

**STATE OF RHODE ISLAND
ENERGY FACILITY SITING BOARD**

In re: Sea 3 Providence, LLC Petition for Declaratory
Order Regarding the Rail Service Incorporation Project
(Providence, RI)

Docket SB-2021-03

**CONSERVATION LAW FOUNDATION'S
LIST OF EXHIBITS**

CLF-1

Brattle Group, *Heating Sector Transformation in Rhode Island* (2020), available at
<http://www.energy.ri.gov/documents/HST/RI%20HST%20Final%20Pathways%20Report%205-27-20.pdf>. Filed Nov. 12, 2021.

CLF-2

Office of Governor Daniel J. McKee and Office of Lt. Governor Sabina Matos, *Rhode Island
2030: Charting a Course for the Future of the Ocean State* (2021) (working draft), available at
https://www.ri2030.com/_files/public/RI%202030_final.pdf. Filed Nov. 12, 2021.

CLF-3

R.I. Dep't of Env'tl. Mgmt., *2016 Rhode Island Greenhouse Gas Emissions Inventory* (2019),
available at <http://www.dem.ri.gov/programs/air/documents/ghg-emissions-inventory-16.pdf>.
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Heating Sector Transformation in Rhode Island

Pathways to Decarbonization by 2050

PREPARED FOR

Rhode Island Division of
Public Utilities and Carriers

Rhode Island Office of
Energy Resources

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NOTICE

- This report was prepared by The Brattle Group, with support from Buro Happold and Jens Ponikau of Buffalo Geothermal Heating, for the **Rhode Island Office of Energy Resources (OER)** and the **Rhode Island Department of Public Utilities and Carriers (DPUC)**. It is intended to be read and used as a whole and not in parts. The report reflects the analyses and opinions of the authors and does not necessarily reflect those of The Brattle Group’s clients or other consultants.
- We are grateful for the valuable contributions of Senior Research Analyst Maria Castaner, the OER, DPUC, the Governor’s office, and the many stakeholders who participated in the process.

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Executive Summary

As part of Rhode Island’s commitment to economy-wide decarbonization, this report examines solutions to transform the state’s heating sector. Dominated by space heating for the residential and commercial sectors, but also including water heating and industrial heating, the heating sector represents approximately one-third of the state’s overall greenhouse gas emissions.¹

There are many solutions for decarbonizing the heating sector, but they fall into three broad categories:

1. Reducing energy needs by improving building energy efficiency
2. Replacing current fossil heating fuels with carbon-neutral renewable gas or oil
3. Replacing current fossil-fueled boilers and furnaces with electric ground source or air source heat pumps powered by carbon-free electricity

The industrial sector may need other types of solutions, which can be very application-specific.

To transition to decarbonized heating fast enough to meet mid-century decarbonization targets, Rhode Island will need substantial policy support. The reasons include low fossil fuel prices (particularly for

natural gas), which also do not reflect the social costs of greenhouse gas emissions; switching to electrified heating solutions requires substantial initial costs for equipment and installation compared to replacing boilers or furnaces; and other more qualitative factors such as information deficits, immature supply chains, a natural reluctance by consumers to change what seems to work well.

Rhode Island must base its policy framework for heating sector transformation on an understanding of the relative economic attractiveness of various decarbonization solutions. **Figure ES 1** shows the projected range of average annual heating costs in 2050 for a representative existing single-family home in Rhode Island, using existing fossil fuels (on the left) or several alternative decarbonized heating solutions (on the right). This figure shows two key insights:

1. For natural gas customers, who represent the majority of heating customers in the state, all of the decarbonized heating solutions will likely result in some increase in overall heating costs. This is less clear for fuel oil and propane customers. However, customer adoption of no-to-low carbon heating solutions will not take place in isolation. Viewing heating transformation within the context of broader decarbonization efforts across the electric

¹ Although not directly a part of the heating sector, cooling will also play a role in the heating sector transformation since some heating equipment (notably heat pumps) can also provide cooling.

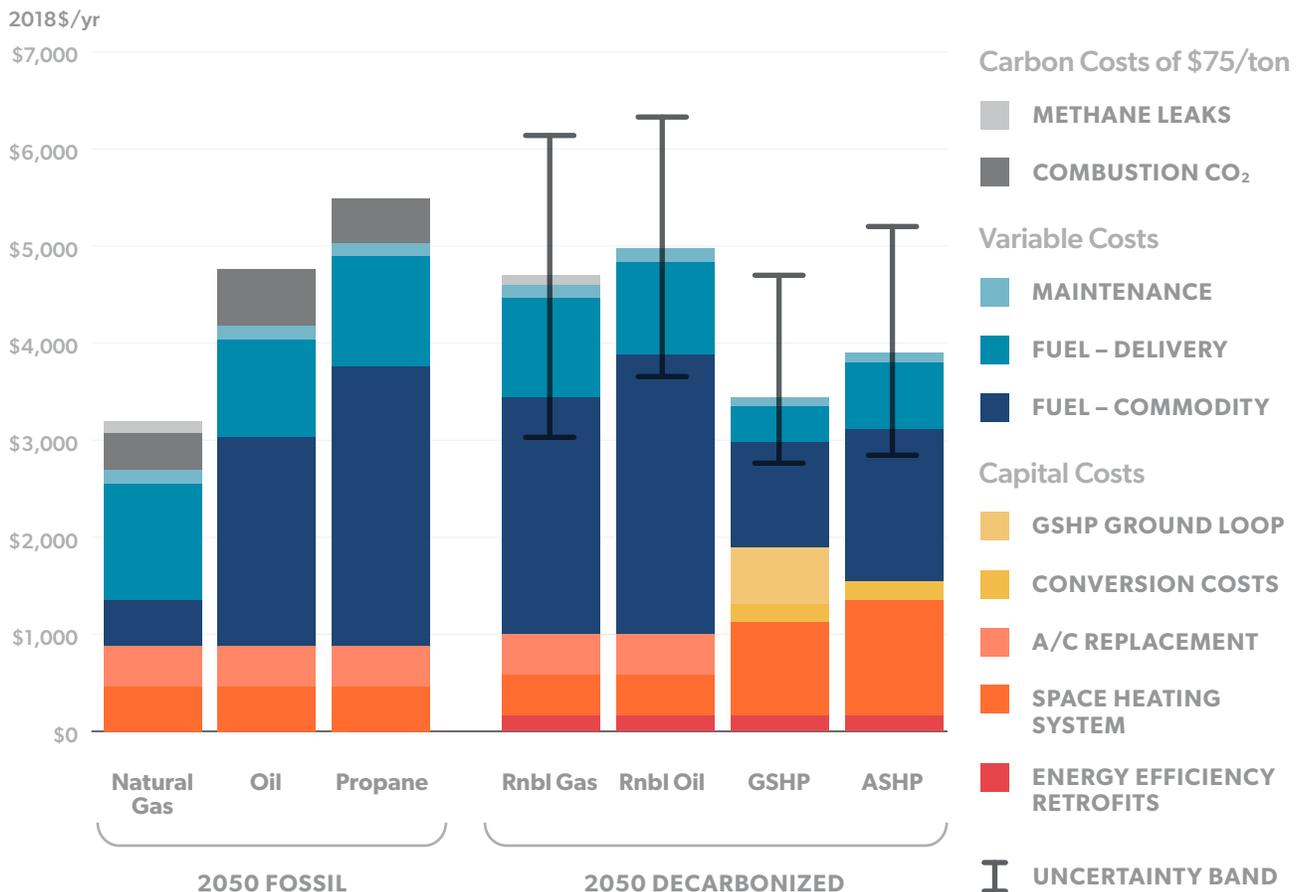


FIGURE ES 1: ANNUALIZED COST OF SPACE HEATING IN 2050, REPRESENTATIVE SINGLE-FAMILY HOME, BOOKEND SCENARIOS, 2018\$

and transportation sectors, total consumer energy expenditures are likely to be similar to what is paid today in a fossil fuel-based system.

- From today's perspective, no single solution is clearly more economically attractive than the others. This is due to the high uncertainty related to how the costs of all decarbonized heating solutions will evolve over the coming decades. The heights of the bars themselves are less important than the uncertainty bands around them (represented by black bands extending above and below the tops of the bars). These uncertainty bands are largely overlapping for the decarbonized technologies, indicating that it is not clear at this point which of these technologies will be most economical in the long run.

The analysis in **Figure ES 1** assumes that as part of decarbonizing the heating sector, cost-effective

energy efficiency measures such as air sealing and attic insulation will be implemented in essentially all Rhode Island buildings. Doing so lowers the challenge to decarbonize heating and saves consumers money, which is relevant for all consumers and may be particularly important for disadvantaged communities.

This particular analysis is based on a set of "bookend" scenarios that assume for each decarbonized technology that this technology provides all heat across New England. It compares cases where fuels (gas and oil, in renewable forms) continue to primarily provide heat; or for electric heat pumps, assumes 100% adoption of either ground source heat pumps (GSHPs) or air source heat pumps (ASHPs). This captures the potential impacts of these technologies on the region's overall energy systems. For instance, the economic attractiveness of electric heat pumps

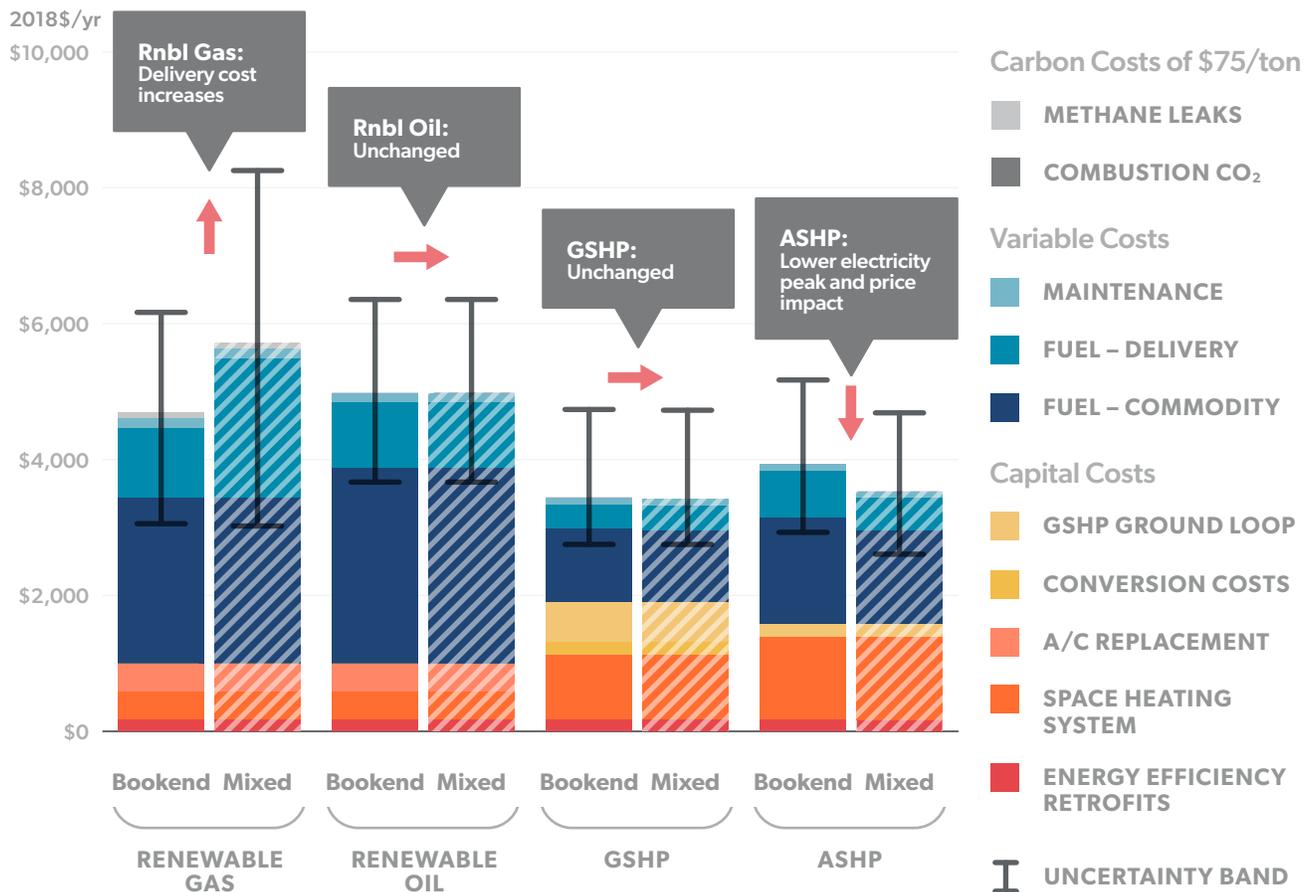


FIGURE ES 2: ANNUALIZED COST OF SPACE HEATING IN 2050, REPRESENTATIVE SINGLE-FAMILY HOME BOOKEND VERSUS MIXED SCENARIOS, 2018\$

depends in part on the cost of (clean) electricity, which in turn depends on the impact that heat pumps will have on the electric system. Heat pumps themselves represent a substantial demand for electricity and can affect the price of power. Similarly, the attractiveness of renewable gas depends on its cost, which depends on the total gas volume demanded regionally and nationally, since low-cost supplies are limited.

One important lesson from these bookend scenarios is that widespread ASHP adoption could require substantial additional investments in the regional electric power system, and could create operational challenges. At very low outside temperatures, when the need for heat is greatest, ASHPs become significantly less efficient. If ASHPs are adopted widely, this could create extremely high peak electric demand during a few very cold days.

Since such bookend scenarios are unlikely to represent actual adoption of decarbonized heating solutions, **Figure ES 2** shows how the results might change under one of many possible more-balanced adoption scenarios. This example shows a scenario that assumes that by 2050, electric heat pumps (one-third each by ASHPs and GSHPs) are providing two-thirds of heating; that (renewable) gas – which loses only 50% of volume relative to today – is providing most of the remaining heat; and that oil is providing the remaining amount.

This more mixed adoption of all the decarbonized heating solutions partially mitigates the extreme impact of 100% ASHP adoption on electric system peaks (and the resulting cost of electricity), making ASHPs relatively more attractive. On the other hand, reducing delivered gas volumes, due to increasing

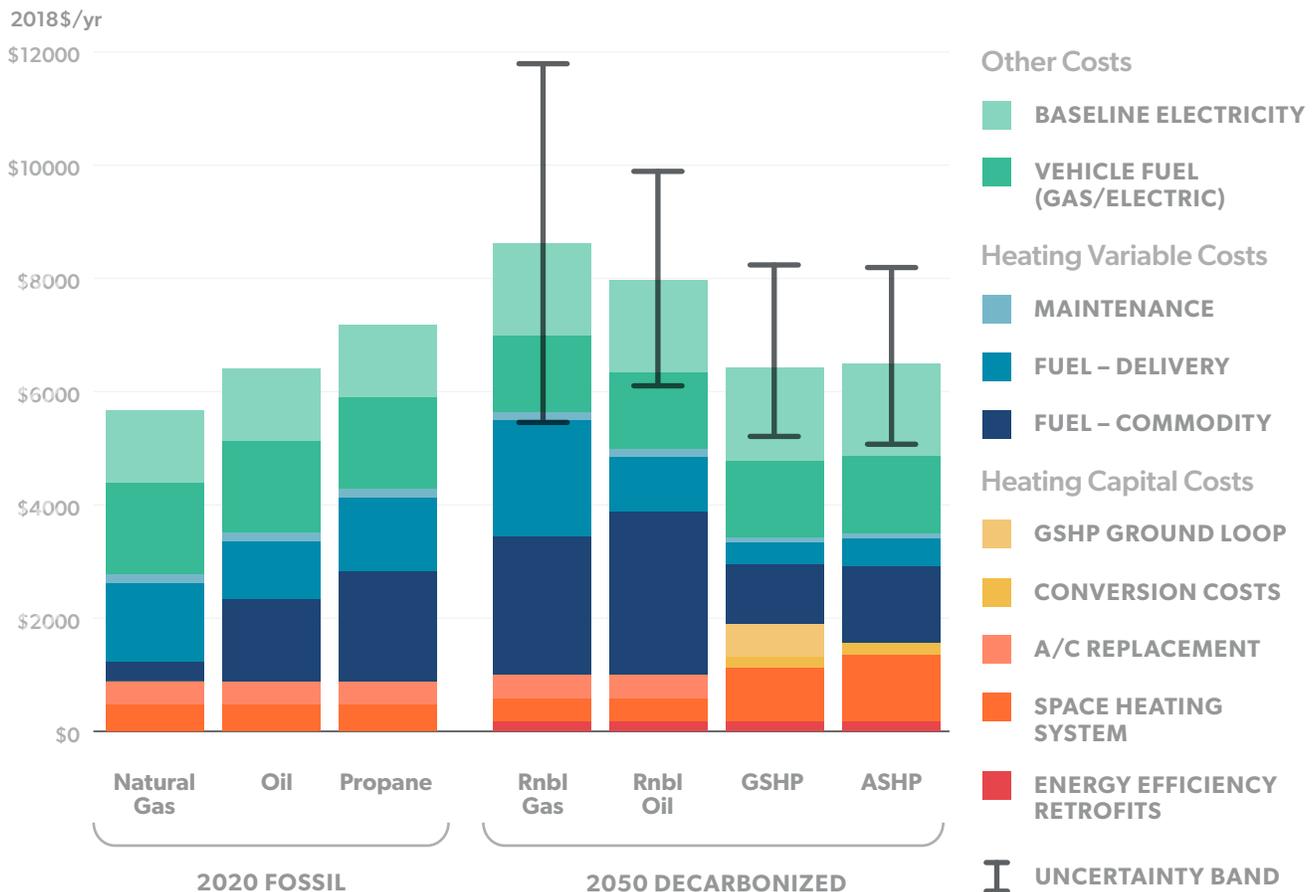


FIGURE ES 3: TOTAL ANNUAL ENERGY WALLET COMPARISON FOR REPRESENTATIVE CONSUMER: 2020 VS 2050 MIXED SCENARIO, 2018\$

Note: Uncertainty band reflects uncertainty on heating costs as above, plus the effect of electricity price uncertainty on other end uses. Gasoline price excludes federal and state taxes. Water heating cost is not broken out explicitly, though to the extent electricity is currently used for water heating, this is included implicitly in Baseline Electricity Consumption.

energy efficiency or conversions to electrified heat, could increase the delivery cost of renewable gas, making it relatively less attractive. But, importantly, the more balanced adoption pattern of the Mixed Scenario does not alter the basic conclusion that no decarbonization solution is clearly preferred. The uncertainty ranges of the decarbonized technologies still largely overlap one another. Because the relative attractiveness of heating decarbonization solutions is sensitive to a) peak electric impacts and b) gas volume impacts, developing a better understanding of these effects, and opportunities to mitigate them, will be an important policy focus in the coming years.

Finally, the decarbonization of heating will not take place in isolation. Rather, it is embedded in broader

economy-wide decarbonization efforts, including a likely shift toward electrified transportation. Heating decarbonization, and in particular the level of electric heat pump penetration, can affect electricity prices. This could have broader impacts on consumers' "energy wallet" – their total energy expenditures on baseline electricity consumption and electric vehicle (EV) charging, in addition to heating. However, changes in heating costs could be offset or exacerbated by impacts on other elements of the energy wallet, particularly transportation. EVs are expected – at least by 2050 – to have lower operating costs than current internal combustion engines.

Figure ES 3 compares a representative consumer's energy wallet spending today with what energy

spending might look like by 2050, considering the various decarbonized heating solutions. The figure indicates that the attractiveness of ASHPs would not decrease substantially when considering the overall energy wallet. It also shows that, compared to 2020, any potential increase in heating cost could be at least partly offset by cost decreases elsewhere in the energy wallet, and by savings through energy efficiency. This does not mean that individual consumers or businesses will not see changes in their heating (and energy wallet) costs. Policy likely plays a key role in mitigating any potential cost increases, particularly where it may affect populations or industries that are vulnerable to increasing energy costs (and thus could be reflected in the state's economy).

The same broad conclusions apply to space heating uses in other settings, such as larger (multi-family) residential and commercial buildings, as well as to domestic water heating. Finally, various decarbonization solutions also exist for the remaining smaller uses of heat, such as electric cooking and clothes drying.

FIVE THEMES TO GUIDE RHODE ISLAND'S PATH FORWARD

The conclusion of this quantitative assessment of the relative attractiveness of various heating decarbonization solutions in Rhode Island is that, at present, there is no clear winning approach. Rather, the relative attractiveness of decarbonizing heating in the state depends on the evolution of the relevant costs – renewable gas, renewable oil, ASHPs, and GSHPs – which are highly uncertain today. Also, the attractiveness of the solutions in specific instances will depend on the particular context – the particular building, location, or application. In addition, each of the decarbonization solutions faces unique adoption and implementation challenges that Rhode Island will need to address to enable broad adoption over time.

This implies that, for policy to support Rhode Island's heating sector transformation, the next 10 years should not focus on advancing a single or limited set of solutions. Instead, Rhode Island should ensure that it is making progress, regardless of which solution (or mix of solutions) ultimately prevails. As illustrated in **Figure ES 4**, a policy framework for the next 10 years should involve five elements: **Ensure, Learn, Inform, Enable, and Plan**.

As an initial step to **ensure** decarbonization, improving the energy efficiency of buildings will provide several immediate benefits. By reducing heat needs, it will reduce greenhouse gas emissions, regardless of what heating technology is utilized (and to the extent heating is electrified, improved building efficiency will reduce heating's impact on electric loads). Importantly, cost-effective energy efficiency measures will reduce the total cost of heating, which will mitigate any potential increase in the cost of providing heat with decarbonized solutions. Finally, existing efficiency programs provide an effective program delivery network that can support the state's expanded heating-sector-related decarbonization efforts.

A second key policy element that will ensure progress towards decarbonizing the heating sector is enacting a set of technology-neutral measures that will reduce the carbon intensity of all energy sources used for heating – electricity, gas, oil, and propane – over time. Such measures may include renewable electricity requirements, carbon pricing or cap and trade policies, renewable fuel or heating standards, or other approaches. Complementary fuel-neutral policies include continued and increased efforts to improve the energy efficiency of Rhode Island's existing buildings, while also tightening the efficiency requirements for new construction.

Rhode Island must emphasize **learning** over the next decade, given the large uncertainties about

Ensure	Increase efficiency and reduce carbon content of all fuels to zero over time – ensures progress no matter which technologies are used
Learn	Data collection, R&D, pilot projects to understand technologies, infrastructure, and customers
Inform	Educate stakeholders – customers, installers, policymakers – about pros and cons of options, system interactions, etc.
Enable	Facilitate deployment with incentives; target natural investment opportunities; align regulations, rules, and codes; expand workforce
Plan	Expand planning horizon; develop long-term, high-level contingency plans now (do not commit yet) and use to guide near-term policy

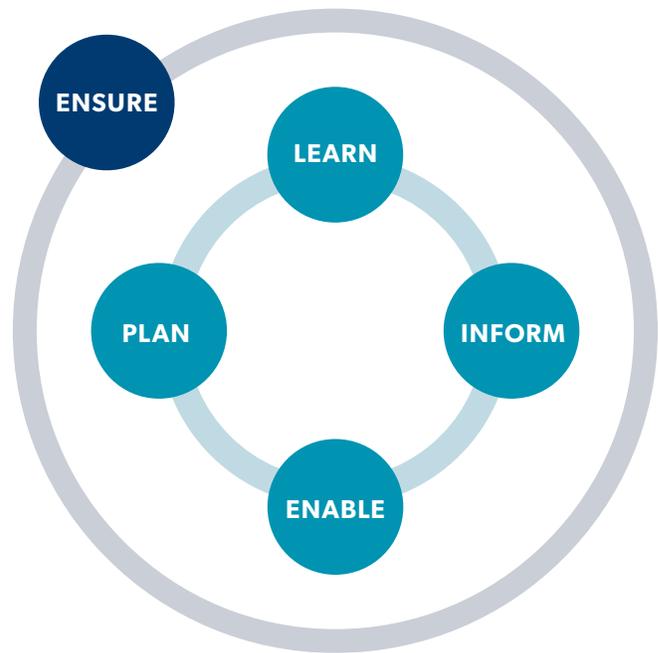


FIGURE ES 4: THEMES TO GUIDE EARLY POLICY RECOMMENDATIONS

both general and state-specific factors related to each of the decarbonized solutions and their implementation. Learning strategies should use pilot and demonstration projects, targeting state-specific issues or in collaboration for more general issues. At a minimum, learning policies should include:

- Information gathering to enable better incentive targeting (such as information on the type and age of heating-related equipment in the state)
- Proper research and development targeting Rhode Island-specific issues
- More general information in collaboration with other states or organizations

Rhode Island must **inform** key stakeholders, including consumers and the building trades, about the technical and economic issues related to decarbonized heat solutions that will require significant efforts to improve information level and flow. Potential policies in this area include broad information campaigns about the available solutions,

including their pros and cons; publicly visible demonstration projects; developing training and certification programs for installers; and making information about qualified and experienced installers available to consumers.

Policymakers will need to enact several additional strategies to **enable** a heating sector transformation. These include policies that identify and address the implementation barriers, which may take the form of incentives to consumers and businesses designed to overcome both overall cost and especially first cost barriers, such as the high upfront cost of heat pumps. In addition, Rhode Island should realign its regulatory frameworks. Examples include removing existing incentives that favor gas system expansion, reconsidering rate structures for both electricity and gas, and exploring ways to integrate the regulatory treatment of National Grid’s gas and electric businesses.

Another important enabling policy principle relates to identifying and capitalizing on “natural investment opportunities” where decarbonized solutions

may be implemented at a lower cost and with less disruption by coordinating with other work being done on the infrastructure or building. Examples include instances where natural gas or electricity infrastructure is being upgraded or replaced, buildings undergoing deep renovations, or existing heating equipment that needs to be replaced as it approaches the end of its useful life. Policies that enable progress can also target existing codes, rules, etc. that may inadvertently create barriers to deploying decarbonized heating solutions that are otherwise attractive. Finally, enabling policies should identify and mitigate instances where heating decarbonization could impose undue burdens on vulnerable populations.

Planning will also be important. Changes to current planning approaches and some specific planning efforts will need to be part of the heating transformation strategy. In general, planning efforts should consider a long time horizon – 2050 or beyond – even if a typical planning exercise might only cover the next 10 years. This will allow Rhode Island to plan for the magnitude of changes needed to decarbonize the heating sector by mid-century, and account for the long lives of most heating-related infrastructure – buildings; pipelines; electric transmission and distribution equipment; GSHP ground loops; and even furnaces, boilers, and heat pumps themselves.

Also, some specific planning efforts will be necessary. An example is planning for the expansion of the electric distribution grid. Significant new electric loads are likely to come online over the next several decades, not just for heat but also for EV charging. This provides an opportunity to better understand the tradeoffs between “future-proofing” the grid by anticipating additional future demands, vs. planning only for near-term demands, which may lead to a series of smaller upgrades that could ultimately cost more. Similarly, even ahead of any clarity about the long-term role of the gas distribution system, developing plans for how

the gas system might be altered to accommodate reduced gas use for heating, and whether there may be ways to do it more economically, will help inform the decisions that Rhode Island must undertake over the next few decades.

This report identifies several important technical issues that will affect the transformation of the heating sector. These include the potential impacts of electrified heat on the power sector, and the future role of the gas system and how reduced gas delivery volumes could affect it. These insights support an economic analysis of the different pathways to decarbonize heating – using renewable fuels with heating infrastructure similar to today’s, or alternatively, electrifying heat with GSHP or ASHP.

That analysis showed that there is substantial overlapping uncertainty about the future economic attractiveness of the decarbonized solutions – regarding the long-run cost of renewable fuels (which is likely to be substantially above the current cost of fossil fuels), as well as the cost of heat pumps themselves and the clean electricity to power them. Because of these overlapping uncertainties, it is not possible to identify a clear winner among the technologies. However, it appears that decarbonized heat is likely to be somewhat more costly than natural gas heat is today, and potentially comparable with oil or propane. Still, overall consumer expenditures on energy in a fully decarbonized economy may be roughly comparable to today’s costs.

This has several policy implications for driving a heating sector transformation over the next several decades. Policy approaches should support enabling early progress on decarbonization – by pursuing energy efficiency to reduce heat needs, and by decarbonizing all the energy sources used for heating – both fuels such as gas and oil, and also electricity to power new electrified heating systems. Beyond this, policies should support both the learning

and informing stages, to begin to address the uncertainties, collect information that will be necessary for the transformation, and ensure a widespread understanding of the solutions and their implications. Regulatory changes can enable the transformation, addressing barriers and facilitating progress on any or all of the pathways. Policies that create structures to identify and capitalize on natural investment opportunities will also enable the transformation.

Broadening planning approaches for both the electric and gas systems will allow policymakers to consider

longer time horizons consistent with the natural lives of heating infrastructure components and the timeframe and magnitude of the transformation. While it seems counterintuitive, Rhode Island must develop action plans knowing that it might not ultimately need them, since developing the plans will inform decisions about whether to implement them. The transformation of the heating sector over the next several decades will be a major undertaking, but it is achievable with early and sustained policy focus.

Introduction and Background

In line with well-established consensus in the scientific community and international commitments such as the Paris Accord, Rhode Island has committed to deep economy-wide decarbonization by 2050. Specifically, the Resilient Rhode Island Act establishes a goal of 80% economy-wide greenhouse gas (“GHG”) emissions reductions relative to a 1990 baseline by 2050 with interim targets of 10% reductions by 2020 and 45% reductions by 2035.¹ Also, Executive Order 17-06 from June 12, 2017 reaffirms Rhode Island’s commitment to the principles of the Paris Climate Agreement.²

As part of this commitment, Governor Gina M. Raimondo’s Executive Order 19-06 requires the DPUC and OER to lead a Heating Sector Transformation and provide a corresponding report with recommendations to the Governor on or about April 22, 2020.³ To fulfill this requirement, the DPUC and OER asked The Brattle Group to analyze options for decarbonizing Rhode Island’s heating sector and

the results of this analysis are presented in this report.

The report is the result of independent analysis conducted by The Brattle Group, supported by an extensive stakeholder effort involving interviews and meetings with over 20 individual stakeholder organizations, as well as three public workshops held to share information, present intermediate results, and collect feedback.⁴ This report is accompanied by a **Technical Support Document**, which provides more detail on the modeling and assumptions underlying its findings. While this report addresses what would be needed to achieve the decarbonization goals of the heating sector, it is not intended to comprehensively address the aggregate costs of decarbonizing, how those costs would be funded, or the time period over which the transformation is achievable, given the practical challenges that will inevitably need to be addressed.

This initiative to evaluate heating sector transformation comes amid the COVID-19 pandemic,

¹ Resilient Rhode Island Act of 2014 – Climate Coordinating Council, Chapter 42-6.2. <http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-6.2/INDEX.HTM>

² “Executive Order 17-06, Reaffirming Rhode Island’s Commitment to the Principles of the Paris Climate Agreement,” State of Rhode Island and Providence Plantations. June 12, 2017. http://www.governor.ri.gov/documents/orders/ExecOrder_17-06_06112017.pdf

³ “Executive Order 19-06, Heating Sector Transformation to Ensure Reliability and Protect Against Climate Change,” State of Rhode Island and Providence Plantations. July 8, 2019. <http://www.governor.ri.gov/documents/orders/Executive%20Order%2019-06.pdf>

⁴ Three public workshops were held during the course of this project – two in-person meetings and one webinar-based presentation. Each workshop attracted more than 60 registered participants and included opportunities for stakeholder Q & A. Written public comments were also accepted via email.

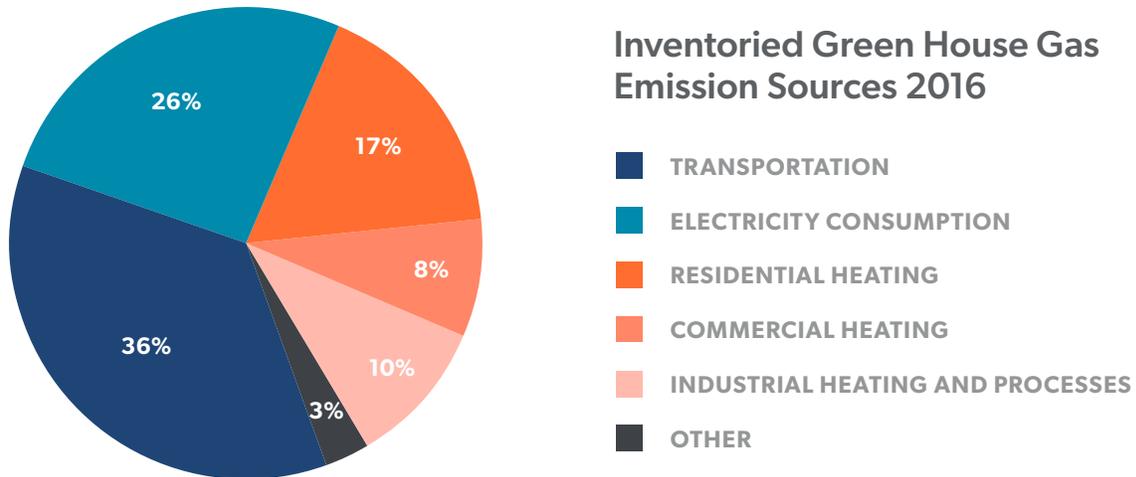


FIGURE 1: COMPOSITION OF RHODE ISLAND GHG EMISSIONS

Source: Rhode Island Department of Environmental Management, Rhode Island's 2016 Greenhouse Gas (GHG) Emissions Inventory Update, EC4 Meeting, September 12, 2019.

which has disrupted much of the state, national and international economy, including the energy sector. While this disruption will doubtless cause many short-term impacts throughout the economy, including the heating sector, we assume that these impacts will be relatively short-term in nature and will not fundamentally alter the long-term, multi-decade needs and goals for decarbonizing the economy. Indeed, climate change is a problem that will still exist and will need to be addressed long after the pandemic has been resolved.

This analysis also comes in the wake of the gas service outage that occurred on Aquidneck Island on January 21, 2019.⁵ While this report addresses heating sector transformation in the context of climate change, it may also have implications for the future of heating service reliability. For most Rhode Island customers, heating currently depends strongly on the interstate and local gas distribution systems to provide natural gas on the coldest days, when gas demand is highest and the gas system is most constrained. Electrifying parts of the heating sector would reduce this reliance on the

gas system, but would create a new reliance on the electric transmission and distribution infrastructure, which might become similarly constrained on those coldest winter days.

The effort to transform the Rhode Island heating sector occurs against the backdrop of concerns about climate change related risks and resulting state-level greenhouse gas reduction targets and efforts. **Figure 1** shows the composition of Rhode Island's GHG emissions as of 2016. As shown, heating related emissions (including industrial emissions) represent 35% of statewide emissions and are roughly equal to transportation emissions. Hence, even if all non-heating sectors were to become completely emissions-free by 2050, the heating sector would still need to be significantly decarbonized to meet the current GHG emissions reduction goals.

More likely, some emissions in the transportation sector, as well as industrial process (and likely some heating related) emissions will be very difficult to eliminate. Consequently, even if the State is successful

⁵ Summary Investigation into the Aquidneck Island Gas Service Interruption of January 21, 2019, October 30, 2019

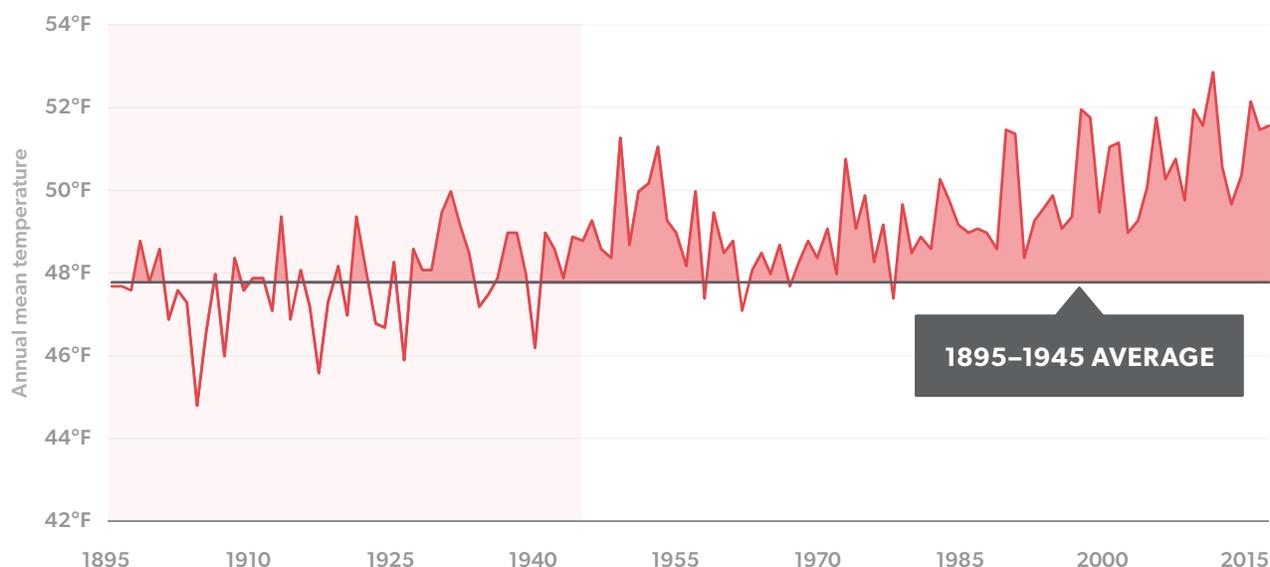


FIGURE 2: ANNUAL MEAN TEMPERATURES IN RHODE ISLAND (1895–2018)

Source: NOAA National Centers for Environmental Information, Climate at a Glance: Statewide Time Series, published January 2020, retrieved on February 2, 2020 from <https://www.ncdc.noaa.gov/cag/>

in fully decarbonizing the electricity sector, even full decarbonization of the heating sector would require very significant reductions in the remaining emitting sectors to achieve 80% GHG emissions reductions by 2050. This is not taking into account uncertainties about the contributions of emissions from methane leaks and/or non-energy emissions, such as land-use changes, which were not included in the State’s most recent draft GHG emissions inventory.

Also, as recognized by Governor Raimondo’s recent executive order to achieve a 100% renewable electricity supply in Rhode Island by 2030⁶ and similar efforts to accelerate decarbonization goals relative to 80% reductions by 2050, evolving science and evidence related to climate change may require an acceleration of decarbonization relative to current policy goals.

For these reasons, this report identifies and evaluates various options and solutions for full decarbonization of the state’s heating sector, recognizing that

achieving full decarbonization may be very difficult for some heating applications and that deeper decarbonization in the other emitting sectors or the emergence of negative emissions technologies (including land-use measures that could increase GHG sequestration to offset some emissions) may create room for some remaining emissions in the heating sector.

However, recognizing the uncertainties described above, developing pathways for a transition to a fully decarbonized heating sector is both in line with existing policy goals and provides insurance value in case either non-heating emissions reductions are harder or more expensive to achieve or if GHG emissions reductions need to be deepened.

Finally, this report assumes that addressing heating sector emissions will remain vital even if climate change is expected to result in increases in average annual temperatures. As **Figure 2** shows, average Rhode Island temperatures have already increased by

⁶ Executive Order 20-01, Advancing a 100% Renewable Energy Future for Rhode Island by 2030, January 17, 2020

more than 3 degrees Fahrenheit since the beginning of the 20th century.

There is also some evidence that higher average temperatures result in warmer average winters in the Northeast,⁷ which would have a tendency to lower the overall energy needed to heat Rhode Island homes and businesses. On the other hand, heating demand is greatest during the coldest days of the year and, somewhat counterintuitively, there is some evidence that suggests that climate change may increase temperature extremes in New England both

in the summer and in the winter, leading to continued (and perhaps more intense) periods of extremely cold temperatures.⁸ Since our energy systems are designed to ensure a reliable supply of energy during essentially all expected conditions, the possibility that winter temperature extremes will remain largely unchanged or worsen even as the state's average temperatures increase therefore needs to be considered when developing a heating sector transformation strategy for Rhode Island.

⁷ See for example USA Today, The Northeast warms ahead of rest of USA: 'Our winters now are not like our winters before (<https://www.usatoday.com/story/news/nation/2019/12/25/climate-change-northeast-warming-faster-united-states/2743119001>), accessed February 2, 2020)

⁸ See for example Axios, The polar vortex splits, sending frigid air howling into the U.S., Europe, January 16, 2019 (<https://www.axios.com/polar-vortex-means-winter-is-coming-to-east-coast-and-europe-5fb653fd-1664-41aa-9a99-549e2541d89a.html>), accessed February 2, 2020)

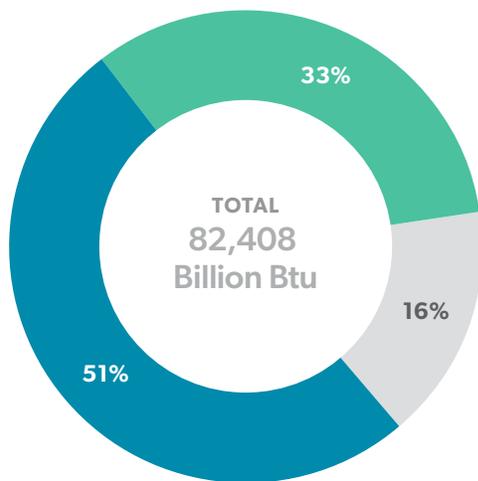
Overview of the Rhode Island Heating Sector and Decarbonization Solutions

THE RHODE ISLAND HEATING SECTOR

Rhode Island's heating sector is comprised of a variety of uses and environments. Heat is primarily used for space heating and water heating in the residential and commercial sectors (with smaller amounts for cooking, clothes drying, etc.), and in various industrial applications, primarily as process heat. At the building level, heating occurs in single- and multi-family residential buildings, in a wide variety of commercial buildings and, finally, in a number of industrial applications. Industrial heating applications

include a multitude of different process heat uses and therefore are significantly different from residential and commercial space and water heating. There is little detailed information available regarding the heating related energy use in Rhode Island's industrial sector.

Figure 3 shows the shares of total energy consumption in the residential, commercial, and industrial sector, respectively. Of total energy use in the state, the residential sector represents roughly 50% of total energy use, the commercial sector one-third, and the industrial sector the remainder. The share of energy



Total 2017 Rhode Island Energy Consumption by Sector

- RESIDENTIAL — 42,541 BBtu
- COMMERCIAL — 26,927 BBtu
- INDUSTRIAL — 12,940 BBtu

FIGURE 3: TOTAL 2017 RHODE ISLAND ENERGY CONSUMPTION BY SECTORS

Source: Buro Happold Analysis.

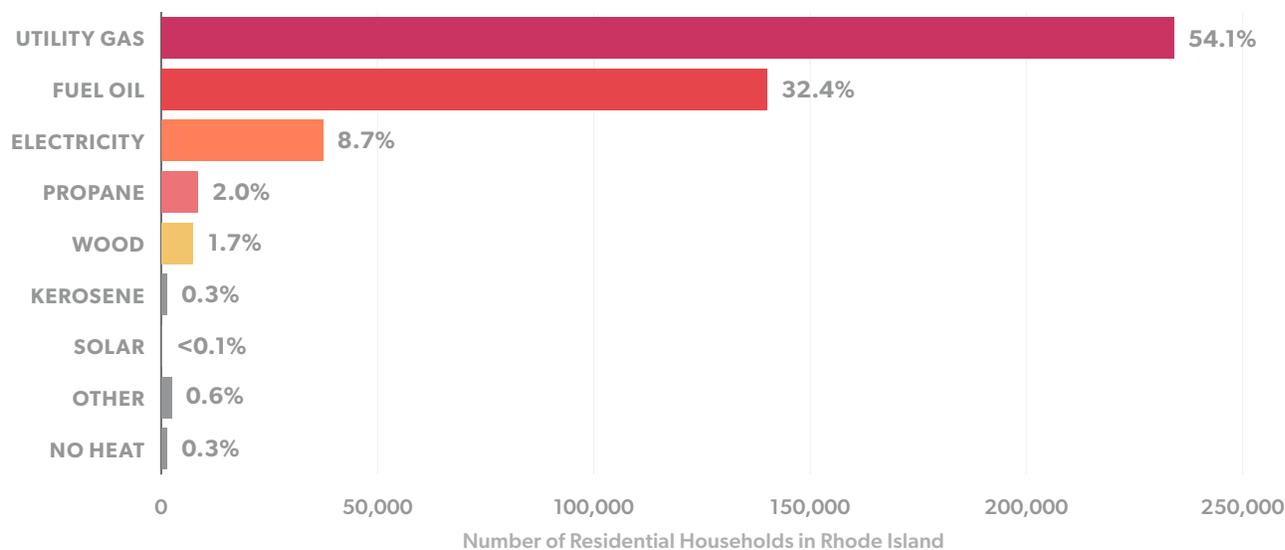


FIGURE 4: HEATING SOURCE FOR RHODE ISLAND RESIDENTIAL CUSTOMERS

Source: Meister Consultants Group, Rhode Island Renewable Thermal Market Development Strategy, prepared for the Rhode Island Office of Energy Resources, January 2017.

use by type (heating, cooling, other) likely differs significantly by sector, with the share of heating in total energy use likely the greatest for the residential sector, followed by the commercial sector. Overall, this implies that transforming the heating sector in Rhode Island will be impossible without a significant focus on the residential and commercial sectors. While decarbonizing the entire heating sector in Rhode Island will be impossible without also addressing industrial heat, which includes space and water heating as well as various types of process heat, decarbonizing process heat will require more tailored approaches.

Figure 4 provides an overview of the composition of heating in New England. **Figure 5** provides additional insights into how total heating-related energy use is distributed across various types of residential and commercial buildings in the state. As shown, single family residential buildings represent close to 60% of all heating-related energy consumption in the state. Consequently, the analysis in this report focuses

particularly on this building type. Larger buildings, such as multi-family and office buildings, are also important consumers of heating-related energy, and are considered separately.

Figure 6 illustrates that the large majority of residential buildings in Rhode Island were built before 1980 and, hence, are relatively old. With few new building permits issued each year,⁹ it is clear that transforming the heating sector in Rhode Island must focus primarily on existing buildings. It also provides information on the heating fuel type by building age, confirming that natural gas is the dominant source of heating across buildings of all ages, followed by heating oil, which is a close second for buildings constructed between 1950 and 1980. The fact that the majority of the residential housing stock is old with existing heating systems designed for fossil fuels highlights the practical challenges Rhode Island may face in converting the heating systems in such a large number of buildings over the next few decades.

⁹ In 2019, 1,138 building permits for new residential housing were issued. (<https://fred.stlouisfed.org/series/RIBPPRIV>). In 2018, the number was 1,192. At this rate, less than 40,000 new housing units will be added by 2050, i.e., less than 10% of the current number of housing units.

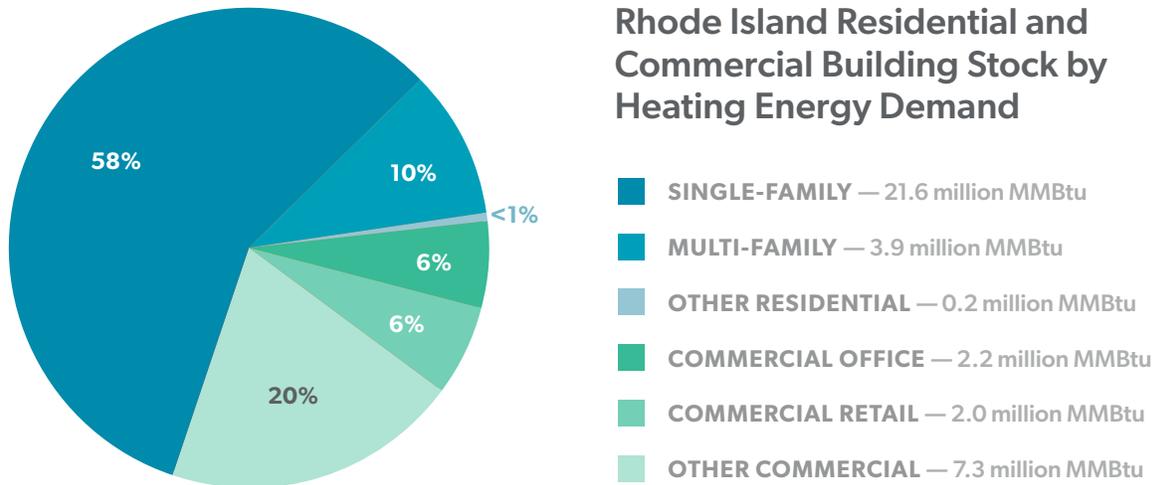


FIGURE 5: RESIDENTIAL AND COMMERCIAL BUILDING STOCK BY HEATING ENERGY DEMAND

Source: Buro Happold Analysis.

Figure 7 shows similar summary descriptions of Rhode Island’s commercial building stock, by building type and square footage. This is the backdrop against which the rest of this report assesses decarbonization solutions for the Rhode Island heating sector.

PRIMARY HEATING APPLICATIONS IN RHODE ISLAND

Heating is used for three broadly defined purposes: space heating, water heating and process heating. Secondary applications include cooking, clothes drying, etc. Within the residential and commercial sectors, which together represent 84% of total heating energy demand in the state, space and domestic water heating represent the largest share of total heating related fuel demand.

Figure 8 indicates that among fuel-based heating, space heating in New England represents more than three-fourths of total energy use and that all uses other than space or water heating represent only four

percent of total energy demand.¹⁰

Figure 9 provides the same summary for the commercial sector and indicates that while other heating uses are more prevalent in the commercial sector (notably cooking), the share of space and water heating in the commercial sector also exceeds 80%.

Because of the dominance of space heating in total heating demand, transforming the Rhode Island heating sector must focus on space and, to a lesser extent, domestic water heating.

For smaller buildings in Rhode Island, such as single family homes, small multi-family buildings, and some small commercial buildings, primary heat is typically provided in one of a few ways. Fuel can be burned in a furnace to heat air, which is then distributed through the building by a forced hot air system consisting of a blower fan and ductwork. Alternatively, fuel is burned in a boiler to heat water in a hydronic system, which pumps the hot water through pipes to distribute the heat to radiators (sometimes boilers produce steam

¹⁰ These figures exclude households using electricity for space and domestic water heating, but it is likely that the respective shares of each heating type are similar. Also, these figures represent New England averages, which are likely close approximations of the relevant shares in Rhode Island.

