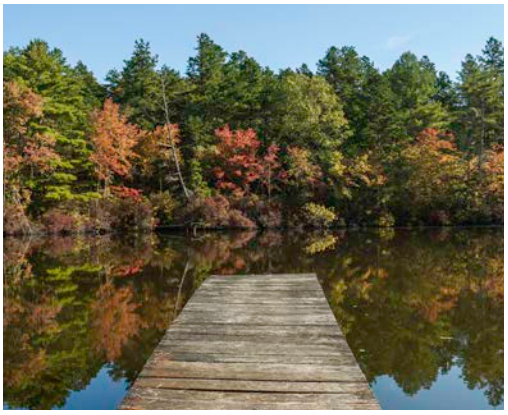
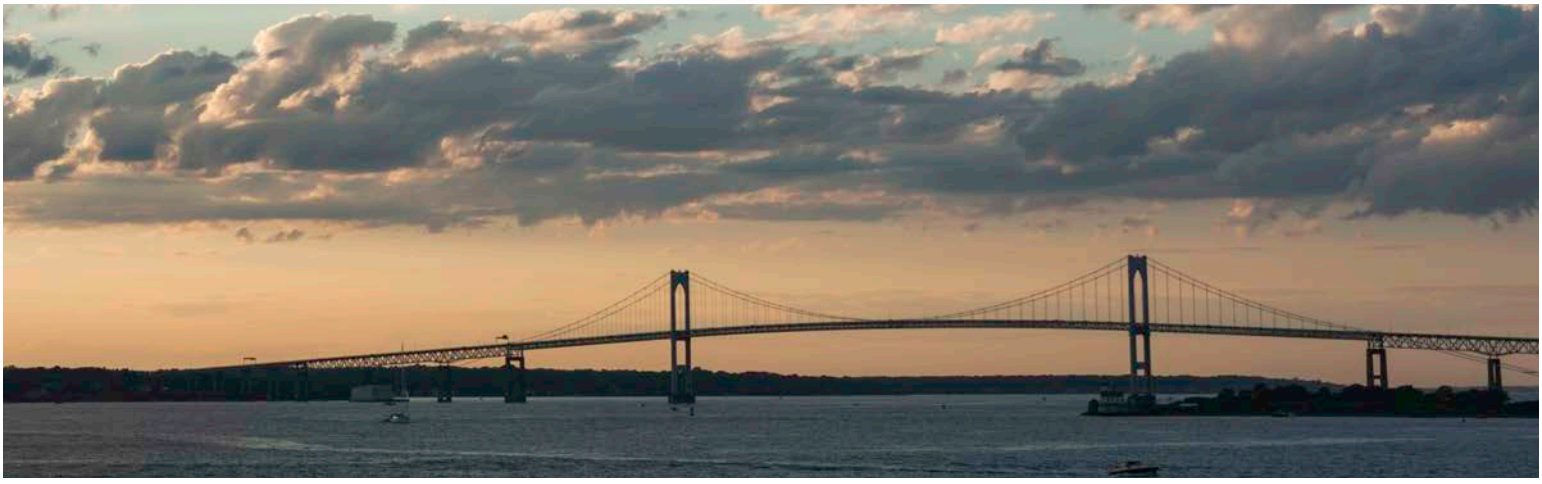
DEM
RHODE ISLAND

DECEMBER 2022

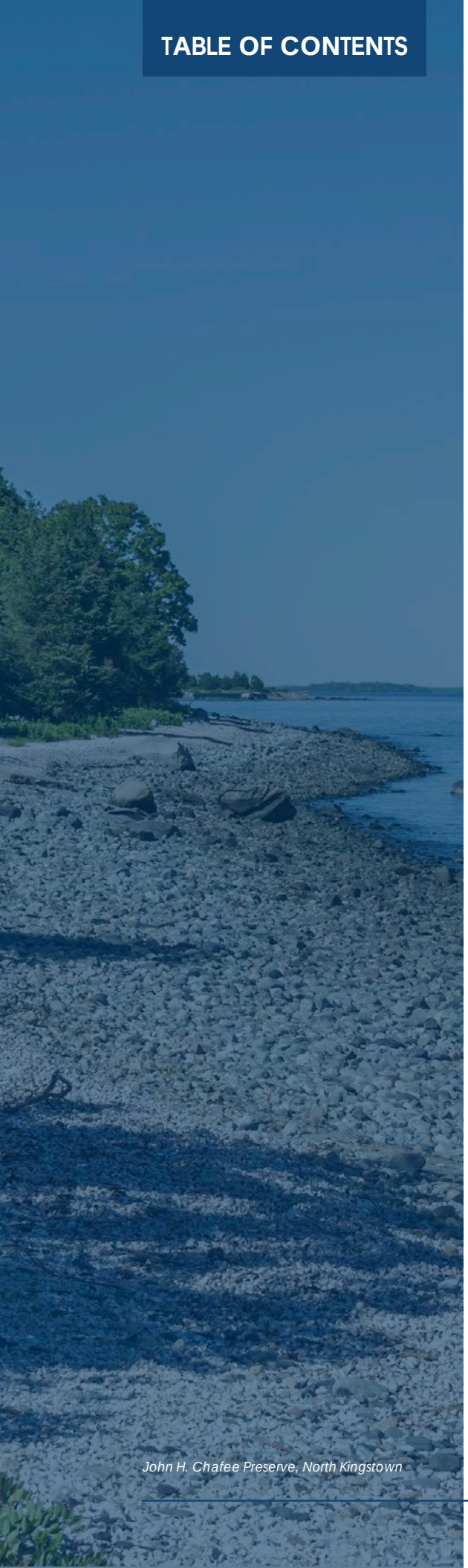


2019 RHODE ISLAND

GREENHOUSE GAS EMISSIONS INVENTORY



AN ASSESSMENT OF RHODE ISLAND'S PROGRESS TOWARDS THE 2021 ACT ON CLIMATE



John H. Chafee Preserve, North Kingstown

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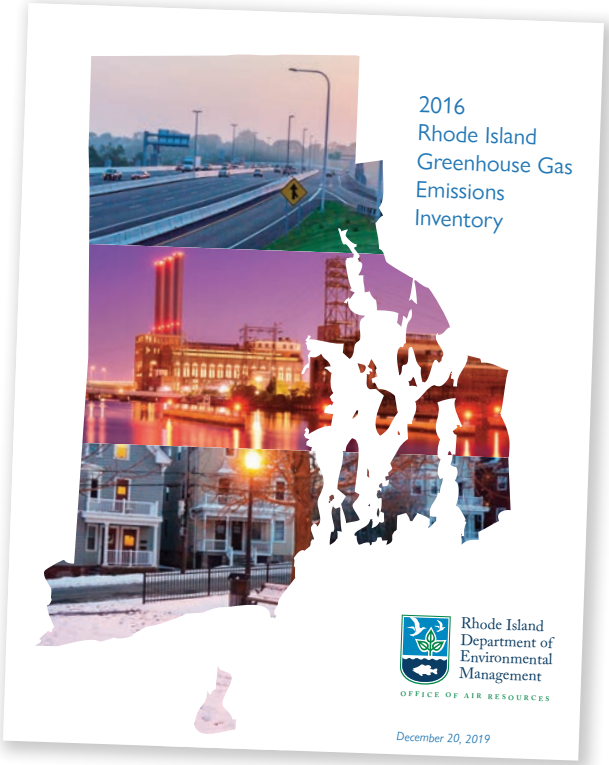
Providence Skyline

Note To Readers

The *2019 Rhode Island Greenhouse Gas Emissions Inventory* is classified as a 'triennial' summary. Every three years, the Rhode Island Department of Environmental Management's (RIDEM) Office of Air Resources publishes an analysis of greenhouse gas emission trends, estimation methodologies, and improvement efforts. Triennial summaries coincide with releases of the U.S. Environmental Protection Agency (EPA) *National Emissions Inventory*. Other state-level GHG emissions inventories exist, such as the EPA's *Greenhouse Gas Inventory Data Explorer* and Rhodium Group's *ClimateDeck*. RIDEM's triennial summaries are the only official GHG emissions inventory for Rhode Island. In an effort to continuously improve the inventory, a few significant changes were implemented for 2019 and are described in this summary. Annual inventories published by RIDEM may be subject to change and quantitative estimates are not official until published in a triennial summary. For more information, visit https:///www.dem.ri.gov/ghg-inventory



First GHG Emissions Inventory Triennial Summary.

