Deeper Decarbonization in the Ocean State:

The 2019 Rhode Island Greenhouse Gas Reduction Study

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Contents:

Executive summary

This study was the result of communications between the Office of the Governor and the Climate and Development Lab at Brown University, indicating that the state could take on more ambitious targets for reducing emissions of greenhouse gases if the efforts were shown to be feasible. Much of the state's 2016 Greenhouse Gas Plan was built on computer models built by the Stockholm Environment Institute's Boston office (SEI), who were contracted again for this study to improve that study's baseline and consider more ambitious pathways of action.

Climate change is real, it's human- caused, it's happening now, and it's happening here. It is even worse than was expected, and the impacts will intensify at an accelerating rate.

Updating science on natural gas leakage rates and methane's impacts in the short term show the state's 2017 emissions are about 45 percent higher than estimated in the 2016 study.

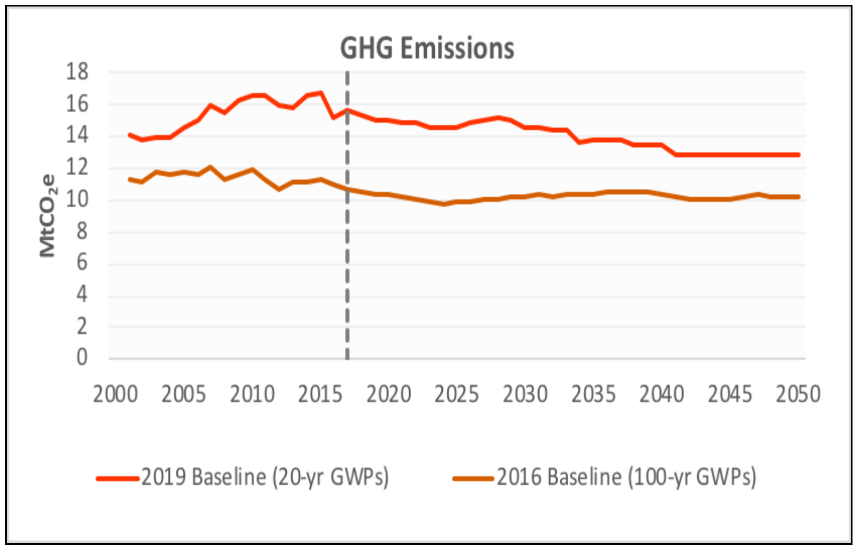
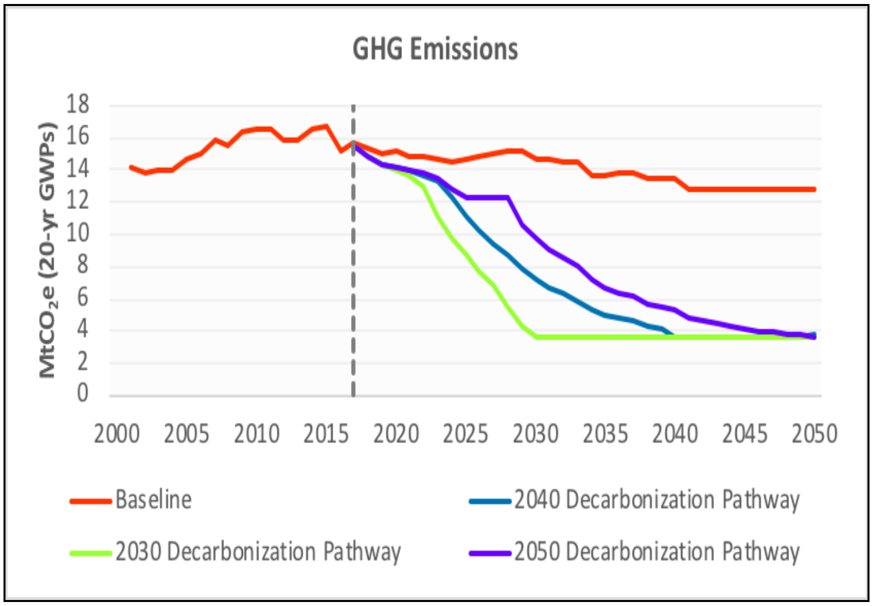


Fig. ES1: Estimated GHG emissions 2016 study baseline vs this study

The targets in the Resilient Rhode Island Act, which guided the 2016 study, were based on science from 1999 and earlier, institutionalized in the 2001 regional climate agreement between Rhode Island and other New England governors and Canadian premieres. In the twenty years since, climate science has advanced rapidly, and it suggests that impacts are coming faster even than some of the worst predictions. At the same time, societal action has barely scratched the surface of changes needed to get off fossil energy and reduce other sources of greenhouse gas emissions. Emissions globally have risen, precisely when they needed to fall. If we had acted two or three decades ago as we knew we had to, then gradual solutions would have been possible. Unfortunately, incremental solutions are now no longer solutions. Business as usual is a recipe for catastrophe.

The goal of this study was not to derive an optimal path, but to improve the 2016 model's scientific rigor and provide "what if" scenarios, to model what technical actions would need to be taken to reach as close to zero net emissions as possible in the state by 2050, 2040, and 2030. Recent scientific assessments suggest that these levels of drastic reductions in emissions are now needed. The study examines only emissions in-state, not including embodied emissions of products we consume here, which research suggests would more than double our carbon footprint.

Rhode Island will reap significant benefits from making a rapid transition off of fossil fuels. Since the state produces none of its own gas, oil or coal, nearly all of the over $3 billion we spend each year buying these products (about 5 percent of Rhode Island GDP) pours out of the state's economy. With an energy system built largely on local sources, with a much smarter grid, and with significant local battery storage, the state could be far more resilient in the face of weather disasters, terrorist attacks, or routine outages. Finally, there are major health benefits to decarbonizing our energy system, such as reducing contamination risks, asthma, and other cardio-pulmonary suffering for thousands of Rhode Islanders who live near energy facilities and highways.



This study's major finding is that emissions can feasibly be reduced 70-80 percent by 2030, 2040 or 2050.

Fig. ES2: 2030, 2040 and 2050 decarbonization pathways vs. baseline case.

To reach beyond the decarbonization approaches from the 2016 study and produce relevant modeling results, we first **revised the baseline scenarios** to include parameters that better describe reality. To do this, SEI updated key indicators to improve historical data and examined the massive impacts of leaking natural gas on climate change in the short term (20-year global warming potential, vs. 100-year in the 2016 study). The study adopted a more realistic leakage rate of methane from natural gas transmission and distribution in-state, updated the impact of methane from the IPCC Second Assessment Report (AR2, which was released in 1995) to Fifth Assessment Report factors (AR5, released in 2014, the most recent report), and modeled a more realistic trajectory for addressing those leaks. The result is seen figure ES1: **due to updated science on natural gas leakage and on its impacts in the short term, the state's emissions are about 45 percent higher than estimated in the 2016 study**.

Figure ES2 compares this study's improved baseline with three decarbonization pathways, seeking to reach near 100% carbon free by 2050, by 2040, and by 2030. **This study's major finding is that emissions can feasibly be reduced 70-80 percent by 2030, 2040 or 2050**, and the implications of doing so are substantial. Continuing on the business as usual pathway will result in hundreds of millions of metric tons of greenhouse gases emitted into the atmosphere that could be avoided. To reduce our impact on the climate system, we need to minimize the amount of carbon dioxide and other greenhouse gases because they remain in the atmosphere for decades or even centuries: **earlier emissions reductions increase the likelihood of maintaining a climate system that can support complex societies** like ours.

Like the 2016 study, this one affirms **three main efforts to get to 70-80 percent emissions reductions: electrify everything (especially cars and heating systems), focus on efficiency, and "green the grid" by replacing coal, gas and oil power plants with renewables.** This study's findings further show the **urgent need to reduce methane emissions specifically**, from natural gas transmission and distribution and other sources, as methane is a much more potent greenhouse gas than carbon dioxide over shorter time scales. The figure also clearly indicates that our pathways do not get us to zero net emissions. All three decarbonization scenarios stall out after getting to about 4 million metric tons of carbon dioxide equivalent emissions. Because we lack rigorous studies on decarbonizing industrial and certain commercial processes, those sectors require more research. Since our baseline is about 15.7 million metric tons, this reduction is a substantial achievement--about a 75 percent reduction from our more rigorous baseline scenario.

lower, toward near net zero emissions. The LEAP model used to generate these model pathways will be made public upon the release of this study, at SEI.org.

The core finding of this study is that 70-80 percent of our state's emissions can be wrung out of our economy *now* by focusing on electrifying transit and heating, sharply improving efficiency, and making other changes in urban form. While we are doing that, we can learn the steps to wring out the last 20-30 percent.

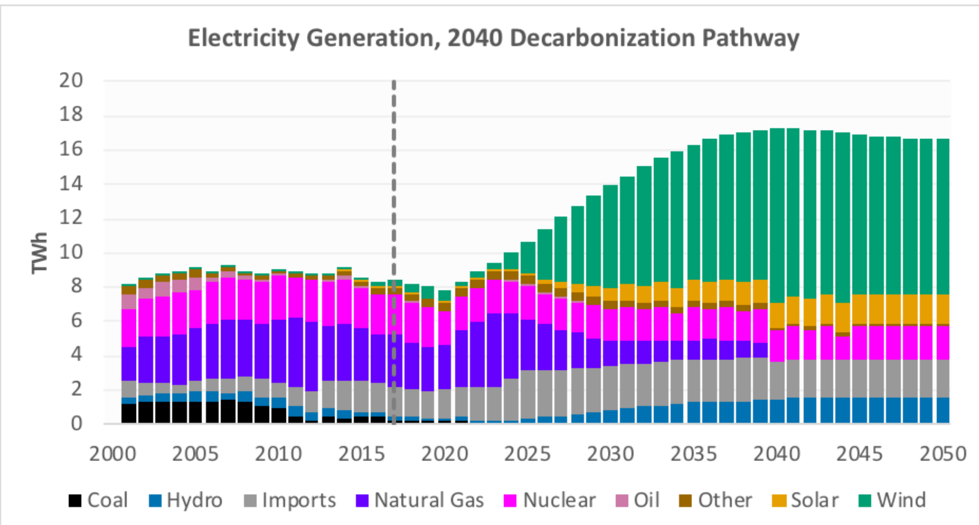


Fig ES3: Offshore wind dominates the energy mix suggested by least-cost pathway modeling of rapid decarbonization by 2040 in Rhode Island.

Still, much is left on the table, to be worked out and requiring further research, policy, and action. In the concluding sections, we lay out a series of areas for future work, especially carbon sinks/sequestration, grid storage, landfill emissions, industrial improvements, behavior change, and equity. **Crucially, this study is only of direct emissions that take place within the state, so all the upstream emissions and other impacts of our consumption are not addressed.** More research is needed to understand the equity implications of these findings, and to identify policy that addresses impacts of climate action and inaction on Rhode Island's frontline communities and on workers in industries that will require major adjustments as we transition off fossil fuels. We are certain there are substantial opportunities to drive these emissions pathways far

This study affirms **three main technical efforts from the 2016 study and adds one more:**

1. **Electrify everything** (especially cars and heating systems);
2. **Focus on efficiency and conservation;**
3. **"Green the grid"** by replacing coal, natural gas and oil power plants with renewables; and
4. **Reduce methane emissions** specifically by addressing leakage from natural gas pipes and transition quickly off the fuel.

Acknowledgements

This study was the result of communications between the Office of the Governor, the Climate and Development Lab at Brown University, and was funded by the Office of the President of Brown University. We wish to thank Governor Gina Raimondo, Former Deputy Chief of Staff Rosemary Powers, Office of Energy Resources Director Carol Grant, and Department of Environmental Management Janet Coit, and Deputy Commissioner of Energy at OER Nick Ucci. Brown University President Christina Paxson provided "innovative learning experiences" funding for this project, for student hourly labor and for recontracting the Stockholm Environment Institute team who ran the original models for important parts of the state's 2016 *Rhode Island Greenhouse Gas Emissions Reduction Plan*. None of the above are responsible for the findings of this study.

The team at the Stockholm Environment Institute was Jason Veysey and Taylor Binnington. The Climate and Development Lab at Brown University team was led by Professor J. Timmons Roberts and included Daniel Traver, Angie Kim, Brett Cotler, Ben Gross, and Matt Ishimaru. We are grateful for the open lines of communication and support with state agencies and the Office of the Governor, and for the opportunity to deliver timely, innovative research to the state's Executive Climate Change Coordinating Council (the EC4) and its Science and Technology Advisory Board (STAB). We acknowledge the use of significant portions of text from the original study in Appendix A, written by staff at state agencies, including Danny Musher at the Office of Energy Resources; these are quoted and cited in text boxes. We hope this study informs ambitious and efficient action in Rhode Island.

Section 1: What are the goals of this study?

Rhode Island has begun to take significant action on climate change, and the pace is quickening. In the early 2000s, the state joined regional agreements to reduce emissions, and in 2014 passed the Resilient Rhode Island (RRI) Act, which established targets for 2020, 2035 and 2050. Those targets, which are technically voluntary, constitute the existing public policy of the state on climate emissions reductions.[1] The RRI Goals were to reduce greenhouse gas emissions from a 1990 baseline by 10 percent by 2020, by 45 percent by 2035, and 80 percent by 2050.[2] As we discuss in Sections 2 and 9, **the 80 percent by 2050 goal is now out of date: we need to decarbonize the Ocean State far more rapidly than previously predicted.**

This study does not seek to develop one pathway for the state to meet emissions reduction targets. Rather, the goal is to improve the 2016 model's scientific rigor and provide "what if" scenarios, seeking to understand what technical actions need to be taken to reach as close to zero net emissions (100% carbon free) in the state by 2050, 2040, and 2030 as possible. The goal is not to reach one pathway/prescription for decarbonization, but to examine how X changes lead to Y possible outcomes, and what set of things have to happen to reach deep decarbonization by these dates. However in response to comments on an earlier draft, we do assess whether the pathways meet basic principles of precaution and equity in Section 9.

Table 1.1: *Targets under the Resilient Rhode Island Act compared to deeper decarbonization pathways examined in this report. Figures are percent reductions of emissions of greenhouse gases below baseline levels). Bold numbers are reductions specified in the 2014 legislation. Right three columns would be from improved baseline estimates in this study, estimated for 2017.*

Year	Resilient RI Act: 80% by 2050	Rapid decarbonization: 100% carbon free by year		
		2050	2040	2030
1990	baseline	--	--	--
2010	0%	--	--	--
2020	**10%**	0%	0%	0%
2025	22%	17%	25%	50%
2030	33%	33%	50%	100%
2035	**45%**	50%	75%	--
2040	57%	67%	100%	--
2045	68%	83%	--	--
2050	**80%**	100%	--	--

A major goal of this study is a list of policy and research tasks that might be undertaken to make these technical and related behavioral changes more likely to take place in the state. This study will add to the decarbonizing policy measures of the 2016 study. The pathways that follow can shed some light upon

[1] Legislation under consideration in recent legislative sessions (the Global Warming Solutions Act) would make the 2035 and 2050 targets binding, and create responsibilities and administrative structure for meeting those targets. There is also a provision for the science of climate change being considered in the revision of the targets.
[2] This is the same year used in the Kyoto Protocol and other major agreements and pledges.

these with modeling and projections; some potential policy interventions need significant further research and policy-making, including the upcoming study of carbon pricing.

A subsidiary goal of this study is to rerun the 2016 study with updated science and **production-based accounting** of state greenhouse gas emissions, which is the customary method used in most state, national, and international analyses. Production- or "generation-based accounting" of greenhouse gas emissions places responsibility for emissions on the jurisdiction in which they occur, where fuels are burned and carbon dioxide, methane, and other GHGs are released. For example, an idling automobile or functioning power plant releasing climate changing gases in Rhode Island counts against Rhode Island's emissions tally. In the 2016 GHG Plan, the state switched to a methodology where the electricity sector alone was counted using a different, "consumption-based, accounting." The **consumption-based accounting** only counted against Rhode Island the emissions of power generating facilities for electricity that would be *used* in Rhode Island. This allowed the state to claim, for example, that only 6 percent of emissions from the major proposed natural gas fired power plant in Burrillville would be counted toward RI's emissions, since 6 percent was Rhode Island's share of electricity use in the integrated New England grid.[3] 94 percent of those emissions would be counted as other states' problem. This may be technically correct, but there is no legal assurance those states would take responsibility for them. No other New England states have officially switched to consumption-based accounting that would have them take responsibility for emissions in Rhode Island.

While **consumption-based accounting** is an excellent tool for understanding our state's impact on the global climate and we encourage the state to study it, to account this way in a complete manner **requires tracing upstream impacts** of all of our consumption, not just electricity use. Below we describe how that effort has only been undertaken by Oregon and San Francisco, although Oregon's research is still underway. In the meantime, without legislation mandating a new accounting method in our state and the others in our electricity service area (all of New England), we elect to return to production-based accounting, which holds jurisdictions responsible for emissions inside their boundaries.

This brings the current study into conformity with the State Guide Plan of 2015, which included the element in the state's *Energy 2035* report and is therefore the law of the land. In practical terms, reverting to production-based accounting means that **the mountain we have to scale is higher**. *Energy 2035* reported that state emissions were about 11.3 million metric tons in the baseline year of 1990, and that our emissions were at a nearly identical level in 2010. To reach even the Resilient Rhode Island Act targets of 80% reductions by 2050, the state needs to reduce those emissions to about 2.3 million metric tons. The current report brings even the 2015 report estimates up to more rigorous scientific standards, as we'll describe, with better accounting for the leakage and impacts of methane.

[3] See, for more explanation of the difference between production and consumption based accounting, and the problem with the partial technique adopted in the 2016 report, the pre-filed direct testimony and rebuttal testimony of J. Timmons Roberts on the Invenergy facility in the Energy Facilities Siting Board. http://www.ripuc.org/efsb/efsb/SB2015_06_CLF_roberts.pdf and http://www.ripuc.org/efsb/EFSB2/SB2015_06_CLF_Roberts2.pdf

Section 2: Why a new study?

It's now plainly perceptible what scientists have been predicting for decades: climate change is real, it's happening now, and it's happening right here. It is worse than was expected, and the impacts will intensify at an accelerating rate. **The targets in the Resilient Rhode Island Act, which guided the 2016 study, were based on science from 1999 and earlier**, institutionalized in the 2001 regional climate agreement between Rhode Island and other New England governors and Canadian premieres.[4] In the twenty years since, climate science has advanced rapidly, and it suggests that impacts are coming faster even than some of the worst predictions. At the same time, societal action has barely scratched the surface of changes needed to get off fossil energy and reduce other sources of greenhouse gas emissions. Emissions globally have risen, precisely when they needed to fall. If we had acted two or three decades ago as we knew we had to, then gradual solutions would have been possible. Unfortunately, incremental solutions are now no longer solutions. Business as usual is a recipe for catastrophe.

The transition to high efficiency and renewable energy has become feasible and economic, as prices of technologies have dropped precipitously

Decarbonization can greatly benefit our state. Rhode Island spends over $3 billion per year on fossil fuel energy, none of which is produced here (EIA, 2016).[5] Reducing energy waste and producing more of our energy in state from renewable resources will keep these billions of dollars in the state, generating jobs and protecting our economy from shortages and price spikes seen in gasoline, diesel, fuel oil and natural gas in recent years. While renewables cost more upfront to install, fuel costs are zero. Fossil fuel energy is extracted far from Rhode Island, fracked and drilled and brought to the state in long-range pipelines, tank trucks, ships and trains, and powerlines. Each is vulnerable to extreme weather, terrorist attacks, leaks and routine outages. **Some recent major weather disasters have shown the benefits of local energy systems which are built for resilience. The transition to high efficiency and renewable energy has become feasible and economic, as prices of technologies have dropped precipitously.** *Forbes* recently reported that "solar photovoltaic (PV) and wind costs have dropped an extraordinary 88% and 69% since 2009, respectively...[and for solar] technological breakthroughs could cut costs up to 80% by 2050."[6]

One local **example of a major Rhode Island institution making an investment in renewable energy and reaping significant economic benefits** is the 2019 power purchase agreement of Brown University of solar and wind power to replace all its purchased electricity. The contracted firms are building a 20 MW solar farm on an abandoned quarry in South County, and another is installing

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[4] The *New England Governors and Eastern Premieres Climate Change Action Plan 2001* reads that "the best science at present that attaining the goal [of avoiding dangerous dangerous threat to the climate] will require GHG emissions reductions of approximately 75-85%." https://digital.library.unt.edu/ark:/67531/metadc226597/

[5] Rhode Island in 2016 was ranked 6th for lowest per capita energy expenditures, at $2866 per person. For a population of 1,057,000 in 2016, this results in an estimate of about $3.03 billion of expenditures on energy by residents of the state. None of the fossil fuel energy is produced in the state.

[6] Mahajan, Megan. Dec. 18. 2018. "Plunging Prices Mean Building New Renewable Energy Is Cheaper Than Running Existing Coal." https://www.forbes.com/sites/energyinnovation/2018/12/03/plunging-prices-mean-building-new-renewable-energy-is-cheaper-than-running-existing-coal/#3f803b2731f3

wind turbines in Texas. In both cases, the contracted costs of this carbon-free electricity are significantly below the rate the university was paying to National Grid for its conventional mix, which includes over 50 percent generated from burning natural gas. The point is, **making this transition now is feasible, it creates jobs, and it has a series of other benefits**. Much of the work to be created in this transition is low-tech, but **the transition also requires many other types of jobs besides just solar installers: we'll need administrators, design specialists, architects, insulators, HVAC installers, electricians, marketers, turbine mechanics, project managers, community relations specialists, maintenance specialists, and on and on**. With good policies and protections, these can be "high road" good jobs.

Three important things are taking place since the 2016 study that this study can inform. First, the Executive Climate Change Coordinating Council (the EC4) is conducting an updated inventory of emissions in 2019 to provide a three year update of the 2016 GHG plan, two years early. The goal is to inform the ramping up of activity in 2020-2025. A major wind farm is being finalized for off Rhode Island's coast between Block Island and Martha's Vineyard. Revolution Wind will increase the state's renewable capacity by 400 megawatts, moving us along towards the Governor's goal of 1,000 MW by 2020. Third, the state's Attorney General's office has allocated $250,000 for a study of carbon pricing, which was mandated by legislation in 2017. The study is to be conducted in the fall of 2019 for completion in February, 2020. The timeline for all three of these is such that a new study is needed, with improved baselines and consideration of what would be needed to more rapidly decarbonize our economy.

More ambition is needed because Rhode Island is small, but we can have an outsized impact. Indeed Rhode Island is responsible for only 0.19 percent of U.S. emissions, and 0.029 percent of global emissions.[7] But if we are not doing our part in meeting the Paris Agreement's goal of keeping global warming "well below 2 degrees C" and as close to 1.5 degrees as possible, who will? Everyone can say they are not important, by themselves, in causing global climate change. But by each claiming this, we all drown. By decarbonizing, we can show the way, pioneering new policy and technology and becoming a hub for innovation and investment. We will speak with authority as ones who have done all they could. Rhode Island can be a leader, bringing along its region and nation. The U.S. is the largest historical emitter in the world. Now, we need to lead on reducing emissions.

Crucially, **the state also will reap significant benefits from making a rapid transition off of fossil fuels**. Since the state produces none of its own gas, oil or coal, nearly all of the over $3 billion it spends each year on these products pours out of the state's nearly $60 billion a year economy. **This is 5 percent of our economy that could be spent creating jobs here.** With an energy system built largely on local sources with a much smarter grid and significant local battery storage, the state will be far more resilient in the face of weather disasters, terrorist attacks or routine outages. The state's experience with spending $60 million of federal funds from the 2008 ARRA stimulus package on energy efficiency had significant impact here on emissions and efficiency, and began the surge in clean energy jobs.[8]

> Over $3 billion spent on fossil fuels pours out of the state economy each year: that's about 5 percent of the state GDP

Finally, there are major health benefits to decarbonizing. A 2016 study by the American Lung Association, for example, estimated that electrifying

[7] For RI's Share of US emissions see: https://www.eia.gov/environment/emissions/state/, For US share of Global Emissions See: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

[8] See the 2018 Rhode Island Clean Energy Industry Report, Office of Energy Resources. http://www.energy.ri.gov/cleanjobs/2018/2018%20RI%20Clean%20Energy%20Industry%20Report.pdf

our vehicles would bring down the health costs of hospitalization of asthma and other cardiovascular and cardiopulmonary patients, saving the country $21 billion a year.[9] That this effect would be seen in Rhode Island is supported by recent research from the state Department of Health showing the greatest air pollution and asthma levels downwind of our major interstates, I-95 and I-195, and Routes 6 and 10. These are just some of the benefits of this transformation: having a livable and healthy future is almost by definition not a benefit that can be put in dollar terms. **Our goal is to help the state develop a set of policy options to substantially reduce greenhouse gas emissions in key areas, and to provide an informational resource to guide prioritization of those decisions.**

[9] Holmes-Gen, Bonnie and Will Barrett. October 2016. "Clean Air Future: Health and Climate Benefits of Zero Emission Vehicles; A report by the American Lung Association in California." https://www.lung.org/local-content/california/documents/2016zeroemissions.pdf.

