Rhode Island Renewable Thermal Market Strategy – An Analysis of Energy, Environmental, Economic, Energy Bill, and Local Job Impacts of an Alternative Renewable Thermal Energy Future for Rhode Island

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Abstract

The thermal energy sector is a major consumer of energy for space heating and domestic hot water in Rhode Island. Relying primarily on fossil fuels, the thermal sector accounts for approximately one third of Rhode Island's total energy consumption and carbon emissions. By diversifying the thermal energy sector to increase use of low-carbon renewable heating and cooling technologies (e.g., air source heat pumps, ground source heat pumps, wood pellet heating, solar thermal), Rhode Island can make significant strides toward achieving GHG emission reduction goals and reap substantial economic benefits in the process.

Thus far, virtually all clean energy policies and programs in the state have focused on electric sector technologies and natural gas efficiency. Consequently, Rhode Island's renewable thermal industry has historically been relatively small and slow-growing.

To address barriers facing the renewable thermal industry and promote renewable thermal technologies, Rhode Island Office of Energy Resources (OER) tasked the authors with analyzing policies and programs designed to grow the industry and conducting a detailed market model of alternative thermal sector energy futures. In one of the alternative scenarios, Rhode Island achieves 5 percent renewable thermal energy penetration by 2035. This paper presents the results and methodologies for analyzing this scenario, including the cost-effectiveness, energy rate and bill impacts, local job impacts, and emission impacts of the alternative future. This study broke new ground by applying standard analysis methodologies and approaches used for energy efficiency measures (e.g., cost-effectiveness tests, rate and bill impacts, job impacts) to renewable thermal technologies.

Background

Renewable thermal (RT) represents a key opportunity to achieve climate and energy objectives in Rhode Island. Approximately one third of Rhode Island's total energy use (63 trillion Btu of energy) is used each year in the thermal sector. This includes residential, commercial, and industrial applications for space heating, space cooling, domestic hot water, and process heat. Currently, almost all of Rhode Island's thermal energy load is served by fossil fuels such as heating oil, propane, or natural gas.

Rhode Island's fossil-based thermal energy industry is a major contributor to greenhouse gas (GHG) emissions in the state. It accounts for approximately 35 percent of the state's GHG emissions. In addition, because Rhode Island has no in-state natural gas or petroleum resources, a large portion of the approximately $1.1 billion in annual expenditure on heating fuels flows directly out of the state.

RT technologies—such as cold climate air-source heat pumps (ASHP), ground-source heat pumps (GSHP), solar thermal, biodiesel, and high-efficiency biomass—offer an emerging opportunity for consumers to access new, affordable, and clean alternative heating options. In 2016, Rhode Island's Office of Energy Resource (OER) engaged consultants, Meister Consultants Group (MCG) and Synapse Energy Economics (Synapse), and a stakeholder task force to evaluate strategies to grow the state's RT markets. The resulting report examined the benefits and impacts to scaling RT adoption, identified key market barriers to deployment, and proposed a series of policy recommendations to promote RT technologies in Rhode Island.[1] This paper describes the findings of the study regarding the benefits and impacts of the scaling of renewable thermal adoption that would result from state and stakeholder initiatives.

Analysis Overview

At the request of Rhode Island OER, MCG and Synapse analyzed the energy, environmental, and economic impacts of policies and programs designed to grow the RT industry within the state under alternative thermal sector energy futures. These scenarios entailed large-scale investments in RT technologies. In the scenario described here, Rhode Island seeks to achieve 5 percent RT energy penetration by 2035 by providing technical support and financial incentives to RT technologies. More specifically, this RT policy scenario aims to increase installations of ASHP, GSHP, wood boilers, and solar hot water (SHW) systems for residential single-family, multi-family, and commercial customers.

Utility energy efficiency programs have evolved to provide robust support and rebates for electric and gas customers.[1] However, these programs rarely include RT technologies (with the exception of ASHPs, which are often installed for their cooling benefits). As such, while there are robust industry standards in place for the evaluation of utility efficiency programs that target reductions in electricity and natural gas consumption, these evaluations rarely consider the impacts of RT measures, particularly those installed in existing oil-heated homes. This analysis offers an application of the standard methodologies for evaluating overlooked heating efficiency measures with the necessary modifications to address RT measures.

Based on discussions with OER staff, we analyzed a scenario wherein renewable thermal technologies displace 5 percent of statewide heating load in the residential and commercial sectors by 2035. Due to the economics of different technologies and the size of current markets, we assumed that ASHP would be the prevailing RT technology deployed in this scenario.

We investigated the following types of impacts: (a) economic impacts; (b) rate and bill impacts; (c) employment impacts; and (d) emissions impacts. The relationships of these impacts are presented in Figure 1. The results of the study provide key information to state policymakers and industry stakeholders as they consider a strong policy investment in RT in Rhode Island.