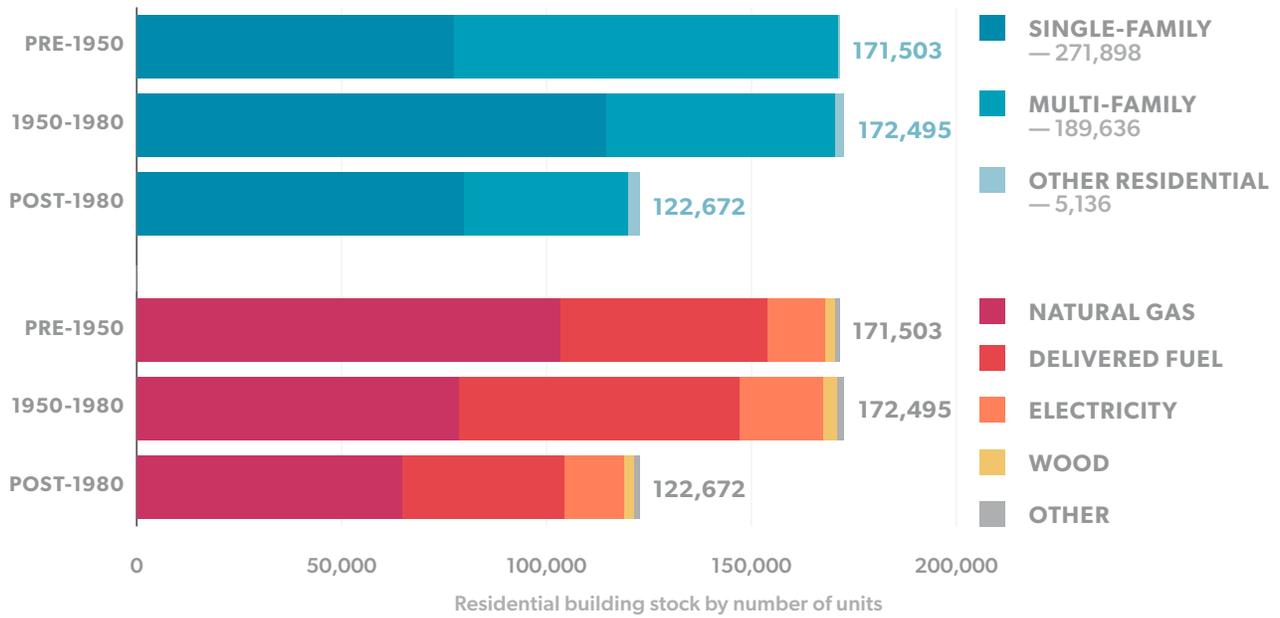


FIGURE 6: RHODE ISLAND RESIDENTIAL BUILDING STOCK BY AGE, HOME TYPE AND FUEL

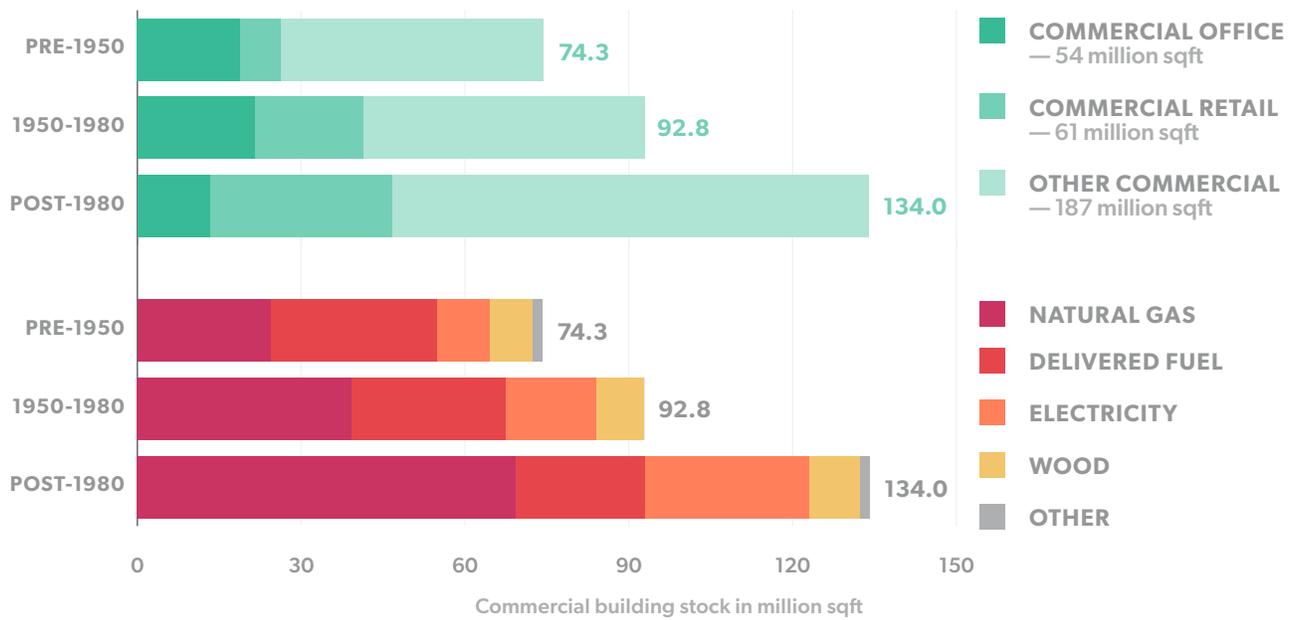


FIGURE 7: RHODE ISLAND COMMERCIAL BUILDING STOCK BY BUILDING TYPE, SQUARE FOOTAGE AND FUEL

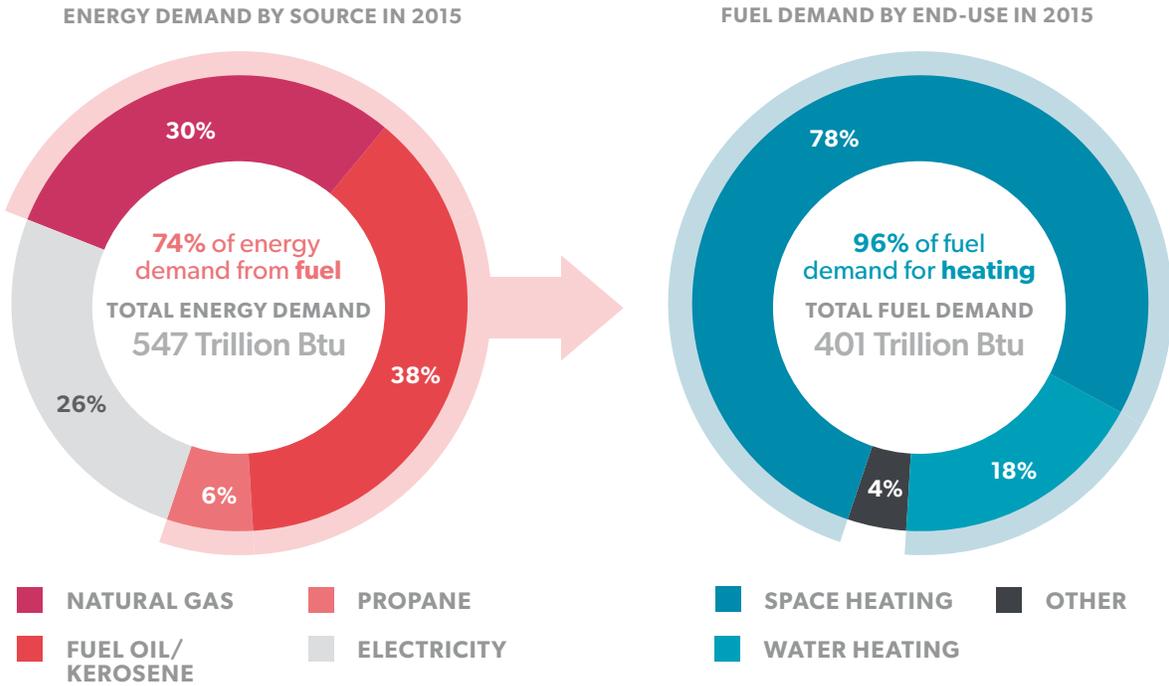


FIGURE 8: ENERGY DEMAND IN NEW ENGLAND FROM HEATING FUELS OTHER THAN ELECTRICITY (RESIDENTIAL SECTOR, 2015)

Source: EIA 2015 RECS Survey Data.

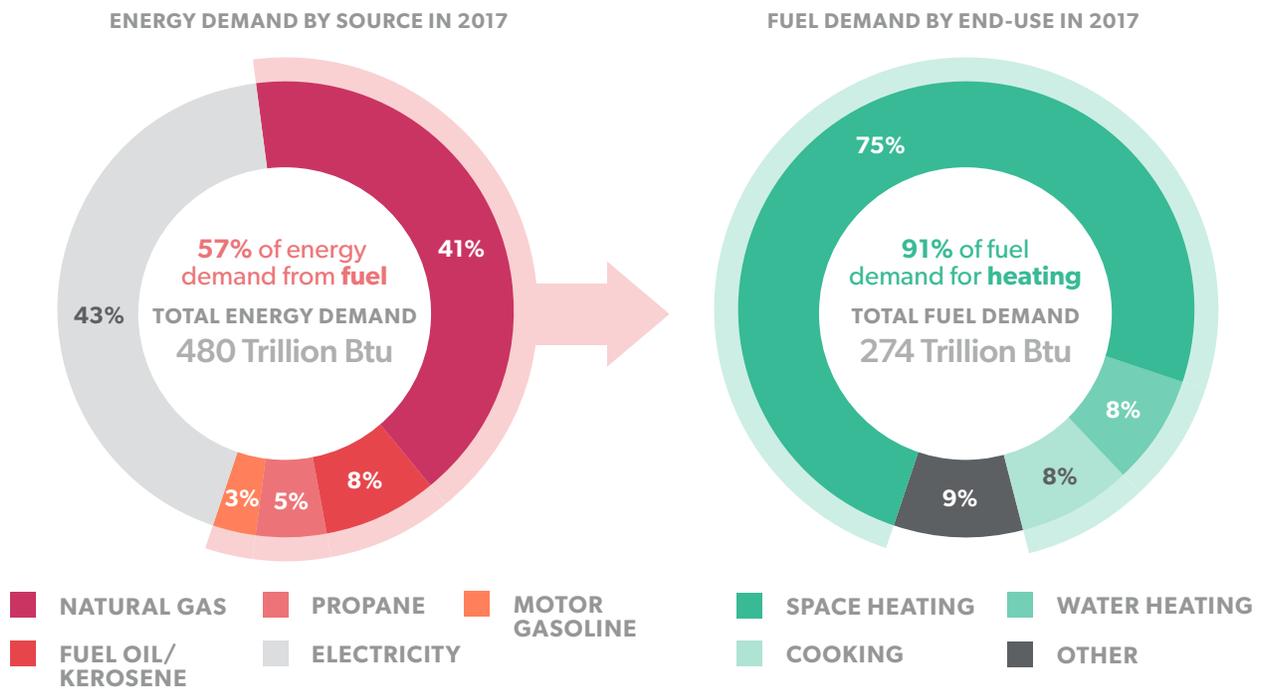


FIGURE 9: ENERGY DEMAND IN NEW ENGLAND FROM HEATING FUELS OTHER THAN ELECTRICITY (COMMERCIAL SECTOR, 2017)

Source: AEO 2019 and EIA 2012 CBECS Survey Data.

Note: "Other" includes office equipment, cooling, refrigeration, manufacturing, and electricity generation.

that circulates through steam pipes to radiators). With both furnaces and boilers, the fuel can be natural gas, heating oil or propane. Less frequently, heat is provided by electricity, usually with electric resistance (baseboard) heat, and rarely, for now, using a heat pump, which works much like an air conditioner (and can be used either in heating or cooling mode). A few buildings are heated by other means, such as wood stoves and solar.

Figure 10 shows an indicative comparison of the costs of the predominant fossil heating options, for a representative single-family home in Rhode Island with average energy use for heating.¹¹ This type of comparison will be used again later in this report to illustrate the relative costs of decarbonized heat solutions as well. The shades of orange at the bottom of each bar depict the annualized cost of the capital equipment required – furnace or boiler that must be replaced periodically in the case of fossil heat; as shown below, the equipment needs for some of the decarbonized heat solutions are different and more involved. The shades of blue above represent the operating costs of the heating systems – primarily the cost of the input energy which is fuel for most current systems, or electricity. Currently, natural gas is the least costly option for heating in Rhode Island with an overall cost of about \$2,700 per year for a representative existing detached single-family home, because the fuel cost of natural gas is much

less than oil (\$3,500) or propane (\$4,300). Heating with electric resistance heating is the most expensive current heating solution (\$5,500 per year). Projections for 2050 costs are also provided, with future fuel costs based on the AEO fuel price projections,¹² and including assumed improvements in furnace and boiler efficiencies, particularly for natural gas-fired heating.¹³ The gray area at the top of each bar represents the cost of carbon emissions at \$75/metric ton CO₂ (based on the current implicit carbon value used to evaluate efficiency investments) for both 2020 and 2050, though by 2050, the relevant carbon price may be higher, and may in fact become part of the fuel prices paid by consumers. (no carbon cost is associated with electric heating in 2050 since it is assumed that electricity will be carbon-free by then, in line with Rhode Island and regional policy goals).¹⁴ The relative ranking of the standard heating technologies remains unchanged, with natural gas heating still being the least costly and electric resistance heating still the most costly.

The demand for heating in larger buildings (e.g., multi-family apartment buildings and large commercial buildings such as office towers) of course tends to be higher in total, though the heat need usually grows less quickly than the building’s square footage (i.e., as building size increases, the outer surface area of the building through which heat is lost grows less quickly than the square footage). These larger

¹¹ The economic analyses here are expressed in real (i.e., inflation-adjusted) 2018 dollars.

¹² U.S. Energy Information Administration, Annual Energy Outlook 2019, Table 3: Energy Prices by Sector and Source.

¹³ Caution should be used in interpreting the 2050 projections, since the fuel price projections by the AEO underlying these values are probably not consistent with the decarbonized future considered by Rhode Island and other New England states.

¹⁴ Estimates of the “social cost of carbon,” measure of the value to society of avoiding one ton of CO₂ emissions, tend to increase over time since the value is equivalent to the value of avoided future damages caused by GHG emissions and as the time when more serious damages due to GHG emissions are expected is closer to the present in 2050 than today. For example, until 2017, the U.S. estimated the social cost of carbon to be \$42/ton in 2020 (expressed in constant 2007 dollars and using a 3% discount rate), rising to \$69/ton by 2050. Using a 2.5% discount rate, the value increases from \$62/ton in 2020 (which represents approximately \$75/ton in 2017 dollars) to \$95/ton (or \$115/ton in 2017 dollars) in 2050. See Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866; Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, August 2016. Electricity prices for 2050 reflect the projected cost of a decarbonized electricity supply.

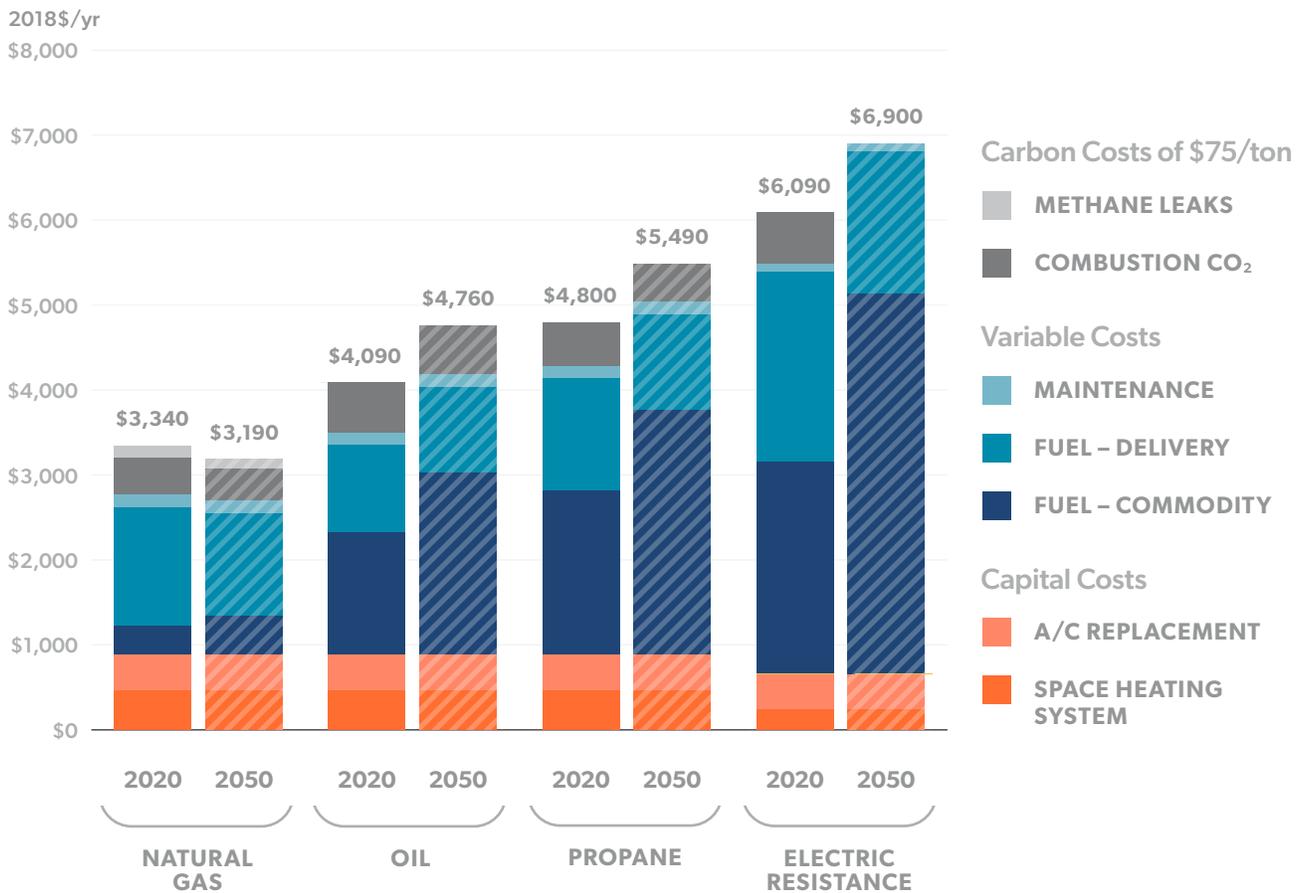


FIGURE 10: ANNUALIZED COST OF CURRENT HEATING TECHNOLOGIES, SINGLE-FAMILY HOME 2020 AND PROJECTED 2050 (2018\$)

Notes: Fossil fuel prices for 2050 are based on Annual Energy Outlook projections. Electricity price for 2050 is based on the cost of an assumed carbon-free electricity supply for New England that would be able to supply traditional electricity uses plus electrification of light-duty vehicles.

buildings can have different types of heating/cooling systems, particularly regarding the internal distribution systems within the building. In addition to needing less heat per square foot, larger buildings typically need some cooling even in the heating season. But larger buildings are highly idiosyncratic in terms of their heating systems, perhaps even more so than small buildings. They typically combine large boilers that provide heat with chillers and cooling towers for cooling, and use hydronic (water-based) distribution systems within the building to move the heat and cool to where it is needed. Fans or forced air systems are used to move the heat or cool from the hydronic system into the various building spaces that require

space conditioning. Still, despite the differences in their heating systems, the relative economics of heat in large buildings is similar to that for small buildings, since both are driven by the relative costs of the different available fuels and the heating equipment

DECARBONIZATION SOLUTIONS FOR RHODE ISLAND

Depending on the heating application and building type, there are several options to decarbonize heating, some of which are substitutes while others can be used in combination. This section discusses the various solutions at a high level. The 2017 Rhode Island

Space and water heat Several primary solutions are feasible across many applications/buildings	Decarbonized Fuel Supply may be limited from less-costly sources	Renewable gas/power-to-gas (P2G) for gas customers <ul style="list-style-type: none"> Landfill gas, anaerobic digesters, gasification, synthetic gas
		Biofuel or power-to-liquids (P2L) for most other customers <ul style="list-style-type: none"> Biodiesel, ethanol, synthetic fuels
	Heat Pumps	Air source heat pump (ASHP)
		Ground source heat pump (GSHP) <ul style="list-style-type: none"> Including GeoMicroDistrict
Industrial heat	<ul style="list-style-type: none"> May be more specialized (e.g., high-temp) May require (decarbonized) fuel, including hydrogen 	

TABLE 1: DECARBONIZATION SOLUTIONS

Renewable Thermal Market Development Strategy report (“Meister Report”)¹⁵ provides a more detailed technical description of many of these technologies. Further information is provided in the **Technical Support Document** accompanying this report. Very broadly, apart from energy efficiency measures, which must play an important role independent of what heat solution is chosen, the decarbonization solutions fall into the categories outlined in **Table 1**.

As the table shows, the two primary pathways include decarbonizing fuels and electrifying heat via heat pumps. The relative attractiveness of these paths has been studied in a variety of contexts and geographies.¹⁶ These and similar studies provide an important background for the analyses in this report as

a basis for developing a heating transformation strategy for Rhode Island.

1. The Role of Energy Efficiency

One of the most obvious approaches to decarbonizing the heating sector is to lower the overall need for heat, which can be achieved through increasing the efficiency of buildings – primarily via weatherization and/or more efficient heating equipment for existing buildings, and via building codes requiring better energy performance for new buildings.¹⁷ Cost-effective energy efficiency measures will reduce GHG emissions, and will reduce the total cost to customers, mitigating the potentially higher cost of decarbonized heat. Of course, energy efficiency efforts targeting

¹⁵ Meister Consultants Group, Rhode Island Renewable Thermal Market Development Strategy, prepared for the Rhode Island Office of Energy Resources, January 2017

¹⁶ See for example KPMG, 2050 Energy Scenarios, July 2016; DNV-GL, The Potential Role of Power-to-Gas in the e-Highway 2050 study, 2017; E3, The Challenge of Retail Gas in California’s Low-Carbon Future, Final Project Report, California Energy Commission, CEC-500-2019-055-F, December 2019; E3, Deep Decarbonization in a High Renewables Future, California Energy Commission, CEC-500-2018-012, June 2018

¹⁷ Switching to heat pumps has also been supported under existing energy efficiency programs, but these are discussed below as a separate decarbonization pathway.

heating demand and electricity demand already play an important role in Rhode Island through the energy efficiency programs implemented by state utilities.¹⁸ Existing efficiency programs provide an effective program delivery network that can be accelerated to further reduce the energy needs for heating (and cooling) in existing and new buildings, and can also be expanded to support providing decarbonized heating systems. Heating related energy efficiency measures can be very cost-effective in new buildings. By designing a building to be energy efficient from the earliest stages, its need for heat (as well as other forms of energy) can be reduced dramatically for very modest initial cost, often just a few percent of the initial cost.¹⁹ Specifically, very tight building envelopes, insulation, efficient windows, and efficient heating and cooling systems are often very cost-effective since they tend to require little or no incremental labor and only modest materials cost, and often pay back in two to three years.²⁰ However, even such easy and cost-effective measures are not always undertaken in new buildings, in part because they are not an integral part of traditional design approaches, complicated by the fact that the designer/developer does not typically pay the building's energy costs and thus has little direct incentive to reduce them. For these reasons, new building codes and standards, as well as energy disclosure requirements, are an important way to ensure that new buildings comport with the goals of decarbonizing the heating sector, causing the state's buildings to become more efficient as the building stock grows renewed and grows over longer time horizons. the fact that new construction will account for a small share of the buildings in Rhode Island by 2050, an effective heating transformation strategy

must ensure that cost-effective efficiency measures for new buildings – likely primarily in the form of building codes – are also part of Rhode Island's heating transformation strategy. Cost-effective efficiency measures save money for customers, and even though the building stock turns over slowly (perhaps especially because it turns over slowly), ensuring that new buildings are efficient will protect Rhode Island customers in the long run.

However, since most of the existing Rhode Island building stock is quite old – almost 75% of residential buildings are over 40 years old – it is very likely that most of the buildings that will exist in 2050 have already been built. Therefore, transforming the heating sector will require a substantial effort to retrofit existing buildings, unless there is a substitute decarbonized fuel that can be used with the existing heating systems and appliances that utilize existing fossil fuels.²¹

Efficiency measures for existing buildings such as weather stripping, air sealing and attic insulation tend to be relatively low cost since they do not require intrusive interventions in the building. They have been shown to be cost-effective and are at the heart of Rhode Island's energy efficiency programs. Such measures have represented the bulk of "building envelope" related energy efficiency measures to date. For example, in the 2018 program year, National Grid's EnergyWise program resulted in over 3,700 weatherization measures implemented, carved out from over 10,000 customers that received an energy audit as part of the program. Counting the overall program expenses for the EnergyWise program, average costs per weatherization were just short

¹⁸ Rhode Island is home to three electric distribution utilities (National Grid, Block Island Utility District, and Pascoag Utility District, with National Grid serving the large majority of customers) and one gas distribution utility (National Grid).

¹⁹ See for example EPA, Rules of Thumb – Energy Efficiency in Buildings, p.2, which suggests an increase in building costs of 2-7% for green high-performance buildings relative to "normal" buildings.

²⁰ See for example EPA, Rules of Thumb – Energy Efficiency in Buildings, p.2, which suggests a payback period for high performance buildings of 2 years, 2.1 years for libraries and 2.6 years for schools.

²¹ This report does not address how comprehensive retrofits of existing buildings would be funded.

of \$4,200, with average participating customers contributing approximately \$575.²² However, these measures typically achieve only a moderate reduction of overall heating demand; in aggregate, they tend to reduce heating energy needs by 10-15%. Further reductions in heating energy needs require additional measures that have a higher cost and are more intrusive to the occupant of the existing structure.²³

Heat energy savings of 40% or more are possible in existing buildings, but require “deep” retrofits with measures such as window replacement and adding insulation not only to attics, but also to exterior walls and floors. Such activities tend to be more disruptive and entail significant cost when retrofitting an existing building. The necessary interventions in an existing building also tend to be highly building-specific and, therefore, difficult to standardize.²⁴ Their cost can exceed \$50,000 or even \$100,000 for a residential home, with comparably high costs for most commercial buildings. Such deep retrofit measures have so far not been deemed to be cost-effective in existing buildings and face significant initial cost and implementation barriers.²⁵

Looking forward, energy efficiency measures in existing buildings that are cost-effective today are even more likely to be so in the future. Implementing cost-effective efficiency measures reduces customer expenses for heating (and electricity) – particularly relevant at a time like the present when the COVID-19 pandemic is affecting the incomes of many local residents and businesses, but important in normal

times as well. Energy efficiency will also need to play an important role in transforming the heating sector in the longer term. At present, National Grid is on pace to complete energy audits of essentially all residential buildings in the state by 2050. However, even though such measures are generally cost effective, only about one-third of residential customers who receive an energy audit also opt for these weatherization measures. Going forward it will be important to develop policies and incentives to improve this conversion rate so that cost-effective weatherization efforts reduce the need to provide decarbonized heat to the greatest extent possible. Energy efficiency programs may also be useful delivery mechanisms for heating transformation solutions such as deploying heat pumps where cost effective. In that case, future policy likely needs to focus on increasing conversion rates (the rate of adoption once cost effectiveness has been established, for example via an energy audit), since the extent of deployment of such solutions across the more than 400,000 buildings will depend critically on what fraction of customers adopt such solutions.

Beyond weatherization, there are also newer, technology-enabled energy efficiency measures that can provide additional heat energy savings. They include behavioral programs to encourage conservation, including those made possible through smart thermostats. At present it seems unclear what the net effect of simple weatherization

²² Calculated based on National Grid, 2018 Energy Efficiency Year End Report, May 15, 2019, p.8 and Table E-3.

²³ When evaluated in a bundle with insulation, an evaluation of Maine weatherization programs found an average reduction of 17.9 MMBtu or 17% relative to pre-measure energy consumption in homes heated with natural gas. A comparison with other air sealing and insulation programs suggests a typical range of savings between 9% and 17%. West Hill Energy and Computing, Efficiency Maine Trust Home Energy Savings Program Impact Evaluation, Program Years 2014-2016, August 23, 2019, p.23, Table 3-5.

²⁴ There are efforts to develop standardized deep retrofit approaches to existing residential buildings. NYSERDA is currently in a phase of pilot project through the RetrofitNY program, leveraging efforts to develop standardized retrofits in the Netherland pioneered by EnergieSprong. (See <https://energiesprong.org/country/new-york/> and <https://www.greenbuildingadvisor.com/article/u-s-looks-to-europe-for-energy-retrofit-model>)

²⁵ Home Energy Services Impact Evaluation (Res 34), Produced in collaboration with Navigant and Cadeo, prepared for the Electric and Gas Program Administrators of Massachusetts, August 2018, page 26.

and such behavioral programs might be. Since smart thermostat penetration will likely increase over time, it is likely that more customers will at least have access to such programs. Beyond conservation, these programs also contribute to reducing demand peaks, which will help lower the cost of electricity in a fully clean power grid of the future.

Two other points need to be emphasized. First, cost-effective energy efficiency measures not affecting heating demand, but electricity demand instead, will likely be critical in enabling a successful heating sector decarbonization. By reducing the demand for electricity relative to what it would otherwise be, they will reduce the challenge of building a portfolio of electricity generating resources capable of supplying the state (and region) with 100% clean electricity. Second, by having been in place for many decades and having steadily improved over time, existing energy efficiency programs and their administration and delivery are likely a key delivery vehicle for implementing other heating related policies. The fact that current state incentives for heat pumps are delivered through existing energy efficiency programs is likely only the beginning of using and improving an existing delivery channel for many of the policies needed to transform the sector.

Recognizing the contribution of cost-effective weatherization on the costs of various decarbonization solutions for customers by 2050, the analysis below assumes that the combination of cost effective energy efficiency measures will lower the total heating requirements of a representative Rhode Island building by 15% and that the remaining (very significant) sources of heat must be decarbonized to achieve the state's decarbonization targets. The two primary pathways for decarbonizing heat in Rhode Island are discussed next – electrifying via

heat pumps (with a decarbonized electric sector) and decarbonizing the heating fuel.

2. Decarbonized Electrification with Heat Pumps

Using electricity to heat homes is not new. In fact, it is the primary heat source for about 9% of Rhode Island's residential customers and 13% of commercial square footage.²⁶ Currently, most of the electric heat in Rhode Island is electric resistance, but an increasing share is using electric heat pumps, particularly in the commercial sector. Heat pumps are based on a technology that is well understood and widely deployed – it is the same approach used in refrigerators and air conditioners. In contrast with furnaces and boilers which generate heat, a heat pump moves heat – from outside the building to the inside (or the reverse in cooling mode). With this approach, heat pumps take advantage of energy available in the environment (even cold outdoor air in the winter contains significant heat energy) and consequently can achieve efficiencies well above 100%. That is, for each unit of electric energy consumed, they provide more than one unit of heat to the building.

There are many types of heat pump applications, but they can be grouped into two broad categories: Air Source Heat Pumps (ASHP) and Ground Source Heat Pumps (GSHP), with the primary distinction being the outside heat source used (or heat sink in cooling mode). ASHPs use outside air as a source for heat, with a fan to move the air across a heat exchanger. The heating efficiency of ASHPs declines with outdoor temperatures, and thus ASHPs consume more electricity, particularly in colder weather. For this reason, despite recent performance improvements, ASHPs are generally installed with a back-up heating system that can substitute or supplement the ASHP

²⁶ Meister Report, Figure 1, Table 5, Table 7.

during very low outdoor temperatures.²⁷ GSHPs, on the other hand, use groundwater or the ground itself, which maintains a stable year-round temperature of about 50 degrees Fahrenheit a few feet below the surface. To access this reservoir of heat, GSHPs require a “ground loop,” piping that circulates a refrigerant that absorbs heat from the ground or water, or injects heat in cooling mode. A ground loop can be installed horizontally as a “slinky” coil of flexible pipe buried a few feet underground, or vertically by drilling one or more boreholes several hundred feet deep. The ground loop typically makes GSHPs more costly to install, but since the ground temperature is constant throughout the year, they can operate at very high efficiency regardless of outdoor temperature.

An advantage of heat pumps over burning decarbonized fuels (e.g., renewable oil or gas) is that they provide cooling as well as heating, whereas furnaces and boilers burning fuels can only provide heat.²⁸ In a warming Rhode Island, air conditioning is likely to become more important and by being able to provide both heating and air conditioning, heat pumps can replace not just a furnace or boiler, but also the need for a separate air conditioning system.

A potential disadvantage of heat pumps is the demand they put on the electric system, particularly in a scenario of wide scale deployment. Heat pumps have

the potential to create a strong winter peak in electricity demand in the coldest weather. This peak impact is particularly acute for ASHPs, as discussed below in Section III.C. While the analysis below finds that decarbonizing the grid and scaling it up to meet such higher peak demand would only lead to moderately higher electricity costs in the long run, projecting the impact of this dual challenge (decarbonization and scaling up) on prices remains a source of significant uncertainty. It also increases the challenge of building out a regional carbon-free electricity supply in time to meet potentially much higher peak demand.

There is also a question about whether ASHPs should be sized to cover all reasonably expected outdoor temperatures. While ASHPs can be sized to meet all reasonably expected heating needs, this analysis assumes that it is likely more cost-effective to use inexpensive electric resistance heating capacity to cover the small number of hours when temperatures are so cold that ASHPs are not much more efficient than traditional resistance heat.

Another practical disadvantage of heat pumps relative to decarbonized fuels is that converting to heat pumps would require that most of the existing buildings throughout the state would need to have their heating systems replaced, abandoning, altering or removing parts of the existing systems. This would require

²⁷ Even though ASHPs can be sized to provide sufficient heat during very low outdoor temperatures, the required “oversizing” of the heat pump tends to be uneconomical. Where heat pumps replace (or complement) an existing heating system, the existing heating system can be retained to provide backup heat, at least until that system requires significant investment (such as replacing a furnace). Electric resistance heating likely provides the most cost-effective back-up heating in the long run, since at temperatures below -5°F the efficiency of an ASHP drops to the efficiency of electric resistance heat. Wood stoves are another potential carbon-neutral back-up heating source. This analysis has not attempted to project the interim use of non-electric backup heat, instead focusing on all-electric Bookend Scenarios to understand the potential magnitude of the electric system impact. However, the analysis below does consider a Mixed Scenario where decarbonized heat is provided from a variety of sources; this scenario offers a good proxy for the interim use of non-electric backup heat sources.

²⁸ A heat pump can also be designed to run on natural gas, and could provide cooling as well as heating, though gas-fired heat pumps are not currently commercially available. Although it would be less efficient than an electric heat pump, a gas-fired heat pump would provide a significant efficiency improvement over gas-fired furnaces or boilers. The COP of a gas-fired heat pump in heating mode is about 1.3 (and 0.6 in cooling mode), relative to efficiencies in the range of 0.80-0.9 for a gas-fired furnace or boiler. (See Baig and Fung, Impact of Carbon Pricing on Energy Cost Savings Resulting from Installation of Gas-Fired Absorption Heat Pump at A Library Building in Ontario, MDPI Proceedings, August 16, 2019). There is currently little information about the likely installed cost of such heat pumps, and so they were not analyzed as a separate option for fully decarbonized heating in this analysis. However, future developments could potentially make them an attractive option. They would likely have relatively high initial costs, potentially similar to electric heat pumps, and would likely require similar modifications to existing buildings, but their fuel costs would be lower than for furnaces or boilers fired by renewable gas.

disruptive construction activity in the homes of most Rhode Islanders, and an initial cost that is much more costly than simply replacing an existing boiler or furnace with a new, more efficient one that is otherwise similar.

3. Decarbonizing Fuels

Rather than installing electric heat pumps to replace the boilers and furnaces that burn fossil fuels, it is also possible to keep the same or similar heating equipment, but to decarbonize the fuels themselves. That is, the fossil natural gas, oil and propane fuels currently in use can be replaced with carbon-neutral “drop-in” substitute fuels, i.e., fuels whose carbon emissions during combustion are essentially releasing carbon that was recently absorbed from the atmosphere to synthesize the fuel. Two examples explained in more detail below are biomass-based fuels, where carbon absorbed through photosynthesis by plants is converted into biofuel and re-released into the atmosphere when burnt, and “Power2Fuels” approaches, which use renewable energy to convert water into hydrogen and add carbon dioxide captured from the atmosphere to make renewable gas, oil, or other fuels. Deploying such drop-in substitute fuels has the advantage that little or no change is necessary inside the building, since for the most part, existing heating equipment and distribution systems can continue to be utilized.

Heating Oil → Renewable Oil

Currently, about a third of Rhode Island customers use heating oil and another 2% heat with propane.²⁹ Many of these customers reside outside of Rhode

Island’s urban core communities. A decarbonized liquid fuel such as biodiesel can be used as a drop-in replacement for heating oil. There are several potential sources for decarbonized heating oil, including those derived from waste oils (used cooking oil), various oil crops (rapeseed, soy, palm) and potentially synthetic liquid fuels produced from water electrolysis and subsequent steps to synthesize carbon-neutral fuels.

In fact, Rhode Island’s Biodiesel Heating Oil Act of 2013 currently requires a 5% biodiesel blend (B5) in heating oil.³⁰ In theory, this blend requirement could be ratcheted up significantly over time. In line with this possibility, the Northeast’s heating oil industry has recently committed to achieving net-zero CO₂ emissions by 2050, with interim targets of a 20% biodiesel blend (15% reduction in carbon intensity) by 2023, and a 50% blend (40% carbon reduction) by 2040.³¹ At higher blending levels, there may be some “blend-wall” issues for biodiesel.³² However, there do appear to be solutions to overcome some of these issues³³ and the opportunity exists for Rhode Island to begin increasing its blending requirements along the lines committed to by the delivered fuel industry.

While there are likely some limits on the quantities available from the relatively less costly sources,³⁴ a synthetic version of biodiesel could be produced in unlimited quantities, at least in theory. The “Power2Liquids” (P2L) pathway, illustrated in **Figure 11**, could use carbon-free electricity, water electrolysis and further refining to provide decarbonized liquid fuel in quantities constrained only by the availability

²⁹ See Meister Report, p.24.

³⁰ State of Rhode Island, Biodiesel Heating Oil Act of 2013, § 23-23.7-4.

³¹ See <https://nefi.com/news-publications/recent-news/heating-oil-industry-commits-net-zero-emissions-2050/andnbb.org>.

³² Today, biodiesel content over 20% may cause several issues with existing equipment – for example, a biodiesel tank must be in a conditioned space since B100 congeals at temperatures below 42°F.

³³ Ibid.; also see a series of modest steps proposed for a conversion to B100 (<https://www.netzeromontpelier.org/blog/2018/10/8/biodiesel-for-home-heating>, accessed February 2, 2020). See also <https://www.hpac.com/heating/article/20925981/b100-makes-the-grade> (accessed February 2, 2020), which discusses a Brookhaven National Laboratory test of a hydronic condensing boiler using B100.

³⁴ See RIEC4, Rhode Island Greenhouse Gas Reduction Plan, December 2016, p.73

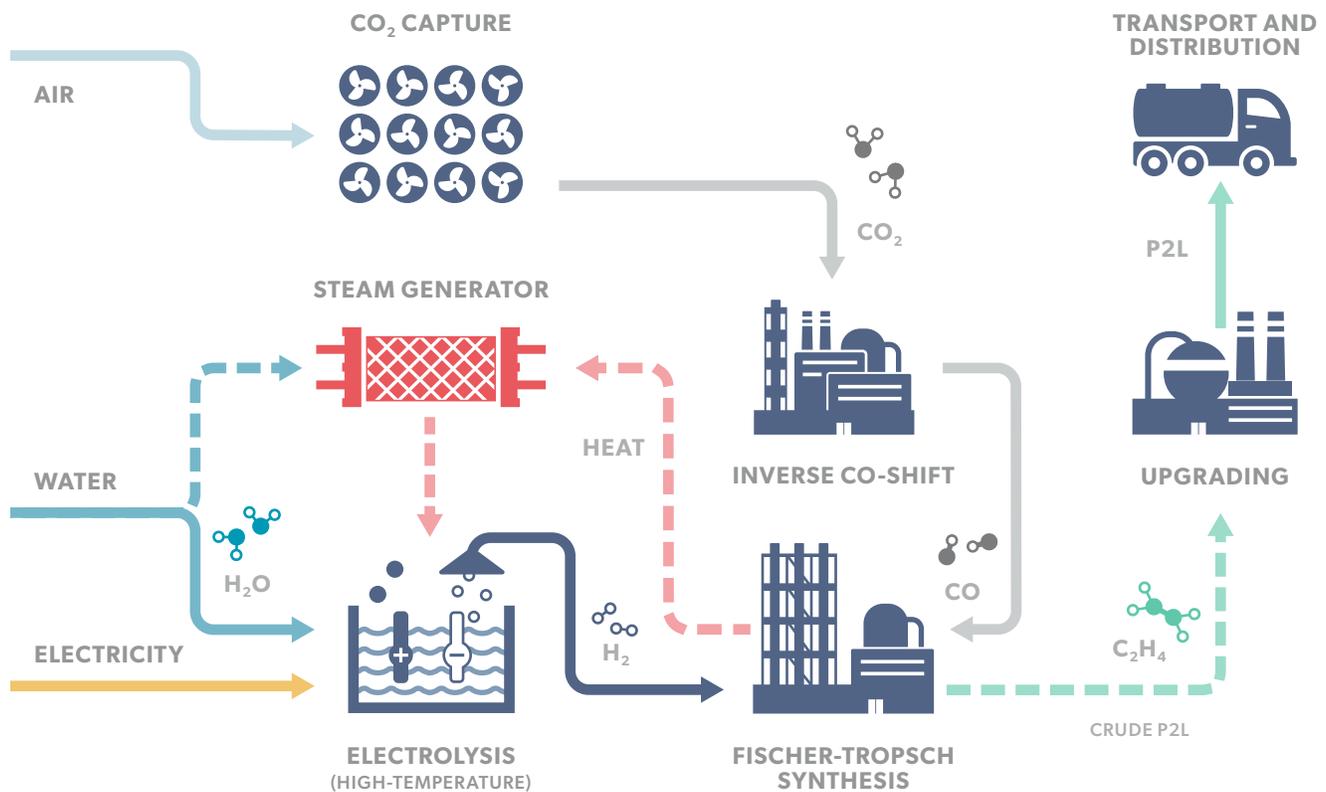


FIGURE 11: POWER2LIQUIDS (P2L) PROCESS

Source: Reproduced from Figure 3, Power-to-Liquids Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel, Umweltbundesamt, September 2016

of renewable electricity and the ability to develop the infrastructure and equipment to produce it. The primary concern with the P2L approach may be the cost of producing fuel in this way. This suggests that even if the supply of relatively low-cost biodiesel from waste products may be limited, the potential for P2L means there is likely no hard limit to the availability of renewable oil.

The remainder of this report will use the term “Renewable Oil” to refer to both biodiesel and synthetic P2L fuels, since the latter is not biologically based.

Finally, while the EPA considers biodiesel to be carbon

neutral,³⁵ some other assessments of the lifecycle emissions of biodiesel conclude that biodiesel production does emit some GHGs. Some estimates suggest that switching to biodiesel could lower GHG emissions by as much as 80%, but not 100%.³⁶ Similarly, a case study of Fulcrum Sierra BioFuels for the California Low Carbon Fuel Standard estimated a potential GHG reduction of 62.1% with biodiesel.³⁷ Hence, the decarbonizing potential of B100 for the RI heating sector would likely depend on the assessed lifecycle emissions of B100, which in turn depends on how (and from what) the B100 is produced.

Propane is also used as a delivered fuel for heat

³⁵ See <https://www.eia.gov/energyexplained/biofuels/biodiesel-and-the-environment.php>

³⁶ See (S&T)² Consultants, BIODIESEL GHG EMISSIONS, PAST, PRESENT, AND FUTURE, A report to IEA Bioenergy Task 39, January 2011, Table ES-2

³⁷ See Life Cycle Associates, Life Cycle GHG Emissions for Fulcrum Sierra Biofuels LLC’s MSW-to-Fischer Tropsch Fuel Production Process, LCA.6060.120.2015, December 2015, Table 6, page 12.

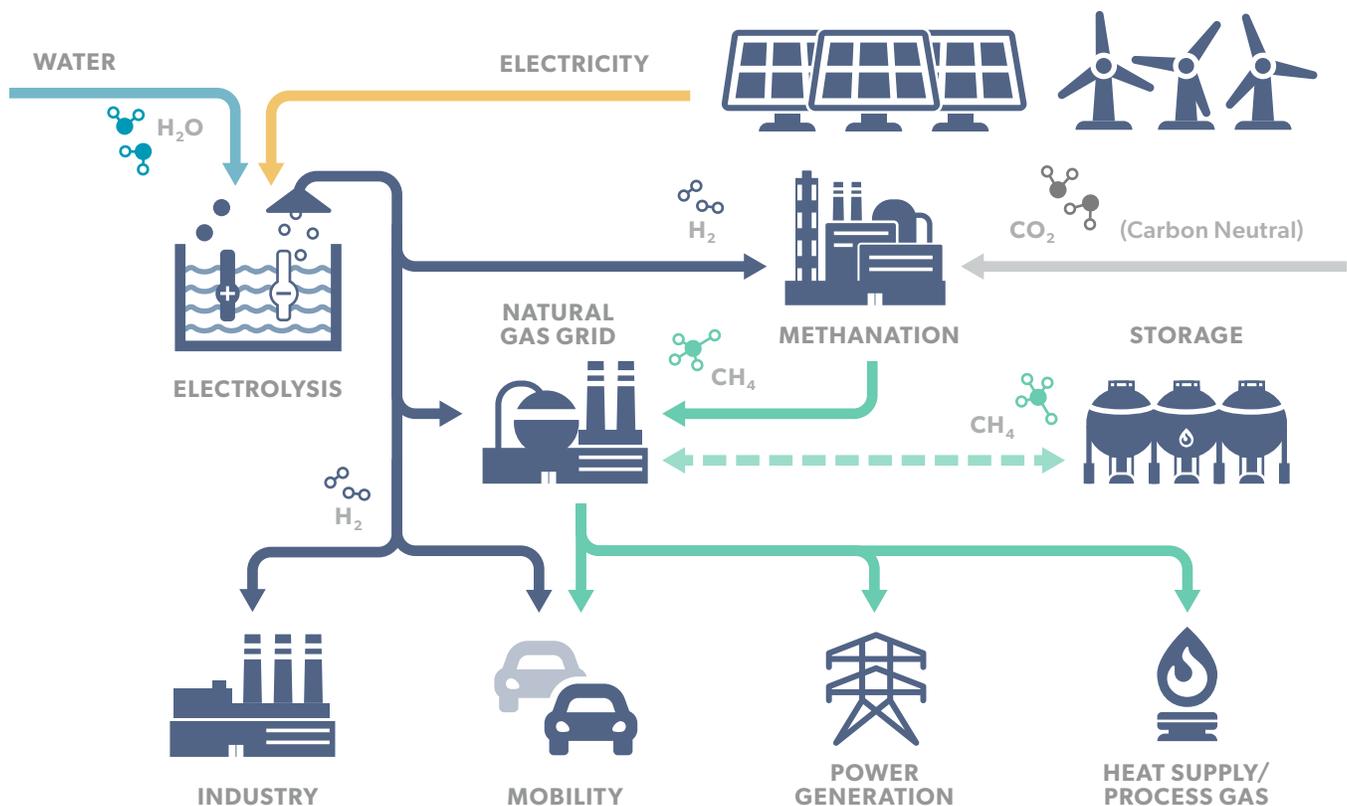


FIGURE 12: POWER2GAS (P2G) PROCESS

Source: Muhammad Akif, Analysis of Gas Power Systems, Today & Tomorrow, 2015, Figure 17, p.21

in Rhode Island, though rarely.³⁸ Conceptually, renewable propane could be produced by similar processes as renewable gas and renewable oil, including P2Fuel pathways, and so the same types of issues discussed for those fuels are likely to apply to renewable propane.

Fossil Natural Gas → Renewable Gas

Natural gas (methane) is the dominant heating fuel in Rhode Island, serving 54% of the state's residential customers.³⁹ Almost all natural gas used today is produced from fossil sources and transported via pipelines to the point of use. Small amounts of methane are available from landfill gas and anaerobic digesters (using animal waste, food and agricultural waste, waste

water, etc.), and can be blended into pipeline gas. Two potential gaseous replacement fuels for natural gas are being widely discussed: hydrogen and bio-methane, and a growing number of reports discuss the potential role of decarbonized gas in a decarbonized energy system.⁴⁰ In addition, methane can be synthesized via "Power2Gas" (P2G) pathways, which begin by producing hydrogen. As with oil, this report will use the term "Renewable Gas" to refer to both bio-gas and synthetic P2G fuels, and will use "Renewable Fuels" to refer to renewable gas and renewable oil collectively.

Figure 12 illustrates the P2G pathway.

Hydrogen can be blended with methane in the gas system, or can be used in pure form as a fuel itself. Most hydrogen is currently produced by splitting

³⁸ See Meister Report, p. 24.

³⁹ Ibid.

⁴⁰ See for example Black & Veatch, The Role of Natural Gas in the Transition to a Lower-Carbon Economy, May 2019; Navigant, Gas for Climate, March 2019

natural gas into hydrogen and CO₂ via a process called steam methane reforming (“SMR”), which releases the CO₂ into the atmosphere. If the CO₂ were to be captured and permanently sequestered, the hydrogen would be carbon-neutral; this is referred to as “blue hydrogen.”⁴¹ Alternatively, “green hydrogen” can be produced from carbon-free electricity by using electrolysis to split water into hydrogen and oxygen. Either of these forms of carbon-neutral hydrogen can be used to replace natural gas as a heating fuel, and potentially in industrial high-temperature process heat applications. However, hydrogen is not a true “drop-in” fuel since it differs from methane in ways that may require significant upgrades and investments to the existing gas infrastructure. This would likely involve equipment both in front of the meter (transportation and distribution pipes, and associated infrastructure) and behind it (internal gas lines, gas appliances).⁴² Thus hydrogen sacrifices the ability to continue using existing infrastructure, as well as the accompanying convenience and cost advantages. For these reasons, we do not focus on hydrogen as a primary candidate for a gaseous heating fuel, but believe that renewable methane is likely to be more suitable.⁴³ Nonetheless, if hydrogen does overcome these disadvantages to be the more attractive version of renewable gas, or if

hydrogen and renewable methane are both viable, the conclusions we reach below about renewable methane are also applicable to renewable hydrogen.

The alternative to hydrogen is to create renewable gas that is the chemical equivalent of natural gas. Methane can be produced from various biological sources – landfill gas, anaerobic digestion or the gasification of biological feedstocks such as wood, food waste, municipal solid waste, etc.⁴⁴ Renewable gas can also be produced synthetically via a P2G pathway by combining hydrogen from water electrolysis with CO₂ from a carbon-neutral source, in a chemical process is called “methanation.” Renewable gas has the advantage of being fully compatible with existing natural gas heating equipment, and with a very large existing gas infrastructure, including pipelines, gas distribution systems and large gas storage fields, where it can be stored for long periods of time (particularly useful for dealing with seasonal storage needs).

One concern with renewable gas is its potential cost, which may be considerably higher than current fossil natural gas prices, particularly for P2G pathways. Another factor is that gas pipeline and local distribution systems leak some of the gas that is transported. Methane is a particularly strong GHG itself, 30 to about

⁴¹ Since natural gas is currently very inexpensive in the U.S., hydrogen produced in this way could be relatively low cost if the cost of carbon sequestration were reasonably low, though sequestration has so far remained disappointingly costly.

⁴² It may be possible to blend hydrogen with natural gas at low concentrations (up to about 10%) without significant infrastructure upgrades. This can achieve near-term GHG reductions, but since such blending is limited to low concentrations, it does not offer a pathway to full decarbonization. The hydrogen “blend wall” beyond which significant infrastructure upgrades may be required depends on the composition of the particular gas distribution system in question, and determining it would require detailed study. For a more detailed assessment of various issues related to hydrogen blending, see for example Melaina et al., *Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues*, NREL, March 2013.

⁴³ Hydrogen may offer advantages in some particular applications, particularly for high-volume uses where dedicated infrastructure might be used, avoiding the need for broader upgrades. This could include large industrial applications, and also power generation, where hydrogen could offer an attractive way to store energy for use in thermal generators, to facilitate matching intermittent generation to load and providing ancillary services. The opportunities for hydrogen to address some of these industrial and power generation needs warrants further study. For one discussion of some of the opportunities for hydrogen, see “Hydrogen in a low-carbon economy,” UK Committee on Climate Change, November 2018, at <https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf>.

⁴⁴ For an in-depth discussion of both biological feed stocks, see American Gas Foundation, *Renewable Sources of Natural Gas: Supply and Emissions Reductions Assessment*, December 2019

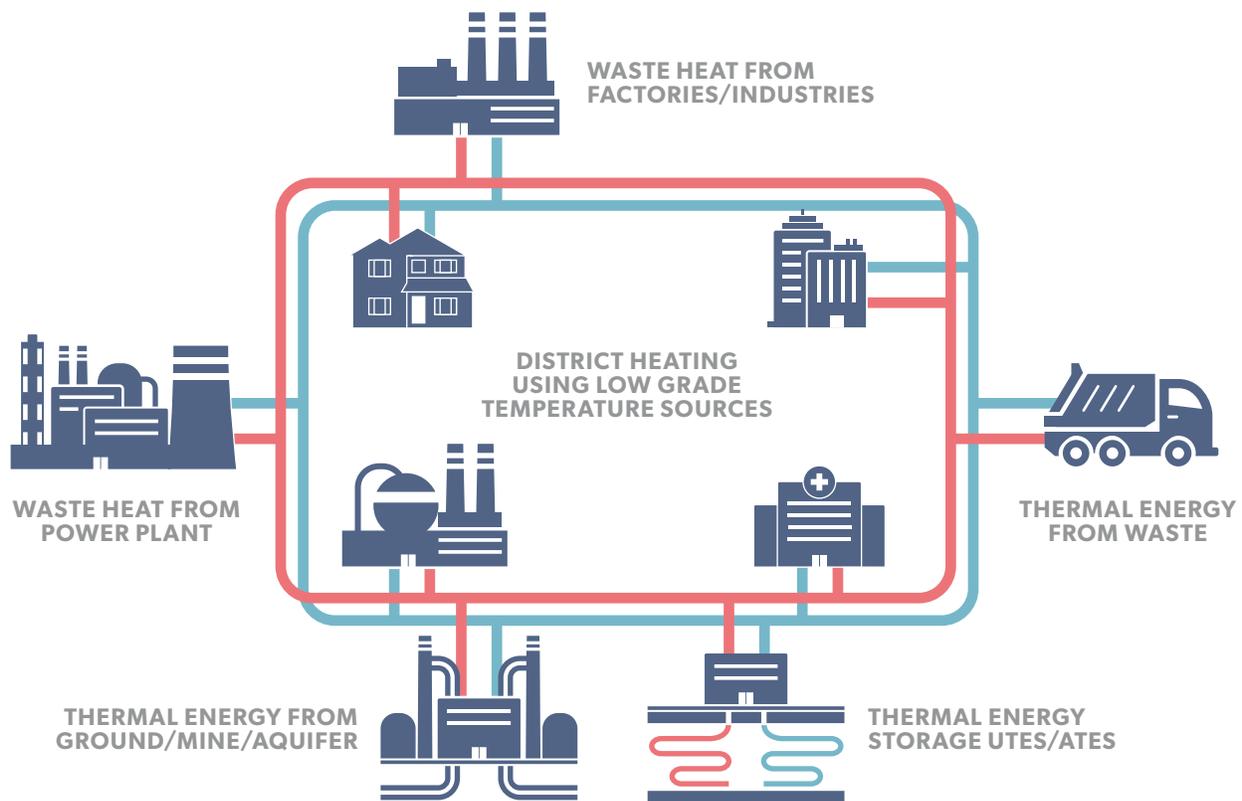


FIGURE 13: ILLUSTRATIVE SCHEMATIC OF DISTRICT HEATING SYSTEMS

Source: <https://www.flexis.wales/research-item/wp9-smart-thermal-energy-grid-prof-hr-thomas/low-grade-district-heating-network/>

85 times stronger than CO₂,⁴⁵ so even if the renewable gas itself is entirely decarbonized, any leaks would partially offset the emissions reductions of replacing fossil natural gas with renewable gas. At the current leak rate, methane leaks can add roughly 30%-85% to the GHG of the CO₂ in the combustion products. While there are ongoing efforts to reduce leaks, it is unlikely that they can be eliminated entirely. Finally, renewable gas, like natural gas, presents safety risks from indoor gas leaks, and health risks related to indoor air quality).