Section 3: What was done in the 2016 GHG plan?

To fulfill its mandate under the Resilient Rhode Island Act, the Executive Climate Change Coordinating Council (EC4) commissioned a *Rhode Island Greenhouse Gas Emissions Reduction Study* (the 2016 Study) to inform the development of a statewide GHG mitigation plan.[10] The EC4 commissioned Northeast States for Coordinated Air Use Management (NESCAUM) to develop the study, with the support of the Stockholm Environment Institute's Boston staff and Abt Associates. The EC4 established a project team composed of staff from the Rhode Island Department of Environmental Management (DEM), the Rhode Island Office of Energy Resources (OER), the Rhode Island Department of Transportation (DOT) and the Rhode Island Division of Planning (DOP) to oversee management of the study's development. Finally, the EC4 established a Technical Committee to participate in the development of the study and provide feedback on key draft work products and deliverables. The Technical Committee consisted of a targeted group of climate and energy stakeholders with subject matter expertise and experience in their respective areas. The Technical Committee met six times over the course of 2016 to provide ongoing input into the study's development.

The core modelling for the study was conducted by the Stockholm Environment Institute (SEI). The same team at SEI was contracted for this study to create updated baselines, projections and recommendations for deeper decarbonization pathways for the state, and to examine their feasibility and likely cost. That study utilized the LEAP model, Long-range Energy Alternatives Planning System, a software tool for energy policy analysis and emissions reduction assessment which has now been used for studies around the world.[11]

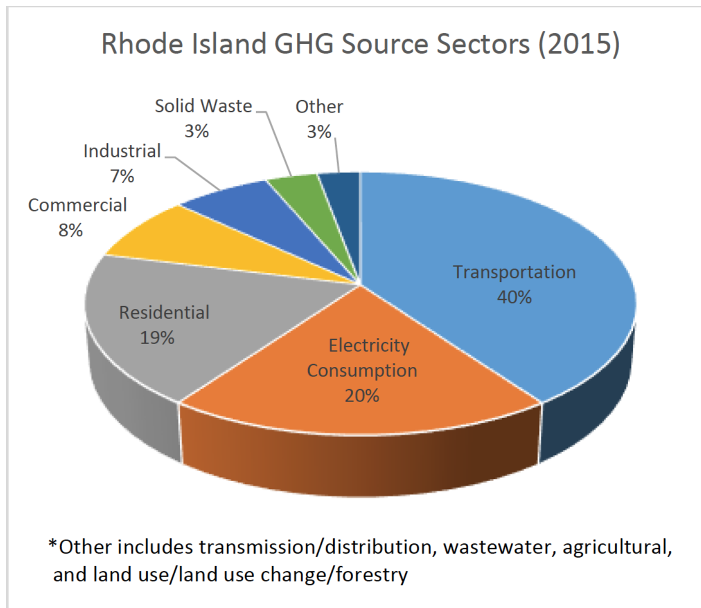

***Figure. 3.1** Approximate proportions of state greenhouse gases from different sectors (2016 plan).*

The 2016 study presented the state's current profile of greenhouse gas emissions. By that report's accounting, **Rhode Island's most significant GHG source sectors are, in order: transportation, electric power consumption, residential buildings, commercial buildings, and industry** (Figure 3.1). Transportation-related GHG emissions are caused by

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[10] The 2016 study can be found at http://climatechange.ri.gov/documents/ec4-ghg-emissions-reduction-plan-final-draft-2016-12-29-clean.pdf

[11] More on LEAP is at: https://www.energycommunity.org/default.asp?action=introduction

fuel consumption in on-road vehicles (e.g., light-duty cars and trucks, short- and long-haul trucking, and buses) and off-road sources (e.g., marine vessels, aircraft, construction and agricultural equipment, and rail).

Electricity consumption-related emissions are caused by electricity usage in all sectors, for applications such as lighting, air conditioning, appliances and devices, and space/water heating. Residential, commercial, and industrial GHG emissions are caused by fuel consumption in buildings, primarily for space and water heating (as well as cooking), and for process heat generation and mechanical assembly in industrial applications. In 2015, Rhode Island's greenhouse gas emissions were estimated at 10.5 million metric tons CO2e, a number we will show below needs to be updated based on more current science.

This deeper decarbonization study strongly affirms the first three steps in the 2016 plan: the state should focus on "electrifying everything," sharply improving energy efficiency and cutting waste, and replacing fossil fuels with renewables (so called "greening the grid"). Liquid fuels are nearly eliminated in our decarbonization pathways--because it results in probably 50 percent of liquid fossil fuel emissions, switching to biofuels is at best a half-measure, as discussed below.

The 2016 study provided a wealth of information for planners and policy-makers in Rhode Island. The study gave a first look at what the main options were for the state to sharply reduce its emissions of greenhouse gases, and showed what it might take for the state to meet the 80 percent reduction goal by 2050 in the Resilient RI Act. In particular, the study showed four main categories of approaches that need to be taken to remove carbon emissions from our economy: energy efficiency, electrification, decarbonization of electricity, and finally the decarbonization of other fuels (Table 3.1).

Table 3.1. *Categories for Deep Decarbonization in the 2016 GHG Plan.*

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

Section 4: How is this study different?

4.1 Improving the baseline

This study seeks to significantly improve how current science is reflected in state estimates and planning on climate change. For this modeling, we began by **updating historical data** used as inputs to the baseline. The scope of our project didn't allow us to update all of the historical data in the model, but we refreshed key data on historical energy demand and electricity exports from ISO-New England.

Table 4.2: *New baseline scenario vs 2016 study*

Baseline	2016 GHG Plan Baseline (Updated)	2019 Baseline improved baseline
Source for Global Warming Potentials (IPCC reports)	AR2 (Second Assessment Report of science, published 1995)	AR5 (IPCC Fifth Assessment Report, published 2014)
GWP Time Horizon	100-year	20-year
Natural Gas Leakage Estimate	0.66%	2.70%
Accounting of Electricity Emissions	Consumption	Production
2017 emissions estimates	10.8 MtCO2e	15.7 MtCO2e

An important area where the science has progressed is in contributions to warming expected from the major greenhouse gases. The 2016 GHG Plan used data from the Second Assessment Report of the Intergovernmental Panel on Climate Change (AR2), which was released in 1995 and was based on science from before that. **We updated Global Warming Potentials (GWPs) of the key greenhouse gases, using the latest Fifth Assessment Report (AR5) of the IPCC, released in 2014.**[12]

Leaked methane's impact is now seen to be far greater than earlier estimates, especially over the shorter term, since it breaks down far faster than the main greenhouse gas, carbon dioxide, which can remain in the atmosphere warming the planet for centuries. Many climate impacts, such as the melting of the permafrost and polar ice caps, are likely to worsen sharply in the next 20 years, and are expected to create cascades of worsening problems. These include the release of massive amounts of methane from melting tundra, and the absorption of sunlight into polar oceans which until recently reflected that light and heat. **From a warming perspective, methane is 86 times worse than carbon dioxide per unit mass in the short term (20 years)**. Therefore to prioritize *prevention* of near-term warming and impacts, the **20-year time horizon is a more rigorous reflection of what we need to do to assure a liveable planet** in general terms, and to stop runaway sea level rise and other impacts for Rhode Island more specifically. Therefore this report analyzes 20-year Global Warming Potentials (GWPs)--the average impacts each unit mass of greenhouse gases will have over 20 years, compared to carbon dioxide.

[12] The 1995 summary AR2 levels are laid out here: https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials. A comparison of radiative forcing factors for methane vs. CO2 in the different assessment reports is here: http://www.sef.org.nz/climatechange/4%20The%20Importance%20of%20Methane%20v5.1.pdf.

Studies suggest we need also to update the science on what **rate methane (natural gas) is leaking in the state**. The 2016 Study used an effective leakage rate of 0.66% of natural gas supplied each year. Based on the best available research, the new scenarios model the rate of leakage at 2.7%, decreasing in accordance with National Grid's proactive leak replacement plan in the Gas Infrastructure, Safety, and Reliability Plan FY 2020 Proposal.[13] See Section 4.2 below for details of the model inputs on methane leakage. Like the 2016 study, this study does not consider emissions from natural gas transmission and distribution occurring outside RI's borders--this is crucial work that should be conducted, and may represent significant increases in the state's warming impact.[14]

As mentioned above and discussed below, the models in this study were run with ***production-based* (generation-based) accounting**, which has been the practice in all planning documents and national statistical reports before the 2016 Greenhouse Gas Emissions Reduction Plan. That plan used *consumption-based* accounting for emissions from electricity supply. **Under production or "generation-based" accounting, all emissions from all sources in Rhode Island are counted against the state's total emissions.** There are positives and negatives to this approach (see Section 4.2). For example, all the food and consumer goods we buy in Rhode Island were produced with substantial inputs of fossil fuel energy around the world. Those emissions are not counted in Rhode Island's total, and would certainly increase that total substantially. It would be right for us to take responsibility for these.

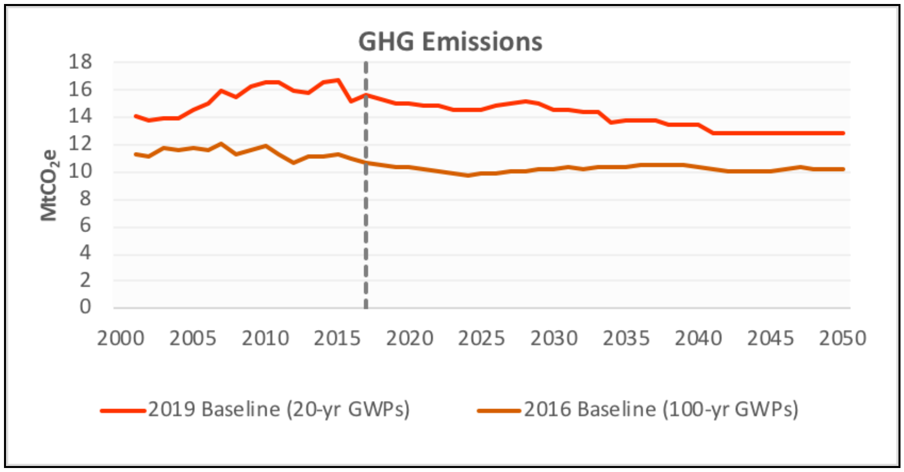

***Figure 4.1:** Greenhouse gas emissions (MtCO2e) for the new baseline and the original 2016 report baseline. The 2016 GHG Plan utilized 100-year global warming potential of methane and lower leakage rates; this 2019 study updates leakage rates and uses 20-year factor for methane's impact.*

However, production-based accounting is much easier to implement and remains the standard in academic research and public policy. And crucially, the state of **Rhode Island currently only has jurisdictional authority over emissions in its own territory.** This fact supports the value of focusing for now on emissions in state: we have no control over promises by other states to reduce emissions.
In conducting this study, our choices on GWPs, methane leakage, and electricity emissions accounting led to multiple possible baselines. We elected to focus on one, with 20 year GWP, a 2.7 percent methane leakage rate, production-based accounting, and the updated IPCC AR5 warming potentials (Table 4.2). As a result, **baseline emissions in 2017 went from 10.8 million metric tons of carbon dioxide equivalents in the 2016 study to 15.7 MtCO2e. This is a 45 percent higher estimated**

[13] See RIPUC Docket No. 4916 http://www.ripuc.org/eventsactions/docket/4916page.html
[14] For example, power plants and transmission lines are seen to emit far more than industry reported rates. See e.g. T. N. Lavoie et al., "Assessing the Methane Emissions from Natural Gas-Fired Power Plants and Oil Refineries." In: Environmental Science & Technology 51.6 (2017), pp. 3373–3381. http://pubs.acs.org/doi/pdfplus/10.1021/acs.est.6b05531

emissions total for Rhode Island. Differences slowly decline between the 2016 study's baseline and the improved one used in this report, but remain significant over the study period (Fig. 4.1).

This study also differs from the 2016 GHG Plan in that in our decarbonization pathway scenarios, **we have removed two expected increases in natural gas combustion for electricity generation:** the Invenergy natural gas power plant proposed for Burrillville, Rhode Island, which has become unlikely and will be unneeded if emission reduction efforts take place, and the previously planned uprating of the Tiverton power plant, which according to USEIA did not occur. These are left in the updated baseline scenario.

Finally, we made a number of other changes in the updated baseline to correct errors in the model and to increase realism and robustness. **We improved baseline modeling of:**

- Commercial non-building energy demand by correcting calibrations to historical data.
- Industrial and commercial ethanol demand by linking it to gasoline consumption.
- Transportation, industrial, and commercial emissions by correcting some emission factors and adding missing emission factors.
- Electricity generation by more realistically simulating dispatch of certain plants.
- Electricity generation costs by properly accounting for input fuel costs.
- Demand-side costs by adding costs for certain industrial, commercial, and residential heating and cooling technologies.
- Transportation by implementing a stock model of on-road vehicles based on Argonne National Laboratory's VISION model (which in turn is based on USEIA's National Energy Modeling System [NEMS]).[15]
- Transportation energy demand by including categories of off-road equipment that were missing in the 2016 study:
    - Construction - diesel
    - Industrial - gasoline
    - Lawn - gasoline, LPG, diesel
- Rail energy demand by allowing for biodiesel blending in diesel used for rail.

Details of all these assumptions and updates are in the LEAP models made public upon the release of this study.

> Baseline emissions in 2017 went from 10.8 million metric tons of carbon dioxide equivalents in the 2016 study to 15.7 MtCO2e. This is a 45 percent higher estimated emissions total for Rhode Island, largely as the result of updating science on methane leakage from natural gas pipes.

[15] Argonne National Laboratory (2018). VISION Model, 2018 Version. https://www.anl.gov/es/vision-model.

4.2 How Should We Account for Emissions?

What emissions are Rhode Island responsible for? This is a very complex issue, and each approach to addressing it has positive and negative sides.

Through decades of international negotiations and national and state-level planning to address climate change by reducing greenhouse gas emissions, these jurisdictions have counted only the direct emissions that occur in their own territories. This is called "production-based" or "generation-based" accounting. Of course the situation is far more complex, for example as power lines cross state or national lines, leaving emissions from burning fossil fuels on one side of the line and consumers of the electricity on the other. Even worse, all the products consumed in one place may be made using processes and materials that resulted in major emissions of greenhouse gases elsewhere. Ideally, one would count those emissions against the people and units that are gaining the benefits from consuming those products and electricity, not just where the supply chain happen to be located.

> Research elsewhere suggests that the state's actual impact on climate change is probably three times higher than what is emitted locally

Oregon and San Francisco are studying the feasibility of accounting for all those emissions; methodologically it is difficult, but doing so would be a more honest assessment of our impact on the global climate system. An **Oregon Department of Environmental Quality study** found that 66 percent of emissions attributable to consumption in the state were not emitted in Oregon. That is, **the state's actual impact on climate change is probably three times higher than what is emitted locally**.[16] The distortions of production-based accounting allow nations, states and regions to export energy-consumptive stages of supply chains, creating the impression they are sharply reducing emissions. Full consumption-based accounting would be the gold standard for an emissions reduction plan such as this one. Firms and institutions like universities are attempting to understand and reduce these indirect emissions, but we are still without good data for many of the pathways and practices for

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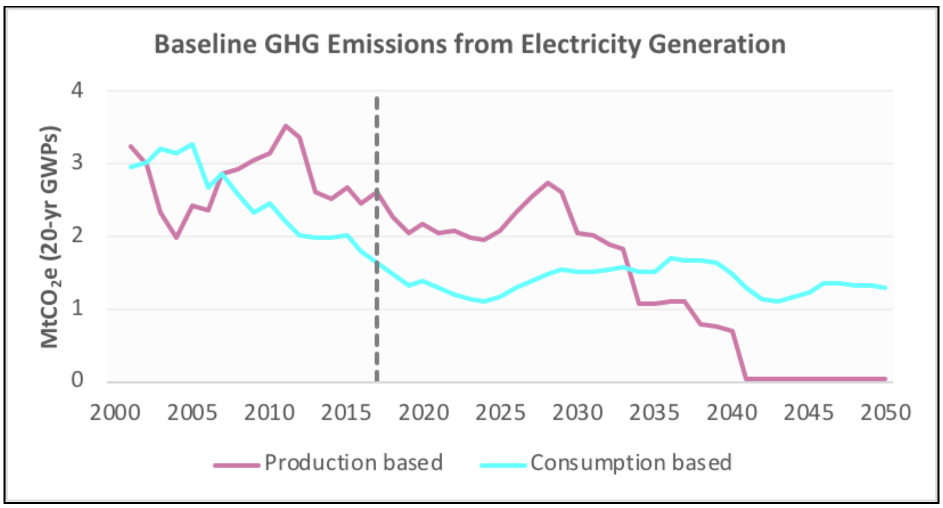
[16] Oregon Department of Environmental Quality. N.d. "Consumption-based Greenhouse Gas Emissions Inventory for Oregon." https://www.oregon.gov/deq/mm/Pages/Consumption-based-GHG.aspx. See also David Allaway. N.d. "Oregon's New Carbon Footprint of Consumption." Oregon State Bar Sustainable Future Sector. https://sustainablefuture.osbar.org/section-newsletter/20114winter4allaway/.
Davis, Steven J., and Ken Caldeira. 2010. "Consumption-based accounting of CO2 emissions." *Proceedings of the National Academy of Sciences* 107, no. 12: 5687-5692. The Oregon Department of Environmental Quality outlines the state's complete consumption-based accounting system. Their consumption-based system measures the emissions due to production, use, and disposal of a product. This system is used as a supplement to an inventory-based accounting system, which is more similar to production in that it includes all of the emissions that occur specifically within the geographic boundaries of the state, in addition to imported energy use emissions. The Oregon system considers three end-use categories: households, governments, and capital investment. Oregon also groups demand for 509 different commodities into four broad categories: electricity, fuels, materials, and services. After grouping organizing emissions sources into these broad categories, Oregon calculated emissions intensities using a complete life-cycle analysis of emissions per dollar spent. Their life-cycle estimates incorporate five-phases, in place of the conventional three-phase analysis. Oregon's analysis concluded that the emissions intensities of materials and services are less than electricity and fuels. A shift towards these modes of consumption can contribute to a transition to a greener economy. This model also identifies the household materials with the highest emissions intensities.

accounting are not yet consistent and formally agreed.

In the *2016 Greenhouse Gas Emissions Reduction Plan*, **Rhode Island adopted a *partial* consumption-based accounting methodology**. The 2016 plan adjusted the state's total emissions by "GHG emissions associated with electricity used within the state."[17] Leaving broader emissions impacts out of their models, the state focused on the electricity sector. Rhode Island is part of the New England electrical grid controlled by ISO-New England, consuming about 6 percent of all electricity produced on that grid. The 2016 study counted only that proportion of emissions generated by power stations in New England: 6 percent. This allowed the state to not count the full emissions from existing and planned natural gas fired power plants in Rhode Island.[18] The results are clear from Figure 4.2: in 2017 the difference is **about 1 million metric tons of carbon dioxide equivalent which are unaccounted for with consumption-based accounting for electricity**, as utilized in the 2016 study.



As mentioned above, there are advantages to consumption-based accounting if done well, and indeed Rhode Island is part of a regional electricity grid. However the other states on our grid have not enacted laws forcing them to count the proportions of emissions generated in Rhode Island but associated with their own consumption of electricity. This matters because if a major power plant were sited in Rhode Island, it would not be counted on the other states' ledgers. Without unified rules mandating strict and complete consumption-based accounting across the region, switching to that methodology is problematic. Most importantly, **states can only regulate the sources of pollution within their own borders.** Therefore in this report we compare production (generation) and consumption-based accounting, and return to the use of production-based accounting. This method brings our report in line with most previous emissions accounting in the state and region, and the state guide plan.

One final related issue arises as Rhode Island takes the initiative to license and/or site major offshore wind facilities, or Rhode Island ratepayers pay for **major renewable or energy storage facilities in federal waters** or in the territory of other states. If Rhode Island is responsible for initiatives to reduce its total carbon emissions, the state should be credited with the full production from those facilities. If other states site wind farms offshore whose electricity comes ashore in Rhode Island, that should not be credited to the state. If the state is a proportional investor in larger projects, the

Figure 4.2: *Comparison of Rhode Island emissions estimates for electricity generation derived from production- and consumption-based accounting (see text).*

[17] RIEC4. 2016. *2016 Greenhouse Gas Emissions Reduction Plan*. p. 7 footnote 2.

[18] See Pre-filed Direct Testimony and Pre-filed Rebuttal Testimony of J. Timmons Roberts at the Rhode Island Energy Facilities Siting Board In Re: Application of Invenergy Thermal Development LLC's Proposal for Clear River Energy Center. Docket SB 2015-16. https://www.clf.org/wp-content/uploads/2016/03/Timmons-Roberts-Testimony.pdf ; http://www.ripuc.org/efsb/EFSB2/SB2015_06_CLF_Roberts2.pdf

state should take credit for its share of renewable energy production. This might be the case for offshore wind projects or pumped hydro facilities that the state licenses or pays for in federal waters or elsewhere in the region or nation, and we have modeled Rhode Island taking credit for offshore wind it facilitates, even those beyond its territorial waters.

4.3: Addressing a major issue: Natural gas/methane leakage

A major finding of this study is that methane presents a serious challenge to reducing Rhode Island's emissions. The main source of methane emissions in Rhode Island is **natural gas leaks**. Natural gas is approximately 90% methane, and there are leaks at nearly every part of the production and distribution process. Studies of natural gas leakage have shown that in addition to leaks from pipelines, major leaks also come from compressor stations, production facilities, gas plants, and other sources.[19] Because this study uses (production-based) accounting of only emissions in Rhode Island (see Sections 4.1 and 4.2), it does not consider the emissions produced out of state through natural gas production facilities, gas plants, or other out of state leakage sources, though they are intrinsically tied to Rhode Island's natural gas usage. Future studies should seek to improve on this accounting (see also Section 4.2).

> Science suggests a methane leak rate four times that used in the 2016 study. National Grid should be required to frequently measure and publicly report gas leaks and provide projections of expected emissions

The 2016 model used the EPA's State Inventory Tool for an estimate of methane leakage. Several studies have shown that the EPA's leakage rate far underestimates the amount of natural gas actually lost in areas with old gas pipes, like Southern New England. A potential explanation for this discrepancy comes from "superemitters," leaks that release a disproportionate share of natural gas. A recent study in Boston, a city with a comparable makeup of pipelines (by material type and age) as Providence, showed that 50 percent of the methane came from just 7 percent of the leaks.[20] Without a similar study in Rhode Island, the exact leakage rate remains unknown. To improve our new scenarios, we updated the leakage rate to reflect the best available information on natural gas leakage. The most representative study of gas leaks comes from McKain et al. 2015, which found a **leakage rate of 2.7 percent** in Boston. Since the composition of the pipes in Boston closely reflects that of Providence, it was deemed most appropriate to use the 2.7% rate in our modeling.[21]

National Grid currently has plans to **repair or replace all of the leak prone pipes by 2035**, so we attempted to include the expected decrease in emissions that will result from that work.[22] Because National Grid does not publish how much gas they lose from specific leaks, it is difficult to estimate the expected leakage rate after all the repairs have been completed. Our attempt to model this involved using the same estimation technique that National Grid uses, which comes from the EPA's State Inventory Tools.[23] We estimated the emissions following

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[19]See e.g. David A. Kirchgessner, Robert A. Lott, R. Michael Cowgill, Matthew R. Harrison, Theresa M. Shires. "Estimate of methane emissions from the U.S. natural gas industry." https://www3.epa.gov/ttn/chief/old/efdocs/methane_dec2000.pdf

[20] Phillips et al., 2016, Fugitive Methane Emissions from Leak-prone Natural Gas Distribution Infrastructure in Urban Systems. https://doi.org/10.1016/j.envpol.2016.01.094

[21] The McKain et al. Study can be found at https://www.pnas.org/content/112/7/1941. Several other studies were considered, including Alvarez et al. 2018 (2.3 percent), Zimmerle et al. 2015, Jackson et al. 2015, and Littlefield et al. 2017, but the 2.7% rate from the McKain et al. Study was deemed the best approximation of Rhode Island emissions.

