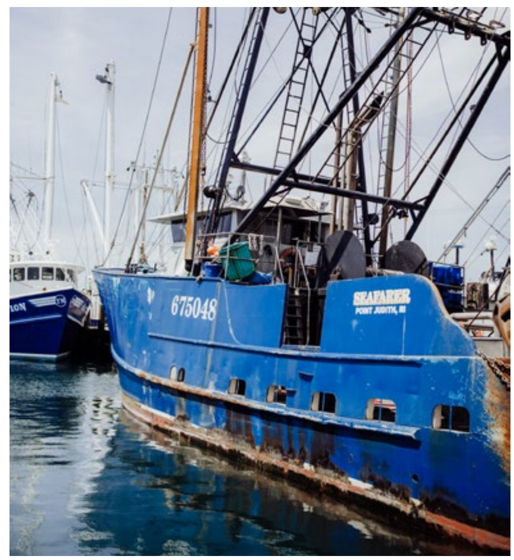
DEM
RHODE ISLAND

NOVEMBER 2025



2023 RHODE ISLAND

GREENHOUSE GAS INVENTORY

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

Copyright Wangkun Jia

Blackstone River and Woonsocket Falls Dam in downtown Woonsocket

Introduction

The ***2023 Rhode Island Greenhouse Gas Inventory*** (GHGI) is produced by the Rhode Island Department of Environmental Management (DEM) to gauge the state's annual climate-warming emissions. This publication is the primary scientific tool used by the Rhode Island Executive Climate Change Coordinating Council (EC4) to assess progress towards the statewide greenhouse gas (GHG) emissions reduction mandates required by the Act on Climate.[1] The GHGI is an estimate of emissions sources and sinks and is recalculated each year based on the best science and data available. Methodologies evolve year-to-year, and emissions estimates from previous iterations should not be used as a direct comparison to this publication. Refer to the **Technical Appendix** for a full explanation of applicable adjustments to the 1990 baseline and subsequent year's data. All emissions are converted to the unit million metric tons carbon dioxide equivalent ($MMTCO_2e$) with the 100-year global warming potential (GWP100) values from the ***Fifth Assessment Report*** (AR5) of the Intergovernmental Panel on Climate Change (IPCC).

KEY FINDINGS

- Rhode Island emitted 9.52 $MMTCO_2e$ in 2023.
- The state's emissions increased by 1.4% since 2022 and decreased by 19.5% since 1990.
- In 2023, emissions levels were 3.02 $MMTCO_2e$ above the Act on Climate's 2030 mandate.

ENERGY SECTOR HIGHLIGHTS

TRANSPORTATION

emissions increased 5.1% in 2023, primarily due to an increase in vehicle miles traveled (VMT)

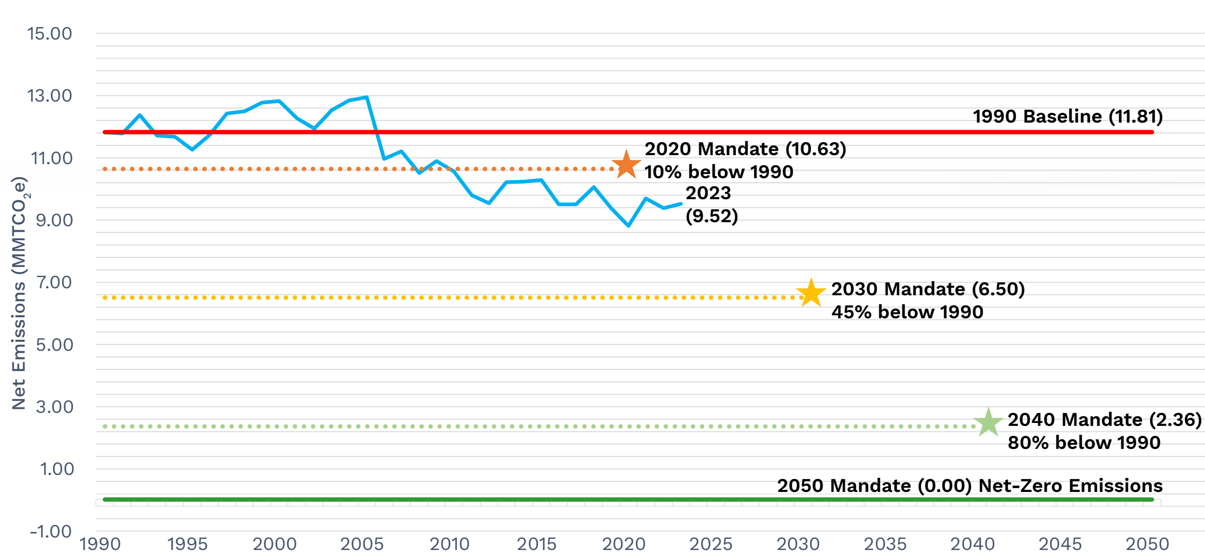
BUILDINGS

2023 marks the third consecutive year residential and commercial building emissions declined

ELECTRICITY

emissions remained flat in 2023, despite the state offsetting 24.2% of its electricity with renewables

