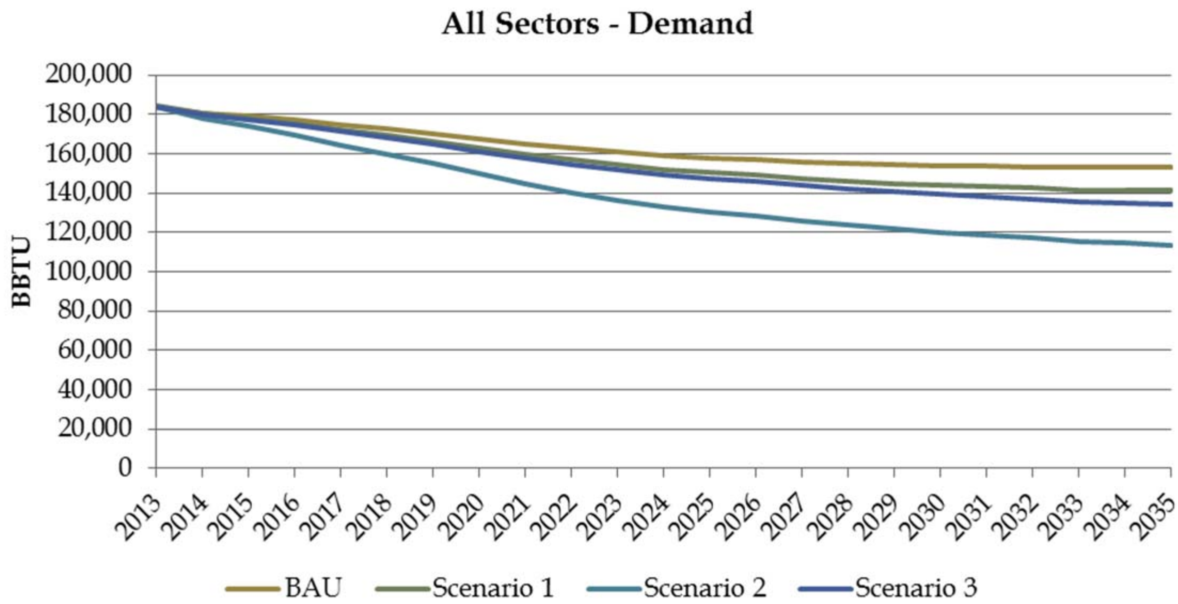



**Figure 56: Aggregate Demand**

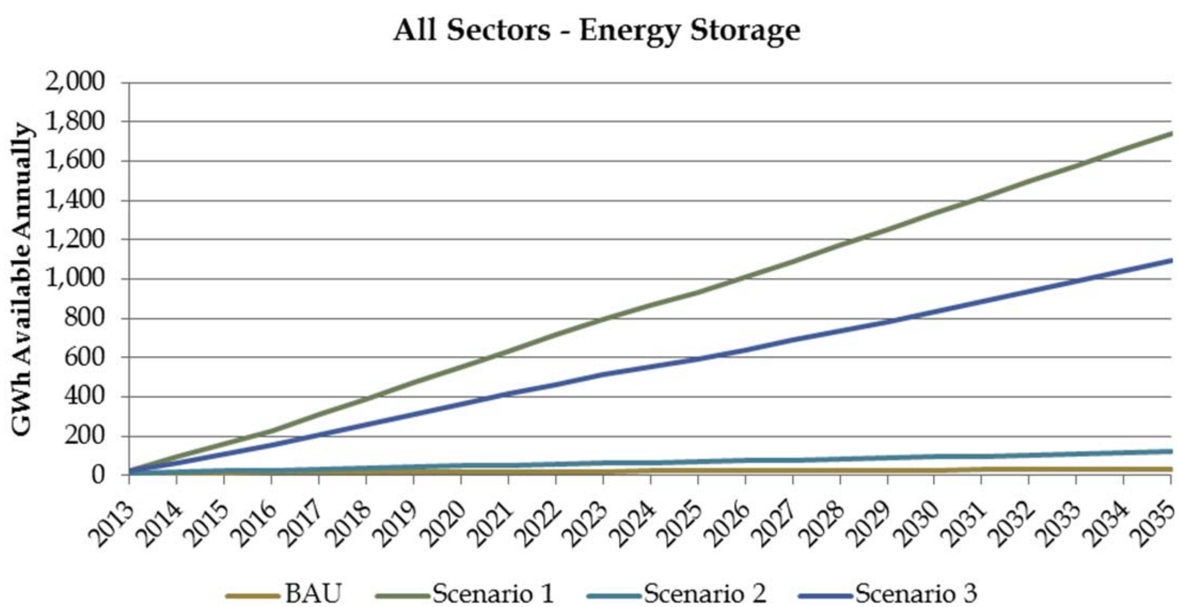



**Figure 57: Aggregate Energy Storage**

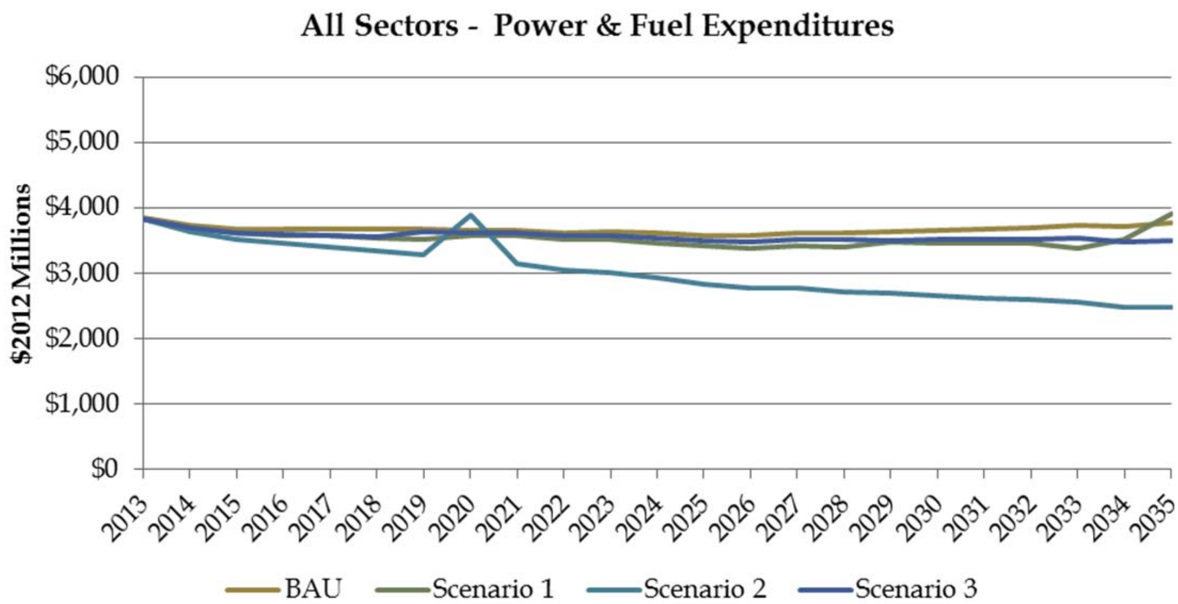



**Figure 58: Aggregate Power & Fuel Expenditures**

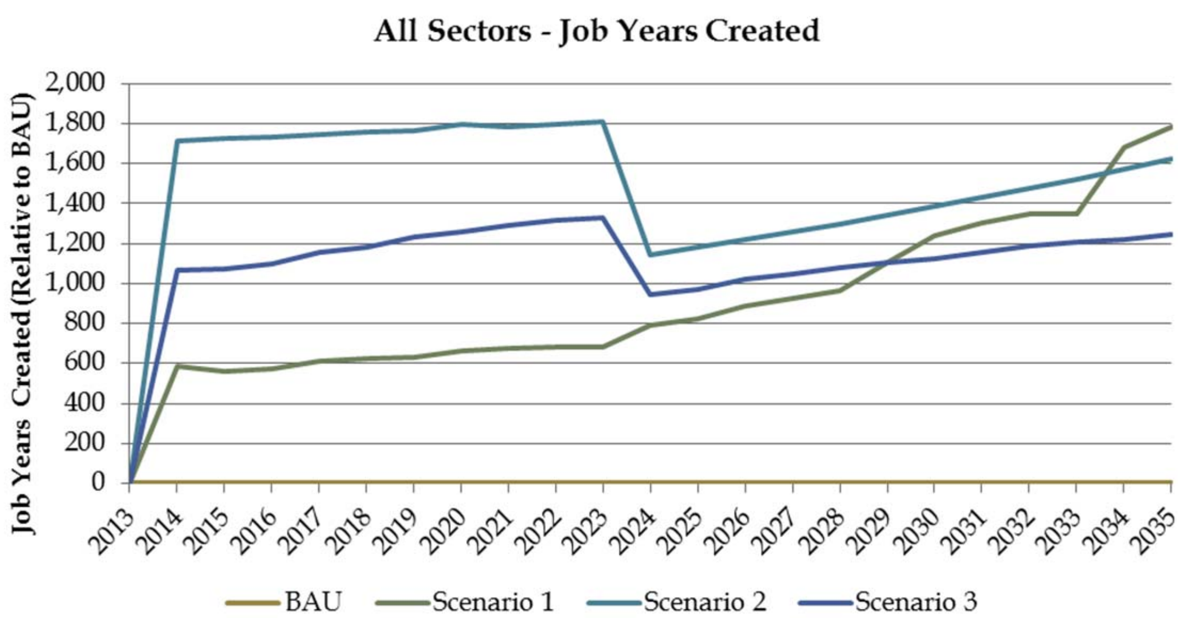



**Figure 59: Aggregate Job Years Created**

Environmental Indicators

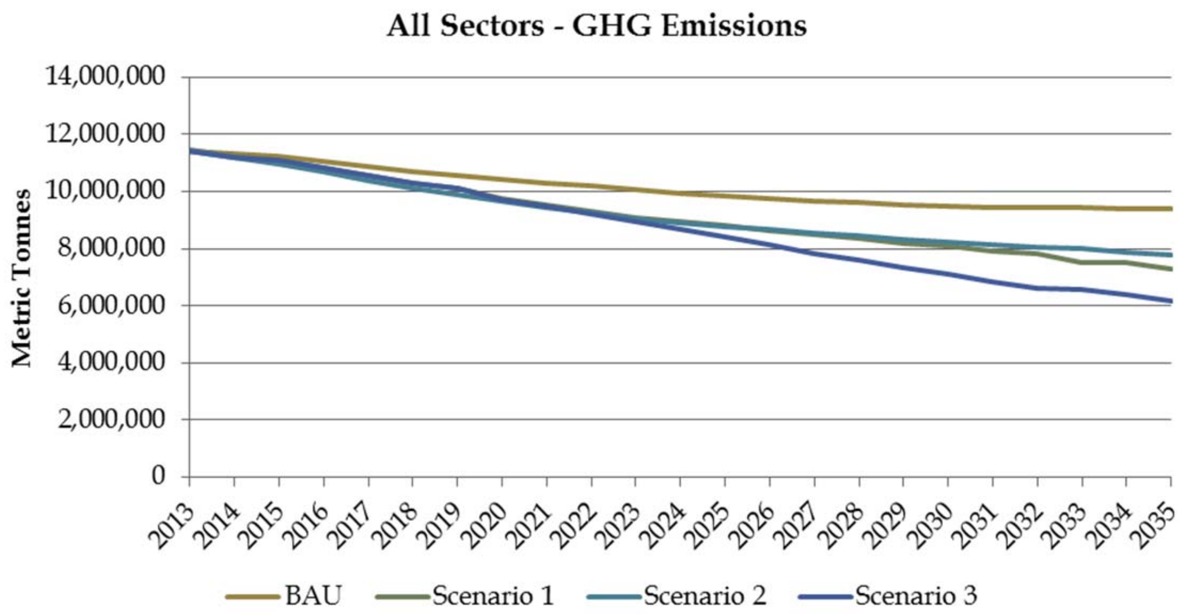



**Figure 60: Aggregate GHG Emissions**

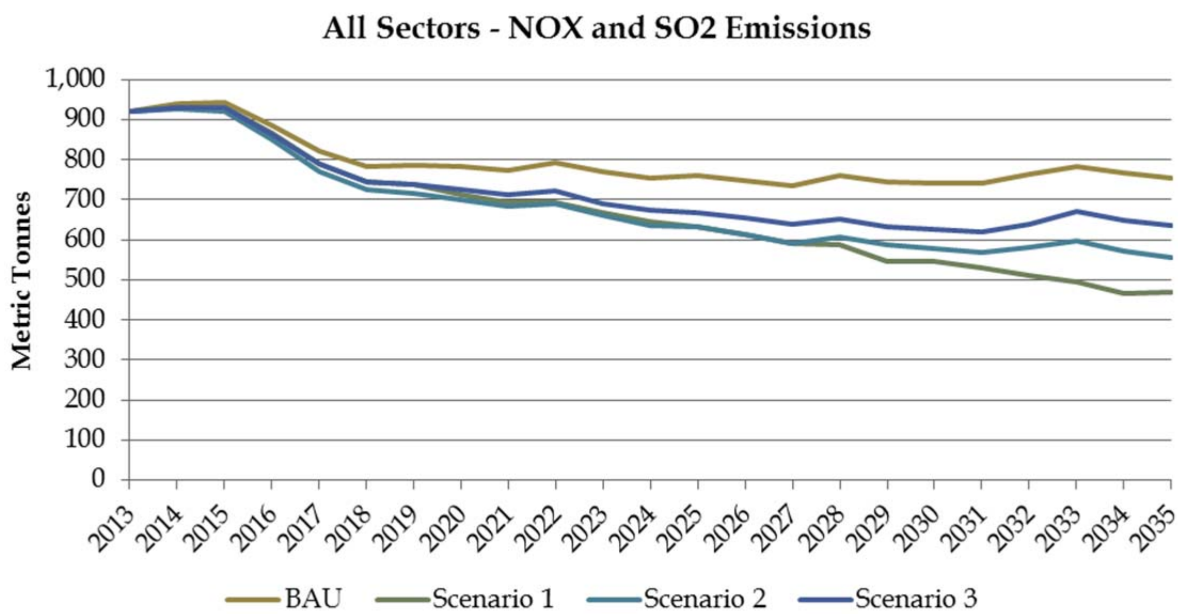



**Figure 61: Aggregate NOX and SO2 Emissions**

# Appendices

## *Electric Sector Assumptions and Supplemental Information*

**Table 12: Electric Sector POM Assumptions**

| POM Assumptions | |
|---|---|
| **Assumption** | **Description** |
| ISO-NE build from Navigant Base Case | The ISO-NE build-out except Rhode Island is taken from Navigant's Summer 13 Base Case. It is derived from the integration of Navigant's suite of market models and expert analysis. A fundamental assumption for this project is that Rhode Island policies do not change ISO-NE builds indirectly. |
| Integrated ISO-NE Market | ISO-NE is modeled as an integrated market with connections to surrounding regions modeled with fixed imports/exports from Navigant's PROMOD modeling. |
| Zonal Modeling | POM is a zonal model that optimizes build-out and dispatch over a simplified representation of transmission. Rhode Island is modeled as a single zone with load met by native generation and imports from other zones in New England. |
| Imports into Rhode Island | Energy imports into Rhode Island from the rest of ISO-NE are prorated by proportion of each energy source in the total market to account for Rhode Island's share of CO2, natural gas generation, and imports from other regions. |
| Existing In-State Thermal Units | ~2,000 MW CC gas |