4. Decarbonized District Heating

All of the decarbonization solutions discussed so far concern the “fuel” or “technology” used to

decarbonize heating. Any of these approaches can be applied in a distributed system, with every individual building unit having its own fuel conversion system such as a boiler, a furnace or a heat pump. However, heating can also be provided through more centralized systems where, rather than distributing fuel (oil, gas, electricity) to individual buildings, the heat itself is produced centrally and distributed to individual buildings for use. The latter is often referred to as “district heating”, which is prominent in several northern European and Asian countries and, on a smaller scale, on university and office campuses, etc. **Figure 13** illustrates how a district heating system works.

⁴⁵ Natural gas leak rates are estimated at 2.7% by Deeper Decarbonization in the Ocean State: The 2019 Rhode Island Greenhouse Gas Reduction Study, September 2019, Stockholm Environment Institute, et al. The 100-year global warming potential for methane is 30, and the 20-year GWP is 85, based on U.S. EPA ranges (U.S. EPA, “Understanding Global Warming Potentials”, available at: <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>). This is consistent with IPCC estimates (IPCC, Fifth Assessment Report, Chapter 8: Anthropogenic and Natural Radiative Forcing, p.714, Table 8.7).

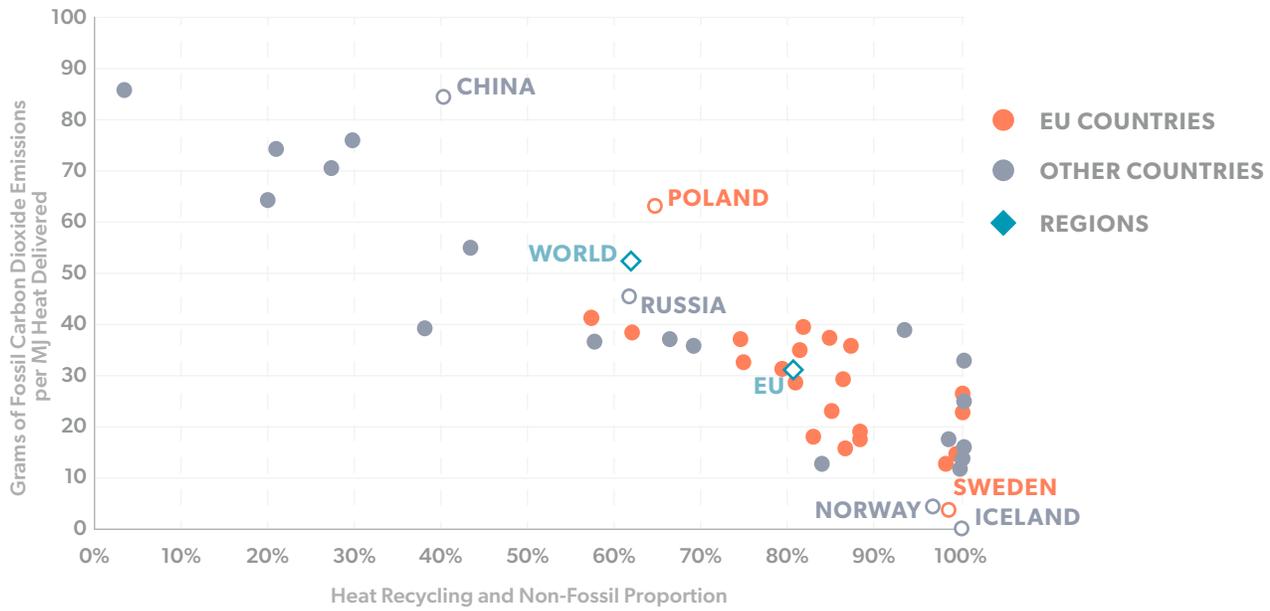


FIGURE 14: CARBON INTENSITY OF SELECT DISTRICT HEATING SYSTEMS

Source: Sven Werner, International review of district heating and cooling, Energy 137 (2017), pp. 617-631

Using district heating as a substitute for the typical distributed heating system provides additional opportunities to decarbonize heating by potentially improving the economics, feasibility or speed of transforming the heating sector.

District heating systems have been around since the 19th century and were initially introduced for a variety of reasons, including to reduce local air pollution (by centrally creating heat through the combustion of coal, oil or gas) and to take advantage of waste energy and heat (by using combined heat and power plants, waste incineration or by directly using waste heat from industrial processes). As a primary source of space and water heating, district heating systems are particularly prominent in the former Soviet Union, China and several northern European countries (Denmark, Sweden, Finland, Germany). In particular, as shown in **Figure 14**, Scandinavian countries have achieved district heating systems with very low carbon emissions.

In most district heating systems, heat is generated centrally – for example in a large combined heat and power plant (a power plant, where the heat that is generated as a byproduct is used rather than wasted) – and then distributed through a network of pipes to end users. The transfer medium can be either steam – such as the district heating system still in place in parts of New York City – or via warm water, which is then used to heat buildings. More recently, “mini district heating” has emerged as a possible alternative to large centralized systems. One particular application that has received recent media attention is the development of so-called [GeoMicroDistricts](#)⁴⁶ that create neighborhood ground source heat loops that can deliver heat to multiple buildings in a particular neighborhood.

Two of the major advantages of district heating are that it takes advantage of large economies of scale by producing heat centrally and thus avoiding the need for furnaces and boilers at the end user site and

⁴⁶ See <http://www.hydrogenfuelnews.com/massachusetts-might-replace-natural-gas-with-geothermal-heating/8538985/>

also that they allow effective use of waste heat. As a consequence, district heating systems have been shown to be very cost effective heating options, especially in new developments such as university campuses or new housing developments, i.e., where the district heating system does not replace an already existing system. Similarly, community-systems using a common ground loop have the potential to significantly lower the cost of the ground loop.⁴⁷ Larger (community) scale systems likely also create opportunities for operational efficiencies by taking advantage of diversity of heating and cooling demands from the various buildings connected to the system. For example, if such systems are installed in neighborhoods with both commercial and residential (and perhaps even industrial) customers, simultaneous demand for both heating and cooling – for example for refrigeration or warm water production – can result in such a system operating at higher average efficiencies (and potentially lower overall costs by requiring a smaller size when compared to systems serving single buildings).⁴⁸

The most significant technical challenges for district heating systems are their proper sizing – once in the ground, it can be costly to change the overall capacity to deliver heat, for example in response to growing demand via population density in a given area, as well as the fact that the cost effectiveness depends on the level of participation. Put differently, district heating systems can be very cost effective⁴⁹ if everybody participates (by spreading the high fixed

costs of such a system over many customers), but less so if participation is low. In areas without preexisting district heating systems, this makes adoption of district heating via switching from existing heating potentially challenging.

Finally, decarbonized district heating solutions face some of the same practical barriers as heat pumps. The buildings to be served by a proposed district heating system would need to have their heating systems replaced, abandoning, altering or removing parts of the existing systems, and requiring disruptive activity in those buildings and in the neighborhood. In addition, converting to a district heating solution requires high participation to obtain the potential efficiencies, which requires the agreement of many individual homeowners and building owners in the affected area.⁵⁰

5. Other Considerations

Several other considerations influence the cost and feasibility of heating decarbonization solutions and should be considered when developing a Rhode Island heating sector transformation strategy.

First, the attractiveness of various decarbonization alternatives for space and water heat may be influenced by building size (up to a point), even though the basic solution pathways are similar. While smaller commercial buildings are often similar to larger residential buildings, most large commercial buildings (and often large multifamily residential buildings) differ. They tend to use

⁴⁷ See Justin Mahlmann and Albert Escobedo, *Geothermal Heat Pump Systems for Strategic Planning on the Community Scale*, ACEEE Summer Study on Energy Efficiency in Buildings, 2012, which claims that for single family residential applications (typically less than 10 tons of heating capacity) the cost of the ground loop is \$50-\$100 per foot of ground loop. For systems with 100 tons or more of heating capacity, the costs decline to \$15-25 per foot. As one example, a system for Ball State University with over 1,000 tons of heating demand requiring 680 boreholes of 500 feet of depth each (the equivalent of 680 single family systems), the costs decline to \$11 per foot. (p.6).

⁴⁸ Ibid, p.6.

⁴⁹ A feasibility study commissioned by HEET concludes that GeoMicroDistricts can result in significant installation cost savings relative to individual GSHPs. Buro Happold, *GeoMicroDistrict Feasibility Study*.

⁵⁰ While the district heating solution also presents a similar up-front cost barrier to other GSHP solutions, this might be mitigated to the extent the distribution utility is authorized to finance, build and operate the system as a part of its business model, including it in rate base. In Massachusetts, the state regulator is considering some pending utility-sponsored geothermal proposals. See <https://www.wbur.org/earthwhile/2020/01/13/heat-eversource-geothermal-energy-climate-change>.

boilers for heating and a combination of chillers and cooling towers for cooling. In these larger buildings, heating is relatively less important and cooling more important than in smaller buildings because of the lower surface area to volume ratio, and the often large density of incidental heat sources within the building (lights, computers, people). Internal heat (and cooling) distribution systems are mostly hydronic, in contrast with the large share of air-based (forced hot air, central A/C) systems in typical residential settings. Although this report does not explore this in great detail, the decarbonized solutions described above can work in buildings that have very different heating loads, different uses and different building-level heat distribution systems, though the particular details of how they are applied will differ from building to building.

Second, different buildings are likely to require different solutions in part because of the considerable diversity of existing buildings. The idiosyncratic features of a given building or site can affect which decarbonization solutions may be feasible or reasonable. Such features can include whether and how well they are insulated, and the ability to add insulation, interior ductwork or hydronic distribution; whether a given building has access to the gas distribution network; or whether the geology is appropriate for a ground loop for a GSHP – indeed even whether there is enough space in an urban area to install a ground loop.

Third, while it seems likely that electricity will play an increasing role in any decarbonized future (for transportation as well as heat), the same is less clear for gas and the gas distribution system. If many existing gas customers adopt electric alternatives for part or all of their heat needs, the throughput on existing gas distribution systems will decline, perhaps significantly. Even if the carbon intensity of the gas flowing through

these pipes can be reduced – e.g., by blending with increasing shares of renewable gas – the reduced throughput will concentrate the (essentially fixed) costs of the gas distribution system more heavily onto each remaining unit of gas. Increasing distribution rates, particularly if combined with higher costs for the decarbonized gas itself, could cause a substantial increase in delivered gas prices for local utility customers. This raises some important issues. For example, low- and moderate-income customers may have limited ability to switch from gas, due to the high initial cost of electrified heat pumps, and because they are more likely to be renters unable to control the heat source in their homes. Absent some way to counteract this, they could bear the brunt of gas cost increases. More generally, it raises questions about whether and how the gas system may need to be reconfigured. This might include reducing or eliminating service in residential areas where heating electrification is widespread, raising the question of how to “unwind” part of the network in an orderly way, and particularly how to protect vulnerable populations in the process, all while maintaining the economic health of the gas utility, so that it can ensure safe and reliable service to those customers who continue to rely on gas. And it could include maintaining or even expanding the gas system in areas like industrial zones where there are few viable alternatives to burning fuel. The potential future of the gas distribution system has thus become an increasingly important topic for a decarbonized future.⁵¹ In Rhode Island, however, one utility provides both electric and gas distribution services. It may be possible to address or mitigate this effect by regulating the utility as an “energy delivery company,” instead of treating the entity as separate gas and electricity businesses for ratemaking purposes.

Finally, the attractiveness of any of the above solutions

⁵¹ For example the California Public Utility Commission (CPUC) has initiated a regulatory proceeding that requires advance planning to explore various potential future paths for natural gas infrastructure. (CPUC, Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and perform Long-Term Gas System Planning, Proceeding R2001007, issued January 27, 2020)

may depend on “systemic” effects. As an example, the price of electricity may depend on how widespread ASHPs are adopted. ASHPs increase the “peakiness” of electricity demand, which increases the cost of electricity and in turn impacts the economic attractiveness of ASHPs (as well as affecting the cost of other electricity uses). The best strategy may also depend on a number of practical implementation issues: How much cost-effective weatherization can actually be achieved by 2050? How many homes can realistically be converted to heat pumps by 2050, given the need

for specialized labor to perform the installations and the current tightness of this labor force? How do geological and other local conditions affect the feasibility and cost of GSHP? How much renewable oil supply is available, and how does this compare with potential demand, accounting for the fact that Rhode Island may not be the only state relying on renewable fuels as a part of their decarbonization strategy? For these reasons, a wide range of cost and implementation issues must be considered when developing a heating transformation strategy for Rhode Island.

Methodology

This section describes the methodology used to analyze various heating decarbonization pathways for Rhode Island at a summary level. A more detailed description of the methodology, including modeling and assumptions, is included in the **Technical Support Document**.

Research Questions

1. Understand the relative economic attractiveness of the decarbonized heat solutions identified, as applied to the primary heating applications in Rhode Island.
2. Understand how decarbonizing may affect related energy sectors that provide the energy for heating (i.e., renewable fuel and clean electricity), and how these feedback effects impact the costs to consumers, for heating and for overall energy consumption.
3. Identify the implications of these analyses that can be used to guide policies for heating sector transformation.

HEATING NEEDS AND DECARBONIZATION SOLUTIONS

To understand the attractiveness and feasibility of various decarbonization pathways various heating situations were mapped to decarbonization solutions, as illustrated stylistically in **Figure 15**.

Figure 15 does not explicitly represent all building types, current fuels, applications or decarbonization solutions, though it does cover the vast majority of heating situations and decarbonization solutions for Rhode Island. Additional options such as the use of solar hot water heating or the use of wood heating may exist, though they will likely play only a relatively small and complementary role in transforming the Rhode Island heating sector.

Two sets of arrows (in different colors) in **Figure 15** provide two examples of “representative” heating situations, for which decarbonization solutions were identified as “applicable” and therefore analyzed for a specific building type/current fuel/application.

Preliminary analysis showed that a significantly smaller subset of “representative” heating situations can be used to analyze the attractiveness of heating decarbonization solutions across the full span of heating applications. This is because, ultimately, the feasibility and attractiveness of heating decarbonization depends heavily on a small number

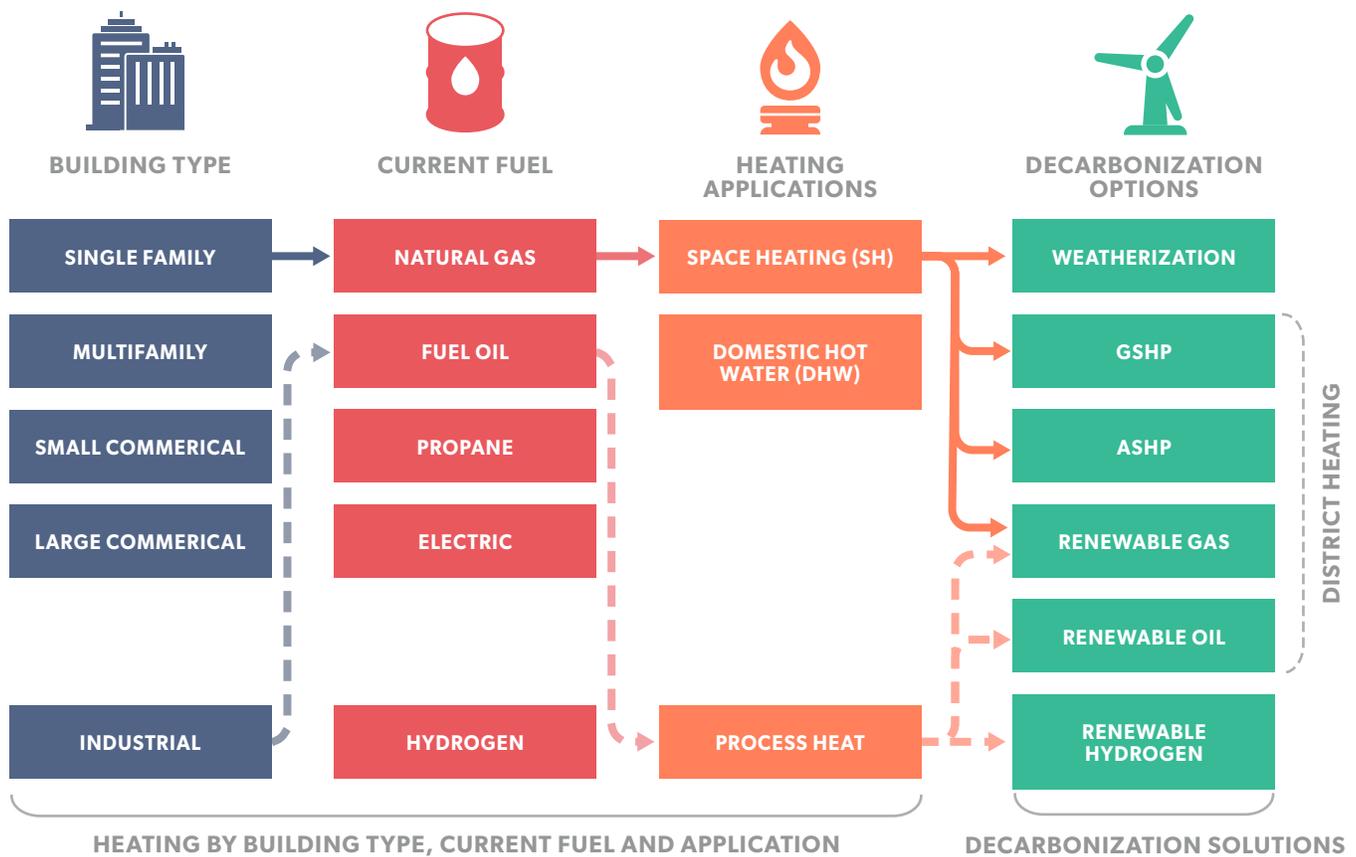


FIGURE 15: STRUCTURE OF HEATING TRANSFORMATION ANALYSIS

Note: Arrows indicate two situations. 1) A single-family home currently using natural gas for space heat could decarbonize using efficiency in combination with a heat pump or renewable gas (solid arrows). 2) An industrial facility currently using oil for process heat could decarbonize by substituting renewable oil, renewable gas, or renewable hydrogen (dashed arrows).

of factors. For space heating, the economics (and in some instances the feasibility) of various decarbonization solutions are primarily driven by the total heating demand for a given building, and the current heating system. Up to a certain size, residential (single- and multi-family) and commercial buildings tend to utilize the same types of fossil heating technologies, and can be transformed using similar decarbonization solutions. Current heating technologies in larger buildings differ from those used for smaller buildings; while this does not fundamentally alter the decarbonization solutions for such buildings, it may affect the cost tradeoffs among the decarbonized solutions. Similar relationships hold true for domestic water heating. Industrial heating represents a small share of the overall Rhode Island

heating demand and is highly specific to particular industrial applications, for which little detailed information is available. For this reason, industrial heating applications were treated separately and more qualitatively.

ECONOMIC MODEL OF DECARBONIZED HEAT

To explore the economics of heating decarbonization for “representative” residential/commercial heating situations, this study uses an economic model to estimate annualized heating costs. This model can be applied to both current fossil and future decarbonized alternatives. Annualized costs include both “fuel” costs (natural gas, oil, electricity) and equipment costs

(furnace or boiler, heat pump, etc.), amortized over the expected life of each major equipment component. Doing this requires the use of a discount rate to enable comparing the initial up-front cost of equipment installation or replacement with a stream of future costs and benefits. When different heating options involve a very different split between upfront costs and ongoing operating costs, the discount rate can matter: a higher discount rate means that the up-front installation costs are more important relative to the costs and benefits that occur in the future; a lower discount rate means the opposite – that upfront costs matter less. Since the available heating decarbonization solutions do differ substantially in that regard – GSHPs, for example, have significantly higher installation costs than ASHPs, which are in turn more costly than traditional furnaces and boilers – this may be an important issue. The quantitative analysis uses a 3% (real) discount rate, reflecting a commonly used “social discount rate”, such as is often used to determine the value of avoided greenhouse gas emissions.⁵² However, there is evidence that individuals, when facing decisions about investments like energy efficiency that trade off upfront costs vs energy cost savings over time, choose as if they have a discount rate substantially higher than 3%. To reflect this, we also show “payback periods” for the tradeoffs between alternatives, to illustrate how various decarbonization solutions might be viewed by consumers and how adoption rates might be influenced by a longer or shorter payback period.

Given that the two primary pathways are the decarbonized electrification of heating and the decarbonization of “fuels,” it is necessary to consider

the impacts of electrifying heating on the electricity sector, which in turn impacts the cost of electricity, and the potential cost of renewable fuels.⁵³ Both will be major factors in the attractiveness of the respective pathways, particularly since widespread adoption of some of these technologies could impact the pricing of the respective fuel. To explore the issue of feedback between decarbonizing heat and the availability and costs of electricity and/or decarbonized fuels, several “Bookend Scenarios”, in which each technology option is evaluated in a context where essentially all the heat in the region being provided by that technology are developed.⁵⁴ These investigations generate several important insights in their own right, which are discussed below in Sections III.C and III.D. **Figure 16** illustrates the analytical modeling structure used to develop quantitative comparisons between various heating decarbonization solutions, incorporating interactions with the electricity sector, and considering the availability and cost of renewable fuels. The primary focus of these analyses is space heating, which represents about 60% of total residential energy demand in Rhode Island; we also examined options to decarbonize domestic water heating (the second largest energy need, at 16%). In addition to these quantitative analyses, we performed a more qualitative analysis of considerations related to decarbonizing industrial heating.

Because projecting the costs of heating three decades into the future necessarily involves significant uncertainties, the model considers a range of potential future costs. There are also a number of non-quantifiable factors related to

⁵² There is no “correct” discount rate per se. There is a large literature discussing the use of a “social discount rate” to evaluate policy that takes into account various societal issues rather than just reflecting private decision making. In general, social discount rates are in the range of 2.5-7%, and some argue for a 0% discount rate (in real terms). For example, U.S. estimates of the social cost of carbon use discount rates of 2.5%, 3% and 5% (See Resources for the Future, Social Cost of Carbon 101, August 1, 2019). See also OMB Circular A-4, September 17, 2003, which includes an in-depth discussion of the rationale for using various discount rates.

⁵³ We do not separately model the cost and availability of renewable oil, but instead rely on existing modeled prices of renewable oil.

⁵⁴ The Bookend Scenarios are: all GSHP, all ASHP, and all Renewable Fuel (where customers retain the fuel type they currently use, but the fuel itself is replaced with a renewable version – fossil heating oil is replaced with Renewable Oil (B100) and fossil natural gas is replaced with Renewable Gas).

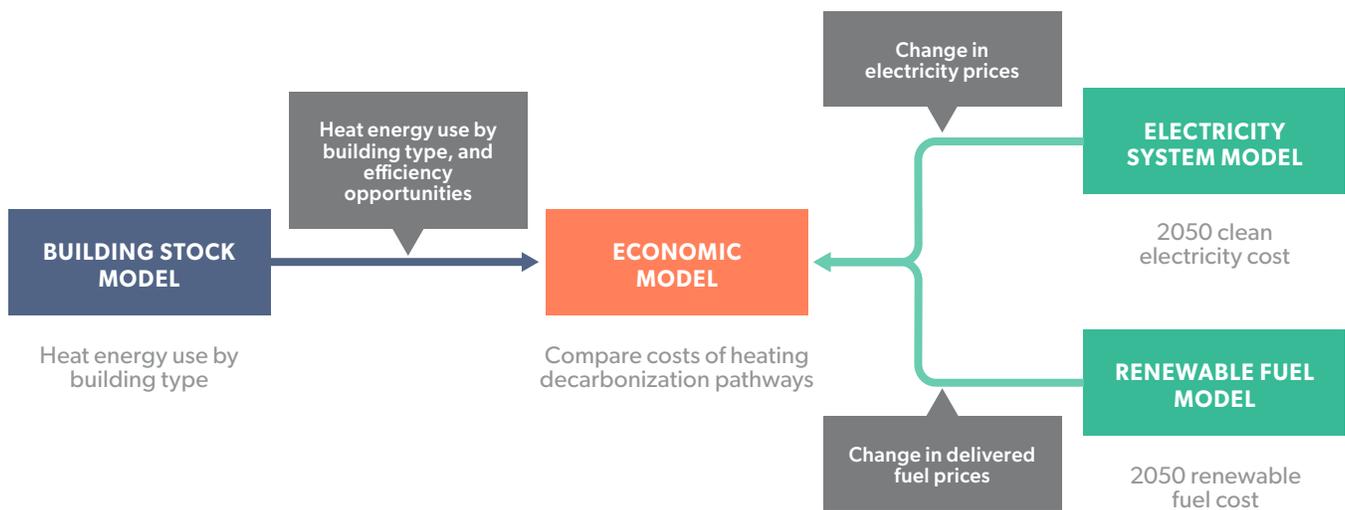


FIGURE 16: ANALYTICAL MODEL OVERVIEW

the heating decarbonization solutions, such as implementation barriers and other not easily quantified benefits and costs. These more qualitative factors are also considered as part of the overall assessment of the attractiveness of a given solution for a given building type. Before describing the financial model itself, the electricity and renewable fuels models are described next.

ELECTRICITY SYSTEM MODEL AND IMPACTS OF DECARBONIZED HEAT

Because heating in northern climates requires a large amount of energy, widespread decarbonized electrification of heating via heat pumps would have a substantial impact on the demand for electricity. The impact on the shape of electricity demand may even be greater, since heat needs are highly correlated across the region, peaking in the coldest weather. These impacts are evaluated using the Bookend Scenarios introduced above, in the context of a decarbonized electricity sector. Electrifying all heating in New England with either GSHP or ASHP would turn the current summer-peaking New England electric system into a strongly winter-peaking system, affecting supply needs and electricity prices. Although electric heating and cooling use essentially the same

technology, the electricity needed to heat a building with a heat pump is much greater than the power required to cool it with an air conditioner, because the temperature differentials that must be maintained between outside and inside are much larger in winter (50-70°F) than they are in summer (20-30°F).

However, there is a distinct difference between air source and ground source heat pumps. Either technology must accommodate the fact that the demand for heat is much greater when outside temperature falls very low. But it is easier for a GSHP to provide the necessary amount of heat than it is for an ASHP. GSHPs draw heat from the ground, which is always about 50°F, whereas the ASHPs draw heat from the outside air, which contains less heat energy at just those times when the demand for heat is greatest. This means that when it is very cold, ASHPs must use considerably more electricity to deliver the same amount of heat as GSHPs. That is, at very low temperatures, its efficiency is much lower.

The efficiency of a heat pump is measured by its “coefficient of performance” or CoP – the ratio of output heat energy to the amount of electric energy consumed. For a GSHP, this CoP is constant at about 3.6 regardless of outside temperature – i.e., for each

kWh of electricity consumed, the GSHP delivers about 3.6 kWh of heat. But for ASHP, the CoP depends on the outside air temperature. At an outside temperature of 50°F, an ASHP has a CoP very similar to a GSHP. But the CoP for an ASHP falls to about 1.0 when air temperature is around 0°F. This means that when it is 0°F outside, an ASHP will require about 3.6 times as much electricity as a GSHP to deliver the same amount of heat. Thus in the ASHP Bookend Scenario, the peak electricity demand from heating would be about 3.6 times what it is in the GSHP scenario. (Of course the overall system peak differs by less than 3.6x because of the other electric load that is similar in either case).

Figure 17 illustrates the projected impact of electrifying all New England heating via all ASHPs vs all GSHPs in 2050, when it is also assumed that transportation will be mostly electrified. As can be seen, the impact of electrifying heating on total energy consumption is modest: Demand increases 12%-15% relative to demand without heating electrification (but with transport electrification). With all GSHPs, peak demand increases by 17%, slightly more than the energy increase. But with all ASHPs, the increase in peak demand would be dramatic at 94%, almost twice the peak demand without electrified heating via ASHPs. As can be seen in the bottom panel of the figure, which ranks hourly demand from highest to lowest, this increase in peak is caused by a very small number of hours, precisely those when outside temperatures decline to levels, where the efficiency of ASHPs approaches 100% (and hence is equal to the efficiency of electric resistance heat; in fact, we assume that electric resistance will be used to supplement ASHPs to meet peak). The almost doubling of peak demand with an all ASHP system could result in materially higher electricity

prices.⁵⁵ Because ASHPs require more electricity, and their disproportionate peak impact would increase electricity prices, widespread ASHP adoption could substantially raise the cost of electric heating.

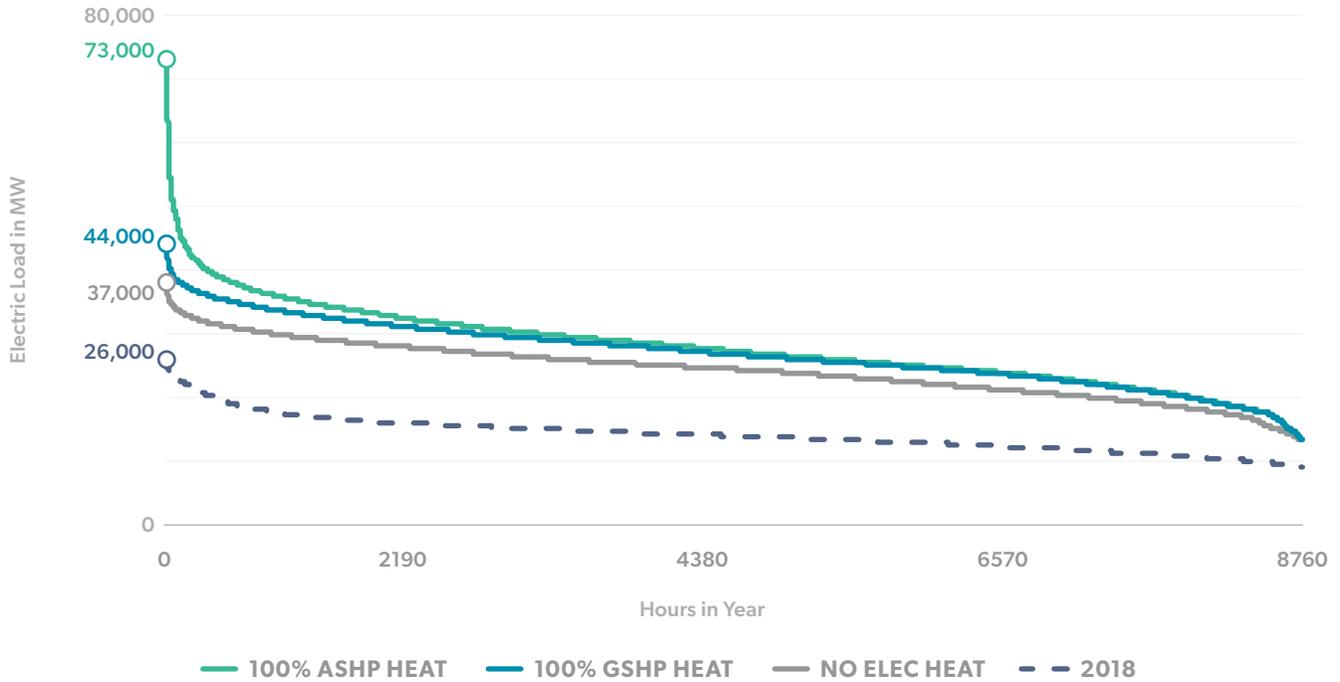
Figure 18 displays estimates of the delivered electricity price in these future scenarios based on the projected cost of building a renewable power system that would serve each of these load profiles.⁵⁶ The current average delivered price for power in Rhode Island is 18¢/kWh. In a decarbonized 2050 system without electrified heat, electricity costs would be somewhat higher than today, at 22¢/kWh (in \$2018). With all heating electrified via GSHP, the electricity price would essentially remain unchanged (21.8¢/kWh), but with ASHP, it would be considerably higher, at 24.6¢/kWh. This accounts for the higher cost of generation, since more peaking capacity would be necessary (in a decarbonized system, this would be a combination of storage such as batteries, and possibly conventional generators using renewable fuel). It also considers the additional costs for the transmission and distribution system, which must be sized to meet the system peak and is thus heavily affected by a higher system peak.

The estimated increase in retail costs for a fully decarbonized power supply able to meet electricity demand in each of the scenarios is relatively moderate, in the range of 10-35%. These estimates are of course uncertain, since the costs of many of the resources to supply 100% clean electricity are evolving rapidly, and the generation component of clean energy is projected to increase more sharply. But some of this increase will likely be offset by lower per-kWh transmission and distribution costs. Even though a considerable amount of new transmission

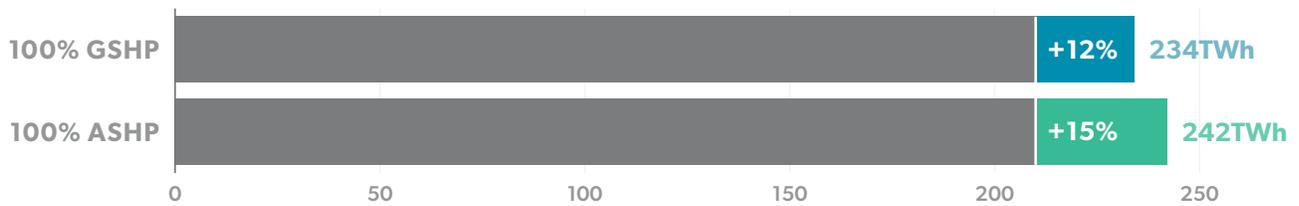
⁵⁵ The modeling of electricity prices assumes some mitigating factors such as the use of batteries to shift demand away from the highest demand hours. Other mitigating options not modeled include the use of thermal storage, which is just emerging as a potential technology option for ASHPs. For more detail on electric sector modeling underlying these calculations, see the Technical Support Document.

⁵⁶ A higher peak demand would affect the cost of both the generation of renewable electricity and the cost of the transmission and distribution system needed to reliably deliver electricity to consumers.

Sorted Electric Load Hours



Annual Energy by Heat Source (TWh)



Peak Demand by Heat Source (GW)

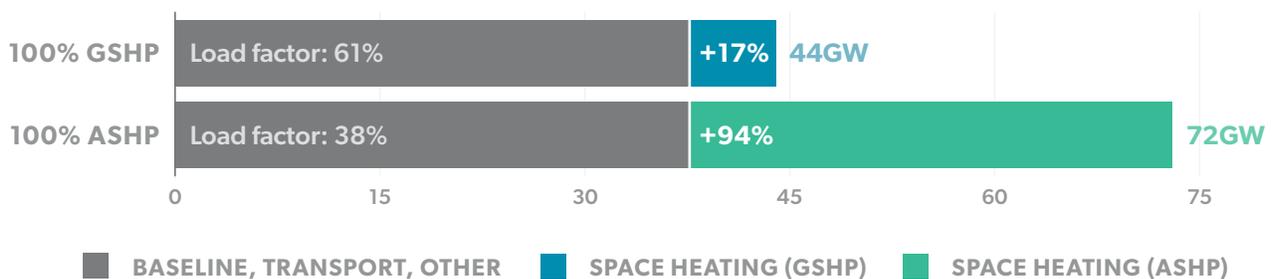


FIGURE 17: IMPACT OF ELECTRIFYING HEAT VIA ASHP VS GSHP – 2050

Note: The 2050 load characterization assumes that the transportation sector is mostly electrified, and also assumes continuing efficiency improvements in baseline uses of electricity (current uses).

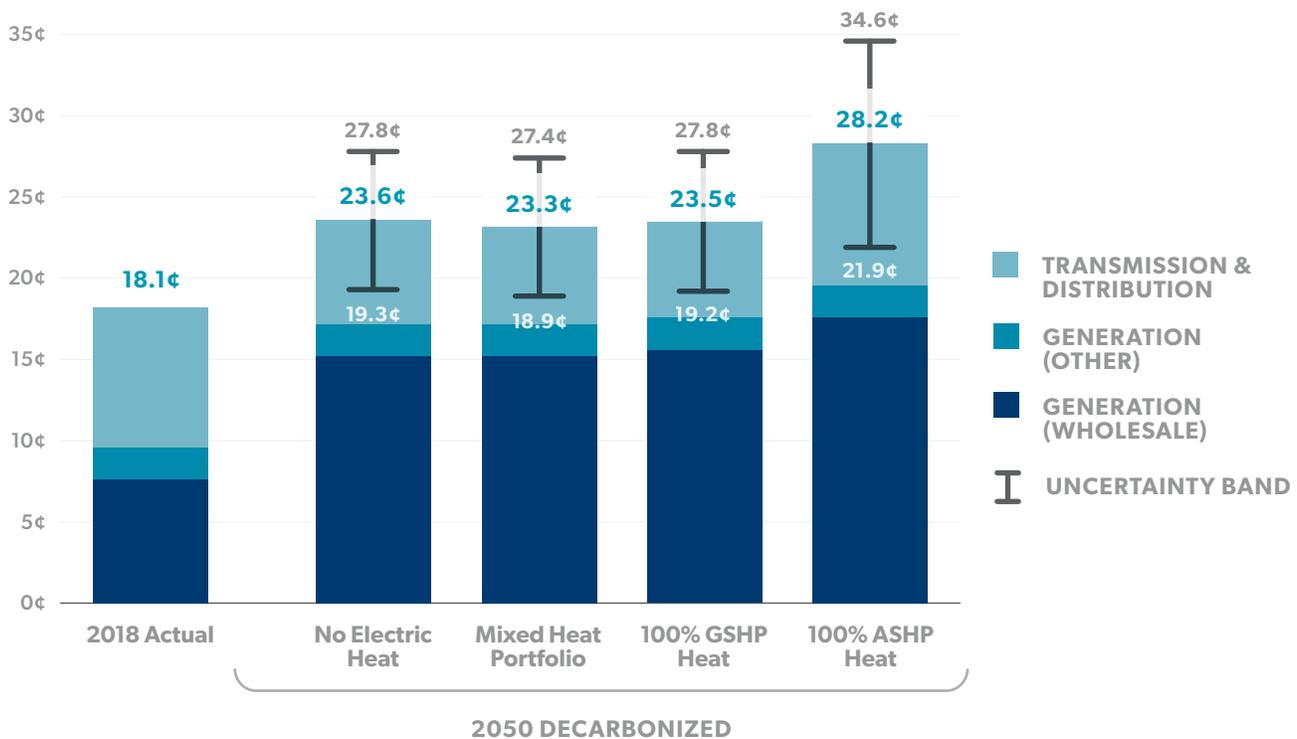


FIGURE 18: RHODE ISLAND ELECTRICITY PRICE BY SCENARIO (cents/kWh, IN 2018\$)

Note: The 2050 Decarbonized estimates assume that transportation is largely electrified. Generation (Wholesale) represents the cost of an emissions-free electricity generation system, based on the electric sector model described in Technical Support Document. Generation (Other) reflects costs related to electricity supply beyond the supply resources themselves (administrative costs of the ISO and utility to manage electricity purchasing, etc.). The high and low electricity price estimates reflect a +20% (high) to -20% (low) change in the generation component. T&D costs reflect the cost of the transmission and distribution system, with required T&D expansions to meet increased load evaluated at National Grid’s approximate embedded T&D cost of \$291/kW-year (high case), at National Grid’s Avoided Energy Supply Components value of \$83.26/kW-year (low case), and at the mid-point of the two (\$187/kW-year) for the nominal estimate.

and distribution infrastructure will be needed in a decarbonized and largely electrified future, and total T&D costs will be higher (especially in the 100% ASHP Heat Scenario), the total volumes of power delivered, including for EV charging as well as electrified heat, are likely to increase by even more, lowering the unit T&D cost. Much of this effect is due to EV charging, which provides significant year-round demand with a somewhat complementary daily load shape relative to other electricity demands, thus increasing the utilization of the existing T&D infrastructure. In addition, the T&D system can accommodate 20-25% more power in winter than in summer, meaning

that the winter peak caused by electrified heat will require substantially less T&D expansion than would a summer peak.

RENEWABLE FUELS MODEL

The second basic pathway for decarbonizing heating is to substitute renewable fuels, such as renewable oil or renewable gas, for the current fossil oil and natural gas used in the vast majority of cases. A major advantage of this pathway is that renewable fuels generally require little or no changes to existing infrastructure and equipment, either at the customer site or in the delivery system.⁵⁷ As discussed above, there are a number of

⁵⁷ As discussed above, renewable hydrogen, if used beyond low concentrations, would likely require upgrades to many components of the gas infrastructure.

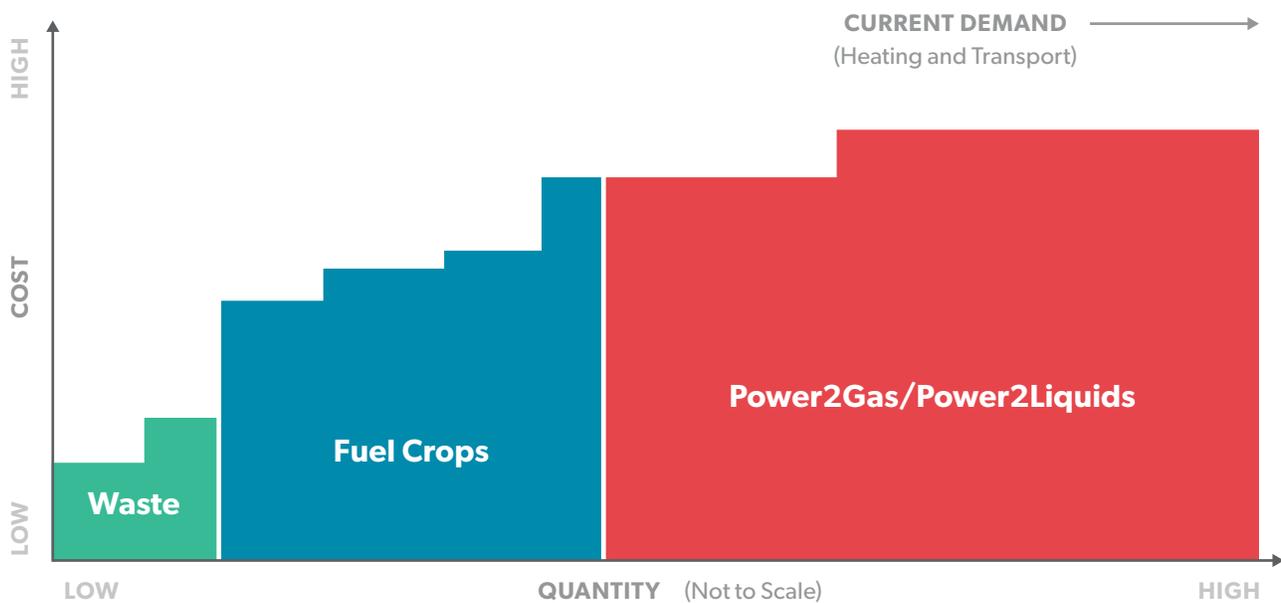


FIGURE 19: SOURCES OF RENEWABLE FUELS

potential sources for both renewable oil and renewable gas, though one of the challenges may be the limited quantities available from less costly sources.

1. Taxonomy of Renewable Fuels

The sources for renewable fuels can be thought of in three categories: waste biofuels, fuel crops, and power-to-fuel technologies, as illustrated in **Figure 19**.⁵⁸ Potential waste sources include used cooking oil for biodiesel, and landfill gas or waste biomass (e.g., food waste, animal manure or wastewater via anaerobic digesters) for natural gas. Some woody biomass may be available as byproducts of agriculture or forestry processes, which can be gasified or perhaps converted to methanol. These are often among the least costly sources for renewable fuels, but because their source is the waste or byproduct of some other process, the quantities available are

limited, and in fact are small compared to current demand for natural gas and heating oil.

The second category is fuel crops – biomass that is grown and harvested specifically for fuel. This includes oil crops (rapeseed, soy, palm), other crops such as switchgrass or sugarcane that can be used to produce ethanol or methanol, and many types of biomass which can be gasified. These types of sources are already in use on a relatively small scale, but if they were to be scaled up to produce the quantities necessary for widespread use as heating fuel, the amount of land and resources they would require could put major stresses on agriculture and the environment. In part because of this, the cost of renewable fuels produced from fuel crops will generally be higher than those produced from waste biomass. Also, both the available quantity and the net greenhouse gas emissions impact of fuel crops remain uncertain.⁵⁹

⁵⁸ There may be some hybrids among these categories, such as combining waste or agricultural feed stocks with P2Fuel technology as a way to facilitate the production of other fuel types.

⁵⁹ There is a very active debate about the impact of fuel crops on land use and greenhouse gas emissions. Apart from the question of land availability to meet high levels of renewable fuel demand from fuel crops, net greenhouse gas emission reductions are also uncertain, given that fuel crops would likely result in direct or indirect land use changes involving conversion of land areas that are carbon sinks into fuel crop land that would at best be carbon neutral. For a discussion of the literature on this issue see <https://farm-energy.extension.org/indirect-land-use-impacts-of-biofuels/>.

The third category includes the Power2Fuels technologies introduced above, in which fuels are synthesized using renewable electricity to create hydrogen, are further converted via what is called methanation to methane, and possibly using additional chemical processes to turn methane into liquid fuels. In principle, P2Fuels processes (illustrated in Figures 11 and 12 above), should be scalable to very high volumes, limited only by the availability of renewable electricity and the capital equipment required. There have even been suggestions that P2Fuels pathways might complement a high-renewable power system, taking advantage of cheap or free renewable electricity at times it would otherwise be curtailed; this might lead to relatively inexpensive renewable fuels since the cost of input electricity is a substantial component of their cost.⁶⁰ It is unlikely, however, that sufficient surplus renewable electricity would be available if P2Fuels production were implemented at a large scale. Demand for renewable electricity for P2Fuels production would consume otherwise curtailed renewable power in most hours, raising the price until it is consistent with the prevailing power price at other times or the economics of P2Fuels production at higher prices are no longer attractive. Also, the equipment needed to produce P2Fuels – electrolyzers, methanizers and, potentially, CO₂ air capture devices - is costly, so it would not be cost-effective to operate only in the relatively infrequent times when electricity remains very cheap or free. In addition, operational constraints may prevent the kind of flexible operation that may be required to take advantage of periods of excess renewable power generation. Therefore, if deployed at large scale, the electricity used as an input to P2Fuels production will likely be priced at or near the average cost of producing renewable power (which includes their capital costs).

Finally, depending on where P2Fuels processes take place – in theory, electrolysis, methanation and CO₂ capture could occur in different places, but there are also likely synergies for co-location – the manufacturers of renewable fuels would incur delivery charges for the electricity used in the process.

2. Markets for Renewable Fuels

Since renewable fuels that can be used for heating can also be used in other sectors, including transportation and industry, and are easily transportable, the market for renewable heating fuels, like current markets for fossil fuels, will not be local or limited to the heating sector. This will cause prices to tend to equilibrate across sectors and regions.⁶¹ This means that the prices of renewable fuels will be set by market forces working across a geographic region much larger than Rhode Island and economic sectors well beyond heating fuel. It also means that, as with all goods, competitive economic forces will ensure that the least costly production sources will be utilized first and that the last, most costly source needed to meet a given level of demand – across sectors and geographies – will set the price at that level of demand.

Thus, the market for renewable fuels will likely be national or international in scope. Sources of waste biofuels are widespread across the country, but not concentrated in the Northeast and, in aggregate, can supply only a small share of current fuel uses.

3. Supply Curve for Renewable Fuels

For all of these reasons, and because P2Fuels processes are still in their infancy, the availability and the costs of renewable fuels – both liquids and gas

⁶⁰ For a discussion of the use of surplus renewable energy to make hydrogen or renewable gas to use in power generation, see for example <https://physicsworld.com/a/oversizing-renewables-to-avoid-shortfalls/> or <https://www.windpowermonthly.com/article/1578773/green-hydrogen-economically-viable-2035-researchers-claim>.

⁶¹ Fossil prices differ across regions in the United States, in part because of how close fuel production is to fuel consumption, but also due to different fuel standards resulting in different production processes. One would expect some price differences for renewable fuels to occur as well, even though price differences would be limited by the opportunity to sell such fuels into higher priced destination markets.

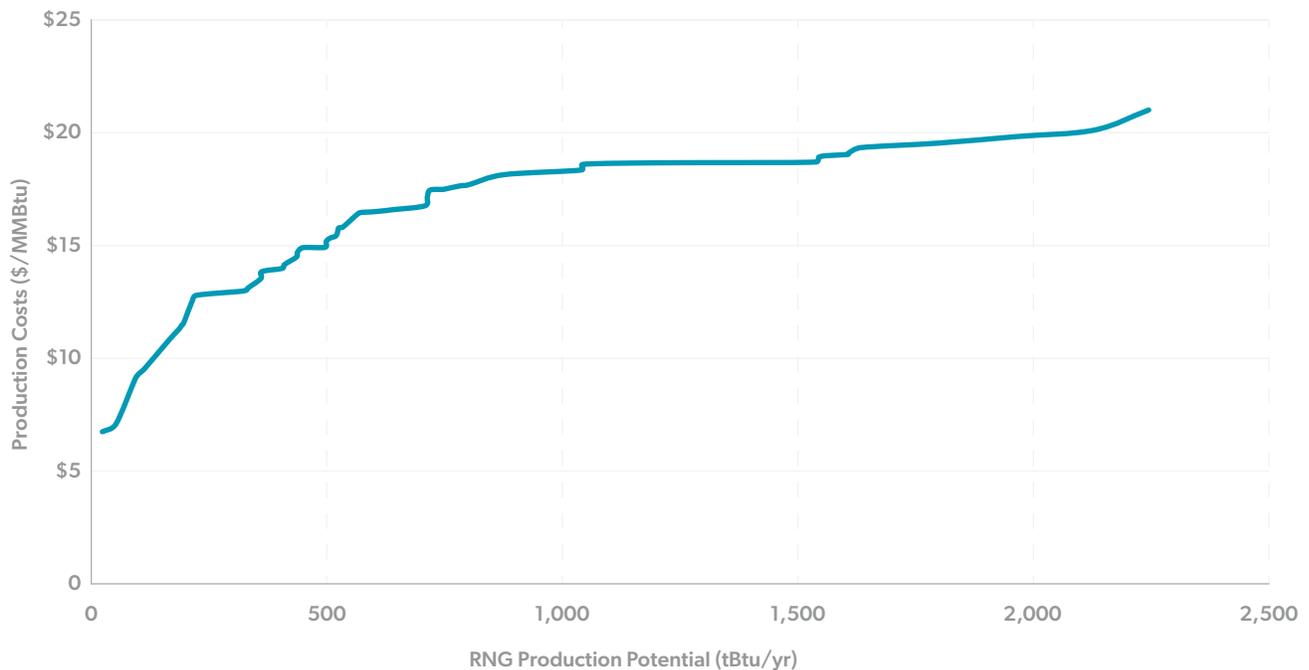


FIGURE 20: AMERICAN GAS FOUNDATION U.S. SUPPLY CURVE FOR RENEWABLE GAS (HIGH RESOURCE POTENTIAL SCENARIO)

Source: Reproduction of Figure 34, Combined RNG Supply-Cost Curve (based on high resource potential scenario), less than \$20/MMBtu in 2040, American Gas Foundation, Renewable Sources of Natural Gas: Supply and Emissions Reductions Assessment, December 2019.

– in the near term and through 2050 remain highly uncertain. It is likely that only limited quantities will be available at relatively low costs.

For renewable gas, a recent report by the American Gas Foundation estimated the supply of renewable gas available at a cost below \$20/MMBtu – which is roughly eight times the current price of natural gas. **Figure 20** reproduces this modeled supply, which reflects the AGF’s High Resource Potential Scenario.

As **Figure 20** shows, the analysis by the American Gas Foundation concludes that in its high resource potential scenario, approximately two trillion Btu per year could be produced at a cost of \$20/MMBtu or less. The total technical potential to produce renewable gas in that scenario is 4.5 trillion Btu per year, roughly equal to total average annual residential natural gas demand between 2009 and 2018, but only about 25% of total average annual natural gas consumption across all

sectors combined.⁶² Consequently, especially given that demand for renewable gas would likely not be limited to the residential sector, the price of renewable gas will likely be set by the cost of Power2Gas technology. This cost is estimated using a bottom-up model of the manufacturing cost of renewable gas via Power2Gas, as explained in greater detail in the **Technical Support Document**. Using a variety of sensitivities, it results in an estimated cost of renewable gas via Power2Gas of \$30/MMBtu by 2050, with a range between \$10/MMBtu and \$47/MMBtu. This range is in line with the estimated range of costs for renewable gas derived from various biomass feed stocks, as well as other studies estimating the cost of renewable gas, as illustrated in **Figure 21**.

The analysis of renewable oil is informed by the Power2Gas model, by currently observed costs for biodiesel (B100) in New England and the United

⁶² See American Gas Foundation, Renewable Sources of Natural Gas: Supply and Emission Reduction Assessment Study, 2 page summary.