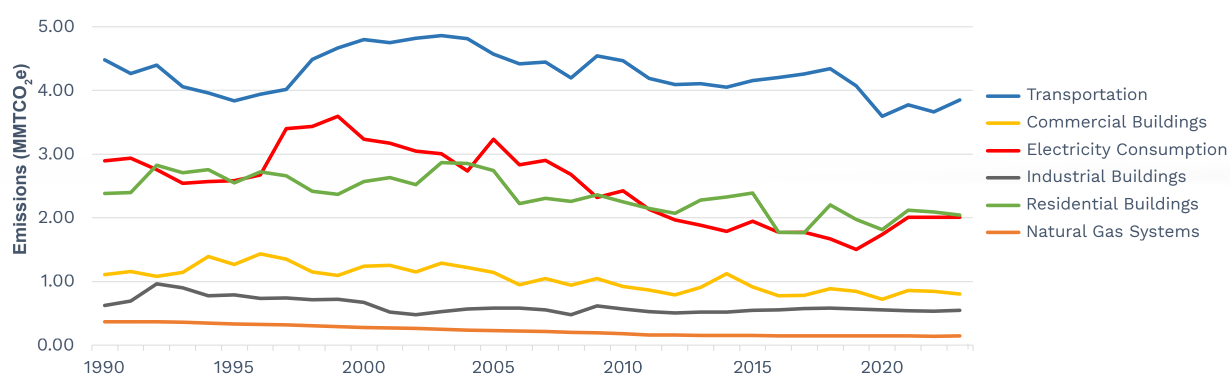
ACT ON CLIMATE REQUIREMENTS



Energy

90.4% of all greenhouse gases (GHGs) emitted in 2023 resulted from energy consumption. Modern life is largely possible because energy can be cost-effectively transferred from one form to another (e.g., from oil stored in the Earth to a car driving on the highway). Emissions from energy are primarily from the combustion of fossil fuels, including coal, petroleum, and natural gas. The transportation, electricity consumption, residential buildings, commercial buildings, and industrial buildings sectors comprise emissions from fossil fuel combustion. Fugitive emissions, or the direct release of a gas to the atmosphere, are also a byproduct of energy use. Natural gas systems are Rhode Island's only source of energy-related fugitive emissions.

GREENHOUSE GAS EMISSIONS FROM ENERGY



Transportation

BACKGROUND

The transportation sector is the single largest contributor to the state's emissions. In 2023, 37.0% of all emissions resulted from the movement of people or goods across Rhode Island. Transportation emissions are organized into three components: aviation, highway vehicles, and non-road sources. Aviation emissions originate from aircraft that fly from airports, airfields, and helipads in Rhode Island to other locations in or outside the state. Aircraft emissions from flights to the state are counted in the originating jurisdiction. Highway vehicles, which contributed 91.4% of all transportation-related emissions in 2023, arise from Rhode Island-registered passenger cars, trucks, motorcycles, buses, refuse trucks, motor homes, and tractor trailers. Vehicles that are registered out-of-state but travel through Rhode Island are not counted in the GHGI.

Non-road source emissions are from watercraft, rail, lawn and garden equipment, and agricultural and construction equipment. A small portion of non-road source emissions – distillate fuel used in agricultural, construction, and heavy-duty utility equipment – is counted in the industrial buildings sector because of data limitations.

METHODOLOGY

Transportation emissions are estimated with several different tools and datasets. For 1990-2009 and 2023, aviation emissions are calculated with a default run of the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT), which leverages state-level aviation gasoline and jet fuel consumption estimates provided by the U.S. Energy Information Administration's (EIA) State Energy Data System (SEDS). Between 2010 and 2022, the Rhode Island Airport Corporation (RIAC) submitted an annual inventory of GHG emissions to DEM as required by The Permanent Air Quality Monitoring Act for all activities at Rhode Island T.F. Green International Airport.[2] RIAC contracted with an environmental engineering firm to perform the analysis, which used the Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT) to calculate full-flight aircraft emissions.

Highway vehicle emissions are estimated with the EPA's Motor Vehicle Emissions Simulator (MOVES), which incorporates state-specific vehicle miles traveled (VMT) data from the Rhode Island Division of Statewide Planning and vehicle registration data from the Rhode Island Division of Motor Vehicles. DEM runs MOVES with state-specific information on vehicle age, average speed distribution, meteorological data, inspection and maintenance (I&M) program details, and road type distribution. Highway vehicle emissions prior to 2020 rely on a default run of EPA's SIT. The methodology employed by SIT is not as sophisticated as MOVES but also uses a VMT-approach to estimate emissions. VMT data in SIT is provided by the U.S. Federal Highway Administration (FHWA).

Distillate and residual fuel oil consumption data from EIA and gasoline consumption statistics from FHWA are used to estimate emissions from agricultural equipment, construction equipment, and watercraft. To estimate emissions from rail, DEM obtains distillate fuel consumption data directly from each railroad that operates in Rhode Island. Fuel consumption data for railroads that operate across state lines, such as the Providence and Worcester Railroad and the Massachusetts Bay Transportation Authority, is apportioned to Rhode Island based on track mileage.