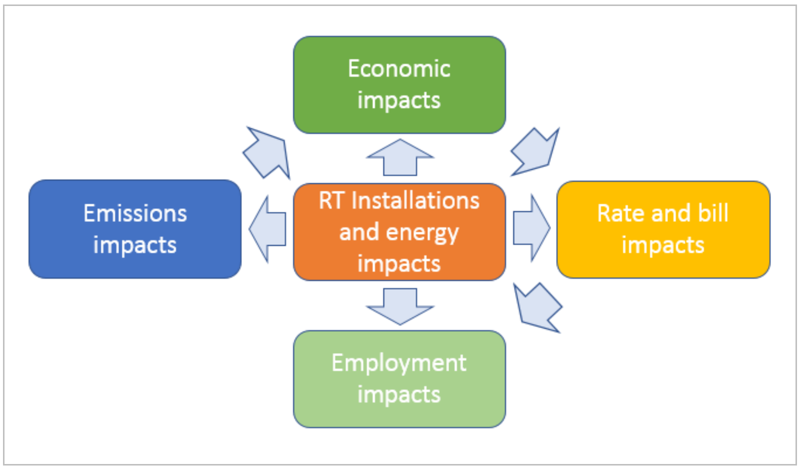

Figure 1. Relationships of Different Impacts

Key Assumptions

Renewable Thermal Installation Assumptions

We sourced typical single-family RT technology costs from the regional rebate databases of programs implemented in Massachusetts and Connecticut. We made some adjustments due to stakeholder group input. To analyze economic impacts, we used the full cost of SHW and ASHP systems and assumed residents and businesses would keep their existing heating equipment as a backup or a

[1] See ACEEE website "Energy Efficiency Programs" available at http://aceee.org/portal/programs

supplemental heating source.[2] We used the incremental cost beyond the cost of a standard system for pellet boilers and GSHP, assuming a replace-on-burnout scenario in which customers would install these systems instead of new standard heating systems (e.g., gas or oil furnaces).[3] We also assumed that ASHP projects would serve 70 percent of a household's heating load and require a three-ton system.[4] Finally, we assumed that pellet boilers would include thermal storage and that solar hot water systems would have two collectors and serve 70 percent of a household's hot water load.

For multi-family cost estimates, we scaled single-family cost estimates based on the economies of scale seen in regional rebate databases and on used cost factors noted in stakeholder interviews. We sourced commercial space heating equipment costs from the midpoint of the ranges displayed in the 2012 Massachusetts DOER Heating and Cooling in the Massachusetts Alternative Portfolio Standard report (2012 MA DOER H&C report)[2], and we assumed commercial SHW costs to be equivalent to multi-family costs given the similar hot water load. A summary of the average installation costs for single-family, multi-family, and commercial buildings is presented in Table 1. [5]

All of the analyses used these static costs, with the exception of one sensitivity analysis conducted as part of the cost-effectiveness assessment in which we assumed a 20 percent cost reduction.

Table 1. Assumed Average RE Thermal Costs (per Building)

Technology	Single-family	Multi-family	Commercial
ASHP	$11,780	$29,450	$71,900
GSHP	$35,000	$87,500	$213,800
Pellet Boiler	$22,561	$56,400	$120,000
SHW	$9,482	$23,710	$23,710

We based program incentive levels for the large-scale RT investment scenario on those currently in place in the rebate programs offered in Massachusetts by the Massachusetts Clean Energy Center (MassCEC).[3] Current MassCEC rebate levels are:

- ASHPs: $625 per single-head system
- GSHPs: $1,500 per ton of system capacity
- Biomass Boilers: 45 percent of project cost up to $10,000.
- SHW: Calculated value multiplying $100 by the Solar Rating & Certification Commission OG-100 product rating, multiplied by the number of collectors, up to 40 percent of project cost.

For ASHPs, we used an average heating seasonal performance factor (HSPF) of 11. This is based on the current equipment list approved by the Northeast Energy Efficiency Partnerships (NEEP) for certification in its cold climate ASHP standard.[4] GSHPs were given a seasonal coefficient of

[2] Installation scenarios where ASHPs served the full load of a household (with an integrated backup system in the form of an electric resistance heater or gas heater) were also considered but ultimately excluded from the analysis due to the wide degree of variability in these installations. This means that the analysis results are very conservative for some ASHP installations because ASHP is sometimes chosen over a standard fossil-based heating system without a backup heating system or with an inexpensive electric resistance heater. This is particularly applicable for new construction or major renovations. In such cases, the cost of an ASHP is its incremental cost beyond the cost of the standard system instead of the full cost of the ASHP. Further, this analysis did not quantify the cooling benefits from ASHP and GSHP, which renders the analysis results even more conservative for these technologies.

[3] Installation costs for residential fossil fuel-based, standard heating systems were obtained from HomeAdvisor's website.

[4] One refrigerant ton of heat pump capacity equals 12,000 Btu (or about 3.5 kW).

[5] For more recent and comprehensive RT cost data, see New York State Energy Research Development Authority (NYSERDA) *Renewable Heating and Cooling Policy Framework: Options to Advance Industry Growth and Markets in New York*. February 7, 2017, available at http://www.synapse-energy.com/project/renewable-heating-cooling-technical-assistance-new-york-state-research-and-development.

performance (COP) of 4.1 based on the closed-loop ENERGY STAR standard. For solar hot water heaters, we used a Solar Rating & Certification Corporation OG-100 rating of 13.7 based on the average seen in the MassCEC rebate program to date. We assumed wood pellet boilers have a heating efficiency of 85 percent and that wood chip boilers have an efficiency of 80 percent, figures based on stakeholder group feedback.

Building Assumptions

We separated buildings into the residential single-family, residential multi-family, and commercial sectors. For average building square footage and thermal energy consumption, we used data from the Energy Information Administration's (EIA) building energy consumption databases.[5],[6] Recognizing the difficulties of determining standard measure inputs for large commercial customer applications, this analysis only considers small commercial buildings under 20,000 square feet (1,858 square meters).