[22] National Grid's Proposed 2020 Gas Infrastructure Safety and Reliability Plan: http://www.ripuc.org/eventsactions/docket/4916-NGrid-FY2020%20Gas%20ISR%20Plan%20(12-20-18).pdf

[23]Docket 4916 - National Grid's Proposed FY 2020 Gas Infrastructure, Safety, and Reliability Plan Responses to PUC Data Requests – Set 3

National Grid's complete replacement of the leak prone pipes using the State Inventory Tool and EPA guidelines. We assumed this rate would persist after 2035 and interpolated between that rate and the 2.7% rate.[24] Because National Grid has and continues to follow a nearly linear rate of pipeline replacement, we believed this was presently the closest approximation to reality.

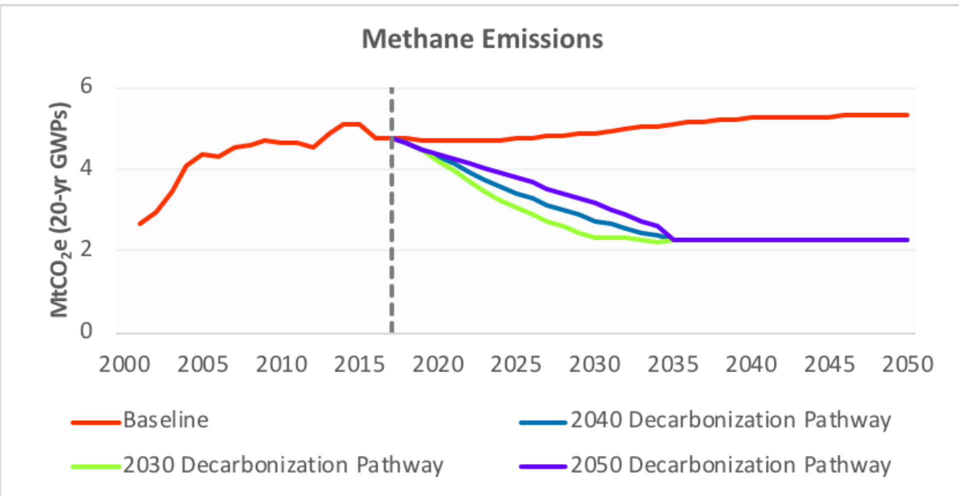

***Figure 4.3** Comparison of methane emissions (in CO2 equivalents) in the four scenarios: baseline and 2050, 2040, and 2030 decarbonization.*

If National Grid tracked - and made publicly available - additional information regarding the leakage rates of the pipelines under repair, then more realistic projections might be made. If there are super emitters that will be remedied more quickly, this information could be used to improve estimates, but new leaks will always be identified. Currently, National Grid reports looking at factors such as leak repair history, pipe material and nearby construction to decide when certain miles of leak prone pipe need to be replaced.[25] **A basic recommendation is that National Grid should be required to frequently measure and report the locations and number of leaks from pipelines and gas infrastructure. It should also report an overall leakage rate for the state of Rhode Island, and provide projections of expected emissions with different amounts of investment going forward.** Ideally, replacement would prioritize safety and higher leaking pipes which are located through a direct measurement of emissions instead of relying on historical information.

Our improved modeling shows that methane accounts for about 4 million metric tons (MtCO2e) of Rhode Island's approximately 15 MtCO2e emissions through the early 2020s, under all scenarios, and drops to about 2 MtCO2e even under the most ambitious reduction targets (Figure 4.4a,b). Given the high potency of methane, up to 85 times worse than carbon dioxide per unit mass in the short term, this suggests that to truly decarbonize our state and legitimately reach targets informed by the latest science, **eliminating methane releases needs to be at the top of the priority list**. In the very short term, that means National Grid must make more ambitious efforts to completely replace all leak prone pipes and leaking compressors. In the medium term, the state has urgently to shift off fossil natural gas entirely.

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http://www.ripuc.org/eventsactions/docket/4916-NGird-DR-PUC3%20(3-1-19).pdf

[24] There is no reference in the 2020 Gas ISR plan to emissions reductions beyond 2035.

[25] An expert witness in National Grid's Gas Infrastructure, Reliability, and Safety Plan for 2020 did not consider National Grid's method's sufficiently accurate. He requested that, "for the Company to develop and maintain a global list of all the aging leak prone infrastructure segments risk ranked in its overall replacement program. If the Company has developed and maintains such a list, then the company should provide the list to the Division. If it does not possess such a list, it should clarify what is needed to develop such a list in the shortest timeframe possible." Walker 3, Prefiled Subrebuttal Testimony of Rod Walker February 26th, 2019. National Grid. 2020 Gas ISR Plan. Docket 4916 - National Grid's Proposed FY 2020 Gas Infrastructure, Safety, and Reliability Plan Responses to PUC Data Requests – Set 3 http://www.ripuc.org/eventsactions/docket/4916-NGird-DR-PUC3%20(3-1-19).pdf

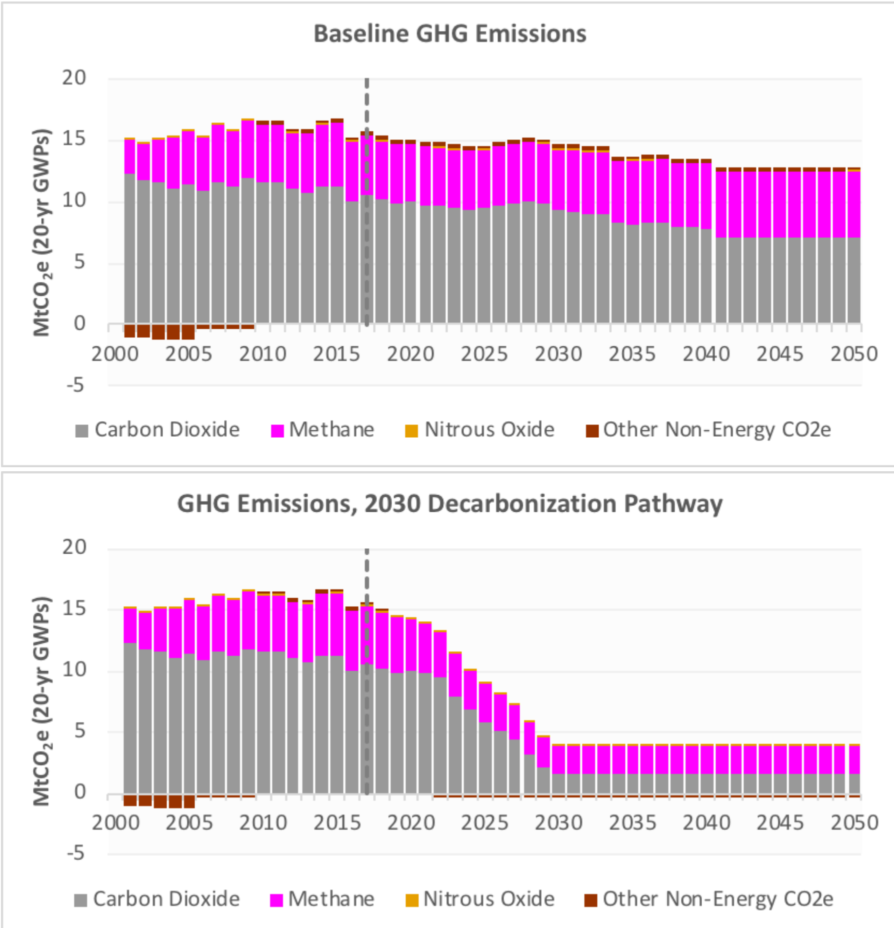

***Figure 4.4a, b:** Methane impacts on Rhode Island's total greenhouse gas emissions under the improved baseline case (a) and 2030 decarbonization pathway (b).*

The state's landfills also are leaking methane, and this has to be addressed urgently. According to the Rhode Island Department of Environmental Management, the state has two active landfills and several dozen inactive landfills.[26] All of these are probably leaking methane, but options to reduce these emissions are limited. The leading mitigation option for emissions from buried waste is landfill gas (LFG) capture. This option has been implemented at the most significant active landfill, Central Landfill in Johnston, as well as at one or two other locations. However, the technology isn't 100% effective, so some methane emissions continue after implementation. It's also impractical for small landfills, a category that probably includes most of the inactive sites in Rhode Island. And the burning of landfill gas, of course, produces carbon dioxide, a greenhouse gas.

Ultimately, **for Rhode Island to be completely carbon neutral, natural gas cannot be a part of the fuel mix.** The forestry sink in RI is not large enough to overcome the methane and carbon emissions associated with the use of natural gas.

Even if carbon capture were somehow instituted for all the gas burners in the state, methane will continue to leak from even the newest compressors, and construction and settling will break pipelines. The scenario projections that follow therefore include a phase-out of natural gas equipment like furnaces and water heaters.[27] At some point, natural gas pipelines and compressors can be removed from the state, or emptied of gas and abandoned, piecemeal by neighborhood or all at once. We were unable to find any evidence that such a plan exists, but the persistence and difficulty of eliminating methane emissions in this study show it is past time to develop one.

[26] RIDEM. " List: all active/inactive waste management facilities http://www.dem.ri.gov/programs/benviron/waste/pdf/swfacs.pdf

[27] See below. The 2016 plan modeled the natural rate of retirement of existing equipment assuming that 1/10th of all this equipment would retire each year until complete retirement. However the study modeled that 10 percent rate exponentially decreasing, which never reaches zero. The current study uses the 10 percent rate, reaching basically zero-carbon heating by 2040.

Section 5: What did we find?

5.1 What was the approach?

The new model examined scenarios with more ambitious approaches than considered in the 2016 study, including more aggressive decarbonization of the electricity supply, electrification of heating, and adoption of electric vehicles.

With a new, more robust baseline that better reflects the reality of Rhode Island's greenhouse gas emissions, we can more accurately assess mitigation options and devise pathways for action. **The new model examined scenarios with more ambitious approaches than considered in the 2016 study, including more aggressive decarbonization of the electricity supply, electrification of heating, and adoption of electric vehicles.** The model included work on different speeds of decommissioning and retention of different fossil fuel and nuclear power plants (namely Pilgrim, Millstone 2 & 3) as back up power as renewables and storage are put on to the electric grid. The model extended and expanded upon existing least cost procurement and other building efficiency policies where applicable.

The 2016 report zeroed out emissions for solid waste after 2038 when the Johnston landfill is expected to close. That is not plausible. The **new model assumed that landfill emissions remain constant after 2038 even if Johnston landfill closes**, taking into account both emissions from future waste management and residual methane leakage from closed landfills. The state cannot count on dumping this problem on neighboring states, who will also be attempting to meet their own emissions targets.

As with the 2016 plan, the modeling for this study was performed with the Long-range Energy Alternatives Planning system (LEAP).[28] The LEAP model created for the 2016 analysis was taken as a starting point and improved with corrections and new pathways (including rough estimates of direct costs of the energy system and mitigation strategies). The 2019 study points to the need to examine how broader behavioral and lifestyle changes may lead to more ambitious scenarios on different timelines, as well as a need to investigate reduction strategies for certain hard-to-mitigate sources like industrial processes and landfill gases. Much of this work is left for future studies, as discussed in the final section.

[28] See https://www.energycommunity.org.

5.2 How low can we go? Overall emissions reductions

Figure 5.1 compares this study's improved baseline with three decarbonization pathways, seeking to reach near 100% carbon free by 2050, 2040, and 2030. It also compares the effects of using the more rigorous metrics of methane's impacts on the climate. **This study's major finding is that emissions can be reduced dramatically by each of those years**, and the implications of doing so is substantial. Continuing on the business as usual pathway will result in millions of metric tons of greenhouse gases emitted into the atmosphere that could have been avoided. To reduce our impact on the climate system, we **need to minimize the space under the emissions curve, because carbon dioxide remains in the atmosphere for decades**. This is why earlier emissions reductions increase the likelihood of maintaining a climate system that can support complex societies like ours.[29] Accounting for total emissions we might be able to emit without causing dangerous climate change, wealthy nations like the USA have already spent nearly all our "carbon budget." This suggests that the most morally and practically viable pathway for avoiding catastrophic impacts is the one that most quickly brings us to zero emissions--the 2030 pathway (see Section 9). Second, these figures also clearly indicate that **our pathways do not get us to zero net emissions**. All three decarbonization scenarios stall out after getting to about 4 million metric tons of emissions (with the 20 year GWP horizon), or about 2.2 MtCO2e (with the 100 year GWP horizon). Since our baseline is about 10-12 MtCO2e in the 100-year global warming timeframe, and 14-16 MtCO2e with a 20-year warming horizon, this reduction is a substantial achievement--about a 70-80 percent reduction from our improved (more rigorous) baseline scenario. Still, much is left on the table, still to be worked out. In particular, our pathways demand only minor improvements in energy efficiency by industry and commerce.

As a reminder, Figure 5.1b and all further figures besides 5.1a specifically consider the 20 year global warming potential of emissions estimates. In doing so, they further emphasizes the need to reduce methane emissions, as methane is a much more potent greenhouse gas than carbon dioxide over shorter time scales. Figure 5.1b therefore highlights the importance of reducing methane leakage in pipes, pipelines and compressor stations along the natural gas supply chain, and in home and business supply lines and appliances.

Finally, the reason for the lack of improvement beyond the 70-80 percent reductions is a **lack of rigorous quantitative research on decarbonizing industrial and certain commercial processes in Rhode Island.** We do not want to drive industry out of Rhode Island, so we did not model changes for which there was no information on how they could take place. This said, we are certain there are substantial opportunities to push these emissions pathways toward near net zero emissions with supportive programs. The next sections detail the major sectors and modeled approaches: electricity generation, transportation, and heating.

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[29] Since discussion of this issue began in the late 1980s, expectations for emissions reductions by nations around the world were always that wealthy nations both caused more of the problem and had more resources to address it, so they were expected to phase out emissions first and fastest. Estimates of national responsibility for emissions reductions are many, and there have been extensive debates on how to "share the burden" of doing so. See http://civilsocietyreview.org; Roberts, J.T. and Parks, B., 2006. *A climate of injustice: Global inequality, north-south politics, and climate policy*. MIT Press.; Klinsky, S., Roberts, T., Huq, S., Okereke, C., Newell, P., Dauvergne, P., O'Brien, K., Schroeder, H., Tschakert, P., Clapp, J. and Keck, M., 2017. Why equity is fundamental in climate change policy research. *Global Environmental Change*, *44*, pp.170-173. Le Quéré, C., Andrew, R.M., Friedlingstein, P., Sitch, S., Hauck, J., Pongratz, J., Pickers, P.A., Korsbakken, J.I., Peters, G.P., Canadell, J.G. and Arneth, A., 2018. Global carbon budget 2018. *Earth System Science Data (Online)*, *10*(4).

Figures 5.1a,b: Estimated total emissions in carbon dioxide equivalents for the improved baseline and three scenarios, using a 100-year warming potential for methane (a);using a 20-year warming potential for methane (b).

Figure 5.1a

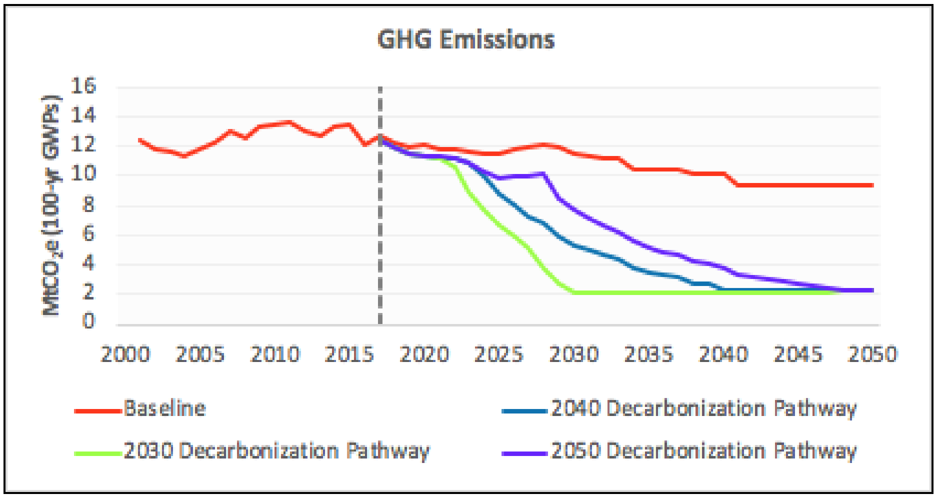
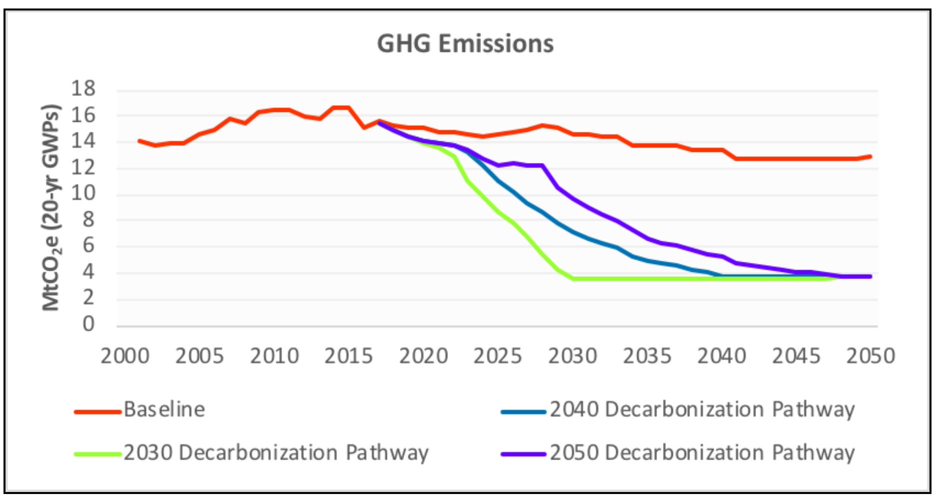


Figure 5.1b



5.3 Electricity Generation: How fast can we green the grid?

Electricity generation has been the focus of most climate initiatives, because a relatively small number of actors (utilities, for example) can bring about major changes. The Regional Greenhouse Gas Initiative (RGGI), which capped greenhouse gas emissions from that sector and auctioned off permits to emit to electricity generators, is a core example.

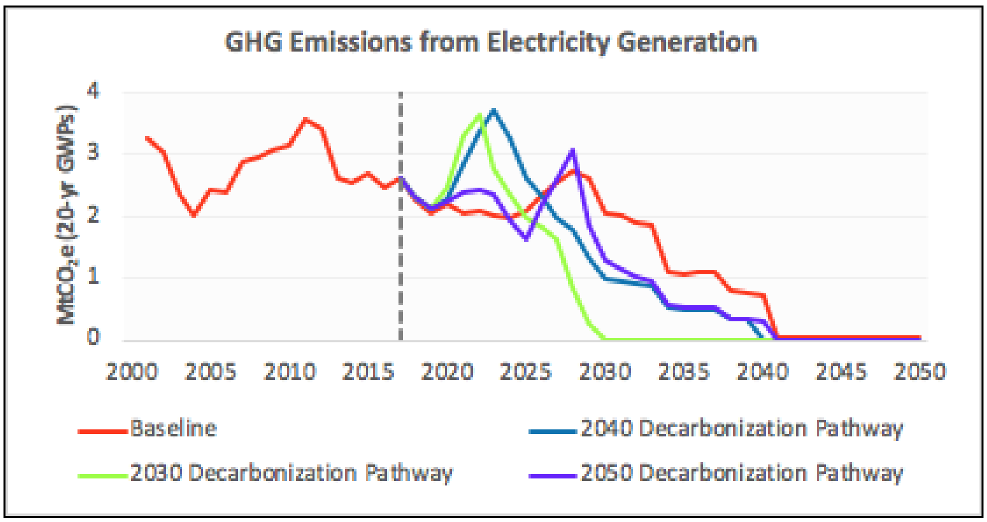


Figure 5.2: *Emissions from the electricity generation sector, improved baseline and 2050, 2040 and 2030 pathways*

During the RGGI period since the first auction in 2008, electricity has improved substantially in estimated emissions per kilowatt hour, mostly from the switching of power plants from coal and oil to natural gas. **Rapidly moving the electricity sector to zero emissions is fundamental in every decarbonization plan out there.**

To understand the results of this modeling, one needs to understand **what assumptions were made**. For the improved baseline of this study, we followed the methods described in the state's 2016 report, except for the changes documented in Section 4.1. We assumed that existing power plants retire at the end of their expected lifetime and that new plants envisioned in the ISO-New England "interconnection request queue" are built, while accounting for typical attrition. The model assumes that if further (endogenous) electricity capacity is needed, technologies are deployed in shares proportional to the shares in the interconnection request queue.

A key factor in running an electricity grid is what order different power plants are turned on and off, called **dispatch**. Our model, as the ISO-New England grid operates, dispatches whenever they are available variable renewables like wind and solar energy, on-peak energy efficiency measures, and on-peak "distributed generation" (smaller scale local electricity production). Other technologies are dispatched using prioritization rules (called "merit orders"), based on historical dispatch patterns.

Box 5.3: Dispatch Method and Merit Order: Dispatch method describes how an electricity generation resource is utilized in the LEAP model. There are two methods we used in our LEAP modeling. First is "full capacity dispatch," where the resource is utilized to its full available capacity, maximally dispatched. This method is used for variable renewables such as wind and solar power, whose production is not "curtailed", when there's an excess. The second method is "merit order dispatch," in which plants are turned on or off according to a ranking system, which gives priority to plants which in the decarbonization scenarios have lowest emissions of greenhouse gases.

In the 2050 Decarbonization Pathway, planned gas and oil additions in the ISO-NE interconnection request queue do not take place. This includes the Invenergy Clear River plant in Burrillville, Rhode Island. Furthermore, 1200 megawatts (MW) of Quebec hydropower are assumed to be added to the New England grid in 2024, which is the schedule for the "New England Clean Energy Connect" project through Maine; another 1000 MW are added in 2025 through the "New England Clean Power Link" project laying two six inch cables under Lake Champlain and other rights of way in Vermont.[30] Nuclear power from Millstone 2 and 3 is expected to continue, as these units are assumed to be relicensed, as in the 2016 study (Nuclear Relicense scenario).

For endogenous capacity inside Rhode Island, all new capacity of fossil-fueled technologies, landfill gas (LFG), and "Wood and Wood Waste" is excluded. For other technologies, the size of additions is based on average size in the ISO-New England interconnection request queue (accounting for assumed attrition in planned projects). Onshore wind additions decrease linearly to 0 by 2030; they are replaced by offshore wind additions. This simulates a developing preference for offshore wind in the state, as offshore winds are stronger and more constant, and larger turbines can be sited and in greater numbers. The models include no new hydro additions (run-of-river or reservoir) after 2041. This ensures our projections respect limits on available hydro resources.

> Truly greening the grid means entirely switching off fossil fuel energy.

Starting in 2030, Quebec hydro's "merit order" is elevated to the highest level (1) to simulate full utilization. Dispatch rules for onshore and offshore wind are changed to merit order from full capacity dispatch in 2021. Merit order is set to 3, rising to 2 in 2050, to simulate some curtailment as renewables capacity becomes much larger. The dispatch rule for on-peak distributed generation is changed from full capacity dispatch to merit order; the merit order is set to 6. This simulates reduced usage as storage capacity comes online in tandem with increased wind and solar. In the model, storage costs are covered under "grid integration" costs, although storage capacity is not explicitly modeled here.

In the 2030 Decarbonization Pathway, the same methods are used as for the 2050 Pathway, except for the following. The maximum availability and capacity credits of fossil-fuelled generating processes, imports from New Brunswick, and imports from New York are reduced - from their value in the 2050 Decarbonization Pathway scenario in 2027 to 0 in 2030. This simulates the forced retirement of these greenhouse gas-producing resources. The merit order for dispatching onshore and offshore wind changes to 2 in 2030 instead of 2050. Methods for the 2040 Decarbonization Pathway are the same as for the 2050 Decarbonization Pathway except that the merit order for dispatching onshore and offshore wind changes to 2 in 2040 instead of 2050.