| Existing In-State Renewables | 45 MW Landfill Gas<br>6 MW Solar<br>4 MW Wind<br>2 MW Hydro |
| Minimum In-State Renewable Builds | 66 MW Solar<br>16 MW On-shore Wind<br>180 MW Off-shore Wind[21] |
| Imports into ISO-NE | Existing connections from NYISO, HQ, and New Brunswick. A new 1200 line from HQ is assumed to come online and provide significant energy to ISO-NE. This resource adds low-carbon generation to the New England mix and so impacts Rhode Island's electric sector emissions as Rhode Island is assumed to receive a share proportional to total Rhode Island imports. However it does not count towards meeting RPS requirements. |
| Financial Assumptions | 14% ROE for new units from ISO-NE wholesale energy and capacity market. |

[21] The minimum In-State renewable construction capital costs are incorporated into the benchmarking to the BAU costs since these are assumed to occur in that case.

**Figure 62: ISO-NE Transmission Representation in POM**

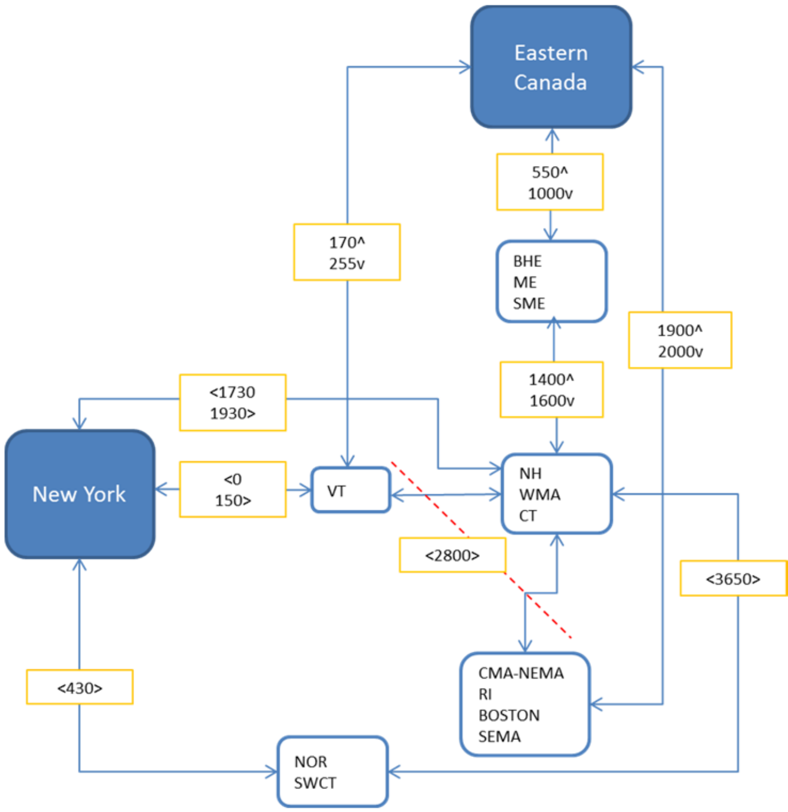



**Table 13: Non-RI ISO-NE Build-Out in BAU[22]**

| Technology | Existing Capacity (MW) | Capacity in 2035 (MW) |
|---|---|---|
| CC Gas | 11,632 | 12,232 |
| Nuclear | 4,674 | 4,674 |
| ST Coal | 2,420 | 2,275 |
| ST Gas | 649 | 649 |
| CT Gas | 2,573 | 3,265 |
| Oil/Coal | 5,838 | 4,449 |
| Hydro (including PS[23]) | 3,262 | 3,262 |
| Landfill Gas | 37 | 37 |
| Biomass | 1,028 | 1,328 |
| Wind | 764 | 4,989 |
| Solar | 4 | 813 |

[22] The Navigant base case considers load growth, capital costs, fuel costs, existing RPS laws, resource limitations, and expert opinion to build up the POM assumptions. For renewables, significant new construction is expected in the forecast. There are some limiting factors for renewable penetration such as resource limitations and resistance to constructing infrastructure necessary to integrate the new renewables.