Table 2. Average Thermal Load per Building

Sector	Building Square Footage (Square Meter)	Space Heating Annual MMBTU (MWh)	Water Heating Annual MMBtu (MWh)
Single-family	2100 (195)	65 (19)	10 (2.9)
Multi-family	5000 (465)	219 (64.2)	36 (10.6)
Commercial	15800 (1,468)	535 (156.8)	33 (9.7)

Heating Fuel Prices and Avoided Costs

Where appropriate, we turned to the 2015 regional *Avoided Energy Supply Costs in New England* (AESC) report as a source for fuel prices.[7] More specifically, the AESC report supplied avoided energy costs and wholesale supply costs for electricity and natural gas. For the distribution components of electricity and natural gas retail rates, we used current National Grid retail tariffs. A database maintained by the Rhode Island OER provided fuel oil prices and avoided costs. Finally, based on feedback from the stakeholder working group, we used prices of $250 per ton for wood pellets and $125 per ton for wood chips. The analysis escalated both oil and wood fuel prices according to the escalation factors included in the AESC report.

Administrative Costs

We estimated administrative costs based on the ratio of administrative to incentive spending planned by National Grid in its 2016 Rhode Island Energy Efficiency Program Plan.[8] In the 2016 Plan, National Grid budgets for non-incentive cost expenditures that are 44 percent of the value of the program incentives provided, and we assumed that a RT program in Rhode Island would experience a similar rate of non-incentive spending.

Cost-Effectiveness Analysis

Our economic impact analysis evaluated cost-effectiveness of the four RT technologies from a few different perspectives. To accomplish this, we used three standard cost-effectiveness tests called the Total Resource Cost (TRC) test, the Program Administrator Cost test, and the Participant Cost test. These tests are often used to evaluate cost-effectiveness of ratepayer-funded energy efficiency programs in the United States.[6] This paper focuses on the results based on the Rhode Island TRC test. The TRC test evaluates costs and benefits in net present values from the system-wide perspective, which includes all costs and benefits experienced by program participants and non-participants. More specifically, TRC benefits and costs included in this analysis are as follows:

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[6] For best practices in cost-effectiveness screening, please see Synapse Energy Economics, *Benefit-Cost Analysis for Distributed Energy Resources: A Framework for Accounting for All Relevant Costs and Benefits*. September 2014, available at http://www.synapse-energy.com/sites/default/files/Final%20Report.pdf. For examples of how energy efficiency programs are evaluated, see Synapse Energy Economics, *Energy Efficiency Cost-Effectiveness Screening in the Northeast and Mid-Atlantic States*. October 2013, available at http://www.synapse-energy.com/sites/default/files/SynapseReport.2013-10.NEEP_.EMV-Screening.13-041.pdf.

- **TRC benefits**: Avoided costs of fossil fuel use, environmental compliance costs,[7] demand-reduction induced price effects (DRIPE),[8] and non-energy benefits (such as improved home comfort and increased property values).[9]

- **TRC costs**: The incremental cost of installed RT equipment (where appropriate), administrative costs of managing an RT incentive program, the added fuel and electricity costs of RT technologies, as well as any DRIPE associated with the added electricity costs.

As mentioned above, we used full system costs for SHW and ASHP given our assumption in this scenario that residents and businesses keep their existing heating equipment as a backup or a supplemental heating source.

The results of the TRC analysis show that an RT portfolio that grows to 5 percent of Rhode Island's thermal load by 2035 can be expected to yield $1,240 million in gross lifetime benefits with $200 million in lifetime net benefits for the state. This results in a benefit-cost ratio of 1.18, as shown in Figure 2. TRC costs are split nearly evenly between measure installation costs and added energy costs (primarily heat pump electricity consumption with some wood pellet or chip consumption included). Administrative costs account for the small remainder. TRC benefits mainly consist of avoided energy costs, with quantified non-energy benefits providing most of the remainder.[10] Lastly, it is important to note that external environmental impacts and employment impacts are not quantified in the Rhode Island TRC and thus are not included here (though they are quantified separately and discussed in the sections below).

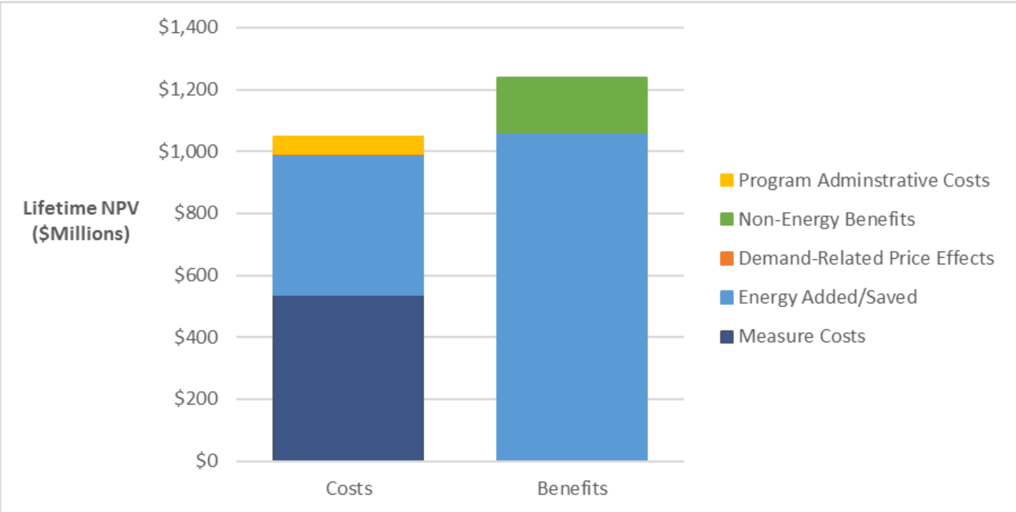

Figure 2. Stacked TRC Costs and Benefits

A separate sensitivity analysis evaluated how results may change in several potential scenarios as follows:

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[7] Environmental compliance costs are based on the AESC study and include expected CO_2 allowance costs under the Regional Greenhouse Gas Initaitive (RGGI). The compliance price starts at about $6 per short ton in 2015 and gradually increases to $34 per short ton by 2030.