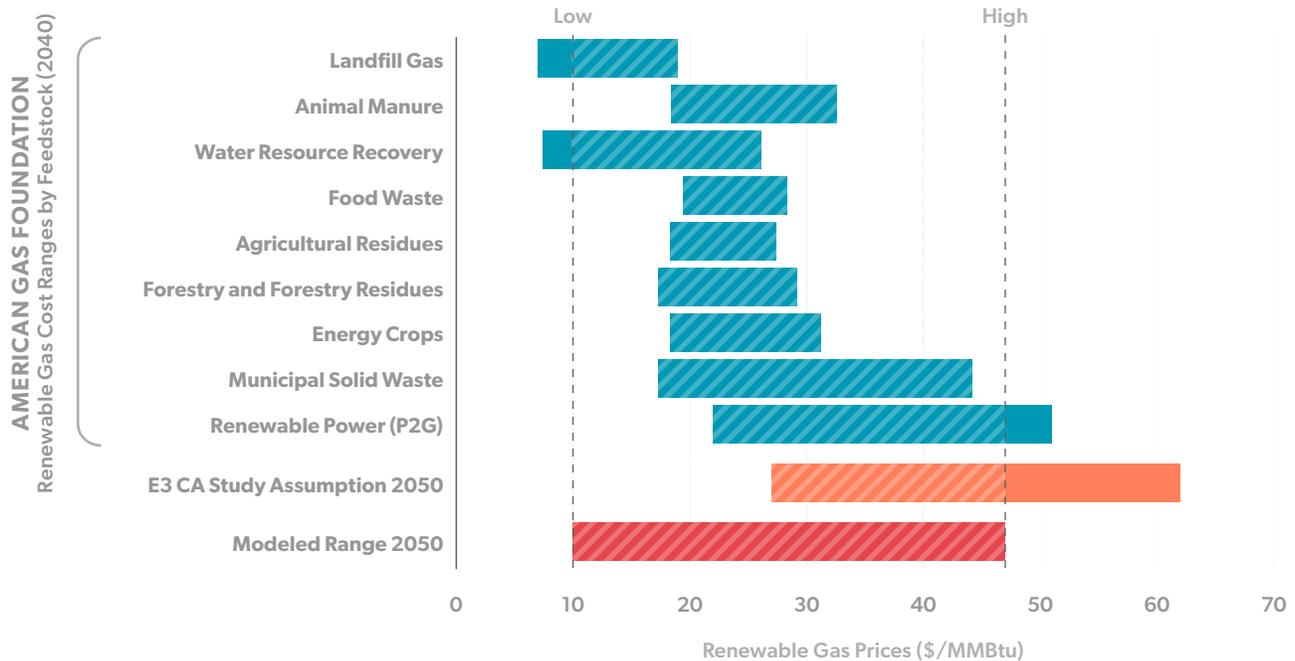


FIGURE 21: ALTERNATIVE COST ESTIMATES OF RENEWABLE GAS

Source: American Gas Foundation, Renewable Sources of Natural Gas, December 2019, E3. Draft Results: Future of Natural Gas Distribution in California, June 6, 2019.

States, as well as by other studies estimating the cost of renewable fuel using Power2Liquids technology, to estimate the potential range of renewable oil cost in 2050. As with renewable gas, limited supply potential from inexpensive sources means the 2050 price of renewable oil is likely to be set by the cost of Power2Fuels technologies, which again here is subject to considerable uncertainties.

At present, the New England B100 price of \$2.75/gallon is actually \$0.39/gallon lower than the price of diesel, though nationally, B100 is consistently about \$0.3-0.8/gallon more costly than diesel.⁶³ Current biodiesel prices are linked to regular diesel (and underlying world oil) prices and, therefore, provide limited insight into the long-term production cost

of renewable oil.⁶⁴ But current sources of biodiesel (largely vegetable oils and waste cooking oil) are unlikely to be able to provide the volumes necessary to utilize it widely as a heating fuel, forcing the market to turn to other, more costly sources such as Power2Liquids. This is particularly true considering that biofuels can also be used in the transport sector, which represents an extremely large and relatively price-insensitive potential demand for decarbonized liquid fuels. The cost (per barrel) of P2L has been estimated to be approximately 3.3 times the average cost of the electricity source used to make it.⁶⁵ Using a cost of \$60/MWh (e.g., low-cost offshore wind power plus transmission costs) would result in a cost of approximately \$200/barrel, or roughly \$5/

⁶³ U.S. Department of Energy, Clean Cities Alternative Fuel Price Report, January 2020, p.21, which shows diesel and B100 prices between 2011 and January 2020.

⁶⁴ In addition, biodiesel and other advanced fuels benefit from a number of financial support mechanisms. Biodiesel currently receives an investment tax credit of \$1/gallon; several other incentive programs are summarized at <https://afdc.energy.gov/fuels/laws/BIOD?state=US>.

⁶⁵ See <http://euanmearns.com/lcoe-and-the-cost-of-synthetic-jet-fuel/>

gallon.⁶⁶ This would represent a little bit less than a doubling of the cost of B100 relative to current diesel prices in Rhode Island.

Since Power2Liquids technology generally converts renewable gas into liquid fuel using an additional production step, it is likely that, per unit of energy, the cost of renewable oil will be slightly higher than renewable gas. This \$5/gallon estimated renewable oil cost corresponds to \$36/MMBtu,⁶⁷ slightly higher than the \$30/MMBtu estimated cost for renewable gas. While both renewable gas and renewable oil are materially more expensive than their fossil

counterparts, the proportional increase is much larger for gas. The long run cost of renewable oil is likely to be 15%-160% above the current cost of fossil oil, but the long-run cost of renewable gas may be 40%-300% greater than the current fossil gas cost. This is because, on an energy basis, natural gas is currently much cheaper than heating oil. This could have implications for the relative attractiveness in the long run of renewable oil vs renewable gas. If their prices are similar, liquid fuels can have some advantages over gaseous fuels – they are easier to handle, store and deliver, and do not require a costly, long-lived and dedicated delivery infrastructure.

⁶⁶ Other bottom-up modeled costs are similar. For example, Fasihi et al. estimate the cost of P2G diesel at \$160.85 USD/barrel. They also observe that the ratio of diesel to crude oil prices is approximately 1.14, which means that to compare biodiesel to regular diesel prices via the price of oil requires an additional adjustment. See Fasihi et al, Techno-Economic Assessment of Power-to-Liquids (PtL) Fuels Production and Global Trading Based on Hybrid PV-Wind Power Plants, Energy Procedia 99 (2016) 243 – 268, p.255

⁶⁷ Based on an assumed energy content of heating fuel of 139,000 Btu/gallon. See https://www.engineeringtoolbox.com/energy-content-d_868.html

Analysis of Decarbonized Heating Pathways for Rhode Island

Section IV considers the economic and other factors that may affect the choice of the preferred heating transformation pathway(s) for Rhode Island in terms of the decarbonized heating solutions identified above. Section IV compares the economics of the decarbonized alternatives for a representative residential home, assuming for each technology that the corresponding Bookend Scenario prevails. For example, the cost of heating with an ASHP is evaluated based on the electricity system and power prices that would prevail if all of New England relied on ASHPs for heat. This would cause an extreme electric load peak at the coldest times in winter, and the electric system resources required to meet this peak would result in higher electricity prices than in the other Bookend Scenarios. Similarly, the cost of heating with decarbonized fuels is evaluated based on renewable fuel prices that are consistent with all heating in the region relying on decarbonized fuels. That implies that demand for decarbonized fuels would be high, and so the price must be high enough to bring forth this amount of supply. In addition to considering a “mid-range” cost estimate for each of the alternatives, an uncertainty range around this estimate is built up from uncertainties on both up-front costs and ongoing operational costs. At the end of this section, the scope of the analysis is broadened to consider the impact of decarbonizing the other major energy sectors – current electricity consumption and electrified transportation

– in combination with decarbonizing heat (using the same Bookend Scenarios) and the resulting cost implications for consumers’ overall “energy wallet” relative to today’s costs.

ECONOMIC MODEL RESULTS – SINGLE-FAMILY HOME

Applying the methodology outlined above allows for a comparison of the future economics of the various heating decarbonization solutions. In this section, the results of this analysis are presented for a representative existing single family home from three different perspectives:

- The first perspective presents several Bookend Scenarios, i.e., the analysis assumes that either consumers maintain their current heating fuel and hence volumes of delivered gas and oil remain constant (in the cases examining the economics of renewable oil and renewable gas), or it assumes that all consumers adopt either GSHPs or all ASHPs (with corresponding impacts on electricity prices). These Bookend Scenarios highlight the feedback effects on individual consumers under relatively extreme assumptions about the adoption rates of individual decarbonization solutions. In reality, these Bookend Scenarios are unlikely for a number of reasons, including that the relative cost and attractiveness of decarbonization solutions will likely vary significantly

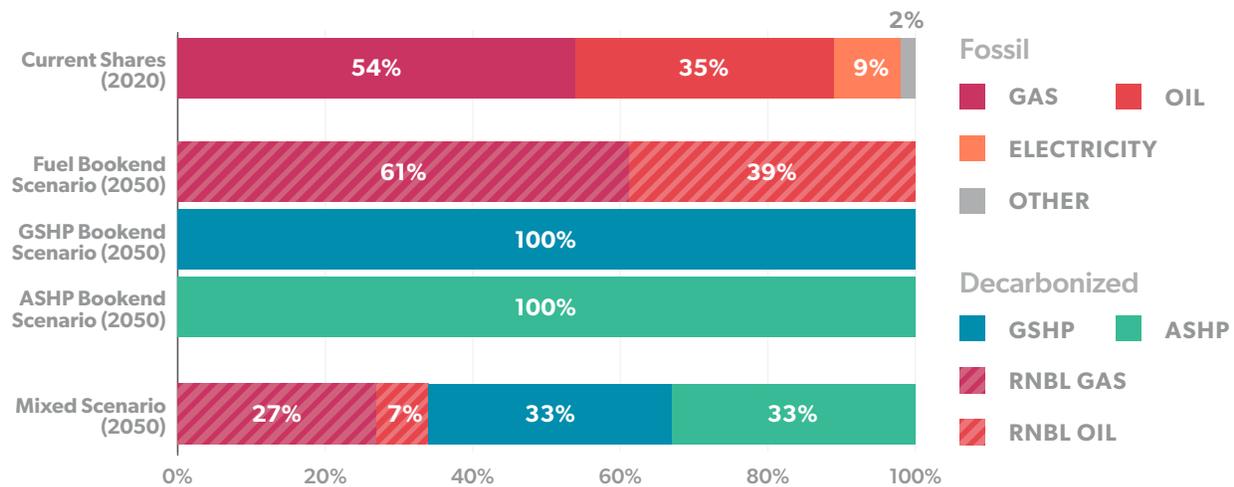


FIGURE 22: HEATING SHARES BY FUEL (NUMBER OF BUILDINGS) CURRENT SHARES VS MIXED SCENARIO (2050)

by building-specific conditions and because of different consumer preferences and other qualitative factors discussed below.

- The second perspective examines the economics of the various decarbonization solutions from a consumer’s perspective, assuming an illustrative “mixed” adoption pattern (recognizing that the relative shares of each of the available decarbonization solutions in the future remains highly uncertain).
- Finally, a third perspective uses the mixed adoption scenario to assess how the economics of various decarbonization solutions affect an individual consumer’s overall “energy wallet” that compares current costs with potential future costs with each of the decarbonized heat solutions, in the context of a fully decarbonized economy. The energy wallet perspective is instructive since statewide and regional adoption rates of various decarbonized heating solutions will have impacts in particular on electricity prices, which in turn impact other energy related spending, including in the short run

current electricity bills and in the longer run likely also spending on transportation assuming personal transportation is decarbonized via a switch to electric vehicles.

Figure 22 illustrates the shares of each heating solution that exist now, in the three Bookend Scenarios, and in the Mixed Scenario.

1. Bookend Scenarios

Figure 23 compares the annualized cost of residential space heating solutions, both fossil and decarbonized, under these Bookend Scenarios for a representative Rhode Island single family home, using projected costs for the year 2050 for alternative heating systems that provide the home’s entire heating needs, not just a partial or supplemental system. The traditional carbon-emitting options of fossil natural gas, oil or propane are on the left using projected 2050 costs, and on the right are the decarbonized options of renewable gas, renewable oil or decarbonized electrification with ground-source or air-source heat pumps (or electric resistance).⁶⁸ The analysis assumes an annual

⁶⁸ As noted above, the analysis of renewable gas here provides a good proxy for a renewable hydrogen solution, since the projected cost of renewable hydrogen is generally within the range considered for renewable gas costs (perhaps toward the lower end, since producing hydrogen with P2G can avoid the methanation step). Such a solution might involve either blending hydrogen with renewable gas, or using it as a standalone heating fuel, though in the latter case, the renewable gas analysis does not account for upgrades to the gas delivery infrastructure that may be necessary to accommodate hydrogen.

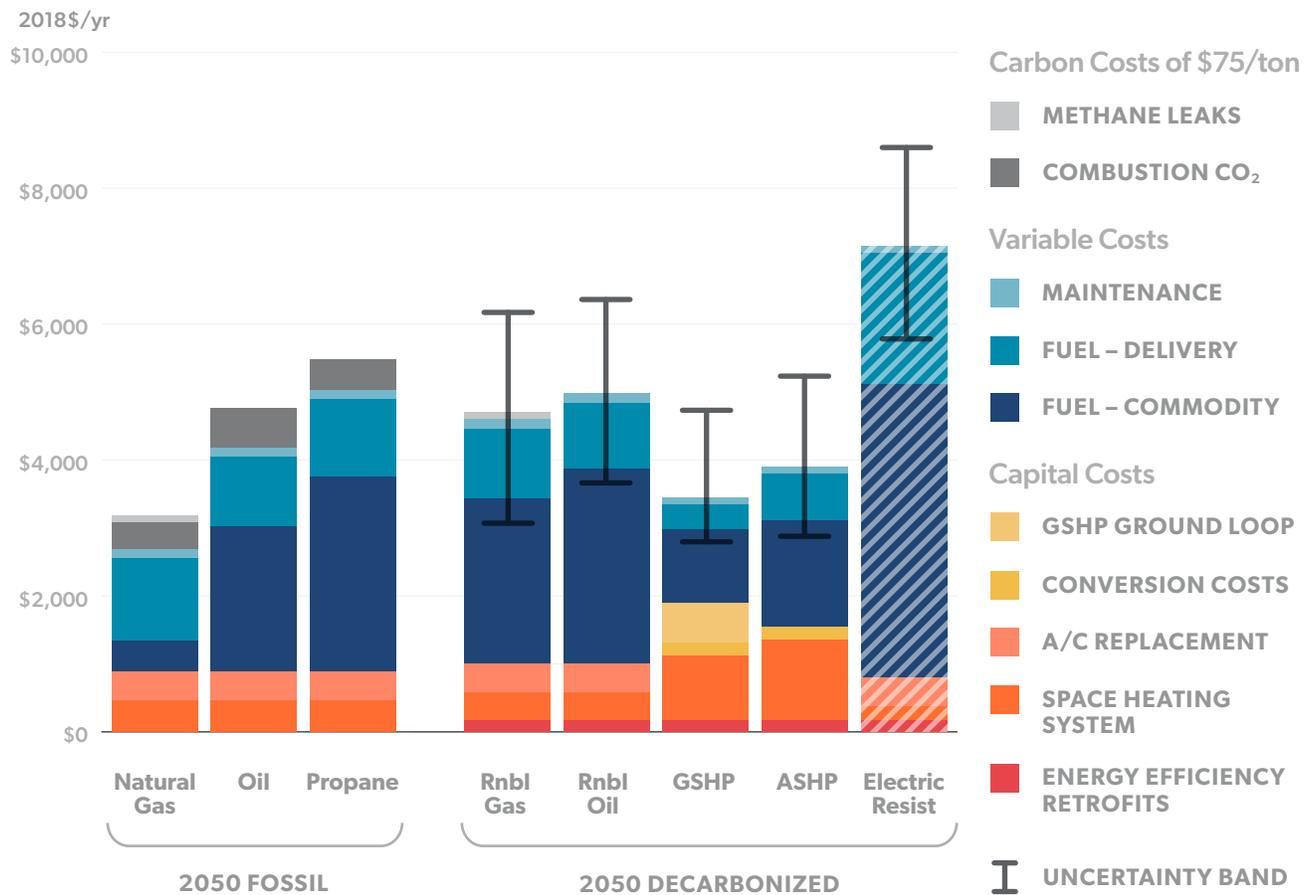


FIGURE 23: ANNUALIZED COST OF SPACE HEATING, SINGLE-FAMILY HOME IN 2050 BOOKEND SCENARIOS (2018\$)

Notes: Discounting at 3% to reflect social discount rate. Carbon price \$75/ton. Heater capacities: 7.5 ton furnace or boiler with energy efficiency and 9 ton furnace or boiler without energy efficiency (sized to meet two times peak demand), 5.0 ton heat pumps (sized so that the system meets at least 120% of peak demand, with ASHP using supplemental electric resistance heating capacity).* Efficiencies: 93% for gas-fired furnaces, 84% for oil-fired furnace/boiler, 360% for GSHPs, 285% (weighted average based on temperature and load) for ASHPs, and 100% for electric resistance. Prices: natural gas \$17.43/MMBtu, oil \$4.14/gal, propane \$3.83/gal, renewable oil \$5.33/gal, renewable gas \$42.57/MMBtu; electricity price 23 cents/kWh (GSHP), 28 cents/kWh (ASHP and electric resistance). Additional inputs and data sources can be found in the Technical Support Document. The modeled heat pump size differs from typically installed heat pumps today as it is sized to meet all heat requirements except on the most extreme days. Design capacity is slightly above the 100-115% size design suggestion by NEEP (See NEEP, Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates rev. 12/7/18, p.5 (Full System Replacement)

heat demand of 76 MMBtu per year, which is 15% below the current average of 89 MMBtu per year for single-family homes in Rhode Island, reflecting cost-effective building efficiency improvements assumed to be implemented for essentially all homes by 2050. The “representative” home modeled is not an actual home, but rather represents a home with the average annual heating energy demand in the state (calculated by dividing total heating energy consumption by the

total number of single family homes). Still, given the Rhode Island housing stock, a “representative” home would be at least several decades old with 1,500 to 2,000 square feet of livable space. The impact of cost-effective energy efficiency measures is based on the range of reported impacts of weatherization programs – expressed in percentage improvements over existing heating demand – from weatherization programs in New England. The precise amount of heat

needed for any particular home will have little impact on the relative costs of the alternatives, and the broad conclusions from this analysis apply across a wide range of building sizes and heat needs.

Figure 23 includes a breakdown of the annualized cost into operating costs (in shades of blue) and annualized capital costs (in shades of orange). Operating costs are mostly the cost of “fuel” – fossil natural gas, oil or propane for the carbon-emitting options, versus renewable gas, renewable oil or electricity for heat pumps for the decarbonized options. The fuel costs are split roughly according to the cost of the commodity itself (lighter blue) vs the cost of delivering that commodity to the building (darker blue). The annualized capital cost of the heating technologies (which includes installation cost) is shown in shades of orange. Furnaces or boilers must be replaced periodically, but the cost is modest since the equipment and installation are reasonably simple and modifications to the home are not necessary. For heat pumps, the capital cost is larger because the heat pump equipment and installation can be more costly, and may also require additional components – a ground loop for GSHP, and additional costs for

adapting the existing building to a different way of providing heat (e.g., ductwork, electrical upgrades).⁶⁹ The capital cost comparison also includes the cost of replacing a central air conditioning system if a furnace or boiler is used; that cost can be avoided with a heat pump, which also provides cooling.

To allow for a better comparison of fossil with decarbonized heating options, **Figure 23** also includes an assumed cost of carbon emissions. Including such a cost is important since it reflects actual costs to society of continued carbon emissions. In addition, it is likely that by 2050 (and earlier), fossil fuel prices faced by consumers will reflect these costs, for example in the form of a carbon tax or fee, cap and trade program, or other mechanism. The analysis uses a cost of \$75/metric ton, in line with current benefit-cost analyses performed by the state.⁷⁰ This cost is applied to the net GHGs from the combustion of fuel (assumed to be zero for the renewable fuel options, which implies that the fuel is carbon neutral),⁷¹ and also the GHG contribution of methane leaks (at the current leak rate).⁷² Renewable gas includes the leak component as well, since even if the source gas itself is carbon-neutral, methane leaks still create GHG

⁶⁹ The idiosyncrasies of individual buildings may have a substantial impact on the relative economics on a case-by-case basis. E.g., some particular building may find it much more costly to convert to a heat pump due to the need for extensive ductwork and a major electrical system upgrade; a different building may not face such costs at all. Recognizing these possibilities, and acknowledging that it is very difficult to obtain representative costs for such retrofit requirements due to the wide diversity of circumstances in individual buildings, the economic analysis assumed that replacing a fossil heating system with a heat pump would require about \$5,000 in upgrades (e.g., ductwork and electrical) to enable the transition.

⁷⁰ A carbon value of \$75/metric ton (\$68/short ton) is used currently as the avoided carbon value in evaluating Rhode Island’s energy efficiency programs. Synapse Energy Economics, “Avoided Energy Supply Components in New England: 2018 Report”, prepared for AESC 2018 Study Group, originally released March 30, 2018 (amended October 24, 2018), available at: <http://riercmc.ri.gov/wp-content/uploads/2019/04/aesc-2018-17-080-oct-rerelease.pdf>. For purposes of this analysis, the same value is used for 2050 comparisons even though, as described above, the value of avoided carbon emissions is likely to increase as reflected in rising values of the social cost of carbon over time.

⁷¹ As described above, most renewable fuels using biological feed stocks are currently not carbon-neutral. The long-term potential to achieve (near) zero net carbon emissions depends on both the feedstock itself and the conversion process. For example, overall carbon intensity can be very significantly reduced if transportation and process energy used in the production of biofuels is itself carbon-free (such as renewable electricity).

⁷² The analysis assumes a distribution system leak rate of 2.7%, from Deeper Decarbonization in the Ocean State: The 2019 Rhode Island Greenhouse Gas Reduction Study, September 2019, Stockholm Environment Institute, et al. It uses a 100-year global warming potential for methane of 30, based on the U.S. EPA range (U.S. EPA, “Understanding Global Warming Potentials”, available at: <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>), and adjusts for the different masses of methane vs. CO₂. Successful efforts to reduce gas leaks would reduce the costs of methane leaks correspondingly.

emissions since methane is a much more potent greenhouse gas than CO₂.

Figure 23 also indicates an uncertainty band around the mid-range estimate, illustrated by the vertical black line that shows plausible high and low cost estimates based on reasonable estimates of the uncertainty in future installed cost for equipment (heat pumps), and uncertainty in the price of renewable fuels and electricity.

For heat pumps, the high initial cost makes up a substantial share of their total annualized cost, whereas renewable fuels have low initial equipment costs but fuel costs that are both substantially higher and also highly uncertain. GSHPs have even higher initial costs than ASHPs, though annualizing the cost makes the difference less pronounced, given that GSHP equipment life is longer (it is housed indoors) and ground loop costs are spread over a longer operating life.⁷³ These higher upfront costs are offset by lower operating cost of GSHP: due to higher average efficiency (especially during cold temperatures as explained above), GSHPs use about 20% less electricity overall, and if ASHP is adopted widely, it would likely raise power prices.

Overall, this analysis shows that among the various decarbonization solutions for a representative single-family home, while there are some differences in the mid-range estimated costs, the uncertainties are significant and the uncertainty bands are largely overlapping. The ranges of annualized costs for all four decarbonized heating solutions are broadly overlapping (around \$3,000-\$5,000 per year). This means that no one technology is a clear winner based on economics, making it difficult to choose one of these decarbonized pathways over the others given the information that is available now. Ground-source heat pumps appear

nominally to be the least costly option, followed by air-source heat pumps and renewable gas. However, the range of uncertainty about the future cost of each of these heating options exceeds the differences in the nominal cost estimates between them, indicating that an alternative (but very reasonable) set of assumptions about how the costs of these technologies may evolve over the coming decades could lead to a different ranking.

It is also worth comparing the estimated cost of decarbonized heating with the cost of continuing to use fossil fuels for heat. Using projected fossil prices for 2050, the decarbonized heating solutions are generally more costly than natural gas heating, but could be competitive with heating oil and propane. Decarbonized heating with renewable fuels is likely to be more costly unless these renewable fuels end up near the low end of their cost uncertainty band. If carbon costs (here illustrated at \$75/tCO₂) are included, the decarbonized alternatives become somewhat more competitive. Still, an overarching observation is that the range of uncertainty makes it difficult to draw any firm conclusions, either comparing decarbonized solutions or comparing those with the continued use of fossil heating (acknowledging that there is also uncertainty about future fossil fuel costs, not characterized here). Current fossil heating costs are modestly lower than the projected 2050 costs (see **Figure 10**), so it is reasonably likely that – for the average consumer – decarbonized heating may increase 2050 heating costs from their current level, *but perhaps not by much more than costs would rise with continued use of fossil fuels*. Importantly, the actual impacts of decarbonizing heating systems may differ significantly for individual consumers, due to the idiosyncrasies of individual buildings. And even if increases in heating costs due to decarbonization are modest on average,

⁷³ Another advantage of GSHP is that it does not require a backup heat system to cover peak heat needs in the coldest weather. With an ASHP, by contrast, output is lowest when heat demand is highest, so a backup system is needed. However, this backup can be provided by electric resistance heat, which has little operating penalty in cold weather and has small up-front cost.

policy – discussed below – must take into account that cost increases could be more pronounced for some consumer groups, and that even modest cost increases may put a significant burden on already disadvantaged consumers, in which case mitigating policy measures will be even more important.

To understand some of the other factors that may drive a heating sector transformation, it is useful to consider another perspective in addition to the societal economic view presented above – that of a consumer contemplating the economics of alternative heating systems. For a variety of reasons, consumer behavior often does not reflect the long-run economics characterized above. Rather than choosing the alternative with the lowest long-run total cost, consumers generally require energy investments to pay back any up-front investment within just a few years, or they will decline to make the investment.⁷⁴ This is a very real issue for a consumer contemplating a switch from fuel-based heat to a heat pump, which can require tens of thousands of dollars of up-front investment and potentially significant modifications to the home (ductwork, electrical upgrades), vs. a few thousand dollars to replace the old fuel-fired boiler or furnace with a new one.

The higher up-front costs of heat pumps might lead customers to remain with the fuel-burning solution (whether the fuel is fossil or renewable) even if the heat pump's much lower operating costs offer significant lifetime savings. This effect is further exaggerated for ground source heat pumps which have the additional ground loop cost. This suggests that even

if heat pumps do have lower long-run economic costs, significant policy intervention and program support may be required to induce customers to adopt them. Such policy intervention could take the form of direct incentives or no-to-low cost capital financing that reduce the up-front costs. For example, a GeoMicroGrid may not only reduce the up-front cost of GSHP, but utility ownership of the ground loop could help to reduce the initial cost barrier.

2. Mixed Adoption Scenario

The Bookend Scenarios analyzed above assume that all New England heat is provided by a single technology (or that current fuel types are maintained in the case of the renewable oil and renewable gas scenarios, respectively) to illuminate their potential impact on other systems. Of course, the actual decarbonized future will almost certainly include a mix of the candidate technologies. To reflect such a more realistic outcome, while still incorporating the feedback effects on electricity prices and gas delivery costs discussed above, a Mixed Scenario, in which the New England heating sector is decarbonized using a mix of the candidate technologies, was also developed. Of course, the particular mix analyzed here reflects only one possibility, but it does illustrate some important potential effects. For this illustrative Mixed Scenario, half of existing gas customers are assumed to electrify their heating, along with 80% of oil customers and essentially all customers using other fuels.⁷⁵ In aggregate, two-thirds of customers switch to electric heat pumps, split equally between ASHP

⁷⁴ This does not necessarily imply that customers are behaving irrationally in such situations. Such a high investment threshold may reflect, for example, the personal disruption associated with a construction project; the possibility that the homeowner may move within a few years and thus would recoup only a few years' operating cost savings; or the fact that consumers' financing costs are typically much higher than the low discount rate used for the societal perspective above.

⁷⁵ This is just one assumption regarding the shares of customers who may electrify; it is not intended as a prediction of customers' switching propensity based on their existing fuels. But a lower electrification rate for gas customers might result from the lower current cost of gas heating vs. other current fuels, and perhaps some customers' desire to keep gas as a cooking fuel rather than from the lack of available renewable oil. In fact, considering building efficiency improvements and the potential for customers to use a heat pump to cover just part of their heat needs, retaining their fossil system as backup perhaps as an interim solution, there are many different ways in which decarbonization could reduce the demand for gas and other traditional fuels. This Mixed Scenario yields insight into such alternative scenarios as well.

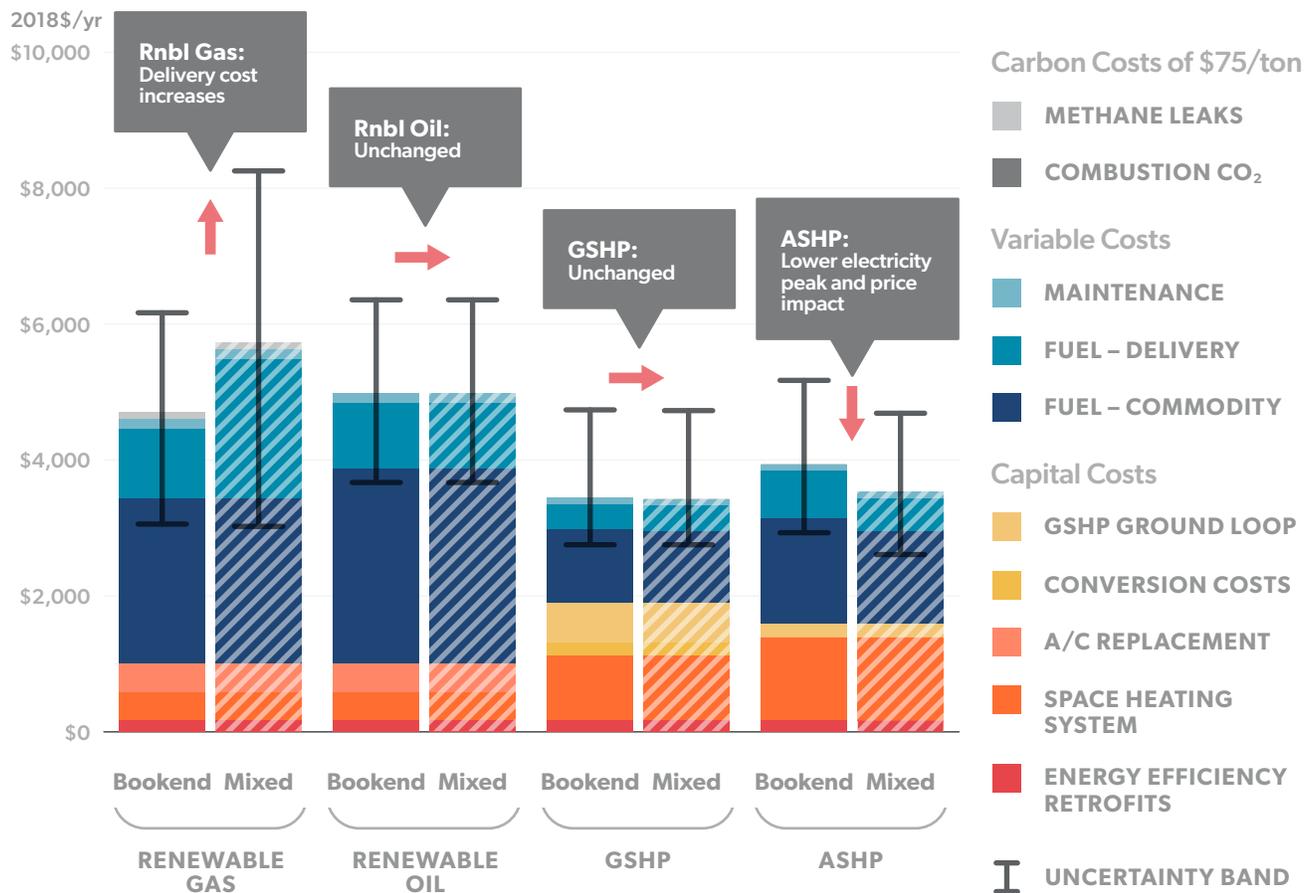


FIGURE 24: ANNUALIZED COST OF SPACE HEATING, SINGLE-FAMILY HOME IN 2050 MIXED SCENARIO VS. BOOKEND SCENARIOS (2018\$)

and GSHP. Those customers keeping their existing fuel type would burn a renewable version of that fuel in 2050. **Figure 22** above illustrates the current heating fuel shares, as well as the shares assumed in the Mixed Scenario.

Figure 24 compares how this Mixed Scenario changes the results from the Bookend Scenarios examined in **Figure 23**. Electric demand and price in the Mixed Scenarios are similar to the GSHP Bookend Scenario, so GSHP costs are very similar, and ASHP costs are lower than in their respective Bookend Scenarios.

The most substantial impact is on the cost of heating with Renewable Gas. Since volumes delivered

through the gas distribution system are substantially lower in this scenario (and assuming the cost of maintaining and operating the gas delivery system is essentially fixed), the delivered price of Renewable Gas would increase markedly. **Figure 25** provides a simple illustration of the potential dynamics affecting delivered gas prices in a decarbonized future. The left side of the figure shows fossil gas prices now and projected in 2050 at current delivery volumes. The right side illustrates how the future delivered cost of 100% renewable gas might be influenced by the gas commodity cost (here, assumed to be \$30/MMBtu independent of the amount delivered)⁷⁶ and reduced delivery volumes. At current volumes, the delivery

⁷⁶ As noted above, the commodity price of renewable gas in Rhode Island will likely not depend on local demand, since a future renewable gas market is likely to be regional or national in scope.

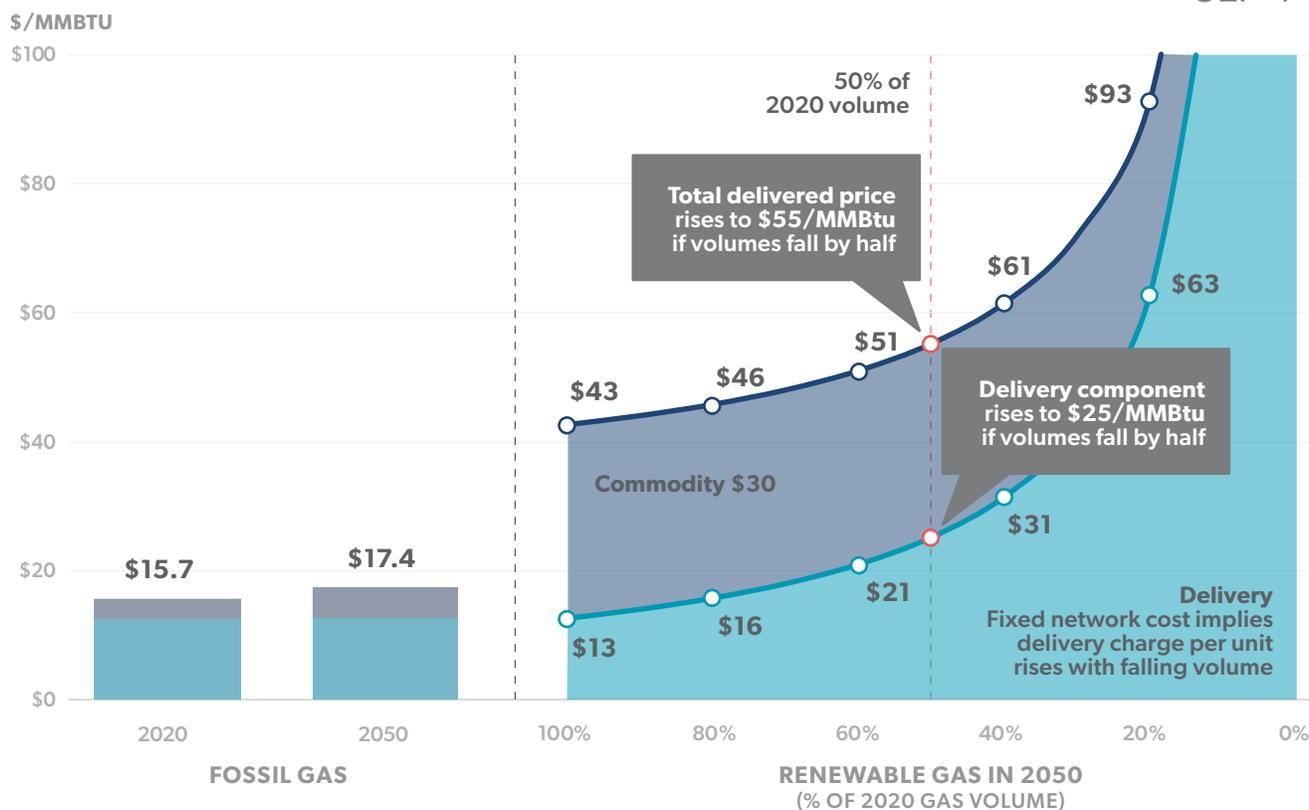


FIGURE 25: DELIVERED PRICE OF GAS: 2020 FOSSIL GAS VS POTENTIAL 2025 RENEWABLE GAS (2018\$)

charge would be \$13/MMBTu as it is today, resulting in a \$43/MMBTu delivered price of renewable gas. If delivery volumes decrease, the delivery cost per unit would rise, since total distribution system costs would not change. For example, if volume fell by half as assumed in the Mixed Scenario, the delivery charge component could double, with the delivered gas price reaching \$55/MMBTu – over three times the current delivered gas price.

A reduction of half or more in gas volumes may not be a particularly extreme assumption; the efficiency improvements assumed here alone would reduce gas demand by 15%, even with no gas customers switching to a different heating solution. This points out an important potential challenge for the gas system: Any volume of gas sales lost to electrification (or to improved building efficiency, or even to

renewable oil which does not have a fixed-cost delivery network) will increase the delivered price of gas as the fixed distribution costs are spread over less gas. This could prompt further volume loss and an upward cost spiral for remaining customers. In turn, this would impose significant risks for customers who cannot easily switch away from gas, as well as for the gas utility. The most obvious way to avoid these issues would be to retain most of the gas volume while decarbonizing the gas. Other approaches could include reducing delivery system costs as volumes fall (e.g., by concentrating losses in some parts of the system and pruning those branches entirely), or sharing the costs of the gas infrastructure more broadly across all “energy” customers, acknowledging the widespread social benefit of decarbonization while protecting individual customers.⁷⁷

⁷⁷ However, even if gas system costs are spread more broadly across customers, it will be important to continue to monitor the mostly fixed costs of maintaining the gas system. This must be compared with the cost of alternative solutions, such as electrifying all remaining gas demand (including the infrastructure requirements that entails), to ensure that the approach pursued is best for consumers overall.

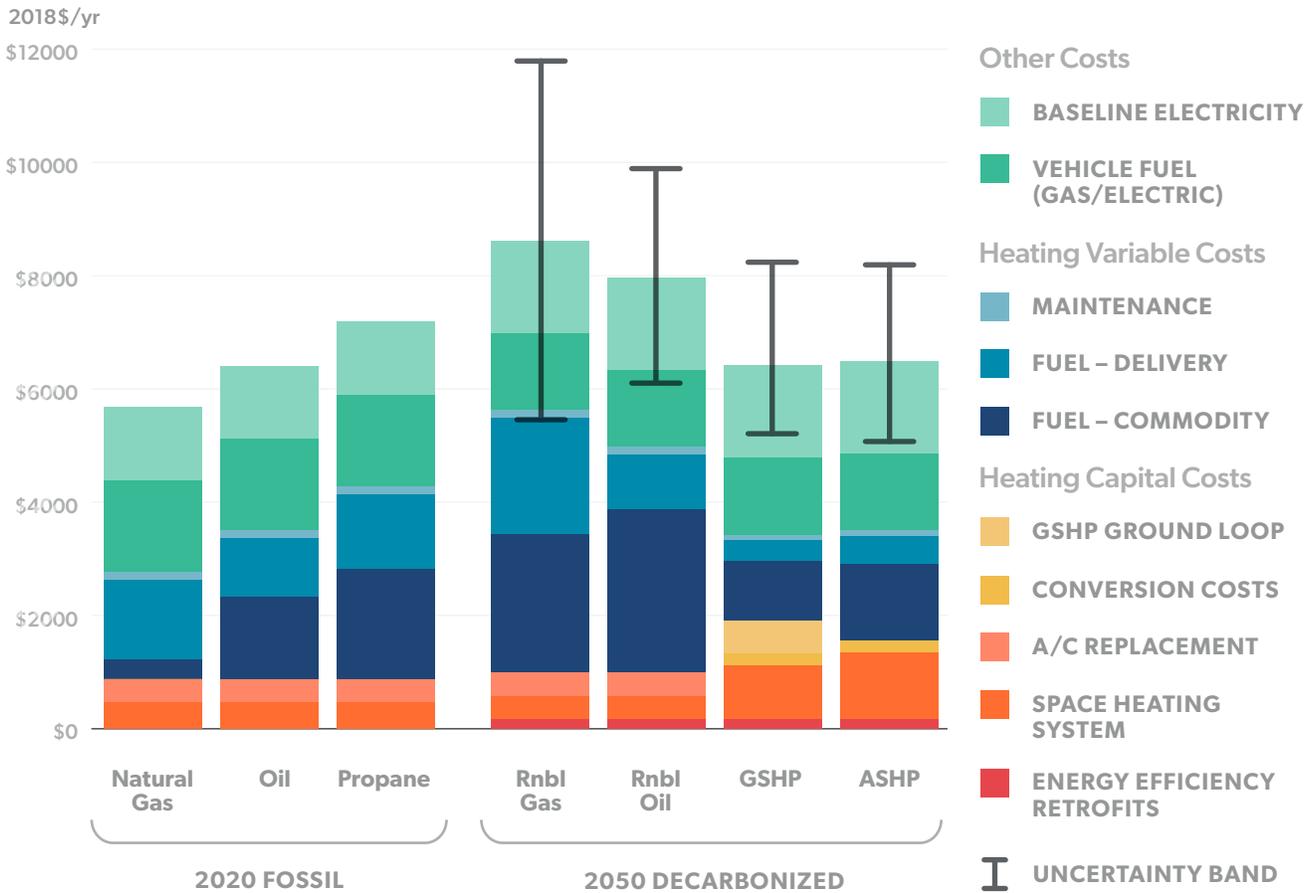


FIGURE 26: TOTAL ANNUAL ENERGY WALLET COMPARISON FOR SINGLE-FAMILY HOME, 2020 VS 2050 MIXED SCENARIO (2018\$)

Note: Uncertainty band reflects uncertainty on heating costs as above, plus the effect of electricity price uncertainty on other end uses. Gasoline price excludes federal and state taxes. Water heating cost is not broken out explicitly, though to the extent electricity is currently used for water heating, this is included implicitly in Baseline Electricity usage.

3. Energy Wallet

It is also important to recognize that heating is only one element of a representative consumer’s overall energy wallet, which also includes spending on traditional electric end uses and transportation. **Figure 26** considers a customer’s total energy wallet comparing current energy expenditures across all sectors on the left with a 2050 projection that shows the cost of various decarbonized heating solutions combined with the average cost of charging electric vehicles and traditional electricity consumption. This analysis assumes that light duty vehicles are fully electrified across New England, and that electricity and gas

prices are consistent with the Mixed Scenario that employs a mix of decarbonized heating technologies, projecting a plausible future. One notable feature of this comparison is that even though total costs for decarbonized heating may be higher than some forms of fossil heating, and electricity prices are likely to be higher with a decarbonized grid, consumers will not necessarily spend significantly more in total energy costs than they do today in a fossil-fuel based environment. Partially offsetting any increase in the cost of heating for some customers, electric vehicles are more efficient, making it somewhat less costly to “fuel” an automobile with electricity than it is today

with gasoline, even though the 2050 decarbonized electricity price is higher than today's price. Still, the energy wallet perspective does not change the fundamental conclusion above. The uncertainty in future costs still outweighs the relatively small differences in expected costs across options (and relative to today), and no single heat decarbonization approach is clearly preferable.

4. Conclusions for Existing Single-Family Home

In sum, for a representative detached single-family home – the most common building type in Rhode Island – a quantitative comparison of annual heating costs for the various decarbonized solutions suggests that, at least according to what can be known now, no single solution provides a clear economic advantage over the others. Rather, which option will have the lowest annual heating costs depends on how several uncertain factors – including the availability and price of renewable fuels and renewable electricity, the installed cost and performance of electric heat pumps, the cost of installing ground loops, etc. – evolve over the coming decade. Any state-level policy promoting decarbonization of the Rhode Island heating sector must take this uncertainty into account.

IMPLICATIONS FOR SPACE HEAT IN LARGER BUILDINGS

The representative single-family residential home analyzed above represents the most common building type in Rhode Island, at the low end of heating demand on a “per-building” basis since they are smaller buildings. There are a significant number of larger buildings in the state as well, both larger multi-family residential buildings and commercial buildings, and of course they must also be addressed in order to decarbonize the heating sector. The same issues discussed above regarding existing vs new buildings tend to apply for larger buildings as well. That is,

building efficiency is relatively straightforward and very cost effective for new buildings, and can dramatically reduce the need for heat in those buildings. But with few new large buildings being constructed and many existing large buildings remaining in use in the state, the heating sector transformation among larger buildings must also focus for the most part on retrofitting existing buildings. Also, as with single-family homes, larger buildings may have some relatively low-cost and cost-effective opportunities to improve building energy efficiency; this will help reduce overall customer costs, but cannot approach full decarbonization. Large buildings will still need heat and that heat must be decarbonized.

The basic decarbonization pathways described above – decarbonized electrification with heat pumps and decarbonized fuels – are also relevant for medium and larger buildings, though the long-run cost tradeoffs, relative to each other as well as relative to typical fossil heating systems, may differ. This is a result of their different scale, different heating (and cooling) equipment with different capital costs and operating efficiencies, and thus different tradeoffs between renewable fuel solutions with lower capital cost but higher operating costs, vs. heat pump solutions with relatively higher capital costs, and often some building conversion costs to reconfigure the building to heat with a different system.

To represent the potential tradeoffs, **Figure 27** shows a comparison of the economics of alternative decarbonization approaches for a stylized larger building. This example uses an average sized commercial building in New England (14,250 square feet), which would correspond to a medium-sized office building. Heating demand is based on Buro Happold's analysis, which estimated that commercial buildings currently consume 38,305 Btu/sq. ft. annually; like the residential analysis above, this is reduced by 15% for assumed building efficiency improvements, yielding an annual heat

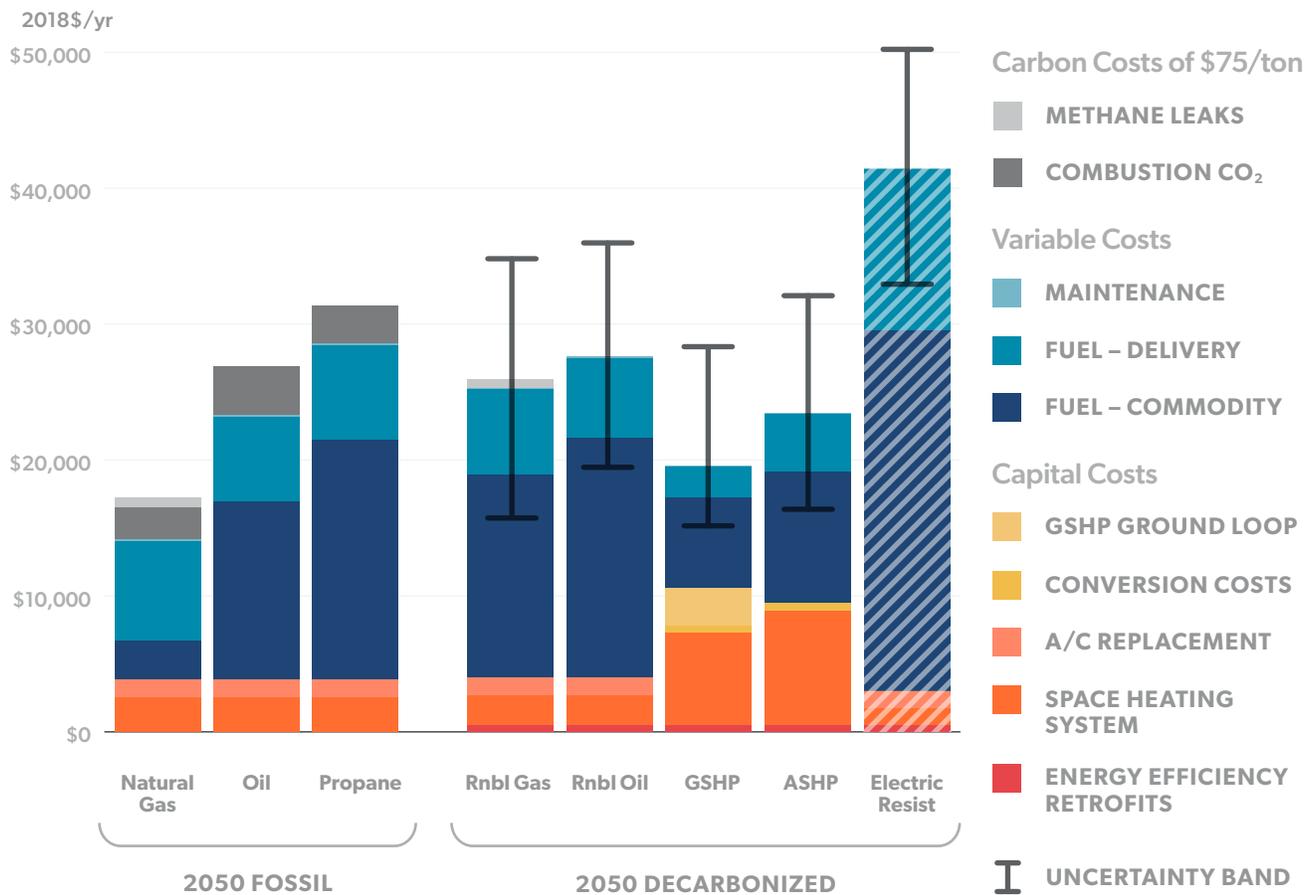


FIGURE 27: ANNUALIZED COST OF SPACE HEATING, STYLIZED LARGE BUILDING IN 2050 BOOKEND SCENARIOS (2018\$)

demand of 464 MMBtu. Heating equipment is more costly because it is larger, though it scales up slightly less than proportionally; in particular, the ground loop cost for GHSP is assumed to exhibit declining unit costs for larger installations. Many of the factors do not depend on the size or type of building. For example, ASHPs face the same declining efficiency in cold weather and the price of renewable fuels does not depend on building size. Similarly, renewable gas leaks contribute to GHG emissions and the per-unit cost of gas distribution rises if the gas volume delivered declines. Still, **Figure 27** shows relative costs that are very similar to those in **Figure 23** for a single family home. Heat pumps have much higher capital cost but lower operating costs; the decarbonized options are generally more costly than natural gas and broadly on par with the

cost of oil and propane; and the uncertainty ranges on the decarbonized options overlap considerably.

Since larger buildings tend to be more idiosyncratic, a comparison like this may be less broadly applicable than the analysis above for a representative single family home. But some additional observations may be possible. For instance, because large buildings often need some cooling even in the heating season, there may be some waste heat available that could provide a useful heat source for a heat pump – either to heat a different part of the building or to store for a later time. Large buildings may also offer some flexibility, e.g., to convert part of a building at a time (such as converting one or more floors of an office tower as it is remodeled between tenants), and to connect different heating and cooling sources

simultaneously to the building's internal distribution systems. As an example, the hot water loop in a building could be configured with both a boiler and a heat pump, which can trade off and supplement one another in operation, with usage potentially transitioning from one to the other over time. Because the heat needs are greater in larger buildings, higher capital cost solutions (such as heat pumps and possibly GSHPs) may be relatively more attractive since there are larger operating costs to be saved, and there may be scale economies in equipment and installation costs.

WATER HEATING

As shown above, domestic water heating represents more than 15% of total energy demand in residential buildings in Rhode Island and moderately less in commercial buildings, making it the second most important source of heating demand. This section considers the relative costs of various decarbonized approaches to water heating. Most of the options are similar to existing water heating approaches, but involve decarbonizing the fuel – renewable gas instead of natural gas or renewable oil instead of heating oil – or using emissions-free electricity in an electric resistance water heater. Electric heat pump water heaters represent a relatively new and promising alternative to traditional electric resistance water heaters. These (air-source) heat pumps integrate the heat pump with the water tank, drawing heat from the surrounding (and typically conditioned) space to heat water in the tank. While a heat pump water heater also utilizes electricity, it does so much more efficiently than an electric resistance heater.