Executive Summary

KEY FINDINGS

- Net GHG emissions in 2019 were 10.04 MMTCO2e
- Gross GHG emissions in 2019 were 10.82 million metric tons carbon dioxide equivalent (MMTCO2e)
- RHODE ISLAND ACHIEVED THE ACT ON CLIMATE'S 2020 GHG EMISSIONS REDUCTION MANDATE
- Statewide net GHG emissions decreased 2.44 MMTCO2e (-19.6%) from the 1990 baseline (12.48 MMTCO2e)
- In 2019, Rhode Island's largest GHG emitting sectors were:

Transportation
4.29 MMTCO2e
39.7%

Residential Heating
2.09 MMTCO2e
19.3%

Electricity Consumption
2.05 MMTCO2e
18.9%

Greenhouse gas (GHG) emissions from fossil fuel combustion have warmed Earth's atmosphere since the dawn of the industrial revolution in the late 1700's. Global warming, the phenomena of increasing average air temperatures over Earth's surface[1], correlates with contemporary climate change. Anthropogenic GHG emissions contribute to warming and rising oceans, degradation of polar ice caps, and more extreme weather. The most prevalent GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. Annual estimation of Rhode Island's greenhouse gas emissions is paramount to understanding the state's contribution to climate change.

The annual GHG emissions inventory is the primary scientific tool for assessing progress towards the 2021 Act on Climate. Signed by Governor McKee in April 2021, the Act on Climate sets economy wide GHG emission reduction mandates to guide Rhode Island to net-zero GHG emissions by 2050.

2021 ACT ON CLIMATE

GHG EMISSION REDUCTION MANDATES:

- 10% below 1990 levels by 2020
- 45% below 1990 levels by 2030
- 80% below 1990 levels by 2040
- Net-zero emissions by 2050

In accordance with the provisions of the Rhode Island General Laws §42-6.2-3(2), the Rhode Island Executive Climate Change Coordinating Council (EC4) directs state agencies to: "Develop short- and long-term greenhouse gas emission reduction strategies and track the progress of these strategies;"

The completion of Rhode Island's annual GHG emissions inventory is a core component of RIDEM's contributions in support of the Act on Climate. In response to the Act on Climate, the EC4 will complete the *2022 Update to the 2016 Rhode Island Greenhouse Gas Emissions Reduction Plan* in December 2022. Rhode Island must also uphold its commitment as a U.S. Climate Alliance (USCA) state to limit average global temperature rise below 1.5 degrees Celsius. States that participate in the USCA commit to reducing collective GHG emissions by at least 26-28% by 2025, and 52% by 2030, both below 2005 levels. USCA states also commit to achieving net-zero emissions as soon as possible, but no later than 2050[2]. External factors that affect GHG emissions such as fuel prices, population, and economics are excluded from this document.

1 *Mann, M. E. (2022, October 7). Global warming. Encyclopedia Britannica. Retrieved November 7, 2022, https://www.britannica.com/science/global-warming*

2 *United States Climate Alliance. (n.d.). Alliance Principles. Retrieved November 7, 2022, http://www.usclimatealliance.org/alliance-principles*

Farmland Solar Array

Background

THE INVENTORY PROCESS

The EPA's State Inventory Tool (SIT) is mainly used to estimate GHG emissions. The tool, which is an interactive top-down spreadsheet, is designed to assist state agencies with GHG emission inventories. The SIT consists of 11 modules that calculate emissions based on numerous state-level data sets, including energy data provided by the U.S. Energy Information Administration (EIA).

The EPA recommends states employ local data whenever it is proven more accurate than the SIT's default data. RIDEM uses data from EIA and the New England Power Pool Generation Information System (NEPOOL-GIS) to estimate electricity sector emissions. Additionally, RIDEM uses data reported to EPA's Facility Level Information on Greenhouse gases Tool (FLIGHT) for two subsectors: natural gas distribution and municipal solid waste. Rhode Island Energy, the state's primary energy provider, reports all emissions associated with natural gas distribution mains, services, and metering stations. Emissions associated with municipal solid waste are provided by the state's primary landfill, the Central Landfill in Johnston.

GHG emissions are converted to the unit million metric tons carbon dioxide equivalent ($MMTCO_2e$) based on their global warming potential (GWP). GWPs compare how much energy the emissions one ton of a gas will absorb over a given period, relative to the emissions of one ton of carbon dioxide[3]. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report's (AR4) 100-year GWPs are used throughout this inventory. *20-year* GWPs are not used for any part of the annual GHG emissions inventory. Table 1 illustrates the historical use of different GWPs in the GHG emissions inventory. SAR stands for "second assessment report," which the IPCC published in 1995.

Table 1: Global Warming Potentials for Greenhouse Gases

Greenhouse Gas	Global Warming Potential (SAR)	Global Warming Potential (AR4)
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	21	25
Nitrous Oxide (N_2O)	310	298
Hydrofluorocarbons (HFCs)	140 - 11,700	12 - 14,800
Perfluorocarbons (PFCs)	6,500 – 9,200	7,390 - 12,200
Sulfur hexafluoride (SF_6)	23,900	22,800

3 *Environmental Protection Agency. (n.d.). Understanding Global Warming Potentials. EPA. Retrieved November 7, 2022, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials*

Manchester Street Power Station, Providence

John H. Chafee Preserve, North Kingstown

DEFINING NET-ZERO EMISSIONS

According to Rhode Island General Laws §42-6.2-2(2)(D), the 2021 Act on Climate procures a mandate to achieve 'net-zero emissions' by 2050. To achieve 'net' emissions, Rhode Island's GHG emissions inventory now includes a sequestration sector, Land Use, Land Use Change, and Forestry (LULUCF). 'Net-zero' emissions are defined in the *2022 Update* to the *2016 Greenhouse Gas Emissions Reduction Plan*:

> *'Net-Zero' refers to the requirement that the summary measure of greenhouse gas emissions emitted over the course of a calendar year less the summary measure of greenhouse gas emissions absorbed or otherwise broken down over the course of a calendar year equals zero. All emissions can be summarized in a measure such as million metric tons carbon dioxide equivalent (MMTCO2e) using global warming potential factors which adhere to international standards, including those of the IPCC and UNFCCC, and are embedded within the US EPA's greenhouse gas emissions inventory tools.*

1990 BASELINE: NET AND GROSS EMISSIONS

Rhode Island's 1990 GHG emissions baseline has previously been referred to as 12.48 $MMTCO_2e$, which is the *net* total for 1990. Inventory years 1991 – 2018 (except 2010) do not include any carbon sequestration component and are *gross* totals only. RIDEM recognizes that these inventory years are not an apples-to-apples comparison to the 1990 baseline of 12.48 $MMTCO_2e$. Henceforth, the 1990 baseline will either be referred to as either the gross baseline of 12.77 $MMTCO_2e$ or the *net* baseline of 12.48 $MMTCO_2e$.

In 2013, the Northeast States for Coordinated Air Use Management (NESCAUM) conducted the first *Rhode Island Greenhouse Gas Emissions Inventory* to determine the 1990 baseline emissions estimate and 2010 inventory. All GHG emissions inventories have since been completed in-house. Table 2 displays the official GHG emissions inventory for select years. Please note the 1990 baseline was derived from the *2016 Rhode Island Greenhouse Gas Emissions Reduction Plan*. Additionally, 2011 and 2012 represent *default* years where 100% of the inventory was obtained from the SIT's pre-loaded data. Since 2012, all inventories have included some local data and are considered non-default. A complete version of this table may be found on RIDEM's GHG emissions inventory webpage[4].

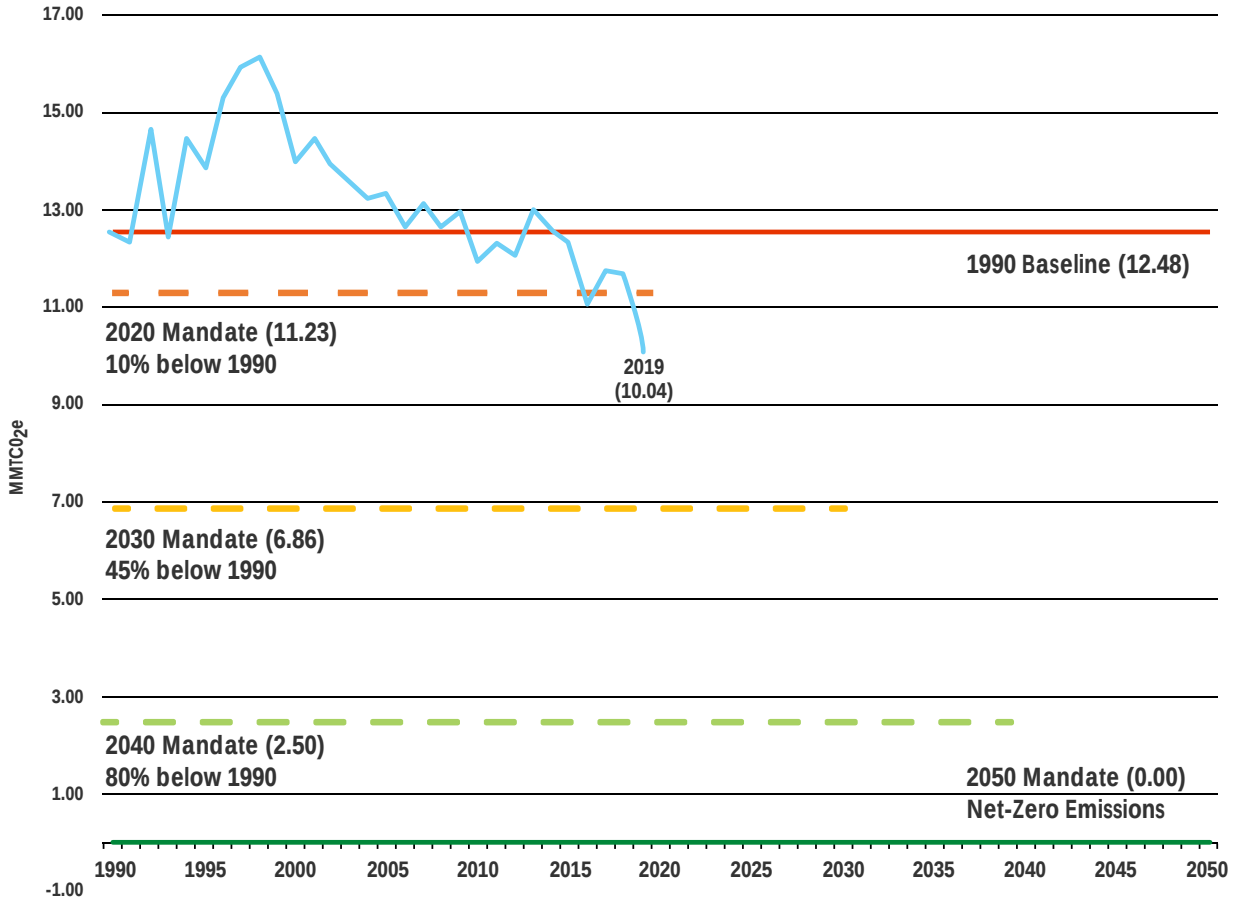
4 *For more information, visit: https://dem.ri.gov/ghg-inventory*