[23] Pumped Storage

$$Capacity\ Margin = \frac{generating\ resources + imports + EE + DR - peak\ load}{peak\ load}$$

**Figure 63: Capacity Margin Calculation**[24]

**Table 14: POM Financial Assumptions**[25]

| Parameter | CC | CT | Wind | Solar PV | Biomass | Offshore Wind |
|---|---|---|---|---|---|---|
| Overnight Cost ($2012/kW) | $956 | $664 | $2,175 | $3,132 | $4,041 | $6,121 |
| Interest Rate | 7% | 7% | 7% | 7% | 7% | 7% |
| Post-tax ROE | 14% | 14% | 14% | 14% | 14% | 14% |
| Pre-tax ROE | 18.41% | 17.4% | 17.4% | 17.4% | 17.4% | 17.4% |
| Equity Participation | 60% | 60% | 60% | 60% | 60% | 60% |
| Effective Tax Rate | 35.0% | 35.0% | 35% | 35% | 35% | 35% |
| Depreciation Period (years) | 20 | 15 | 15 | 15 | 15 | 15 |

[24] Capacity margin requirements are pulled from the 2011 NERC Long-Term Resource Assessment 2011. Imports are fixed and regions are not assumed to be able to do further trading economically. Subzones in ISONE are defined using data from those region's capacity markets.

[25] The primary difficulty is to ensure that the POM financing assumptions are consistent with the ProMOD ROE tool which includes a representation of EVM multipliers to the unit energy revenue. Note: overnight costs are adjusted for EIA regional cost multipliers for the runs. Solar PV costs are updated with recent project information.

### *Thermal Sector Assumptions and Supplemental Information*

**Table 15: Thermal Sector Replaced Fuel Mix**

| Replaced Fuel Mix | | | | |
|---|---|---|---|---|
| *Fuel* | *Residential* | *Commercial* | *Industrial* | *Units* |
| Distillate Fuel Oil | 47.7% | 24.9% | 7.0% | % of Consumption |
| Kerosene | 0.2% | 0.0% | 0.0% | % of Consumption |
| Propane | 2.1% | 1.7% | 1.4% | % of Consumption |
| Natural Gas | 50.0% | 69.4% | 78.5% | % of Consumption |
| Residual Fuel Oil | 0.0% | 4.0% | 5.6% | % of Consumption |
| Gasoline | 0.0% | 0.0% | 7.5% | % of Consumption |
| *Source: ENE BAU Forecast 2013 distribution* | | | | |

**Table 16: Thermal Sector Avoided Investment Fuel Mix**

| Avoided Investment Fuel Mix | | | | |
|---|---|---|---|---|
| *Fuel* | *Residential* | *Commercial* | *Industrial* | *Units* |
| Distillate Fuel Oil | 50.8% | 34.3% | 6.6% | % of Consumption |
| Kerosene | 0.0% | 0.0% | 0.0% | % of Consumption |
| Propane | 1.2% | 1.5% | 0.0% | % of Consumption |
| Natural Gas | 48.0% | 63.4% | 72.8% | % of Consumption |
| Residual Fuel Oil | 0.0% | 0.9% | 7.0% | % of Consumption |
| Gasoline | 0.0% | 0.0% | 13.6% | % of Consumption |
| *Source: ENE BAU Forecast 2035 distribution* | | | | |

**Table 17: Thermal Sector Capital Requirements**

| Capital Requirements | | | | |
|---|---|---|---|---|
| *Fuel* | *Residential* | *Commercial* | *Industrial* | *Units* |
| Distillate Fuel Oil | $21,043 | $20,575 | $18,004 | $/BBTU at average Capacity |
| Kerosene | n/a | n/a | n/a | $/BBTU at average Capacity |
| Propane | $9,394 | $8,267 | $7,233 | $/BBTU at average Capacity |
| Natural Gas | $9,394 | $8,267 | $7,233 | $/BBTU at average Capacity |
| Residual Fuel Oil | n/a | $20,575 | $18,004 | $/BBTU at average Capacity |
| Gasoline | n/a | n/a | $18,004 | $/BBTU at average Capacity |
| CHP | n/a | n/a | $133,217 | $/BBTU at average Capacity |
| Solar Thermal | $546,409 | $546,409 | n/a | $/BBTU at average Capacity |
| Geothermal | $79,195 | n/a | n/a | $/BBTU at average Capacity |
| ETS | $306,667 | n/a | n/a | $/MW |
| Efficiency | $98,484 | $62,144 | $79,657 | $/BBTU at average Capacity |
| *Source: Navigant Research* | | | | |

**Table 18: Thermal Sector Salaries and Wages**

| **Salaries and Wage Rates** | | | | |
|---|---|---|---|---|
| *Fuel* | *Fuel Supply Wages* | *Labor % of Fuel* | *Installation Wages* | *Labor % of Capital* |
| Distillate Fuel Oil | $39,813 | 8% | $61,250 | 55% |
| Kerosene | $22,462 | 13% | $61,250 | 55% |
| Propane | $22,462 | 13% | $61,250 | 50% |
| Natural Gas | $72,420 | 5% | $61,250 | 50% |
| Residual Fuel Oil | $22,462 | 13% | $61,250 | 55% |
| Gasoline | $16,469 | 3% | $61,250 | 55% |
| Biodiesel | $22,462 | 13% | $61,250 | 55% |
| CHP | $72,420 | 5% | $61,595 | 32% |
| Solar Thermal | n/a | n/a | $60,028 | 75% |
| Geothermal | n/a | n/a | $66,146 | 60% |
| ETS* | $83,063 | 10% | $59,218 | 9% |
| Efficiency | n/a | n/a | $52,794 | 81% |
| *Source: Bureau of Labor Statistics, US Census* | | | | |

**Table 19: Thermal Sector Resource Allocation**

| **Sector Allocation** | | | |
|---|---|---|---|
| *Resource* | *Residential* | *Commercial* | *Industrial* |
| CHP | 0% | 0% | 100% |
| Solar Thermal | 65% | 35% | 0% |
| Geothermal | 100% | 0% | 0% |
| ETS | 100% | 0% | 0% |
| *Source: Navigant Research* | | | |

### *Transportation Sector Assumptions and Supplemental Information*

**Table 20: Transportation Sector Replaced Fuel Mix**

| Replaced Fuel Mix | |
|---|---|
| *Fuel* | % of Consumption |
| Distillate Fuel Oil | 16.4% |
| Jet Fuel | 7.1% |
| Propane | 0.2% |
| Motor Gasoline currently E10 | 73.4% |
| Natural Gas | 2.7% |
| Residual Fuel Oil | 0.2% |
| Fuel Ethanol E85 | 0.0% |
| *Source: ENE BAU Forecast 2013 distribution* | |

**Table 21: Transportation Sector Avoided Investment Fuel Mix**

| Avoided Investment Fuel Mix | |
|---|---|
| *Fuel* | *% of Consumption* |
| Distillate Fuel Oil | 17.7% |
| Jet Fuel | 0.0% |
| Propane | 0.0% |
| Motor Gasoline currently E10 | 79.3% |
| Natural Gas | 2.9% |
| Residual Fuel Oil | 0.0% |
| Fuel Ethanol E85 | 0.0% |
| *Source: ENE BAU Forecast 2035 distribution* | |

**Table 22: Transportation Sector Capital Requirements**

| Vehicle Capital Requirements | |
|---|---|
| *Fuel* | *$/vehicle* |
| Distillate Fuel Oil | $40,834 |
| Jet Fuel | n/a |
| Propane | n/a |
| Motor Gasoline currently E10 | $27,462 |
| Natural Gas | $28,167 |
| Residual Fuel Oil | n/a |
| Fuel Ethanol E85 | n/a |
| Electric Vehicles | $39,268 |
| Biodiesel | $40,834 |
| Public Transit Vehicle | $675,789 |
| *Sources: Cars.com (www.cars.com) and the National Transit Database (www.ntdprogram.gov)* | |

**Table 23: Transportation Sector Salaries and Wage Rates**

| Salaries and Wage Rates | | | | |
|---|---|---|---|---|
| *Fuel* | *Fuel Supply Wages* | *Labor % of Fuel* | *Capital Sales Wages* | *Labor % of Capital* |
| Distillate Fuel Oil | $39,813 | 8% | $42,800 | 7.2% |
| Jet Fuel | n/a | n/a | n/a | n/a |
| Propane | n/a | n/a | n/a | n/a |
| Motor Gasoline currently E10 | $16,469 | 3% | $42,800 | 7.2% |
| Natural Gas | $72,420 | 5% | $42,800 | 7.2% |
| Residual Fuel Oil | n/a | n/a | n/a | n/a |
| Fuel Ethanol E85 | n/a | n/a | n/a | n/a |
| Electric Vehicles | $83,063 | 10% | $42,800 | 7.2% |
| Biodiesel | $22,462 | 13% | $42,800 | 7.2% |
| Public Transit Vehicle | n/a | n/a | $19,928 | 32.0% |
| *Source: Bureau of Labor Statistics, US Census* | | | | |