RESULTS AND TRENDS

Transportation emissions have declined 14.0% since 1990, primarily due to advances in vehicle fuel economy, driven by state and federal air pollution control regulations. Rhode Island became the seventh state to adopt California's more stringent emissions standards for model year 2008 passenger vehicles under Section 177 of the federal Clean Air Act.[3] The relatively recent rise of electric vehicles (EVs) has not yet made an impact on highway vehicle emissions, as EVs comprised only 1.1% of all Rhode Island-registered vehicles in 2023.[4] VMT continues to drive annual trends in transportation emissions. Since 2022, transportation emissions increased 5.1%. Much of this change was due to a 0.28 $MMTCO_2e$ increase in highway vehicle emissions. Per the Rhode Island Division of Statewide Planning, VMT increased ~6.29% from 2022 to 2023. Some of this increase is likely due to different data sources, as VMT for prior years originates directly from FHWA. DEM regards VMT from the Division of Statewide Planning as more robust than data provided by FHWA because it is processed through the State's travel demand model. Highway vehicle emissions from 1990 may not be comparable to this and future iterations of the GHGI because different methods were used to estimate VMT. Non-road source emissions (agricultural equipment, construction equipment, watercraft, and rail) decreased 9.2% (-0.02 $MMTCO_2e$) in 2023.

Aviation emissions also declined in 2023 (-31.7%), but this change resulted from an unforeseen methodology switch. DEM was notified by RIAC on March 18, 2024, that they will no longer provide an inventory of all GHG emissions associated with Rhode Island T.F. Green International Airport as required by The Permanent Air Quality Monitoring Act.[2] Without this data, DEM was forced to estimate 2023's aviation emissions with EIA SEDS fuel consumption data. This abrupt switch introduced significant uncertainty to the GHGI because fuel consumption data from EIA SEDS is less representative of Rhode Island's aviation emissions. Considering this development, DEM purchased FAA's AEDT in August 2025 to estimate aviation emissions in house, but lacks the aircraft operations data required to run the model. **It is critical to the scientific integrity of this publication that RIAC provides DEM with complete aircraft operations data for all six state airports to run AEDT.**

Electricity Consumption

BACKGROUND

A significant portion of Rhode Island's emissions are from electricity consumption. The ***2006 IPCC Guidelines for National Greenhouse Gas Inventories*** (2006 IPCC Guidelines) and its refinements, which is the default accounting framework for the GHGI, suggests the tabulation of electricity generation emissions.[5] In 2016, the EC4 unanimously endorsed a consumption-based approach for electricity-related emissions to ensure progress with the Renewable Energy Standard (RES) is captured in the GHGI.[6,7] This is the only sector of the GHGI to include imported emissions (i.e., those emitted outside of Rhode Island's geographic borders). The electricity that Rhode Island consumes originates from a fleet of fossil-fueled power plants and renewable energy generators across the ISO New England control area. Electricity from New York, Quebec, and New Brunswick also flows into the region via high-voltage interconnections to meet demand.

METHODOLOGY

The ISO New England residual mix is the unclaimed electricity and associated emissions that is assigned to a state after considering the settlement of NEPOOL GIS certificates.

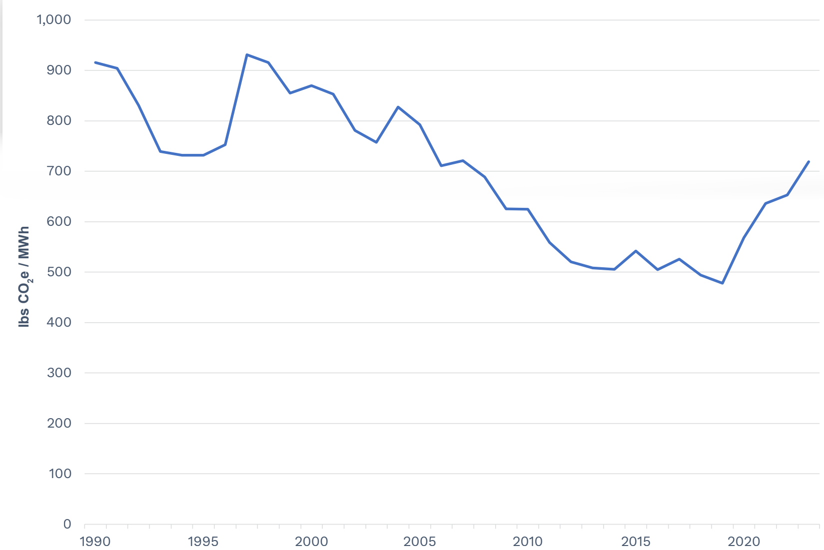
Electricity consumption emissions are estimated with the ***New England States Electricity Consumption Emissions Calculator***. This tool was developed by DEM and underwent a rigorous peer-review by the Rhode Island Public Utilities Commission from October 2024 to July 2025. Data from EIA, ISO New England, the New England Power Pool Generation Information System (NEPOOL GIS), and Statistics Canada are used to estimate emissions. NEPOOL GIS certificates, also known as "renewable energy certificates" (RECs), are settled in Rhode Island by obligated entities to comply with the RES or aid the growth of renewable energy. Zero-emission and low-emission certificates offset a portion of Rhode Island's electric load, which reduces the total amount of energy the state uses from the ISO New England residual mix. DEM calculates a unique emissions factor for the residual mix that considers the carbon intensity of electricity generated in and imported in New England. This emissions factor fluctuates based on which power plants ISO New England calls upon to satisfy demand at the lowest marketable price. Rhode Island's electricity consumption emissions are determined by multiplying an emissions factor for the residual mix by the portion of the state's electric load not served by certificates. Any emissions from certificates (e.g., non-CO_2 GHGs from inefficient combustion) are added to the total.