Table 2: Historical GHG Emissions

Sector	1990* Emissions ($MMTCO_2e$)	2015 Emissions ($MMTCO_2e$)	2016 Emissions ($MMTCO_2e$)	2017 Emissions ($MMTCO_2e$)	2018 Emissions ($MMTCO_2e$)	2019 Emissions ($MMTCO_2e$)
Energy	**3.12**	**3.37**	**3.00**	**3.46**	**2.47**	**2.19**
Electricity Consumption	*2.82*	*3.21*	*2.84*	*3.31*	*2.33*	*2.05*
Natural Gas Distribution	*0.30*	*0.16*	*0.15*	*0.15*	*0.14*	*0.14*
Residential Heating	**2.37**	**2.46**	**1.84**	**1.87**	**2.32**	**2.09**
Commercial Heating	**1.15**	**1.00**	**0.86**	**0.88**	**0.98**	**0.94**
Transportation	**4.97**	**4.09**	**3.94**	**4.17**	**4.45**	**4.29**
Aviation	*0.33*	*0.28*	*0.30*	*0.34*	*0.38*	*0.30*
Highway Vehicles	*4.38*	*3.66*	*3.62*	*3.57*	*3.85*	*3.61*
Nonroad Sources	*0.27*	*0.14*	*0.02*	*0.25*	*0.23*	*0.38*
Industry	**0.81**	**1.12**	**1.14**	**1.12**	**1.19**	**1.03**
Industrial Heating	*0.71*	*0.59*	*0.61*	*0.62*	*0.63*	*0.61*
Industrial Processes	*0.09*	*0.53*	*0.53*	*0.50*	*0.55*	*0.42*
Agriculture	**0.04**	**0.05**	**0.04**	**0.05**	**0.05**	**0.05**
Waste	**0.31**	**0.22**	**0.20**	**0.20**	**0.22**	**0.23**
Solid Waste	*0.23*	*0.10*	*0.09*	*0.09*	*0.10*	*0.12*
Wastewater	*0.08*	*0.12*	*0.11*	*0.11*	*0.12*	*0.12*
Land Use, Land Use Change, & Forestry	**-0.29**		**-**	**-**	**-**	**-0.78**
TOTAL GROSS EMISSIONS	**12.77**	**12.31**	**11.02**	**11.74**	**11.69**	**10.82**
TOTAL NET EMISSIONS	**12.48**		**-**	**-**	**-**	**10.04**

**1990 has been adjusted as done in the 2016 Rhode Island Greenhouse Gas Emissions Reduction Plan*
For more information, visit: https://dem.ri.gov/ghg-inventory

Figure 1: 1990 – 2019 GHG Emissions and Act on Climate Reduction Mandates

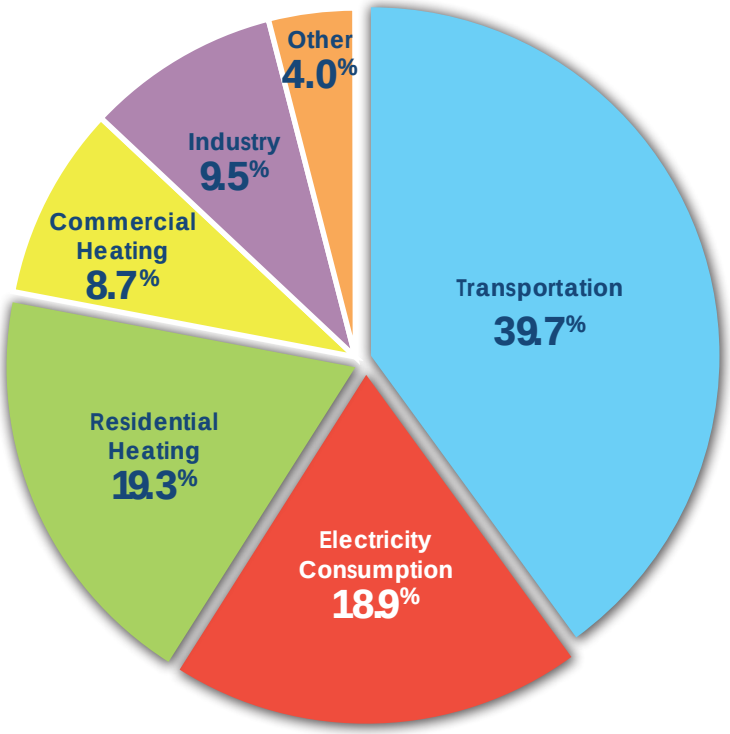


*Inventory years 1991-2018 (except 2010) are gross totals and are not an apples-to-apples comparison to the 1990 baseline.

2019 STATEWIDE GHG EMISSIONS INVENTORY RESULTS

- Total gross GHG emissions were 10.82 MMTCO2e in 2019
  - A decrease of 15.3% since 1990
- Total net GHG emissions were 10.04 MMTCO2e in 2019
  - A decrease of 19.6% since 1990
- 2019 GHG emissions are below the Act on Climate's 2020 GHG mandate of 11.23 MMTCO2e

Figure 2: 2019 Greenhouse Gas Emissions by Economic Sector



East Matunuck State Beach, South Kingstown

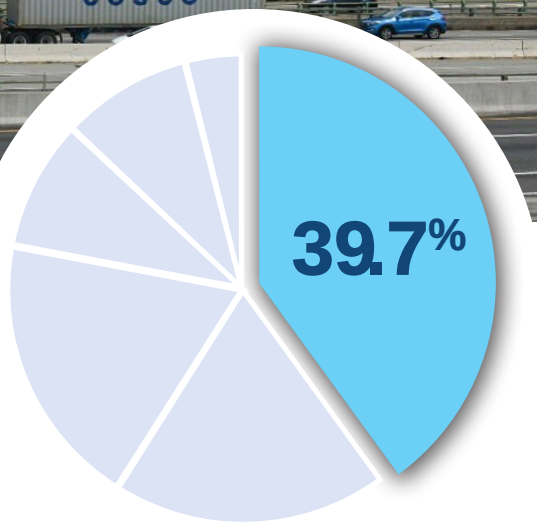
The majority of GHG emissions in 2019 were from the transportation sector (39.7%), followed by the residential heating sector (19.3%) and the electricity sector (18.9%) as shown in Figure 2. The "other" category includes agriculture, waste, and natural gas distribution. Figure 2 displays rounded GHG emissions by economic sector. Detailed information on the inventory process for the transportation, residential heating, and electricity consumption sectors are outlined in this summary. An explanation of the Land use, land use change, and forestry (LULUCF) sector is provided. Please note, in the *2022 Update to the 2016 Rhode Island Greenhouse Gas Emissions Reduction Plan*, residential heating, commercial heating, industrial heating and processes, and natural gas distribution is referred to as the thermal sector.

Table 3 compares GHG emissions from 1990 to 2019 for all economic sectors. Emissions from the three largest sectors: transportation, residential heating, and energy have decreased. Only two sectors have higher emissions in 2019 than 1990: industry (+27.3%) and agriculture (+24.1%). Industry-related emissions include industrial heating and industrial processes. Between 1990 and 2019, emissions from industrial heating decreased 14%, while emissions from industrial processes increased 343%. The significant increase in industrial process emissions is attributed to a methodology difference between the 1990 baseline and 2019 inventory. Since the 1990 inventory's completion, the agriculture sector has acquired more in-house data from RIDEM's Division of Agriculture and Forest Environment. The additional 0.01 $MMTCO_2e$ causes a large percent change between the two inventories.