After a literature review on grid integration costs, we based our modeling of these costs for variable renewables on the work of Reichenberg et al. (2018).[31] We did not model the energy effects of storage, but our estimate of grid integration costs covered typical amounts of storage for variable renewables penetration up to about 80% of the electricity supply. The net result is that we probably modestly overstate the amount of renewable capacity and generation in the deep decarbonization scenarios, as well as the capital and fixed operation and maintenance costs for renewable generatorFigure 5.2 shows how the electricity sector could be

[30] See https://www.necleanenergyconnect.org; http://www.necplink.com.

[31] Reichenberg, L., Hedenus, F., Odenberger, M. and Johnsson, F. (2018). The marginal system LCOE of variable renewables – Evaluating high penetration levels of wind and solar in Europe. Energy, 152. 914–24. DOI:10.1016/j.energy.2018.02.061.

decarbonized for the region and the state under these scenarios: **the baseline case has emissions from the sector going to zero by 2041, without further intervention**. Major progress has been made in New England on increasing renewable electricity production. According to a 2018 ISO New England report, renewable resources are "growing rapidly," and "New England states have goals and requirements for clean energy that serve as a major driver of the growth of renewable resources in the region."[32] The region remains reliant on significant **nuclear power**, with aging plants continuing to supply about one-fifth of our electricity. These are expensive but reliable, and provide an important foundation for a transition to renewables and other zero carbon electricity sources, as long as they remain safe to operate.

The improved baseline shows that emissions dropped from 2000 to 2004, and then rose for the rest of that decade, before reversing and then leveling off from 2013 until the end of historical data in 2017. The net effect is that emissions at the end of that period were about the same as the average over the first 17 years of the century. This is contrary to the picture put forward by RGGI and ISO publicly, likely because of the role of leaking methane described extensively above. Although gas-fired plants have lower direct emissions than older coal and oil plants, leaks from gas supply infrastructure erode much of that advantage. The point is that **truly greening the grid means shifting entirely off of fossil fuel electricity generation. The question this study seeks to answer is, how quickly can we do so, and what might that cost?** Relatedly, if we do nothing, will renewables naturally replace the over 50 percent of our electricity that comes from burning natural gas?

Hydropower is complex and somewhat controversial. Hydroelectric power is both *regional*, from installations in New England, and *imported*, particularly from large hydropower plants in Quebec. Power generated in Quebec is brought to New England by high voltage transmission lines, the siting of which has been difficult but seems to be advancing, as mentioned above.[33] Hydropower provides a crucial backup for intermittent renewables like wind and solar: when the wind dies or the day turns cloudy, more water can be sent over the dams to spin the turbines. **Grid-scale energy storage** can also be developed with batteries, pumped hydro facilities, and other technologies. The Northfield Mountain pumped hydro plant in central Massachusetts is a good example, pumping water uphill from the Connecticut River to a reservoir for 11 hours a day at times of surplus, then reversing the turbines and running it downhill, producing up to 1100 megawatts of electricity for 8 hours when needed.[34]

Figure 5.3 shows the assumptions built into the improved baseline scenario. Note that demand increases from about 8 to about 11 Terawatt Hours, even with efficiency measures, as new electric vehicles and building heating units are installed. **The baseline scenario shows** that without new policy, coal will be nearly eliminated by 2017. Nuclear energy will stay quite steady until dropping in 2035 and again in 2045 with the closure of key plants. The baseline case shows that with expected costs and policies, some substantial onshore wind might be developed in the 2030s and 2040, but only modest offshore wind facilities. Natural gas remains important to 2050 in the baseline case, providing about a third of electricity over the modeling period. Wood-based biofuels expand to be about 10 percent of our electricity, ramping up somewhat in the late 2030s. Solar is inconsequential in the baseline case, including both "distributed" (rooftops, small arrays) and utility scale solar farms. This suggests that

[32] ISO New England, Operation Fuel Security Report https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

[33] Massachusetts has made a major effort to develop connections to Quebec, which appear to have paid off with a new agreement for a 1200 MW line through western Maine. Hydro Quebec's facilities themselves are controversial, since many were built without full consultation with the First Nation tribes whose land they permanently transformed.

[34] https://www.firstlightpower.com/facilities/?location_id=346

polluting energy sources for our electricity are not likely to naturally go away by themselves.

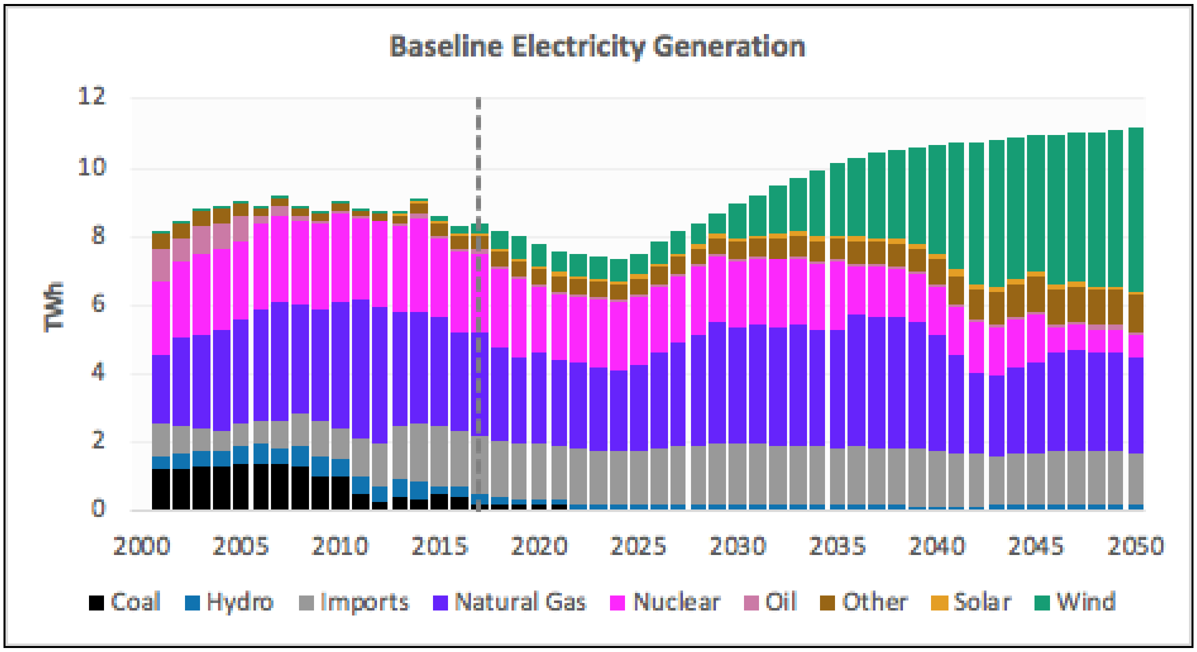


Figure 5.3: *Expected state energy sources, the improved baseline.* (Note: Other includes demand resources, landfill gas, sludge waste, black liquor, coal sub bituminous, tire derived fuels, municipal solid waste, biomass, geothermal).

Now we can finally move on to what happens if the the New England Region were to take more concerted action on climate change. **The 2050 decarbonization pathway** we model here (Figure 5.4) differs from the baseline by seeing a **sharp upturn in energy demand** with the switch to electric vehicles and building heat, and the installation of offshore wind at the end of the 2020s. **Offshore wind provides over half of all energy** (8 of 16 TWh), with utility solar and hydro each bringing in about 10 percent of electricity supply by the end of the period. **Under the 2050 pathway, these changes take place at lowest cost largely as natural gas plants reach the end of their useful life and need to be replaced at the end of the 2020s and after.** Utility scale solar and hydro both increase in the 2030s. Hydro capacity increases in the 2030s to fill large proportions of the capacity listed as "technical potentials" by the National Renewable Energy Labs (NREL).[35] As discussed in Section 6 below, the **2050 pathway involves almost no additional costs until well into the 2030s.** Onshore wind and wood are nearly inconsequential.

[35] https://www.nrel.gov/docs/fy15osti/64503.pdf Table A.5.

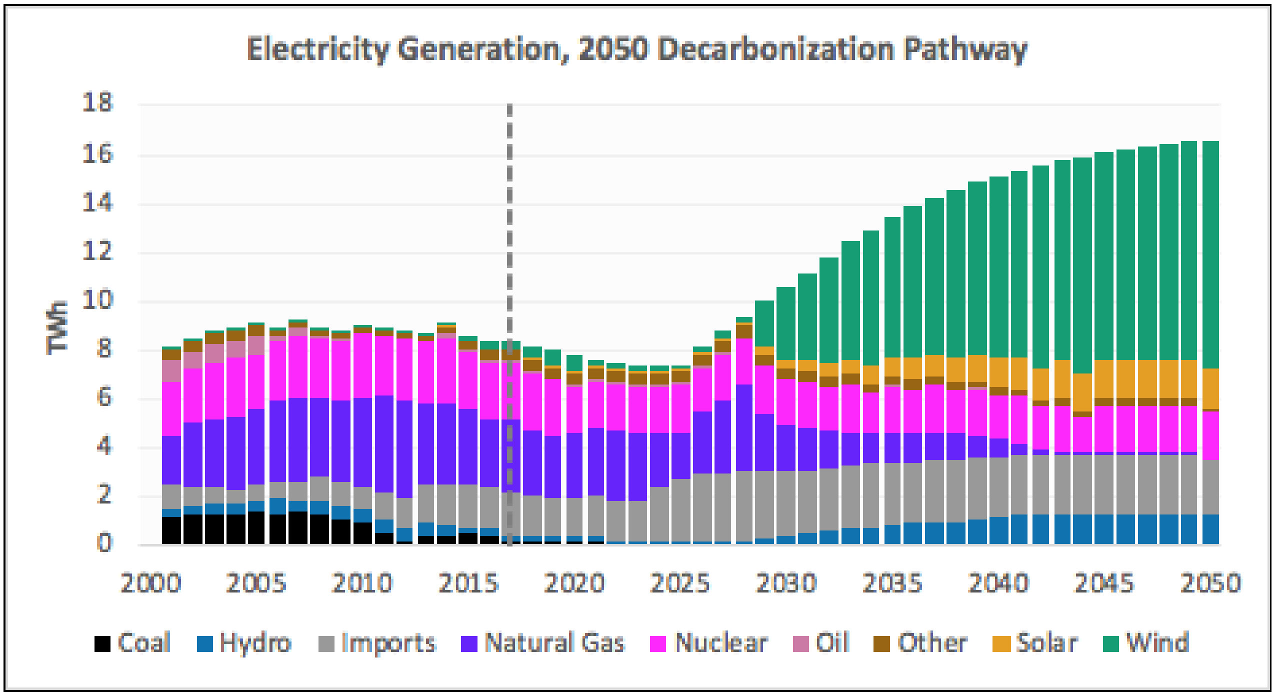


Figure 5.4: Expected state energy sources, 2050 decarbonization pathway

The 2040 decarbonization pathway is quite similar, bringing forward the shuttering of gas-fired power plants to the mid-2020s, and onshore wind plays a bigger part in the transition off of gas. The rest of the mix is quite similar to the final 2050 pathway. For both pathways, it's important to know that total amounts of electricity increase over time, as greater portions of the vehicle fleet and heating systems in homes are shifted from fossil fuels to electric. This transition is nearly complete in the 2050 pathway by about 2040; it's nearly complete for the 2040 pathway by 2035 (see Section 5.5).

The **2030 pathway** moves those transitions up: offshore wind gets spun up starting 2023 and is largely installed by 2028, onshore wind likewise rises in the 2020s but is less important as time goes on. Utility scale and distributed solar, hydro, nuclear, and imported energy each continue to provide about 10 percent each of the state's electricity mix from 2030 until 2050

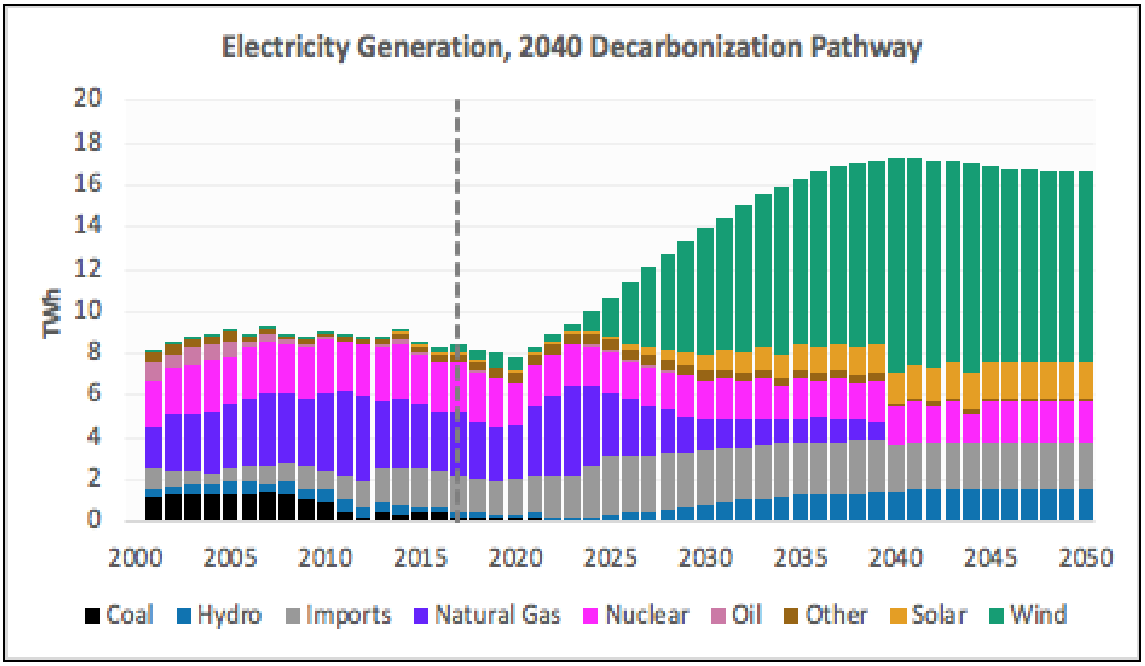


Figure 5.5: *Expected state energy sources, 2040 decarbonization pathway.*

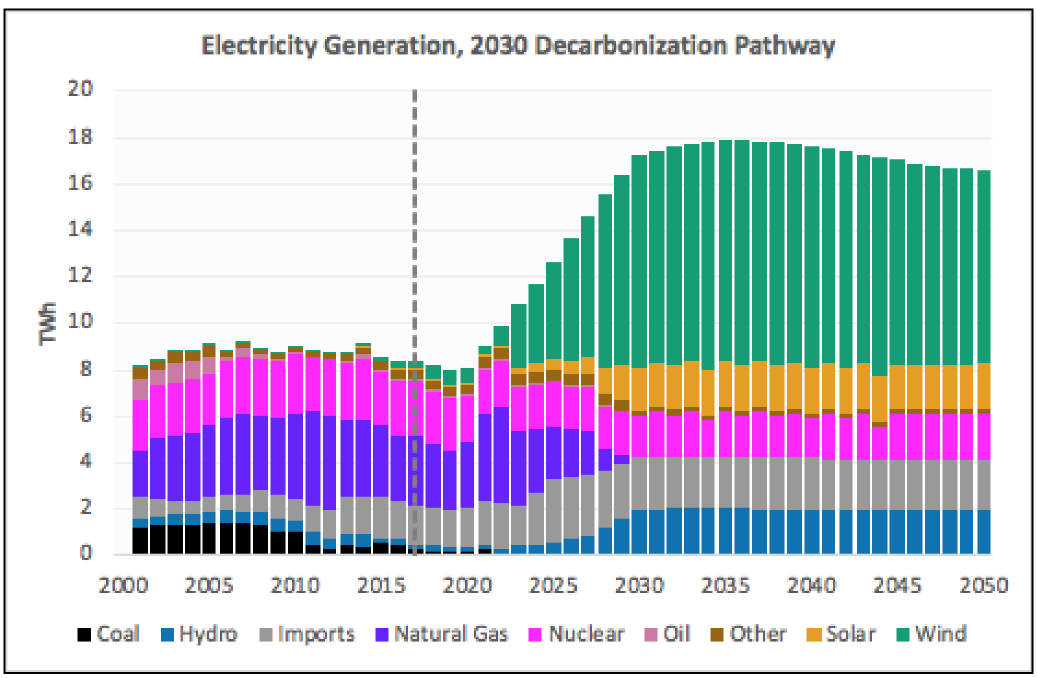


Figure 5.6: *Expected state energy sources, 2030 decarbonization pathway*

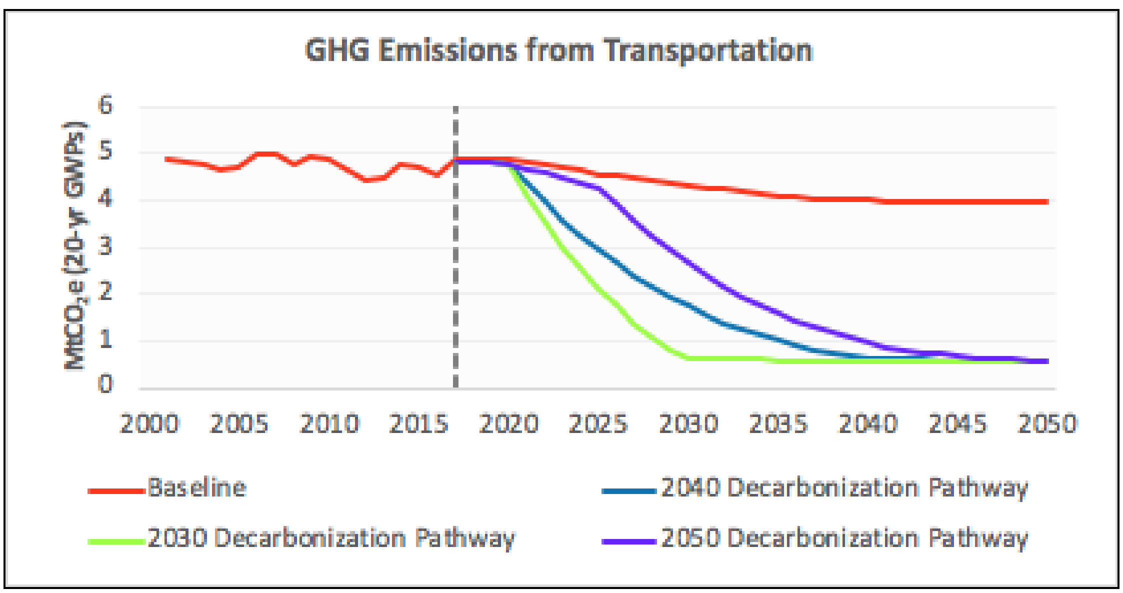
5.4 The biggest slice: Transportation

Transportation is now the largest slice of greenhouse gas emissions in Rhode Island, so this sector is crucial in determining whether and how fast we can decarbonize our state. The sector includes air travel, water transport, and some off-road equipment (like lawn and garden equipment), but most of the emissions come from cars and trucks.

Our analysis is built on downscaled estimates from the national NEMS and VISION models, using Rhode Island's share of national vehicle miles traveled. Therefore, it makes important assumptions. The downscaled projections imply that we will have a million cars and light trucks with a current state population of only a million; there is an assumption of population growth but it is not as substantial as the increase in the number of vehicles. In Section 7 we test the impacts of these assumptions and whether we can do better.

Figure 5.7: *Estimated emissions from the transportation sector, improved baseline and 2050, 2040 and 2030 pathways.*

All of the decarbonization pathway scenarios here include an electric rail mitigation option that was used in the 2016 study (most rail is electrified). This is realistic for passenger rail, as currently MBTA trains run diesel locomotives from Boston's South Station to Providence and Wickford directly under electric wires in the Northeast Corridor. Some stations and sidings would need electrification and new locomotives and expertise and equipment in the maintenance shop would be needed, but these are virtually inevitable investments, whether done under MBTA or a Rhode Island-specific commuter rail system. Freight rail also is mostly along the Northeast Corridor, but some further electrification will be needed under the decarbonization scenarios. Rail emissions are a tiny fraction of the state's CO2e greenhouse gases currently. Note that for 2017, historical data shows that emissions from all rail in the state is just 0.1345 percent of those from cars and light trucks combined.



All of the pathway scenarios include the 2016 study's assumptions about maximal deployment of **biofuels**.

- 79% ethanol in gasoline by 2041, 31% biodiesel in diesel by 2050.
- 20% biodiesel in distillate heating oil by 2043.
- 99% of ethanol is cellulosic by 2023.

We believe these are reasonable, if conservative, estimates. The increase of biofuels in diesel and heating fuels could probably be accelerated significantly. The 2016 GHG plan described them as "Biofuels are liquid fuels derived from renewable organic substances (e.g., recycled cooking grease, plant residues, animal fats, and other renewable feedstocks)." Biofuels can be mixed with diesel, and cellulosic ethanol can replace ethanol and gasoline in increasing proportions, but there are important equipment modifications or replacements that are needed at higher levels. As the 2016 GHG Plan reported, "There are no current policies in Rhode Island promoting the use of transportation **biofuels**."

However biofuels still take petroleum to produce: in our study, greenhouse gas emissions from biodiesel and cellulosic ethanol are assumed to be 50% of emissions from conventional fuels, so they are truly "half-measures." Therefore **investments in biofuel equipment is not useful if the larger goal is to reach full decarbonization; moving to full electric vehicles and heating systems can be a way to leapfrog that spending.** For this reason, the pathway scenarios assume that starting in the 2020s, all new road vehicle sales are for EVs (the exact year depends on the scenario).

Figure 5.7 shows how quickly the main parts of the transportation sector could be decarbonized: the **2050 pathway largely replaces cars and trucks with electric vehicles only when they reach the end of their expected lives. The 2030 and 2040 pathways speed up the replacement of the oldest vehicles with electrics.** Note that all scenarios have a residual half million metric tons of CO2e greenhouse gas emissions, from sectors we are not certain can be readily electrified. These include **air travel, long- and shorter-range marine fleets, including ferries, and off-road vehicles** (see Figures 5.8 for this analysis). Figure 5.8 shows how these decreases in emissions are achieved. Figure 5.8a shows how emissions would slowly decrease over 2020-2035 by about 10 percent in the baseline scenario, from 4,500 MtCO2e to just below 4,000. Each category of vehicles would see modest reductions, including passenger cars. The 2050 pathway (Figure 5.8b) shows little change until 2025, and then sharp reductions in passenger car emissions and those from light trucks between 2025 and 2038 as those fleets are electrified, starting with the oldest vehicles. The 2040 pathway starts the transition immediately in 2020, and has most emissions from cars and light trucks removed by 2031. The 2030 pathway has all emissions from lighter on-road vehicles eliminated by 2030.

Investments in biofuel equipment is not useful if the larger goal is to reach full decarbonization; moving to full electric vehicles and heating systems can be a way to leapfrog that spending.