[8] DRIPE refers to short-term market price-suppression effects that decreased energy usage will have on the wholesale energy prices. As demand will decrease, prices are expected to decline slightly for all ratepayers. However, for ASHP and GSHP, DRIPE is used to increase wholesale electricity market prices as they increase electricity use during the winter time. No price suppression effect was assumed for fuel oil, given the global nature of the market.

[9] Specific non-energy benefits included in this analysis are based on the values used for assessing cost-effectiveness of National Grid Rhode Island efficiency programs.

[10] Rhode Island has adopted two cost-effectiveness screening best practices for the TRC test: a discount rate less than 1 percent and the quantification and inclusion of non-energy benefits. If Rhode Island had not adopted such policies, like many other jurisdictions that use a higher discount rate and ignore NEBs, the results of this analysis might not provide positive lifetime net benefits.

- **A reversion to 2013 fossil fuel prices**. The prices of fuel oil and natural gas are primary drivers of the economic viability of RT technologies. This is particularly notable for fuel oil which, as a more expensive fuel than natural gas, presents a better financial opportunity for conversion to RT. In recent years, the price of fuel oil has declined substantially, limiting the cost-effectiveness of RT technologies. This scenario considers cost-effectiveness of RT, if the recent price decrease in fossil fuels were reversed, by utilizing 2013 fossil fuel prices (which entails an increase in the price of fuel oil of roughly 50 percent).

- **A 20 percent reduction in RT installation costs**. Another key driver of RT cost-effectiveness is a reduction in the installed costs of RT technologies, either as a natural result of market growth or as driven by policy intervention. This scenario considers a hypothetical installed cost reduction of 20 percent.

- **The interaction of the two above effects**.

As shown in Table 3, each of these scenarios represents an improvement in the benefit-cost picture compared to the base case discussed above, with the greater impact coming from a return to 2013 fossil fuel prices. This reflects the central role that oil prices have in determining the opportunities for cost-effective RT market growth in Rhode Island.

If the recent decline in oil prices were to reverse, and RT installation costs were also to decline 20 percent through either hard or soft cost reductions, the overall benefit-cost ratio of the portfolio of RT installations would increase to 1.80. The state’s net lifetime benefits would increase to over $740 million.

Table 3. Sensitivity Analysis on TRC Cost-Effectiveness

Sensitivity Scenario	Lifetime Benefits	Lifetime Costs	Lifetime Net Benefits	Benefit-Cost Ratio
Base Case	$1,239,572,340	$1,046,388,849	$193,183,491	1.18
2013 Fossil Fuel Prices	$1,670,366,899	$1,046,389,287	$623,977,611	1.60
Reduced RT Costs	$1,239,572,340	$926,494,420	$313,077,920	1.34
Interaction of Effects	$1,670,366,899	$926,494,858	$743,872,040	1.80

Table 4 shows measure level results that aggregate sector-specific results. RT systems replacing fuel oils resulted in better economics than other systems, while RT systems replacing natural gas are often not cost-effective. Under the sensitivity case that combines impacts of 2013 fossil fuel prices and reduced RT costs, the economics of RT systems replacing fuel oil improves substantially with positive net benefits across all systems. At the same time, their economics replacing natural gas still result in a benefit-cost ratio of less than 1.0. However, if avoided emissions values are included in this economic analysis, it is likely some ASHP systems will become cost-effective against natural gas fuels. Furthermore, the ASHP systems installed as part of major renovations and new construction—not considered in this analysis—are expected to be highly cost-effective against natural gas when they avoid the installation of new natural gas heating systems. Finally, if we include the benefits of cooling from ASHP and GSHP, or if we allocate the installed costs assumed for these technologies between heating and cooling services, the economics of ASHP and GSHP improve further.

Table 4. TRC Results at Measure Level for the Base Case and Sensitivity Case

Technology	Base Case			Sensitivity Case		
	Electric	Gas	Oil	Electric	Gas	Oil
ASHP	1.39 - 3.26	0.66 - 0.83	1.42 - 1.66	1.59 - 3.68	0.78 - 0.98	2.41 - 2.68
GSHP	0.62 - 1.99	0.4 - 0.44	0.83 - 1.01	0.75 - 2.49	0.5 - 0.56	1.46 - 1.84
Pellet Boiler		0.38 - 0.48	0.86 - 1.05		0.43 - 0.56	1.35 - 1.75
Solar hot water	0.58 - 1.72	0.37 - 0.53	0.96 - 1.38	0.72 - 2.15	0.46 - 0.64	1.75 - 2.52

Green cells indicate all systems are cost-effective. Orange cells indicate all systems are not cost-effective. Yellow cells indicate mixed results.

Rate and Bill Impact Analysis

We analyzed rates and energy bills to assess ratepayer impacts from the alternative thermal energy scenario. Expected rate changes from the alternative thermal energy scenario only show a partial picture of the entire impact. Customers care about rates, but their ultimate concern is the amount on their utility bills. Thus, the ratepayer impact analysis investigated both rate and bill impacts.