Figure 28 compares the annualized cost of several water heating solutions for a representative

single-family home: two fossil options (natural gas and heating oil) and four decarbonized options: renewable gas, renewable oil, electric resistance and electric heat pump. As shown, annualized water heating costs with an electric heat pump are expected to be lower than the other decarbonized options, lower than fossil oil, and comparable to natural gas if carbon costs are included. Although it has slightly higher capital cost than most of the other options, its variable operating cost is much lower, largely because of the efficiency with which it uses electricity. This results in electric heat pumps having not only a lower total annual cost relative to the other decarbonized technologies, but also a notably short payback period of less than two years relative to those other decarbonized technologies. This suggests that electric heat pump water heaters may be the most cost-effective decarbonized water heating alternative in the long run, as well as an attractive energy investment opportunity from a customer's perspective, given their short payback period. Moreover, since this analysis conservatively uses cost and efficiency parameters for heat pump water heaters available today, improvements over time for this still relatively immature technology could make heat pump water heaters relatively more attractive in the future.⁷⁸

The above analysis assumes the choice of water heating solution is independent of the choice of space heating. In reality, the two choices are potentially linked. Since essentially every building in Rhode Island is connected to the electric system (and will be in 2050), a heat pump or electric resistance water heater can be used with any space heating technology. This may not be true for water heaters using gas or oil. If space heating is converted to an electric heat pump, maintaining the gas distribution

⁷⁸ One potential impact whose effects are not yet fully understood and thus not included here is the potential impact on space heat requirements if – as is typically the case – a heat pump water heater is installed in conditioned space and thus draws heat from inside the building. This could increase the total space heating needs in winter, adding to the cost of space heating. This effect, if present, would work in the opposite direction in summer to reduce the building's cooling needs, particularly if there is a way to circulate the cooled air within the building.

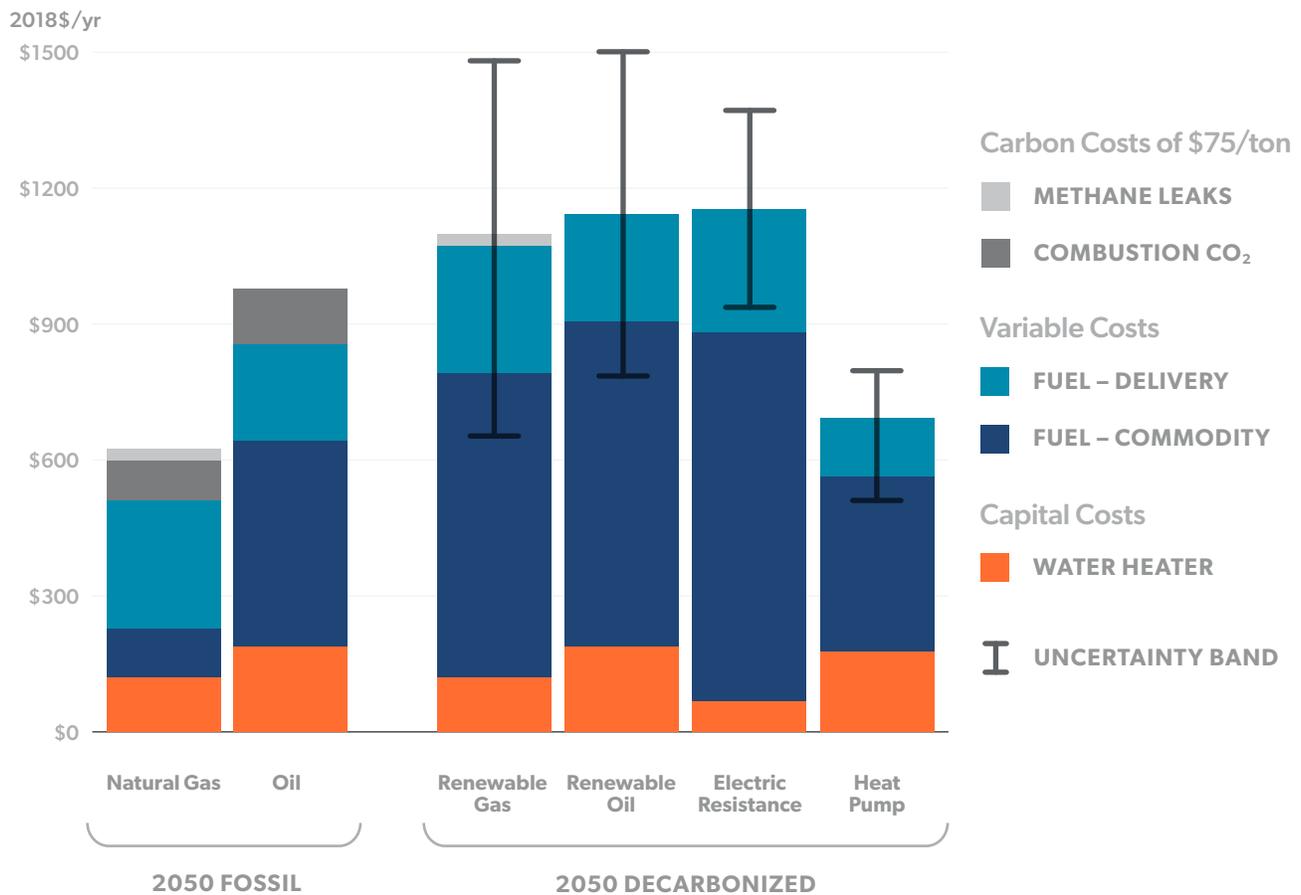


FIGURE 28: ANNUALIZED COST OF WATER HEATING, RESIDENTIAL IN 2050 (2018\$)

Notes: Assumes 50-gallon capacity, 15 million Btu annual consumption, and a \$75/metric ton carbon price. Efficiency assumptions: 67% for gas water heaters, 95% for resistance water heater and 200% for heat pump water heaters.* Price assumptions: \$17.4/MMBtu for natural gas, \$4.1/gal for oil, \$42.6/MMBtu for renewable natural gas, \$5.3/gal for renewable oil, and \$0.23/kWh for electricity. Assuming 5% discount rate and an average economic life of 13 years for all technologies except for heat pump water heaters (10 years). Data sources in Technical Support Document. ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2018.

connection (or an oil tank) just for water heating may be much less cost-effective. This may further increase the potential for heat pump water heaters.

In larger buildings, such as large multi-family apartment buildings and large commercial office buildings, water heating systems, like those for space heating, tend to be more idiosyncratic and specific to the particular building. The qualitative tradeoffs for water heating would generally be similar, though the larger scale could enable cost savings or improved efficiency in heat pump water heaters. In some buildings, water heat is currently integrated with the

space heating system, and thus might be addressed with the same decarbonized system as space heat.

INDUSTRIAL HEAT

Beyond the residential and commercial applications for space and water heating discussed above, Rhode Island's industrial sector also requires heat, which must be decarbonized as well. The state's industrial sector accounts for approximately 15% of total energy use. Although detailed information is not available on the breakdown of energy uses within the industrial sector, some of it is for space and water heating for

buildings (much like in residential and commercial buildings), some is for industrial process heat needs, and some fuel may also be used as a feedstock. That said, Rhode Island's industrial sector as a whole is not characterized by large industrial sectors where process heat is an important input to production (such as steelmaking), nor as feedstock (fertilizer or plastics). This suggests that a substantial portion of industrial sector heating needs may be for space and water heating. Where this is the case, the decarbonized solutions and their relative attractiveness discussed above for larger buildings would apply similarly to industrial needs.

Beyond space and water heat in industrial facilities, there is also an array of specialized industrial process heat needs and applications that may go beyond the technologies discussed so far.⁷⁹ These can vary widely, with the type of heat required and the technologies able to provide it often being highly specific to the particular industrial process. Heat pumps can only provide relatively low-temperature heat; while this is adequate for space heating, it is not well suited for most high-intensity industrial process heat needs. For some industrial applications that require intermediate temperatures, electric resistance heat may be useful, though whether a heat source can be utilized in a particular instance is a function not only of the temperature it can provide but also how the heat source can be physically integrated with that particular industrial process. Very high temperature applications typically require burning fuel which, if it is to be decarbonized, would require renewable gas or oil, or possibly renewable hydrogen. Other applications that can use induction, lasers, microwaves, etc. likely exist but will tend to be less common and the opportunities are highly specific to the particular application in question.

Because industrial process heat needs tend to be very specific to particular industrial applications, the availability and cost of decarbonized solutions is also likely to be process-specific. In many instances where natural gas or fuel oil are used today, it should be possible to substitute renewable gas or renewable oil. Renewable (green) hydrogen could play a more important role in the industrial sector than in the residential and commercial sectors. Unlike in those sectors, hydrogen could be stored on-site or potentially delivered via dedicated pipelines to targeted industrial sites that have large, concentrated demand. Given the diversity of industrial applications and the sparse information about both current industrial activities and especially how decarbonized alternatives might be implemented, this study has not attempted to analyze the relative economics of decarbonization solutions for the industrial sector.

However, where industrial decarbonization involves substituting renewable fuels (gas, oil, hydrogen) for the current fossil fuels used, the cost of fuels will be higher – potentially much higher, especially for gas fuels – and this may increase manufacturing costs for energy-intensive industries. These higher operating costs may create a competitive disadvantage for firms whose competitors do not comply with similarly ambitious decarbonization goals, unless otherwise mitigated through state- or utility-administered incentive structures. Further, to the extent industry does relocate to regions without similar decarbonization targets, this may simply relocate overall global GHG emissions, rather than reducing them. The Policy section below discusses some ways to address this, and the **Technical Support Document** accompanying this report provides further detail on issues related to the industrial sector.

⁷⁹ Overall industrial heat needs represent a smaller share in Rhode Island than in the U.S. as a whole.

QUALITATIVE ASSESSMENT AND OTHER FACTORS

In addition to the results of the quantitative assessment of alternative heating decarbonization solutions presented above, a number of other, more qualitative factors need to be considered. Many of these factors were raised by heating sector stakeholders. In some cases, the ideas presented here represent perspectives expressed by some particular stakeholders, but may not be shared by all. Broadly, qualitative factors that impact the attractiveness and feasibility of certain decarbonization solutions in various applications fall into the following categories:

- **Information deficits.** In addition to the unavoidable uncertainty about future developments that may affect the performance and cost of decarbonized heating solutions, there is a significant lack of current information among consumers, installers, and even utilities and policymakers about the available alternatives, how they work when applied at scale, the buildings and geographies where they may be applicable, what they cost and how they perform. This is, in part, because these decarbonized technologies are relatively new and not yet widespread, especially in the United States. Related to this, there is also no “one-stop shop” where stakeholders can go to understand and compare heating alternatives. The providers of various heating solutions tend to be small and, while each may be familiar with the solutions they deliver, few are able to put the alternatives into context and compare among the options. Greater industry collaboration, coupled with strategic partnerships with the utility and state government, may assist in reducing this barrier.
 - **Affordability of energy is key.** Energy costs throughout New England have long been higher than in other regions of the country. Keeping energy affordable throughout the transition to
- a decarbonized economy is imperative for all the state’s residents and its businesses. This is particularly true for low- and moderate-income consumers and disadvantaged populations; policies aimed at decarbonizing the heating sector (as well as other sectors) should be designed to protect these populations in particular. One approach that can help with this is to improve the efficiency with which energy is used, and therefore the state’s cost-effective energy efficiency programs must remain in place as a way to help reduce energy consumption and manage longer-term customer costs.
- **Acknowledge the needs of vulnerable customers.** Many low-income customers live in lower-quality housing with less effective, less efficient heating systems. Energy costs are already a burden for many of these customers. It will be important to ensure that decarbonization does not add to the burdens of these customers and policies create opportunities for them to participate in the advantages of decarbonization – both as consumers and potentially offering employment on the supply side.
 - **Health and safety concerns about natural gas.** Natural gas use presents both real and perceived health and safety risks that can be avoided by electrification. Gas is combustible and creates risks when gas leaks occur indoors. In addition, indoor combustion of gas causes indoor air quality problems (NOx) that lead can lead to detrimental health effects. In this respect, the use of natural gas for cooking can have a greater impact than heating; while heating consumes much more gas than cooking, heating is almost always vented outdoors, but gas cooking is often not vented, or not completely.
 - **Consumer preferences.** Some consumers’ unwillingness to give up their gas cooking stoves creates a barrier for switching away from gas as a heating fuel. Electric induction cooktops offer

performance comparable to gas (arguably better), but induction is not a well-known technology.

- **Methane leaks mean renewable gas also emits GHGs.** Even renewable gas that is produced entirely without GHG emissions will contribute to GHGs through leaks, due to methane’s high global warming potential (about 30 times that of CO₂ over a 100-year timeframe; 85 times over 20 years). Current leak rates are substantial, on the order of 2.7%, which means that the GHG impact of leaked methane can add roughly 30%-85% to the GHG of the CO₂ in the combustion products. While leaks may be reduced, they will not reach zero. This limits the ability of renewable gas to provide fully decarbonized heating.
- **Weatherization effectiveness.** Even if weatherization measures are cost-effective, adoption rates are relatively low. This can likely be attributed at least in part due to non-cost barriers such as the fact that even the kinds of weatherization measures covered by programs like EnergyWise involve “intrusions” into individuals’ homes and potentially disruptions to normal use of the home. This is even more the case for deeper retrofits. Energy efficiency policy has evolved to address some of these barriers – for example, by bundling the timing of some energy efficiency measures with the energy audits – but “convenience” likely remains an important barrier to more adoption of cost-effective weatherization measures.
- **Availability of installers.** There is a shortage of available installers for heat pump technologies and stringent licensing requirements may create a barrier to increasing the number of licensed installers. A countervailing concern is that heat pump technology requires a well-trained installer to design and implement a system that will perform well. Effective training programs and industry coordination may help to address these concerns.
- **Electrification depends on decarbonizing electricity production.** Electrifying heat, such as with heat pumps, only results in decarbonization to the extent the electric grid itself is decarbonized. Both perceived and actual delays in decarbonizing the electric system could reduce consumer willingness to switch to electrified solutions. Full decarbonization of the New England electric system to meet traditional and new sources of demand, such as electric vehicles and heat pumps, by 2050 is likely a very significant challenge.⁸⁰
- **High initial costs are a barrier to adoption.** Heat pump technologies, particularly ground source heat pumps, have high initial costs that create a significant barrier to consumer adoption. This is particularly the case for low-income consumers in the absence of policies to mitigate upfront costs. Utilities may be able to help address this to the extent they can finance the initial costs through on-bill financing or rate-basing some of the cost. Mechanisms such as securitization or financing with green bonds may help to further reduce the cost to consumers.
- **Low deployment levels mean non-competitive pricing.** Heat pump technologies, particularly those relevant for heating in Rhode Island (GSHP and cold climate ASHP), are relatively new and costly. This results in consumers facing a relatively immature (and perhaps not very competitive) market

⁸⁰ For details on the magnitude of this challenge, see The Brattle Group, *Achieving 80% GHG Reduction in New England by 2050*, September 2019. The report suggests that an acceleration of annual renewable energy deployment of 4-8 times the annual pace currently planned for the decade 2020-2030 will be necessary to accomplish a fully decarbonized system with significant demand from electrified heating and transportation.

of installers, with pricing for heat pumps higher than pricing for installations of more mature technologies such as boilers and furnaces. This is likely particularly true for GSHPs, where the market for geothermal wells is also immature and pricing of drilling such wells potentially higher than it would be in a more fully developed market with higher volumes enabling economies of scale and competition.

- **Local codes and standards.** Rhode Island’s building codes and permitting requirements should be reviewed through the lens of wide scale heating sector decarbonization. In particular, the state should work with local communities and the construction industry to ensure heat pump installations can be viably deployed, while reducing construction-related soft-costs to improve affordability. Examples include rules for drilling geothermal wells in dense urban environments, set-back requirements for outside condenser units and different permit requirements across localities.
- **Split incentives.** A large share of the Rhode Island population, in particular more economically disadvantaged populations, do not own their residence. When non-tenant owners make decisions about heating technology, their economic incentives may disfavor high capital costs since they tend to incur those while they tend to pass on fuel and other operating expenses. This in turn may create a barrier to heat pump adoption.

Table 2 is organized according to the various solutions for decarbonized heating technologies, and summarizes some of the less easily quantified attributes that may impact their attractiveness from the perspective of individual consumers or the state, and identifying whether these factors have positive or negative implications for the given technology.

CONCLUSIONS FROM ANALYTIC MODELING AND STAKEHOLDER INTERVIEWS

The analytic modeling efforts and the series of stakeholder interviews and public workshops that were undertaken in this project have raised a number of important issues and conclusions about the transformation of Rhode Island’s heating sector. In addition to reinforcing many of the analytical conclusions, stakeholders pointed out further implications that were beyond the scope of the analyses.

Decarbonizing the heating sector in Rhode Island will mostly mean decarbonizing residential and commercial space heating, since these account for the majority of heating needs in the state. And it will occur mostly by retrofitting existing buildings, since the rate of new building construction is quite low; most of the buildings that will exist in Rhode Island by 2050 already exist now.

Energy efficiency improvements to existing buildings will be an important component of decarbonization, since they reduce the amount of heat that must be provided. Heating requirements for an existing building can typically be reduced by roughly 15% at reasonable cost with simple efficiency improvements (weather stripping, air sealing, attic insulation), saving consumers money while reducing emissions. But much greater efficiency improvements tend to be costly and disruptive in existing buildings, and may not be cost-effective. This means that it will still be necessary to deliver significant amounts of heat to these buildings, and that heat must be decarbonized.

Two broad pathways to decarbonize space heating exist – electrifying heating using heat pumps with decarbonized electricity or using decarbonized renewable fuels (gas or liquid fuels) in boilers and furnaces like those in current use with fossil heating fuels. Each of these pathways and the technologies

Approach	Challenge	Comment
ASHP, GSHP	Market Maturity	<ul style="list-style-type: none"> The market for ASHPs and GSHPs is underdeveloped. Knowledge about quality of installation, competitiveness of bids, etc. are underdeveloped among both consumers and contractors.
GSHP	Installation Constraints	<ul style="list-style-type: none"> Installing GSHPs requires drilling or digging. There are both physical and potentially permitting constraints that make installing GSHPs challenging in certain instances, such as densely populated neighborhoods and certain geologic formations.
GSHP (some ASHP)	Upfront Cost	<ul style="list-style-type: none"> GSHPs require significantly higher upfront costs than ASHPs and traditional boiler and furnace systems. This creates adoption barriers due to the unwillingness or inability to afford these higher upfront costs (even if beneficial on average over the life of the equipment).
GSHP, ASHP, Energy Efficiency	Split Incentives	<ul style="list-style-type: none"> Solutions with high capital cost can be challenging to implement in rental situations; since the tenant benefits from energy savings, the landlord may have little incentive to invest in a more efficient heating system.
Renewable Gas	Methane Leakage	<ul style="list-style-type: none"> Renewable gas delivered over pipeline infrastructure will result in residual methane leaks. Given the high climate forcing potential of methane, this reduces the ability of renewable gas to provide fully decarbonized heating.
Renewable Gas	Indoor Air Quality	<ul style="list-style-type: none"> As with natural gas, the use of renewable gas for heating and especially cooking results in indoor combustion, which can lead to poor indoor air quality and health risks.
Renewable Gas	Effects of gas leaks	<ul style="list-style-type: none"> As with natural gas, indoor leaks of renewable gas present health and safety risks.
Renewable Fuels	GHG Reductions	<ul style="list-style-type: none"> Largely due to land-use issues, it is difficult or impossible to eliminate all GHG lifecycle emissions of some renewable fuels, such as those derived from fuel crops.
Deep Retrofits	Implementation and Disruption	<ul style="list-style-type: none"> Deep energy efficiency retrofits (wall insulation, window replacements, etc.) require disruptive interventions, which create additional barriers beyond potential issues of cost-effectiveness.

TABLE 2: QUALITATIVE CHALLENGES AFFECTING DECARBONIZED HEATING ALTERNATIVES

Note: Challenges for one solution represent an advantage for those alternative solutions that do not face a similar challenge.

that implement them has advantages, and each faces challenges.⁸¹

Renewable fuels have a significant advantage in that they allow for the continued use of existing infrastructure with little or no changes, both for the supply infrastructure and at the customer site. However, there are likely to be only limited quantities available at moderate prices, and if they are used widely for heating (anywhere in the United States since the market for such fuels will be regional or national), the price of renewable fuels is likely to be quite high, especially the price of renewable gas compared to current very affordable natural gas. Renewable gas faces additional challenges. Leaks from the pipelines, the distribution system, and on the customer's premises create substantial GHG emissions, even if the gas itself is entirely decarbonized. Indoor leaks can also create safety risks, and indoor combustion is associated with health risks due to the effect on indoor air quality.

Among the decarbonized electrification solutions, both ground source heat pumps and cold climate air source heat pumps are able to deliver the heating requirements of Rhode Island buildings. Even though air source heat pumps do experience efficiency loss at low outside temperatures, they are able to provide all of a building's heat requirements.⁸² This efficiency loss may create some challenges if ASHP is implemented widely, though. The electricity needed to power many ASHPs operating inefficiently in extreme cold would create a significant spike in electric system peak demand, which would raise electricity prices. Ground source heat pumps draw heat from underground where the temperature is nearly constant, so they do not experience this efficiency

loss at cold outside temperatures or contribute unduly to peak electric load and prices. They do, however, require a significant additional up-front cost to install the ground loop. For both ASHP and GSHP, installing heat pumps by itself does not decarbonize heat – it is also necessary to decarbonize the electricity supply.

All the alternatives for decarbonized heat are likely to be somewhat more costly than fossil natural gas heat is today, and perhaps very roughly on par with the cost of heating with oil, propane or electric resistance. Based on information available now, and accounting for the substantial uncertainties that affect the future costs of all decarbonized heating solutions – renewable fuel price, the initial cost of installing heat pumps and ground loops, and the price of electricity – it is not clear that any of the decarbonized solutions will be materially more cost effective than the others. This is true both for single-family residential homes, and by extension, for larger multi-family residential and commercial structures.

In fact, the wide diversity of existing buildings and situations suggests that the cost effectiveness and sometimes the feasibility of any approach depends significantly on local and building-specific circumstances. As an example, there may be challenges installing GSHPs in dense urban environments and where the local geology is unsuited for a ground loop. This will lead to different solutions being chosen in different circumstances, and Rhode Island will likely have some broad mix of these decarbonized heating technologies – ASHP, GSHP, renewable gas and renewable oil – in 2050 and beyond. This likelihood of a mix of technologies is reinforced by the fact that relying entirely on any one of them for all heat needs would tend to exacerbate

⁸¹ One of the practical challenges will be funding the incentive and consumer education programs necessary to achieve the decarbonization objectives. This report does not address the aggregate cost of such initiatives nor the best means of funding them, but they will be crucial to ensuring delivery of a decarbonized heating future that works for all Rhode Islanders and the state's economy.

⁸² For an air source heat pump system, it may be economical to use a supplemental heat source (e.g., electric resistance, or maintaining an existing fossil heat system for an interim period) to avoid having to install a very large ASHP to cover peak heat needs.

its own disadvantages: the electric peak impact of ASHP, the high initial cost of GHSP, and the limits on supply for renewable fuels. And the analysis of a mixed solution highlights a particular challenge for the current gas system – that gas volume lost to electrification or efficiency will increase the delivered cost of gas, imposing risks on customers who cannot easily switch away from gas.

This observation about a lack of a dominant technology solution is reinforced by a qualitative observation from stakeholder interviews. On top of the unavoidable uncertainty about future performance and cost, there is a “huge information deficit” and lack of understanding of the decarbonized heating alternatives among consumers, installers, and even policymakers. There are also few providers of decarbonized heat solutions, and

no one-stop shop for information that would allow consumers to understand and compare them. This lack of information itself presents a barrier to getting started on the transition.

One important implication that can be drawn from the inability to identify a “preferred decarbonization pathway” is that it is likely premature to cut off options. For example, it is not time to begin dismantling the existing gas infrastructure, since maintaining it, at least for now, keeps options open. By the same token, it may also be best to avoid large, long-lived investments in any particular technology or infrastructure, since there is no guarantee the investment will continue to be useful in the long run.

The next section explores in some depth a number of policy implications of these observations that came from the analytic effort and the stakeholder interviews.



Policy Choices to Transform the Rhode Island Heating Sector

The heating sector is characterized by a number of features that justify policy intervention, including the presence of externalities or public goods, economies of scale, information failures, financing barriers, natural monopolies, etc. Greenhouse gas emissions are a classic externality, though not the only one here – the impact of individual heating technology choice on peak load and electricity price is another. There is also a considerable lack of awareness among consumers, policymakers, and even installers about the current state and likely future development of decarbonized heating technologies. And there are natural economies of scale and scope where coordinated action may facilitate, accelerate, and reduce the cost of heat decarbonization. The widely shared benefits and system interactions that will accompany decarbonization make policy interventions both warranted and necessary. Such interventions can accelerate and facilitate the transformation of the heating sector, and share the disparate individual costs that will likely be borne by individual customers.

The analyses underlying this report conclude that, based on the currently available information, none of the identified decarbonization pathways is clearly better than the others. The most appropriate and most economical decarbonized heating solution remains uncertain, and may depend on a customer’s unique circumstances. For example, the long-run cost

of renewable fuels is highly uncertain, particularly if they must supply fuel volumes similar to today. Also uncertain is the ability to overcome deployment barriers for ground source heat pumps, and the cost of heat pumps and the price of electricity from a fully decarbonized grid. In addition, the cost and applicability of these solutions to any particular (existing) building will often depend on its unique circumstances. It does seem likely that, on a purely economic basis, decarbonized heat will be more costly than the cheapest fossil solution today (natural gas), though not necessarily when compared to oil or propane.

For these reasons, rather than discrete technology mandates that may prematurely dictate technological and economic outcomes, it is appropriate to develop a set of policy principles to guide policy development, giving flexibility to respond to changing circumstances and information. In the short- to medium-term, policy should remain technology-agnostic about the long-term transformation, while promoting early demonstration and development of a number of promising technologies and program structures to learn and fill the information gap, and taking action to future-proof the heating system by not locking into any particular path. The focus should be on early activities that not only achieve emissions reductions (though that is important), but also facilitate a dramatic acceleration of decarbonization in the future.

POLICY PRINCIPLES

The uncertainty about the best long-run decarbonization approaches, the lack of information and experience, as well as the need to make early progress on the heating transformation suggest several principles for policy development, laid out below in this section.

Ensure progress: Collectively, the chosen set of policies should ensure that material progress is being made on decarbonization. One way to do this is to decarbonize all possible heating pathways, so that whatever path is chosen by individual consumers, the overall heating sector in Rhode Island is making progress toward decarbonization. This could take the form of decarbonizing the electricity that will power heat pumps that are deployed, while simultaneously decarbonizing fossil-based heating fuels for customers who continue to rely on traditional furnaces and boilers. On the electric side, Governor Raimondo’s Executive Order requiring 100% renewable electricity by 2030 (EO 20-01) is an important step forward.⁸³ Rhode Island has also taken an initial step toward decarbonizing traditional fossil heating fuels with a 5% biodiesel blending requirement for heating oil in the state. Extending such a blending requirement to the natural gas system and increasing the share over time, ultimately to 100% for both gas and oil, will ensure ultimate decarbonization, regardless of which pathway is ultimately chosen by customers.

Take advantage of “natural investment opportunities”: Heating infrastructure, such as building envelope components, boilers or furnaces, gas distribution pipes, power lines, etc., is very long-

lived and is replaced or updated only infrequently. It is generally much less costly (and thus more cost-effective) to change such infrastructure at a time when the existing infrastructure would otherwise be replaced (or is soon to be replaced), serviced, or even just accessed in the normal course of operations. This has two implications. First, it will often be best to time a change to the heating system to coincide with such interventions, since at that point it will involve less incremental cost and less disruption – for instance, by timing the installation of a heat pump with the end of life of a furnace to save costs. Since a typical furnace or boiler life is roughly 25 years, a prompt start means that such natural investment opportunities may occur about once on average for each building by 2050.⁸⁴ Similarly, modifications to improve the efficiency of a building envelope are most economical when the building shell is otherwise being modified, particularly for some of the more invasive and costly interventions. Such intervention points may only occur once over the next 30 years. For customers with recently-installed heating systems and/or newly-constructed homes, it may not occur at all. This principle applies at several levels – to the replacement of a furnace or boiler in an individual residential home at the end of its normal life, as well as to the gas and electric distribution infrastructure when components of it are being replaced or upgraded. In either case, it will be less costly to transform the system if decarbonization activities are timed for when a significant investment otherwise must be made in the normal course of business. Taking advantage of natural investment opportunities also implies avoiding lock-in to GHG emitting heating solutions when larger investments are being made.

⁸³ Even with Rhode Island achieving a 100% renewable goal by 2030, the state remains interconnected and dependent upon the regional New England generation and transmission system. Since it will continue to be affected by fossil-fired electricity in this way, efforts to reduce greenhouse gas emissions in the rest of New England will be equally important.

⁸⁴ This raises another point, which is that it may be quite difficult to transform a building’s heating system when the heating system has actually failed. The urgency to restore heat will probably lead to an emergency replacement with a similar furnace or boiler (quick and relatively simple since other parts of the system need not change), which would not allow time to consider, plan and implement a different heating solution. This points to the value of planning such changes systematically and well in advance to occur when the heating system is aging but prior to actual failure.

Extend the planning horizon, and future-proof:

Because many heating-related investments will last for decades, investments should be made keeping this in mind. This may be particularly important for the electric transmission and distribution system, where upgrades to the distribution system will likely become necessary over the coming decades to accommodate electric vehicle penetration and potentially more decentralized energy production (such as rooftop solar PV). Since distribution system upgrades likely involve a significant element of “fixed costs” (deploying workers and equipment), the incremental cost may be modest to make larger upgrades than those immediately needed, and would create additional capacity to accommodate longer-term needs, including potential electrification of heating, thus avoiding the need to upgrade capacity multiple times in smaller increments.

Implement no-regrets improvements – but don’t stop there:

There are likely some changes that can be made that would qualify as “no-regrets” actions in that they will be valuable regardless of future developments in the heating sector. Such policies should be pursued where they can be identified, but policies will likely need to go well beyond such no-regrets actions. The magnitude and speed of the transformation needed means that a broad array of approaches must be implemented in order to make enough progress quickly enough. This will include some that may not be guaranteed to be “successful” in all future states of the world, though even policies that appear unsuccessful often yield valuable information and experience that can advance the ultimate objective. Fortunately, there are many policy actions that do not require large resource expenditures or irreversible commitments, or foreclose major alternative solutions. Many of these involve relatively small investments to learn or disseminate information about the cost and effectiveness of decarbonized heat technologies. Pilot and demonstration projects, or information campaigns directed at the public (consumers), equipment installers

and even policymakers can be relatively low-cost ways to expand the information set and enable a faster, smoother transition. Planning is also relatively low-cost and facilitates considering multiple alternatives rather than foreclosing options. This includes developing plans for actions that may never be taken, where the act of planning draws out useful information and identifies what actions would be necessary to implement the plan, well ahead of an actual decision point. The gas and electric utilities may be in a good position to develop high-level plans for how they might implement or facilitate a transformation along any of the pathways, and can identify barriers so they can be addressed before they slow progress.

Learn and share information: Given the limited state of information about decarbonization pathways in the heating sector, there is substantial scope for efforts to promote learning and information sharing. Efforts could take the form of public information campaigns, pilot and demonstration projects (best if well-publicized), etc. Such efforts can accelerate and facilitate decarbonization along several of the potential pathways, in part by helping to generate the public and political support necessary. Much can be learned from projects already done or in process, and systems already available elsewhere. But local pilot and demonstration projects can also be useful for learning about how technologies and approaches may apply in Rhode Island circumstances, and they can also play an important role in publicizing and disseminating information.

Plan for contingencies: In light of the scope and unfamiliarity of the transformation that is necessary, and the uncertainties about the ultimate cost and performance of alternative pathways, an early start to planning the transition is crucial. This does not mean (only) planning what specific actions will be taken, though that is ultimately necessary. It also means developing reasonably well-specified though still high-level contingency plans for a range of potential pathways and possible futures, as a way

to identify the opportunities and obstacles that may be encountered and to begin to make progress on addressing them. For example, given there is at least a possibility of heavy reliance on air-source heat pumps, it will be useful to explore how the electricity peak impacts might be handled, and potential ways to mitigate them. Similarly, while it is not yet clear that decarbonization would involve a large decrease in delivered gas volumes, it will nonetheless be useful to understand how this would affect the gas system and develop approaches to address it. Over time as the transformation progresses and more is learned, the contingency plans can be updated, and ultimately some of them will likely be implemented.

Keep options open: Because of the large uncertainties about the cost (and to a lesser extent, the performance) of the various decarbonization pathways, it is not clear now which, if any, will ultimately dominate. In this circumstance, it is important to avoid foreclosing potentially promising decarbonization pathways, and will be equally important to open up potential pathways by using some of the principles noted here to determine how they might be implemented and learn about their benefits and costs. Learning and contingency planning activities can be used to identify and select the right pathway, and will also facilitate its ultimate implementation. As an example, it is almost certainly too soon to commit to abandoning or paring back the gas delivery system, but it will be useful to plan how to optimize it to take advantage of renewable gas where it is most important. This might involve expanding the gas system in industrial zones with few alternatives to burning fuel, while perhaps restricting new residential connections where alternatives are available.

Planning ways to decarbonize both paths (renewable fuels and electric heat pumps) can preserve a diverse set of alternative solutions while clarifying the tradeoffs. In fact, because of the diversity of buildings, geology,

infrastructure, etc. in Rhode Island, it is very unlikely that any single decarbonization technology will dominate in all instances. This implies that the ultimate solution will probably include at least some of each approach – building efficiency, ground and air-source heat pumps, renewable fuels. Since the amount of each that must ultimately be implemented will almost certainly be more than currently exists, beginning now to pursue all these pathways simultaneously is likely to be a positive step toward decarbonization, and can be particularly useful where actions are targeted to learning and information sharing opportunities. As more is learned, if one of the technologies begins to look relatively better than the others, implementation efforts can shift toward it, giving it a larger role in the ultimate mix without regretting the early implementation of other approaches.

A POLICY ROAD MAP FOR THE NEXT 10 YEARS

Transforming Rhode Island’s heating sector over the next three decades is a major challenge and requires making significant progress not just in the distant future, but also (and perhaps critically) within the coming decade. While it may be tempting to try to identify the single best technological solution or strategy, the analyses conducted for this project and presented above suggest that, at least at present, such a policy approach would be at best premature.

Hence, a policy roadmap for the next ten years must address the lack of clarity about what specific decarbonization approach(es) are most cost effective and hence worthy of support, the reality that both cost and implementability will likely be customer and application specific, and that making real progress and establishing the groundwork for accelerating heating sector decarbonization in the following decades is an urgent task for the coming decade. This comes against a background in which decarbonized heat is, in many cases, not currently economic when compared against the continued use of fossil

Ensure	Increase efficiency and reduce carbon content of all fuels to zero over time – ensures progress no matter which technologies are used
Learn	Data collection, R&D, pilot projects to understand technologies, infrastructure, and customers
Inform	Educate stakeholders – customers, installers, policymakers – about pros and cons of options, system interactions, etc.
Enable	Facilitate deployment with incentives; target natural investment opportunities; align regulations, rules, and codes; expand workforce
Plan	Expand planning horizon; develop long-term, high-level contingency plans now (do not commit yet) and use to guide near-term policy

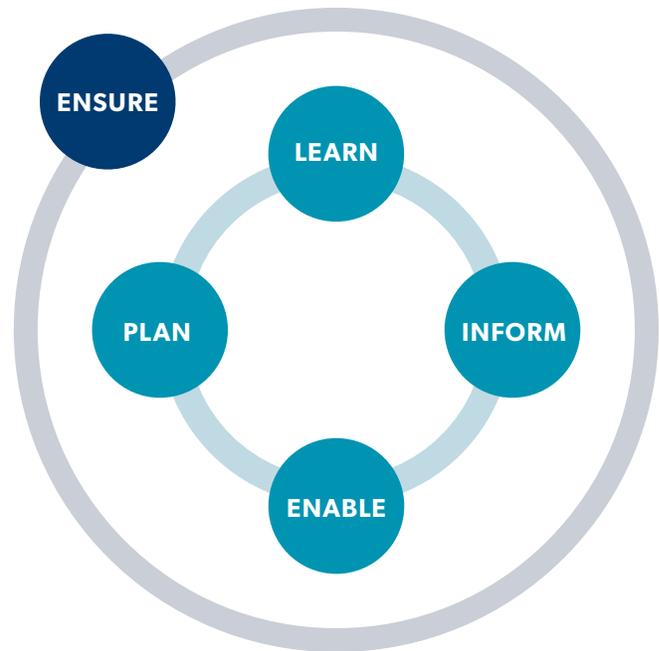


FIGURE 29: THEMES TO GUIDE EARLY POLICY RECOMMENDATIONS

fuels, in particular natural gas – although it may be in time, based on the analysis performed. On the positive side, policy measures that help advance any of the identified approaches are unlikely to cause large regrets in hindsight. With learning and more information becoming available over time, it will be valuable to periodically reevaluate the relative attractiveness of the various solutions and potentially revise policies accordingly.

1. Policy Themes for the Near Term

Against this backdrop, several themes should guide concrete policy actions over the coming decade. They are summarized in **Figure 29** and described further below, along with some specific policy suggestions. These themes overlap to an extent; they are not mutually exclusive categories but rather serve as a useful way to organize the policy ideas below, based on their objectives and effects.

a. Ensure

Policy measures that ensure early progress towards zero-carbon heating is made, independent of which heating technology may ultimately be favored, represent the backbone of more specific policies designed to learn, inform, enable and plan. For example, to the extent the carbon content of all available heating “fuels” declines over time to (near) zero, successful decarbonization can be assured. There are many policy approaches to ensuring progress. They include fuel- and technology-neutral GHG reduction policies, maintaining or expanding support for ongoing activities contributing to heating decarbonization, etc. If structured properly, policies that ensure early GHG reductions may also offer longer-term benefits such as learning, informing or expanding delivery capabilities, which can increase their impact. Some of these policies can be relatively easily implemented by Rhode Island alone, while others would likely benefit significantly from regional or even national coordination. Examples of such policies include:

- **Develop policies that guarantee gradual decarbonization of all heating “fuels,”** so that even if fuels continue to be burned, GHG emissions will fall.⁸⁵ Policies in this category include, but are not limited to, renewable “fuel” standards or fuel-specific decarbonization mandates, cap-and-trade programs, or a carbon tax construct. Given the size and connectedness of Rhode Island to New England, it is likely that any such policy would benefit significantly from regional coordination. Some existing policies could be expanded or used as a blueprint for developing heating related approaches. For example, the Regional Greenhouse Gas Initiative (RGGI) is a cap-and-trade program that covers emissions from most power plants in the electric sector. It could be broadened to include more plants or sectors, just like the cap-and-trade program in place in California was expanded over time to include sources of greenhouse gas emissions other than those in the electricity sector. Similarly, renewable energy standards (RES) can be expanded to the heating sector, requiring decreasing carbon content (or an increasing share of clean or renewable “fuel”) across all heating “fuels” or for each fuel separately. Examples include California’s low carbon fuel standard (LCFS), which is a program that requires decarbonization across all transportation fuels, or fuel-specific blending requirements, such as the 5% biodiesel blend requirement for heating fuel currently in place in Rhode Island. Finally, Renewable Thermal RPS programs are beginning to be introduced in a number of states, including elsewhere in New England. Renewable Thermal RPS can take many forms, but they generally result in the creation of “renewable energy certificates”

(RECs) that are counted against an increasing target. In some states, renewable thermal requirements are bundled with renewable electricity requirements, while in others thermal and electric targets are developed separately.⁸⁶

The Rhode Island electric sector already has both regional and state-level decarbonization targets such as those included in RGGI,⁸⁷ the existing Rhode Island Renewable Energy Standard⁸⁸ as well as the recently issued executive order to reach 100% renewable electricity supply by 2030.⁸⁹ One approach would therefore be to develop similar decarbonization policies for the other heating fuels, either under one program or on a fuel-specific basis, with fuel-specific approaches being likely more easily implemented than policies covering multiple fuels. The biodiesel blending requirement currently in place could be used as a basis for requiring decarbonization of delivered fuels over time. Depending on the desired pace of decarbonization, the biodiesel blend requirement would ramp up over time as illustrated in **Figure 30**.

To achieve full decarbonization by 2050, the renewable content of heating fuels would have to increase by almost 3.5% each year, which would result in a biodiesel blend requirement of about 36.5% by 2030.

It is currently not clear how such a mandate (or a broader Clean Heating Fuel Standard) would affect the price of delivered fuel over time, or how potentially increasing fuel prices would affect the demand for each heating fuel. However, given the uncertainty about how the costs and supply

⁸⁵ “Fuels” refers to all sources of heating energy including electricity, natural gas, oil, propane and wood.

⁸⁶ For a description of recent renewable thermal RPS approaches, see Clean Energy States Alliance, *Renewable Thermal in State Renewable Portfolio Standards*, July 2018

⁸⁷ For details on RGGI see <https://www.rggi.org/program-overview-and-design/elements>

⁸⁸ For details on the Rhode Island RES, see <http://www.ripuc.ri.gov/utilityinfo/res.html>

⁸⁹ http://www.governor.ri.gov/documents/orders/ExecOrder_17-06_06112017.pdf

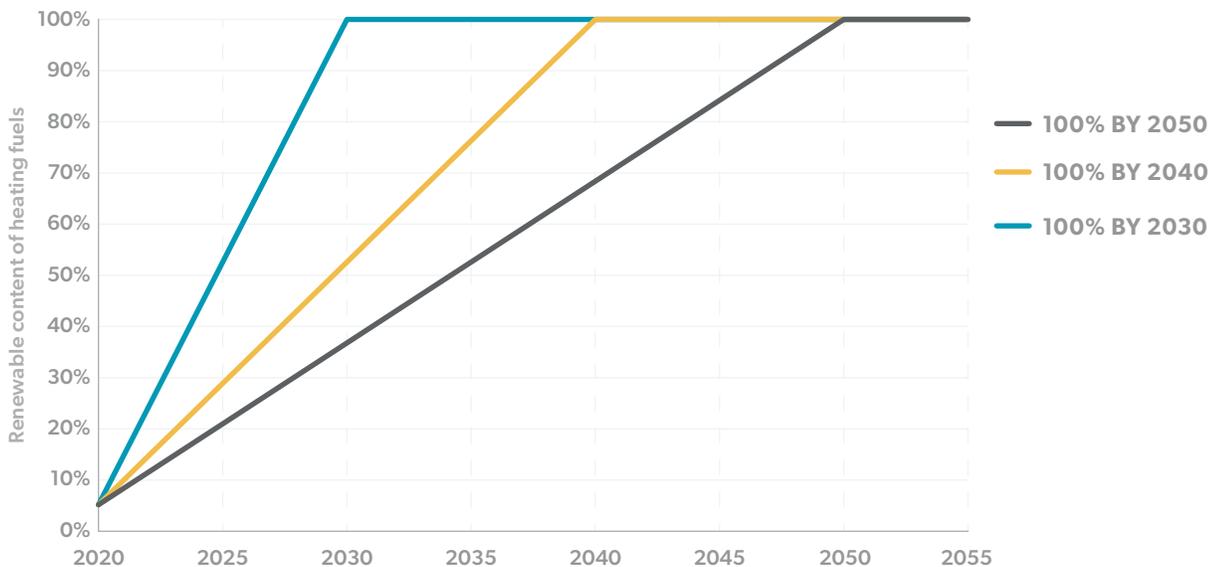


FIGURE 30: ILLUSTRATIVE BIODIESEL BLEND MANDATES RESULTING IN FULL DELIVERED FUEL DECARBONIZATION BY 2030, 2040 OR 2050.

of various decarbonized heating solutions evolve over time, mandating gradual decarbonization of all heating fuels provides precisely the ability needed to let market forces, technological progress and consumer preference determine how the heating sector in Rhode Island decarbonizes over time.

- Acknowledge the cost impacts of decarbonizing fuels and proactively address them.** Decarbonizing fuels through one of the approaches outlined will create cost impacts for customers of all classes. Consider policies that account for and potentially mitigate these impacts. This may be particularly important for low- and moderate-income customers, as well as industrial customers competing in globalized markets. It is crucial that state policymakers, agencies, and regulators actively collaborate with utilities and consumer advocacy organizations to thoughtfully structure heating investment strategies, and unlock creative opportunities for cost efficiencies. These strategies should be developed within the context

of other crucial climate change-related investments, such as accelerating renewable generation and transforming the electric grid to enable higher penetration of clean energy resources.

- Expand cost-effective energy efficiency improvements** to reduce overall heat needs and support delivery of no-to-low carbon heating solutions. Rhode Island has exhibited national leadership and innovation on energy efficiency and least cost procurement measures. It should maintain and expand these efforts to further develop the workforce, supply chain and markets needed to deliver additional cost-effective building efficiency measures, e.g., by renewing and strengthening the least cost procurement statute.⁹⁰ This should include finding additional opportunities for intervention, particularly at “investment moments” where efficiency can be improved at low incremental cost in connection with building improvements or maintenance that is being undertaken for other reasons. Also, building efficiency programs should

⁹⁰ <http://www.energy.ri.gov/policies-programs/ri-energy-laws/least-cost-procurement-2006.php>

be fuel-neutral, independent of the heating fuel used, and coordinating the delivery of alternative heating solutions through energy efficiency programs may facilitate their delivery. Recent experience shows that National Grid is essentially on pace to perform efficiency audits of all Rhode Island buildings in the next few decades, though only about one-third of audits lead to weatherization projects.⁹¹ In line with the policy theme of taking advantage of natural investment opportunities, this suggests that increasing the conversion rates of audits into weatherization should be one of the focal areas over the coming decade. Additional cost-effective efficiency measures reduce overall costs to Rhode Islanders – particularly important in the context of decarbonizing the heating sector.

- **Voluntary green tariffs** that allow customers to source a higher share of their energy from renewable sources (perhaps for gas as well as electricity) could engage customer sentiment to accelerate the pace of decarbonization.

Once policies to ensure progress towards heating sector decarbonization no matter what heating fuel or technology is being used are in place, efforts over the coming decade should focus on learning, informing, enabling and planning.

b. Learn

One obvious response to uncertainty is to learn more about the costs, performance and practical feasibility of the decarbonized heating system alternatives. Learning can be supported by policy via theoretical and applied research as well as pilot and demonstration projects. In particular, applied research requires data, and the collection of relevant data – not just about the decarbonized

technologies, but also about Rhode Island’s buildings and electric and gas utility infrastructure – represents an important precondition for learning. Installing decarbonized heat systems that yield near-term GHG savings will often also create opportunities for learning more about how (or how not) to implement these technologies and the programs that deliver them; similarly, early experience can guide a better understanding of consumer reactions, preferences and information needs. Some specific ideas about policies that could foster learning include:

- **Gather information.** Additional information in a number of areas would be very helpful in developing more targeted policies and incentives and in evaluating progress. Information that should be gathered falls into several categories: more detailed information about the “status” of the current heating sector, such as type, and remaining life of customer-sited equipment; cost and performance information on deployed new technologies such ASHP and GSHP, and issues affecting use of these in individual buildings (need for ductwork, electric upgrades, ground loop, etc.) This information gathering might be implemented by expanding existing efficiency program EM&V work to also include collecting such data. Recognizing that customers likely cannot be required to provide information, policy could tie incentives (or other “carrots”) to voluntarily providing relevant information, which can help target or refine policy. For example, information about the remaining life of current heating systems may help target incentives to heating systems when they need to be replaced, rather than replacing systems only upon failure.
- **Research.** Given the uncertainties about various heating decarbonization solutions and the fact

⁹¹ In its most recent update, National Grid reports that of the more than 10,000 customers receiving energy audits under the EnergyWise program, 3,700 proceeded with weatherization measures. The Narragansett Electric Company d/b/a National Grid, 2018 Energy Efficiency Year-End Report, May 15, 2019, p.8

that Rhode Island is not alone in attempting to decarbonize heating, policy over the next decade should have a significant research focus. Research and studies to provide more information about the performance, cost, barriers and policy solutions outside of Rhode Island can help focus and improve policy measures in the State. Since Rhode Island is a small state and markets for renewable fuels are likely to be national or international in scope, it may be most effective for the state to partner with other jurisdictions on research (and demonstration) projects. Some examples of research activities include:

- ▶ Studies for all of the pathways to identify experience gained elsewhere, understand how that may apply to Rhode Island.
 - ▶ Studies to identify information gaps, which may then be amenable to studies, pilots or demonstration projects in the state, or in partnership with other states.
 - ▶ Studies to better understand the potential local, regional and national sources for renewable fuels as well as barriers to their development, including conditions for interconnecting potential renewable gas supplies to the existing gas delivery infrastructure.
 - ▶ Studies to understand potential geological obstacles to deploying GSHPs or at least to better understand how ground loop costs may differ by area, based on sub-surface conditions and other factors.
- **Understand how the gas distribution system responds to volume loss.** Develop a much better understanding of how the operations and costs of the gas distribution system are likely to respond to heating sector transformation, which may cause both increasing commodity cost (as an increasing share of more costly renewable gas is blended with

fossil gas) and decreasing delivered gas volumes (as customers displace some or all of their gas heating needs with alternative heat sources such as heat pumps). Identify opportunities to reduce costs by concentrating volume loss in particular sub-parts of the distribution system and selectively paring back those sub-parts, as opposed to experiencing more or less proportional reductions in volume across the entire system, which would require that the entire system continue to operate with little opportunity to save costs.

- **Understand opportunities and limitations on GSHPs, particularly regarding the ground loop and GeoMicroDistricts.** These may face constraints because of geology and may also be affected by the density of buildings and other infrastructure, perhaps differently for individual ground loops vs GeoMicroDistricts. E.g., can GeoMicroDistricts be used in more dense areas where individual ground loops might be difficult, perhaps by taking advantage of public rights-of-way?
 - ▶ Understand the feasibility and cost of GeoMicroDistricts, identifying what types of areas are suited to them in terms of geology, presence of other infrastructure (which might complicate installation) and density of buildings and heating requirements. Understand what extent and participation levels are necessary to make a GeoMicroDistrict viable, e.g., for retrofitting an existing neighborhood with GSHP.
- **Use pilot and demonstration projects to explore options.**
 - ▶ For example, use pilot projects to characterize the peak implications of air source heat pumps on the electric system peak in the coldest weather, and options to mitigate, shift or otherwise address them. Potential solutions could include onsite thermal storage systems that shift electricity usage away from peak to

nearby hours, battery backup to store power, or a backup (non-electric) heat system. Pilot and demonstration projects could help to estimate the cost of these measures, and barriers that may exist to implementing them.

- ▶ Similarly, use pilots or demonstrations to understand technical issues with blending renewable fuels into the existing fossil fuel streams during a transition period. Identify operational issues that arise with retrofitting equipment to handle very high blends of biodiesel, up to B100.
- **Understand the industrial sector and its heat needs to identify energy-intensive industries that may be vulnerable to the higher cost of decarbonized heat** (e.g., substituting higher-cost renewable fuels for fossil), especially those with competitors in other jurisdictions that may not need to decarbonize.

c. Inform

The current level of knowledge about low- and zero-carbon heating solutions remains low, as was raised several times in stakeholder interviews and public workshops. The transformation of the heating sector will require better information on the part of many stakeholders in the heating system. The individual owners of most or all existing buildings must adopt new heating approaches, and they will be better equipped to take the necessary actions if they have a better understanding of the technologies, and confidence in their advantages (and disadvantages) in terms of cost, comfort, and disruption and in the quality and reliability of installation. It is not only end-use customers who would benefit from better information about the available decarbonized heating alternatives. Even installers and policymakers often do not have good information or shared knowledge bases. Some potential policy options to create better information for all stakeholders include:

- **Use public information campaigns**, such as utility bill inserts, billboards, online or television and radio advertisements, to create familiarity with the alternative technologies and approaches, and to communicate their advantages and disadvantages.
- **Use demonstration projects to inform.** Well-publicized projects, such as public buildings heated with ASHP, GSHP or renewable fuels, can inform customers and make decarbonized heating solutions more familiar and acceptable. Such projects can include not only publicly-owned buildings (Town Hall, library, etc.) but also private buildings frequented by the public (retail stores, restaurants, movie theaters, hotels). Providing consumers the ability to experience decarbonized heating in action can play a major role in overcoming adoption barriers. This also applies to other heating applications that are deemed essential by consumers, such as cooking. Highlighting restaurants that cook with induction stoves might be one opportunity to begin addressing misconceptions about this and similar technologies.
- **Formalize training and certification programs** for professional installers to improve their understanding and make them more willing to undertake installations, and to recommend them to clients where they are warranted. An additional benefit is that this may avoid under-performing installations that could give the technology an unrealistically negative word-of-mouth reputation.
- **Provide information about qualified installers.** Often, consumers are worried about whether or not a given installer is skilled and qualified. Public agencies could provide information about installers that have received proper training and certification and perhaps additional information, such as the number of installations performed and potential consumer feedback (assuming private sector information sources do not provide sufficient information about consumer experiences).

d. Enable

Decarbonization of heating along any of the identified pathways will likely require significant ramping up of a range of activities. The next ten years must set the stage for the deployment of decarbonized heating solutions at large scale by enabling the transformation at many levels. This includes removing barriers and addressing challenges to enable the technologies themselves, the workforces needed to install and implement them, customers' willingness to adopt them, and utility programs, regulatory structures, etc. There is still uncertainty about the long-run cost and performance of many of the potential decarbonization technologies, and it is not yet clear which one (if it is one and not multiple) may ultimately be the best solution in the long run. But that is not reason to wait; it is in fact a reason to push forward, since experience, and not just the passage of time, accelerates the resolution of this uncertainty.