**Table 24: Transportation Sector Other Assumptions**

| Other Transportation Assumptions | | |
|---|---|---|
| Average Vehicle Miles/Year per Vehicle: | 9,157 | miles/year per vehicle |
| Average Passengers/Vehicle | 1.3 | Passengers/Vehicle |
| Maintenance and Repairs Cost | $0.06 | $/mile |
| Vehicle Ownership Fixed Cost | $6,421 | $/car-year |
| Maintenance and Repairs Labor Percentage | 27.0% | % of Capital Expenditure |
| Vehicle Ownership Labor Percentage | 8.8% | % of Capital Expenditure |
| Maintenance and Repairs Average Salary | $37,089 | $/year |
| Vehicle Ownership Average Salary | $65,127 | $/year |
| *Source: AAA, Federal Highway Administration, Bureau of Labor Statistics* | | |

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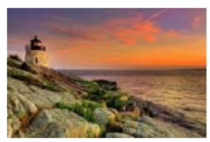
Experts in Renewable Energy and Sustainable Development

# RHODE ISLAND STATE ENERGY PLAN TECHNICAL ASSISTANCE

*Implementation Team Meeting: Resource Targets Supplement*

RIEDC Rhode Island Economic Development Corporation
Rhode Island, Working Again.

REF Renewable Energy Fund
A Program of the Rhode Island Economic Development Corporation



August 26, 2013



DISPUTES & INVESTIGATIONS • ECONOMICS • FINANCIAL ADVISORY • MANAGEMENT CONSULTING

Targets: Electric

**Navigant modeled changes to the electric sector using the low, moderate, and aggressive targets for change across the following 8 resources.**

## ELECTRIC

- Develop Offshore Wind Resources
- Develop Onshore Wind Resources
- Develop Rooftop Solar PV (Residential & Commercial)
- Develop Ground Mount Solar PV (Utility-Scale)
- Develop In-State Hydropower Resources
- Develop Biomass Resources
- Expand Combined Heat and Power Capacity
- Develop Grid Tied Electric Storage
- Increase Residential, Commercial, and Industrial Efficiency*

* While targets for additional increases in residential, commercial, and industrial energy efficiency were initially evaluated as potential areas for resource improvement, they were dropped from the scenario modeling exercise due to forecasted improvements approaching the technical potential in the business as usual case, thus precluding additional gains.

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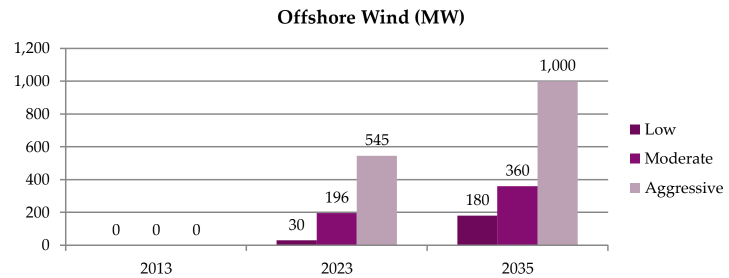
ENERGY

Targets: Electric

## Develop Offshore Wind Resources




- The low target is based on planned capacity from Block Island Wind Farm and the realization of projects evaluated as part of the PUC long-term contracting statutes.
- The moderate targets are based on the realization of twice as many offshore projects being built by 2035.
- The aggressive goals are based on the equivalent of successful execution of a proposal for 1,000 MW of offshore wind by 2035 and back cast to set interim targets.


Assumptions and Resources

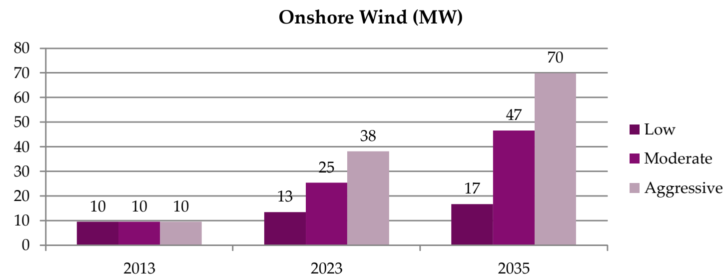
## Develop Offshore Wind Resources

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • 30MW by 2023 to reflect the Deepwater Wind project in Block Island Sound. An additional 150MW (totaling 180MW) by 2035 to reflect the realization of projects evaluated as part of the PUC long-term contracting statutes[1]. | 1.http://webserver.rilin.state.ri.us/Statutes/title39/39-26.1/39-26.1-8.HTM |
| **Moderate** | • The moderate targets are based on completing twice as many projects as in the low case by 2035. | |
| **Aggressive** | • The 2035 aggressive target assumes the Deepwater Wind project, which is proposing 1,000 MW, gets built by 2035[2]. | 1.http://dwwind.com/dww-energy-center/deepwater-wind-energy-center-overview |

Targets: Electric

## Develop Onshore Wind Resources




- The low target is based on historical growth rates and adjusted to achieve a maximum of 3% of load.
- The moderate target is based on a 2011 NREL Study examining wind potential of land with greater than 30% capacity factor at 80 meters, suitable for 1.5MW turbines and larger.
- The aggressive target assumes an additional 50% of capacity could be achieved through distributed deployment of a mix of 100kW and 250kW turbines.

Assumptions and Resources

## Develop Onshore Wind Resources

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • The low target is based on historical growth rates and adjusted to achieve a maximum of 3% of load. | |
| **Moderate** | • The 2035 moderate target is based on a 2011 NREL Study examining wind potential of land with greater than 30% capacity factor at 80 meters, suitable for 1.5MW turbines and larger. | http://www.windpoweringamerica.gov/pdfs/wind_maps/wind_potential_80m_30percent.pdf |
| **Aggressive** | • The aggressive target assumes an additional 50% of capacity could be achieved through distributed deployment of a mix of 100kW and 250kW turbines. | |

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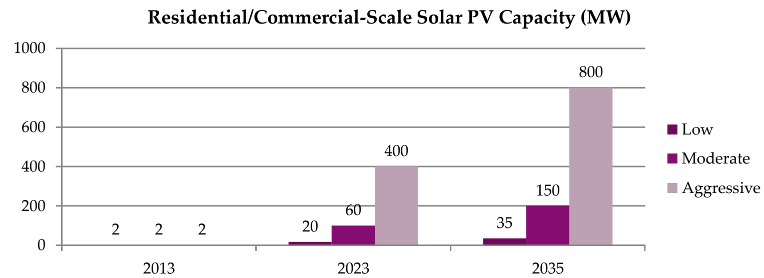
Targets: Electric

## Develop Rooftop Solar PV (Residential & Commercial)




- The residential solar PV capacities are based on data from National Grid, SEIA, and the US Census Bureau.
- The moderate goal targets 150 MW of solar PV capacity by 2035.
- The aggressive goal targets 800 MW of residential solar PV capacity by 2035, which corresponds to 20% of residential buildings installing a 5kW system and 20 % of commercial buildings installing a 25kW system and back casts to arrive at the projected 2023 level.



Assumptions and Resources

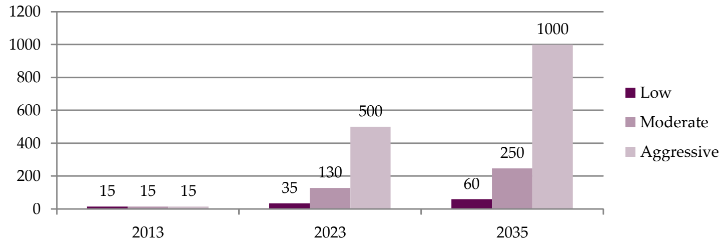
## Develop Rooftop Solar PV (Residential & Commercial)

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • 2013 data from National Grid[1]<br>• 2023 and 2035 projections assume the addition of 1.5 MW/year | 1.http://www.ripuc.org/eventsactions/docket/4371-NGrid-DR-PUC2(12-4-12).pdf |
| **Moderate** | • The 2035 moderate target correspond to ~20% of the change between the aggressive and low targets. | |
| **Aggressive** | • The 2035 aggressive target corresponds to the residential and commercial sector solar technical potential in RI.<br>• The residential solar potential was estimated by assuming:<br>  • Average residential PV system: 5 kW[1]<br>  • ~60% of housing units are single family in RI[2]<br>  • PV can be installed on 35 % of buildings[3]<br>• The commercial solar potential was estimated by assuming:<br>  • Average commercial PV system: 20 kW<br>  • ~50,000 commercial buildings in RI (estimated based on average commercial building energy consumption and total energy consumption at the commercial scale in RI)<br>  • PV can be installed on ~35% of buildings | 1. http://www.seia.org/research-resources/solar-photovoltaic-technology<br>2.http://quickfacts.census.gov/qfd/states/44000.html<br>3.http://www.frontiergroup.org/reports/fg/building-solar-future |

Targets: Electric

## Develop Ground Mount Solar PV (Utility-Scale)

Utility-Scale Solar PV Capacity (MW)




- The utility-scale solar PV capacities are estimated from National Grid data and the Renewable Energy Siting Partnership report.
- The moderate goal targets 250 MW of solar PV capacity by 2035.
- The aggressive goal targets 1,000 MW of utility-scale solar PV capacity by 2035, which represents the maximum solar PV capacity on landfills (500 MW) and an equal amount of solar PV on non-landfill plots. It back casts annual changes to arrive at the projected 2023 level.