RESULTS AND TRENDS

Electricity consumption contributed 19.3% (2.01 $MMTCO_2e$) of all emissions in 2023, unchanged from 2022. State law partially governs emissions from this sector. In 2023, Rhode Island offset 24.2% of its total electricity use with zero-or-low emissions sources: 23% as required by the RES and 1.2% from voluntary clean energy programs.[7] Electricity consumption emissions did not decrease in 2023 because the electricity Rhode Island received from the ISO New England residual mix was more carbon intense than in 2022. This is the continuation of a trend that began in 2020. After reaching a low of 477.8 lbs CO_2e/MWh in 2019, the carbon intensity of Rhode Island's electricity from the ISO New England residual mix increased to 719.3 lbs CO_2e/MWh in 2023. One plausible reason is because less hydropower was imported from Canada in 2023 due to widespread drought conditions that limited run-of-river hydropower production.[8] Additionally, electricity consumption emissions in Rhode Island increase when neighboring states claim ***existing*** renewable energy that was formerly part of the ISO New England residual mix. There was over 10,000,000 MWh of nuclear power claimed by other states in 2023 that was formerly part of the electricity Rhode Island received from the ISO New England residual mix prior to 2020.

Since 1990, emissions from this sector have dropped by 30.6% (-0.89 $MMTCO_2e$) as electricity generation transitioned from oil and coal to natural gas and renewables. The implementation of the RES in 2007 further reduced emissions by encouraging the development of renewable electricity generators. The RES will continue to incrementally decrease Rhode Island's reliance on the ISO New England residual mix to serve its electric load. The 704 MW Revolution Wind project is key to the decarbonization of this sector because it will supply electricity at a competitive price in the winter when natural gas prices spike. Annual fluctuations in electricity consumption emissions are expected prior to the RES reaching 100% in 2033 since the wholesale energy market will continue to supply part of Rhode Island's electric load.

CARBON INTENSITY OF RHODE ISLAND'S ELECTRICITY FROM ISO NE RESIDUAL MIX



Residential, Commercial, and Industrial Buildings

BACKGROUND

Residential, commercial, and industrial buildings produce emissions from the combustion of fossil fuels for space heating, water heating, air conditioning, and cooking. Industrial buildings also use fossil fuels to power district heating systems and manufacturing processes. A small portion of industrial-related emissions arise from products consumed for ***non-energy purposes***, such as lubricants (i.e., engines burn a small amount of motor oil) or special naphthas (e.g., paint thinners, cleaners, and solvents). The industrial buildings category also includes emissions from distillate fuel used by agricultural, construction, and heavy-duty utility equipment. These end-uses, which are ideally counted as transportation emissions, are included in the industrial buildings category. Wood and biodiesel also produce emissions in residential and commercial buildings. Wood burning stoves are commonly used for space heating in rural areas of Rhode

Island, though they produce less than 1% of all residential building emissions. In 2023, the Biodiesel Heating Oil Act required all distillate fuel oil sold in Rhode Island for building heating to meet the minimum standards for B10 (a biodiesel blend in which the volume of biodiesel fuel in the blend is between 9.5% to 10.5%) after July 1.[9] Prior to July 1 of that year, the Biodiesel Heating Oil Act required B5. Both wood and biodiesel are ***biogenic*** in origin and are treated as CO_2e-neutral for purposes of compliance with the Act on Climate.[10]

METHODOLOGY

Emissions from residential, commercial, and industrial buildings are estimated with fossil fuel consumption data from EIA's SEDS. Rhode Island Energy (RIE), as the sole natural gas utility in the state, provides data to EIA on the quantity of natural gas delivered to residential, commercial, and industrial customers. For fuels delivered via truck, EIA uses a linear regression model to estimate state-level consumption. Historical fuel consumption statistics from EIA's now-extinct ***Fuel Oil and Kerosene Survey*** and heating degree data from the National Oceanic and Atmospheric Administration (NOAA) are used to calibrate the linear regression model. Prior to 2021, delivered fuel consumption data in SEDS was a direct product of the ***Fuel Oil and Kerosene Survey***. All fossil fuel consumption data from SEDS is imported into EPA's SIT to calculate emissions. DEM elects to use SIT's default emissions factors and combustion efficiencies.

> ***Combined emissions from residential, commercial, and industrial buildings were 3.39 MMTCO_2e in 2023.***

RESULTS AND TRENDS

Residential and commercial building emissions are correlated with winter weather through heating degree days (HDDs).[11] Statewide, Rhode Island experienced an average of 8.4% less HDDs in 2023 than 2022.[13] The winter months of January, February, and December were particularly warmer in 2023. Residential building emissions declined 2.4% (-0.05 MMTCO_2e) and commercial building emissions declined 5.3% (-0.05 MMTCO_2e) from 2022 levels. Residential and commercial buildings that heat with natural gas witnessed a larger drop in emissions compared to buildings that use distillate fuel oil. 2023 marks the third consecutive year residential and commercial building emissions declined. This trend is likely tied to advances in energy efficiency, building weatherization, and the conversion of homes from distillate fuel oil to natural gas. It is unclear whether nascent building electrification (i.e., the conversion of fossil fuel-based heating systems to heat pumps) is impacting residential building emissions. Industrial building emissions increased slightly by 2.3% (0.01 MMTCO_2e) in 2023.