Figure 5.8a,b,c,d: *Breakdown of estimated emissions from the transportation sector in the improved baseline, 2050, 2040 and 2030 decarbonization pathways.*

Figure 5.8a

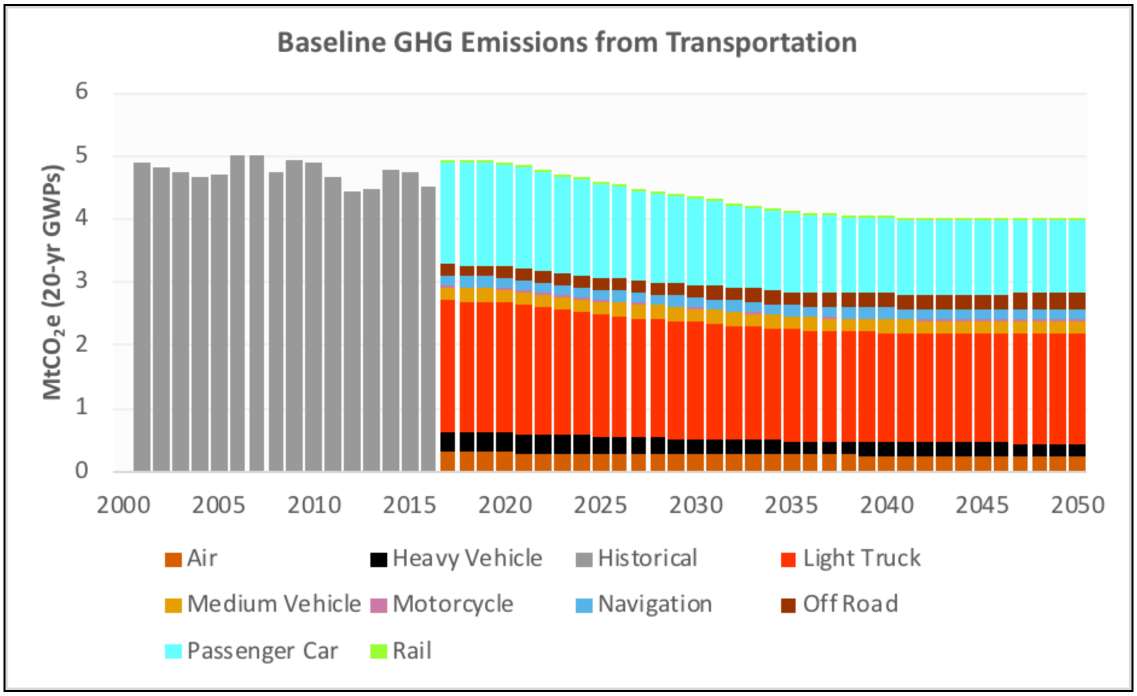


Figure 5.8b

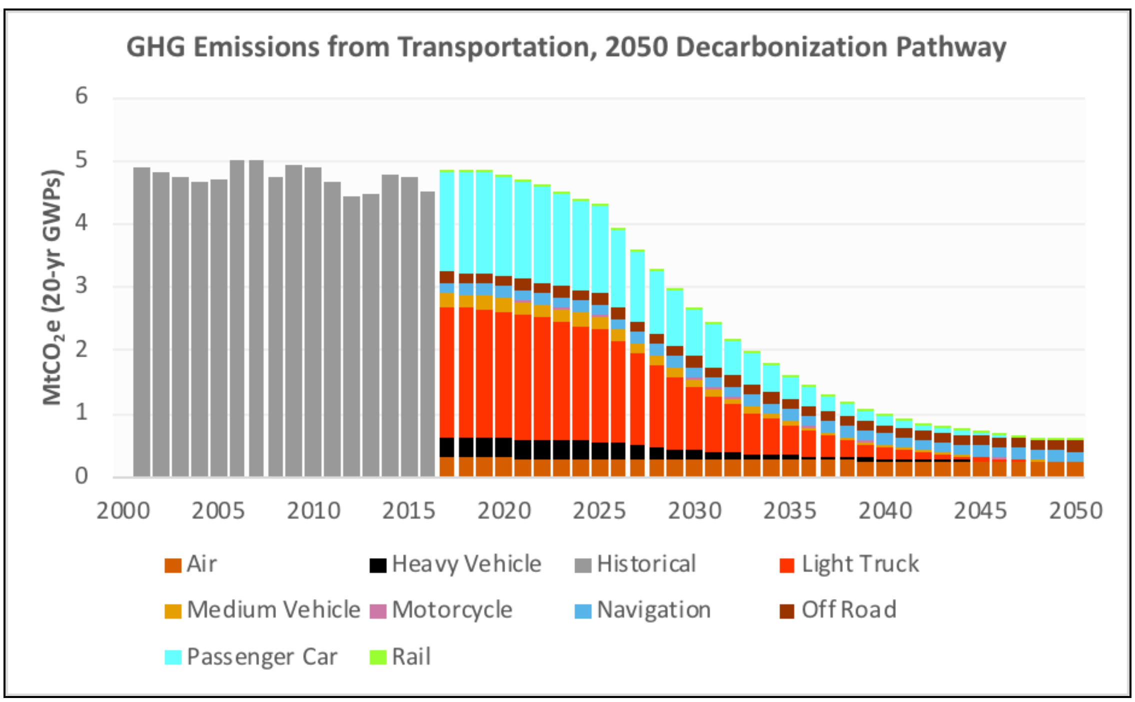


Figure 5.8c

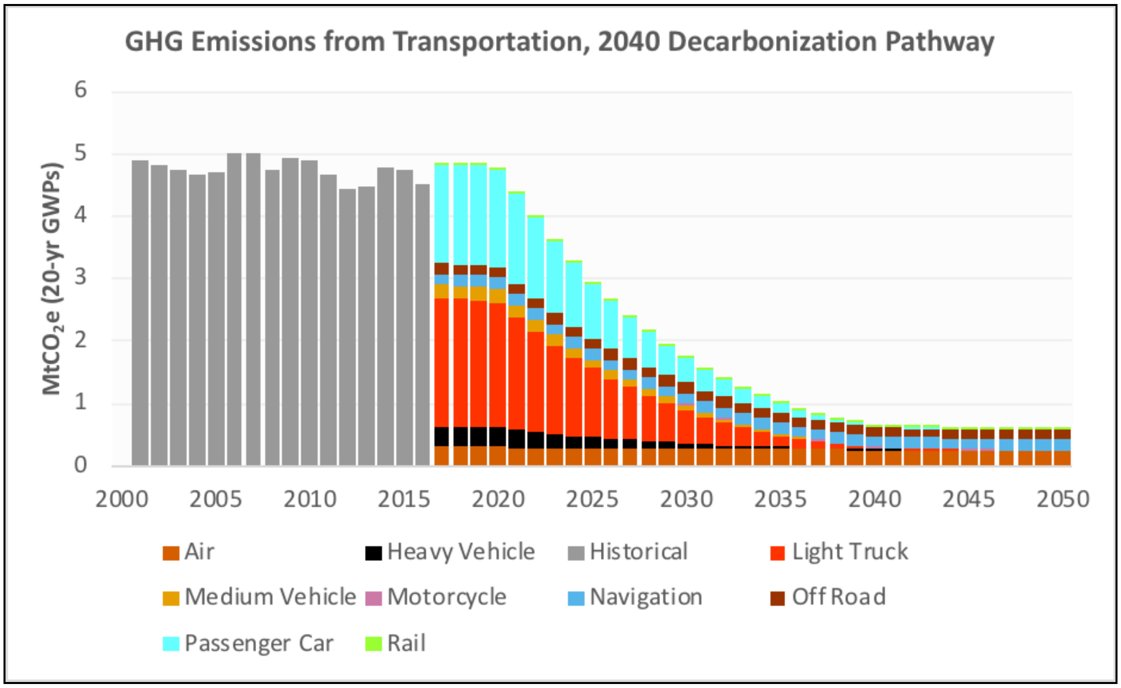
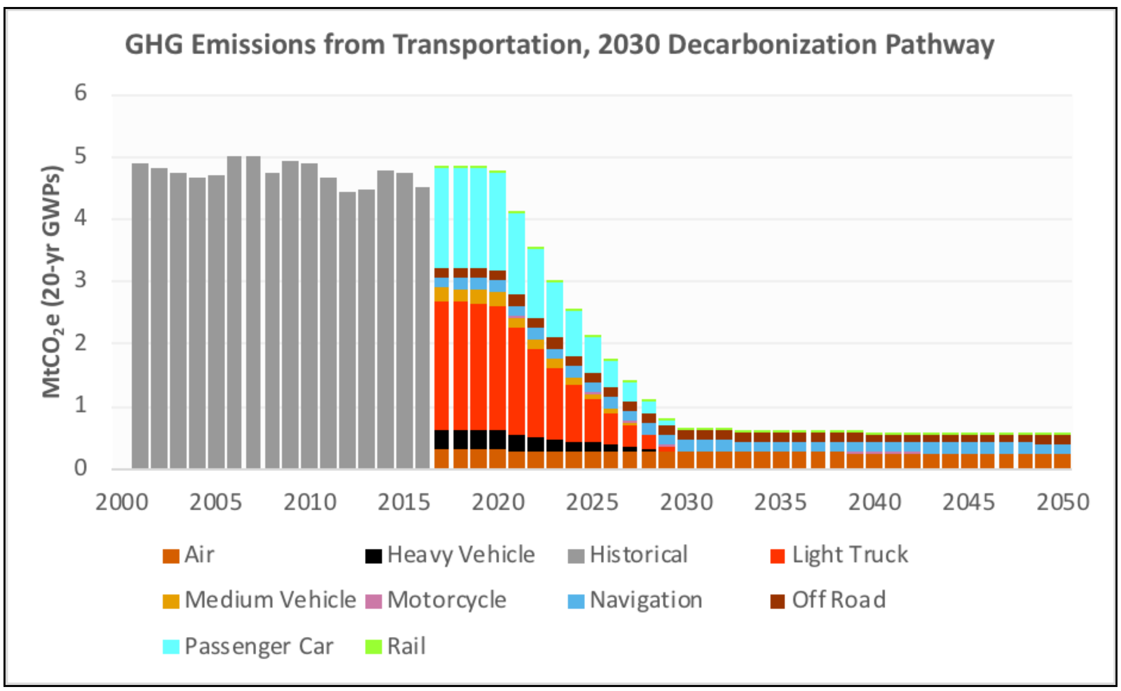
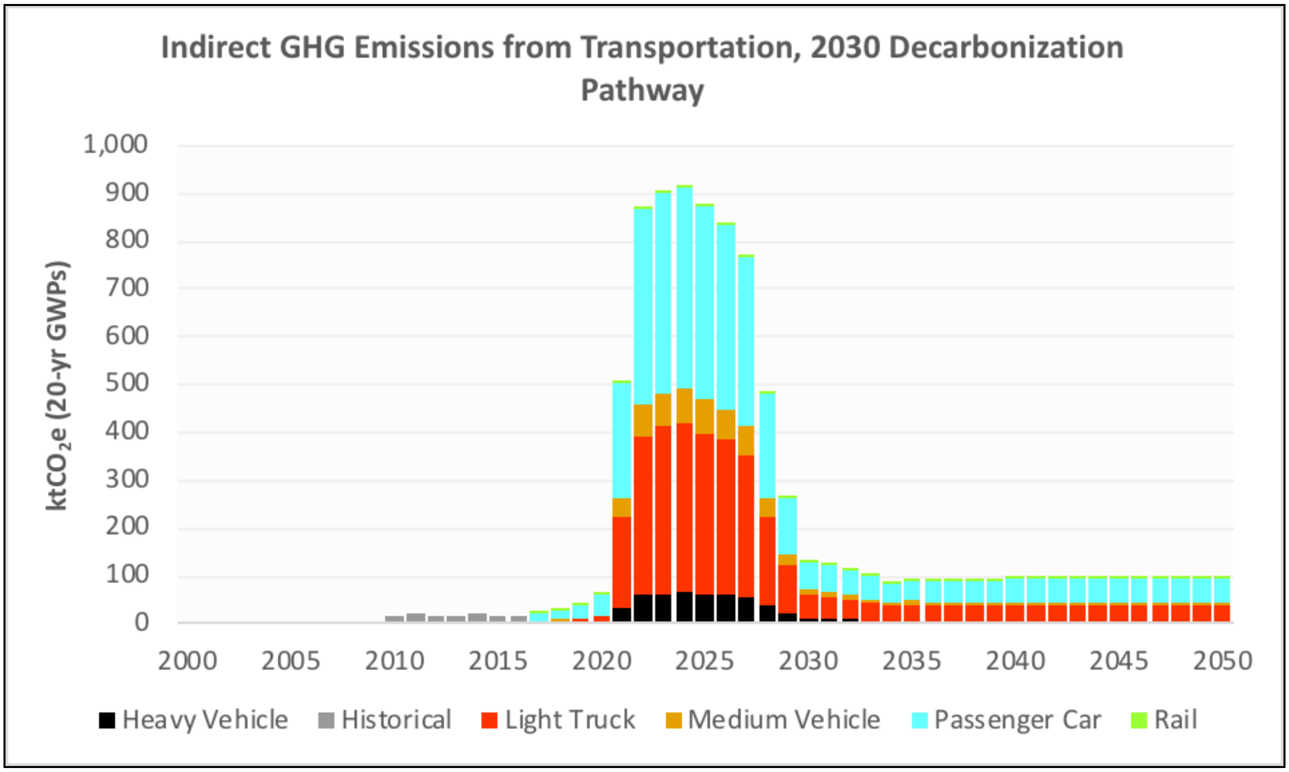


Figure 5.8d



An important part of the transition in transportation story is the **bump in emissions early in adoption of electric vehicles before the New England electrical grid is brought fully onto carbon-free power sources** (Figure 5.9)**.** During the transition to electric vehicles, there will be a period when the New England electric grid is still powered by some fossil fuels. In the rapid decarbonization scenario, these "indirect emissions" could be a substantial factor during a 6-8 year spike. In slower decarbonization scenarios, these indirect emissions will last longer. In all cases, EVs are significantly cleaner than gas and diesel ones in emissions inside the state, and they get cleaner as the grid greens.

__Figure 5.9:__ Indirect emissions from transportation. These are emissions from the electricity utilized in electric vehicles before the New England grid is fully greened with zero carbon energy sources.



The big picture here is that cars and light trucks can now be electrified--the question is how quickly we do so. Other subsectors are somewhat more complicated. To improve the analysis of the transportation sector we would need to know more about technology currently deployed and the prospects for fuel switching or prospects for energy efficiency improvements, especially for off-road equipment. The on-road, light vehicle fleet is well-characterized and modeled. However **lawn and garden tools** are the single largest offroad emitter. Some of these could use rechargeable batteries or electrical cords; some could not.[36] Air travel was left virtually untouched in this study--some efficiency improvements were modeled, but no fuel switching (and demand for plane trips continues to rise--see Section 7). For **water travel**, we need to consider international and domestic shipping; both are included in the model. Domestic shipping uses mostly diesel fuels, whereas for international shipping bunker fuels are common. It is once again a question of efficiency potential: when can ships and planes get more efficient? What fuel-switching is possible and for which functions? What other means of travel and transport are available? Can some demand be reduced through, for example, conservation, teleconferencing or local products? On this final point, **vehicle miles traveled could be sharply reduced in the state**, and we look into how this could unfold in Section 7, below.

[36] A trip to the Providence Home Depot in June, 2019 found no plug-in weed trimmers, but many Lithium Ion battery models, which were significantly cheaper than gasoline-powered two-stroke engine models. With enough back-up batteries, lawn services and homeowners could conceivably switch immediately to that technology, with many co-benefits in noise and local air quality, in addition to greenhouse gas emissions reductions as the grid goes to renewable power. Policies could speed that transition.

5.5 Staying warm: Electifying heating

Warming the state's homes and businesses, schools, and hospitals is a significant source of emissions. **Heating sector emissions can be reduced by electrifying heaters, replacing them with air source and ground source heat pumps.** The pathway scenarios assume we stop buying fossil-fueled heating systems between now and 2030 (the exact year depends on the sector and scenario). Consistent with the 2016 GHG plan, we modeled a 90/10 ratio for air source and ground source heat pumps: most homeowners and businesses will opt for the cheaper air source heat pumps, which have been markedly improved in recent years, over geothermal systems, which are far more expensive to install (but significantly cheaper to run). The current study does not model projected purchase cost decreases for future heating systems (i.e., current purchase costs are assumed to apply in the future)--we believe this is a conservative assumption that could change significantly in the future. On particularly cold days, backup "resistive electric heating" (basically a wire coil like old baseboard heaters) is assumed to be used to supplement heat pumps.

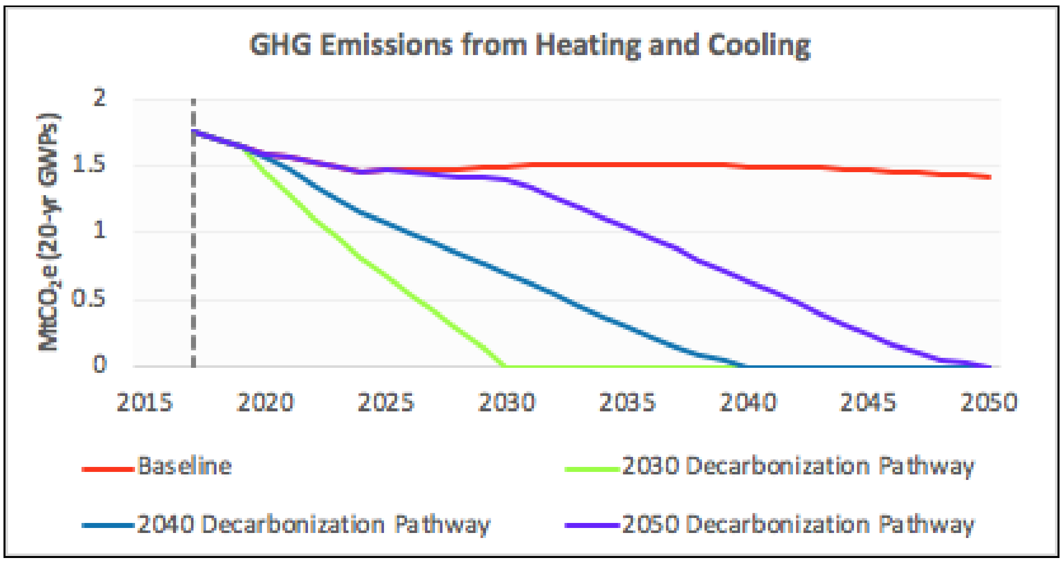


Figure 5.10: *Heating and cooling emissions over time by scenario.*

The baseline scenario shows gradual emissions reductions from the heating and cooling sector; the decarbonization pathways project these could be brought to zero much earlier (Figure 5.10). Heating is electrified in the residential, commercial, and industrial sectors. We assumed that conventional fuels are retired according to the natural lifetime of the most common equipment using the fuels, with some acceleration (premature retirement) needed in the deeper decarbonization scenarios. That happens through a fraction of existing fossil fuel systems being replaced each year to arrive at the endpoint of zero in 2030, 2040 or 2050.

Heating and cooling therefore appears to be a sector that **can be decarbonized entirely in Rhode Island, but the speed at which it happens will depend very heavily upon state programs and regulations. The r**elative prices of natural gas and heating oil vs. electric heating needs to reverse to bring faster adoption of electric heat pumps--the fuller costs to society of natural gas and oil extraction and burning need to be incorporated into their prices. Homeowners and businesses need to see the value in making the upfront investment in heat pumps, and incentives such as financing, tax credits or rebates can tip the balance. Education and support will clearly be needed, for residents and for installers of furnaces and AC units. As the state’s summers get hotter and more homes and businesses install or upgrade their air conditioning systems, there is a crucial opportunity for them to switch to heat pump systems, utilizing existing ductwork or wall-mounted “mini-split” units. The inertia in the system is very great, as decisions for homeowners and small businesses are often made in crisis situations when systems fail and budgets are tight. This situation often drives simple replacement of existing oil and natural gas heating systems with new models, providing only very incremental improvements and foreclosing the possibility of real decarbonization for another decade or three.

Section 6: How much might it cost? Partial estimates of costs (without pricing benefits)

This section represents an initial exploration of what the costs might be of rapid decarbonization of the state of Rhode Island's economy. It is *essential* to note that **these results do not include costs to society of *not acting*, nor do they include a full accounting of the substantial benefits** residents and businesses will see in cleaner air and a stable climate system in which to live and work. The point here is to get some indication from the LEAP model of where the costs are likely to be incurred in decarbonizing the state's economy by different target dates. **This analysis is entirely new to this 2019 study: no cost estimates were included in the 2016 report**. Also important to remember is that these represent **initial estimates of the overall costs to society** of a scenario relative to the baseline, not the particular costs seen by particular producers or consumers. Even without taking on the project of decarbonizing the state economy, **there will be expenses in the baseline scenario, simply for replacing equipment at the end of its useful life**. For example, estimates of baseline costs for space heating and cooling equipment, on-road vehicles, electricity generation and imported fuels begin above $5 billion a year for the state economy in 2017, rising steadily to about $8 billion a year by 2050. This is an important reminder that even staying in place has substantial costs.

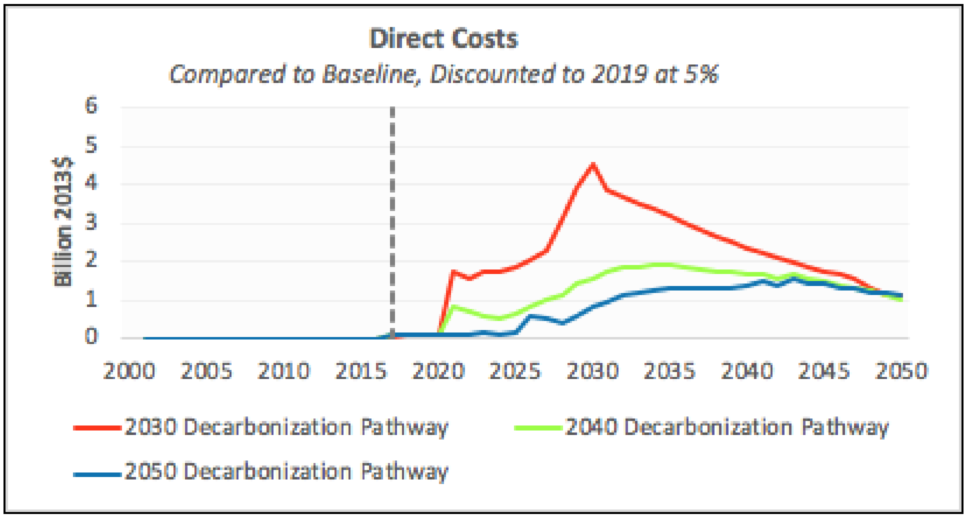


Figure 6.1: *Annual estimated costs to Rhode Island per scenario, vs. improved baseline. These are absolute, not relative costs: benefits are not deducted.*

The 2050 decarbonization pathway shows that for the state to reach near-zero carbon emissions by that year, the annual estimated costs are **nearly identical to the baseline until about 2025**. These costs are discounted to 2019 dollars at 5 percent a year, which is standard practice in this kind of study of future costs. Thereafter, particularly as natural gas plants reach the end of their useful life and are replaced by renewables, storage and alternative energies, costs begin to rise above the baseline. Supplemental costs for mitigation increase to around $500 million for the last years of the 2020s, then rise to about $1.3 billion per year by the late 2030s, and never exceed $1.6 billion per year. Clearly, the first decade of that pathway can be afforded -- it is nearly costless until 2025 compared to the baseline, and revenue streams can be developed for later years. Technology costs may drop further than assumed in the model, making this a potential over-estimate of costs.

Figure 6.1 shows **costs rising much more quickly for the state to nearly fully decarbonize its economy by 2030**. Spending -- this includes private and public expenditures to replace equipment -- would jump to nearly $2 billion over baseline in 2021, and spike to just over $4.2 billion in 2030 before dropping steadily back under $2 billion a year by 2043. The expenditure transforming the economy would then level off. This is essentially a model for a Green New Deal in Rhode Island, and this pulse of spending over 15 years to transform the economy can be seen as an engine of job creation, economic development and resilience. The 2030 pathway requires about 4-7 years of peak spending above $3 billion.

The 2040 decarbonization scenario has much lower cost spikes than the 2030 pathway, investing in offshore wind in the short term and replacing vehicles and furnaces with electrics in the early 2020s, but doing so on a more "cost effective" basis (i.e., less early retirement of equipment). Estimated costs do not exceed $2 billion over the baseline scenario, and, after peaking in the early 2030s, they decrease to below $1 billion a year in 2050, compared to the baseline. The 2040 pathway achieves significantly lower emissions than the 2050 approach, especially in the late 2020s, but avoids many of the costs seen in the 2030 scenario.

The LEAP model allows us to get some ideas on **which sectors of the economy will bear the costs and reap the benefits** from decarbonization, and when those costs and gains will arise. Figures 6.2a, b and c show for each of the scenarios the major types of estimated costs compared to the baseline case. In these figures, "**demand costs**" cover the residential, commercial, and industrial sectors, while "**transformation**" covers electricity generation and infrastructure. "**Resources**" reflect costs for fuels imported into the state. Supplemental mitigation costs for the residential, commercial, transportation, industry, and electricity production sectors are for purchasing, maintaining, and operating equipment (notably, vehicles, HVAC systems, power plants, electricity storage facilities, and transmission components). They include extra costs associated with the early retirement of equipment.