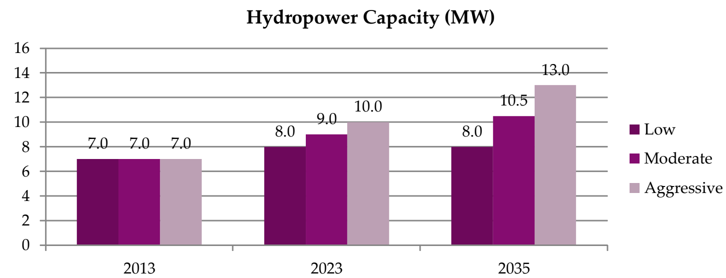

Assumptions and Resources

## Develop Ground Mount Solar PV (Utility-Scale)

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • 2013 data from National Grid[1]<br>• 2023 and 2035 projections assume the addition of 2 MW/year | 1.http://www.ripuc.org/eventsactions/docket/4371-NGrid-DR-PUC2(12-4-12).pdf |
| **Moderate** | • The 2035 moderate targets correspond to 20% of the change between the aggressive and low targets. | |
| **Aggressive** | • It was deemed unreasonable to evaluate the aggressive target for utility-scale PV on technical potential since the potential would be larger than reasonable considering RI's electric load and current generating capacity.<br>• The utility-scale solar, under the aggressive case, in 2035 is estimated at 1,000 MW (~50% of generating capacity in RI). | |

Targets: Electric

## Develop Hydropower Resources




- The hydropower capacity estimates are based on FERC data on hydro projects in the US and a 2011 RI Renewable Energy Fund study evaluating the potential Tier 1 hydropower in Rhode Island.
- The moderate goal targets achieving 10.5 MW of hydropower capacity by 2035, an average of the low and aggressive targets.
- The aggressive goal targets 13 MW of hydropower capacity by 2035, which represents the maximum Tier 1 hydropower capacity.





Assumptions and Resources

## Develop In-State Hydropower Resources

| Target | Assumptions | Sources |
| --- | --- | --- |
| **Low** | • 2013 data from FERC[1]<br>• 2023 and 2035 projections assume that project permits set to expire prior to 2035 will be renewed and 1 MW of current projects with licenses will obtain permits. | 1.http://www.ferc.gov/industries/hydropower.asp |
| **Moderate** | • The 2035 moderate target correspond to the average of the aggressive and low targets in 2035. | |
| **Aggressive** | • The 2035 aggressive target corresponds to the hydropower technical potential in RI. This value was extracted from a 2011 RI Renewable Energy Fund Study1. | 1.http://seagrant.gso.uri.edu/resp/pdfs/resp_volume_1.pdf |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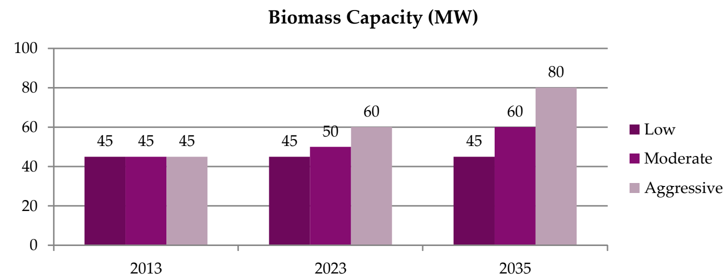
Targets: Electric

## Develop Biomass Resources




- The biomass capacity is based on data from the EERE Renewable Energy Data Book, ACORE, and input from the RISEP Project Team.
- The moderate goal targets 60 MW of biomass capacity by 2035.
- The aggressive goal targets 80 MW of biomass capacity by 2035, estimated to be the maximum capacity in RI considering the in-state biomass resources, and back casts annual changes to arrive at the projected 2023 level.



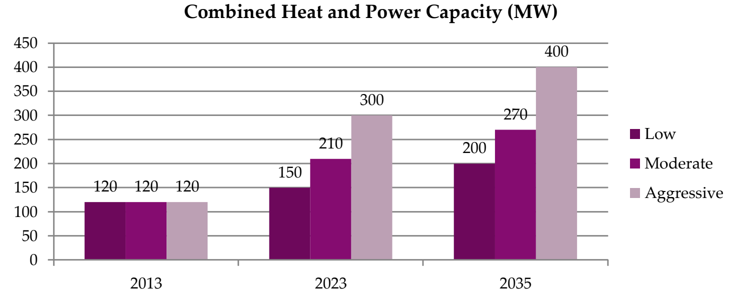

Assumptions and Resources

## Develop Biomass Resources

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • 2013 data from EERE Renewable Energy Data Book (2011)[1]<br>• 2023 and 2035 projections assume that average addition of 1 MW/year in biomass capacity | 1.http://www.nrel.gov/docs/fy13osti/54909.pdf |
| **Moderate** | • The 2023 and 2035 moderate targets correspond to 120% of the BAU targets. | |
| **Aggressive** | • The 2035 aggressive target assumes the yearly biomass resource potential in RI will be fully utilized by 2035 in-state. This resource potential is ~175,000 metric tons of biomass resource/year[1]. | 1.http://acore.org/files/pdfs/states/RhodeIsland.pdf |

Targets: Electric

## Expand Combined Heat and Power Capacity




- The CHP capacity estimates are based on 2012 CHP Study for DOE EERE, a 2000 DOE CHP Potential Study and EERMC's Opportunity Report, Phase 1*.
- The moderate goal targets an in-state CHP capacity of 270 MW by 2035, which is reached through an annual additions of 7 MW.
- The aggressive goal targets an in-state CHP capacity of 400MW by 2035, which is reached through an annual penetration rate 2 times that of the low target.

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NAVIGANT ENERGY

Assumptions and Resources

## Expand Combined Heat and Power Capacity

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • 2013 data from a 2012-2013 Navigant study on CHP for the Department of Energy EERE[1]<br>• 2023 and 2035 projections assume a market penetration of 3-3.5 MW/year. | http://www1.eere.energy.gov/manufacturing/distributedenergy/ |
| **Moderate** | • The moderate goal targets an in-state CHP capacity of 270 MW by 2035, which is reached through an annual additions of 7 MW. | |
| **Aggressive** | • The aggressive case assumes a penetration rate two times more aggressive than in the BAU. The resulting CHP capacity in 2035 is close to the economic potential of CHP in RI according to a KEMA study[1]. | http://www.env-ne.org/resources/detail/ri-opportunity-report |

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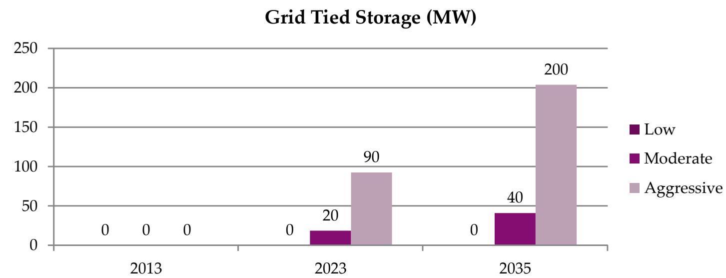
NAVIGANT ENERGY

Targets: Electric

## Develop Grid Tied Electric Storage




- The electric energy storage estimates were derived from the Market Evaluation for Energy Storage in the US study by Kema.
- The moderate goal targets 40 MW of grid tied storage by 2035.
- The aggressive goal targets 200MW of grid tried storage by 2035, which corresponds to 11% of 2013 generating capacity in Rhode Island.




Assumptions and Resources

## Develop Grid Tied Electric Storage

| Target | Assumptions | Sources |
|---|---|---|
| **Low** | • It is assumed that there is currently no grid tied storage in RI and no grid tied storage would be added through 2035. | Market Evaluation Study for Energy Storage in the US study by KEMA. |
| **Moderate** | • The 2035 moderate target correspond to 20% of the change between the aggressive and low targets added on top of the low target. | |
| **Aggressive** | • The 2035 aggressive target assumes that grid tied electric storage will be equivalent in capacity to ~10% of the 2013 electric generating capacity in RI. | |

NAVIGANT

Targets: Thermal

**Navigant modeled changes to the thermal sector using the low, moderate, and aggressive targets for change across the following 9 resources.**

## THERMAL

- Expand Combined Heat and Power Capacity
- Increase Thermal Efficiency in Residential Applications
- Increase Thermal Efficiency in Commercial Applications
- Increase Thermal Efficiency in Industrial Applications
- Increase Heating from Natural Gas
- Develop Solar Thermal Resources
- Develop Geothermal Resources
- Deploy Electric Thermal Storage (ETS)
- Increase Heating from Biofuels

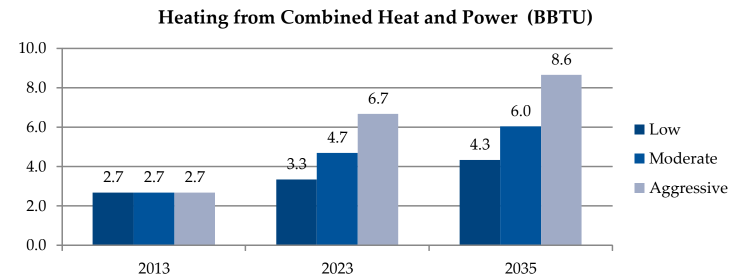




NAVIGANT ENERGY

Targets: Thermal

## Increase Heating from Combined Heat and Power




- The CHP capacity estimates are based on a 2012 CHP Study for DOE EERE, 2000 DOE CHP Potential Study, the EERMC's Opportunity Report, Phase 1 and EIA data.
- The moderate goal targets 6.0 BBTU of thermal energy from CHP by 2035.
- The aggressive goal targets 8.6 BBTU of thermal energy from CHP by 2035, which was derived from the CHP capacity (MW) previously estimated and an assumed 75% capacity factor.