Rate Impact Approach

We estimated rate impacts from the RT policy scenario by comparing the expected electricity and natural gas rates for a business-as-usual (BAU) scenario and for the RT policy scenario. The expected annual energy rates for the RT policy scenario ("RT annual energy rates") are calculated simply by dividing expected annual revenues ("RT annual revenues") by expected annual energy sales ("RT annual sales") under the scenario as follows:

$$\textit{RT annual energy rates} = \frac{RT\ annual\ revenues}{RT\ annual\ sales}$$

Where,

RT annual revenues = BAU revenues +/- expected system cost changes due to RT

RT annual sales = Adjusted sales due to RT

Develping a revenue forecast for the RT policy scenario started with developing a BAU revenue forecast using estimates of future BAU sales and total retail rates through 2055.[11] The data for this sales forecast were from the most recent historical sales data and from EIA's annual growth rate projection for the New England region.[12][9] To forecast retail rates, we escalated the current full retail rates by the projected avoided energy cost escalation rates. The avoided retail energy costs consist of (a) avoided energy supply costs based on the 2015 AESC study and (b) avoided delivery costs based on National Grid's current tariffs for electricity and natural gas, which are conservatively estimated to increase at a rate of 1 percent per year.

We then estimated a revenue forecast for the RT policy scenario by taking into account expected system cost changes to the BAU revenue forecast for electricity and natural gas under the RT policy scenario. Likely cost changes consist of those due to (a) sales increases and the decrease of various fuels associated with the RT portfolio of installation, as well as (b) the expected recovery of program costs through an added ratepayer charge on a customer's electricity bill. The surcharge for RT technologies is set at the same level in terms of cents per kWh for residential and commercial customers.

We based the expected system cost changes on the AESC avoided costs. Decreased natural gas sales will provide system benefits in the form of avoided energy costs, thereby decreasing revenue. In

[11] Revenue data used in this analysis represent all electricity revenue including electricity supply, transmission, and distribution.

[12] EIA provides sales forecast through 2040. After 2040, we escalated sales based on the average annual sales growth rate in the last five years of the EIA forecast.

contrast, increased electricity sales will result in increased system costs, which in turn will increase revenue requirements to some extent.

Bill Impact Approach

The bill impact analysis considers both changes in rates and changes in customers' consumption patterns. This provides a better indication of a new policy's impact on customers. Non-participant bill impacts show bill impacts experienced by utility customers who do not install RT systems. These impacts take into account all of the expected rate impacts discussed above. Participants experience the same rate impacts but have mitigated those impacts by adjusting their consumption levels through the installation of RT systems.

Our analysis estimated non-participant average annual energy bills for all customers by sector. Average annual bills were estimated based on the expected average energy use by customer by sector, and on the estimated rates in the BAU and policy cases. We estimated the average energy use by sector by dividing the BAU sales forecast by the BAU customer forecast by sector. We then forecasted BAU sales based on the most recent historical sales data and EIA's annual growth rate projection for the New England region.[9] Using the most recent customer data based on EIA statistics, we forecasted the BAU customer counts and projected it using the average growth rate in customers from the previous five years.[10]

Rate Impact

Overall, estimated changes in electricity and natural gas rates are negligible. Natural gas residential rate impacts start at a very small scale and peak at 1.1 percent in 2035, with a long-term average impact of about 0.5 percent. At different time periods, the impacts range from less than 0.2 cents per therm (or 0.1 percent) in the first 10 years to about 1.3 cents per therm (or 0.7 percent) in the second 10 years (Table 5). The natural gas rate impacts on commercial customers are considerably smaller because the commercial program scale is quite small. Natural gas commercial rate impacts peak at about 0.1 percent in 2035 and range from less than 0.1 cents per therm (or 0.01 percent) in the first 10 years to about 0.12 cents per therm (or 0.08 percent) in the second 10 years (Table 5). The long-term average rate impact for commercial gas customers is about 0.1 percent.

Table 5. Natural Gas Rate Impact Results

	Residential		Commercial	
	Cents/Therm ($2015)	% change	Cents/Therm ($2015)	% change
First 10 Years	0.18	0.11%	0.01	0.01%
Second 10 Years	1.34	0.72%	0.12	0.08%
Remaining Years	1.35	0.62%	0.17	0.06%
All Years	1.01	0.51%	0.08	0.05%

Figure 3 shows annual residential electric rate impacts. Our analysis assumed program costs will be recovered through a system benefit charge (SBC) (in cents per kWh) placed on both residential and non-residential electric customers' bills.[13] This charge gradually increases from zero in 2017 to about 0.3 cents per kWh (or about 1.3 percent relative to a BAU rate) in 2035, the year in which new installations are assumed to end. The downward pressure on rates from increased electricity sales is expected to peak in 2035, before gradually decreasing through 2055. This reduction in rates will absorb about half of the SBC's upward pressure, keeping the maximum net rate impact at about 0.07 cents per kWh. Throughout the entire study period, the average net electric rate impact for residential customers is -0.07 cents per kWh or a 0.3 percent decrease.