- **Provide buyer incentives for “all.”** Depending on the policy approach adopted to ensure decarbonization of all heating “fuels”, it is possible that all decarbonized heating solutions remain more expensive than current fossil-fuel based heating. Also, as shown above, payback periods for some solutions may well be longer than the short payback often demanded by consumers, even if they are lower cost in the long run. This is particularly the case for solutions with higher upfront cost, such as heat pumps and especially ground source heat pumps. Finally, learning about the performance and potential cost trajectory of various solutions requires some ramp up of experience across all the decarbonization solutions. For these reasons, incentives that encourage (early) adoption of each of the promising technologies (i.e., all those identified here) are likely needed to jump-start the market for
- **Improve regulatory structures.** The current gas distribution revenue decoupling law in Rhode Island has the effect of encouraging gas growth and discouraging electrification as an alternative means of heating. Specifically, when the gas utility increases the number of gas distribution customers on its system, the utility receives more revenue per customer in between rate cases. Conversely, when the number of gas distribution customers decreases, the gas utility loses revenue. This ratemaking principle is referred to in the industry as a “revenue per customer” decoupling mechanism. The mechanism was put in place before the impacts of carbon emissions were fully appreciated and policymakers understood that the addition of gas customers would lower the unit cost of gas distribution for the benefit of all gas distribution ratepayers. The regulatory

decarbonized heating solutions. These incentives can take many forms, ranging from incentives directed at installers or manufacturers, to purchase price rebates for equipment, on-bill financing or full ratepayer funded installations (via utility ownership) directed at consumers. They could potentially be supported by “green bonds.” Ratepayer funding and/or utility ownership are likely most appropriate for solutions that are similar to those traditionally provided by utilities, such as the GeoMicroGrids discussed above (where utility ownership of ground loops would mirror electric distribution wires or natural gas distribution pipes, with end-user equipment such as heat pumps being privately owned). The specific design of incentive programs for various stakeholders is beyond the scope of this study, but, any such undertakings must be planned and implemented carefully, understanding the cost impacts on various consumer groups, and interactions with other initiatives.⁹²

⁹² Caution may be particularly important in the near term, given the unpredictable impact of the economic crisis resulting from the COVID-19 pandemic.

framework should be changed to provide the Public Utilities Commission with the authority to develop a framework that de-emphasizes gas growth and encourages decarbonizing solutions in a fuel-neutral way. However, in Rhode Island, the “revenue per customer” mechanism for the gas business is embedded in statute and, thus, prevents the commission from changing this ratemaking mechanism. An amendment to the law would be required to alter it.

- **Enable a regulatory planning process.** A comprehensive and objective planning process could be created by a funding mechanism in gas and electric distribution rates that facilitates a study and statewide planning process that is coordinated and guided by the state energy and regulatory agencies in collaboration with the utility and other stakeholders.
- **Improve rate design,** both existing rates and potential changes, where existing rate structure may give incentives that are inconsistent with decarbonization, or changes may create opportunities to encourage the transition. For example, decoupling rates so that they better reflect fixed and variable cost causation (perhaps adjusted to better reflect GHG costs which do not actually appear in rates, absent a carbon price) may improve incentives. Including the initial gas interconnection cost in the rate base may not be consistent with the potential for scaling the system back in the relatively near future. Similarly, if the transition may cause gas system assets to have a useful life that differs from traditional assumptions, consider adjusting asset lives, both for assessing proposed investments and potentially for recovering the costs of existing assets. Rate design issues may be a useful way to address the peak impact of heat pumps, e.g., with capacity pricing, or time-of-use or real-time pricing. And of course, issues regarding the ability of low-income consumers to have access to low-carbon heat sources can be addressed through rate structures and ratemaking.
- **Explore a combined energy utility.** Consider a joint ratemaking framework and rate design to enable a single combined rate base for both the electric and gas distribution company. Since the primary electric and gas distribution company in Rhode Island provides both services, utility customers could be treated as “energy distribution” customers for purposes of allocating decarbonization costs, rather than segregating “gas distribution” and “electric distribution” customers. This will address the costs of decarbonizing as a single inter-related initiative, which can facilitate a more equitable distribution of costs and protect customers (including low-income customers and renters) who might otherwise be forced to bear high transition costs as a result of their historical energy system.
- **Take advantage of “natural investment opportunities.”** As discussed above, any time the building envelope or heating infrastructure is being replaced, serviced, etc., this creates a scarce opportunity to reduce heating requirements or change the heating system. It will help to find ways to identify such situations prospectively so that efficiency improvements and heating decarbonization alternatives can be fully considered, and to take steps to encourage interventions at these points, e.g., through LCP efficiency programs. Also, the addition or replacement of a central air conditioning system in an existing building (which may become more frequent with warming summers) creates a similar

opportunity, and could become an important driver of heat pump adoption.⁹³ Such intervention points can be used to upgrade electrical systems to accommodate future electrification demands from both heat and transportation. One challenge will be to gather and systematize data that will enable the identification of these natural investment points.

- **Substantially tighten building efficiency standards.** New buildings, and also major building interventions such as rehabs, should meet very high efficiency standards, perhaps net zero energy use. Consider also requiring the use of decarbonized heating systems, perhaps electric heat pumps, in new and renovated buildings, since a missed opportunity is unlikely to arise again soon.
- **Identify and remove barriers.** Enabling will involve identifying and removing important barriers to technology deployment (such as rules, building codes and permit requirements for deploying both ground- and air-source heat pumps, developing clearer rules for biofuels, etc.), efforts to increase the number and skill-level of the work-force that will be needed to deploy rapidly advancing heating technologies, overcoming unwillingness to give up gas for cooking, etc. In part, pushing the early implementation of these technologies will help to identify these barriers.
- **Build supply capacity.** Since heat pump installation is not currently a fully-developed market, Rhode Island will likely need considerably more installers of heat pump systems. To achieve that, it may be necessary to destigmatize the building trades and provide incentives to attract enough talent. Installers will also need high quality training provided to them to properly design and install heat pump systems for the Rhode Island climate.
- **Create separate incentives for heat pumps and for building envelope improvements.** Each helps reduce GHG emissions, independent of the other, and requiring the two to be linked may inhibit adoption.
- **Reserve limited resources for high-value uses.** Renewable fuels likely have an increasing supply curve, with modest quantities available at costs that are not too high, but high demand pushing prices very high. Consider decarbonizing in ways that reserve renewable fuels for high-value uses, like some specialized industrial uses, that do not have a ready substitute, and using other decarbonization approaches where they are available.
- **Understand and consider strategies to mitigate adverse effects.** As the analyses above indicate, decarbonizing heating in Rhode Island may increase the cost of heating for some consumers, particularly those currently using natural gas, and it may similarly increase total energy wallet expenditures for some consumers. The diversity among customers means that cost impacts will likely differ across customer groups and individual customers. Some customers, such as economically disadvantaged customers and industries exposed to competition, may be particularly exposed to any such cost impacts. In this context, it will be important in the near term to identify policies that promote solutions that reduce overall long-term system costs. This will put the state in a better position to consider additional policy alternatives to mitigate remaining impacts on vulnerable customers.

⁹³ In the most recent evaluation of Maine energy efficiency programs including heat pump incentives, 64% of survey respondents listed “Add air conditioning” as the install reason, the third most frequent response after improving energy efficiency and saving on heating costs. See West Hill Energy and Computing, Efficiency Maine Trust Home Energy Savings Program Impact Evaluation, Program Years 2014-2016, August 23, 2019, Appendix G, p.4

e. Plan

Finally, policy could support a change in approaches to planning by various entities including state agencies and regulated entities, notably National Grid. Today's planning activities often have a relatively limited time horizon of ten years or less, and presume that the utility systems will continue to operate much as they have in the past. The focus is on planning for "expected outcomes" – forecasting and planning for the most likely future developments, perhaps considering a few sensitivities. Transforming Rhode Island's heating sector over the next three decades in the presence of the fundamental uncertainties discussed throughout this report likely requires an augmented approach to planning. This should include developing a broader set of high-level contingency plans with longer time horizons – likely with a view at least towards 2050, in addition to current planning horizons – and planning for outcomes and actions that may never materialize, in order to be ready in case they do. Developing such plans does not imply an intention to implement all of them; in fact, some of the plans developed may be inconsistent with others. But developing such plans now will serve several purposes. First, they can guide near-term actions to ensure they are consistent with long-term goals. Second, the process of developing these plans will promote a better understanding of what is likely to be involved with each of the pathways, including the identification of major barriers, allowing solutions to be developed early and avoid delays later. Finally, such plans help provide "shovel-ready" responses if/when some of the contingencies studied should in fact arise. Some concrete examples of this enhanced type of planning include:

- **Use longer-term planning for the electric distribution grid.** Current planning of the distribution grid, including grid modernization plans, tend to be focused on shorter time horizons such as ten years and based on expected demand as well as its potential evolution. Understanding the

implications of electrification of both transportation and heat for demands on the electric transmission and distribution system over the long-run, i.e., through 2050, would allow improving investment decisions. For example, the cost of building out the distribution system as the heating system decarbonizes may be reduced through a better understanding of the additional cost of future-proofing. Rather than expanding system capacity to accommodate expected demand changes over just the coming decade, the planning process should also consider potentially larger capacity increases that could accommodate greater demand growth in the longer term due to high penetration of heat pumps and electric transport. Such planning may also allow targeting first those areas that may be likely to electrify earlier – e.g., non-gas areas where the economics of electrified heat are better.

- **Develop a gas system transition plan.** There is much uncertainty about how usage of the natural gas system will evolve as it delivers an increasing share of lower carbon gas at potentially higher cost, while the cost and availability of other decarbonized heating solutions improve. In this light, the question of the long-run role of the gas distribution infrastructure is one of the most complex and important questions. As the analysis in this report shows, it is too early to draw conclusions about this ultimate role, but developing plans for various eventual roles of the gas system will help the state to prepare for alternative trajectories, as well as identify mechanisms for reducing the impact and cost of a transition away from gas, should it need to be reconfigured, reduced in scope, or even ultimately decommissioned. Such planning should consider possibilities such as paring back some branches while retaining or perhaps even expanding others, e.g., if some industrial customers have no alternatives to gas or for whom renewable gas is substantially more attractive than using decarbonized liquid fuels.

- **Develop a heating transformation implementation plan.** While this report and the Meister Report provide important policy guidance, neither is sufficient to drive the choice and implementation of concrete policy proposals. But these studies could provide a starting point for state agencies to develop an implementation plan with a coherent set of concrete policy proposals that could be implemented directly. Since it is likely that over the coming decade new information will help better understand the attractiveness and barriers to the various heating decarbonization approaches analyzed here, both the heating transformation strategy (this document) and the resulting Heating Transformation Implementation Plan should be revisited periodically. Revisions of the Implementation Plan will be warranted if key metrics such as the ones developed in this report change significantly. For example, while this report suggests policies to scale up any and all of the promising decarbonized heating options are beneficial, from today's perspective, future revisions may conclude that certain approaches become clearly preferred and should be the focus of further policy measures, and others should not.
- **Plan a centralized heat pump conversion effort.** Although it is too early to commit to mass conversion to heat pumps, it will be instructive to begin to develop a plan for how the state and its utilities would organize and implement a widespread decarbonized electrification program for heating (e.g., installation of ASHP and/or GSHP,

and perhaps community GeoMicroDistricts) for many buildings across the state. The plan should be informed by smaller programs focused on supporting early adopters and currently cost-effective conversions. The plan could also proactively identify existing heating systems near end-of-life to facilitate the economics, and making the program opt-out rather than opt-in would increase participation. Planning should consider what costs should be recovered and how, and whether the cost recovery mechanisms could be tailored to address equity issues.

- **Expand planning horizons.** State agency and utility planning may require longer horizons than have been used historically. For example, while it might be appropriate to plan component replacements and upgrades just 5-10 years in advance on an "evergreen" system that is expected to last longer than the components being replaced, this is not true when the system must change fundamentally over a shorter horizon. Facing the need to decarbonize over the next few decades, system planning needs to take into account not just the lives of the components that will be replaced, but also the potential life of the system that they are a part of. Policy could therefore encourage or require that any planning processes be enhanced by adding a decarbonized 2050 perspective to all existing planning time horizons.

The background image shows the Rhode State House building at dusk. The building is a large, classical-style structure with a prominent central dome and multiple windows. The sky is a deep blue with some clouds, and the building's lights are on, creating a warm glow against the cool tones of the twilight. The title 'Conclusions and Next Steps for Rhode Island' is overlaid in white text on the left side of the image.

Conclusions and Next Steps for Rhode Island

The quantitative and qualitative analyses presented here for heating sector decarbonization solutions lead to the conclusion that, as of today, no dominant heating sector solution fits all situations and is sure to minimize the cost to consumers and businesses. The analysis does suggest that overall, the cost of decarbonizing the heating sector along several possible pathways is likely to be relatively modest on average. The increased heating costs for some customers may be at least partially offset by savings in other energy sectors. However, the cost of decarbonizing heat remains uncertain, both on average and especially as it relates to any particular building, business, or customer.

For these reasons, Rhode Island's heating transformation strategy must ensure that early progress towards decarbonization is made, regardless of which solution or solutions are ultimately adopted. For example, by increased implementation of cost-effective energy efficiency measures and by putting all the energy sources used for heating on a pathway to decarbonization. Beginning with the insights here, Rhode Island can promote this transformation through a range of policy options that focus on learning and informing, to help address inherent uncertainties, and by

taking steps to enable and plan for the transformation. These steps will include and are not limited to, creating incentives for customers to decarbonize, while ensuring that vulnerable populations are protected and that policies do not have unintended consequences.

Policymakers should use the coming decade to lay the groundwork and build the infrastructure for increasing the scale and speed of heating sector decarbonization – at least initially pursuing multiple different solutions. As time passes and learning increases, it may become clear that some solutions are better than others, at least for some customer segments, but that will not invalidate the early progress made with other solutions. Indeed, that early progress and the lessons learned from it will lay the foundation for later progress along whatever pathways are ultimately most advantageous.

Although three decades may seem a long time, the scale of the transformation needed in over 400,000 existing residences, corresponding numbers of small and large commercial buildings and industrial facilities, and an entire energy delivery infrastructure is a difficult challenge that will require sustained and careful attention, beginning urgently today.

Glossary

District Heating	A heating solution that provides heat to a number of buildings through a common system, rather than each building providing its own heat. District heating systems traditionally use a centralized boiler and distribute heat through a series of pipes, but the concept has been broadened to include a common ground loop to support GSHP systems in a number of buildings
GeoMicroGrid	A district heating system consisting of a common ground loop that supports GSHP systems in a number of buildings
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
GWP	Global warming potential, the heat-trapping potential of a gas, relative to CO ₂
MMBtu	Million Btu, a unit of heat energy (approximately equal to 10 therms)
MW	Megawatt, a unit of electric capacity (rate of delivering electric energy), equal to one thousand kW
MWh	Megawatt hour, a unit of electric energy, equal to one megawatt for one hour , equal to one thousand kWh
Power2Fuels (P2Fuel)	Power2Gas or Power2Liquids
Power2Gas (P2G)	Conversion of renewable electricity into renewable gas via electrolysis and methanation
Renewable Gas	Methane made from renewable sources, e.g., landfill gas, anaerobic digesters, gasified biomass, Power2Gas
Renewable Oil	Oil made from renewable sources, e.g., waste cooking oil, oil crops, Power2Liquids
TWh	A unit of electric energy, equal to one million MWh, or one billion kWh



Study Participants and Stakeholder Process

This study involved an extensive stakeholder outreach effort and interactions with a number of key stakeholders to help inform the work. Stakeholder engagement was an integral part of this study and an invaluable source of information and insights. Personnel from the Rhode Island Office of Energy Resources and Division of Public Utilities & Carriers, the state agencies responsible for directing this study, were integral members of the study team. This team benefitted from numerous meetings, calls and communications with National Grid, the electric and gas utility in Rhode Island, throughout the process. The effort also included interviews and meetings

with over 20 individual stakeholder organizations, as well as three public workshops (the first two held in Providence, the third conducted virtually as a webinar due to restrictions imposed by the COVID-19 pandemic). These workshops were held to share information, present intermediate results and collect feedback from stakeholders. Throughout the process, stakeholders provided guidance and commentary regarding the key issues that should be addressed, their own perspectives and positions on issues, what information they had and what they lacked. Stakeholders also provided substantial data input and validation, as well as insights to support the analyses.

Acadia Center

Aquidneck Planning Council

Brown University

Cadmus Carbon Pricing Team

Center for Justice

Conservation Law Foundation

Daikin

Efficiency Maine Trust

GEM Plumbing

Green Energy Consumers Alliance

HEET

National Grid

Oil Heat Institute of Rhode Island

Providence Housing Authority

Rhode Island Association of Realtors

Rhode Island Builders Association

Rhode Island Housing

RIMA

Stash Energy

Summit Utilities

Tec-RI

Maine Office of Energy Efficiency

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RHODE ISLAND 2030

Charting a Course for the
Future of the Ocean State

A Working Document

A LETTER FROM THE MCKEE-MATOS ADMINISTRATION

Dear Rhode Islanders:

As Rhode Island emerges from a once-in-a-century public health crisis, we have a once-in-a-generation opportunity to build a more resilient, prosperous, and equitable state for all. Making the most of this opportunity will require a collaborative effort to address not only the issues caused by the pandemic, but also those that existed long before.

That's why our Administration launched RI 2030: to craft a vision both for the state's economic recovery as well as for what we want Rhode Island to look like in the years ahead. As Governor and Lt. Governor, we are pleased to share this RI 2030 working document and preliminary recommendations that, once finalized, will help guide policy priorities, federal spending, strategic collaborations and legislative initiatives. While RI 2030 is not aimed solely at addressing the federal dollars coming into the state, a key goal of this initiative is to help Rhode Island leverage the State Fiscal Recovery Fund towards achieving the goals set through our RI 2030 process.

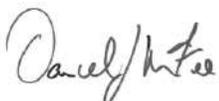
The RI 2030 process began with a series of virtual community conversations focused on key topics of interest for Rhode Islanders such as housing, tourism, small business, climate change, children and youth services, health, higher education, and more. These conversations included discussions with a panel of diverse Rhode Island community stakeholders, keynote speakers with national expertise on the topic, and members of the General Assembly. So far, our virtual community conversations have been viewed more than 15,000 times and garnered more than 500 comments from the public. From these discussions, and with input from all State agencies, we created the RI 2030 working document.

To build on this momentum, and with this document as a starting point, our Administration will be launching a series of in-person regional community conversations as part of a five-county listening tour. In partnership with the University of Rhode Island (URI) and its faculty, the URI Research Foundation, and faculty from other institutions around the state, the planning process will culminate in a 2030 visioning document that can be used to guide future investments.

We will present our RI 2030 vision thus far and continue to develop this document with your thoughts and feedback in mind. The document provided below is intended as an initial draft to guide the work to come, with a formal 2030 framework to emerge from this process over the next several months.

We look forward to working with all Rhode Islanders as we continue to build our vision for 2030 together.

Sincerely,



Daniel J. McKee
Governor of Rhode Island



Sabina Matos
Lt. Governor of Rhode Island

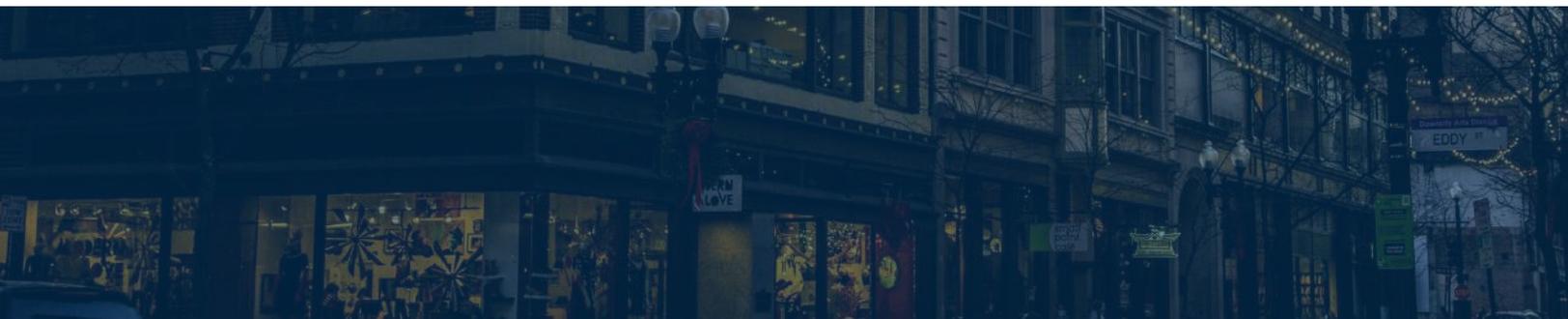
RI 2030 PRIORITY: SUPPORTING SMALL BUSINESSES

Rhode Island has been called the quintessential small business state. Small businesses in Rhode Island make up 98.9% of all businesses in the state and employ more than half (52.2%) of all workers (compared with 46.8% nationally). These firms range from small family-owned retail and restaurant businesses to larger professional services, construction, and advanced manufacturing businesses. Some of our small businesses started small and want to remain that way, while others have their sights set on rapid growth. Not only are small businesses a crucial part of Rhode Island's economy, but entrepreneurship represents an important opportunity for job creation, wealth building, and economic growth.

Small businesses face several challenges, from accessing capital to navigating regulatory requirements at the federal, state, and local levels, and the COVID-19 pandemic has exacerbated many of these challenges while introducing new ones like reduced consumer confidence and workforce shortages. This is especially true for COVID-impacted industries such as Rhode Island's prized tourism and hospitality sector, as well as disproportionately impacted minority-owned businesses. Additionally, during the pandemic supply chains and business models were disrupted for many industries, including manufacturers, retailers, agricultural businesses, and others. Addressing these challenges are key to facilitating the full and broad-based recovery of Rhode Island's small business community.

WHAT WE HEARD FROM YOU

- While Rhode Island provided a range of small business supports throughout the COVID-19 crisis and is outperforming many neighboring states, small businesses and impacted industries such as retail, tourism, hospitality, and child care continue to face challenges as they emerge from the global pandemic.
- Disparities and barriers persist for small business owners in historically disadvantaged groups and marginalized communities.
- Small businesses confront multiple barriers that impede their long-term success—especially in areas like licensing, zoning, regulatory compliance, and access to capital.



CURRENT STATE AGENCY INITIATIVES

Through the pandemic, the State has provided more than \$140 million in federal funds to assist more than 9,000 small businesses. This included multiple rounds of direct relief as well as more targeted rounds of assistance, including the \$3.6 million Business Adaptation program, the \$7.4 million Take It Outside program, and the \$15 million Hospitality Arts Tourism (HArT) program. The small business supports launched in response to the global pandemic built upon a range of existing agency initiatives, including the Innovation Voucher program, SupplyRI, and the John H. Chafee Center for International Business at Bryant University. Additionally, to address ongoing inequities in business ownership across the state, Commerce has partnered with the Rhode Island foundation to fund a \$150,000 minority-owned business landscape analysis and strategic planning report to lay the foundation for future initiatives to increase the number of minority-owned businesses in the state.

RI 2030 SMALL BUSINESS GOAL: By the next decade, Rhode Island will have a thriving, vibrant, and diverse small business ecosystem that has emerged stronger and more resilient from the global pandemic and is a key driver of opportunity, job creation, and economic growth for Rhode Island.

SMALL BUSINESS OBJECTIVES

- Support a full and broad-based recovery for Rhode Island's small business community and COVID-impacted industries such as retail, tourism, hospitality, and many others.
- Expand the number of small businesses with access to the knowledge, technology, service providers, local vendors, procurement opportunities, and capital they need to operate and grow their businesses.
- Increase the dollar amount of federal and Community Development Financial Institutions Fund (CDFI) funding for small businesses as well as the number of CDFIs operating in Rhode Island.
- Increase the number, percent, and long-term success of minority-owned businesses in the state.
- Make Rhode Island the premier state in the region for the speed, predictability, and ease of starting or running a business while also increasing Rhode Island's competitiveness with peer states in terms of the cost of doing business.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

As it did with the rest of the country, the global pandemic hit small businesses in Rhode Island hard. Consumer confidence for activities like dining out at restaurants, going to movie theaters, and attending large in-person events declined considerably. Additionally, to mitigate the most severe effects of the global pandemic, Rhode Island implemented a series of temporary public health measures that impacted small business' operations. These and other factors resulted in revenue and employment declines and led many small businesses to change business models, create new revenue streams, and shift from in-person to online selling. The global pandemic had a disproportionate impact on small businesses and minority-owned businesses since many of these businesses operate without financial safety nets.

A range of federal and state programs—from the Small Business Administration's Paycheck Protection Program to the state's Restore RI grant program—delivered critical support to Rhode Island's small business community. Additionally, the state and many municipalities eased certain restrictions on businesses, such as temporarily relaxing business filing requirements, permitting additional outdoor dining capacity, and allowing carry out alcohol from restaurants. These and other interventions provided a key lifeline to businesses to survive the economic downturn. While certain segments of the small business community (e.g., manufacturing and construction) have experienced a strong recovery, others (e.g., tourism, hospitality, Main Street retailers, and others) have yet to fully recover. Supporting COVID-impacted industries and addressing the broader range of COVID-related challenges are essential to facilitate a full and broad-based recovery of Rhode Island's small business community.

Beyond the COVID-19 pandemic, small businesses face several challenges. Hiring workers with the appropriate skillsets remains a major challenge. In July 2021, the U.S. had a record 10.9 million unfilled positions, and 51% of small business owners reported having open positions that cannot be filled (the highest rate on record). Small businesses, especially those owned by people of color, often face barriers and/or higher costs for financing as well. According to the Federal Reserve's 2021 Small Business Credit Survey, 53% of small businesses report that their credit needs are not met. CDFIs play an important role in expanding small business access to capital; however, Rhode Island lacks an established CDFI focused exclusively on the state. With fewer employees, small business owners and employees are often playing multiple parts in the business and lack access to specialized roles or service providers (e.g., legal and accounting). Many businesses struggle to navigate federal, state, and local regulations. The complexity surrounding matters like business formation, annual registration, tax filing, licensing, and regulatory compliance not only pose barriers to entrepreneurship and growth but can also increase the cost of doing business. Assisting businesses with these requirements and advancing policies that simplify and reduce regulatory burdens are important for improving the business climate, supporting entrepreneurship, and facilitating economic growth over the long-term.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

As with the rest of the U.S., there are ongoing inequities in small business ownership in Rhode Island. Whereas Black/African American people comprise 6.8% of the Rhode Island population, they only represent 3.7% of business ownership. Similarly, Hispanic/Latino people make up 16.9% of the population, but they represent a mere 3.7% of business ownership. Women make up 51.2% of the population but represent only 40.5% of business ownership. Addressing these disparities is critical for advancing a more inclusive and equitable economy, creating meaningful opportunities for wealth building, and catalyzing entrepreneurship, innovation, and economic growth.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Provide support for small businesses and COVID-impacted industries like tourism and hospitality to upgrade HVAC systems, increase outdoor capacity, and make other pandemic-related adaptations with an eye towards boosting consumer confidence, catalyzing additional economic activity, and increasing resiliency.
- Evaluate rule and regulation changes instituted during the pandemic (e.g., outdoor dining expansion, liquor-to-go) that can be continued to benefit both businesses and consumers.
- Increase and enhance marketing efforts to bring tourism and business travel back to the state as the pandemic comes to an end.
- Fund new and support the expansion of existing direct and technical assistance programming for small businesses. This should include: (1) direct business assistance; (2) back office services and supports that can be offered to clusters or categories of businesses, (3) educational resources to support businesses with activities like applying for grant programs and developing marketing plans; and (4) programming to encourage small businesses to improve operations and increase productivity through investments in technology.

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"As we emerge from the COVID-19 pandemic, the hospitality industry will have several needs. However, in the short term, we've identified the top three. That would be: workforce development using Real Jobs spending; funding for inside HVAC systems for clean air; and assisting us with expanded outdoor dining, particularly as we work with the cities and towns, and also to step it up a little bit and make the outdoors much more convenient, much more friendly, and much more comfortable for our consumer." - **Dale Venturini, President & CEO, RI Hospitality Association / Community Conversation Participant**

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THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Expand access to capital by (1) leveraging federal funding to create capital/funding programs for small businesses—particularly small businesses with strong growth potential and those pivoting in response to the global pandemic; (2) strengthening and growing capital programs—supported through public and private funding—for historically underserved and marginalized business owners; and (3) establishing or attracting CDFIs focused on providing financing to small businesses in Rhode Island—especially businesses that are often excluded from traditional funding sources.
- Expand successful workforce development programs (such as Real Jobs RI and Back to Work RI) and continue the partnerships that have been developed between educational institutions and small businesses in order to address ongoing workforce shortage and skills gap challenges.
- Explore models such as health insurance cooperatives and other collective services to help streamline the process, increase the buying power, and increase affordability for small businesses to provide employee benefits and secure other services.
- Eliminate paper forms for business licensing permits and more at both the state and municipal level, replacing them with digital, and where possible, integrated versions.
- Draw upon this digital integration to create a gateway or coordinated approach to government support for small businesses.
- Help retiring small business owners keep ownership of the firm local and encourage employee ownership (ESOP) takeovers where possible.
- Continue to ease licensing and permitting requirements and reduce costs to encourage additional small business formation and otherwise improve the business climate.
- Increase and simplify access to federal, state, and local procurement contracts for small businesses.
- Create a Taxpayer Advocate to help small businesses navigate tax administrative processes.

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“I have been the only female, the only Black person, or the only immigrant in many different scenarios, and I think that there needs to be a connection for entrepreneurs, or mentorship for people who look like me from people who look like me, so I think that’s another really big gap that I have noticed throughout my time.” - **Saron Mechale, goTeff, Inc. / Community Conversation Participant**

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RI 2030 PRIORITY: INVESTING IN OUR CHILDREN, FAMILIES AND EARLY EDUCATION

Healthy children and families are the foundation of a resilient and productive state. Strengthening early childhood education, health care and behavioral health care, improving child welfare and juvenile justice systems, and reducing child poverty are vital to Rhode Island's success. Investments in children and families not only support our state today, but also ensure the future strength of Rhode Island's economy. Despite the importance of supporting children, we know that families struggle to afford and access early education and health services, the care workforce that provides those services is not adequately compensated, and children have inequitable experiences due to historic and systemic racism. It is vital that Rhode Island prioritize the health, well-being, and positive development of our children in every decision as we look towards the future to ensure that Rhode Island is a place where every family would want to raise their child.

WHAT WE HEARD FROM YOU

- To ensure children are successful in school and beyond, children and their families must have access to holistic, community-embedded supports, including health, behavioral health, and high-quality early education. This requires additional investment and partnership among government, communities, and providers.
- Inequitable access to high-quality services continues to drive disparities in our state, particularly for children in low-income, immigrant, and/or households of color and for children with special needs.
- Progress for children cannot happen without ensuring that the people who care for and create opportunities for kids—i.e., families, educators, and service providers—are meaningfully engaged and supported.



CURRENT STATE AGENCY INITIATIVES

Rhode Island has implemented several key initiatives to support children and families, with a focus on addressing opportunity gaps existing among the youngest children and supporting working families to access supports and services. During the pandemic, Rhode Island took action to address gaps in care for children, including focused actions to increase routine vaccination rates and well-child visits. Even prior to the pandemic, there had been growing concern about behavioral health supports for children; the State is in the process of collaborating with internal and external stakeholders to develop a comprehensive system of care plan for children's behavioral health. Within child welfare and juvenile justice, the State has focused on prevention and getting back to basics with strong results.

RI 2030 CHILDREN, FAMILIES, AND EARLY EDUCATION GOAL: By the next decade, Rhode Island will have a comprehensive, culturally responsive system of services and supports that ensures each and every child has the opportunity to thrive in a system that eradicates disparities.

CHILDREN, FAMILIES, AND EARLY EDUCATION OBJECTIVES

- Reduce and eliminate disparities by race and ethnicity in child poverty, early educational opportunities, health care outcomes, and behavioral health care outcomes by using a race equity lens in all policy development and by developing policy in collaboration with the community.
- Work towards ensuring all children, starting in infancy, have access to high-quality affordable child care in which no family in the state must spend more than 7% of income to access high-quality childcare (the federal standard of childcare affordability).
- Implement universal, high-quality Pre-K for children ages 3 and 4 through a mixed delivery system.
- Ensure that children enter Kindergarten ready to learn and are on a path to reading proficiently in third grade.
- Implement universal access to health insurance for children, regardless of immigration status, and ensure families can access health resources equitably.

CHILDREN, FAMILIES, AND EARLY EDUCATION OBJECTIVES (CONT.)

- Ensure that all children experiencing behavioral health challenges have access to a comprehensive system of care.
- Ensure that the child welfare system is meeting the needs of children and families by having the response, placement, goals, and timing required to best support children, and address child welfare with an equity lens.
- Ensure that families experiencing poverty have access to the resources they need to support themselves and their children to lead healthy lives, including food, housing, education, and job training.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

The pandemic forced many parents out of the labor force because they had to take care of their children. The labor force participation rate fell from 64.2% in 2019 to 63.4% in 2020, and participation in the Child Care Assistance Program (CCAP), the State's program to subsidize child care costs for lower-income families, fell by as much as 40% during the pandemic, leaving child care providers with low enrollment and thus lower revenues causing them to close classrooms. However, as families look to re-enter the workforce, the early learning system – including Head Start, Pre-K, infant/toddler care, center-based, and Family Child Care – is struggling to find qualified educators to keep existing classrooms open and also to open new rooms due to the persistent low wages within the field. This is a pay equity concern, as the majority of early childhood education staff are women, and many are women of color.

Even before the pandemic, the child care system was not meeting the needs of families. In Rhode Island, the average annual cost of child care for an infant is approximately \$13,000. Based on the federal child care affordability guidelines that families should spend no more than 7% of their income on child care, Rhode Islanders would need to earn over \$180,000 a year on average for infant care to be considered affordable. According to the U.S. Treasury Department, the child care system represents a market failure, in which workers are paid low wages but the service is still unaffordable for many families. While CCAP is designed to help lower-income families afford child care, the current rates do not cover the true cost of high-quality care. Programs like Head Start and Rhode Island Pre-K are vital to supporting access to quality early childhood education for low-income families, but there is limited capacity available.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

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The pandemic also impacted children's overall engagement in services and supports that are vital to healthy physical and behavioral development. While Rhode Island leads the nation for rates of children's health insurance coverage (with 98.1% of children covered, ranking #2 in the nation), our system does not ensure that every child can equitably access care; in particular, children who are undocumented do not have access to health insurance. As families sheltered in place, the systems that typically identify and support families were unable to reach families. Due to the pandemic, there was approximately a 45% decrease in Child Outreach screening to identify children for Early Childhood Special Education and a 15.3% decline in referrals to Early Intervention. As a result, many children who would benefit from services have not received them during a crucial part of their development. During the pandemic, Rhode Island has accumulated more than 70,000 "lost doses" of routine childhood vaccines and is still missing over 5,000 lead screenings. In addition, the national journal "Pediatrics" reported that 14% of parents are reporting worsening behavioral health issues due to the pandemic from their children, and the state has seen an increase in child and adolescent uses of psychiatric emergency departments. Racial disparities exist across all health measures, and there are significant racial disparities in addressing children's behavioral health, as children of color are more likely to be criminalized, less likely to be identified for supports, and less likely to have supports that are culturally competent.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

The COVID-19 pandemic has had significant impacts on child welfare and juvenile justice operations. Though the State continues to see a lower level of reports to the child abuse and neglect hotline, it is unclear how the start of the 2021-22 school year will affect this trend. As with other child service providers, community providers have also been hit hard by the pandemic and are experiencing severe difficulties in adequately staffing their programs due to reimbursement rates that have not kept pace with the cost of living. Despite the impacts of the pandemic, in the last two years, the Department of Children, Youth & Families (DCYF) has made significant strides in keeping children safe at home with their family and out of the juvenile justice system. Compared to September 2019, there are now 192 fewer children involved in the child welfare system (6% decrease), 131 fewer children in out-of-home care (7% decrease), 61 fewer children in congregate care settings (16% decrease), 100 fewer youth being overseen by Juvenile Probation (35% decrease), and 12 fewer children at the Training School (26% decrease).

Historic and ongoing systemic exclusion of people of color from economic opportunity has led families of color in Rhode Island to be trapped in the cycle of poverty at higher rates than White families. Between 2015 and 2019, 55% of Native American, 33% of Hispanic, and 27% of Black children in Rhode Island lived in poverty, compared to 12% of Asian children and 13% of White children. The experience of living in poverty can have adverse impacts on a child's growth and development. While pandemic programs such as the Child Tax Credit have temporarily helped to reduce child poverty, longer-term systemic changes must be implemented to eliminate child poverty and support families in achieving economic self-sufficiency.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Ensure that there is enough capacity in child care across the mixed delivery system to serve families as they return to work through investing in temporary wage enhancements for the child care workforce and supporting a pipeline of new family child care providers.
- Invest in increased Child Care Assistance Program rates for child care providers so low-income families can access high-quality child care and return to work.
- Deliver community services tailored to meet the needs of children disproportionately impacted by the pandemic.
- Invest in preventative health and behavioral health initiatives to ensure children are on track for child and adolescent well visits, vaccinations, lead screenings, and behavioral health screenings to address the impacts of the pandemic on early health and avoid expensive healthcare costs in coming years.
- Ensure that providers of key children's services – such as Early Intervention, pediatricians, and child welfare supports – are able to recover from the pandemic, hire and retain staff, and address the need for services without creating waiting lists or restricting access. This requires that the rates paid to providers are sufficient to ensure quality and access for all children, as well as ensure fair compensation for the workforce.
- Divert families from entering the “front door” of DCYF by investing in community-based prevention supports and meet the goal of licensing 250 new foster families.
- Strengthen family-friendly workplace policies such as paid sick leave and economic support for families.

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"I really feel like [at] the state and [federal level] we need to invest in early childhood education in order to make sure we can attract and retain qualified educators during those critical years where the relationship between a child and their teacher is so important. You know, it's building that foundation of security and that foundation so that they can be successful when they enter school. I believe these early years, it's not really an achievement gap, it's an opportunity gap. And especially our youngest children in Rhode Island, about 45% of them are children of color. We really could benefit from investing in quality family-based child care and center-based child care." - **Khadija Lewis-Khan, Executive Director, Beautiful Beginnings Child Care Center / Community Conversation Participant**

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THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Increase public investment in early childhood education – with a focus on increased Child Care Assistance Program rates that cover the true cost of quality care – to ensure that families can find high-quality, affordable care and that providers can make needed investments in quality and staff compensation with a dedicated funding source.
- Expand eligibility for the Child Care Assistance Program to ensure that all families making at least state median salary have access to financial supports for child care, putting Rhode Island on a path to ensuring no family pays more than 7% of their income to access high quality child care.
- Provide wage incentives and free or reduced-price educational opportunities for early childhood educators to increase their certifications.
- Expand Rhode Island’s nationally top-ranked Pre-K program to all three and four years olds through a mixed delivery system that strengthens the entire birth through age 5 system, inclusive of Head Start, Family Child Care, and center-based care.
- Increase coordination and alignment between the early learning system and the K-12 school system in each community to ensure all children are on a path to academic success.
- Expand and enhance health insurance to cover all children and invest in innovative, community-based, integrated health models that address social determinants of health.
- Build the Family Home Visiting First Connections program to be universally accessible and increase capacity for long-term evidence-based Family Home Visiting programs.
- Implement a comprehensive children’s behavioral health system of care.
- Shift child welfare and juvenile justice systems to be more prevention-focused, beginning with implementation of the five-year Family First Prevention Services Act plan and achieving national human services accreditation from the Council Accreditation.
- Expand in-state psychiatric and high-end residential care to meet the needs of children and adolescents.
- Decrease child poverty by implementing enhanced RI Works supports and coordinating state policies and programs for job training, adult education, housing, food access, and more to support families to achieve economic self-sufficiency.

RI 2030 PRIORITY: STRENGTHENING K-12 EDUCATION

Primary and secondary education are essential for both individual and community success. High-quality learning experiences help ensure students of all backgrounds are prepared to lead fulfilling, productive lives. Learning can occur inside and outside of the traditional classroom setting, as local communities must also be invested and involved in ensuring the educational success for youth; school systems, municipalities, community-based organizations, and parent organizations should intentionally partner and collaborate to meet the needs of ALL students.

In the 21st century economy, a high school diploma is no longer the guaranteed ticket to success it once was as more and more jobs require a post-secondary degree or other credential. Rhode Island's K-12 education system must focus on creating college, career and technical education pathways. Each of our 39 cities and towns is preparing students for these continuing education and training opportunities and for success in college, careers, and life.

Educators across Rhode Island demonstrate a deep commitment to providing excellent instruction for students. However, as is the case in much of the country, students in our state face inequitable access to high-quality educational opportunities. There are varying factors, but some of these disparities result from local control and funding of education. While education is a service provided by local cities and towns in Rhode Island, state government plays a critical role in ensuring access to equitable opportunities by equalizing funding, making sure local school districts comply with state and federal guidelines, and providing support to local districts as needed.

As our state emerges from the COVID-19 pandemic, a national public health and economic crisis that laid bare root inequities in education, we have a tremendous opportunity to rebuild a high-quality public education system that provides all Rhode Islanders with equitable access to a world-class primary and secondary education.



WHAT WE HEARD FROM YOU

- As more careers today and in the future require a post-secondary degree or credential, we need to ensure that our high school graduates are well prepared for the next steps they choose in their education.
- The pandemic highlighted the digital divide that still exists for our K-12 students in which some students and districts were able to transition much more easily to virtual learning than others.
- Education inequities by race, language, socioeconomic status, ability, or other identities continue to be a dominant force holding back both individual Rhode Islanders and our state.
- We need to build on the strong Career and Technical pathways we have created so Rhode Island students can access high paying jobs in the trades and 21st Century green economy jobs.

CURRENT STATE AGENCY INITIATIVES

Rhode Island has set high standards for students, educators, and schools, and is committed to providing holistic support to meet these goals. To ensure all Rhode Island students are prepared for success in college, careers, and life, the State is taking steps to ensure that students have equitable access to high-quality curriculum materials aligned to rigorous college- and career-ready standards, and that educators have the professional learning opportunities and supports they need to implement research-based, culturally responsive, and equitable pedagogical approaches that address the needs of the whole child.

RI 2030 K-12 EDUCATION GOAL: By the next decade, Rhode Island will have a public education system that provides all Rhode islanders, regardless of their race, ethnicity, language, or geography, with equitable access to a high-quality primary and secondary education, which supports student learning and the development of the whole child and prepares students for post-secondary training and education.

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"Student-centered learning: creating individualized learning plans for our students and making sure that they're setting their own goals and that they're making sure that they are getting their education tailored to them, because students are the experts in their own education, and that's a really important thing that we seem to forget a lot, is the fact that our students know what we need, and we know what we need in order to succeed as well... And then also looking at a culturally relevant curriculum, and making sure that we are teaching our students about African-American history and about the history of women." - **Jaychele Nicole, Gen Z: We Want to Live / Community Conversation Participant**

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K-12 EDUCATION OBJECTIVES

Education systems have a responsibility to identify and dismantle the root causes of educational inequity so that all students, regardless of race, language, socioeconomic status, ability, or other identities, have access to equitable opportunities.

- Ensure that all students, regardless of race, language, socioeconomic status, ability, or other identities, achieve at least one year's worth of learning every year.
- Increase the 4-year graduation rate and decrease the level of chronic absence among students.
- Significantly increase proficiency in reading, math, and science.
- Enhance engagement and collaboration between families, community members, school administrators, teachers, and students to improve student-centered policies and decisions.
- Promote professional development opportunities for educators.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

Throughout the COVID-19 pandemic, Rhode Island educators, school staff, and families have gone to tremendous lengths to support student learning while prioritizing the health and safety of school communities. Rhode Island led the way in returning to the classroom reopening schools in September 2020, and then returning to full in-person learning in the 2020-21 school year.

Despite these efforts, students' academic growth continues to be impacted by the learning disruption created by the pandemic. The consequences have been greatest on those students already facing systemic educational disparities that the pandemic has magnified and exacerbated: namely, students from low-income communities, students of color, differently-abled students, and multilingual learners. The Rhode Island Department of Education quickly worked to identify the impact of the pandemic on students and develop strategies to accelerate learning and help students get up to speed through the convening of the Learning, Equity & Accelerated Pathways (LEAP) Task Force, which released its report and recommendations in April. These inequities continue to have profound impacts on students' lives. According to the U.S. Department of Education, Rhode Island has the lowest four-year high school graduation rate in New England at 84%, two points below the national average of 86%. While Black students in Rhode Island are somewhat less likely to graduate than their white counterparts, the big difference is between white students and Hispanic students (88% vs. 76%).

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

The pandemic has magnified numerous longstanding systemic inequities impacting Rhode Island students, some of which relate to the local control and funding of public schools. There exists a vicious cycle in which higher-income residents leave a struggling school district, further reducing the resources available to the students in that district. In Rhode Island this often leads to lower-income districts that struggle to meet their students' needs while higher-income districts face many fewer challenges. In light of the ways that COVID-19 has exacerbated existing inequities, Rhode Island has an unprecedented opportunity and responsibility to address the roots of systemic inequity in the state and build a system that guarantees all students' equitable access to high-quality, culturally responsive instruction that prepares them for success in college, careers, and life.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Energize our school communities— students and educators— by launching a back-to-school campaign and statewide toolkit, with attention to students who are chronically absent.
- Ensure all students have access to high-quality and personalized support from adults, both during the school day and through extended learning, partnerships for before/after school, and summer learning opportunities.
- Universally screen all students academically and social-emotionally and align resources to need.
- Improve and support student transitions, across grades and systems.
- Close the digital divide.
- Provide funds for schools to update physical buildings with better HVAC equipment to reduce the potential spread of disease.
- Work to turn around the Providence Public Schools and transition the district back to local control after goals of the Turnaround Action Plan, which was crafted with significant input from the community, have been met.
- Reform the policy and legislative foundations of statewide transportation and foster the associated conversation regarding regional cooperation.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Provide additional resources to support lower-income districts in addressing the causes of educational inequities based on race, language, socioeconomic status, ability, or other identities.
- Strengthen the instruction of core subjects (English and Language Arts, mathematics, and science) by providing local school districts with high-quality instructional materials, focusing particularly on multilingual learners and others who need additional support and providing professional learning for educators to support curriculum implementation.
- Increase collaboration between traditional school systems and local communities, including leveraging community partners, to provide additional instruction, enrichment, extended learning opportunities, and summer learning programs.
- Work with Rhode Island's colleges and universities to ensure all high school graduates are prepared for the next step in their education.
- Continue to build Career and Technical Education programs designed to provide students with the academic and experiential skills to be equipped to succeed in a range of high-wage, high-skill and high demand careers.
- Reimagine the high school experience by revising graduation requirements to align with college and career readiness standards so students graduate ready for college and prepared to work.

RI 2030 PRIORITY: ENHANCING WORKFORCE DEVELOPMENT AND POSTSECONDARY EDUCATION

Workers with a college degree earn a higher income and are less likely to be unemployed than those without a degree. As an increasing number of jobs require a college degree or another postsecondary credential, it will become increasingly important that the State works with all levels of its educational and training institutions to help all Rhode Islanders receive the education and workforce development that will benefit them most. This includes removing barriers to education and working with graduates to ease post-graduation burdens, such as student loans and job opportunities.

Well-designed workforce development programs help both workers and employers by providing workers with in-demand skills and training necessary for an ever-changing economy. The State plays a critical role in coordinating these training programs to match the skills needed by Rhode Island employers with the workers looking for better pay and better career opportunities. Workforce development can play a crucial part in the state's regional economic development strategy by providing training to employees and workers to firms in potential growth clusters.

WHAT WE HEARD FROM YOU

- Although Rhode Island has expanded access to training and postsecondary education, significant growth must occur to ensure most Rhode Islanders are on a path to a postsecondary credential of value to their careers (whether a college degree, trade union certificate, or professional license)—especially for underrepresented segments of the population.
- Continued investment in innovation (e.g., research, entrepreneurship, tech transfer) is a key driver of broad-based economic growth and prosperity.
- Rhode Island needs to address the many challenges (e.g., disenrollment, child care access) and opportunities (e.g., hybrid learning, increased institutional collaboration, credentialing) stemming from the global pandemic.



CURRENT STATE AGENCY INITIATIVES

As one of Rhode Island's premiere workforce development initiatives, Real Jobs RI provides targeted education and skills training for workers with the aim of ensuring employers have access to employees with the necessary skills to compete and grow, as well as to support Rhode Island workers who were displaced as a result of the COVID-19 pandemic. Back to Work RI has facilitated the training, support, and hiring of thousands of workers to-date.

In the area of education, PrepareRI is an interagency initiative that supports college readiness, overall credential attainment and Career and Technical Education (CTE) to help students earn an industry credential and prepare them to enter the workforce that will lead to a range of high-wage, high-skill, and high-demand careers. Rhode Island Promise provides free tuition for recent high school graduates at the Community College of Rhode Island for up to 2 years which has been proven to increase the degree rate in the State.

RI 2030 WORKFORCE DEVELOPMENT & POSTSECONDARY EDUCATION GOAL: By the next decade, Rhode Island will have a dynamic and integrated workforce development and postsecondary education system that provides opportunity to all Rhode Islanders, drives job creation, economic growth, and innovation over the long-term.

WORKFORCE DEVELOPMENT & POSTSECONDARY EDUCATION OBJECTIVES

- Increase the percent of Rhode Islanders with a bachelor's and/or graduate degrees to the level of its southern New England neighbors and increase the percent of Rhode Islanders with a postsecondary credential to 70% by 2025.
- Create a longitudinal data system across K-12 education, higher education, and workforce data to better identify and meet the needs of Rhode Island workers and employers.
- Continue to invest in and develop the Higher Ed Academy. The State has set up this robust system that allows for multiple high-quality pathways for all learners, including supporting students transitioning from K-12 and pathways that support adults.
- Prepare Rhode Island's workers for careers in emerging growth sectors. Establish an Unemployment Insurance interface system that allows users more access to their information, prompt service, and access to additional tools such as job postings, career coaching, and career-readiness assistance.

WORKFORCE DEVELOPMENT & POSTSECONDARY EDUCATION OBJECTIVES (CONT.)

- Bolster Rhode Island's Office of Apprenticeship (DLT). "Registered Apprenticeship is a proven model of job preparation that combines paid on-the-job learning with related instruction to progressively increase workers' skill levels and wages." Because the higher education route is not for everyone, Rhode Island must work to expand access to the skilled work and, further, increase trade programming, particularly with the federal Infrastructure Package. This includes expanding work in the more traditional trades, like construction and steel work, but also investing heavily in Green Economy trades like wind and solar. All of Rhode Island's municipalities, from landlocked, rural Foster to the small island of New Shoreham, will benefit from investing in skilled trades.
- Make the labor market more equitable. Increasing wages in various underpaid fields is long overdue. In 2021, Governor McKee signed the Fight for 15 into law. However, child care workers, nursing home staff, and tipped workers are severely underpaid. There must be a target focus on these workforce fields, specifically in lieu of the recent trend of workers leaving their jobs (now known as "The Great Resignation").
- Invest in all 39 cities and towns. All of Rhode Island's municipalities will benefit from investing in workforce and postsecondary education as it will increase the per capita income in each community. From farms to fisheries each community has unique industries to build upon.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

The pandemic has had a devastating impact on employment here in Rhode Island and across the country. In April 2020, at the height of the pandemic-related business closures, Rhode Island's unemployment rate hit 17.4%. Substantial progress has been made with the State's unemployment rate decreasing to 5.8% by August 2021. People who had degrees fared better throughout the pandemic. According to the study, America's Divided Recovery, conducted by Georgetown University's Center on Education and the Workforce, data shows that more than 95% of jobs created out of the 2008 Recession went to those with more than a high school education. Those with 4- year degrees earn more than their non-degree counterparts. Increasing 2- to 4- year degree production and wrap around supports is necessary to ensure that Rhode Island's workforce is accessible, competitive, and equitable. Aligning education with workforce is essential to both employees and employers.

Workforce development is a collaborative process between education (K-12 and postsecondary), business, labor, and government with the goal of increasing a worker's skills and pay. The challenge of such programs is in matching the skills provided by workers with those needed by employers to ensure that both worker and employer benefit; this can be difficult in a changing and developing economy. Workforce development programs can work with regional economic development plans to train workers for jobs in identified growth clusters.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

Rhode Island has taken a strong lead in workforce development through programs such as Real Jobs RI, working with colleges, universities, and partner employers. This helps to ensure that workers attain the skills and competencies that will increase their pay and employability while also placing these workers in permanent employment. While these programs have been successful, there is still work to do, particularly around helping workers who have historically been disadvantaged in the labor market, including women, people of color, immigrants, and the formerly incarcerated. Women and people of color were disproportionately impacted by the pandemic; the State has made significant strides in addressing inequity through its workforce development programs and legislation, including the Fair Pay Act and the Fight for 15. In order to address these ongoing disparities, the State will need to address barriers such as child care, transportation, and technology assistance to provide equal and accessible opportunities.