NAVIGANT ENERGY

Assumptions and Resources

## Expand Combined Heat and Power Capacity

| Target | Assumptions | Sources |
|---|---|---|
| Low | • 2013 data from a 2012-2013 Navigant study on CHP for the Department of Energy EERE[1]<br>• 2023 and 2035 projections assume a market penetration of 3-3.5 MW/year. | 1. Not yet published but will be on the DOE EERE website once it is finished. |
| Moderate | • The moderate goal targets an in-state CHP capacity of 270 MW by 2035, which is reached through an annual additions of 7 MW. | |
| Aggressive | • The aggressive case assumes a penetration rate two times more aggressive than in the BAU. The resulting CHP capacity in 2035 is close to the economic potential of CHP in RI according to a KEMA study[1]. | 1. http://www.env-ne.org/resources/detail/ri-opportunity-report |

*Note: For CHP projections in the thermal sector, the CHP projections in the electric sector [in MW] were used and converted to thermal units considering the electric and thermal efficiencies as well as the average institutional CHP unit capacity factor. See discussion of CHP in electric section to know low /aggressive growth assumptions.*
Main assumptions:
On average, electric efficiency: 33 %
On average, thermal efficiency: 30 %
Capacity factor: 75% (average for institutional-scale CHP, which is most prevalent in RI)

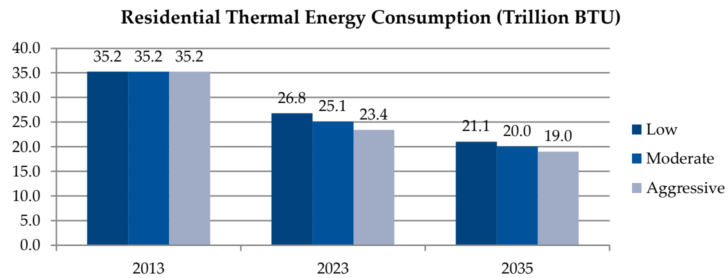
Source: Data from Navigant's CHP study for DOE EERE.




NAVIGANT ENERGY

Targets: Thermal

## Increase Thermal Efficiency in Residential Applications




- The residential thermal energy consumption data were from ENE's BAU forecast and a study by Lawrence Berkeley National Laboratory.
- ENE's thermal energy forecasts for the residential sector predicts a decrease in thermal energy consumption of 40% between 2013-2035.
- The aggressive bound targets 20.6 T BTUs of thermal energy consumption in 2035, corresponding to a 46% decrease in thermal energy consumption between 2013-2035. It back casts annual changes to arrive at the projected 2023 level.



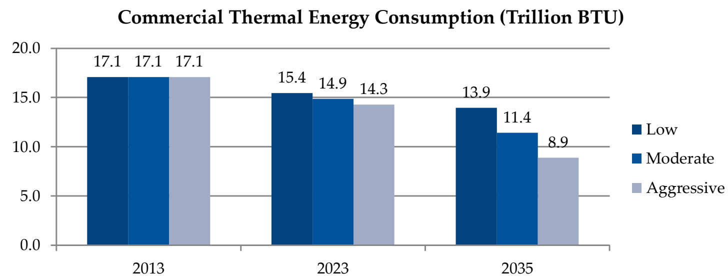

Assumptions and Resources

## Increase Thermal Efficiency in Residential Applications

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The low target is obtained from ENE's BAU | |
| Moderate | • The 2035 moderate target is based on the midpoint between the low and aggressive targets in 2035. | |
| Aggressive | • In 2035, the aggressive target corresponds to the weighted average EIA growth factors for space conditioning and water heating in the residential sector identified for 2050, back cast to 2035 (1). | 1. http://www.aceee.org/sites/default/files/publications/researchreports/e121.pdf |

Targets: Thermal

## Increase Thermal Efficiency in Commercial Applications




- The commercial thermal energy consumption data were from ENE's BAU forecast and a study by Lawrence Berkeley National Laboratory.
- The moderate goal targets 11.4 T BTUs of thermal energy consumption in 2035.
- The aggressive bound targets 8.9 T BTUs of thermal energy consumption in 2035, corresponding to a 48% decrease in thermal energy consumption between 2013-2035. It back casts annual changes to arrive at the projected 2023 level.





NAVIGANT ENERGY

Assumptions and Resources

## Increase Thermal Efficiency in Commercial Applications

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The low target is obtained from ENE's BAU | |
| Moderate | • The 2035 moderate target is based on the midpoint between the low and aggressive targets in 2035. | |
| Aggressive | • In 2035, the aggressive target corresponds to the weighted average EIA growth factors for space conditioning and water heating in the commercial sector identified for 2050, back cast to 2035 (1). | 1. http://www.aceee.org/sites/default/files/publications/researchreports/e121.pdf |





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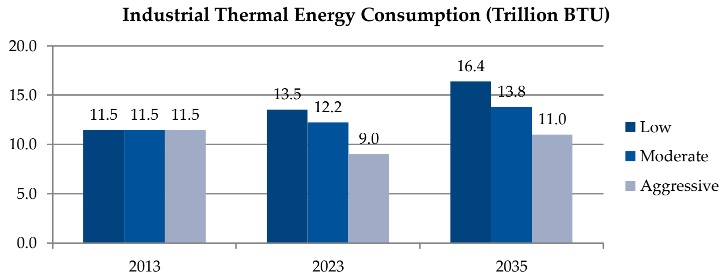
NAVIGANT

Targets: Thermal

## Increase Thermal Efficiency in Industrial Applications




- The industrial thermal energy consumption data were from ENE's forecasts and the PEW Center*.
- The moderate goal targets 13.8 TBTU of thermal energy consumption in 2035.
- The aggressive bound targets 11.0 TBTU of thermal energy consumption in 2035, corresponding to a 33% decrease in thermal energy consumption below the BAU.





*Now known as the Center for Climate and Energy Solutions.

NAVIGANT ENERGY

Assumptions and Resources

## Increase Industrial Thermal Energy Efficiency

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The low target is obtained from ENE's BAU | |
| Moderate | • The 2035 moderate target is based on 40% of the difference between the low and aggressive targets in 2035. | |
| Aggressive | • In 2035, the aggressive target corresponds to the 'energy efficiency technical potential' – that is the reduction in thermal energy consumption in the thermal sector if industrial buildings/ plants undergo deep energy efficiency retrofits, achieving ~40% decrease in thermal energy consumption1. | 1.http://www.c2es.org/docUploads/10-50_Price%20and%20Worrell.pdf |

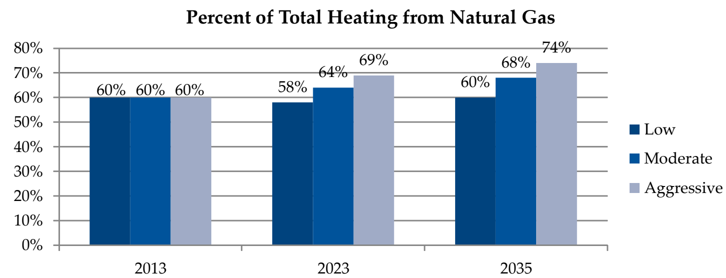




NAVIGANT ENERGY

Targets: Thermal

## Increase Heating from Natural Gas




- The heating from natural gas data were extracted from ENE's forecasts, which rely on data from the EIA.
- The moderate goal targets an average between the low and aggressive cases.
- The aggressive goal targets 74% of heating from natural gas by 2035, based on conversion to gas of all near-main customers.



Assumptions and Resources

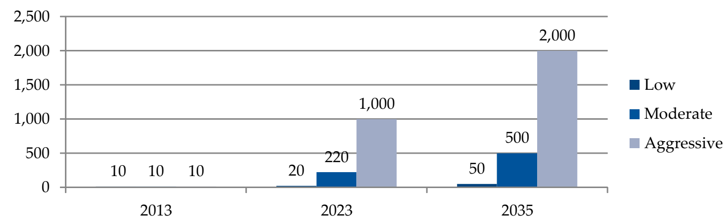
## Increase Heating from Natural Gas

| Target | Assumptions | Sources |
| --- | --- | --- |
| Low | • The low targets are obtained from natural gas (NG) consumption in ENE's BAU forecast. | |
| Moderate | • The 2035 moderate targets correspond to the average of the low and aggressive targets in 2035. | |
| Aggressive | • The 2035 aggressive target assumes that all on-main customers not using NG at all or for non-heating purposes convert to using NG, in both the residential and commercial sectors. | National Grid Natural Gas Consumption Data (on main customers vs. off main customers). |

Targets: Thermal

## Develop Solar Thermal Resources

**Residential/Commercial Thermal Energy from Solar Thermal (Billion BTU)**




- Hot water heating from solar thermal estimates were derived from ENE's forecasts, EIA data, and the US Census Bureau.
- The moderate goal targets 500 B BTU by 2035.
- The aggressive goal targets 2,000 B BTU of solar thermal by 2035, which corresponds to 20% of residential and commercial buildings using solar thermal for hot water heating by 2035. It back casts annual changes to arrive at the projected 2023 level.