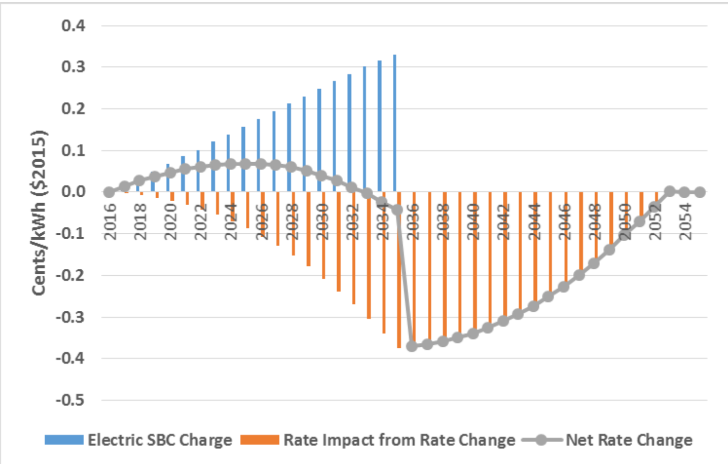

Figure 3. Residential Electric Rate Impacts

Figure 4 shows expected commercial electric rate impacts. Overall, the impact for commercial customers is likely greater than the impact for residential customers. This is primarily because electricity sales increases due to the commercial program are significantly smaller than those due to the corresponding residential program. Yet commercial SBCs are essentially the same as residential SBCs. The figure shows that the maximum SBC charge is about 0.33 cents per kWh in 2035, while the maximum downward pressure on rates from increases sales is just about -0.1 cents per kWh. Throughout the entire study period, the average net electric rate impact for commercial customers is slightly positive, at about 0.05 cents per kWh or a 0.2 percent increase.

[13] A system benefit charge is a typical funding mechanism for utility energy efficiency programs across the Untied States. Annual SBC is estimated by dividing the expected program costs by the expected electricity sales for each year.

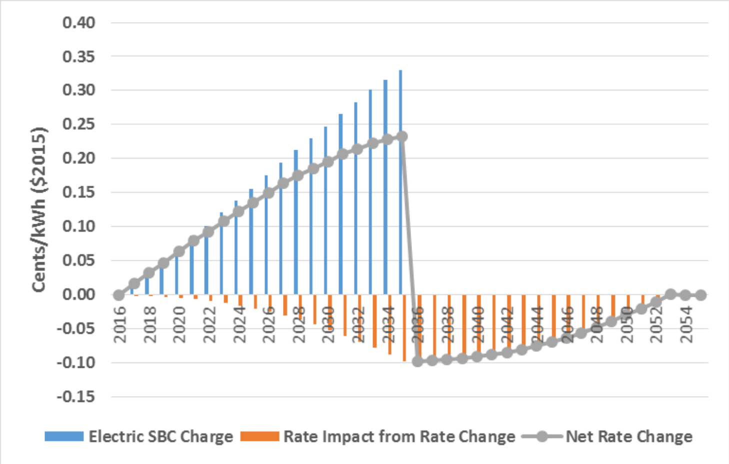

Figure 4. Commercial Electric Rate Impacts

Non-Participants Bill Impact

To calculate the non-participant bill impacts for natural gas and electricity, we used the rate impacts estimated above and data on average monthly energy consumption. First, we estimated bill impacts for the electricity and natural gas sectors separately. We then combined these to present a full bill impact analysis for customers who use both electricity and natural gas. For customers who use oil for space heating, the electric bill impacts represent the full bill impact from the RT policy scenario because oil prices are not expected to change.

Table 6 provides the results of this analysis. Throughout the study period, the average change in bills for residential non-participant electric customers is negligible, with an overall bill decrease of about 0.26 percent (or about $4 per year). The average change in bills for commercial non-participant electric customers is about a 0.23 percent increase (or about $24 per year). These results represent a complete bill impact for oil heating customers. For residential customers who use both electricity and natural gas, the bill impact is negligible with about a 0.1 percent increase (or about $3). For commercial customers, the average combined bill impact is also small, with a 0.15 percent increase (or about $28).

Table 6. Natural Gas and Electric Bill Impacts Results for Non-Participants

	Natural Gas Bill		Electricity Bill		Combined Bill	
	%	$ per year	%	$ per year	%	$ per year
Residential	0.50%	$7	-0.26%	-$4	0.10%	$3
Commercial	0.05%	$4	0.23%	$24	0.15%	$28

Employment Impact Analysis

IMPLAN Model Approach

We based our employment impacts analysis on projected cost inputs, the bill impact analysis, and the IMPLAN model.[14] To translate these inputs into job impacts in Rhode Island, we used this information along with state-specific data from the IMPLAN model. The measure-specific spending informed the “direct impacts” estimate, which represents new jobs at RT measure installation sites. These impacts represent the increased labor from installing the RT measures minus the reduction in labor from standard measures that were not installed as a result of the RT program. The IMPLAN model also estimated the spin-off activity from both RT and standard equipment installations, including (1) “indirect impacts,” which comprise equipment and services needed to support the installation but that are not directly related to installation labor and (2) “induced impacts,” which occur when contractors

[14] IMPLAN is a standard commercial input-output model that is used in assessing economic impacts across the United States.

spend their wages and customers spend their savings. Where contractors and consumers spend these dollars determines the impacts on the state.[15]

To determine the breakdown of labor and equipment costs for standard measures that would have been installed absent the RT case (e.g., gas furnaces), we drew on cost data for RT and standard measures, as well as on a breakdown of labor and equipment costs for RT measures. We used net labor spending (new labor spending minus avoided labor spending on standard installations) to calculate direct job impacts for installation, assuming the average wages from relevant industries.[16] Modeling of labor income captured the impacts of contractors spending their income in Rhode Island. The net spending on equipment (new RT equipment minus avoided spending on standard equipment) was assigned to specific IMPLAN industries in order to capture the impacts of equipment purchases in Rhode Island.[17]

The analysis also took into account the shifts in fuel spending caused by the program, but determined that changes in electricity and natural gas demand would have little to no effect on Rhode Island jobs for several reasons.[18] However, changes in demand for fuel oil and wood pellets would have an effect on jobs because each delivery requires more labor. Therefore, this analysis assumed that jobs changed commensurately with increases or decreases in volume of these fuels. Fuel oil jobs lost were based on the historical jobs per million gallons delivered in Rhode Island multiplied by the fuel oil savings attributed to the program.[19] Our analysis also assumed that oil and wood delivery jobs were equivalent on a weight basis.[20] These two activities have a slightly negative net impact on the state's economy because the program creates a large reduction in oil delivery but only a small amount of new demand for wood pellets.