In the past 33 years, emissions from residential, commercial, and industrial buildings have all decreased. Commercial building emissions have seen the sharpest decline, 27.6% (-0.31 MMTCO_2e) since 1990, due to the widespread transition of commercial buildings from distillate fuel oil to natural gas. Distillate fuel oil was responsible for 59.2% of commercial building emissions in 1990, but only 28.9% in 2023. Unlike commercial buildings, the share of residential building emissions from distillate fuel oil has not substantially decreased (58.1% in 1990, 53.2% in 2023). Warmer winter temperatures, alongside improvements in building weatherization and energy efficiency, likely caused the 14.2% (-0.34 MMTCO_2e) drop in residential building emissions since 1990. The average winter temperature in Rhode Island for January, February, and March 1990 was 32.1°F. Comparatively, the same three months in 2023 averaged 35.4°F across the state.[12] Industrial building emissions have also declined, though the 12.7% decrease is modest compared to other building types since emissions from high-heat processes cannot be reduced through weatherization. Industrial building emissions are also less affected by winter temperatures.

Natural Gas Systems

BACKGROUND

CO_2 and methane (CH_4) are emitted fugitively (i.e., through direct leaks to the atmosphere) from natural gas systems. Natural gas first enters Rhode Island via interstate transmission pipelines, which carry the fuel hundreds of miles from production basins. Transmission pipelines leak through small perforations in the piping. Two compressor stations maintain pressure for the transmission pipelines and emit natural gas through blow-down events. Liquified natural gas (LNG) storage facilities, which are used to fulfill peak gas demand, also leak CO_2 and CH_4 through small perforations in the tanks. In Rhode Island, the distribution system is the largest source of natural gas system emissions. 3,223 miles of underground mains, 195,158 underground gas services, and tens of thousands of gas meters cause over 53.5% of all natural gas system emissions. The distribution system was constructed over the span of 160 years. The transition from manufactured gas to natural gas in the 1950s, along with New England's frequent frost/freeze cycles, are the primary reasons why underground mains and services produce fugitive emissions. Gas-fired equipment such as stoves, furnaces, boilers, and clothes dryers inside buildings also leak small amounts of natural gas, in addition to utility-scale electric power plants.

METHODOLOGY

The methodology to estimate natural gas system emissions mirrors EPA's annual ***Inventory of U.S. Greenhouse Gas Emissions and Sinks*** (U.S. GHGI).[15] DEM leveraged the CO_2 and CH_4 emissions factors in Annex 3[6] of the U.S. GHGI to estimate Rhode Island's fugitive emissions from natural gas systems.[15] Massachusetts also employs this method for its annual GHGI. This approach is known as a "bottom-up" method, which requires knowledge about the physical characteristics of the system and the rate at how quickly and intensively emissions occur. Data for transmission pipelines, LNG storage facilities, and distribution mains and services were obtained from the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA). DEM used existing regulatory authority under 250-RICR-120-05-14 to obtain data on natural gas compressor stations.[13] RIE provided information on the number and type of meter and regulator stations across the state, and information on customer meters was obtained from EIA. Residential and commercial post-meter leaks were estimated with customer meter data. Industrial and electric power generation post-meter leaks are based on natural gas consumption data from EIA, as done in the U.S. GHGI.[15]