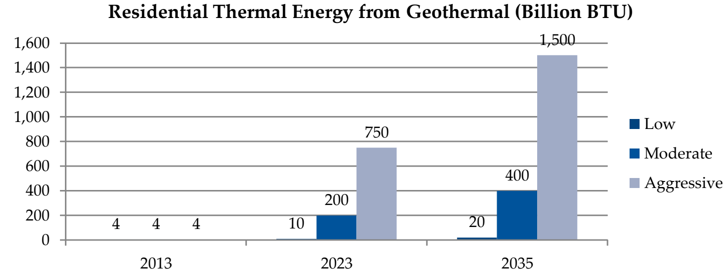
Assumptions and Resources

## Develop Solar Hot Water Heating Resources

| Target | Assumptions | Sources |
| --- | --- | --- |
| Low | • The 2013 data was calculated from ENE's forecast and US Census bureau data from 2000 (to get the percent of homes using solar thermal). It was assumed the number of buildings using solar heating tripled between 2000 and 2013.<br>• The 2035 target assumes thermal energy consumption from solar thermal will increase by a five-fold between 2013-2035. | 1.http://www.eia.gov/consumption/residential/ |
| Moderate | • The 2035 moderate targets correspond to ~25% of the change between the aggressive targets in 2035. | |
| Aggressive | • In 2035, the aggressive target is assumed to be the residential and commercial sectors solar hot water heating technical potential in RI.<br>• ~60% of housing units are single family and 35% of houses are suitable for solar panels. Solar hot water heating can provide 60% of a home's hot water heating needs.<br>• The potential commercial consumption of thermal energy from solar thermal was calculated by assuming the percent of thermal needs met by solar thermal at the residential scale would be roughly the same at the commercial scale. | http://www.seia.org/policy/solar-technology/solar-heating-cooling |

Targets: Thermal

## Develop Geothermal Resources




- The space and water heating from geothermal estimates were derived from ENE's forecasts and a 2009 study by Navigant for DOE EERE.
- The moderate goal targets 400 B BTU by 2035.
- The aggressive goal targets 1,500 B BTU by 2035, which corresponds to 15% of single-family homes using geothermal space and hot water heating by 2035. It back casts annual changes to arrive at the projected 2023 level.



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Assumptions and Resources

## Develop Geothermal Resources

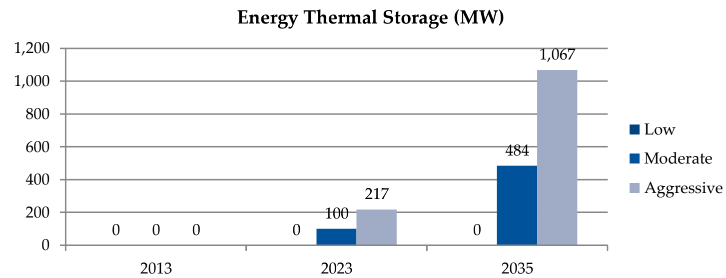
| Target | Assumptions | Sources |
|---|---|---|
| Low | • The number of single-family homes with geothermal was estimated based on the number of single-family homes with solar thermal.<br>• It was assumed that there are ~75% fewer homes with geothermal than homes with solar thermal in RI.<br>• 2035 projection: thermal energy consumption from geothermal will increase by a five-fold between 2013 and 2035. | |
| Moderate | • The 2035 moderate targets correspond to ~20% of the aggressive target in 2035. | |
| Aggressive | • In 2035, reach the residential geothermal potential in RI, which is estimated by assuming:<br>  • The national average of homes which could use geothermal is 30%. Since the population density of RI is 2nd highest in nation therefore less available space for geothermal systems – assumed ~ 15 % of single-family homes could use geothermal in RI.<br>  • Geothermal heating can provide 40% of a home's heating requirements | http://www1.eere.energy.gov/geothermal/pdfs/gshp_overview.pdf |



NAVIGANT ENERGY

Targets: Thermal

## Deploy Energy Thermal Storage (ETS)




- The energy thermal storage capacities were estimated from data by VCharge, an ETS start-up.
- The moderate goal targets 484 MW by 2035, an average of the aggressive and low cases.
- The aggressive goal targets 1,067 MW of ETS by 2035, which corresponds to having 20% of homes heating with oil/propane using ETS by 2035.

  NAVIGANT ENERGY

Assumptions and Resources

## Deploy Electric Thermal Storage (ETS)

| Target | Assumptions | Sources |
|---|---|---|
| Low | • In 2013, no ETS<br>• The 2023 and 2035 projections assume no ETS deployment | |
| Moderate | • The 2035 moderate target correspond to 20% of the change between the aggressive and low targets added on top of the low case. | |
| Aggressive | • In 2035, the aggressive target corresponds to the technical potential of ETS in RI estimated by:<br>  • Average ETS unit size at the residential scale: 15 kW[1]<br>  • ETS could be deployed in homes that heat with oil/propane/electricity (~50%) [2]<br>  • 1/3 of homes heating with oil/propane/electricity use ETS by 2035. | 1.Communication with ETS start-up VCharge.<br>2. From 2010 Census data |

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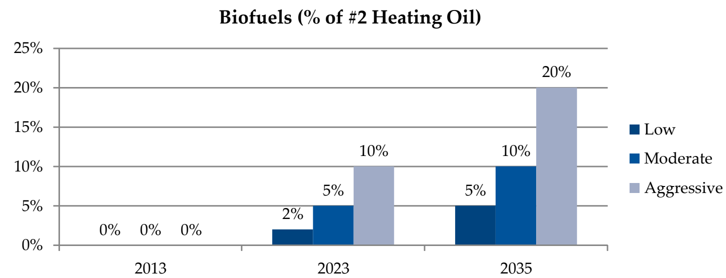
Targets: Thermal

## Increase Heating From Biofuels




- The low goal for biofuels use tracks the current mandate for use in #2 home heating oil.
- The moderate goal effectively doubles this mandate, or examines if a B20 blend addressed 50% of demand for heating oil.
- The aggressive goal targets a B20 blend for all heating oil in the thermal sector.





Assumptions and Resources

## Increase Use of Biofuels in Distillate Fuel Oil

| Target | Assumptions | Sources |
|---|---|---|
| Low | • In 2013, there is no state requirement on biofuel % in distillate fuel oil. However, the RI Senate recently approved the 2013 Biodiesel Heating Oil Act, which will require:<br>  • 2% of D.F.O to be biobased by 2014<br>  • 5% by 2017<br>• It is assumed that the limit will plateau at 5% in the 'low' target case. | http://webserver.rilin.state.ri.us/News/pr1.asp?prid=9356 |
| Moderate | • The 2035 moderate target corresponds to 2 times the low target in 2035. | |
| Aggressive | • The 2035 aggressive target considers a requirement of 20% of biobased products in distillate fuel oil. | |

Targets: Transportation

**Navigant modeled changes to the transportation sector using the low, moderate, and aggressive targets for change across the following 6 resources.**

## TRANSPORTATION

- Improve Vehicle Average Efficiency
- Increase Adoption of Electric Vehicles
- Increase Adoption of Natural Gas Powered Vehicles
- Increase Use of Biofuels in Transportation
- Reduce Vehicle Miles Traveled
- Increase the Use and Options for Public Transit





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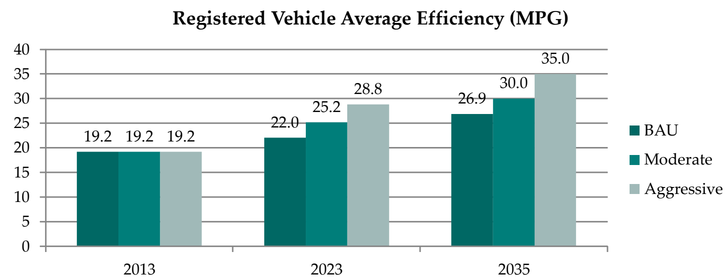
Targets: Transportation

## Improve Vehicle Average Efficiency




- Vehicle average efficiency is based on ENE's BAU forecast for fuel consumption (gasoline and diesel) compared against the U.S. DoT VMT statistics for the same period (2003 – 2012).
- The moderate target forecasts a low linear improvement in the efficiency of available vehicles and calculates the resulting fleet efficiency based on a 9% annual replacement rate.
- The aggressive goal targets 35 MPG on average by 2035 and back casts annual changes to arrive at the projected 2023 level.