Meaningful criminal justice reform is critical. We know that righting past injustices and creating new opportunities for Rhode Islanders is some of the most important work of the state. This means building career pathways to high-paying, in-demand jobs and providing educational opportunities, not only in our schools, but in our cities and towns and behind prison walls. This means investing in the physical and mental health of Rhode Islanders to foster the kind of strong, flourishing communities we want to see in RI 2030. But this also means tearing down barriers – to healthcare access, jobs, education, and housing.

Currently, Rhode Island lags behind most of its New England neighbors in percent of the population with a bachelor's or graduate degree, which leads to lower incomes and higher unemployment rates. While only 52.3% of working-aged Rhode Islanders had some form of post-secondary credential in September 2021, it is estimated that 72% of jobs in the state will require postsecondary education by 2030. During COVID-19, institutions realized that much could be done online so they improved their online offerings by offering digital or hybrid programming. However, to meet the needs for an educated and trained workforce, the state will have to better align postsecondary credentials with the demands of the labor market while also ensuring that the programs that provide these credentials are accessible, affordable, and scaled.

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"When you're able to offer livable wages to a training program, people want to be a part of it. They want to keep growing, they want to keep learning, they want to learn and thrive. But we also have to make it attractive for them to be able to do so ...[and] you need dollars and resources for that."

- Nina Pande, SkillsRI / Community Conversation Participant

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RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Continue investing in and expanding workforce development initiatives like Real Jobs RI and Back to Work RI.
- Provide increased financial support to Rhode Island post-secondary students who saw their education disrupted or delayed because of the pandemic. Additionally, work to assist those who have not completed their education, for whatever reason, to complete their degree program, so that Rhode Island has a more educated, more competitive workforce. This will allow Rhode Islanders to make more money and garner more opportunities. This specifically will help close equity gaps in higher education.
- Continue to support and promote flexibility in options for education and training, including online and hybrid models, to ensure programming is accessible to students and trainees who may need to work or have other commitments while in a program. The pandemic has demonstrated that flexibility is important in all programming as it increases access to opportunities for all. It is important to note, however, that while there is an important place for online/hybrid models, it does not work in every scenario; continued flexibility for in-person/traditional models is also key.
- Expand sector-based workforce development programming across additional industries to create a wider array of options for workers. This includes creating “earn-and-learn” and apprenticeship-style career pathways in a variety of industries and sectors. Traditional degree-conferring education tracks are expensive, lengthy, and time-consuming. For many Rhode Islanders, these barriers put this approach out of reach. Creating a pipeline to career that allows individuals to learn on the job while earning wages, developing skills and experience, will not only position those individuals to work a good, sturdy job, but will also fill employer needs rapidly while creating a workforce with portable, applicable skills.
- Expand targeted support for adults (18+) to enroll and succeed in high-quality postsecondary options by establishing a Higher Ed Academy. This would be a 4–8-week program with navigation support, wrap-around services, advising, and college readiness with the intent to enroll adults in postsecondary education opportunities that end in credentials of value. It would expand existing programming to provide support for adult learners by navigating government programs and options needed for many Rhode Islanders to be able to continue their education.
- Develop explicit equity initiative(s) to address the socio-economic and race gaps across the enrollment, retention, and completion of postsecondary credentials spectrum.
- Support college readiness programming through increased investment in early college opportunities (e.g., dual and concurrent courses, AP and youth apprenticeships), counseling, and advising supports.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS (CONT.)

- Better align the system of re-skilling and up-skilling, including with the Adult Ed program, programming overseen by the Department of Labor & Training, and alignment with our postsecondary institutions.
- Codify proven workforce and education models into law to ensure the continuity of beneficial programs.
- Expand the RI Reconnect program. To date, this program has supported people with advising to enter postsecondary programs and provided support services to individuals in the Back to Work Program. Expansion will ensure that adults who qualify and need the additional wraparound supports get this support (e.g., child care, housing, transportation).
- Invest in graduates. The state is facing serious issues with employee recruitment and retention, particularly in the STEM field. Reducing the barriers to workforce, regardless of the field, will benefit all. The creation of programs to give a student loan stipend for employees, assisting in cost of various forms of education and requirements for targeted populations, will benefit the workforce and overall economy.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Expand Real Jobs RI and commit that most training investments go towards jobs in in-demand sectors and at least half goes to targeted industry clusters, specifically the Blue Economy and biosciences.
- Commit funding for training and employment for formerly incarcerated Rhode Islanders through Real Jobs RI.
- Establish a coordinated approach between Rhode Island's higher education facilities and targeted industry clusters, creating a network of innovation campuses.
- Create a comprehensive career pathway approach that aligns Rhode Island's workforce and postsecondary system to ensure that the wide range of workforce training and credential programs across the state's colleges and universities is demand-driven and coordinated to meet the needs of employers and Rhode Islanders.
- Expand small and medium business resource hubs across the state for talent and business services. Rhode Island's economy is small business-based, so this is essential to aid the state in employee retention and recruitment.

THE ROAD TO RI 2030: LONG-TERM ACTIONS (CONT.)

- Focus intentionally on student supports and outcomes across postsecondary education that focus on mental health services and civics education. Pre-pandemic, mental health and civics made headlines as some of the top areas of focus needed in schools. COVID-19 has exacerbated all issues, but it has highlighted the need for mental health supports and civic engagement in particular. Students want to be able to learn and participate in their home state, and Rhode Island can better prepare its future adult population by supporting these areas.
- Perform extensive research on Rhode Island's economy to understand areas of potential growth and need, allowing the State to focus on key areas to advance its economy. Rhode Island can harness its unique natural tools to compete with a changing global economy.
- Refine the State's capacity to identify employees in industries that are at risk from forces such as automation. Develop a targeted approach to providing them with 360-degree career and supportive services to prepare them to enter a new line of work and flourish in a changing economy.

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"Sometimes meeting a person where they are is about providing them with something that can get them started and make them incrementally more competitive. You can look at certificate programs in software development, in data analytics, in some of these emergent fields...We not only need to create and innovate—we need to operate. Once all those innovations come to the fore, they require an enormous number of people to develop the knowledge and skills and ability to make those entities happen." - **Sara Enright, Chief Outcomes Officer and VP for Student Services, Community College of Rhode Island**

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RI 2030 PRIORITY: PRIORITIZING HOUSING

Having enough housing at each level of affordability, from subsidized affordable housing to rental units to starter homes and beyond, is a key attribute of a healthy and growing region. While Rhode Island's overall population growth has been slow, natural loss of units coupled with demand for housing from both Rhode Islanders and those from out of state has been strong. This increased demand has pushed up prices and reduced the available supply for Rhode Islanders across the state. For Rhode Island to be an attractive place to live, work, and raise a family, the State needs to address the availability, quality and affordability of housing while also paying particular attention to those Rhode Islanders with specific housing needs: those with less income, those with disabilities, those who want to age in their home, and those who are experiencing homelessness. Housing and homeownership also have important roles to play as we seek to create opportunities for families throughout Rhode Island – across the regions of our state and across income levels – and to build wealth for themselves and future generations.

WHAT WE HEARD FROM YOU

- Housing affordability is a statewide challenge across all income, racial, and age groups—but especially for low- and moderate-income households. Households of color are disproportionately impacted.
- Housing supply has consistently fallen short of demand, resulting from a range of barriers (e.g., financing challenges, workforce shortages, local planning, and zoning factors).
- Specific housing challenges face Rhode Island, including homelessness, inadequate senior housing, an aging housing stock, and inequity in homeownership rates.



CURRENT STATE AGENCY INITIATIVES

Rhode Island has several programs and initiatives that address housing challenges in the state, including eviction assistance, affordable housing support, permanent supportive housing, and more. This includes deploying more than \$11.6 million in rental assistance through Safe Harbor and Housing Help RI and more than \$53 million (and counting) through Rent Relief RI to thousands of Rhode Island families throughout the pandemic; implementation of a five-year Pay for Success permanent supportive housing pilot; and efforts to eliminate health hazards (lead, asbestos, etc.) and improve accessibility in our housing stock.

RI 2030 HOUSING GOAL: By the next decade, Rhode Island will have a growing and ever-improving housing stock that is affordable, accessible, and meets the needs of all Rhode Islanders.

HOUSING OBJECTIVES

- Establish a target level of housing production, drawing from pre-2008 levels as a reference point and through the development of a statewide housing plan informed by stakeholder and community input, to approach and meet the level of demand demonstrated across the array of income levels and communities.
- Reduce the percent of families in Rhode Island that are housing cost burdened.
- Reduce the disparity of homeownership rates for Rhode Island households of color.
- Increase the accessibility of Rhode Island's housing stock to seniors and those with disability challenges and reduce housing conditions contributing to health issues.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

The main issue facing many Rhode Islanders looking for housing is one of affordability driven by low supply. The lack of consumer spending and generous fiscal policy during the pandemic has increased demand for real estate. In addition, buyers from other states accounted for 26% of total sales in the second quarter of 2021, compared with 21% in the spring of 2020, and the average single-family home was on the market for only 27 days in June 2021, compared to over 50 days in June 2019 and 2020. Furthermore, Rhode Island's older housing stock needs updating with everything from disability access to weatherization to lead abatement. Finally, Rhode Island is facing a lack of skilled workers in the construction sector.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

Building construction employment increased 28% from 2010, which is ahead of most New England states, but still lags behind Massachusetts and the country as a whole. While the increase in home prices has provided a boon for Rhode Island homeowners, the increase in housing prices exacerbates affordability challenges across income levels, as well as the lack of affordable housing, appropriate housing to allow people to age in place, and permanent supportive housing needed to reduce and eventually eliminate homelessness.

Homeownership is an important tool for building wealth. While homeownership rates in Rhode Island have been increasing since 2016 and are almost back to their pre-financial crisis high, there are large disparities by race and ethnicity. Moreover, approximately half of Rhode Island renters are cost burdened (spending over 30% of income on housing) and between 20-25% are severely cost burdened (spending over 50% of income on housing). Black and Latino owners are more likely to face a cost burden than White homeowners. In addition, Rhode Island's homeless shelter system is currently overburdened and, coupled with the broader housing system, does not meet demand. As of September 2021, there are 174 adults, 80 families with children, and 39 adult families currently living outdoors or in cars and on shelter waiting lists. After decreasing from 2017 to 2019, there was a 4.6% increase in homelessness in Rhode Island from 2019 to 2020, and the share of Black and Latino individuals experiencing homelessness exceeds their proportion of the state's population. We must do more to better serve the housing needs of Black and Latino Rhode Islanders.

In the short run, Rhode Islanders also face a potential wave of evictions as the federal moratorium ends. Prior to the COVID-19 pandemic, Rhode Island had one of the highest rates of eviction in the region (3.04% in 2016 compared to 2.34% in the country and 1.52% in Massachusetts, according to Eviction Lab data), while the state currently faces a low rental vacancy rate of 2.2% in Q2 of 2021. The economic crisis as a result of COVID-19 has presented major challenges to keeping impacted Rhode Islanders in their homes. If there was any doubt that housing is an essential component of the social determinants of health, Rhode Island's experience during the pandemic has shown the importance of having a safe and stable home, not only to safely quarantine and isolate to mitigate the spread of the virus but also to take care of ourselves and our families' overarching health needs.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Decrease the housing disparities by race and ethnicity that are currently common in the state.
- Increase the availability and ease of applying for financing for projects that advance the state's housing goals and would otherwise not be funded.
- Explore ways in which former commercial real estate can be creatively converted into residential housing.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS (CONT.)

- Decrease the housing disparities by race and ethnicity that are currently common in the state.
- Increase the availability and ease of applying for financing for projects that advance the state's housing goals and would otherwise not be funded.
- Explore ways in which former commercial real estate can be creatively converted into residential housing.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Increase housing production overall
 - Establish a statewide plan for increasing housing production and meeting the needs of Rhode Islanders in all 39 cities and towns, drawing upon stakeholder and community input.
 - Work with interested cities and towns across the state to create a more favorable planning, zoning, and development environment.
 - Invest in infrastructure so that more and denser housing can be built where there is demand while paying particular attention to current and future transit locations and economic development plans.
 - Support builders in conducting workforce development and help them find and train the carpenters, plumbers, electricians, and others who will build the housing we need.
 - Work with builders and educational institutions to invest in the construction workforce by creating internship opportunities for those interested in going into the trades.
- Increase affordable housing production in particular
 - Increase funding for affordable and supportive housing to levels that are, on a proportionate basis, equal to or exceed our neighboring states.
 - Utilize publicly owned property to develop affordable housing. Doing so may require legislative changes to property disposition processes as well as proactive analysis, technical assistance, and investments in preparing sites for development.
 - Explore innovative models to enable the acquisition of properties for development or conversion to affordable housing and accelerate their development.
 - Streamline the application process for affordable housing financing and development. Reduce the number of forms and application processes and explore unified or “one-stop” solutions.
 - Engage interested municipalities in a robust dialogue about how to reach the state's affordable housing goals and how municipalities can help achieve these goals. To be successful, cities and towns need the tools to focus on zoning within their local context so that more housing can be built in areas where there is demand and land. Work with municipalities on thoughtful reforms to land use, permitting, and code enforcement processes. Explore ways to increase incentives for interested municipalities to provide affordable housing to meet municipal and statewide goals, including measures such as accessory dwelling units (ADUs).
 - Invest in increased staff capacity at state, municipal, nonprofit, and development partners.

THE ROAD TO RI 2030: LONG-TERM ACTIONS (CONT.)

- Decrease homeownership racial disparities
 - Invest in significant levels of down-payment and other assistance to help bridge the racial and income-based divide in homeownership.
 - Expand opportunities for financial literacy and homebuyer training, homeowner counseling, and mortgage assistance products that take into consideration non-traditional income and credit histories, in multiple languages.
- Prevent homelessness
 - Create a centralized diversion assistance initiative to help households remain housed and to prevent homelessness.
 - Expand funding for rental assistance programs as well as services delivered through permanent supportive housing.
 - Increase availability of housing-based solutions in addition to shelter-based solutions and supportive solutions.
- Support healthy and accessible housing
 - Increase funding for property owners to make improvements to existing housing, including weatherization, lead abatement, and disability access.

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"When we talk about housing affordability challenges, whether it's affordable housing or for-sale housing, it really is limitations on the availability of supply, and without additional construction, we're really not going to be able to address these affordability challenges."

-Robert Dietz, Chief Economist and Senior Vice President for Economics and Housing Policy, National Association of Home Builders / Community Conversation Participant

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"I think zoning is the racial justice issue of our time and... when I look at those numbers around homeownership rates for minorities in the state, which have not significantly budged since the late 1960s...that means that generations of families have been left out of the one solid way of creating wealth and stability for your family."

- Brenda Clement, Director, HousingWorks RI / Community Conversation Participant

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RI 2030 PRIORITY: DRIVING ECONOMIC GROWTH

Before the pandemic, the Rhode Island economy and labor market were in a strong position. In 2019, the state's unemployment rate stood at 3.6% (the lowest level in more than three decades), and employment was at an all-time high in the state. Despite the progress Rhode Island has made recovering from both the Great Recession and decades of impact from technological transformation and the loss of manufacturing jobs, several weaknesses in the economy persist, some of which have been exacerbated by the pandemic. For example, Rhode Island has lower average household income than our southern New England neighbors, in part because our firms and workers are less productive. There are also enduring inequities in Rhode Island's economy. Whereas the White unemployment rate was 3.3% in 2019, the Black/African American unemployment rate was 4.6%, and the Hispanic/Latino unemployment rate was 6.1%.

A key reason Rhode Island has historically struggled with regaining economic momentum following the loss of manufacturing jobs stems from the fact that, despite meaningful strengths, Rhode Island is not home to deep regional specializations in the same way as some other states with more mature and potent focuses. These specializations drive economic growth by drawing on the region's relative strengths, which may be a result of geography, history, accident, or coordinated planning. Well-known examples of regional clusters include biotechnology in Boston, finance in New York, and Silicon Valley technology in the San Francisco area. Regional clusters foster productivity and innovation, as firms benefit from a skilled labor market and a high density of suppliers and customers. In addition, workers find it easier to find good jobs in the positions and firms that best suit them.

Regional industry clusters often result from careful economic development planning. Historically, Rhode Island has benefited from industry clusters such as traditional textiles and jewelry (where it still enjoys a regional advantage), but these are no longer major drivers of economic growth. Today, there are significant opportunities in advanced textile clusters, as well as new industries in the Blue Economy and biosciences. By focusing our efforts on building a regional advantage in these industries and working across sectors to increase productivity, the state can ensure a thriving economy that will have the resources to support the kind of state in which we all want to live and work in 2030 and beyond.



WHAT WE HEARD FROM YOU

- The State has made progress expanding traditional industries, supporting small businesses, and cultivating advanced industries. This broad-based approach is necessary to ensure a strong recovery and a prosperous, dynamic, and resilient economy over the long term.
- For success over the long-term, Rhode Island must prioritize building an inclusive, equitable, and sustainable economy -- with special focuses on innovation, entrepreneurship, and expanded opportunities for historically disadvantaged groups and marginalized communities.
- Rhode Island has geographic, research, workforce, and business advantages when it comes to the Blue Economy, especially in ocean science, maritime, offshore wind, and defense, and the state also benefits from its growing expertise and proximity to the major metropolitan areas of New York City and Boston for industries like life sciences, tech, and advanced business services.

CURRENT STATE AGENCY INITIATIVES

Rhode Island has a broad range of initiatives in place to support the state's recovery from the COVID-19 crisis and drive economic growth over the long-term. To support Rhode Island's economic recovery, the state (1) implemented a careful reopening strategy that enabled businesses and consumers to safely resume economic activity, (2) provided more than \$140 million in funds to assist more than 9,000 small businesses and pandemic-impacted organizations, and (3) assisted small businesses with accessing key federal programs like the Paycheck Protection Program (PPP), Restaurant Revitalization Fund (RRF), and Shuttered Venue Operators Grant (SVOG) program.

Rhode Island also has many programs in place to catalyze economic growth over the long-term, including: (1) tax credit programs like the Investment Tax Credit, the Qualified Jobs Incentive Tax Credit, and the Rebuild RI Tax Credit; (2) innovation-oriented programs like the Industry Cluster Grants program, the Innovation Campus initiative, the Innovation Network Matching Grants program, and the Innovation Voucher program; and (3) thoughtful reforms to improve the state's business climate, such as repealing the sales tax on energy and eliminating more than 150 regulations. Key initiatives under development by the State are intended to promote economic and racial equity by assisting small and minority-owned businesses, aid unemployed and underemployed Rhode Islanders and increase economic opportunities in low-income communities.

RI 2030 ECONOMIC GROWTH GOAL: Rhode Island will have an ever-more prosperous, equitable, and resilient economy with more economic opportunity and family-sustaining jobs for Rhode Islanders where businesses – both big and small – can thrive and meet the many challenges of the 21st century, from climate change to technological innovation.

ECONOMIC GROWTH OBJECTIVES

- Fully recover from the impacts of the COVID-19 pandemic.
- Lead the region in median wage and household income growth.
- Reduce enduring inequities throughout Rhode Island's economy including the disparate levels of unemployment, wages, wealth, and business ownership by race, ethnicity, and gender.
- Strengthen our position as the national leader in the Blue Economy and grow key industry clusters such as bioscience and advanced manufacturing.
- Increase the resiliency of Rhode Island's industry sectors, such as tourism, that are especially susceptible to seasonality and economic downturns.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

A key short-run problem for the Rhode Island economy is centered on the labor market. The pre-COVID Rhode Island economy saw employment at an all-time high of 507,000 jobs and an unemployment rate of just 4% in February 2020. Two months later, those numbers were 399,200 jobs (-21%) and an unemployment rate of 17.4%. While the state has experienced a strong recovery, in July 2021 employment was at 478,700 (5.6% below the peak) and the unemployment rate was 5.8%. Federal and state relief programs, for both businesses and individuals, proved effective for many (but not all) Rhode Islanders, and total personal income rose from \$61 billion in Q1 2020 to \$71.7 billion in Q1 2021. Combined with a lack of spending opportunities during the pandemic, this has led to a large amount of pent-up demand.

While Rhode Island's 2019 median household income of \$71,169 exceeded that of the U.S. (\$65,712), its income lags those of neighboring states like New York (\$72,108), Connecticut (\$78,833), and Massachusetts (\$85,843). In the long run, the state must work – in partnership with industry, labor, community stakeholders, and others – to increase economic growth and productivity – with an eye towards lifting household income and increasing the number of higher-wage, family-sustaining jobs for Rhode Islanders. Rhode Island has lower worker productivity than its New England neighbors, with many Rhode Islanders currently working in lower productivity industries. Output per employee had fallen between 2010 and 2016 before rising modestly before the pandemic. In addition, the population of the state is projected to grow slowly until 2035 and then start to slowly decline. Those who are typical working age (20-64) are projected to fall from 59% of the population to 55% of the population, posing additional challenges.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

Rhode Island has already done significant work in identifying its strategic advantages and potential growth industries, including (1) the Blue Economy focused on the ocean and offshore wind, (2) Life Sciences, (3) IT, Data Analytics, and Cyber Security, (4) Design, Food, and Custom Manufacturing, and (5) Advanced Business Services. While these industries still represent a relatively small percentage of the Rhode Island economy in terms of employment, they show strong growth potential in terms of employment and productivity. These sectors take advantage of Rhode Island's geographic location and expertise as the Ocean State as well as the state's strategic position between the two metropolitan areas of Boston and New York City.

Successful regional clusters attract new and existing firms to the area by offering access to talented workers, critical infrastructure, and relevant trade groups. In addition, a focus on the Blue Economy has the potential to benefit Rhode Island in a world that is increasingly affected by climate change. Several industry groups, such as the Southeastern New England Defense Industry Alliance and the Rhode Island Marine Trades Association, already focus on areas of the Blue Economy (defense and marine trades) while other industry groups have grown up focusing on advanced manufacturing (such as Polaris MEP) and design (DesignXRI).

The global pandemic has had a significant and varied impact on Rhode Island's economy. While some sectors like construction and manufacturing quickly rebounded and have already recovered the jobs lost during the pandemic (in fact, the state's construction industry currently has the highest number of jobs on record since 2007), the leisure and hospitality industry is still 9,300 jobs below its pre-pandemic peak.

There is also considerable uncertainty about the future of office work and the small businesses, workers, and downtown districts that depend upon offices and the foot traffic they generate (e.g., restaurants, custodial services, dry cleaners). According to an analysis by Harvard's Project on Workforce, 32% of Rhode Island's workforce can work remotely. Additionally, according to the Providence Foundation's survey of downtown employers, 62% of respondents plan on offering hybrid work arrangements. The shift to new work arrangements and workplace practices may have impacts on office districts, urban downtowns, and main street corridors that serve as centers for office work and the small businesses that cater to this segment of the economy.

Finally, the pandemic has had a disproportionate economic impact on women and people of color. Whereas the unemployment rate for men was 9.1% in 2020, this figure stood at 9.6% for women. Additionally, while the unemployment rate for white people was 8.6% in 2020, this figure was 9.4% for Black/African American people, 9.9% for Asian people, and 15.2% for Hispanic/Latino people. Addressing these and other economic disparities should be a central focus to support an inclusive and broad-based economic recovery and to advance economic growth over the long-term.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Fund programs that train and match unemployed workers and others re-entering the labor force with firms that are having trouble finding the workers they need through additional funding for programs like Real Jobs RI and Back to Work RI.
- Identify government rules, regulations, and practices at both the state and local levels that were changed during the pandemic and that can remain changed in the long run to benefit both businesses and consumers.
- Provide direct and technical assistance to small businesses and impacted industries that have seen a pandemic-related drop in revenue and that need financing to survive.
- Continue providing key supports (e.g., rental assistance, SNAP benefits) to COVID-impacted workers and households to help them weather the economic downturn.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Invest in Blue Economy and Bioscience innovation campuses and other initiatives to spur innovation and workforce development in these clusters.
- Expand workforce development programs with both high school and post-secondary education with a focus on identified industry growth clusters to increase productivity with a particular emphasis on disadvantaged groups.
- Facilitate private capital financing – including the creation of a venture fund or early-stage growth fund – to foster growth clusters. Such a fund might be based in the private or non-profit sectors.
- In conjunction with efforts to support small businesses, continue to implement targeted policy reforms – from supporting lower energy costs to partnering with cities and towns on sensible municipal tax reforms and beyond – that make the cost of doing business in Rhode Island more competitive with other peer states.
- Develop a new or support an existing Community Development Financial Institution (CDFI) to specifically support small business owners from historically disadvantaged groups.
- Work with municipalities on site readiness to prepare sites for development to attract new and growing firms in innovative industries such as the Blue Economy, life sciences, and advanced manufacturing.
- Create a GlobalRI initiative to expand the state’s ability to secure foreign direct investment and to increase Rhode Island firm exports by increasing training and networking opportunities.

THE ROAD TO RI 2030: LONG-TERM ACTIONS (CONT.)

- Expand SupplyRI to increase the number of small and minority-owned businesses benefiting from procurement connections to anchor institutions, firms in high-growth industries, and the public sector. This will entail conducting intensive industry-specific supply chain analysis to identify key opportunities, boosting the number of SupplyRI events, increasing staffing to provide additional technical assistance, and integrating access to capital into SupplyRI program offerings.
- Execute a tourism marketing plan for domestic and international markets that differentiates Rhode Island from other states by focusing on our competitive strengths: environmental and coastal assets, culinary offerings, arts, history, and culture, as well as our proximity to the international markets of New York City and Boston.
- Enhance and establish attractions and destination events that bring tourists to the state, especially during the “shoulder” weeks and off-season time frames. Examples of existing events to potentially strengthen include seafood festivals in South County, a public art festival in Providence, the Glass Float Project by Eben Horton on Block Island, Newport Mansions art exhibits, the Sandcastle Competition in South County, and the Polar Express in Blackstone Valley, while examples of new events include an international design convention or a global maritime convention.

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"Clean energy is going to be an important driver to our economy, climates, and investments over the course of the next couple decades. Rhode Island has an advantage in clean energy, and that's offshore wind. It's got the only fully operational offshore wind farm in the United States. The Biden Administration has made the environment and clean energy a priority. Rhode Island's got the expertise to contribute to its growth." - **Joseph Zidle, Chief Investment Strategist, Blackstone Group / Community Conversation Participant**

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"Everyone has a role in our economic recovery. It's going to take every state leader, every city and town leader...every citizen to really work together on making sure that we exploring these industries and we are setting ourselves up for success." - **Suzy Alba, President, Smithfield Town Council / Community Conversation Participant**

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RI 2030 PRIORITY: ENHANCING PUBLIC HEALTH AND WELLNESS

The global pandemic has emphasized the importance of our public health systems and access to services that drive optimal health for all Rhode Islanders. Working to ensure that Rhode Islanders are healthy includes providing accessible and affordable, quality health care for all Rhode Islanders, focusing on the social determinants of health – where people, live, work and play at the community level, and carrying out our work with a race equity lens. Together, these strategies can drastically improve our quality of life.

High-quality healthcare – beginning with primary care, community health clinics, behavioral health services, and oral health providers, and ensuring access to hospitals and nursing homes when necessary, will create a more balanced public health system, where care is provided how and when it is needed and help attract professionals and other people to the state. Although Rhode Island's rate of those without health insurance has declined significantly since 2008, the last 18 months have emphasized the importance of health and health infrastructure in Rhode Island and beyond.

WHAT WE HEARD FROM YOU

- The pandemic highlighted significant challenges for Rhode Island's health system (e.g., health disparities, a behavioral health crisis, unequal access, solvency of providers, particularly primary care providers) but also showed opportunities for innovation (e.g., telehealth, enhanced partnerships).
- Rhode Island's health system requires additional investments to expand capacity, address workforce shortages, ensure diversity, and tackle the many challenges highlighted by the pandemic.
- Race equity, health access, and a focus on social determinants of health, including access to safe and affordable housing, are key components of a successful health system.



CURRENT STATE AGENCY INITIATIVES

Rhode Island's health-focused state agencies have a broad and diverse set of health initiatives, with significant interagency communication and alignment to ensure maximum effectiveness toward our shared goals, all carried out with a race equity lens. While a complete list is in the appendix, some of the most critical initiatives include the shared focused on social determinants of health through the Executive Office of Health and Human Services (EOHHS) Accountable Entities, the Health Equity Zones, and the State Data Ecosystem.

RI 2030 PUBLIC HEALTH & WELLNESS GOAL: By the next decade, Rhode Island will have a health system that supports affordable and accessible services to maximize good health outcomes for all Rhode Islanders, emphasizing preventive care, addressing social determinants of health, supporting our healthcare providers and increasing their diversity, and eliminating health disparities.

PUBLIC HEALTH & WELLNESS OBJECTIVES

- Eliminate health disparities and promote health equity by race, ethnicity, languages spoken, sexual orientation and gender identity, and geography for all Rhode Islanders.
- Move toward a unified state health system that prioritizes Prevention and Primary Care, and Physical and Behavioral Health System Transformation as it simplifies access, payment, and data collection and analysis by:
 - Addressing Rhode Island's workforce challenges
 - Continuing to rebalance the provision of healthcare from the most restrictive and expensive services toward prevention and home and community-based services and to support

“The pandemic really challenged healthcare delivery and capacity in Rhode Island. While telehealth was one of the silver linings, we must recognize the gaps in services for behavioral health, including community step down facilities, and the shortages in our workforces. The pandemic especially highlighted the shortage of linguistically- and clinically-competent providers across the board, particularly in the area of behavioral health. This has clearly disproportionately impacted communities of color.” -**Teresa Paiva-Weed, President, Hospital Association of Rhode Island / Community Conversation Participant**

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

The COVID-19 pandemic showed both the strengths and weaknesses of the Rhode Island health system. From March 2020 through October 2021, over 17% of Rhode Islanders have tested positive for COVID-19 and since December 2020, almost 80% have been at least partially vaccinated against the disease. The state was able to step up with high-quality COVID-19 testing and treatment, but the pandemic highlighted inequities in access to care. It also emphasized the necessity of ensuring the availability of quality behavioral health services across the lifespan (for children, youth, families, and single adults) addressing mental health and substance use. Here are descriptions of some of the highest areas of need as Rhode Island emerges from the pandemic:

Workforce Shortages: The pandemic highlighted struggles of nursing homes and hospitals to address workforce shortages and retain the workforce necessary to provide safe and quality care during the pandemic, as they experienced Emergency Department and hospital bed overcrowding from the COVID-19 surges and behavioral health and overdose challenges. Providers of home and community-based services for behavioral health and long-term care have also experienced significant and sustained workforce shortages throughout the pandemic. The lack of capacity for home and community-based services exacerbates the pressure on health care institutions.

Behavioral Health System Challenges: EOHHS's recently released Rhode Island Behavioral Health System Review documents Rhode Island's behavioral health opportunities as well as the system capacity challenges and gaps in key service lines. The stresses arising from COVID-19 underscored the tremendous need for more behavioral health services – and made the workforce shortages worse. In particular, Rhode Island has a shortage of linguistically and culturally competent providers, that together disproportionately negatively impact communities of color. The underlying drivers that worsen these challenges are state agency fragmentation, need for payment reform and increased rates for some services, insufficiently modern infrastructure of behavioral health providers,

Rising Numbers of Overdoses: One critical component of the state's behavioral health crisis is our overdose epidemic – and combined with the COVID-19 pandemic, together they are a syndemic. Starting in November 2019, the Governor's Overdose Task Force Co-Chairs and other members recognized that accidental fatal drug overdoses were rising. During the fall of 2020, the Task Force Co-Chairs asked the Executive Office of Health and Human Services (EOHHS) to examine the rising numbers with an Evidence Update and Strategic Program Review. The review identified fentanyl, Covid isolation, and structural racism as the key drivers of the rising numbers of deaths, all made more challenging by the need to strengthen the governance system for the work.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

Oral Health Disparities: Historically, oral health has been deprioritized for health system reform—despite large and inequitable access issues remaining—and is fragmented from both the physical and behavioral health systems. The last significant investment in oral health was a 1992 rate change within Medicaid. In Rhode Island, significant disparities exist in oral health which create further fundamental inequities pertaining to the overall health, employment, education, and social identification of our State’s vulnerable populations—including racial/ethnic minorities, low income and older adults and, those with behavioral health conditions. These populations tend to have highest rates of dental disease. The majority are also Medicaid recipients who struggle to find dental care due to low dental participation in the Medicaid program. As COVID-19 spread, dental offices were shut down for many months, and while some offices turned to tele-dentistry, many older providers decided to retire, shrink staffing, sell their practices, or close completely. Post-pandemic, dental needs are high among patients because of stress-related impact on teeth, lack of preventive services, and increasing poor dietary choices while home during lockdown. Increasing access is needed for those who may speak another language besides English, live in a high-density community, be in a lower socio-economic status, have a developmental disability, substance use disorder, and/or have other social determinants that may have prevented them from seeking dental care in the past.

Rhode Island’s Aging Population: In addition, Rhode Island has an aging population, with the highest percentage of people over 85 years old in New England. Even before the pandemic, groups such as the AARP provided data showing that an overwhelming number of seniors prefer to age in place. This trend has increased during the pandemic, as the state saw a drop in nursing home admissions. The state must take the needs and preferences of its long-term care population into consideration in future investments in the health field, especially as the need for these services continues to increase.

Health System Issues: While the rates of those who are uninsured are at a very low level, there are still issues with access and affordability for many Rhode Islanders. Access may be limited due to travel requirements, language, culture, or cost, especially high co-pays and deductibles. Continued vertical and horizontal consolidation in Rhode Island’s healthcare markets, including the proposed merger of two large healthcare providers in the state, will also have a significant impact on costs, access, and quality for healthcare in the years to come. One way to reduce the overall cost of healthcare is to make sure everyone has easy and regular access to preventive care so that the system can address issues before they become acute – and that we particularly invest in preventive care and services for pregnant women and children. This is true for both physical and behavioral health.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC (CONT.)

Health Innovations Healthcare: providers across the state did find new and innovative ways to deliver healthcare, some of which should continue when the pandemic comes to an end. Examples of these pandemic-related innovations include the statewide COVID-19 testing and contact tracing program, enhanced public-private partnerships, and expanded telehealth opportunities.

Disparities in Social Determinants of Health: The pandemic has highlighted the need to focus more closely on the social determinants of health and disparities by geography, race, ethnicity, and education. For example, lack of affordable, safe, and healthy housing contributes to poor health outcomes such as overdoses and infectious disease spread (as demonstrated during the pandemic), as well as reincarceration, stigma, and further systemic oppression. Rhode Island has seen a four-fold increase in street homelessness since the 2019 Point in Time Count and the COVID-19 pandemic has heightened the awareness of homelessness as a public health issue and the state's shelter system, already at capacity, was mandated to reduce beds by 146. Consequently, there are approximately 500 individuals and families living in a hotel or sleeping in places not meant for human habitation. As a result, Black or African American and Other/Multiple Races experience a higher burden of homelessness in various settings, particularly given their representation in Rhode Island compared to White counterparts. This is unacceptable and requires systemic change.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Focus upstream on root causes and investing in affordable housing, food security, and transportation to address underlying inequities and influencers of health disparities.
- Expand immediate housing stabilization and homelessness services to implement Housing First and address community-identified priorities that will improve the health, social, and economic security of Rhode Islanders.
- Invest in health literacy campaigns and programs for all Rhode Island communities as the state pushes towards 100% vaccination rates.
- Continue to support the integration of physical and behavioral health
- Investing in physical, behavioral, and oral health system transformation as detailed throughout this document, including:
- Ensure that all Rhode Islanders have access to quality primary care and is going to a well-visit at least once a year
 - Prioritize investments in the Rhode Island System of Care for Children and Youth Plan
 - Support a statewide Behavioral Health Mobile Crisis System, tied in to the new 988 3-digit emergency phone number created by Congress

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS (CONT.)

- Addressing Rhode Island's workforce challenges.
 - Stabilizing the Direct Care Workforce to increase access to home and community-based services.
 - Addressing the gaps in services identified in the recently completed Rhode Island Behavioral Health System Review that include gaps in key service lines and a shortage of linguistically and culturally competent providers, that together disproportionately negatively impact communities of color.
 - Making direct care work and family caregiving work expert, valued, supported, and encouraged.

- Continuing to rebalance the provision of healthcare from the most restrictive and expensive services toward prevention and home and community-based services, and to support.
 - Pursue Value-Based Payment health system transformations.
 - Continue toward the state's goal to spend 50% of Medicaid funding for Rhode Islanders over 65 in home and community-based settings (set forth in RIGL 40-8.9-9)
 - Prospective budget-based payment, with quality-linked financial implications, should be the primary advanced value-based payment model used for all provider types wherever feasible.
 - Continue to secure federal funding in pediatrics, family home visiting, and Early Intervention to ensure that children have access to services that promote healthy development, and to supplement pediatric practices in vaccinating children ahead of expected approval of the COVID-19 vaccine for children under 12 years of age.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Move forward on Social Determinants of Health
 - Together, expand and sustain whole of government and cross-sector investments in place-based, defined geographic areas to develop sustainable infrastructure and align a diverse set of resources that support community-identified priorities and positively impact the socioeconomic and environmental conditions driving disparities and poor health outcomes in Rhode Island. Additionally, ensure Rhode Island is poised for future investments.
 - Target investments in social determinants for health, especially in housing, transportation, clean air, and teams of community health workers to support existing investments through Health Equity Zones to create healthy communities.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Continue to spark innovation in Rhode Island's health system.
 - Continue system reforms in integrated health, behavioral health for adults and children, and long-term services and supports, with significant investments in these programs and the workforce that provides them.
 - Continue to implement the Behavioral Health System of Care for Children and Youth, the Certified Community Behavioral Health Clinics, and the recommendations of the Governor's Overdose Task Force.
 - Meet our goals of expanding value-based payment reforms, redirecting investments away from institutional settings and towards prevention and primary care, and expanding access (e.g., to oral health services).
 - Through the Medicaid Accountable Entity program and its Health System Transformation Project, regulations through the Office of the Health Insurance Commissioner, and the Rhode Island Cost Trends Committee, continue to promote the growth of provider-led practices where care coordination and care management can be closer to the patient.
 - Solidify a sustainable funding source for the Rhode Island Health Care Cost Trends Project.
 - Support the implementation of the Office of the Health Insurance Commissioner's Next Generation Affordability Standards.
 - Continue the state's commitment to data-driven decision-making, by ongoing investments in the State Data Ecosystem.
 - Invest in one-time technology enhancements that increase efficiency in accessing services, eliminate outdated legacy systems, and improve the customer experience.
- Ensure care for priority populations:
 - Use a race equity lens to address the needs of Rhode Islanders who experience structural racism and provide culturally, linguistically, and developmentally appropriate care within all health systems.
 - Provide trauma-informed care and make trauma-informed policies to address the needs of Rhode Islanders who live with the impact of trauma on their lives.
 - Address and counter the bias and discrimination against Rhode Islanders who use substances and who are made to feel stigmatized.
 - Ensure access to services for and counter the bias and discrimination against Rhode Islanders who are undocumented.
 - Develop a strategy to ensure services continue to meet the demands of the aging population in Rhode Island
 - Collaborate with EOHHS to enhance the State's Aging and Disability Resource Center, The POINT, to assist our aging adults with long-term care options and decisions.
 - Work closely with Rhode Island Housing and other community housing partners to address homelessness and the impact it has on older adults in Rhode Island.
 - Diversify Office of Health Aging contracted partner networks to ensure all older Rhode Islanders and adults with disabilities feel included and have their needs met.

THE ROAD TO RI 2030: LONG-TERM ACTIONS (CONT.)

- Collaborate with federal partners at the Veterans Administration on behavioral health services for veterans, members of the military, and their families.
 - Focus on behavioral health care, particularly for mid-acuity patients, individuals with Traumatic Brain Injury, and those with dementia.
 - Ensure transient populations (college students, immigrants, military, etc.) in Rhode Island can access adequate care.
- Ensure appropriate interconnectivity within and regulatory oversight of the health system:
 - Monitor the competitive landscape in health care services to better address cost increases and keep health care as affordable as possible.
 - Develop and implement regulatory oversight capacity.
 - Ensure information sharing across systems of care through health information technology is efficient, effective, and appropriate.
 - Develop mechanisms to connect and analyze data, monitor quality measures performance and health outcomes, and innovate programs to identify and address emerging trends.

“We need to think differently about public health and healthcare and how they intersect. If we look back at the greatest success of our state over the last 16 months, those came from moments of innovation and cross-sectoral collaboration. I would say that looking forward, we must think about public health and healthcare as not being two separate things but rather being synonymous.” - **Dr. Megan Ranney, Director, Brown-Lifespan Center for Digital Health; Warren Alpert Endowed Associate Professor of Emergency Medicine, Brown University / Community Conversation Participant**

RI 2030 PRIORITY: ADDRESSING CLIMATE CHANGE

The costs of climate change are becoming clearer and clearer as the planet warms and significant weather events increase in their intensity and frequency. While some areas are likely to experience drought conditions, the northeastern part of the United States is likely to see increased rain and flooding in the coming decades. As a coastal state, Rhode Island will have to make the decisions and investments necessary to protect its communities, economy, and the natural environment, grounded in values of environmental justice throughout.

There are many aspects of climate change that make it particularly difficult to address. Unlike pollution that stays in the local air or water, greenhouse gases (GHG) add up across the globe to affect the entire planet. While Rhode Island can and should do its part to reduce these gases, we are not able to eliminate the problem single-handedly. Climate change is also a problem that has been building since the dawn of the industrial revolution – for example, fossil fuels burned over the last 200 years are still having an effect and warming the planet. Our society is now facing the very real consequences of widespread, generational impacts on our atmosphere, and we in the Ocean State must be part of the solution.

WHAT WE HEARD FROM YOU

- Climate change policies need to be equitable and make sure that they benefit all Rhode Islanders and no group is left holding an unfair share of the costs.
- As a coastal state, Rhode Island needs to be prepared for the flooding, rising seas, and increased storms that will come from climate change.
- Rhode Island is well-positioned to take advantage of the opportunities that addressing climate change head-on presents, including offshore wind, coastal resiliency, and sustainable aquaculture.
- Reaching net zero emissions by 2050 will require significant investments in changes to home heating, electricity generation, and transportation.



CURRENT STATE AGENCY INITIATIVES

The 2021 Act on Climate updated Rhode Island's climate-emission reduction goals, positioning the state to boldly address climate change and prepare for a global economy that will be shifting to adapt to clean technology. Under the 2021 Act on Climate, the state will develop a plan to incrementally reduce climate emissions to net-zero by 2050, including measures to address environmental injustices and public health inequities. The plan will be updated every 5 years and will address areas such as environmental injustices, public health inequities and a fair employment transition as fossil-fuel jobs are replaced by green energy jobs. The Executive Climate Change Coordinating Council (EC4) charged with producing this plan, will, as of September 2021, meet more frequently and in locations across the state to encourage robust public engagement throughout. At the September 2021 EC4 meeting, the EC4 Advisory Board presented a draft set of climate justice priorities to the EC4, to be further socialized and refined in furtherance of advancing environmental justice.

RI 2030 CLIMATE GOAL: By the next decade, Rhode Island will be a national leader in renewable electricity generation, will be on the path to net zero emissions by 2050, and will be making the investments needed to protect its coast and other areas under threat by climate change, particularly environmental justice communities.

CLIMATE OBJECTIVES

- Codify and implement a 100% Renewable Energy Standard by 2030 and examine opportunities for a renewable thermal standard and/or clean peak standard or similar policy mechanism to reduce emissions across sectors, particularly heating and transportation.
- Replace fossil fuel electricity generation with renewable resources, while recognizing the benefit of protected green space.
- Protect people and infrastructure in coastal and riverine communities from storms and floods due to climate change.
- Modernize the electrical grid to support increased use of electricity, renewable energy generation, and battery storage and explore opportunities to invest in advanced metering functionalities.
- Reduce the cost of electricity to encourage transition away from fossil fuels.
- Invest in wastewater treatment facilities that are resilient to threat from climate change and protects coastal waterways.
- Reduce our consumption of single-use plastics.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

Rhode Island has adopted aggressive goals to address climate change. The 2021 Act on Climate has established incremental greenhouse gas emissions reduction targets culminating in a net-zero standard by 2050. In addition, there are several nonprofit organizations, agencies, businesses, and municipalities focused on the effects of climate change in the state. We now need to make the necessary investments to achieve these ambitious goals while also preparing the state for the inevitable impacts driven by global climate change.

Just as climate change will inevitably bring increased costs to Rhode Island, it also brings opportunities. Investments in renewable electricity generation, as well as electric transportation and heating, will not only provide business and employment opportunities for Rhode Islanders, but it will also put the state in a much better position for the future in terms of climate resilience. It must be noted that climate change is having a significant impact on broader economic and societal systems. For example, increased pollution and changing weather patterns are affecting air quality, which, in turn, fosters public health challenges such as increased asthma, increased exposure to pollen and mold, and diminished lung functioning. This is especially true for at-risk populations, such as the elderly, children, and those suffering from heart or lung disease.

Furthermore, we must do more to address the inequitable impacts of a changing climate on frontline and historically marginalized communities. These often include low-income communities and communities of color that face the brunt of pollution and climate change impacts, but face significant barriers in accessing the necessary tools, resources, and investments needed to address them. It is crucial that Rhode Island's future mitigation and resiliency investments center on equity and foster more equitable outcomes for people and businesses in these communities.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- **Implement the Act on Climate:** In upcoming budgets, the state needs to identify new positions and funding so the Department of Environmental Management, Office of Energy Resources and other Executive Climate Change Coordinating Council-related agencies can continue to make progress on meeting the state's ambitious climate goals. Support for FTEs, outside consultant services, and economic incentives (e.g. electric vehicles, electric heat pumps, renewable energy) should all be considered.
- **Procure utility-scale offshore wind.** This will leverage cross-state market development with strong local economic development impacts, advancing the state toward 100% renewable energy.
- **Pass 100% Renewable Energy Standard** to ensure we are on track to decarbonize the power sector as we work toward net-zero by 2050.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- Identify sustainable funding to incentivize thermal electrification. This will reduce greenhouse gas emissions, create jobs, and fill a funding gap that would advance the market for decarbonized heating solutions in the state.
- Continue investment in foundational energy efficiency. Rhode Island has been recognized as a national leader for its energy efficiency programs, which support economic recovery, reduce utility bills, build financial resilience, and support clean energy jobs – 6 out of every 10 clean energy jobs created in Rhode Island pre-COVID.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- The creation of a whole of government approach to resilience and mitigation of greenhouse gas emissions will be required if Rhode Island wants to meet its statutorily required reduction targets. As resources are dedicated to housing, infrastructure and transportation, and workforce development, ensure that these investments are being made with climate change in mind so that we are properly preparing Rhode Island for the future. This means building energy efficiency and renewable energy generation into our long-term planning, particularly the state's housing plan, and ensuring the economic benefits and job growth that come with Rhode Island's clean energy future are fairly distributed across the state.
 - Make the necessary investments in our coastal resources to help protect them from the effects of climate change with a specific focus on ensuring that low-income neighborhoods do not bear the brunt of the effects of climate change.
 - Assemble a state agency steering committee focused on the topic of voluntary buyouts and property acquisition for floodplain easements by developing guidance and running possible pilot programs for voluntary buyouts as an adaptation option designed to minimize risk of losses in existing and future coastal and riverine floodplains resulting from rising seas and more frequent and intense storm events.
 - Electrification of personal and public transportation as well as home and business heating.
 - Fully fund The Ocean State Climate Adaptation and Resilience (OSCAR) Fund and pass the Transportation and Climate Initiative (TCI) to reduce greenhouse gas emissions from the transportation sector through a cap-and-invest model that will accelerate the adoption of electric vehicles and other zero emission vehicles.
 - Support efforts and initiatives that drive down electricity rates.

THE ROAD TO RI 2030: LONG-TERM ACTIONS (CONT.)

- Investments made in the Blue Economy should be made to help prepare the state for the effects that will come with climate change. This goes beyond development of an offshore wind supply chain; there will be a variety of employment opportunities at all levels as the Blue (and Green) Economy grows, and it will be crucial to begin strengthening those career pathways now to ensure our success in 2030 and beyond.
 - Focus on needed climate-related job skills training in programs such as Real Jobs RI and Pathways RI including solar roof installation, electricians, and construction, particularly for frontline communities.
 - Continue and expand financial incentives for individuals to install rooftop solar and switch to electric vehicles while working with public-private partnerships to provide the charging infrastructure that will be needed for electric vehicles.

“There’s a huge drive to produce technologies, the supply chain, vessels, transportation, manufacturing to be completely zero carbon in the future. So as this enormous industry comes into our front yard, we’ll be pushed to develop and support true green technologies to support that industry.” - **Drew Carey, CEO, INSPIRE Environmental / Community Conversation Participant**

“What we really need is climate in all policies in a way similar to we’re seeing in the Biden Administration, where climate is part of transportation, it’s part of economic developments. There’s no green economy— it’s the economy. All the investments we make need to be made with climate change as a lens.” - **Sue AnderBois, Climate & Energy Program Manager, The Nature Conservancy / Community Conversation Participant**

RI 2030 PRIORITY: ADVANCING INFRASTRUCTURE AND TRANSPORTATION

Infrastructure and transportation are what allows a modern economy to function and helps us live the lives we want. Goods and people travel on the roads and highways in our buses, cars, and trucks while electricity is generated and distributed to homes and businesses around the state. The clean water we have available keeps us healthy, along with the sewer systems that keep our cities and towns clean and free of disease. Broadband internet allows us to communicate more readily with colleagues, classmates, health care workers, potential employers, and our loved ones. All of these are some of the most important pieces of infrastructure in a modern community. In Rhode Island we also depend on our bridges, airports, and ports to keep us connected to one another and to the rest of the world. As we move deeper into the 21st century, we recognize the importance of decreasing our use of fossil fuels in everything from electricity generation to transportation to heating.

WHAT WE HEARD FROM YOU

- Rhode Island—like the rest of the U.S.—has historically underinvested in infrastructure and transportation. As such, the State needs to boost investments in these areas to propel long-term economic growth.
- The state must think broadly about its infrastructure needs—focusing not only on traditional areas like transportation and utilities, but also areas like housing, historic buildings, hospitals, and foundational broadband connectivity.
- There is ample opportunity for regional collaboration in areas like rail, airports, highways, broadband, and offshore wind.
- Improved access to broadband across all of Rhode Island is essential for equitable development.



CURRENT STATE AGENCY INITIATIVES

Rhode Island must continue to leverage the use of Rhode Works and the ten-year State Transportation Improvement Program to bring our roads and bridges to a state of good repair. Continued collaboration between the Rhode Island Department of Transportation (RIDOT) and the Rhode Island Public Transit Authority (RIPTA) will move the State's public transit goals forward by creating more bus routes, streamlined connections, and ease of use. Moreover, Rhode Island recognizes that all Rhode Islanders must have access to the internet.

RI 2030 INFRASTRUCTURE & TRANSPORTATION GOAL: By the next decade, Rhode Island will have a state-of-the-art infrastructure and a 21st century transportation system that improves quality of life, connects all Rhode Islanders, integrates Rhode Island with the broader region, and drives economic growth over the long-term.

INFRASTRUCTURE & TRANSPORTATION OBJECTIVES

Provide well-maintained roads and bridges that are safe, reliable, structurally sound, and meet or exceed current design standards, at both the state and local level.

Have ubiquitous, reliable broadband internet coverage across the state that is affordable and upgradeable to meet the ever-evolving needs of residents and businesses.

A transit system that easily connects workers and employers both within Rhode Island as well as connecting us to the economic hubs of Boston and New York.

Infrastructure that supports the Blue Economy and life sciences, including ports that support offshore wind activity and site readiness work that enables future industrial and commercial development.

- Infrastructure that supports both the mitigation of greenhouse gas use (renewable power generation, modern updated electrical grid, charging stations for electric cars, etc.), as well as the resiliency of the state in the face of climate change.

WHERE WE ARE TODAY AS RHODE ISLAND EMERGES FROM THE PANDEMIC

Infrastructure, including transportation, touches every component of the Rhode Island economy, from workforce development to child care to healthcare. Robust and functional infrastructure provides the foundation for economic growth and allows residents and visitors to access everything the state has to offer. The pandemic also emphasized the need for robust healthcare infrastructure along with the need for modern HVAC systems throughout the state in schools, commercial buildings, and homes.

As many workers moved online and education, healthcare, and everyday communications became increasingly digital, the pandemic underscored the need for reliable internet access across the state. Even before the pandemic, 80% of 8th graders needed the internet to complete their homework, while 90% of job applications were online. At the same time, Rhode Islanders currently face significant inequities in internet access despite the state's robust middle mile. Preliminary speed test data show that 45% of Rhode Islanders live in census blocks that lack access to reliable internet above the new federal minimum threshold. With an eye towards the future, only 2% of Rhode Island reliably receives 200/200mbps speeds, which is necessary to ensure a family of 2-4 can email large files and stream videos concurrently.