Table 3: Rhode Island Greenhouse Gas Emission Changes 1990-2019

Sector	Emissions ($MMTCO_2e$)	Percent Difference
Energy	**-0.94**	**-29.9%**
Electricity Consumption	*-0.77*	*-27.4%*
Natural Gas Distribution	*-0.16*	*-53.1%*
Residential Heating	**-0.29**	**-12.0%**
Commercial Heating	**-0.21**	**-18.3%**
Transportation	**-0.68**	**-13.7%**
Industry	**0.22**	**27.3%**
Agriculture	**0.01**	**24.1%**
Waste	**-0.07**	**-24.2%**
Land Use, Land Use Change & Forestry	**-0.49**	**168.4%**
TOTAL GROSS EMISSIONS	**-1.95**	**-15.3%**
TOTAL NET EMISSIONS	**-2.44**	**-19.6%**

I-95, Providence



Transportation Sector

TRENDS

In 2019, the transportation sector continues to be the largest source of GHG emissions in the state (40%) as seen in Figure 2. GHG emissions from transportation decreased 0.16 MMTCO$_2$e (- 3.6%) from 2018 levels. Most transportation sector GHG emissions originate from all on-road vehicles. Since 1990, there has been a 13.7% reduction in transportation sector emissions. Emissions from this sector will ebb and flow as decarbonization efforts ramp up across sectors, further reductions from transportation are critical to meet the 2030, 2040, and 2050 Act on Climate mandates. It is challenging for high fuel-efficient vehicles to impact overall transportation sector emissions since vehicle miles traveled (VMT) continues to increase. Significantly more zero-emission vehicles (ZEVs) across weight classes will be required to meet Act on Climate emission reduction mandates. Figure 3 displays the relatively steady transportation sector GHG emissions trend since 2010.

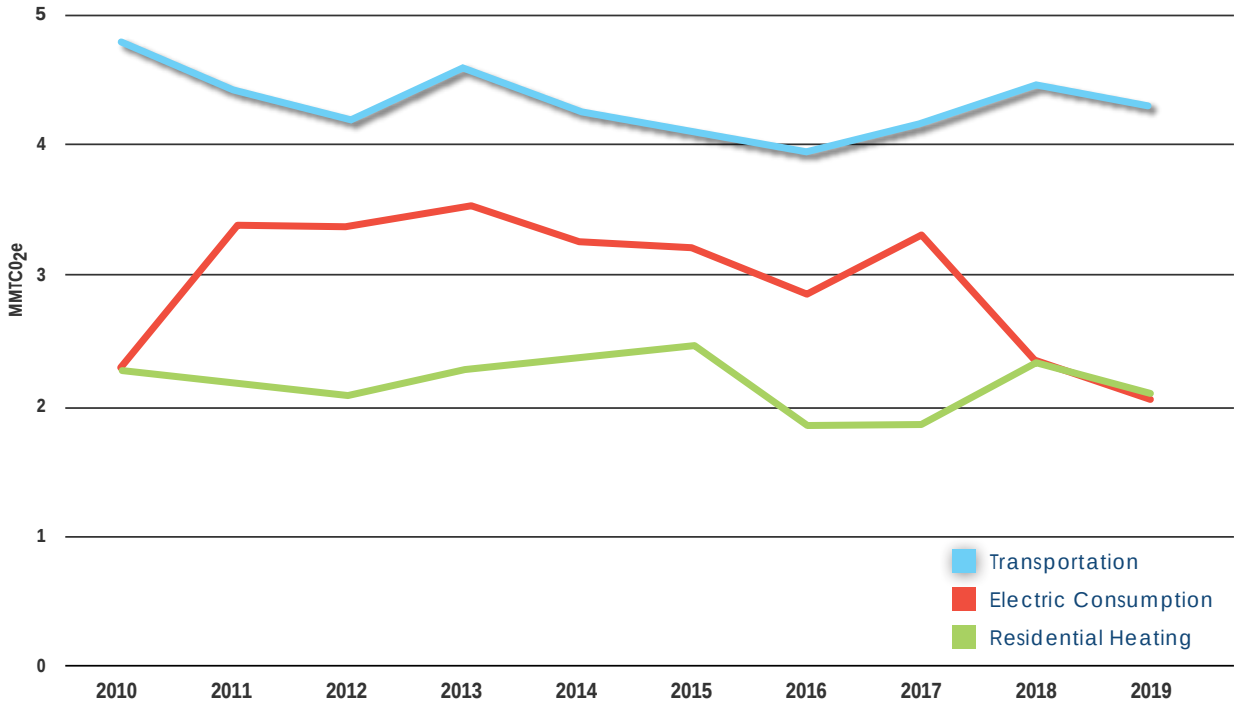
TRANSPORTATION SECTOR METHODOLOGY

In previous GHG inventories, the EPA's Motor Vehicle Emission Simulator (MoVES) was used to estimate emissions from highway vehicles. MoVES was not used for inventory years 2018 or 2019 because exact state-level inputs such VMT, vehicle age, and meteorological conditions were not generated for Rhode Island. The EPA's SIT was used instead to estimate emissions from the highway vehicle and non-road source subsectors. The SIT uses a "top-down" approach to calculate CO_2 emissions from transportation, beginning with VMT and fuel consumption. This approach uses data on fuel sales within each state as a proxy for fuel consumption. One drawback to this method is a lack of detail: motorists in southern New England do not always purchase fuel in the state traveled in. Thus, fuel sale data may not provide an accurate estimate of state-level fuel consumption. The three classes of on-road vehicles (light duty, medium duty, and heavy duty) are also not represented in fuel sale data. RIDEM will resume use of the EPA's MoVES for the *2020 Rhode Island Greenhouse Gas Emissions Inventory*.

Although less precise for highway vehicles, the SIT continues to be the most reliable resource for all other transportation related GHG components. These are represented in the nonroad source sector, which include off-road diesel, off-road gasoline, residual fuels, and lubricants. Specific examples of non-road sources include boats, locomotives, tractors, construction equipment, and gasoline-powered snowmobiles. Since the SIT was used to estimate emissions from highway vehicles in 2019, lubricants were omitted from the inventory to avoid double-counting emissions.

For aviation related GHG emissions, the Rhode Island Airport Corporation (RIAC) provides an annual GHG emissions inventory associated with the state's largest airport, Rhode Island T.F. Green International Airport. All GHGs (CO_2, CH_4, N_2O, and refrigerants) are included in RIAC's inventory. Adjustments are made in RIAC's to avoid double counting emissions from the airport's solid waste and the solid waste subsector within the waste sector.

Figure 3: Transportation Sector GHG Emissions



ACCOUNTING IMPROVEMENTS SINCE 2016

For the 2019 GHG emissions inventory, RIDEM amended how individual SIT inputs are categorized into the various subsectors. Please note all previous year's transportation subsectors have been adjusted to match the new subsector classifications.

Between 2016 and 2019, an off-road gasoline estimate was included for the first time. Additionally, lubricants were migrated to the nonroad source category and natural gas was migrated to the highway vehicles category. The 0.36 $MMTCO_2e$ increase in nonroad source emissions between 2016 and 2019 can be attributed to the addition of an off-road gasoline estimate and the adjustment of the transportation subsectors. The 0.16 $MMTCO_2e$ (68.3%) increase in nonroad source emissions between 2018 and 2019 can be attributed to higher emissions from off-road gasoline and off-road diesel vehicles.

2016 SUBSECTORS

AVIATION
- Aviation

HIGHWAY VEHICLES
- On-road Gasoline
- On-road Diesel
- LPG

NONROAD SOURCES
- Off-road Diesel
- Residual Fuels
- Natural Gas

LUBRICANTS
- Lubricants

2019 SUBSECTORS

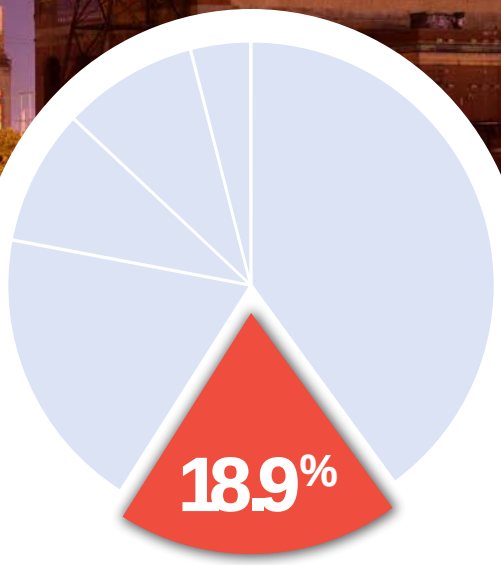
AVIATION
- Aviation

HIGHWAY VEHICLES
- On-road Gasoline
- On-road Diesel
- LPG
- *Natural Gas*

NONROAD SOURCES
- Off-road Diesel
- Residual Fuels
- Off-road Gasoline
- *Lubricants*

Manchester Street Power Station, Providence

Electricity Consumption Sector



TRENDS

In 2019, GHG emissions from electricity consumption were 2.05 $MMTCO_2e$ and accounted for 18.9% of gross GHG emissions in Rhode Island. Between 2018 and 2019, electricity sector emissions decreased 12%. Emissions from this sector remained relatively stable between 2011 and 2017. For inventory years 2018 and 2019, RIDEM adopted a methodology update developed by the Connecticut Department of Energy and Environmental Protection (CTDEEP). The updated methodology ensures all Renewable Energy Certificates (RECs) that are settled or reserved in Rhode Island are counted towards the state's inventory. New England's 'system mix', which represents all combined sources of electricity generated in the region, was cleaner in 2019. Other factors that affect electricity sector emissions such as extreme weather and rate prices were not analyzed.