Shifts in customer spending due to the program also impact jobs. By estimating economic impacts from customer savings using a bill impact analysis, along with an estimate of the out-of-pocket costs for participants, the IMPLAN model captured the full costs paid by customers.

Finally, based on the share of program costs dedicated to administration of the program, we estimated direct job impacts in Rhode Island associated with running the program and modeled the total impact from these jobs in the state.

Job Impact

Figure 5 shows the results of the employment impact analysis, indicating that both residential and commercial RT programs increase employment in Rhode Island. Between 2017 and 2055, residential programs have the greater impact with 165 average annual jobs. Commercial programs generate 32 average annual jobs. Job impacts peak in the mid to late 2030s—toward the end of the program period—as an increasing amount of measures are installed through 2035. After 2035, there are no new measure installations but impacts persist as consumers spend their savings in the state economy. These savings impacts diminish through the end of the analysis period as the measures installed earlier expire.

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[15] For best practices in employment impact modeling, please see Bower et al. *Economic Impacts of Efficiency Spending in Vermont: Creating an Efficient Economy and Jobs for the Future*. 2012. ACEEE Summer Study on Energy Efficiency in Buildings, available at http://aceee.org/files/proceedings/2012/data/papers/0193-000157.pdf

[16] Average income values were derived from the following IMPLAN industries: "maintenance and repair construction of residential structures" for residential installations, and "maintenance and repair construction of nonresidential structures" for commercial installations.

[17] The IMPLAN industry "heating equipment (except warm air furnaces) manufacturing" was used for boiler and solar hot water equipment. For furnace, ground-source heat pump, and air-source heat pump equipment, the IMPLAN industry "air conditioning, refrigeration, and warm air heating equipment manufacturing" was used.

[18] First, Rhode Island has no natural gas production and, second, jobs associated with the distribution of natural gas and electricity do not fluctuate with volume distributed.

[19] US County Business Patterns data (http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl) provided the number of fuel oil delivery jobs, and the Energy Information Administration (EIA) form 821 databases (https://www.eia.gov/dnav/pet/pet_cons_821use_dcu_SRI_a.htm) provided fuel oil volume. The jobs factor was based on the 5.65 jobs per million gallons delivered in the 2014 and 2015.

[20] The weight of fuel oil is 7 pounds per gallon. Along with the 5.65 delivery jobs per gallon, this leads to a factor of 1.61 jobs per thousand tons.

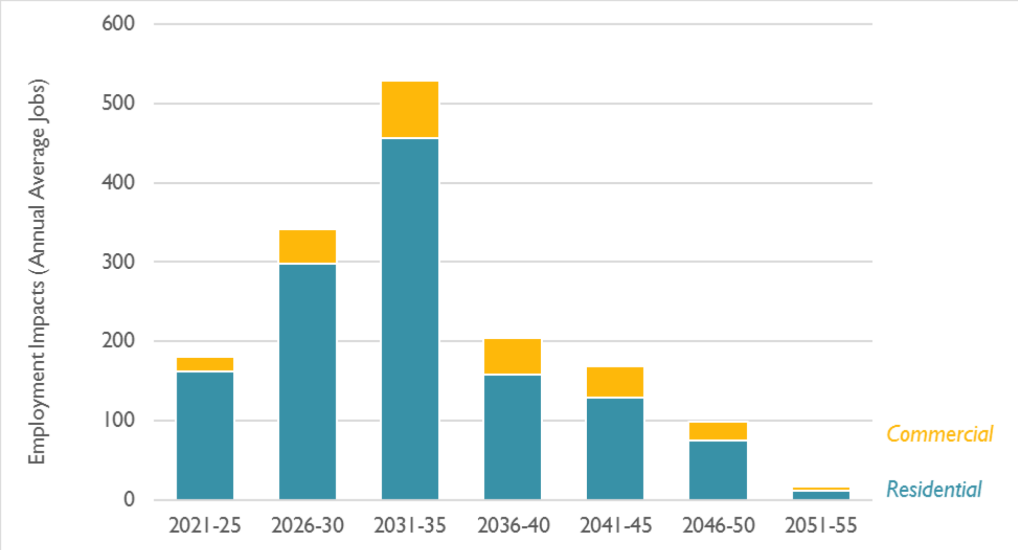

Figure 5. Average Annual Job Impacts by 5-Year Period (2021-2055)

Emission Analysis

Emission Impact Approach

Regarding carbon emissions, we modeled impacts for the portfolio of RT projects by deriving technology-specific carbon emissions factors associated with both baseline and RT equipment.

For electricity impacts, we used the U.S. Environmental Protection Agency's Avoided Emissions and Generation Tool (AVERT). [11] AVERT models the expected change in electricity consumption occurring in each hour of the year and compares this to the emissions rate of the marginal generating plant active in the region in that hour. To calculate natural gas and fuel oil emissions impacts, we used emissions factors listed by EIA on its CO_2 FAQ website [12].

In addition, our analysis separated electricity impacts into emissions increases (installation of ASHPs and GSHPs) and emissions reductions (conversion from electric resistance heat).[21] Given the wide degree of variability in emissions from and emissions accounting frameworks for bioenergy projects and the resulting inconsistency in emissions estimates, we did not include biomass installations in this emissions analysis.[22]

These avoided emissions are estimated based on static hourly electricity avoided emission rates in 2015 from AVERT. Future electricity emissions will likely be less than the outputs of the AVERT model, as we can reasonably expect the emissions per unit of electricity consumption to decrease over time as Rhode Island and other regional states pursue renewable energy targets. Therefore, this emissions impact analysis yields a conservative result; the future emissions of ASHP and GSHP units that lead to a net increase in electricity consumption will likely be less than what is projected by the AVERT model today.