Figure 6.3 shows the **"bump" in investments needed to electrify the transportation sector, after which equipment costs drop substantially**. This bump is quite different for the three scenarios: spiking to nearly $2 billion a year for the 2030 scenario before tapering down below $100 million a year, as compared to maximum levels of just $800 million for 2040 decarbonization and $500 million for the 2050 pathway. The spike for the 2030 and 2040 pathways occurs in the early 2020s, while for the 2050 pathway it is delayed by about five years. Note that Figure 6.3 does not show supplemental **cost savings** associated with reduced fuel imports due to electrification (these are depicted in the "Resources" category in Figures 6.2).

Figure 6.2a,b,c: *Major types of estimated costs in the three decarbonization scenarios. Demand covers residential, commercial, and industry sectors while transformation covers electricity generation infrastructure, and resources reflects all fuel costs for electricity generation.*

Figure 6.2a

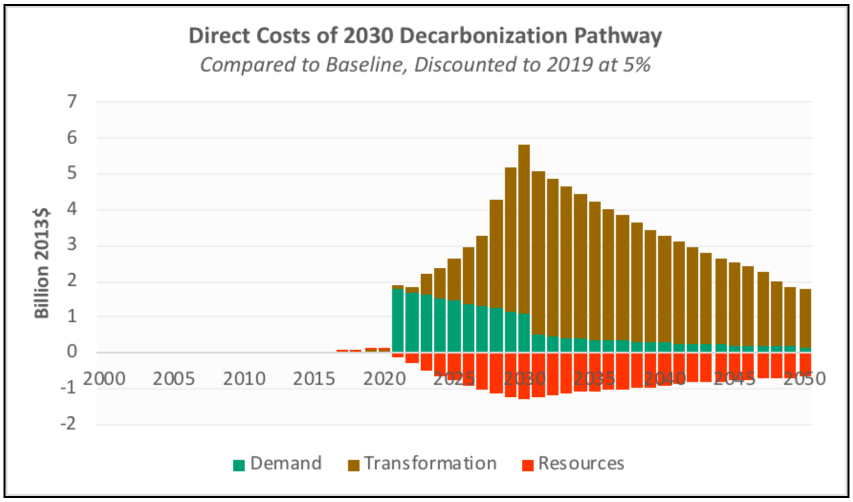


Figure 6.2b

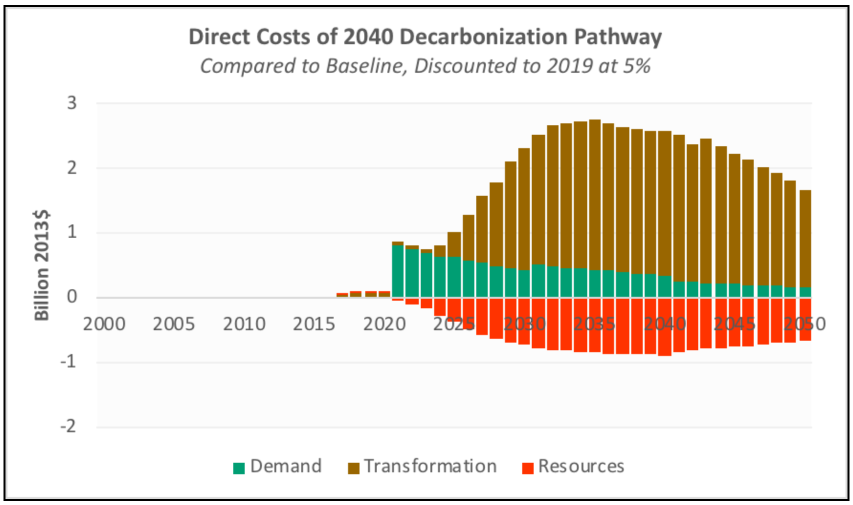
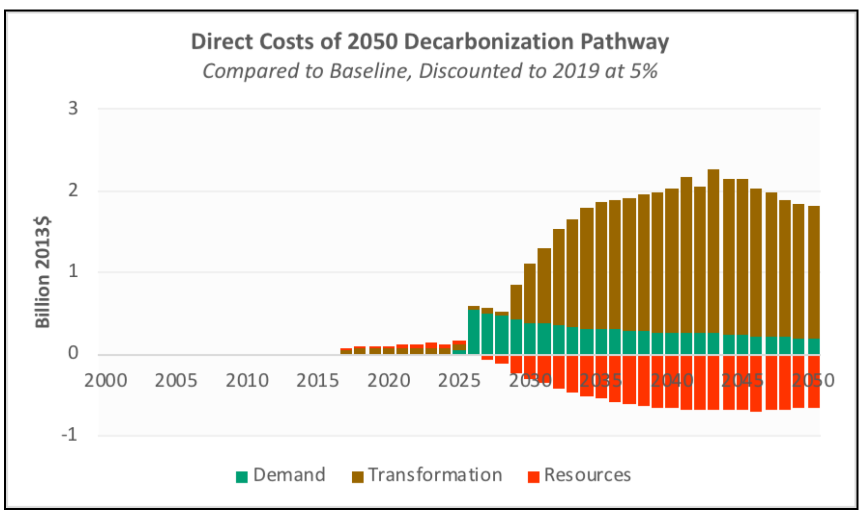


Figure 6.2c



Electrifying and decarbonizing the transportation sector will involve important costs, as charging infrastructure is installed and people and institutions retire gasoline and diesel vehicles and replace them with EVs. The three scenarios vary sharply in when these costs come and how high they are (Figure 6.3). The 2030 scenario has incremental costs of about $1.7 billion in 2013 dollars, incurred in the early 2020s and dropping sharply to 2030, when they return to the cost level of the other two pathways. This cost is for the very rapid move away from internal combustion vehicles. The 2050 pathway starts spending on vehicle replacement only in the late 2020s, and maxes out at about $500 million in 2026, dropping back to under $200 million a year later in the study period. The 2040 pathway is just slightly more expensive at its highest level than the least aggressive scenario, but begins the process in 2021, rather than waiting until 2026. Its overall costs in the transport sector are less than half those of the most aggressive pathway, and quickly become nearly identical to the 2050 approach.

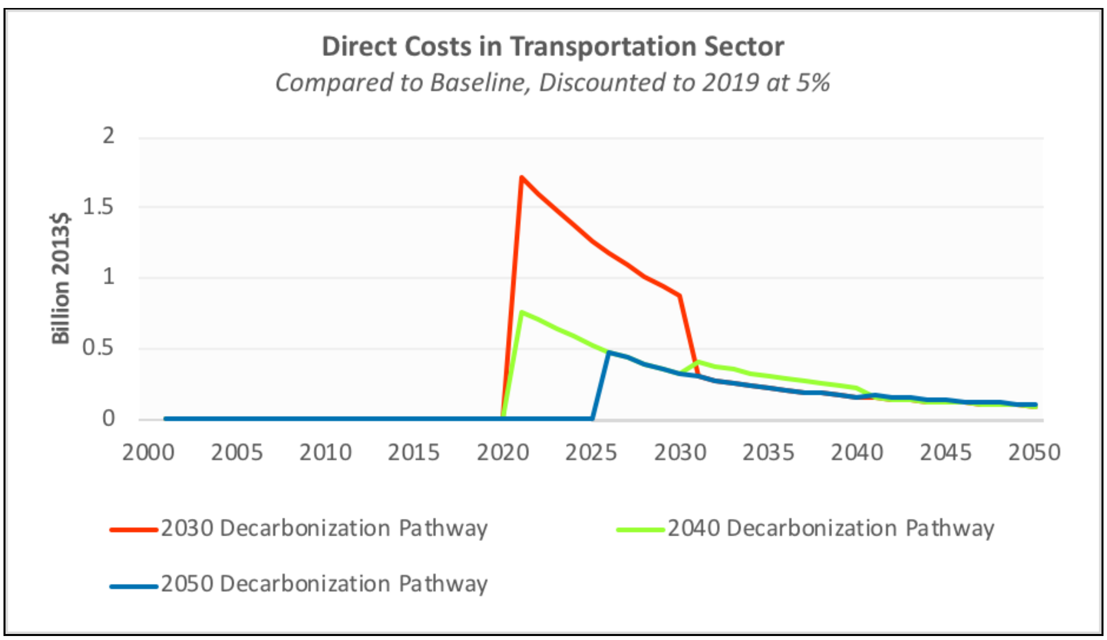
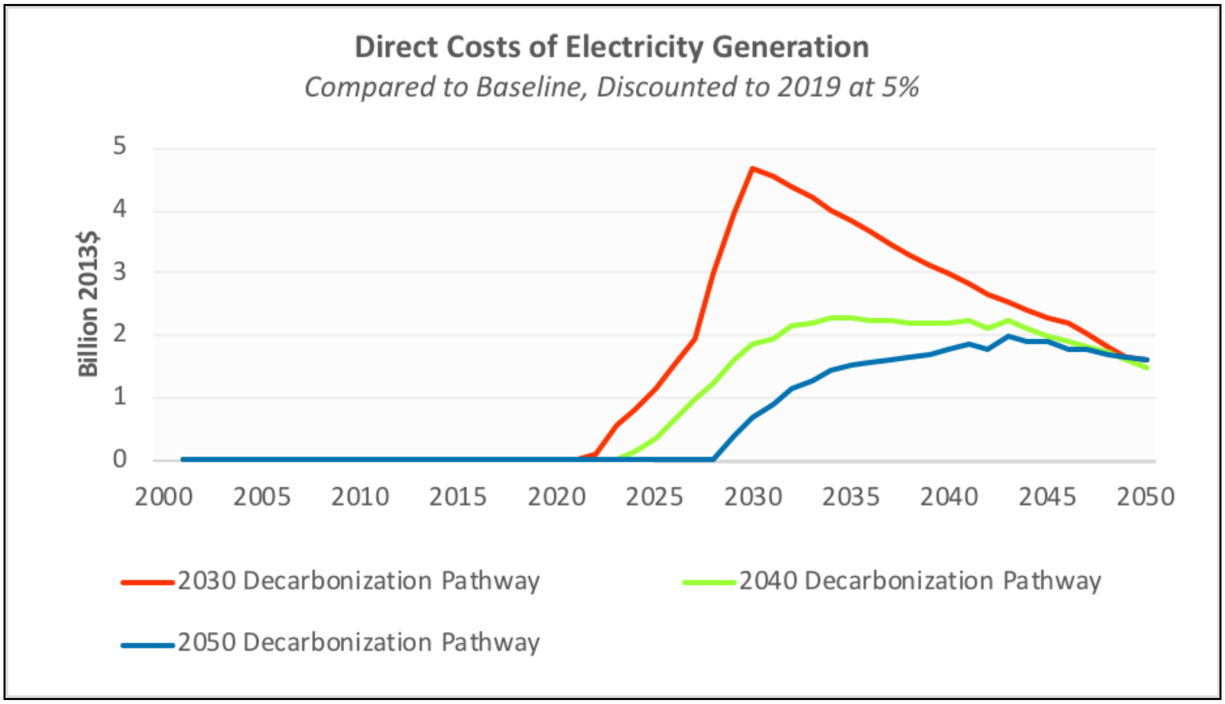


Figure 6.3: *Estimated costs for transformation of the transportation sector, improved baseline versus the four scenarios.*

This study, for the first time, also estimates the incremental costs of generating electricity for Rhode Island with near-total decarbonization by 2050, 2040 and 2030 (Figure 6.4). The study model shows that generation costs, driven by the cost of integrating renewables into the grid, **begin to exceed the baseline around 2028 for the 2050 decarbonization pathway**, and rise steadily but not sharply. The 2040 decarbonization pathway also has steady increases in investment needed in grid integration, but these start around 2024. Both of those pathways estimate maximum incremental costs above the baseline of $2 billion or less per year. By contrast, **the 2030 decarbonization pathway shows that accelerated spending for grid integration would need to begin almost immediately** and would sharply increase from the mid-2020s, eventually entailing over $4 billion per year of additional expenditures for a handful of years before dropping to half that level by 2050. As with vehicles, this level of investment is consistent with a Green New Deal approach to decarbonizing the economy. These changes, referred to as grid integration costs, don't disappear after a single application; they continue, for tasks such as maintaining energy storage, "balancing costs" of dealing with intermittency in renewable energy, and curtailing variable renewable energy generation when there's excess. This suggests that **a mixed approach focused on energy stability, with modest use of fossil fuels as backup, could reduce these**

costs significantly, especially in the shorter-term.[37] Further research and modeling are needed on these approaches in the Rhode Island context.

Figure 6.4: *Estimated costs of electricity generation, improved baseline and 2050, 2040, and 2030 decarbonization pathways.*



[37] See, for example, Jenkins, Jesse D., Max Luke, and Samuel Thernstrom. "Getting to Zero Carbon Emissions in the Electric Power Sector." *Joule* 2, no. 12 (2018): 2498-2510; Harvey, Hal, Robbie Orvis, and Jeffrey Rissman. *Designing climate solutions: a policy guide for low-carbon energy*. Island Press, 2018.

Section 7: Going deeper: Conservation and other behavioral change

This study shows that we now have the technology to eliminate 70-80 percent of the state's greenhouse gases, and that we can do so in relatively short periods of time: by 2030 or 2040 if we retire older cars and furnaces earlier, or certainly by 2050. After the first round of modeling effort focused on technological implementation of low carbon strategies, we built a **new conservation and behavioral change scenario**. This was inspired by the substantial 20-30 percent of the state's emissions that initial model runs could not resolve how to eliminate. We consider this a very initial pass at this kind of modeling, which merits further development in the future.

> The most effective approaches combine "soft" educational and behavioral change campaigns with "hard," "structural" reforms like zoning laws, carbon taxation, and major investments in pedestrian facilities and public transportation.

Many comments on an earlier draft of this study, including from the state's Science and Technology Advisory Board of the Executive Climate Change Coordinating Council, suggested that other approaches should be considered besides just technology adoption. Crucial were the points that impacts of decarbonization include building a whole new fleet of vehicles, which requires mining and manufacturing with substantial environmental and social costs.[38] We conducted a brief literature review on the subject, and uncovered some indications of what might be possible for lifestyle changes in America today. It is clear that the crisis of climate change requires we do more than just switch cars and furnaces.

The assumptions in this new "Conservation and Behavior Change" scenario are based on this literature review, especially a major 2016 review piece of 147 articles from the peer-reviewed literature by Creutzig et al. in the *Annual Review of Environment and Resources*,[39] as well as our own observations of waste reduction and low-impact efforts we've taken and seen others take that are largely cost-free or cost-negative.

The transportation sector is illuminating on the opportunities and the complexity of driving deeper emissions reductions.[40] Creutzig et al. report studies showing that "Overall, behavioral and infrastructural measures in cities can potentially reduce GHG emissions from urban passenger transport by

[38] A good study by the Union of Concerned Scientists documents the benefits of converting, even with these costs. "Cleaner Cars from Cradle to Grave (2015)" https://www.ucsusa.org/sites/default/files/attach/2015/11/Clean-Cars-from-Cradle-to-Grave-full-report.pdf. The issue of life-cycle impacts points to the need for conservation and sharp reductions in Vehicle Miles Traveled, and new types of "ownership," e.g. sharing and formal "ride-sharing."

[39] Creutzig, F., Fernandez, B., Haberl, H., Khosla, R., Mulugetta, Y. and Seto, K.C., 2016. Beyond technology: demand-side solutions for climate change mitigation. *Annual Review of Environment and Resources*, *41*, pp.173-198.

[40] See also Capstick, S., Lorenzoni, I., Corner, A. and Whitmarsh, L., 2014. Prospects for radical emissions reduction through behavior and lifestyle change. *Carbon management*, *5*(4), pp.429-445.

20–50% until 2050 (32). This may be achieved via three routes, technological change, modal shift, and reduced travel demand, and information technology plays a key role in all three areas of innovation (37)....Parking prices can lower distance traveled by 2–12%, and congestion charging, as implemented in London, Stockholm, and Singapore, can reduce distance traveled within the charging zone by 10–20%...Combining pricing with investment in bicycle infrastructure and public transport, along with long-term land use planning (which is most relevant where populations are growing), could realize a 50% reduction in urban transport GHG emissions..” **The most effective approaches combine “soft” educational and behavioral change campaigns with “hard,” “structural” reforms like zoning laws, carbon taxation, and major investments in pedestrian facilities and public transportation.**[41] These often save money immediately, and can actually improve health and quality of life. Similar initiatives have been attempted in many other areas of life that cause emissions: space heating and cooling, water use and heating, cooking, lighting, refrigeration, dwelling size, living arrangements and airline travel. **The point is that another world is possible where basic needs are well met with very low emissions.**[42]

The major assumptions we tested were more modest than some radical approaches out there, but the effort illuminates where there is room for improvements beyond the technological approaches taken by Rhode Island in the 2016 study and in the rest of this study. Based on the Creutzig (2016) review, we tested the impact of reducing consumption and waste in these sectors:

- **Vehicle miles traveled** – we tested the **impact of a 20% decrease in on-road passenger transport**, which could be driven by congestion or carbon pricing, marketing, information provision, and other low/no cost measures. Reforming infrastructure and expanding public transit could offer further carbon emissions reductions, but we don't know the costs and realistic timeframes for these options, so they were not included. The 20% decrease in vehicle miles traveled (VMT) could be from increased telecommuting (one day per week, for example), or telebanking, shopping online, carpooling, etc. We believe this level could go far deeper if there was intentional supporting policy and education, and community-building to satisfy human needs closer to home.
- **Space heating – 15% decrease in residential and commercial requirements** through thermostat adjustment. Many workplaces and homes are over-heated in the winter and over-cooled in the summer. More careful use of thermostats, including programmable and “learning” artificial intelligence models can sharply reduce thermal system waste. Clothing adjustments can significantly improve the range of settings at which homes and workplaces are comfortable.
- **Space cooling – 40% decrease in residential and commercial requirements** through thermostat adjustment and changing dress codes. Many unoccupied workplaces and residences are cooled and heated unnecessarily in off hours and on weekends. Behavioral actions such as changed clothing provide immediate cost (and health) savings, but systems like incentives or requirements for installing programmable thermostats are probably needed for deeper penetration and maintaining gains.

[41] Capstick, S., Lorenzoni, I., Corner, A. and Whitmarsh, L., 2014. Prospects for radical emissions reduction through behavior and lifestyle change. *Carbon management*, *5*(4), p 439.
[42] O’Neill, D.W., Fanning, A.L., Lamb, W.F. and Steinberger, J.K., 2018. A good life for all within planetary boundaries. *Nature Sustainability*, *1*(2), p.88; Creutzig, F., Roy, J., Lamb, W.F., Azevedo, I.M., de Bruin, W.B., Dalkmann, H., Edelenbosch, O.Y., Geels, F.W., Grubler, A., Hepburn, C. and Hertwich, E.G., 2018. Towards demand-side solutions for mitigating climate change. *Nature Climate Change*, *8*(4), p.268; Lamb, W.F. and Steinberger, J.K., 2017. Human well-being and climate change mitigation. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(6), p.e485.

- **Clothes washing and drying – 25% decrease** in residential requirements due to operating at full load, line drying, and reducing unnecessary laundering. Hotel programs to avoid linen over-washing can be stepped up; residents can reduce washing of barely used items. Again, education and incentives will be crucial for greater penetration.
- **Water heating – 50% decrease** in residential requirements through conservation; this could be on top of switching to tankless instant electric hot water heaters now widespread in Europe and much of the rest of the world. Shortening lengthy showers or adjusting pool temperatures seems a reasonable price to pay for a liveable global climate.
- **Cooking – 25% decrease** in residential and commercial requirements due to alternative cooking practices.
- **Lighting – 50% decrease** in residential requirements and **25% decrease in commercial requirements** by turning off unnecessary lights. These are suggested in the literature as possible.
- **Refrigeration – 30% decrease** in residential requirements due to smaller and fewer appliances. For example having a chest freezer or second refrigerator for drinks is highly energy consumptive, and could be avoided.
- **Dishwashing – 40% decrease** in residential requirements due to operating at full load.
- **Air travel** – the baseline model includes a 27 percent increase in airline travel. We modeled the number of **trips being held constant** at the last historically observed (2014) level. We believe this measure could go much further. For example, as part of a "fly less" campaign, residents could be encouraged to vacation locally, to the substantial benefit of Rhode Island's economy.
- **Average size of single-family residences** – We modeled the impact of a 10% decrease (from about 2,700 ft^2 per average residence) due to constructing smaller homes and dividing existing larger homes into condos. Housing markets are changing, as people of all ages are seeking smaller units, especially when they are within walking distance of stores, jobs, and public transit. In many cases, this could drop far more than 10 percent, if, for example, enough people move from a 3,000 square foot homes to 1,200 square foot townhomes.
- **Average size of multi-family residences** – Similarly, we modeled a **10% decrease** in average residence size (from about 1,200 ft^2 per residence currently) due to constructing smaller units and condo-izing larger homes.
- **Share of households in multi-family housing** – We also envision more people moving to condo and apartment living situations, so we modeled an increase from 41% to 50% doing so.

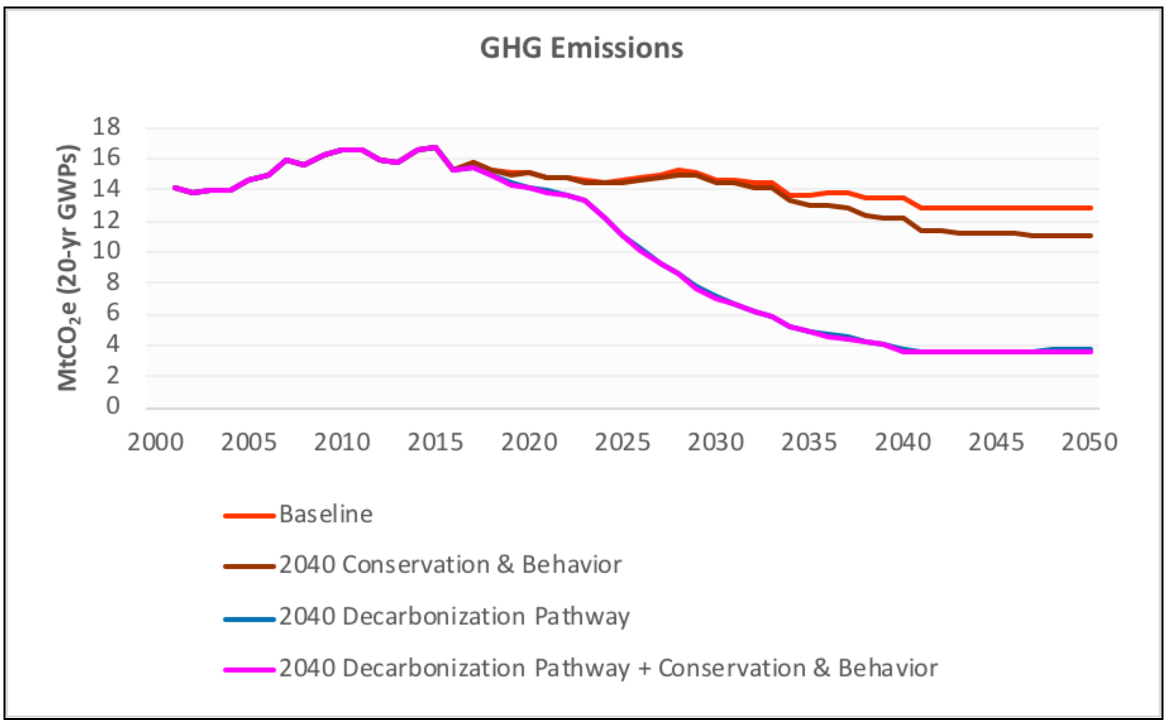
The last four assumptions were our own, informed by our observations in housing trends (including the size and type of new apartments going up in downtown Providence) and several background sources such as U.S. Census data. These factors are intended as just a first cut at how behavioral change and conservation measures could be modeled for the state: all of the assumptions can easily be modified in future modeling, and we look forward to others' proposed parameters, justifications for them, and policy measures that would move us in these directions. The point is that if we are to take the science of climate change seriously, we must consider new roads to more radical emissions reductions, and make them attractive to Rhode Island residents and workers.

The Conservation and Behavior Change scenario is configured so that the above changes (except the change in air travel) are realized by a target year – e.g., 2030, 2040, or 2050 if the scenario is added to one of our mitigation pathways. The air travel change applies equally in all years after 2014.