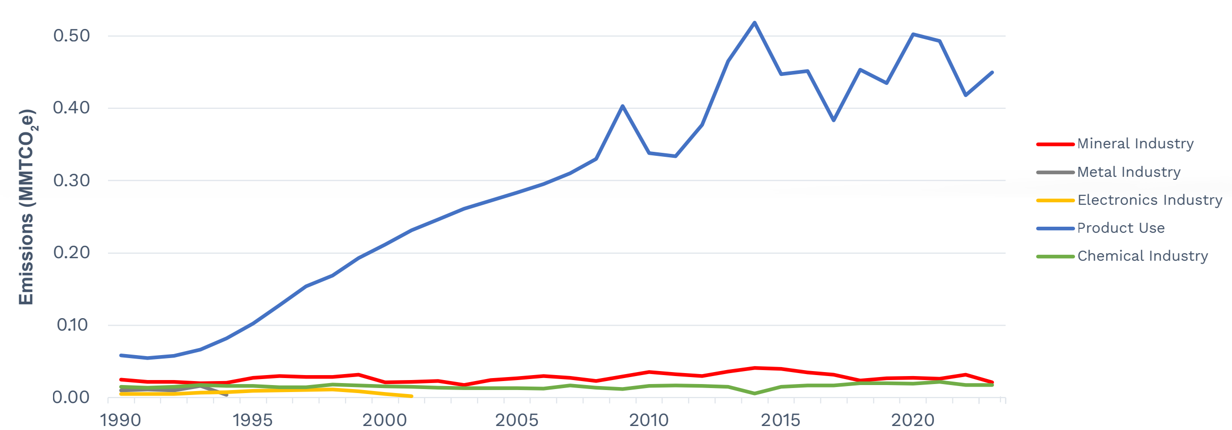
RESULTS AND TRENDS

Fugitive CO_2 and CH_4 emissions from natural gas systems produced 1.4% (0.15 $MMTCO_2e$) of total emissions in 2023, up 3.5% from 2022 levels. This unusual annual increase is because more fugitive emissions were estimated to occur from natural gas-fired electric power plants. The volume of gas that passed through Rhode Island's power plants increased by 21 billion cubic feet in 2023. Additionally, the number of gas meters in the RIE service area increased by 2,049 in 2023. It is evident that (1) homeowners and business owners continue to switch their heating fuel to natural gas and (2) that natural gas heating systems are installed in newly constructed buildings. All other sources of natural gas system emissions decreased or remained flat in 2023. RIE abandoned or replaced 39 miles of leak-prone cast iron and unprotected steel mains and 1,607 antiquated unprotected steel and copper services in 2023. Since 1990, natural gas system emissions have dropped by 59.5%. Improvements to leak-prone cast iron and unprotected steel mains drove the lion's share of this decrease. Specifically, 474 miles of cast iron, 333 miles of unprotected steel, and 163 miles of protected steel mains have been removed or abandoned since 1990. This has occurred while the total miles of natural gas mains have grown by 395 miles over 33 years.

Industrial Processes and Product Use

In 2023, Rhode Island's emissions from the industrial processes and product use (IPPU) sector accounted for 4.7% of total emissions. The state's light amount of heavy industry result in the IPPU sector occupying a small percentage of the entire GHGI. IPPU emissions are delineated into five categories: chemical industry, mineral industry, metal industry, electronics industry, and product use. Many processes of these industries emit air pollution in Rhode Island. However, only those that fugitively emit GHGs are counted in the GHGI. Two components of the IPPU sector – the metal industry and the electronics industry – have fully decarbonized since 1990. 89.4% of this sector's emissions result from product use and all remaining IPPU emissions are from the chemical and mineral industries.

GREENHOUSE GAS EMISSIONS FROM INDUSTRIAL PROCESSES AND PRODUCE USE



Chemical Industry

BACKGROUND

Chemical industry emissions in Rhode Island are only tied to urea (carbamide) consumption for non-agricultural purposes. Urea is formed via an exothermic reaction between ammonia and CO_2 that forms carbamate salt. Per the American Chemical Society, ammonia and urea are often manufactured in the same facility because some of the CO_2 by-product can be re-used to make urea.[14] Urea emits CO_2 wherever it is used, not only where the ammonia feedstock was produced. While in highest demand as a fertilizer, urea is also consumed in many non-agricultural applications. Adhesives, binders, sealants, resins, fillers, solvents, dyestuffs, fragrances, deodorizers, flavoring agents, paint and coating additives, photosensitive agents, and surface treatment agents are all end-uses of urea.[15]

METHODOLOGY

Statistics on urea production, in conjunction with urea imports, exports, and use of urea for agricultural purposes, are used to estimate the supply of urea in the U.S. for non-agricultural applications. The amount of urea consumed in the U.S. for non-agricultural purposes is then multiplied by the ratio of CO_2 to urea, which represents the amount of CO_2 used as a raw material in urea production.[15] DEM leverages EPA's SIT to estimate urea consumption emissions for Rhode Island, which apportions total U.S. non-agricultural urea consumption emissions to each state.

RESULTS AND TRENDS

In 2023, chemical industry emissions were 0.02 $MMTCO_2e$ and have increased by 0.003 $MMTCO_2e$ since 1990. Year-over-year, urea consumption emissions decreased by 1% (-0.0002 $MMTCO_2e$). Urea consumed for non-agricultural applications have fluctuated in the past 33 years. Relative to the rest of the IPPU sector, chemical industry emissions have remained stable. Since Rhode Island's urea consumption is apportioned from the U.S. total, national trends influence emissions. There is greater uncertainty with chemical industry emissions than other areas of the GHGI.

Mineral Industry

BACKGROUND

Rhode Island's mineral industry primarily consists of sand and gravel produced for construction and crushed stone produced for riprap and jetty stone.[16] Neither process emits any GHGs, however, emissions from a small quantity of carbonates consumed for specific industrial processes occur in the state. Soda ash (sodium carbonate) is used for soap and detergent manufacturing. CO_2 is released when soda ash is consumed during the soap manufacturing process. Many soap manufacturers operate throughout the state, including several small-batch producers. Additionally, carbonates used for flue gas desulfurization (FGD), as a flux in metallurgy (flux stone), and for acidic water treatment produce a small amount of CO_2 emissions.

METHODOLOGY

Mineral industry emissions from other process use of carbonates are directly obtained from EPA's ***Inventory of U.S. Greenhouse Gas Emissions and Sinks by State*** (U.S. GHGI by State).[33] EPA allocates total U.S. soda ash consumption emissions to Rhode Island based on U.S. Geological Survey (USGS) ***Mineral Commodity Summaries*** and state population. DEM does not obtain soda ash consumption statistics directly from manufacturers in Rhode Island, though this could be a potential future improvement to the GHGI. CO_2 emissions from carbonates used for FGD, metallurgy applications, and acidic water treatment are also obtained from EPA's U.S. GHGI by State.[33]

RESULTS AND TRENDS

In 2023, Rhode Island's mineral industry produced 0.02 $MMTCO_2e$ – approximately 0.2% of total emissions. All emissions that stem from other process use of carbonates, including soda ash, FGD, flux stone, and carbonates used for acidic water treatment, have remained stable since 1990. Mineral industry emissions have decreased by 0.004 $MMTCO_2e$ in the past 33 years. Since Rhode Island's mineral industry emissions are apportioned from the U.S. total, national trends influence emissions. There is greater uncertainty with mineral industry emissions than other areas of the GHGI.