Emissions Impact

Over the lifetime of the measures included in the base model (target 5 percent of thermal load), RT installations would result in a carbon dioxide (CO_2) emissions reduction of 2.2 million short tons, or an

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[21] Emissions impacts related to biomass installations were not modeled due to the wide variety of emissions impact categories and the difficulty of accurately measuring emissions impacts. The expected contribution of biomass conversions to overall emissions impacts would be minor given the small number of wood boilers included in the RT project portfolio in this analysis. This analysis also did not take into account emissions changes in GHGs other than CO_2, and did not account for potential GHG emissions associated with losses in the natural gas distribution system.

[22] For a detailed discussion of emission accounting frameworks for biomass, see Synapse Energy Economics, The Carbon Footprint of Electricity from Biomass, 2012, available at http://www.synapse-energy.com/sites/default/files/Carbon-Footprint-of-Biomass-11-056.pdf

average of just less than 60,000 short tons per year from 2017 to 2054. Emissions reductions would peak in 2035, with a reduction of 127,000 short tons of CO_2.[23]

Over the life of the program, converting to RT technologies from fuel oil equipment would avoid 4.19 million short tons of CO_2, converting from electric resistance heat would avoid 860,000 short tons of emissions, and reductions in natural gas consumption would avoid 444,000 short tons (see Figure 6). These emissions reductions would be partially offset through 1.925 million short tons of added emissions from increased electricity consumption due to newly installed heat pumps over the life of the project portfolio.

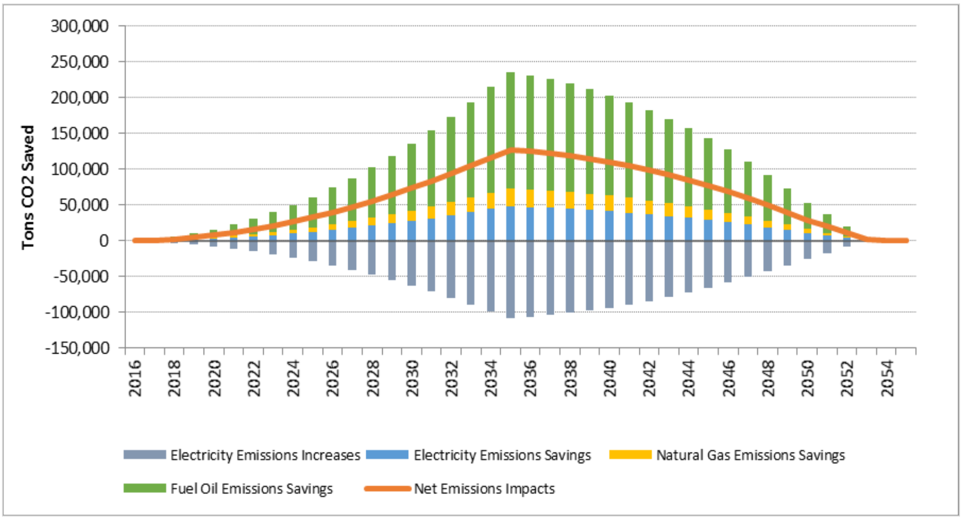

Figure 6. Annual Emissions Impacts by Year (Short Tons)

Conclusion

Statewide, our analysis shows the 5 percent impact portfolio accruing nearly $200 million in lifetime Net Present Value (NPV) economic benefits to the state of Rhode Island, as measured by the Rhode Island TRC. In a scenario in which RT technology costs were to decline by 20 percent through hard or soft cost reductions, the lifetime net economic benefit to the state would increase by 62 percent to $313 million. In a scenario in which the global fossil fuel prices were to recover from the recent collapse, net statewide economic benefits would increase by 323 percent to $624 million.

In the base analysis, such a portfolio of RT projects would require $193 million in statewide funding (cumulative, undiscounted) through 2035 for program incentives and non-incentive costs (which are accounted for in the calculation of net state economic benefits). This analysis assumes these costs would be provided through a system benefit charge for statewide energy ratepayers.

Financial impacts on non-participating ratepayers would be minimized, however, by the electricity load-building nature of the RT portfolio, which includes large numbers of ASHP and GSHP installations. To put it plainly, the electrification of space and water heating means more electricity sales for utilities even as efficiency improves. Through the combination of an added systems benefit charge to recover program costs, downward pressure on electricity rates due to increased electricity load, and upward pressure of natural gas rates due to decreased natural gas load, residential energy costs for combined electricity-natural gas ratepayers not participating in the RT program would increase by an average of about 0.1 percent to 0.15 percent during the program impact period. In contrast, bill impacts for residential oil customers, solely based on expected electric bill impacts, are expected to decline very slightly at about 0.26 percent on average. These impacts are likely to increase slightly for commercial oil customers at about 0.23 percent on average.

[23] One short ton equals approximately 0.9 metric tons.

In addition to direct financial impacts, this portfolio of RT installations will likely contribute to state job creation efforts. Our analysis found that such an investment in RT in Rhode Island would lead to an average net increase of 197 jobs in the state during the program impact period.

Finally, such a portfolio of RT installations would lead to a net reduction of 2.2 million short tons of CO_2 emissions during the program impact period—an average reduction of 60,000 short tons per year.

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