There are a number of areas of focus within infrastructure where investments will allow Rhode Island to have a significant positive impact on our vital and connecting systems:

(1) traditional transportation infrastructure, such as roads and bridges, need to be brought to a state of good repair; (2) transit to improve the ability of the state's workers and firms to more fully connect the state to our neighbors, especially Boston; (3) broadband connectivity for the state's residents and businesses; (4) port infrastructure to support the Blue Economy; (5) industrial infrastructure to boost site readiness across the state; and (6) more resilient infrastructure to combat the effects of climate change. This last area is especially important and comes with significant opportunities in renewable electricity generation, storage, and distribution.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS

- With existing transportation and transit plans in place and being operationalized, as well as a strong broadband middle mile, Rhode Island is in a good position to take advantage of federal funding to aid in the state's economic recovery and allow the state to accelerate and enhance ongoing strategic efforts to provide high-speed, affordable broadband and reliable, well-connected transportation options.
- Invest in workforce development and training to make sure construction companies and associated professions have the workers they will need to implement these plans and help people earn credentials that will increase their income.
- Invest in the healthcare infrastructure of hospitals, community health clinics, water and sewer, and broadband access and adoption to help the state be prepared for the next potential public health crisis.

RECOVERING FROM THE PANDEMIC: SHORT-TERM ACTIONS (CONT.)

- Continue and increase investment in water, sewer, and stormwater management to ensure a high quality of life and improvement in building healthy, green communities statewide.

THE ROAD TO RI 2030: LONG-TERM ACTIONS

- Continue to invest in infrastructure needed for offshore wind in pursuit of the State's renewable energy goals and establish a statewide network of charging stations for electrical vehicles.
- Implement the vision outlined in the state Long Range Transportation Plan, including the Rhode Island Transit Master Plan 2040, to better connect Rhode Islanders with each other and neighboring states. Research and pursue the opportunity of high-speed rail connections between Boston, Rhode Island, Connecticut, and New York.
- Collaborate with municipalities to invest in downtown and Main Street areas to facilitate transit, denser housing, broadband access, and business opportunities.
- Connect more Rhode Islanders with inexpensive, fast, reliable broadband, following recommendations developed through proposed strategic mapping and planning process.
- Build out the State's first ever Infrastructure Data for Effective Action (IDEA) center. Provide FTEs for data management and analysis, working hand in hand with the Office of Management and Budget (OMB) and Division of Information Technology (DOIT), as well as the many agencies who need and utilize infrastructure data. Fund the positions through federal appropriations, grants, state revenue, and public/private partnerships. House this group with staff to the State's single Metropolitan Planning Organization (MPO), the Division of Statewide Planning. The development of the IDEA center can position the Governor to actively manage the State's infrastructure portfolio.

“

“[T]he transit master plan proposed a set of light rail and bus rapid transit investments that will link the urban core of cities large and small across Rhode Island with each other, with the airport, and into the main stem of the Northeast corridor and the connections to New York and to Boston...A major focus, of course, is going to be on the development of offshore wind facilities at Quonset and other locations across the state, making sure that we have the road and rail access to those locations to make sure that Rhode Island gets its fair share or more than its fair share of the economic impact associated with the offshore wind industry.” - **Bob Yaro, President, North Atlantic Rail Alliance / Community Conversation Participant**

”

RI 2030 PRIORITY: MOVING STATE GOVERNMENT INTO 2030

With the emergence of the global pandemic, the State of Rhode Island faced unprecedented challenges in 2020. As the footprint of remote work activities increased, so did the demand on the core IT network, HR, web and security infrastructure, necessitating an immediate response by the DoIT enterprise IT team and Division of Human Resources. Innovative new platforms needed to be implemented rapidly to increase remote work capacity, improve network performance, enable more online services, and ensure the safety of our both state employees and residents. The State's Division of Information Technology, Division of Purchasing and Division of Human Resources have successfully met the unique challenges of this past year by rapidly deploying solutions to meet needs created by the pandemic and to improve the level of service residents receive.

However, throughout the state, numerous agencies still rely on outdated legacy systems and network architecture. As the world has gone increasingly digital, governments around the country have been some of the last to update both their resident-facing services and internal processes from legacy paper formats. It was not until an executive directive in 2014 that the federal government introduced a requirement for all executive agencies to move to digital recordkeeping. It is now time for the Rhode Island state government to follow that lead and move to update both services for the residents and businesses of Rhode Island as well as internal processes and recordkeeping into the digital world.

Modernizing government services will take thoughtful and careful planning through 2030, and efforts have already begun within the Department of Administration to progress the state towards this goal. There are three main benefits to having the state government go digital.

First, it will allow state agencies to continue to offer more services online, allowing Rhode Islanders easier access to everything from business registration to paying taxes to signing up for unemployment benefits. Rhode Island agencies have already made significant strides in this area and citizens will increasingly expect to interact with government online.

Second, updating the backend government systems, from HR to IT to procurement will increase government efficiency. This will allow state government employees to access benefits online, move purchasing online, and much more, saving time and cost.

Third, digital recordkeeping will open increasing amounts of data that will allow the state and researchers to better evaluate programs to find out what is working, what is not, and suggest changes.

2016 Rhode Island Greenhouse Gas Emissions Inventory



Rhode Island
Department of
Environmental
Management

OFFICE OF AIR RESOURCES

December 20, 2019

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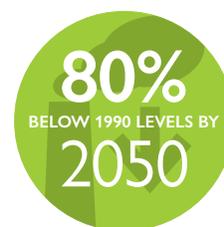
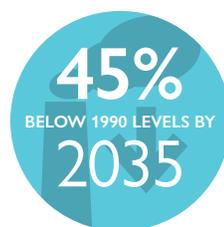
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Executive Summary

Increasing atmospheric concentration of greenhouse gases (GHG) caused by emissions from human activities is leading to global climate change. To understand Rhode Island's contribution to climate change we must understand the contributions of Rhode Island and Rhode Islanders to global emissions of greenhouse gases. This update provides an overview of Rhode Island GHG emissions from 1990 to 2016, the most recent year for which full data are available.¹ The statewide GHG emissions inventory is an important tool for tracking Rhode Island's progress towards the targets set by the 2014 Resilient Rhode Island Act.²

In accordance with the provisions of the Rhode Island General Laws §42-6.2-2(2), the Rhode Island Executive Coordinating Council (EC4) produced the "EC4 Greenhouse Gas Emissions Reduction Plan" in December 2016. The plan included strategies, programs, and actions to meet the targets for GHG emissions reduction as established in the Resilient Rhode Island Act.

2014 Resilient Rhode Island Act GHG Emissions Reduction Targets



Per the statute, the EC4 provided the following recommendations for state agencies to monitor progress on an ongoing basis:³

1. Monitor progress using a triennial schedule of GHG reductions based on the Resilient Rhode Island GHG targets.
2. DEM will develop a triennial GHG emissions inventory for Rhode Island and report on progress towards meeting Resilient Rhode Island GHG targets.
3. DEM will evaluate the possibility of meeting higher targets through cost-effective measures in the triennial report.

The information in this update provides a comprehensive view of GHG emissions in Rhode Island. It can be used to evaluate Rhode Island's GHG emissions, discuss where the emissions are coming from, and determine whether they are increasing or decreasing over time. External factor analysis (i.e. fuel prices, population, economics, etc.) that impact GHG emissions are excluded from this update.

Key Findings:

- Achieved 2020 GHG Emissions Reduction Target.
- Rhode Island's 2016 total GHG emissions were 11.02 million metric tons carbon dioxide equivalent (MMT_{CO₂e}).
- Rhode Island's 2016 total emissions have decreased 1.46 MMT_{CO₂e} (-11.67%) from the 1990 baseline of 12.48 MMT_{CO₂e}.
- In 2016, Rhode Island's largest contributors of GHG emissions by sector:
 - Transportation at 36%
 - Electricity Consumption at 26%
 - Residential Heating at 17%

¹ The Rhode Island Department of Environmental Management (RIDEM) greenhouse gas inventory relies in part on U.S. EPA State Inventory Tool (SIT), 2016-year full data available.

² For additional information, go to: <http://StateofRhodeIslandResilientRhodeIslandAct>

³ For additional information, go to: <http://climatechange.ri.gov/ec4GHGReductionPlan2016>

Working Towards GHG Reduction

Greenhouse gases (GHG) trap heat in the atmosphere causing a temperature increase known as global warming. The most common GHGs are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases. GHGs primarily from fossil fuel combustion create a multitude of problems ranging from a decrease in air quality to an increase in extreme weather events. A GHG inventory provides an estimate of statewide GHG emissions and trends from which strategies and policies can be developed to reduce these emissions. The Resilient Rhode Island Act (2014) created reduction targets and established a council to assess climate change impacts in Rhode Island. The Executive Climate Change Coordinating Council (EC4) discusses climate issues in Rhode Island and develops strategies to address undesired impacts.

The Inventory Process

Like many other states that regularly preform economy-wide GHG emissions inventories, Rhode Island relies heavily on the U.S. Environmental Protection Agency’s State Inventory Tool (SIT).⁴ The tool is an interactive top-down spreadsheet model designed to help states develop GHG emissions inventories.

The SIT consists of 11 modules which calculate sector-by-sector GHG emissions based on numerous state-level data sets, including energy-related data provided by the U.S. Energy Information Administration (EIA). The U.S. Environmental Protection Agency (EPA) recommends that states employ their own data when these are likely to be more robust than the tool’s default data.

The SIT estimates GHG emissions by applying pollutant-specific emission factors to Rhode Island activity data. EPA updates the SIT annually with the latest activity data. If needed, any updates to emission factors and/or Global Warming Potentials (GWP) are made as well.

GHG emissions are typically converted to a unit of measure called carbon dioxide equivalent (CO₂e) based on their GWP that allows for better comparison of the impact of different GHGs. These conversions are completed within the SIT. For this 2016 GHG emissions inventory, the SIT uses the GWPs from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). Table 1 below illustrates the differences in GWP of different gases between the AR4 and the IPCC’s Second Assessment Report (used in RI’s initial 1990 & 2010 GHG Inventories).⁵

Global Warming Potentials (GWP)
Allows for comparisons of the global warming impact of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of gas will absorb over a given period of time, relative to the emissions of 1 tons of carbon dioxide (CO₂).

Emissions Factor
An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.

Source: United States Environmental Protection Agency

Table 1: Global Warming Potential Factors for Greenhouse Gases

Greenhouse Gases (100 YR)	Global Warming Potential (SAR)	Global Warming Potential (AR4)
Carbon dioxide (CO ₂)	1	1
Methane (CH ₄)	21	25
Nitrous oxide (N ₂ O)	310	298
Hydrofluorocarbons (HFCs)	140-11,700	12-14,800
Perfluorocarbons (PFCs)	6,500-9,200	7,390-12,200
Sulfur hexafluoride (SF ₆)	23,900	22,800

⁴ For additional information, go to: <https://www.epa.gov/StateInventoryProjectionTool>

⁵ For additional information, go to: <https://www.ipcc.ch/reports/>

In 2013, the Northeast States for Coordinated Air Use Management (NESCAUM) conducted the first GHG emissions inventory to determine a 1990 baseline and 2010 emissions inventory. The 1990 baseline and 2010 emissions totals used in this inventory came from the 2016 GHG Reduction Plan (see pages 51 and 52 for detailed information). Since then, the Office of Air Resources has completed a GHG emissions inventory annually. As mentioned above, the SIT is preloaded with default data or States can input more state-specific data if available. As Table 2 shows, RIDEM has completed inventories for years 2011-2016. However, inventory years 2011, 2012, and 2015 were default runs. In other words, the emissions for these three years were estimated using primarily default data in the SIT. Inventory years 2013, 2014 and 2016 were non-default runs. In these years, state-specific data was utilized to obtain the most robust emissions estimates. In addition, for all years (2011-2016), RIDEM chose to use reported data to EPA's Facility Level Information on Greenhouse gases Tool (FLIGHT) for two sectors: emissions from natural gas distribution and solid waste. For the natural gas distribution sector, the SIT does not contain certain values needed to estimate emissions and National Grid reports its emissions from natural gas distribution in Rhode Island directly to EPA. The report includes emissions associated with distribution mains, services, and metering regulated stations. The SIT apportions national data as well as makes certain assumptions based on landfills in general, therefore, RIDEM chose to use the emission reported by the RI Resource Recovery Corporation for the Central Landfill for the solid waste sector in lieu of the SIT. The Land Use, Land Use Change and Forestry (LULUCF) sector has not been estimated in this update or any recent inventory. The SIT has been unreliable for estimating emissions and/or sequestration of emissions for this sector and no alternative methodology has been developed. When a reliable methodology becomes available, RIDEM anticipates including the LULUCF sector in future inventories.

Table 2: Rhode Island Total Annual GHG Emissions (MMTCO₂e)

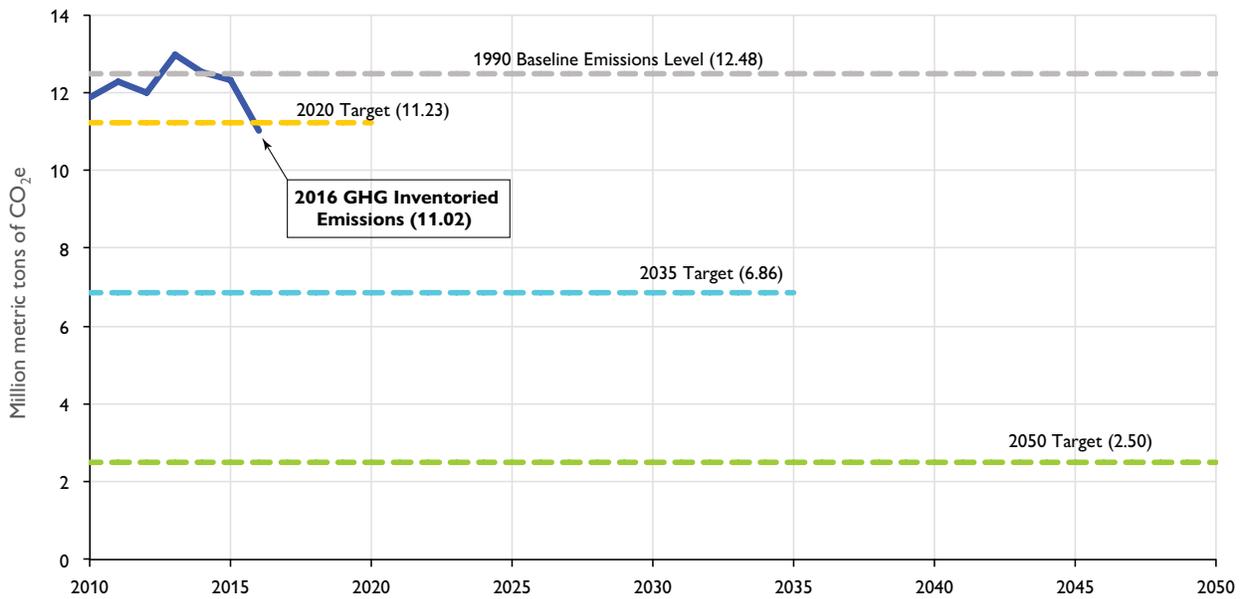
Rhode Island Greenhouse Gas Emissions Inventory								
	1990	2010	2011	2012	2013	2014	2015	2016
Model Run Type (Default or Non-Default)	Non-Default	Non-Default	Default	Default	Non-Default	Non-Default	Default	Non-Default
Energy	3.12	2.44	3.53	3.53	3.69	3.42	3.37	3.00
Electricity Consumption	2.82	2.29	3.38	3.38	3.52	3.25	3.21	2.84
Natural Gas Distribution	0.30	0.15	0.15	0.15	0.17	0.17	0.16	0.15
Residential Heating	2.37	2.24	2.15	2.08	2.27	2.34	2.46	1.84
Commercial Heating	1.15	0.92	0.87	0.79	0.91	1.13	1.00	0.86
Transportation	4.97	4.79	4.40	4.19	4.59	4.25	4.09	3.94
Aviation	0.33	0.27	0.31	0.29	0.29	0.30	0.28	0.30
Highway Vehicles	4.37	3.70	3.76	3.61	4.09	3.62	3.66	3.62
Nonroad Sources	0.24	0.33	0.31	0.27	0.19	0.30	0.12	0.00
Lubricants	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Industrial	0.81	1.04	1.06	1.05	1.24	1.14	1.12	1.14
Industrial Heating	0.71	0.61	0.56	0.54	0.67	0.57	0.59	0.61
Industrial Processes	0.09	0.43	0.50	0.51	0.56	0.57	0.53	0.53
Agriculture	0.04	0.02	0.05	0.04	0.03	0.05	0.05	0.04
Waste	0.31	0.47	0.22	0.33	0.25	0.21	0.22	0.20
Solid Waste	0.23	0.39	0.11	0.21	0.15	0.10	0.10	0.09
Wastewater	0.08	0.08	0.11	0.11	0.11	0.11	0.12	0.11
Land Use, Land Use Change, and Forestry (LULUCF)	-0.29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL (Million Metric Tons MMTCO ₂ e)	12.48*	11.86*	12.28	12.01	12.98	12.54	12.31	11.02

*1990 & 2010 Data has been adjusted as done in the Rhode Island Greenhouse Gas Reduction Plan, December 2016.
<http://climatechange.ri.gov/documents/ec4-ghg-emissions-reduction-plan-final-draft-2016-12-29-clean.pdf>

2016 Statewide GHG Emissions Inventory Results

In 2016, total Rhode Island GHG emissions were 11.02 million metric tons carbon dioxide equivalent (MMT CO_2e) as shown in Table 2 and Figure 1. This is a decrease of 1.46 MMT CO_2e (11.7%) from the 1990 baseline of 12.48 MMT CO_2e . As seen in Figure 1 below, the 2016 GHG emissions are below the 2020 GHG target of 11.23 MMT CO_2e .

Figure 1: Rhode Island 2016 GHG Emissions and Reduction Targets



Detailed information on the inventory process can be found in each major sector highlighted specifically, the transportation, electricity consumption and residential heating sectors within this update.

2016 GHG Emissions Inventory Results by Sector

The majority of GHG emissions in Rhode Island in 2016 were from the transportation sector (36%), followed by emissions from the electricity consumption sector (26%), and residential heating sector (17%) as shown in Figure 2. The “other” category includes agriculture, waste and natural gas distribution.

Figure 2: 2016 GHG Emissions by Sector

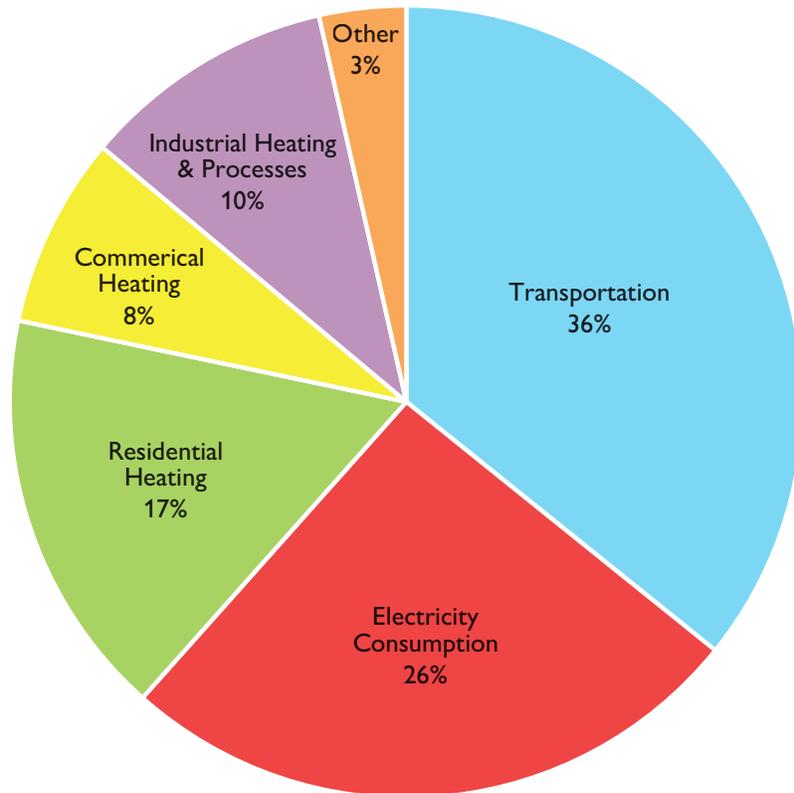
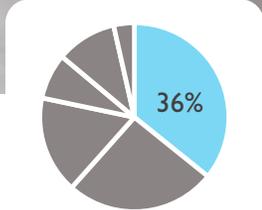


Table 3 below compares the change in sectors from the baseline year 1990 and 2016. Both the electricity consumption and industrial heating & processes sectors have trended upward from 1990. Emissions from the industrial sector have increased approximately 41% from 1990 to 2016. Although this increase may appear significant, the change between 1990 (0.81 MMTCO₂e) and 2016 (1.14 MMTCO₂e) is relatively small. The increase in the electricity consumption sector is discussed in further detail within the electricity consumption section.

Table 3: Rhode Island Greenhouse Gas Emissions Changes 1990-2016

Sector	Change in MMTCO ₂ e	Percent Change	Trend
Transportation	-1.03	-20.7%	↓
Electricity Consumption	0.02	0.7%	↑
Residential Heating	-0.53	-22.4%	↓
Industrial Heating & Processes	0.33	40.7%	↑
Commercial Heating	-0.29	-25.2%	↓
Other (Agriculture, Waste and Natural Gas Distribution)	-0.26	-40.0%	↓
Total	-1.46	-11.7%	↓



Transportation Sector

Trends

In 2016, the transportation sector continues to be the largest source of GHG emissions in the state, 36%, as seen in Figure 2. GHG emissions from transportation decreased 0.15 MMTCO₂e (3.67%) from the previous year. Most of the GHG emissions are coming from passenger vehicles as seen in Figure 3.

While there has been a 20% reduction in GHG emissions since 1990, further reductions are critical to meeting the State's 2035 and 2050 targets. Much like other Northeast states, vehicle miles traveled (VMT) continues to trend up, as seen in Figure 4.⁶ This makes it challenging for the improved fuel efficiencies of modern-day vehicles to affect total transportation GHG emissions. Increased deployment of zero-emission vehicles across all vehicle sizes, but specifically passenger vehicles, will be required to meet RI's targets, as well as a reduction in personal vehicle miles traveled.

Figure 3: 2016 Vehicle Population Breakdown

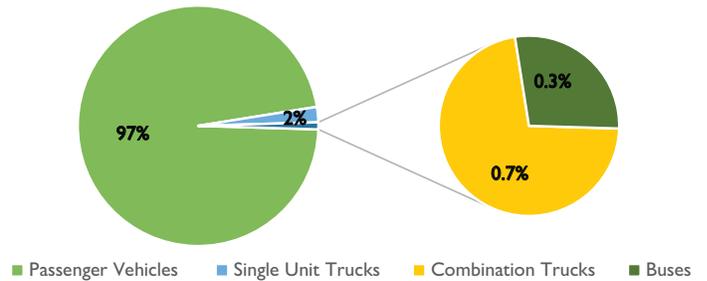
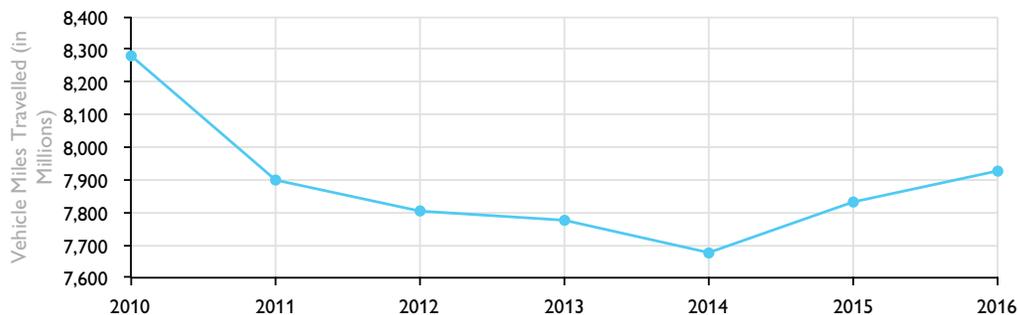
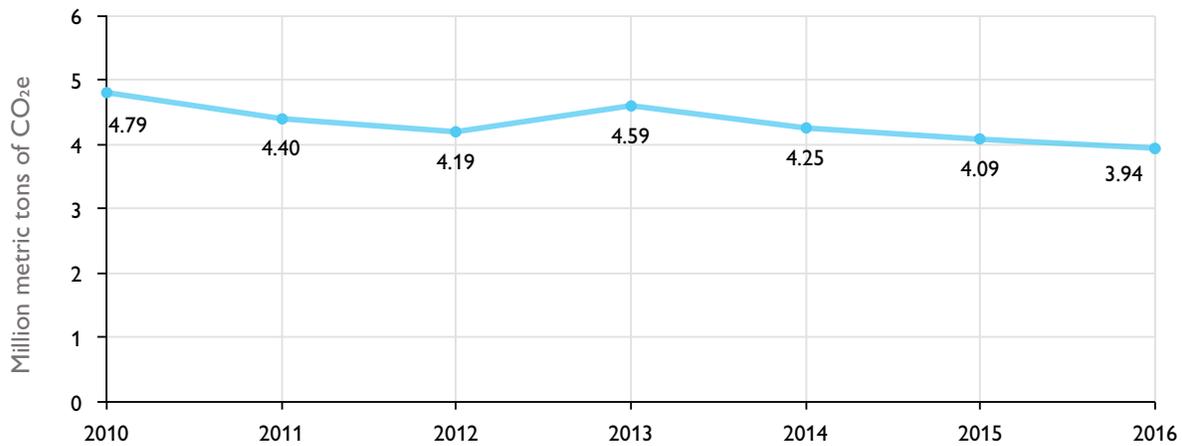


Figure 4: Rhode Island VMT Trends



⁶ For additional information, go to: <https://www.fhwa.dot.gov/>

Figure 5: Rhode Island Transportation GHG Emissions 2010-2016



Transportation Sector Methodology

A range of tools is available to calculate GHG emissions from the transportation sector. These tools vary significantly in their capabilities. EPA recommends the SIT and the Motor Vehicle Emissions Simulator (MOVES)⁷ for statewide emissions inventories.

The SIT uses a “top-down” approach to calculate CO₂ emissions from transportation, starting with fuel consumption and VMT. This approach uses data on fuel sales within each state as a proxy for fuel consumption. The major shortcoming of this method is a lack of detail. Drivers do not always use their vehicles in the same state that they purchase fuel. As a result, fuel sales may not provide an accurate estimate of fuel consumption at the state level. Data on fuel sales also does not provide information on different types of on-road vehicles.

MOVES is an all-in-one program that converts all GHG emissions to CO₂e using a “bottom-up” approach. VMT and vehicle data determines fuel consumption and emissions produced. The tool includes a great deal of opportunity for user-supplied inputs and simplifies analysis at different levels of geography (e.g. nation, county). For the purposes of state GHG inventories, EPA recommends county level inputs requiring the user to supply local, state and county data. Inputs to MOVES includes data on vehicle population, vehicle age, average speed distribution, meteorological data, I/M program details, road type distribution, and VMT. The model simulates vehicle drive cycles for the defined time period and geographical area specified. Data from all five Rhode Island counties are summed to produce a transportation sector inventory.

Although MOVES provides the strongest and most up-to-date methods for analyzing the GHG impacts of on-road vehicles, the tool is not the best option for state inventories to address every potential GHG analysis component (e.g. non-road modes, lubricants, and aviation). As a result, the SIT tool is used to determine the non-road and lubricant associated emissions of the transportation sector. Some examples of non-road emission sources are boats, locomotives, tractors, construction and snowmobiles (gasoline only). For aviation related GHG emissions, as required by the Permanent Air Quality Monitoring Act (Rhode Island General Laws 1-7-6),⁸ the Rhode Island Airport Corporation (RIAC) provides an annual inventory of GHG pollutants associated with the State’s primary airport, T.F. Green Airport, to RIDEM. This 2016 GHG emissions inventory update used the data provided in the 2016 Air Emissions Inventory submitted to RIDEM’s Office of Air Resources by RIAC.

⁷ For additional information, go to: <https://www.epa.gov/moves>

⁸ For additional information, go to: <http://StateofRhodelslandStatute/PermanentAirQualityAct>

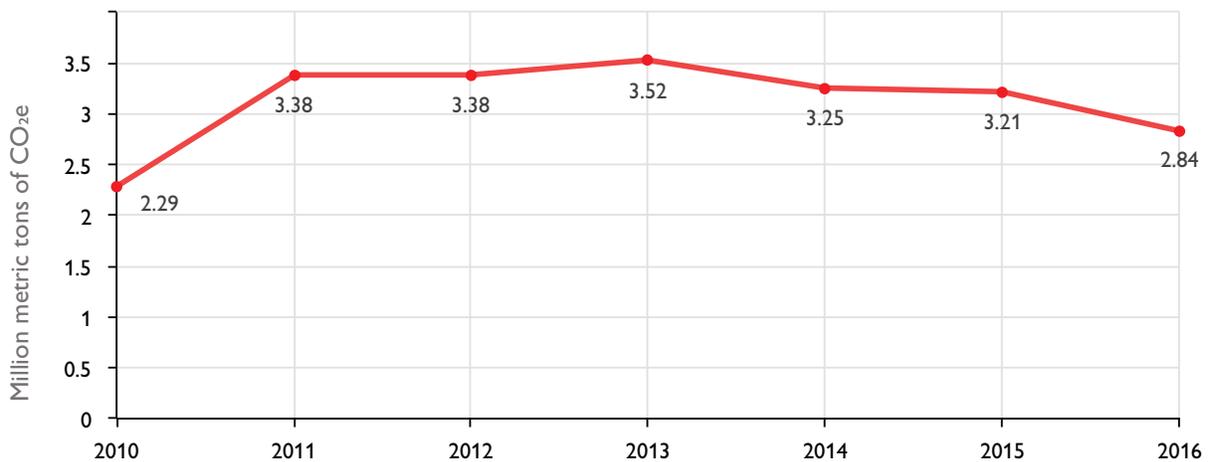


Electricity Consumption Sector

Trends

In 2016, the electricity consumption sector continues to be the second largest source of GHG emissions in the state, 26%, as seen in Figure 2. Electricity consumption emissions have increased slightly from 1990 whereas the other top emission sources, transportation and residential heating, have trended downward (refer to Table 3). It should be noted that the 1990 baseline inventory did not include three of the five power plants in Rhode Island. The RI State Energy Center, Manchester Street Power Station and Tiverton Power started operation between 1995 and 2002. The 2010 emissions of 2.29 MMCO₂e is the GHG emissions estimate from the 2016 RI GHG Reduction Plan. As Figure 6 below shows, the emissions from the electric sector have remained relatively flat averaging 3.30 MMTCO₂e for last five years (2011-2015). However, in 2016, emissions from electricity consumption dropped by 0.37 MMTCO₂e (-11.50%) to 2.84 MMTCO₂e. This decline in emissions from 2015 to 2016 is attributed to Rhode Island's ambitious energy efficiency measures as well as using an improved emission accounting methodology. Rhode Island has consistently scored in the top five in the nation for energy efficiency as ranked by the American Council for an Energy-Efficient Economy.⁹ In 2016, RI ranked fourth and in 2019 RI tied for third with Vermont. These scores reflect RI's commitment to energy efficiency as a means to reducing emissions in this sector.

Figure 6: Rhode Island Electricity Consumption GHG Emissions 2010-2016



⁹ For additional information, go to: <https://aceee.org/state-policy/scorecard>

Electricity Consumption Sector Methodology

The SIT has been used to estimate electricity consumption-based GHG emissions from the electric power sector. In an effort to continuously improve RI's GHG emissions inventory, it is recognized that renewable energy is playing a larger role in RI's energy portfolio. As a national leader in energy policy, RI's ambitious Renewable Energy Standard (RES) requires that an increasing amount of renewable power be sold each year (38% by 2035).¹⁰ Since the RES requires increasing amounts of renewable energy (RE), it is possible that the SIT methodology would have caused an increasingly less accurate GHG emissions inventory over time.

For this 2016 emissions inventory update, the electric sector GHG emissions inventory methodology has been revised and aligns with RI's neighboring states, Massachusetts (MA) and Connecticut (CT). This method for estimating GHG emissions from electricity consumption accounts for emission reductions from Renewable Energy Certificates (RECs) purchased and/or sold by Rhode Island retail electricity sellers. RECs are counted in the state in which they are settled (retired) and not where they are minted (generated). Utilizing the New England Power Pool Generation Information System (NEPOOL GIS) data, RIDEM accounted for the total number of RECs used for in-state RES compliance. These RECs were "credited" to Rhode Island thereby reducing the total emissions associated with energy needed to meet statewide electric demand. This inventory update is the first time RI has accounted for RECs in estimating electricity consumption GHG emissions.

In 2016, RI was a net importer of electricity.¹¹ RI's demand for electricity exceeded its generation. This inventory assumes that CO₂ emissions from RI's power plants are attributed to Rhode Islanders energy demand. The additional electricity consumed by RI is imported from other New England states that are net exporters of energy. This inventory uses RI-specific generation and annual electricity load data from the Independent System Operator, New England (ISO-NE) to determine an imported emissions estimate. In years that New England receives net imports of electricity from adjacent control areas (NY, NB and Quebec), the associated emissions from this imported energy is included as well. If pumped hydro has been used, the megawatt hours of losses and associated emissions are calculated. The total energy consumed is multiplied by emission factors consistent with the MA methodology to obtain emissions from RI's electricity consumption.

Consumption vs. Generation Accounting

GHG emissions from the electric power sector can be estimated by using either a consumption-based or a generation-based accounting methodology. Generation-based accounting is the total of GHG emissions from the combustion of fossil fuels at power plants located within RI, whereas GHG emissions associated with electricity used within the state is referred to as consumption-based. In 2016, RI imported approximately 20% of electricity from outside the state (1,637 Gigawatt hours). A consumption-based approach is used in this inventory captures the emissions of this imported electricity. In addition, a generation-based method may not fully account for GHG emission reductions achieved through energy efficiency programs and/or give appropriate credit for electricity obtained from renewable energy sources. Electricity in RI is obtained from a regional (New England) transmission grid and the majority of New England states including neighboring states of MA and CT utilize consumption-based accounting to estimate GHG emissions from this sector. In February of 2016, the EC4 formally adopted the consumption-based accounting methodology for use in the 2016 RI GHG Emissions Reduction Plan.¹²

¹⁰ For additional information, go to: <http://StateofRhodeIslandStatute/RenewableEnergyStandard>

¹¹ For additional information, go to: <https://www.iso-ne.com/EnergyLoadandDemandReport>

¹² "Memo Re: Electricity Generation vs. Consumption GHG accounting approaches" prepared by Paul Miller to Liz Stone and Danny Musher, January 8, 2016 – <http://www.dem.ri.gov/programs/air/documents/ghg-memo.pdf>



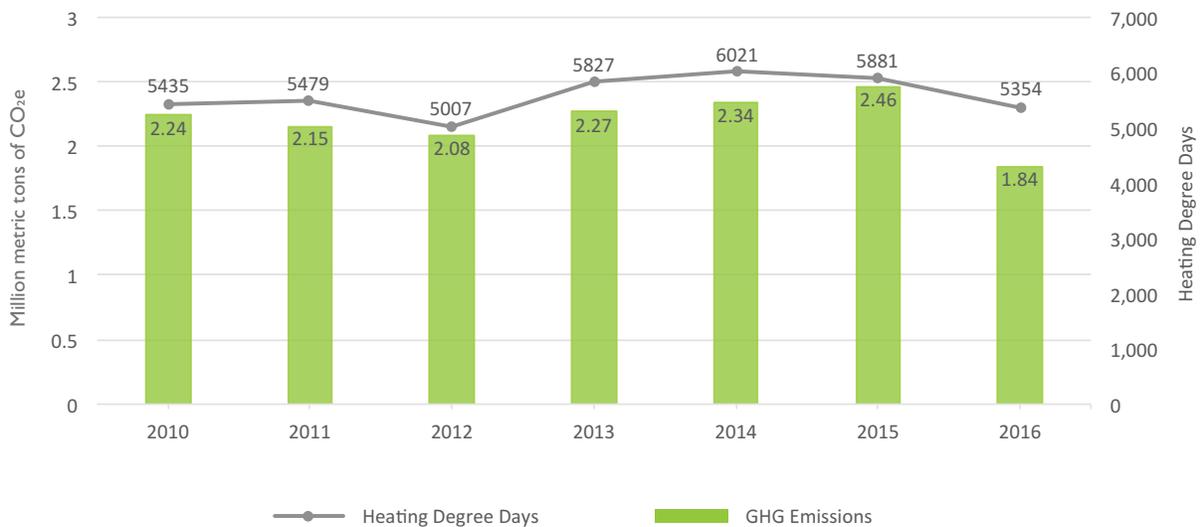
Residential Heating Sector



Trends

The residential heating sector emitted 1.84 million metric tons of CO₂e accounting for 17% of Rhode Island’s GHG emissions in 2016. Rhode Island has experienced a decrease in emissions from the residential heating sector, most notably a 22.4% decrease in GHG emissions since 1990. Major fuels used to heat Rhode Island homes include natural gas and distillate fuel oil.¹³ 53% of homes use natural gas¹⁴ and approximately 31% of homes use distillate fuel oil.¹⁵ Electricity and other miscellaneous fuels¹⁶ account for the remaining approximately 16%.¹⁷ Heating fuels produce different amounts of GHG emissions because “dirtier” fuels produce more emissions.

Figure 7: Rhode Island Residential Heating GHG Emissions and Heating Degree Days 2010-2016¹⁸



¹³ Also commonly referred to as #2 fuel oil or home heating oil.

¹⁴ Natural gas emits about 20-30% less CO₂ than oil. For additional information, go to: <https://www.eia.gov/energyexplained/natural-gas>

¹⁵ For additional information, go to: <https://www.eia.gov/state/RIStateEnergyProfile>

¹⁶ Miscellaneous fuels include propane, kerosene, wood, solar and geothermal sources.

¹⁷ For additional information, go to: <https://www.eia.gov/state/seds/2016>

¹⁸ For additional information, go to: <https://www.NOAA/HeatingDegreeDays>

Distillate fuel oil plays a central role in heating approximately one-third of Rhode Island homes. However, over the course of the past century, consumption of delivered fuels in Rhode Island, New England and across the U.S. have declined steadily.¹⁹ Market economics, public initiatives, increases in heating equipment efficiencies, advancements in control technologies, building improvements, and alternative fuel options (particularly, natural gas conversions) have all contributed to a trend in reduced consumption of distillate fuel and other delivered fuels. Further information about the decline in distillate fuel consumption is provided in the “Factors Impacting Heating Emissions” section.

Temperature changes from year to year play a large factor in emissions from the heating sector. For example, during a mild winter, lower fuel consumption for space heating can be expected. This reduction in fossil fuel use results in lower emissions. Heating degree days alleviate the variability of temperature by determining the weather’s impact on fuel consumption. Figure 7 shows the relationship between residential heating emissions and heating degree days.²⁰ Additional information about heating degree days is provided below.



Factors Impacting Heating Emissions

Rhode Island’s weather provides a level of uncertainty for heating emissions because colder temperatures require more energy to keep residents comfortable inside their homes. Cold winters demand more heat, and likely result in increased fuel usage and GHG emissions. Wintertime possesses a variability for Rhode Island’s GHG emissions; an attempt to mitigate this uncertainty with heating degree days determines if Rhode Island’s change in heating emissions is a result of temperature change, energy efficiency or other factors (such as fuel consumption).

Heating degree days are used to normalize emissions associated with fuel use and differences in weather. Heating degree days are calculated by subtracting the average daily temperatures from a baseline temperature of 65°F; 65°F is when neither air conditioning nor heating are required to maintain a comfortable temperature.²¹ The concept of heating degree days is tricky because there can be multiple heating degree days in a 24-hour period. Heating degree days provide useful information about the intensity of winter and the fuel usage required to provide adequate heat. Assuming all variables are identical from year to year, a 10% increase in heating degree days should experience a 10% increase in heating emissions. A 24-hour temperature average greater than the baseline temperature (65°F) results in 0 heating degree days because heating units will not be turned on.²²

Rhode Island’s residential heating sector emitted 2.46 MMTCO₂e in 2015 and 1.84 MMTCO₂e in 2016. There were 5,881 heating degree days in 2015 and 5,354 heating degree days in 2016. The warmer winter of 2016 experienced a 9% decrease in heating degree days and a 25% decrease in GHG emissions. Weather alone did not contribute to a 25% decrease in GHG emissions from 2015 to 2016. Further emissions reductions are likely a result of decreased fuel consumption and increased energy efficiency.

¹⁹ For additional information, go to: <https://www.eia.gov/state/seds/2016>

²⁰ For additional information, go to: <https://www.NOAA/HeatingDegreeDays>

²¹ For additional information, go to: https://www.weather.gov/key/climate_heat_cool

²² For additional information, go to: https://www.weather.gov/key/climate_heat_cool

U.S. consumption of distillate fuel use in heating has declined from 28% in 1985 to 11% in 2015 (the most recent year with sales data to end-use consumers).²³ This trend is even more prominent on the East Coast, and for our purposes, Rhode Island. The Rhode Island distillate fuel consumption drastically decreased from 17,289 Billion Btu in 2015 to 10,912 Billion Btu in 2016. Emission reductions from distillate fuel accounts for a 0.47 MMTCO₂e decrease from the residential heating sector, responsible for a 19% drop in residential heat GHG emissions. Since 1990, distillate fuel oil use has decreased from residential heating, but distillate fuel usage for highway transportation has continued to increase. As residents shift away from distillate fuel to heat their homes, it makes sense that Rhode Island will see a decrease in emissions from the heating sector. Lastly, like all heating fuels during a warm winter, consumption decreases. Reductions in fuel usage in 2016 may be attributed to the warmer than average winter; however, distillate fuel experienced unprecedented drops in consumption from 2015 to 2016. There is no singular reason for emissions to drop as they have. Purchasing trends, energy efficiency improvements, and warmer than average weather may have all played a role in the reduction of heating emissions.

Heating Degree Day Calculation

February 2nd, 2016

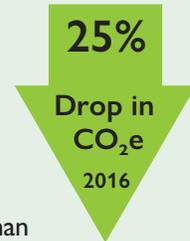
24-hour temperature average: 22°F

Baseline temperature: 65°F

24-hour average temperature (22°F) is colder than the baseline (65°F), therefore, heating degree days

$65^{\circ}\text{F} - 22^{\circ}\text{F} = 43$ heating degree days on February 2nd, 2016

Calculate for 365 days in a year, sum of all heating degree days equals annual heating degree days



Residential Heating Sector Methodology

Residential heating emissions are estimated using the SIT's Fossil Fuel Combustion module and the Stationary Combustion module. EIA collects fuel consumption data throughout the United States by requiring mandatory surveys for all companies that deliver natural gas to consumers or transport natural gas across state lines. In Rhode Island, National Grid is responsible to report natural gas consumption data to the EIA via Form EIA-176.²⁴ Distillate fuel, propane, and kerosene are other fuels used to heat RI homes. These are deliverable fuels because they must be delivered to your house for use. Consumption estimates for deliverable fuels are estimated by EIA. Fuel consumption data is a key component in order to estimate emissions. The SIT estimates Rhode Island's 2016 residential heating emissions to be 1.84 million metric tons of CO₂e.

Rhode Island enacted the Biodiesel Heating Oil Act of 2013 to require the mixing of biodiesel in heating oil.²⁵ Biodiesel is a renewable fuel made from waste such as plant oils, cooking oils and animal fats. Biofuel can be mixed with conventional heating oil to create different blends of oil. For example, a B5 blend contains 5% biodiesel and a B50 blend contains 50% biodiesel. B5 is the minimum blend required in Rhode Island as outlined in the Biodiesel Heating Oil Act of 2013. Biodiesel reduces GHG emissions in Rhode Island because biodiesel burns 85% cleaner than conventional oil.²⁶ Currently, biodiesel is not included in the emissions inventory due to a lack of state-level data on biofuel consumption. Residential heating emissions may be overestimated because this inventory's calculations do not include the use of blended biofuels. Adjustments and improvements to accurately represent biofuel may be considered in future inventories to create a more detailed emissions calculation.

²³ For additional information, go to: <https://www.eia.gov/DistillateFuelInventories>

²⁴ For additional information, go to: <https://www.eia.gov/NaturalGasReporting>

²⁵ For additional information, go to: <http://StateofRhodeIsland-BiodieselHeatingOilActof2013>

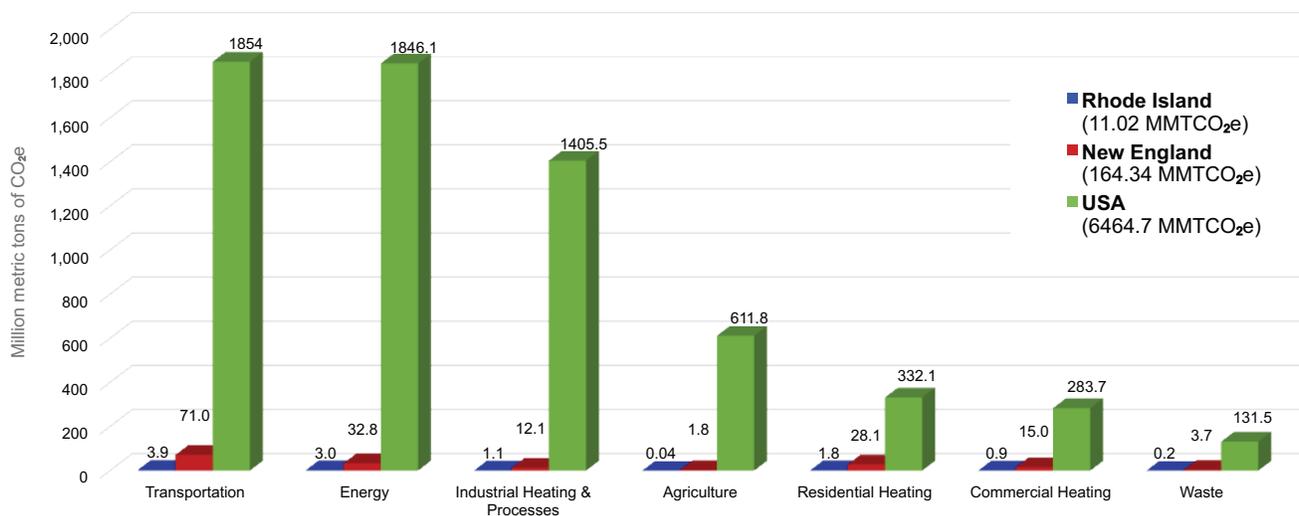
²⁶ For additional information, go to: <http://www.rilin.state.ri.us/pressrelease>

Trends by Sector: Rhode Island, New England and the United States

Rhode Island is one of the Nation’s lowest GHG emitters behind Vermont and the District of Columbia.²⁷ Vast differences including population, electricity prices, climate and fuel options creates a large variability in a state’s GHG emissions. Rhode Island emits approximately 11 MMTCO₂e, only 0.17% of the 6464.70 MMTCO₂e the United States is responsible for emitting in 2016. The three largest sectors of GHG emissions on a national level are transportation, energy, and industrial heating and processes. The three largest sectors in Rhode Island are transportation, energy, and residential heating. These sectors are also the largest emitters in New England. In comparison to national averages, residential heating produces a large proportion of emissions in New England due to the colder than average climate.

Per capita consumption is important to determine how well Rhode Islander’s utilize their resources. Per capita consumption is the amount of emissions produced by one person on average in a year.²¹ On average each Rhode Islander produces 10.43 metric tons of CO₂e in a given year. The average United States citizen produces 20.15 metric tons of CO₂e in a given year.²⁸ Rhode Island is a small piece of the puzzle; however, continuous improvements to heating systems, renewable energy, and transportation will help achieve the reduction targets mapped out in the Resilient Rhode Island Act.

Figure 8: Rhode Island, New England, & U.S. Greenhouse Gas Emissions 2016



ME & NH Greenhouse Gas Emissions data collected from 2015 inventories. All other New England data compiled from 2016 inventories. National Greenhouse Gas Emissions data collected from EPA. Methodologies to calculate sector totals may vary in different states.

²⁷ For additional information, go to: <https://www.eia.gov/environment/CO2EmissionByState2005-2016>

²⁸ For additional information, go to: <https://www.census.gov/quickfacts>

Going Forward

Rhode Island must stay diligent to further reduce our carbon footprint in all sectors to meet the state's 2035 and 2050 reduction targets. To do so, Rhode Island has enacted programs and policies to limit emissions and push the state towards a cleaner future.

On July 8, 2019, Rhode Island's Governor, Gina Raimondo, signed executive order 19-06 highlighting the urgency to transform the heating sector to protect against climate change. The executive order establishes the commitment to reduce emissions in the heating sector while limiting impacts to ratepayer costs, public health and the environment. The Division of Public Utilities and Carriers (DPUC) and the Office of Energy Resources (OER) have been tasked with providing the Governor with heating sector recommendations by 2020.

Rhode Island has also been selected to receive assistance from the National Governors Association (NGA) to integrate electric vehicle measures, to modernize the electrical grid, and to electrify the heating sector. NGA staff, with the help of the U.S. Department of Energy, will provide financial and technical support to lead Rhode Island towards a clean electrical grid.

The Office of Energy Resources has developed a pilot program to save energy and reduce costs in Rhode Island communities. The Achieving Community Efficiency Program (ACE), launched in Spring 2019, has been tasked with reducing energy usage and associated costs in the Towns of Warren, South Kingstown and North Providence and the public-school systems of Barrington, Scituate and North Providence.



The State of Rhode Island stays committed to upholding the Paris Agreement by pursuing ways to limit the temperature increase from rising 2°C above pre-industrial levels. By 2050, the United States pledged to reduce greenhouse gas emissions by 80% of 2005 levels. Executive Order 17-10 outlines the action Rhode Island must take to protect itself from temperature increase, coastal changes, and severe weather events.

Transportation and Climate Initiative (TCI)²⁹

Rhode Island continues efforts to reduce GHG pollution from transportation through the TCI regional low-carbon transportation policy. The TCI policy would work by setting a cap on GHG emissions from cars, trucks, buses and other modes of transportation in the region. The cap would lower each year, meaning less and less pollution would be allowed. Regulated entities would have to purchase allowances at auction for each ton of carbon they emit. Proceeds from the sale of carbon allowances would go toward state projects that further reduce transportation emissions, such as program to boost cleaner public transit.

Zero-Emission Vehicle MOU (ZEV)³⁰

In 2013, the Multi-State ZEV Task Force was formed when the governors of eight states signed a Memorandum of Understanding committing to a coordinated action to support successful implementation of state ZEV programs. Transportation electrification is essential to achieving near and long-term GHG reduction goals.

In 2015, Rhode Island released a state specific ZEV Action Plan identifying key actions necessary to promote the responsible growth of the ZEV market in Rhode Island. The state's Lead by Example Program focuses on increasing ZEVs in the state, municipal, and other public fleets.

The state also rolled out new regulatory framework for its electric system as part of the Rhode Island Power Sector Transformation.³¹ As an important part of transitioning the transportation sector to vehicle electrification and lowering GHG emissions, the grid will be modernized and investments in electric vehicle infrastructure will be made.

²⁹ For additional information, go to: <https://www.TCI.org/RegionalPolicyDesignProcess2019>

³⁰ For additional information, go to: <https://www.nescaum.org/ZEVs>

³¹ For additional information, go to: <http://www.ripuc.org/utilityinfo/electric/PST>

Regional Greenhouse Gas Initiative (RGGI)³²

A significant portion of RIDEM's work has focused on reducing GHG emissions. Since the program's inception in 2009, Rhode Island has participated in the Regional Greenhouse Gas Initiative ("RGGI"), the nation's first market-based regulatory program to reduce carbon dioxide emissions ("CO₂") from the electric sector. RGGI establishes a regional cap on CO₂ emissions from power plants, which declines over time, and by issuing a limited number of tradable allowances. Tradable allowances provide market flexibility for states and emitting power plants to set their own compliance path. Proceeds from the allowance auctions are returned to participating states. Rhode Island's auction proceeds (approximately \$70 million to date) are invested in clean energy and other consumer benefit programs including energy efficiency.

These energy efficiency investments reduce demand for electricity which in turn reduces power plant emissions. Power sector carbon pollution in the RGGI region has declined significantly over the past decade. The RGGI states have experienced more than 50% reduction in power sector carbon pollution since 2005. In December of 2017, the RGGI states committed to further reducing the regional cap on CO₂ emissions an additional 30% by 2030. In part due to the funds from RGGI, Rhode Island is one of the top states in the nation when it comes to energy efficiency.

National Grid Northeast 80x50 Pathway³³

In June 2018, National Grid, one of the nation's largest investor-owned utilities, released the "Northeast 80x50 Pathway," a blue-print for drastically reducing greenhouse gas emissions 80% below 1990 levels by 2050. National Grid's goal is consistent with the states they serve - New York, Massachusetts, and Rhode Island. The Northeast 80x50 Pathway includes in-depth modeling and analysis addressing the three most carbon-intensive sectors in the Northeast - transportation, power generation, and heating.

Conclusion and Future Considerations

This inventory provides a snapshot of 2016 GHG emissions in Rhode Island and an analysis of the three largest emitting sectors in the state. Every three years, RIDEM's Office of Air Resources will update the GHG emissions inventory data. Through this effort of identifying key emissions sources and benchmarking progress, RIDEM will provide the foundational information needed to develop and implement targeted and strategic actions for meeting GHG reduction targets. In the next data update, we will strive to improve by using the most recent science and coordinate GHG emissions accounting methodologies with other bordering states.

³² For additional information, go to: <http://www.dem.ri.gov/RGGI>

³³ For additional information, go to: <https://www.nationalgridus/80x50-White-Paper>