Metal Industry

BACKGROUND

Rhode Island has a rich history in the metal industry, as the state was home to the world's first large-scale producers of files, machine tools, and screws during the 19th century. By 1990, only one steel manufacturer remained in Rhode Island. Ocean State Steel, located along the Seekonk River in East Providence, produced steel billets from recycled cars with two electric arc furnaces. The facility was Rhode Island's single largest source of air pollution and was the last remaining steel mill in New England when it permanently closed in July 1994. CO_2 is emitted as a byproduct of iron and steel production. The metal shops and foundries that currently operate in Rhode Island do not produce fugitive CO_2 emissions since they do not manufacture iron or steel from raw materials.

METHODOLOGY

Annual steel production data for Ocean State Steel was obtained from DEM's Office of Air Resources file archives and used as a customized input for EPA's SIT. CO_2 emissions were calculated with an emissions factor for electric arc furnaces with EPA's SIT. The emissions factor for electric arc furnaces was obtained from the ***2006 IPCC Guidelines***.

RESULTS

Ocean State Steel's process-related CO2 emissions were 0.01 $MMTCO_2e$ in 1990. The facility's production peaked in 1993 when 227,763 tons of steel was produced, resulting in 0.02 $MMTCO_2e$. CO_2 emissions from steel production accounted for 11.7% of the IPPU sector in 1990. This component of the GHGI was the first to fully decarbonize, as no other facility produced iron or steel in Rhode Island after 1994. It is unlikely metal production will resume in Rhode Island in the future because of industry economics and stricter air pollution control regulations.

Electronics Industry

BACKGROUND

The electronics industry in Rhode Island presently consists of small manufacturers of resistors and circuitry. Semiconductor manufacturing emits hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF_3), sulfur hexafluoride (SF_6), and nitrous oxide (N_2O). The state was previously home to one semiconductor manufacturer. Cherry Semiconductor Corporation (CSC) began operations in East Greenwich in 1972 and was acquired by ON Semiconductor Corporation (onsemi) in 2000. In December 2003, onsemi announced it would close its Rhode Island manufacturing operations the following year, ending all semiconductor manufacturing in the state.

METHODOLOGY

EPA's SIT was used to estimate emissions from semiconductor manufacturing for 1990-2004. Since DEM does not possess GHG emissions data from CSC or onsemi for the years it operated, a nationally scaled down approach was used to calculate emissions. SIT apportions national semiconductor emissions to states using the ratio of each state's semiconductor shipments (found in the 1997, 2002, 2007, 2012, and 2017 Economic Census) to the value of national semiconductor shipments. Rhode Island semiconductor shipment data was only available through 2001, since the quantity of in-state semiconductor shipments significantly decreased after onsemi acquired CSC in 2000.

RESULTS AND TRENDS

Emissions from semiconductor manufacturing in Rhode Island produced 0.005 $MMTCO_2e$ in 1990 and peaked at 0.011 $MMTCO_2e$ in 1998. By 2001, emissions declined to 0.002 $MMTCO_2e$. This was the second component of the GHGI to fully decarbonize. No electronics manufacturers in Rhode Island currently produce any GHGs as byproducts of their process. If semiconductor manufacturing resumes in Rhode Island, all process-related GHG emissions will be counted in the GHGI.

Product Use

BACKGROUND

The lion's share of IPPU emissions originate from product use, which include CO_2, PFCs, HFCs, and SF_6. Many consumer products and industrial applications generate product use emissions. HFCs are fugitively emitted by large central cooling systems, such as those found in ice rinks and supermarkets. Foam blowing agents, solvents, and other aerosols also produce emissions. PFCs are commonly used in fire protection applications. SF_6 is another powerful GHG that is consumed in very small quantities. Often used by electric power companies for voltage electrical insulation, current interruption, and arc quenching, SF_6 warms the atmosphere 23,500 times more than CO_2 over a period of 100 years.[17]

Examples of products that produce fugitive emissions include air conditioners, large central cooling systems, foam blowing agents, solvents, and aerosol canisters.

METHODOLOGY

The GHGI leverages EPA's U.S. GHGI by State for HFC and PFC emissions.[33] EPA calculates state-level HFC and PFC emissions by apportioning national-level emissions to states based on population and adjusts for regional air conditioning use. SF_6 consumption and fugitive emissions data is provided to DEM by RIE for their electric power distribution system. Data from RIE is available for 2016 and later. For 1990-2015, DEM uses EPA's U.S. GHGI by State, which allocates national SF_6 emissions to Rhode Island based on EIA state electricity sales data.[33] A potential future improvement is to obtain SF_6 leak estimates for electric power distribution systems operated by the Block Island Utility District in New Shoreham and the Clear River Electric & Water District in Burrillville. Additionally, SF_6 emissions from electric power transmission systems could be included in future iterations of the GHGI.