ELECTRICITY CONSUMPTION METHODOLOGY

The original methodology to estimate emissions from electricity consumption was developed by the Massachusetts Department of Environmental Protection (MassDEP). RIDEM adopted the methodology for the 2016 Rhode Island Greenhouse Gas Emissions Inventory. MassDEP's methodology was a significant improvement over default data in EPA's State Inventory Tool because it considered Rhode Island's Renewable Energy Portfolio.

MassDEP's original methodology can be summarized in three steps:

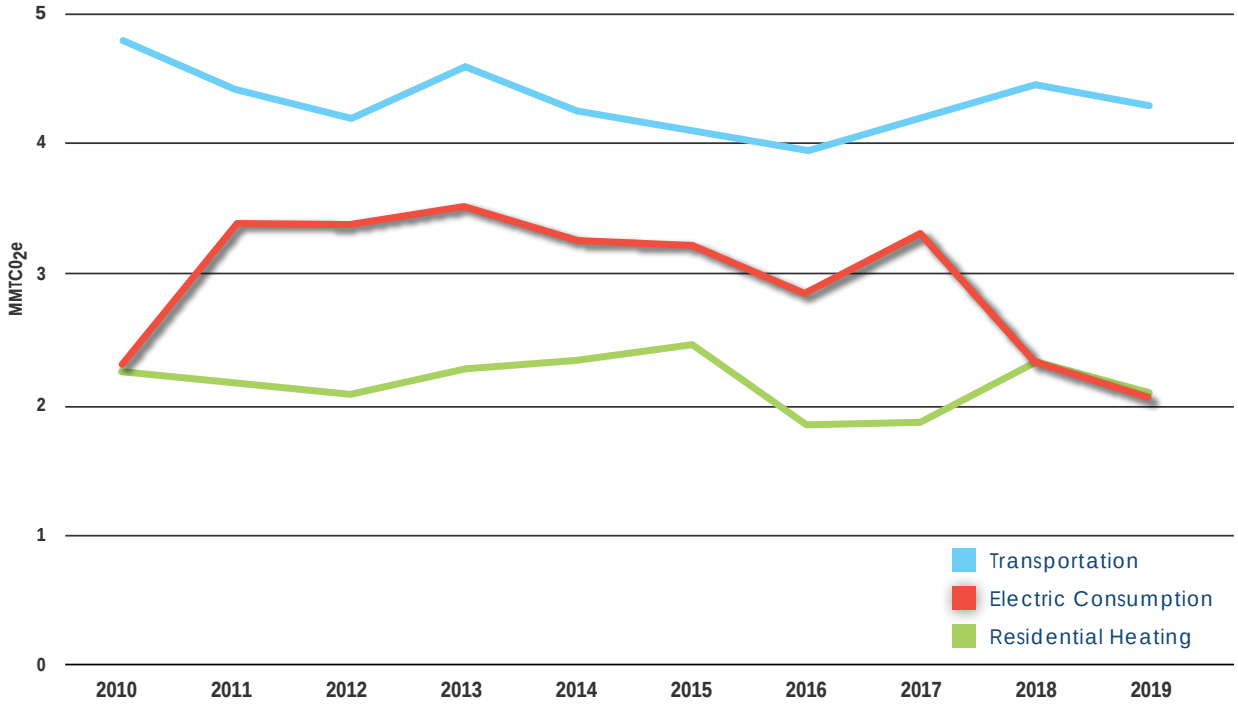
1. **Analyze megawatt hours of electricity from energy certificates.**
2. **Analyze megawatt hours of electricity from electric generation.**
3. **Omit overlapping megawatt hours and calculate emissions for a total.**

Each state has an electric power load, which is a unique combination of electricity served by two components. Energy certificates, colloquially known as RECs, are the first component. Each REC represents one

RENEWABLE ENERGY CERTIFICATE

1 REC = 1 MEGAWATT HOUR OF ELECTRICITY GENERATED BY A RENEWABLE SOURCE

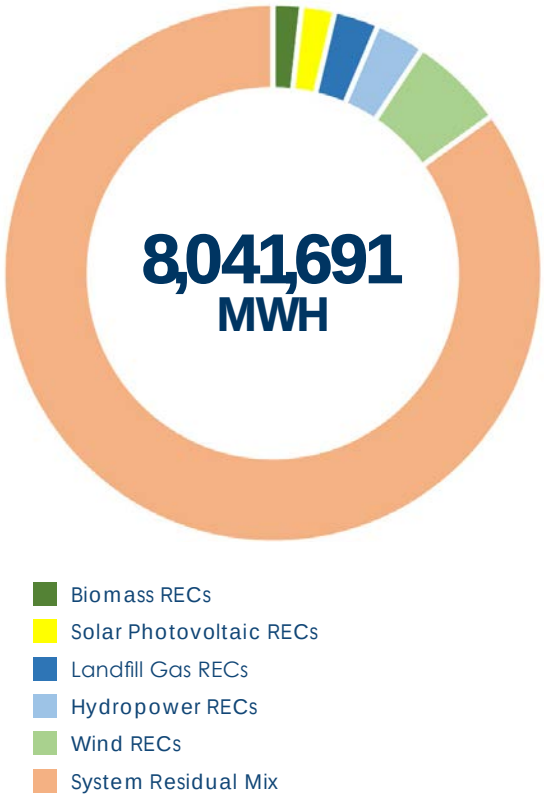
Figure 4: Electricity Sector GHG Emissions



megawatt hour of electricity that is claimed by a state/province. The second component of the load is the system mix, which includes electricity from a plethora of generators in New England and New York.

First, megawatt hours served by RECs in New England are gathered from the New England Power Pool Generation Information System (NEPOOL-GIS). Next, megawatt hours served by the system mix in New England and New York are collected from the U.S. Energy Information Administration. The regional system mix is used to obtain a unique emissions factor for New England. Since the regional system mix captures every megawatt hour on the grid, there will be double counting if REC and system mix megawatt hours overlap. Thus, system mix megawatt hours from NEPOOL-GIS are omitted from each state's load served by RECs. Rhode Island's load served by RECs is subtracted from the state's overall load to obtain the state's load served by the system mix. Finally, the New England emission factor is then multiplied by Rhode Island's load served by the system mix to obtain a statewide emission total.

Figure 5: Sources of Megawatt Hours* for Rhode Island Electricity Consumption (2019)



** Megawatt hours generated from wood RECs and digester gas RECs are too small to appear on this chart.*

Block Island Wind Farm

Block Island Wind Farm

UPDATE TO THE ORIGINAL METHODOLOGY

To continuously improve the GHG emissions inventory, RIDEM contacted colleagues at CTDEEP to align electricity sector accounting practices. In October 2021, CTDEEP proposed an amendment to the original methodology that more accurately reflects where RECs are settled. In the original methodology, RECs were pooled into a hypothetical 'bank' and apportioned to states based on load size. The New England state with the largest load size would receive the largest share of RECs. Although not explicitly calculated in the original methodology, CTDEEP observed this trend annually based on how RECs were assigned.

In October 2021, CTDEEP proposed an amendment to the original methodology that more accurately reflects where RECs are settled. In the original methodology, RECs were pooled into a hypothetical "bank" and apportioned to states based on load size. Based on this, the New England state with the largest load size would receive the largest share of RECs. CTDEEP observed this trend annually based on how RECs were assigned.

The State of Connecticut previously agreed to settle a higher quantity of RECs from the Millstone Nuclear Power Station. For all Millstone RECs to appear in Connecticut's electric sector, the updated methodology would need to ensure all Millstone RECs were counted only in Connecticut. CTDEEP's update certifies that all RECs that are settled or reserved in the state they are assigned to and are counted in that state only. There is no REC "bank" and no apportioning of RECs based on an individual state's load size. RECs are simply counted towards the state they are settled or reserved in. Additionally, CTDEEP revised how the regional system mix is applied to each state's emissions estimate.