We calculated results for the mitigation pathways with and without behavioral change. Conservation and behavior change efforts made an important difference in the baseline scenario. That is, **without other technical efforts envisioned in the decarbonization pathways, individual efforts like these led to about a 15 percent reduction in the state's greenhouse gas emissions.**

But when more aggressive decarbonization is undertaken with technological solutions, including behavioral change doesn't substantially decrease emissions when compared to the corresponding pathway without behavioral change. There is a reduction of only a few percent, depending on the year (Figure 7.1). This is because **most of the behavioral changes target energy uses that are already decarbonized on the original mitigation pathways.** This is a very important finding of this set of models--it doesn't say we shouldn't make these changes in our lives, but rapid adoption of efficient and zero-emissions technology will have much the same impact in the state's emissions, within the world modeled here. Upstream and downstream impacts of high-consumption vs. low-consumption pathways will be very different.

Figure 7.1: *Comparison of baseline with 2040 decarbonization pathway, and pathway including conservation and behavior change elements.*



Importantly, however, there is a substantial difference in costs: conserving energy saves a lot of money. Discounted costs of mitigation come down by 10-20% (again depending on the year) when behavioral change is included. These findings are intriguing, suggesting that **to really accelerate emissions reductions, behavior changes need to either be much deeper** than the modest ones we modeled, **or focused on particular areas that technological change is not able to address.**

This would include especially airline travel, waste minimization, lawn and garden equipment, and household residence size and location. On the latter, Rhode Island law requires the maintenance of a State Guide Plan, which "directs the long-term growth and development of the state" (2016 GHG Plan). The *Land Use 2025* portion of the plan addresses the problem of sprawling land use by envisioning "land use decisions and direct[ing] growth and development to areas within the Urban Services Boundary." *Transportation 203*5 "guides investment of federal transportation dollars at the local level. Strategies in this plan include reducing VMT through use of alternative travel modes, ride-sharing, and integration of bicycle and pedestrian facilities." That plan included targets seeking to "reduce single occupancy vehicle commuting and increase transit mode share of work trips from 2.5% in 2000 to 2.8% in 2010, 3.0% in 2020 and 3.2% in 2030." We believe these are important efforts but their expected levels are far too low for true decarbonization of our state, which we must undertake. Reducing emissions by conserving energy and reducing other waste and overconsumption in our lives goes well beyond housing size and location, and the state should undertake to understand where the opportunities are for deep reductions. Again, many of these will end up being low cost or even net positive for family incomes, and improve health and build our communities.

Figure 7.2: *Cost comparison with conservation and behavior change, 2040 pathways. Values are shown in 2013 dollars, discounted to 2019 values at 5% per year*

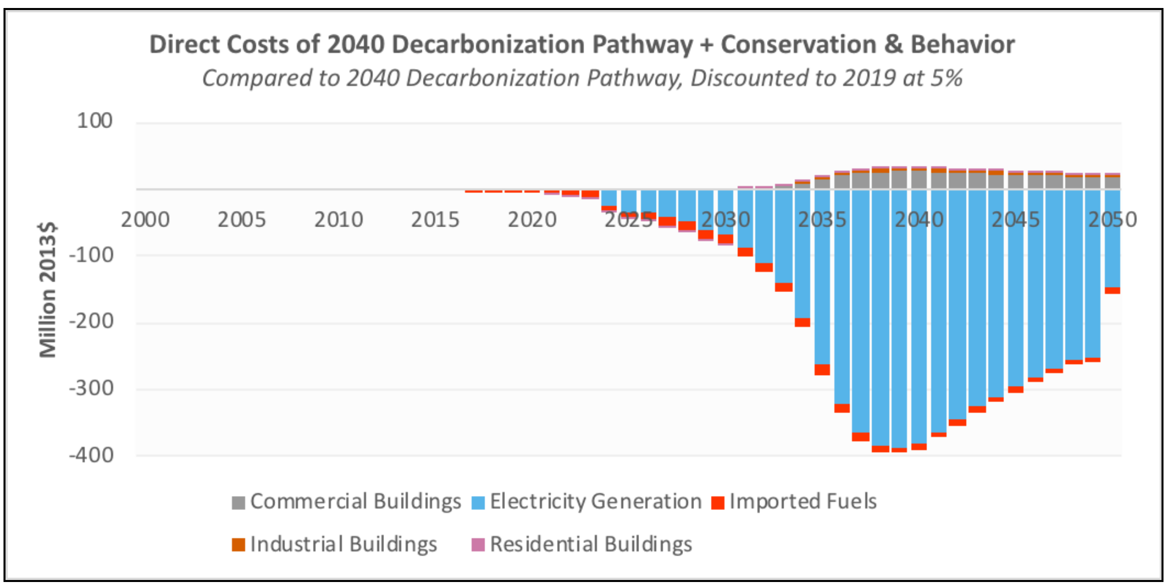
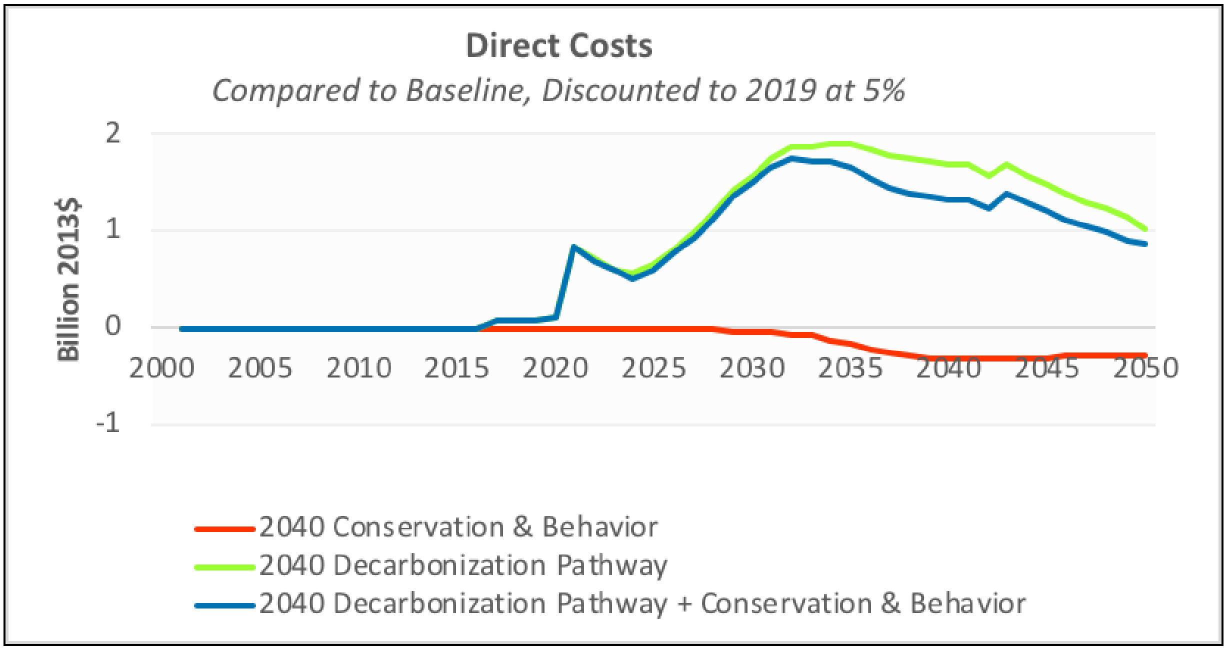


Figure 7.3: *Cost comparison between 2040 pathway including conservation and behavioral changes and 2040 pathway, showing sectors where costs and benefits are experienced. Values are shown in 2013 dollars, discounted to 2019 values at 5% per year*



Section 8: Remaining issues, ways forward

This exercise has shown that **it is possible to rapidly achieve 70 or 80 percent emissions reductions in Rhode Island's greenhouse gases using existing technologies**. This **can be done at quite a low cost for the 2040 and 2050 decarbonization pathways** because fossil fuel-consuming equipment is switched to electric at the time of normal replacement. However, this study shows that the transitioning off fossil fuels **could be done more quickly**, without waiting for future technology. We can wring nearly four-fifths of the emissions out of our state economy in just ten years. To do so would be at a greater expense, as we'd have to forcibly retire substantial equipment before its normal end of life.

If Rhode Island is serious about addressing climate change and cares about being a climate leader and standing up for the Paris Agreement, this study shows that **the first thing we need to do is to stop buying new fossil fueled capital equipment**. Any new equipment will be around and functioning for one, two, or even three or more decades. That delay in ambitious emissions reductions is expected to bring devastating impacts to our state, nation, and the world.[43] We need to stop installing new fossil fuel heating systems, cars, and power plants. Even using our existing equipment has costs, both for procuring fossil fuels to run them and for maintaining them; for example, this study estimates that just **keeping our baseline energy system for vehicles, heating systems, and electricity generation will cost about $6 billion a year for Rhode Island**. This is a substantial proportion--about one-tenth of our state economy, which was estimated to be about $59 billion in 2018.[44] Making the transition to carbon-free technology by electrification and "greening the grid" will require retirement of fossil assets and the costs of grid integration of variable renewables such as solar and wind power.

> The first thing we need to do is stop buying fossil fueled capital equipment

There are many questions this study did not address, and which will need to be taken up in other studies. How much can **distributed renewables** reduce the demand for utility-scale power in Rhode Island? Rooftop residential and commercial solar arrays are starting to make a difference in the region, with a growing "duck curve" of demand for electricity where solar supply sharply reduces the afternoon peak until sunset, when there is a spike. What **energy storage** sources are feasible for Rhode Island? Will hydroelectric energy brought in from Quebec and Labrador meet that afternoon peak demand, or will we need to keep biofuel or even natural gas or oil peaker plants online for these hours or days without adequate renewable electricity in the short- or medium-term? These are crucial areas for agency, independent or collaborative research.

This study shows that making the big changes envisioned will take care of 70-80 percent of Rhode Island's emissions, but we are left with are a **few sources of emissions that require further switching** from fossil fuels to other energy sources. There may not be easy solutions for things like air travel, where behavior and buying carbon offsets might be key. Process and assembly in industry need substantial

[43] First, P.J., et al. 2018. Global warming of 1.5 C An IPCC Special Report on the impacts of global warming of 1.5 C above pre-industrial levels and related global greenhouse gas emission pathways. IPCC.; USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp.

[44] https://www.usnews.com/news/best-states/rhode-island

further research to understand which reductions may be possible and at what expense or benefit. With just under ten percent of state workers employed in the sector, more research is needed in the areas of industrial emissions, to be able to model their pathways for decarbonization.[45] There are **six areas we'd flag here for future research and enhancements:** carbon sinks/sequestration, grid storage, landfill emissions, industrial improvements, behavior change, and equity.

There are six areas we'd flag here for future research and enhancements: carbon sinks/sequestration, grid storage, landfill emissions, industrial improvements, behavior change, and equity.

How much carbon can realistically be sequestered by Rhode Island's forests if managed carefully, and how much could be captured and stored with biochar, a charcoal soil amendment, or other soil management practices? The 2016 GHG plan listed some of the possibilities: "Strategies include protecting existing forest acreage, reforestation, conservation of riparian buffers, enhanced forest management programs (on both private and public lands), reductions in soil erosion to minimize losses in soil carbon storage, coastal wetland protection (e.g., blue carbon), and enhanced urban tree canopies." Quantifying this potential sink is a major research challenge, and mobilizing society to develop it will require significant attention. The 2016 plan made fairly generous assumptions about what was possible in the state in **carbon sequestration**, emissions that could be absorbed each year after a ramp-up period. To estimate well what's possible, we need a disaggregated view of Rhode Island forests and fields, in natural types, ages, and ownership/management status. There may be other forms of carbon capture the state can engage in safely, but **we cannot realistically expect major negative emissions.**

Energy storage and solid waste are not well modeled in this study, and also require future work. In the 2016 study, virtually no **grid-scale or distributed energy storage** was expected, and the issue was treated as beyond the study's scope. As with electric vehicles, technology and prices have changed significantly in the three years since the 2016 report was written, and certainly will in the near term. Massachusetts has focused on energy storage research and implementation. Our LEAP model does not at present model energy storage explicitly (see section 5.3), but this capability could be added. We hope to see much further research and action on grid-scale storage in future work in Rhode Island: it could be a game-changer.[46]

Strategies to reduce **methane emissions from the Central Landfill and other "legacy" dumps and landfills** around the state were inadequately modeled in the 2016 study. In that study, emissions from the Johnston landfill suddenly dropped to zero in 2038, when the landfill is expected to close. This is unrealistic, because the state will still need to dispose of its solid waste, and because aging landfills will continue to leak methane as long as their contents continue to rot. As discussed above, methane is a highly potent greenhouse gas. To

[45] RI Dept of Labor and Training. 2017. Rhode Island Labor Employment Trends and Workforce Issues. http://www.dlt.ri.gov/lmi/pdf/trends.pdf. We have some other categories of emissions sources in the commercial sector that need exploration. After water heating, the largest category is "other." There are categories called "non-building" in the NEMS data that is the basis of this modeling: some of these are outdoor street lights and cell phone radio towers. Natural gas non-building usage apparently is usually for space heating. This is distinct from consumption in other building categories, likely assembly. Again, this is an area where significantly more research is needed.

[46] On grid-scale energy storage in Rhode Island's history, see Roberts, Timmons 2017, "Grid storage in the 1830s: Lessons for innovation in today's energy market." https://www.brookings.edu/blog/planetpolicy/2017/08/23/grid-storage-in-the-1830s-lessons-for-innovation-in-todays-energy-market/

improve the scientific rigor and realism of the current model, we kept emissions at the same level post-2034. Efforts to capture methane leaking from the state's landfills and dumps should be advanced, and targets developed and enforced. These leaks make getting to a truly carbon-free state quite difficult, suggesting the need for more carbon sequestration, as just discussed.

The decarbonization pathways we present here do not assume that we have to erase **Rhode Island's industry**. To the contrary: they leave it nearly exactly as is. Our models incorporates only modest and cost-negative energy efficiency measures, as advanced by the Department of Energy's Industrial Assessment Centers (IACs) in interventions around the United States.[47] We are confident the state's industry can transform itself for an age of climate change, and would benefit substantially from the energy efficiency and cleaner production methods that already exist and which are coming online in the next few years. Again, there is a major need to understand better the potential for industrial fuel and feedstock switching and efficiency: some producers can switch fuels and efficiency can be improved, but we need more research, especially with consideration of costs and energy management changes needed. Similar points can be made for the decarbonization of the commercial sector.[48] Some redesign of industrial and commercial processes clearly could improve worker health and safety.

No group is more likely to suffer from climate change than low-income and minority Rhode Islanders

Finally, we stuck just one toe into the water of understanding what role **behavioral change and broader structural change** might play in decarbonizing the state. Things like flying, driving single-passenger cars, and sprawling land use were unaddressed in the 2016 study and only preliminarily explored in our modeling (Section 7). **These are areas where we are confident the state could do *much better* than in our modeling**, and they are areas where we probably *need* to make deep changes if we hope to reach near zero net emissions well before 2050, as the science suggests we need to. They include using low-flow shower heads, laundry temperatures, thermostat setbacks, line drying clothes, driving behavior, carpooling, telecommuting, doing better auto maintenance and tune-ups, and on and on. Some deeper behavior changes might appear to some people to require some sacrifice, like choosing to live in smaller homes, in denser neighborhoods, or near public transit, but these are all seen by other residents as huge benefits and reasons to live and seek work in Rhode Island. Each could sharply reduce our emissions, often with *lower* costs than in a business-as-usual scenario. Policy tools like zoning and incentives for transit-oriented-development can speed these transitions and make our state far more sustainable, healthy, and resilient in the face of climate change.

This brings us to a final and crucial area unaddressed in this effort and the 2016 Greenhouse Gas Emissions Reduction Plan: equity. **Not addressing climate change endangers the lives and livelihoods of many groups of Rhode Islanders: the elderly, coastal homeowners, youth, those living in floodplains, construction workers, farmers and the state's fishing and tourism industries**.[49] No group is

[47] See https://iac.university/. We assumed that all manufacturing establishments in Rhode Island undergo an IAC-style energy audit and implement the resulting efficiency recommendations.

[48] These models are based on square feet of commercial floor space. The study is based on average square feet that can be heated or cooled with a piece of equipment, but there is no information on how the square footage in buildings is arranged. That is, one large space could be efficiently heated and cooled by fewer units than a similar square footage divided into many small offices. Similarly, water heating requirements differ for different commercial buildings, and there simply is not adequate data to model it.

[49] See e.g. RI Dept. of Health. 2015. *Climate Change and Health Resiliency.* http://health.ri.gov/publications/reports/ClimateChangeAndHealthResiliency.pdf and other reports at the RIDOH Climate Change

more likely to suffer from climate change than **low-income and minority Rhode Islanders, especially those living in urban heat islands and "frontline communities," near hazardous facilities and unwanted land use**. These residents are already suffering disproportionately from asthma and other health ailments from the fossil-fueled economy; warming temperatures and storm surges risk exacerbating these impacts.

The flipside of this issue is that even acting aggressively on climate change may create disruption for key groups of Rhode Islanders. Some workers may face job loss in their sector, and will require job training and direct assistance to locate new work, survive and thrive during periods of transition. **Attention to "just transitions" for communities and workers is essential** to making the transitions envisioned in this report--and even the baseline scenario--pathways to a better Rhode Island.

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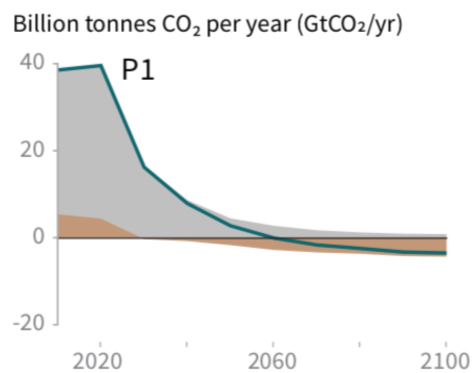
and Health website: http://health.ri.gov/programs/detail.php?pgm_id=174. Also science at https://naturestrustri.org; and points discussed in Rhode Island Attorney General's lawsuit against major oil corporations based on infringements on our Public Trust. E.g. Climate Liability News. 2018. Why States May Turn the Tide in Climate Liability, Led by Rhode Island. https://www.climateliabilitynews.org/2018/09/11/rhode-island-states-climate-liability/

Section 9: Which pathway should Rhode Island choose?

So which pathway should Rhode Island choose? At the outset of this report, we stated that its goal was not to develop or choose one route to decarbonization in the state, but rather to lay out options and begin to weigh different tradeoffs. However, we agree with comments on an earlier version that the issues of precaution, equity today, and justice for future generations require we weigh the implications of taking each of the four pathways detailed in this report. We do so here in two steps, considering precaution in the first, and then equity in the second.[50]

<u>Step 1, Precaution:</u> First, the IPCC 1.5 degree special report released in fall, 2018 suggests that **global emissions need to drop by 58 percent by 2030,** and reach near zero by 2050, to stay within safer levels of warming. Global levels of CO2 in the atmosphere are already above 415 parts per million, far above the 280 ppm before the fossil fuel era. Expected climate impacts such as floods, droughts and storms become far worse above 1.5 degrees C, especially in vulnerable parts of the world.[51] Figure 8.1 shows the IPCC's "P1" 1.5 degree pathway, which avoids the assumption that elusive technologies will materialize that can easily and safely suck carbon out of the air. To act with precaution, the pathway is the relatiely safest one to take.

***Figure 8.1:** IPCC 2018 Special Report P1 Pathway for global emissions to stay below 1.5 degrees, without negative emissions.*



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

From this estimate—the widest scientific consensus yet available on the actions needed to avoid dangerous climate change—we can eliminate two of our four pathways based on precaution. First, the

[50] The Natures Trust RI actions on behalf of youth's right to a liveable climate are also focused on precaution and justice issues. See https://naturestrustri.org.

[51] See IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. P.rtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. P.an, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. IPCC. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf. Most of the IPCC models assume "negative emissions" in the second half of this century through carbon sequestration. The problem with "Carbon Capture and Sequestration" technologies is that they require significant energy to run, and safe areas for storage are often at long distances from areas of energy demand. A major form of sequestration in many IPCC and other scenarios is BECCS, or Biomass Energy Carbon Capture and Storage. In this scheme vast areas of the tropics would be converted to the cultivation of sugarcane or other cellulosic plants (to absorb carbon dioxide), which then would be burned in power plants and the carbon captured and stored underground. Doing this at the massive scales required in slow-action scenarios risks impacts on food systems in developing nations, and potentially destabilizing core ecosystems balancing weather and climate systems.

baseline case, namely continuing on with "business as usual" in the state, would result in only marginal emissions reductions by 2030 or 2050. Our 2017 emissions are estimated at 15.5 MtCO2e; they would be about 14.3 MtCO2e in 2030 in the baseline case, and about 13.0 MtCO2e in 2050. These represent only 8 percent reductions by 2030 and 16 percent by 2050. **Based on precaution, the baseline case must be eliminated as an acceptable way forward.**

> Based on precaution, the baseline case must be eliminated as an acceptable way forward.

The **2050 Decarbonization Pathway** in this study projected Rhode Island's emissions to be about 10 MtCO2e in 2030, and about 4 MtCO2e in 2050. These represent 35 percent reduction by 2030 and a 74 percent reduction by 2050. Therefore, even without considering equity issues, **this pathway is inadequate to secure a safe future for our children, or to do even our global average share of emissions reductions**.

> The 2050 pathway is inadequate to secure a safe future for our children, or to do even our global average share of emissions reductions.

The 2040 decarbonization pathway reaches approximately 7.5 MtCO2e by 2030, a 52 percent reduction from our 2017 start. The 2030 Decarbonization Pathway is down to 3.8 MtCO2e by 2030, as low as we could confidently model (see discussion above). By the measure of making global average reductions, the 2040 pathway is almost adequate for the 2030 waypoint.

__Step 2, Equity:__ Achieving average required emissions reductions can in no way be considered a just effort by Rhode Island. Rather, as part of the United States, Rhode Island has emitted massive amounts of greenhouse gases in the past on a per capita basis, much of which remain in the atmosphere today warming the planet. There is no easy agreement on how far back we should be held responsible for, but the Climate Equity Reference Calculator shows a few options: to 1990, 1950, or even 1850, when the industrial revolution began.[52] The United States' responsibility for emissions varies little for those periods. If we consider emissions just back to 1990, when the science was established and just before the globally-universal UNFCCC framework treaty was signed, **the USA is responsible for 35 percent of global warming gases, while making up only about 4 percent of the world's population.**[53]

Principles agreed and reaffirmed by the world's nations since 1992 from the United Nations Framework Convention on Climate Change to the Paris Agreement state that developed nations should act first, according to their responsibility for causing the problem and their ability to act. The United States scores near the top on both of these indicators (responsibility and capability), suggesting we by rights need to reduce our emissions much faster than developing nations, who still lack adequate sanitation, education, health, and living conditions. The Equity Reference Calculator actually shows that **considering our responsibility and our capabilities, the U.S. should reach zero net emissions by around 2025**. Failing that, the Calculator and decades of global agreements agree that developed nations should provide

[52] See Ecoequity.org's Climate Equity Reference Calculator. https://calculator.climateequityreference.org/#.

[53] Taking the full 160 years of industrialization into account raises this to 38 percent. On measuring responsibility, vulnerability and effort on climate change, see e.g. Roberts, J.T. and Parks, B., 2006. *A Climate of Injustice: Global inequality, north-south politics, and climate policy*. MIT press; Dellink, R., Den Elzen, M., Aiking, H., Bergsma, E., Berkhout, F., Dekker, T. and Gupta, J., 2009. Sharing the burden of financing adaptation to climate change. *Global Environmental Change*, *19*(4), pp.411-421.

substantial financial support to developing nations to help them reach a good life without relying on fossil fuel infrastructure.

This logical step suggests that **equity and precaution require that the state of Rhode Island act according to its responsibility for global warming and eliminate its emissions of greenhouse gases by as close to 2025 as possible**. This proposition appears extreme, but this emergency situation is the result of our country having delayed acting on climate change for over 30 years. Now, the slope of reductions is incredibly steep: the 2040 decarbonization pathway gets us only to about 52 percent reductions by 2030. By comparison, the 2030 pathway brings emissions to an estimated 75 percent of what they were at the start of the study period, still inadequate by the criteria of precaution and equity.

Our modeling shows how 70 to 80 percent reductions in our impact could take place very quickly, and relatively affordably, allowing time to plan for the other 20-30 percent over the next 5-10 years.