NAVIGANT ENERGY

Assumptions and Resources

## Improve Vehicle Average Efficiency

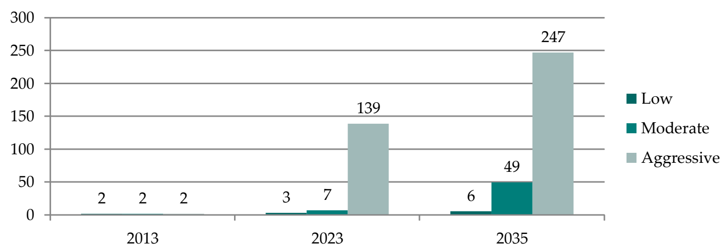
| Target | Assumptions | Sources |
|---|---|---|
| Low | • The business as usual forecast for average fleet efficiency was developed using ENE's fuel consumption forecast for Gasoline and Distillate Fuel Oil divided by the forecast for Vehicle Miles Traveled, which was developed from the FHWA traffic monitoring program. | http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm |
| Moderate | • The moderate target forecasts a low linear improvement in vehicle efficiency (based on average new stock from 2008 to 2012) and uses a rolling stock model with a 9.3% replacement rate through 2035. | |
| Aggressive | • The aggressive target is set to 35 MPG for 2035 and back casts the average annual improvement to fleet efficiency to arrive at the 2023 interim target. | https://www.polk.com/company/news/polk_in_the_news_americans_are_keeping_new_vehicles_an_average_six_years |




NAVIGANT ENERGY

Targets: Transportation

## Increase Adoption of Electric Vehicles




- The low target is based on the BAU forecast for electricity consumption in the transportation sector, and corresponds to 0.3% of fleet electrification by 2035.
- Targets are based on Bass diffusion models from University of Michigan Study: Market Models for Predicting PHEV Adoption and Diffusion and US DOE data on average EV efficiencies of 100 MPGe and annual travel of 15,000 miles. Moderate and aggressive EV market penetration in 2035 are 2.7% and 13.8% respectively.

 0 NAVIGANT ENERGY

Assumptions and Resources

## Increase Adoption of Electric Vehicles

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The low target is based on ENE's BAU forecast for electric consumption in the transportation sector. | |
| Moderate<br><br>Aggressive | • Targets are based on Bass diffusion model from University of Michigan Study: Market Models for Predicting PHEV Adoption and Diffusion and US DOE data on average EV efficiencies of 100 MPGe and annual travel of 15,000 miles. Moderate and aggressive EV market penetration in 2035 are 2.7% and 13.8% respectively<br><br>• Estimates were reconciled with Navigant Research report forecasting EV sales through 2020. | http://deepblue.lib.umich.edu/bitstream/handle/2027.42/64436/102399.pdf;jsessionid=D24908A220404259A2B304800B7221C0?sequence=1<br><br>http://www.navigantresearch.com/newsroom/though-falling-short-of-u-s-targets-sales-of-plug-in-electric-vehicles-will-grow-strongly-through-2020 |

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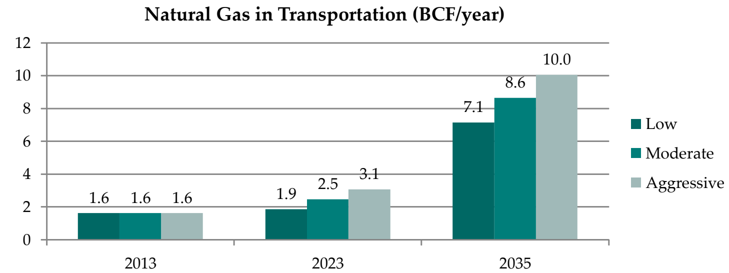
Targets: Transportation

## Increase Adoption of Natural Gas Powered Vehicles




- The low target is based on ENE forecast of NG consumption in transportation, which is based on AEO date forecasting a sharp increase in demand for CNG in heavy duty vehicles.
- Moderate targets based on conversion of all public and private busses to CNG by 2035.
- Aggressive target based on conversion of all publicly owned busses and a fraction of passenger vehicles to CNG by 2035.

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Assumptions and Resources

## Increase Adoption of Natural Gas Powered Vehicles

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The low targets are based on ENE's forecast of Natural Gas use in transportation. | |
| Moderate<br>Aggressive | • Moderate and aggressive targets are based on the EIA AEO forecast for increases in natural gas consumption in the transportation sector broken out by for light-duty vehicles, busses, and heavy-duty vehicles.<br>• Current rates of national consumption of natural gas for were scaled to match the Rhode Island fleet profile.<br>• Both moderate and aggressive targets follow EIA AEO forecasts for growth in consumption of natural gas for light-duty vehicles and busses.<br>• Heavy-duty vehicle NG consumption was de-rated to 25% and 50% of the growth forecast by EIA for the moderate and aggressive targets respectively. | http://www.eia.gov/forecasts/aeo/source_natural_gas_all.cfm#netexporter<br><br>http://www.fhwa.dot.gov/policyinformation/statistics/2011/mv1.cfm |

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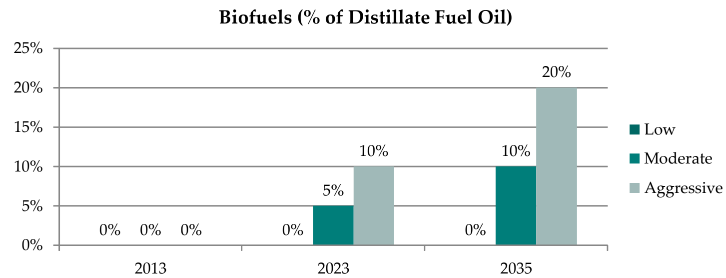
Targets: Thermal

## Increase Biofuels in Transportation




- The low target is based on ENE forecast of Fuel Ethanol (E85) Consumption and US DOE Alternative Fuels Data Center which identified two bio-diesel stations (recycled cooking oil) and zero E85 filling stations in-state.
- Aggressive biofuel targets based on a phased in B20 blend mandate by 2035.



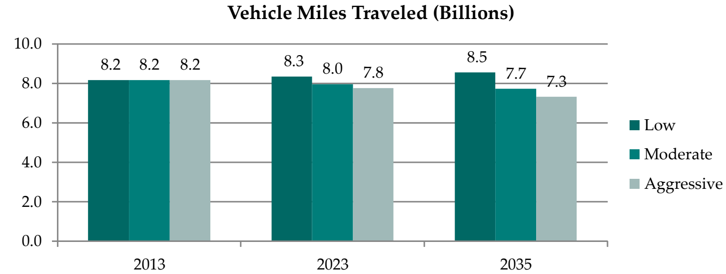


Assumptions and Resources

## Increase Use of Biofuels in Transportation

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The low target assumes no additional adoption of biofuels in transportation | |
| Moderate | • The moderate target establishes a B10 mandate to be phased in through 2035. | |
| Aggressive | • The aggressive target establishes a B20 mandate to be phased in through 2035. | |

## Reduce Vehicle Miles Traveled by Low Occupancy Vehicles




- The VMT forecast is based on U.S. DoT Office of Highway Policy Information Traffic Volume Trends Reports for Rhode Island (monthly data from 2003 – 2012)
- The moderate and aggressive targets represent 5% and 10% reductions from current levels following examples from Denver, Sacramento, and San Francisco Bay Area plans directed at reducing VMT while promoting economic growth.



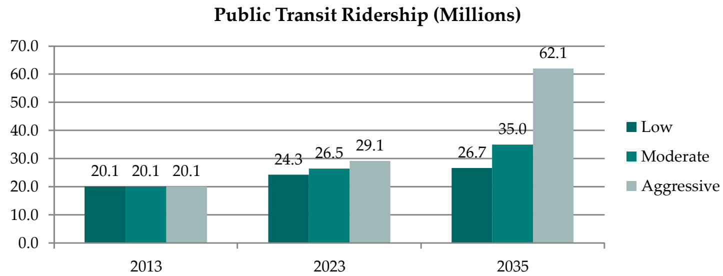


## Reduce Vehicle Miles Traveled by Low Occupancy Vehicles

| Target | Assumptions | Sources |
|---|---|---|
| Low | • VMT forecast created by linear forecast based on 2003 to 2012 trends from FHWA travel monitoring | http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm |
| Moderate<br>Aggressive | • Moderate and aggressive targets for absolute reductions in VMT were developed following examples from Denver, Sacramento, and San Francisco Bay Area plans directed at reducing VMT while promoting economic growth.<br>• VMT reductions from transit development related activities we then removed to correct for the non-transit related component of VMT reduction. (e.g. telecommuting, bicycling, walking) | http://www.fhwa.dot.gov/policy/otps/pubs/vmt_gdp/index.cfm#sect4 |

Targets: Transportation

## Increase the Use and Options for Public Transit




- The low target is based on RIPTA 5 year program to expand ridership by 10%. Assumes similar growth through 2023 and 2035.
- Moderate targets assumes all public transit could maintain twice the growth as that outlined in the 5 year plan through 2035.
- Aggressive targets use the MBTA ratio of bus ridership to all other ridership to examine extensive expansion of light and heavy rail options for public transit.





Assumptions and Resources

## Increase the Use and Options for Public Transit

| Target | Assumptions | Sources |
|---|---|---|
| Low | • The BAU forecast carries forward the five year RIPTA strategic plan through 2035, at which point in time RIPTA will provide an estimated 26.7 million rides annually. | http://www.ripta.com/stuff/contentmgr/files/0/3fa283056d6e9f63c8b9a317240b29be/files/12.pdf |
| Moderate | • The moderate target is based on a 20% increase by 2023 and a 75% increase through 2035. | |
| Aggressive | • The aggressive target considers the development of a multimodal transit system with ridership profiles similar to the MBTA (e.g. expanded rail service) and applies this expanded service to the BAU ridership numbers. | http://www.mbta.com/uploadedfiles/documents/Bluebook%202010.pdf |

*Key*
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