The adoption of CTDEEP's methodology update significantly impacts Rhode Island's electricity sector emissions:

	2018	2019	Percent Difference
Original MassDEP Methodology	3.34 $MMTCO_2e$	3.12 $MMTCO_2e$	**-6.59%**
New CTDEEP Methodology	2.33 $MMTCO_2e$*	2.05 $MMTCO_2e$*	**-12.02%**
Percent Difference	**-30.34%**	**-34.29%**	-

** Official electricity sector total*

The decrease in Rhode Island's electricity sector emissions is attributed to the following:

- Electric sector *emissions* trended downward in 2019, regardless of which methodology was used. CTDEEP observed a similar trend.
- The new methodology certifies that all RI *RECs are explicitly counted as "settled"* in Rhode Island. Since REC emissions are lower than system mix emissions, overall emissions decreased.
- Emissions decreased because CTDEEP adjusted how the regional system mix is applied to states.

Rooftop Solar Array

FUTURE CONSIDERATIONS

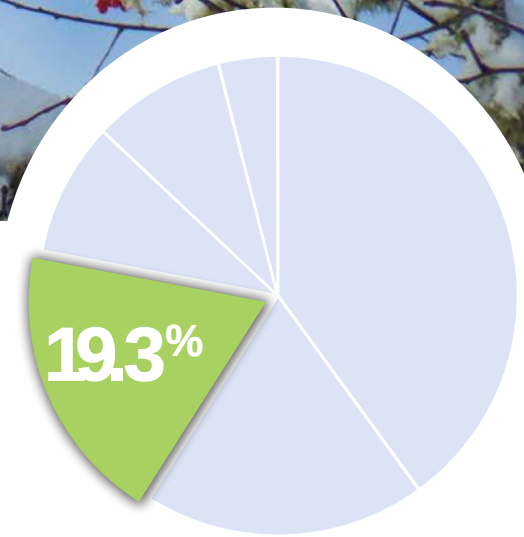
The adoption of CTDEEP's updated methodology aligns Rhode Island's inventory more closely with the state's energy portfolio. Accounting improvements will continue in the future; RIDEM is currently evaluating whether to apply the updated methodology to inventory years 2016 and 2017. Additionally, it is noteworthy that tailpipe emission factors, which count biogenic emissions (biomass, wood, etc.) higher than non-biogenic emissions (natural gas, diesel, etc.) are still used to estimate emissions. The current methodology cannot accurately assess Rhode Island's 100% renewable energy standard (RES) with tailpipe emission factors. As discussed in the residential heating sector, biogenic emissions are scope three emissions that occurred outside of Rhode Island. RIDEM will continue to work with partners at the Rhode Island Public Utilities Commission (RIPUC) and CTDEEP to improve the electricity sector's methodology.

TAILPIPE EMISSION FACTORS

'Tailpipe' emission factors (EF) represent a fuel type's emissions at the point of combustion and differ based on carbon content. For example, the tailpipe EF of natural gas is 117 lbs CO_2/MMBtu, while wood has a tailpipe EF of 207 lbs CO_2/MMBtu. Since pure wood contains more CO_2 than pure natural gas, it has a higher tailpipe EF and thus produces more carbon emissions at the point of combustion.

Great Swamp Management Area, West Kingston

Residential Heating Sector

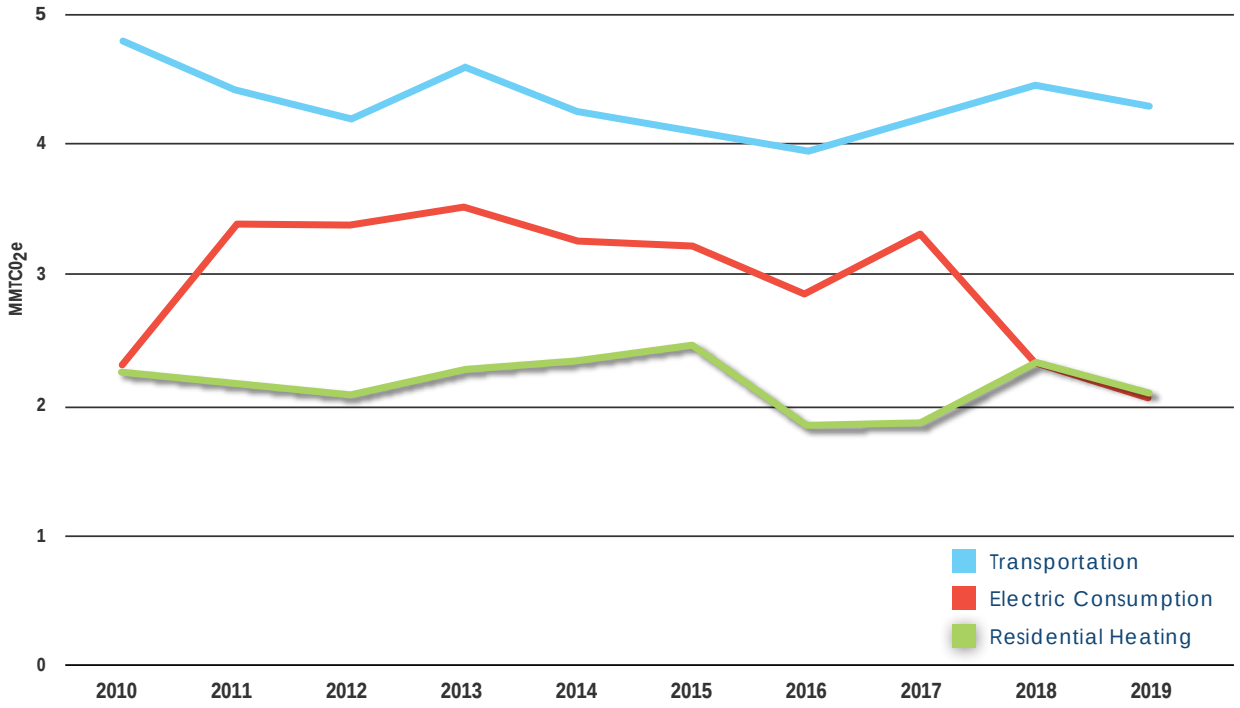


TRENDS

The residential heating sector emitted 2.09 $MMTCO_2e$, accounting for 19.3% of Rhode Island's GHG emissions in 2019. Emissions from this sector reached a low point in 2016 (1.84 $MMTCO_2e$) and have fluctuated annually since. Residential heating emissions increased 13.5% between 2016 and 2019 but decreased 10.2% between 2018 and 2019. Natural gas and distillate fuel oil are the most common fuels used to heat homes in Rhode Island. 55.3% of homes use natural gas and approximately 28.6% of homes use distillate fuel oil[5]. Electricity, propane, kerosene, wood, solar, and geothermal processes account for the remaining approximately 16.1%. Residential heating fuels are not created equal: the amount of GHGs each emit are based on fuel composition. Figure 6 displays the trend in residential heating emissions since 2010.

5 *U.S. Energy Information Administration. (n.d.). Rhode Island State Energy Profile. U.S. Energy Information Administration - EIA – independent statistics and analysis. Retrieved November 7, 2022, https://www.eia.gov/state/?sid=RI*

Figure 6: Residential Heating GHG Emissions



RESIDENTIAL HEATING SECTOR METHODOLOGY

Residential heating emissions are estimated through the SIT's CO_2 from Fossil Fuel Combustion (CO_2FFC) module and Stationary Sources module. CO_2FFC handles carbon dioxide emissions only, while the Stationary Sources module estimates methane and nitrous oxide emissions. EIA gathers fuel consumption data through mandatory surveys for companies that deliver natural gas to consumers. Rhode Island Energy is responsible to report natural gas consumption data to the EIA annually. Distillate fuel, propane, and kerosene are examples of deliverable fuels, which must be brought to homes by truck. Consumption estimates for deliverable fuels are estimated by EIA and then placed into the SIT as default data. RIDEM also uses EIA estimates from the SIT to estimate commercial and industrial heating emissions.

USEPA Photo

FACTORS THAT INFLUENCE HEATING EMISSIONS

New England's variable winter weather significantly impacts Rhode Island's residential heating emissions. Cold winters demand more heat, which requires more fossil fuel combustion. Heating degree days (HDDs) are helpful to evaluate the impact of outdoor temperature on residential heating fuel use. To calculate the number of HDDs, the recorded daily temperature is subtracted from 65 degrees Fahrenheit, which is the temperature determined to require neither heating nor cooling. A 24-hour temperature average greater than the baseline temperature (65°F) results in 0 heating degree days. It is important to note that there can be (and often are) multiple HDDs within a 24-hour period. Assuming all variables are identical from year to year, a 10% increase in HDDs should correlate to a 10% increase in heating emissions.