It would be tempting to throw up our hands at information like this, that because we are late starting this effort, we must act so fast. The other side of this coin is that making the transition brings substantial benefits, as discussed at the outset of this report, such as cleaner air, less dependence upon foreign and imported oil and gas, healthier homes, zero fuel costs, greater resilience in the face of more extreme weather events, and a surge in good jobs, as seen already in the state's *Clean Energy Jobs Report*.[54] Every ton of avoided emissions makes a difference in confronting this crisis, and having a state committed to leading this transition and reaping the benefits and investment could make a difference in the region, the country, and the world. Seven other states have already established 100% renewable or "100% carbon free" by 2050 or 2045 targets, and are developing plans to get there.Nearly any targets in this range will require the efforts suggested by this study's deepest decarbonization pathways.

Our modeling shows how 70 to 80 percent reductions in our impact could take place very quickly, and relatively affordably, allowing time to plan for the other 20-30 percent over the next 5-10 years. These considerations of precaution and equity strongly point to Rhode Island adopting the deepest decarbonization model and use that experience as proof of concept for reaching the full 100% decarbonization.

[54] Rhode Island Office of Energy Resources. 2018. *2018 Clean Energy Jobs Report.* http://www.energy.ri.gov/cleanjobs/2018/2018%20RI%20Clean%20Energy%20Industry%20Report.pdf

Section 10: Recommendations

This study has shown that Rhode Island can take immediate steps to decarbonization and must at the same time develop a fully detailed plan for more deeply decarbonizing its economy.

Immediate Steps:

The state can and should **build upon existing policies (See Appendix A)** to sharply increase efforts to decarbonize by focusing on slashing waste, electrifying everything, greening the grid, and stopping the leaks:

1. **"Slashing Waste:"** Existing energy efficiency programs can be boosted sharply to reduce waste with stricter building codes for insulation and furnace/AC efficiency, appliance standards, rebates for trading in old appliances and cars, etc.; specifically, RI should support and require Department of Energy Industrial Assessment Centers **efficiency audits for industrial establishments**, providing capacity and financing for instituting the efficiency improvements they suggest.
2. **"Electrify Everything:"** Shifting transportation to electric vehicles, and switching space heating to electric heat pump technologies is now urgent and possible. RI should sharply enhance incentives such as rebates and tax credits. We should focus on building and supporting programs to reach to low-income residents and rental properties. Consider hard phase-out dates for non-electric vehicle and heater sales.
3. **"Greening the grid:"** This study shows that nearly two-thirds of the state's energy can be supplied by offshore wind. Rapid installation is needed to meet the rising electricity demand foreseen in this study. Serious attention must be given to the concerns of the state's fishing industry, to minimize disruption and and support adjustments and transitions to new equipment and fisheries. Similarly, onshore solar and wind siting require urgent state attention to local community and landowner issues with the need to ramp up installations.
4. **"Stopping the leaks:"** National Grid must frequently measure and report the **locations and number of gas leaks** from infrastructure, report an overall leakage rate for the state, and chart expected emissions reductions with different amounts of investment going forward. These programs must be prioritized and accelerated to get to zero.

Longer-term planning needed:

Rhode Island needs to think bigger and longer-term: where do we want to get, and how will we get there? The state needs to:

1. Develop a **comprehensive decarbonization plan** for the state, with a timeline compatible with science and detailed sector-by-sector plans.
2. Build a **plan for the systematic decommissioning of natural gas infrastructure**.
3. Conduct a study and **plan for the insulation and heating of buildings**, reviewing best practices and policies in other states, with approaches focusing on specific sectors such as rental properties of different types.
4. An exploration of **methods to decarbonize industrial processes** both by the state and from Industry creating its own plans to decarbonize.
5. GIS, forestry, and land use planning teaming up to examine how Rhode Island forests and wetlands are managed, and **how we can shift those land management policies towards carbon sequestration**.

6. An in-depth **study of grid storage** in other states and how those models could be implemented in Rhode Island.
7. Study different models of **economy-wide carbon pricing**--these can drive efficiency, switching off fossil fuels, and raise substantial funding for transition efforts.
8. Examine the feasibility of capture of landfill gas on all of Rhode Island's existing and past landfills.
9. A **complete upstream and downstream consumption-based study** for Rhode Island's emissions, to establish a more complete picture for planning.

Appendix A: Existing Rhode Island policies and programs which can be enhanced right now

There are a series of important existing policies that have already improved the state's energy efficiency and carbon emissions to make us among the best in the U.S. These excerpts are useful in considering what could be done right now with or without legislative action to scale up action in the state, and which can be of service in more ambitious decarbonization pathways which are laid out here. To meet deeper decarbonization targets, dates could be moved up, voluntary programs made mandatory, or incentives like tax rebated or direct rebates and broader economy-wide programs are needed. (These are excerpts from the state's 2016 GHG Plan)

1. "Slash Waste"/ Boost Energy Efficiency:

"Energy efficiency means using less energy (e.g., electricity, natural gas, heating oil, propane) to provide the same or greater level of energy services. Energy efficiency in the context of this mitigation option refers to energy use reduction or management in buildings (i.e., residential dwellings as well as commercial and industrial facilities). Examples of energy-efficient technologies include weatherization, and high- efficiency lighting, appliances, and HVAC equipment. Energy efficiency gains can also be achieved through changes in consumer or business behavior (i.e., conservation). Finally, energy efficiency as a mitigation option can be considered to include advanced technologies and strategies such as load management/demand response and Volt/VAR optimization (VVO)." (2016 GHG Plan)

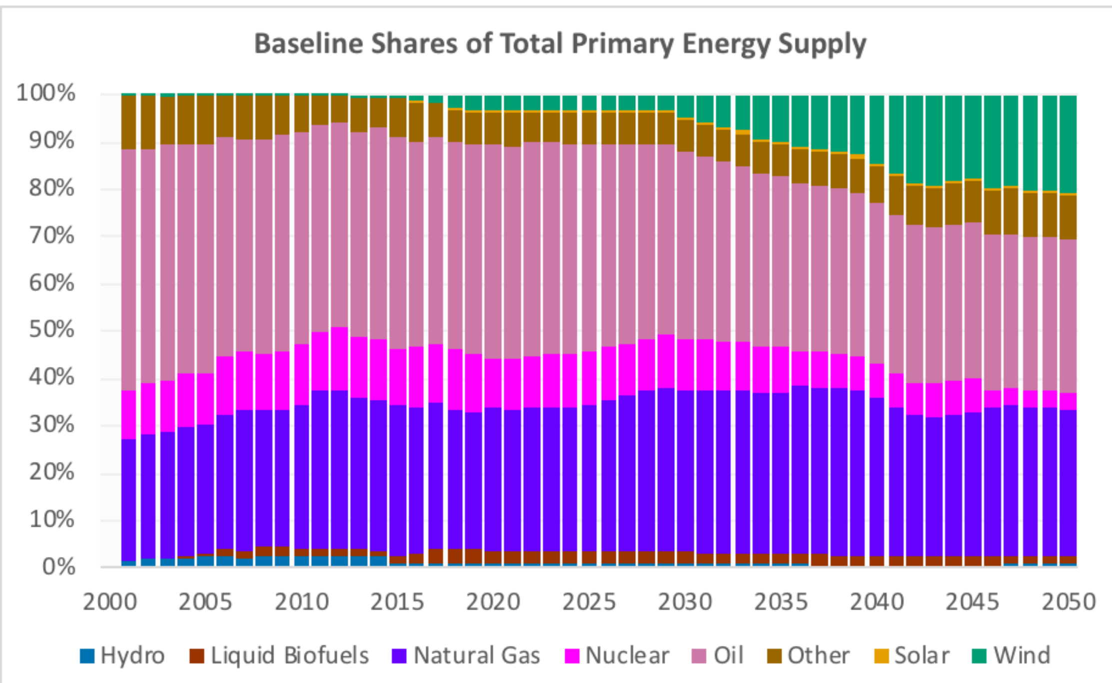
"Existing statutes in Rhode Island set **minimum energy efficiency standards for appliances and buildings.** As of December 2016, Rhode Island had adopted the 2012 International Energy Conservation Code (IECC) with Rhode Island-specific amendments for both residential and commercial buildings. A 2016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

Least-Cost Procurement (LCP), enacted in 2006, requires electric and natural gas utilities (i.e., National Grid) to invest in all cost-effective energy efficiency that costs less than conventional energy supply resources. Under Least-Cost Procurement, Rhode Island has achieved nation-leading levels of electricity and natural gas savings in recent years.13 A statutorily-authorized consumer stakeholder board – the

Energy Efficiency and Resource Management Council (EERMC) – oversees National Grid's development and implementation of programs, all with public input. The EERMC sets annual energy savings targets for investing in all cost-effective electricity and natural gas energy efficiency. LCP is currently scheduled to sunset in 2024." (2016 GHG Plan)

2. "Electrify Everything": Vehicles, Heat/AC, Lawn Care, etc.

"**Battery electric or plug-in hybrid electric vehicles** offer GHG reductions in the transportation sector by displacing emissions from conventional gasoline- and diesel-powered vehicles. Electric vehicles produce a GHG reduction benefit due to the inherent efficiency of the motor and drivetrain as well as the relatively cleaner emissions profile of New England's power grid supply c



ompared to that of traditional transportation fuels (i.e., gasoline and diesel). This GHG reduction benefit increases over time as the electricity supply shifts toward higher clean energy penetration.

Rhode Island is a signatory to the multi-state **Zero Emission Vehicle Memorandum of Understanding (ZEV MOU)**, with a goal of deploying 43,000 ZEVs on Rhode Island roadways by 2025. To advance progress toward this goal, Rhode Island has invested in a statewide network of publicly- accessible electric vehicle charging stations, initiated an electric vehicle rebate incentive program (Driving Rhode Island to Vehicle Electrification, or DRIVE), and established a ZEV Working Group.[23] The Rhode Island State Rail Plan contains goals, objectives, policies, and implementation actions for Rhode Island's passenger and freight rail transportation system.[24]

RIPTA provides 9.6 million miles of fixed route bus service annually, with a fleet comprised of 27% hybrid-electric vehicles." (2016 GHG Plan)

"High-efficiency electric cold climate heating systems (i.e., **air source heat pumps** (ductless mini-split or central systems) or ground-source heat pumps) offer GHG reductions in the thermal sector by displacing emissions from fossil fuel heating systems (i.e., natural gas furnaces and oil boilers). Electric heat pump systems produce a GHG reduction benefit due to the inherent efficiency of the heating technology as well as the relatively cleaner emissions profile of New England's power grid supply compared to that of natural gas or oil heating systems. This GHG reduction benefit increases over time as the electricity supply shifts toward a more decarbonized resource mix. Under Least-Cost Procurement, energy efficiency programs have incentivized the installation of higher-efficient heat pump systems, especially those that can heat at cold winter temperatures, where they are replacing older, inefficient heat pumps or electric resistance systems." (2016 GHG Plan)

3. "Green The Grid: Renewables:

"Rhode Island has a number of **existing policies in place to promote the use of renewable and clean energy**:

•**The Renewable Energy Standard (RES)** requires electricity providers to supply an increasing percentage of their retail electric sales from renewable resources. Rhode Island's RES is currently set at 38.5% by 2035.

•**The Long-Term Contracting Standard for Renewable Energy (LTC)** requires National Grid to solicit proposals from renewable energy developers and enter into long-term contracts with terms of up to 15 years. The LTC provides for 90 megawatts (MW) of contracts and for up to 150 MW of a utility-scale offshore wind farm.

•**The Affordable Clean Energy Security Act (ACES)** authorizes National Grid to participate in multi-state or regional efforts to procure large hydropower and/or renewable energy resources.

•**The Renewable Energy Growth Program (REG)** requires National Grid to enroll a total of 200 MW[19] of local renewable energy projects by 2019.

•**Net Metering** requires National Grid to credit power supplied by renewable energy projects onto the grid. Net metered projects must be located on-site, with certain exceptions for public sector projects, farms, affordable housing, and residential projects." (2016 GHG Plan)

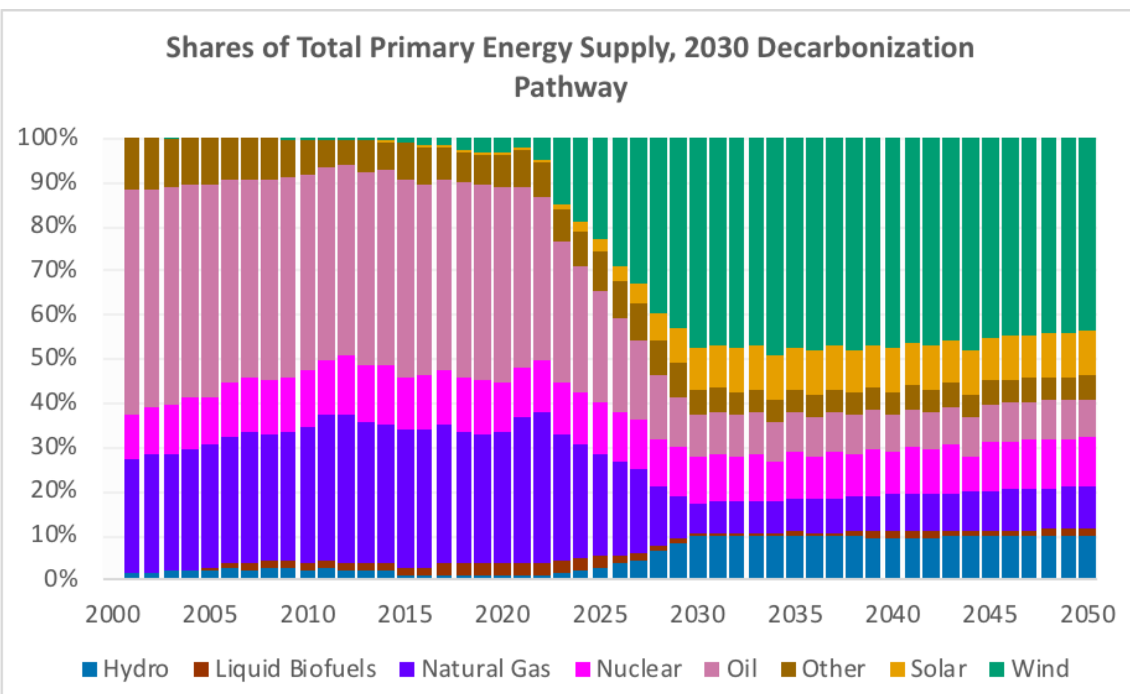
Other Initiatives:

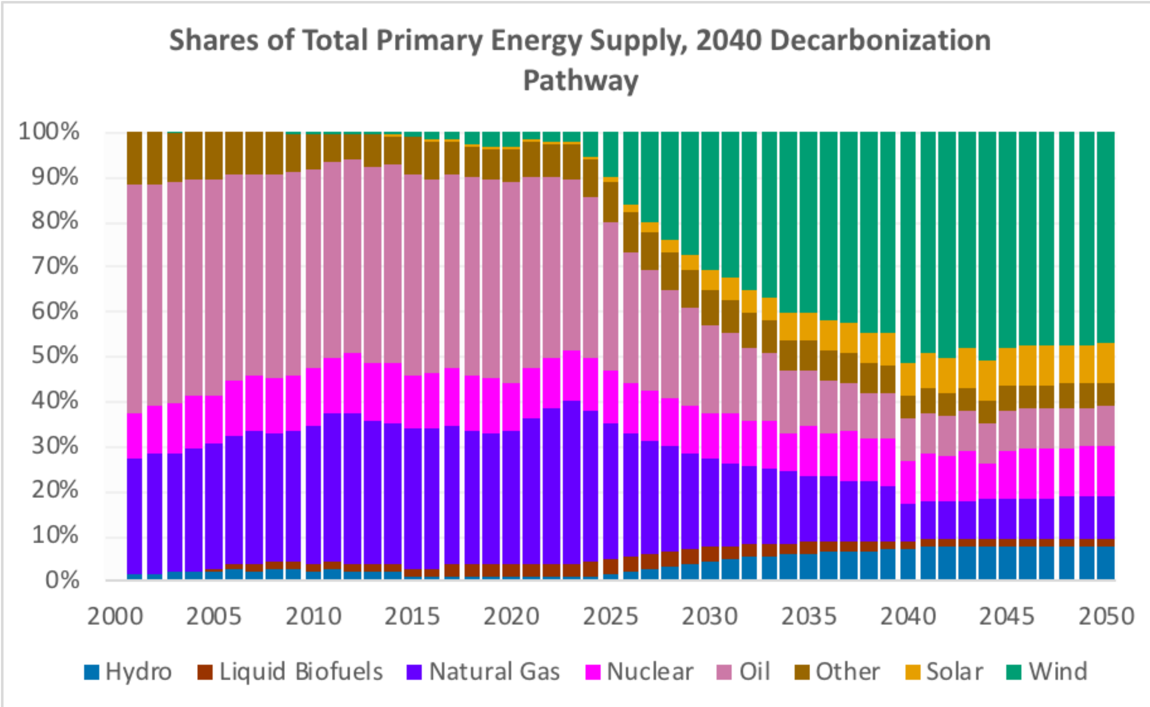
"**Biofuels** are liquid fuels derived from renewable organic substances (e.g., recycled cooking grease, plant residues, animal fats, and other renewable feedstocks). Biofuel can offer GHG reductions in the thermal sector by displacing lifecycle emissions[22] from fossil fuel heating systems using heating oil. **The 2013 Biodiesel Heating Oil Act** established a 5% bioblend requirement for all heating oil sold in the state by July 1, 2017." (2016 GHG Plan)

Approximately 22% of Rhode Island is in permanent conservation status, and 55% of Rhode Island is forested; however, our forest resource is being lost and fragmented by a wide variety of development pressures. Existing programs like the **Forest Legacy Program, the Forest Stewardship Program, and Urban and Community Forestry** help reduce those pressures and allow forest land to be preserved and utilized as a carbon sink. Continued public support for funding **open space protection** continues to be a critical component of the State's land protection efforts.[27] Additionally, the State can minimize loss of existing forest acreage by prioritizing investments to support new growth within the existing **Urban Services Boundary** (as delineated in Land Use 2025) and in State-approved growth centers....Ensuring the survival of Rhode Island's **wetlands** is an important component of GHG and resiliency/adaptation priorities. (2016 GHG Plan)

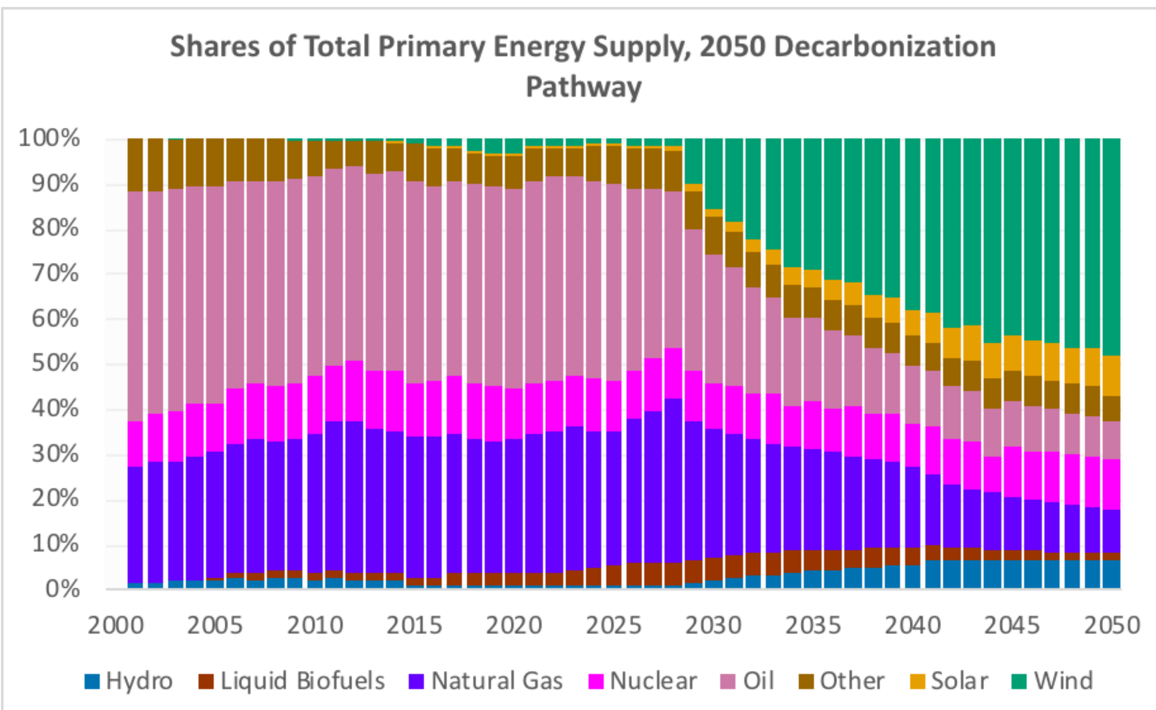
Appendix B: Secondary Resources

Figure A1. Percent share of total primary energy supply, a. improved baseline, b. 2030, c. 2040 and d. 2050 decarbonization pathways





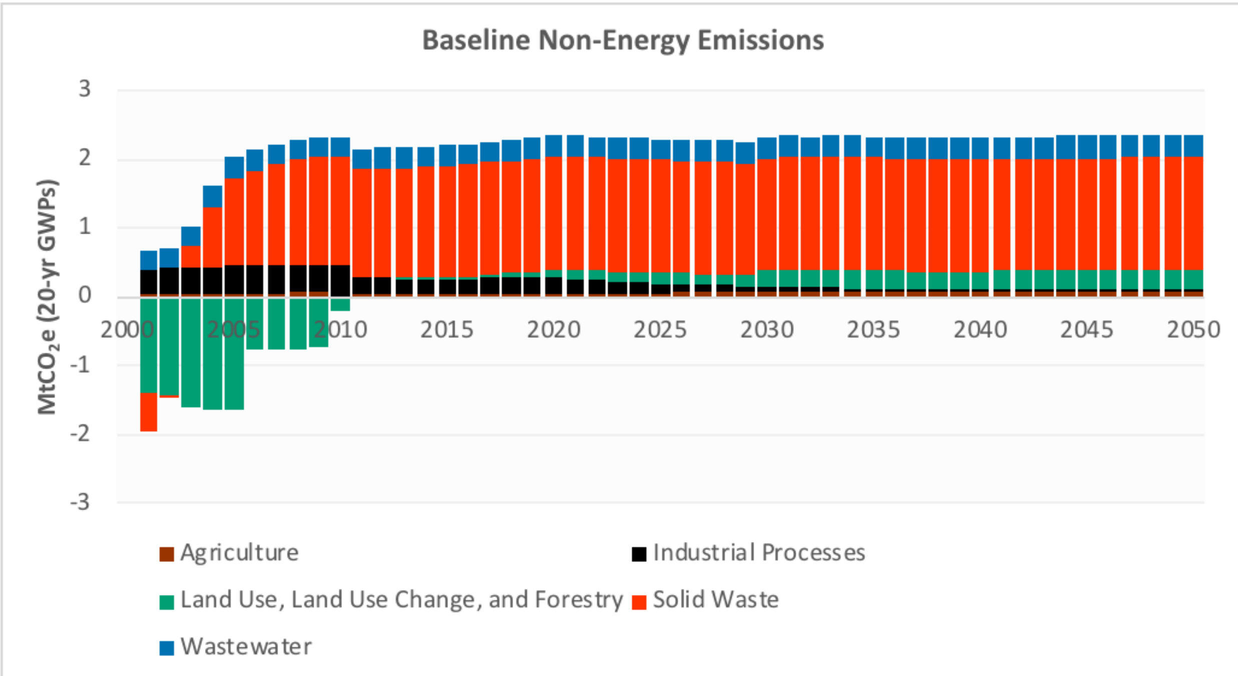
Shares of Total Primary Energy Supply, 2040 Decarbonization Pathway
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Hydro
Liquid Biofuels
Natural Gas
Nuclear
Oil
Other
Solar
Wind



Shares of Total Primary Energy Supply, 2050 Decarbonization Pathway
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Hydro
Liquid Biofuels
Natural Gas
Nuclear
Oil
Other
Solar
Wind

Non-energy emissions:

Figure A2: Non-energy emissions over time, all scenarios.



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For further information and comments, contact Professor Timmons Roberts timmons@brown.edu or Jason Veysey jason.veysey@sei.org.