USEPA photo

Thomas Street, Providence

For this analysis, the National Weather Service's automated surface observing station (ASOS) at Rhode Island TF Green International Airport was used as a proxy for the entire state. In 2019, there were 5,569 HDDs compared to 5,639 HDDs in 2018[6]. Since 2018 had 70 more HDDs than 2019, it can be inferred that 2018 was a colder year. It is expected the amount of fuel used for home heating, alongside GHG emissions, decreased in 2019 since there were fewer heating degree days. Although a helpful metric, HDDs do not directly correlate with GHG emissions. Between 2018 and 2019, residential heating emissions decreased 10.2%, but HDDs only decreased 1.24%. Other factors such as the percent biofuel blended into heating fuel and the price of heating fuel influence GHG emissions from residential heating.

In the U.S., 85% homeowners that use distillate fuel oil for residential heating are in the Northeast[7]. About 29% of Rhode Island households use distillate fuel oil as their primary source for home heating, which is seven times more than the U.S. average[8]. Although the Northeast relies heavily upon delivered fuel, many homeowners are switching to cleaner burning natural gas. In Rhode Island, distillate fuel consumption has declined over the past decade. The state consumed 3,045,000 barrels of distillate fuel oil in 2009, but only 2,054,000 barrels in 2019[7]. Rhode Island will continue to witness shrinking residential heating sector emissions as homeowners switch from distillate fuel to natural gas and air source heat pump technology.

6 *Northeast Regional Climate Center. (n.d.). CLIMOD 2. Retrieved November 7, 2022, from http://climod2.nrcc.cornell.edu/*

7 *U.S. Energy Information Administration. (n.d.). U.S. Energy Information Administration - EIA -independent statistics and analysis. Use of Heating Oil. Retrieved November 7, 2022, from https://www.eia.gov/energyexplained/heating-oil/use-of-heating-oil.php*

8 *U.S. Energy Information Administration, Residential Sector Energy Consumption Estimates, Selected Years, 1960-2019, Rhode Island (2019). Washington, DC.*

Urban Edge Farm, Cranston

BIOFUELS IN THE RESIDENTIAL HEATING SECTOR

The Rhode Island General Assembly enacted the Biodiesel Heating Oil Act of 2013 to reduce GHG emissions from the residential heating sector. Biodiesel is a biofuel made from plant oils, cooking oils, and animal fat. Biofuels, including biodiesel, are mixed with conventional heating oil to create different blends. As of 2022, B5 (~5% bioproduct) is required in all heating fuel sold in Rhode Island[9]. The percent bioproduct will greatly increase over the next decade. B50, or ~50% bioproduct, will be required in all home heating oil sold in the state by 2030. The use of biofuels reduces in-state GHG emissions since biodiesel burns significantly cleaner than distillate fuel oil at the point of combustion[10]. Residential heating emissions may be slightly overestimated.

Biofuels are not included in this annual GHG emissions inventory due to a lack of household-level data.

Whether biofuels truly reduce GHG emissions on a global scale is an ongoing scientific debate. For example, bioproduct blended into heating oil in Rhode Island may include plant oil from corn grown in the Midwest. The production of corn, and its transportation to Rhode Island, creates GHG emissions in various economic sectors. Corn does sequester some GHG emissions during growth, but the timescale of sequestration is different than the timescale of emission. Even though these emissions occur outside of Rhode Island's borders, they are still associated with in-state biodiesel consumption. Indirect emissions from biodiesel are a *scope 3* emission. Methodology adjustments to the residential heating sector are warranted to accurately represent emissions associated with biofuels. Partnership with the U.S. Climate Alliance's (USCA) emissions work group will help facilitate this improvement.

SCOPE 1, 2, AND 3 EMISSIONS

- SCOPE 1 EMISSIONS ARE DIRECT EMISSIONS.
  An example is the emissions released from the direct burning of fossil fuels to power a boiler, furnace, or vehicle.
- SCOPE 2 EMISSIONS ARE INDIRECT EMISSIONS THAT OCCUR ALONGSIDE SCOPE 1 EMISSIONS.
  An example is the emissions associated with the purchase of electricity.
- SCOPE 3 EMISSIONS RESULT FROM ASSETS NOT OWNED OR CONTROLLED BY THE REPORTING ORGANIZATION, BUT THAT THE ORGANIZATION INDIRECTLY IMPACTS IN ITS VALUE CHAIN[11].
  An example is the emissions released from the fabrication and transportation of a tube of toothpaste to the end user.

**All emissions included in this inventory are Scope 2.*

9 *Biodiesel Heating Oil Act of 2013, Definitions, R.I. Gen. Laws § 23-23.7-3. (2022). http://webserver.rilin.state.ri.us/Statutes/TITLE23/23-23.7/23-23.7-3_1.htm*

10 *U.S. Department of Energy. (n.d.). Biodiesel Basics - Energy. Alternative Fuels Data Center. Retrieved November 7, 2022, from https://afdc.energy.gov/files/u/publication/biodiesel_basics.pdf*

11 *Environmental Protection Agency. (n.d.). Scope 3 Inventory Guidance. EPA. Retrieved November 7, 2022, from https://www.epa.gov/climateleadership/scope-3-inventory-guidance*

Wickaboxet Management Area, West Greenwich

Land Use, Land Use Change, and Forestry Sector

The EC4 sharing session on March 16, 2022 highlighted the need for a carbon sequestration sector in Rhode Island's annual GHG emissions inventory. Carbon sequestration, or removal, is the process of capturing and storing atmospheric carbon dioxide[12]. The state's 1990 GHG inventory and 2010 GHG inventory account for seven GHG emission sectors and one GHG sequestration sector, known as Land-Use, Land-Use Change, and Forestry (LULUCF). The presence of this sector in 1990 and 2010 prevents an apples-to-apples comparison to inventory years 1991-2009 and 2011 - 2018. To meet properly account the 2021 Act on Climate's emission reduction mandates and achieve net-zero in 2050, all new inventories will include a LULUCF sector.

BACKGROUND

Rhode Island's small and diverse landscape is inherently difficult to account for carbon sequestration. The 1990 baseline's LULUCF sector was calculated through a one-time contract with NESCAUM and is not replicable. Additionally, the 2010 LULUCF estimate was estimated through the Long-range Energy Alternatives Planning (LEAP) model used in the *2016 Rhode Island Greenhouse Gas Emissions Reduction Plan* and is not replicable. RIDEM is unable to replicate either methodology since they were completed by third-party contractors.

LULUCF was omitted from the inventory prior to 2019 due to a lack of confidence in the EPA's SIT default data. State environmental agencies in Connecticut, Massachusetts, and Vermont followed a similar approach. In early 2022, the EPA released an update to SIT that included more state specific LULUCF data. RIDEM chose to utilize the following data sources: carbon stored in yard trimmings, agricultural soil carbon flux, and nitrous oxide emissions from settlement soils. These sources combined account for less than 5% of the entire LULUCF sector.

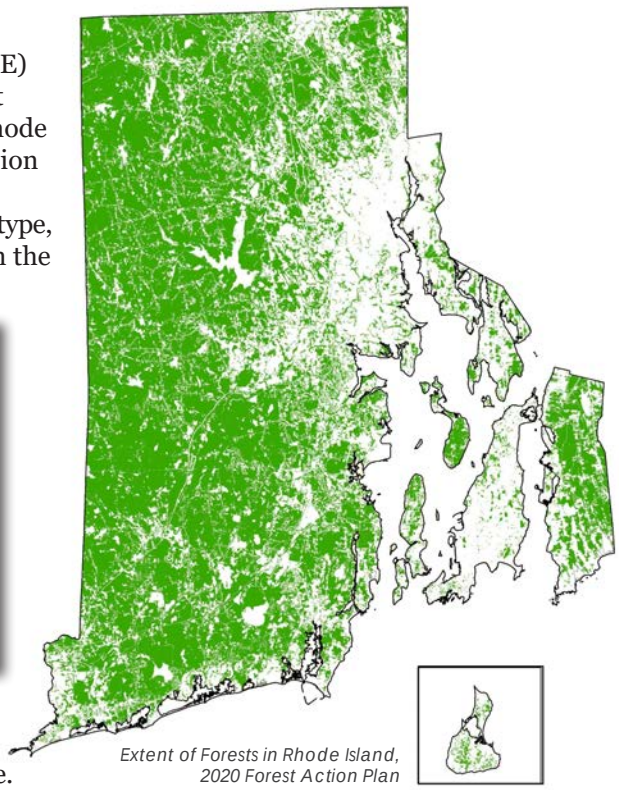
12 *U.S. Geological Survey. (n.d.). What is carbon sequestration? Retrieved November 18, 2022, from https://www.usgs.gov/faqs/what-carbon-sequestration#:~:text=Carbon%20sequestration%20is%20the%20process,of%20reducing%20global%20climate%20change.*

LULUCF METHODOLOGY

For 2019, RIDEM developed an in-house methodology with data from the Division of Agriculture and Forest Environment's (DAFE) *2020 Forest Action Plan*. Both DAFE's data and the SIT's default data originate from the U.S. Forest Service (USFS). To ensure Rhode Island's LULUCF sector reflects the local landscape, DAFE's version of the data was used to estimate carbon removed by forest land. Estimates for the total forest land in RI, percentages of each forest type, and sequestration factors for each forest type were obtained from the USFS's Forest Inventory and Analysis (FIA) program.

EXAMPLE CALCULATION FOR AN OAK/HICKORY FOREST:

- Oak/hickory sequesters an average of 1.46 MTCO2/acre/year
- Oak/hickory covers ~61.0% or 220,287.47 acres of RI forest
- 1.46 MTCO2/acre * 220,287.47 acres / 1,000,000 = 0.32 MMTCO2/year



Extent of Forests in Rhode Island, 2020 Forest Action Plan

This calculation is repeated for all nine forest classifications found in Rhode Island and summed for a total. In 2019, the state's forest land removed 0.47 MMTCO2e from the atmosphere. DAFE acknowledged the *2020 Forest Action Plan*'s FIA data is reliable for Rhode Island. New percentages of each forest type and total forest land will be provided annually. When the next forest action plan is published in 2030, sequestration factors for each forest type will be updated. Until then, DAFE confirmed the current sequestration factors are adequate.

DAFE also provided an acreage estimate for settlement, colloquially know as urban, tree cover. In 2019, settlement trees removed 0.28 MMTCO$_2$e from the atmosphere. Although small, RIDEM also incorporated DAFE's inventory of Rhode Island forest fires into the LULUCF sector. Since the definition of 'forest land' and 'urban area' potentially overlaps, a small amount of over counting is possible. With DAFE's forest land, settlement tree data, and forest fire data, 94% of the LULUCF sector's data is provided by in-state sources and 6% originates from the SIT.

In total, LULUCF was estimated to sequester 0.78 MMTCO2e, equivalent to 7.2% of gross GHG emissions.

FUTURE IMPROVEMENTS AND CONSIDERATIONS

RIDEM recognizes 2019's LULUCF methodology has several drawbacks. Although the amount of carbon removed by forest land is included (aboveground biomass), carbon stored in belowground biomass and forest soils are omitted. Additionally, the carbon flux associated with wetlands and most croplands/ grasslands is not included. The EPA intends to align the SIT's data sources with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* state-level disaggregation in the near future. When EPA facilitates this change, RIDEM will be able to incorporate more RI-specific LULUCF data into the inventory.

The 2019 LULUCF sector represents a first step towards a reliable carbon sequestration estimate and should not be compared with other state's carbon removal sectors. In the future, RIDEM plans to utilize more state specific LULUCF data. RIDEM will also strive to categorize LULUCF according to the reporting conventions developed by the IPCC for Agriculture, Forestry, and Other Land Use (AFOLU), which is used in the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. Future improvements will be facilitated through partnerships with DAFE, the U.S. Climate Alliance, and neighboring state environmental agencies.

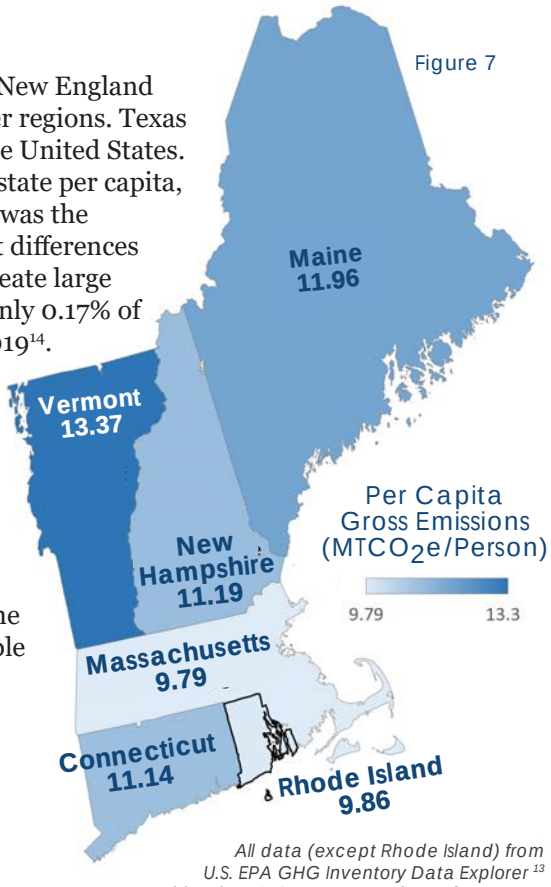
Beavertail State Park, Jamestown

Regional Emission Trends

Rhode Island is one of America's lowest GHG emitting states. The New England region, as seen in Figure 7, emits far less GHG emissions than other regions. Texas emitted 30.41 MTCO2e per person in 2019, one of the highest in the United States. In New England, Rhode Island is the second lowest GHG emitting state per capita, only behind Massachusetts[13]. In terms of total emissions, Vermont was the only U.S. state to emit less GHG emissions than Rhode Island. Vast differences including population, electricity prices, climate, and fuel choices create large variability between state's GHG emissions. Rhode Island emitted only 0.17% of the 6,571.73 MMTCO2e the United States was responsible for in 2019[14]. Nationally, the three largest sectors of GHG emissions are transportation, electricity generation, and industry.

Per capita consumption metrics are important to determine how efficient a state utilizes resources. The average United States citizen produced 19.83 metric tons CO_2e in 2019, down 1.6% since the last triennial summary[13]. Strategic use of fossil fuel resources will help Rhode Island achieve the Act on Climate emission reduction mandates. Although the Ocean State is a small piece of the puzzle, continuous improvements in energy efficiency set an example for other states to follow.

Figure 7



All data (except Rhode Island) from U.S. EPA GHG Inventory Data Explorer [13]
Map Powered by Bing. ® GeoNames, Microsoft, TomTom

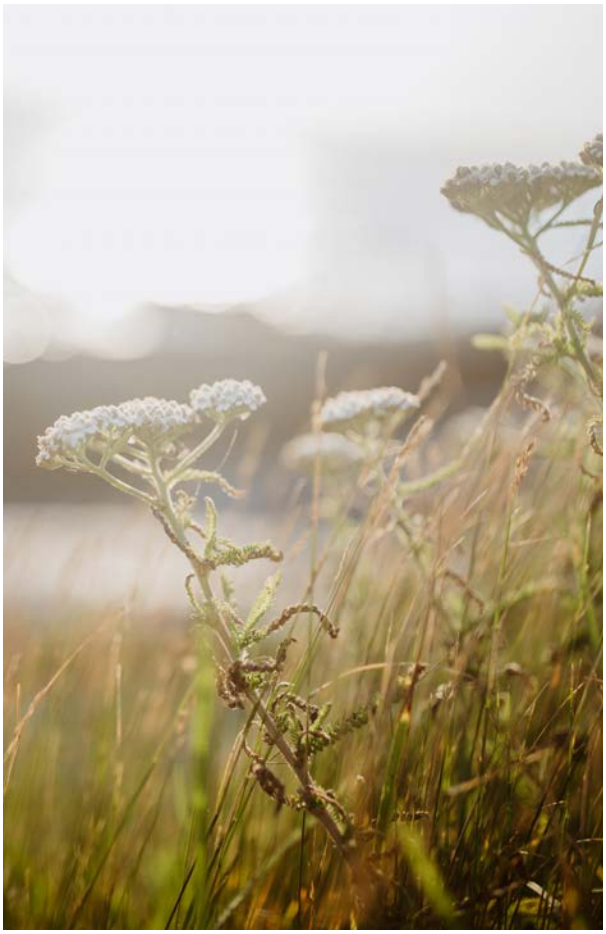
13 *Environmental Protection Agency. (n.d.). Greenhouse Gas Inventory Data Explorer. Retrieved November 7, 2022, from https://cfpub.epa.gov/ghgdata/inventoryexplorer/*

14 *U.S. Geological Survey. (n.d.). What is carbon sequestration? Retrieved November 18, 2022, from https://www.usgs.gov/faqs/what-carbon-sequestration#:~:text=Carbon%20sequestration%20is%20the%20process,of%20reducing%20global%20climate%20change.*

Crescent Park, East Providence

Conclusion

The *2019 Rhode Island Greenhouse Gas Emissions Inventory* provides a historical estimate of 2019 GHG emissions. The state's three largest sectors: transportation, residential heating, and electricity consumption were analyzed in-depth. The inaugural inclusion of the LULUCF sector also warranted an explanation of impacts relative to Act on Climate emissions accounting. The next triennial summary will be published in December 2025 alongside the EC4's *2025 Climate Strategy*. It is important to note the 2020 GHG emissions inventory will likely display the impacts of the COVID-19 pandemic and may not be a just comparison to 2019. GHG emissions inventories published by RIDEM provide the foundational information needed to develop and implement the Act on Climate's emission reduction mandates. RIDEM will continue to work with research partners, stakeholders, and other state agencies to continuously improve accounting methods. Incorporation of cutting-edge climate science remains a priority for future inventories and triennial summaries.



Beavertail State Park, Jamestown