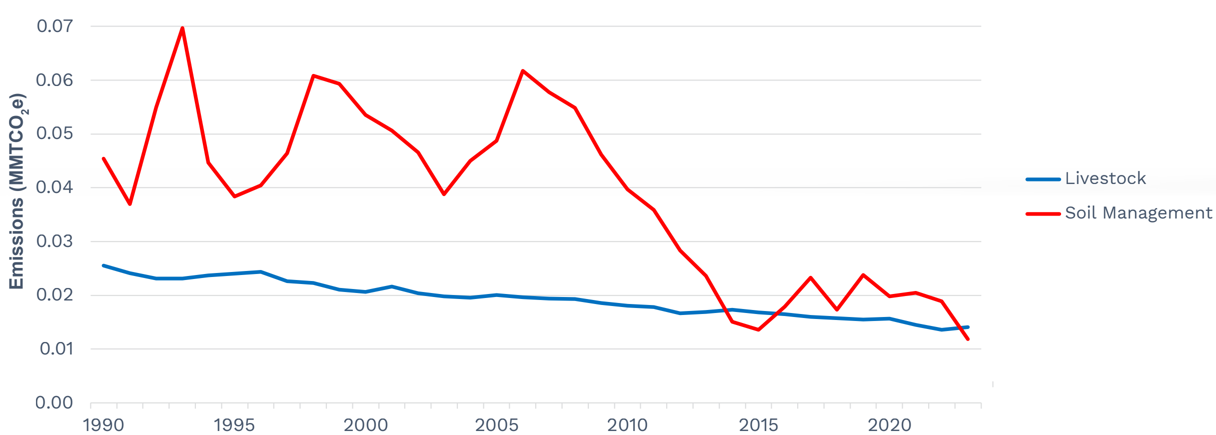
RESULTS AND TRENDS

In 2023, product use was responsible for 0.45 $MMTCO_2e$ – an increase of 7.6% from 2022. Nearly all product use emissions in 2023 (88.1%) were HFCs emitted by air conditioning and refrigeration. Foam blowing agents, aerosols, solvents, and fire protection applications comprised a smaller portion of emissions. PFCs and HFCs are ozone depleting substance substitutes, which replaced chlorofluorocarbons (CFCs) after the Montreal Protocol phased out their use in 1987. Product use emissions in 1990 (0.06 $MMTCO_2e$) were almost entirely SF_6. Since there were only 0.0001 $MMTCO_2e$ of HFCs emitted in 1990, product use emissions have increased 668.9% since that year. No PFCs were known to have been emitted in 1990. In 2022, the U.S. ratified the Kigali Amendment to the Montreal Protocol to phase down the use of HFCs. Rhode Island, as part of the U.S. Climate Alliance, took further action in 2021 to reduce HFC emissions and prohibited the use of certain HFCs in specific end uses through a gradual phase-out.[18]

Agriculture

Agriculture is the smallest sector of the GHGI, accounting for just 0.2% of total emissions in 2023. Emissions from agriculture originate from livestock and soil management practices. Fossil fuels combusted for agricultural practices (i.e., in farm equipment) are counted in the energy sector. Livestock such as cattle, swine, and poultry produce CH_4 and N_2O. In Rhode Island, soil management emissions are a byproduct of the state's three largest agricultural commodities: nursery stock, turf grass, and fruit/vegetable crops. Soil management emissions occur when lime and fertilizer are applied to enhance soil productivity. Emissions that occur directly from disturbing carbon in agricultural soils (e.g., tillage) are counted in the natural and working lands sector.

GREENHOUSE GAS EMISSIONS FROM AGRICULTURE



Livestock

BACKGROUND

Rhode Island is home to a variety of livestock, predominantly cattle (dairy and beef), swine, and poultry (chickens and turkeys). A smaller number of sheep, goats, and horses are also kept for various agricultural purposes. All livestock produce CH_4 through their digestive system – a process known as enteric fermentation. Ruminant animals, such as cattle and sheep, produce more CH_4 through enteric fermentation than non-ruminants (i.e., horses and swine). The storage and disposal of livestock manure also leads to emissions. CH_4 is produced via methanogenesis and N_2O through nitrification. When manure is stored under conditions without oxygen, such as in a lagoon or tank, CH_4 forms. Manure management produces N_2O under conditions with oxygen (e.g., when manure is spread across a pasture).

Rhode Island DEM photo

METHODOLOGY

Livestock population data was gathered from the U.S. Department of Agriculture's (USDA) ***U.S. Census of Agriculture***, which is a complete tally of farms in the United States that sell more than $1,000 worth of agricultural commodities. The ***U.S. Census of Agriculture*** provided population data for dairy cows, beef cows, laying hens, pullets, roosters, broiler chickens, turkeys, sheep, goats, and horses (including mules, burros, and donkeys). Population data for bulls, calves, dairy heifers, beef heifers, breeding swine, and market swine are only available through USDA's less-robust annual surveys. Since the ***U.S. Census of Agriculture*** is only taken on years ending with two or seven (i.e., 2022 and 2027), linear interpolation is necessary to estimate the interim years. For 2023, livestock population data was proxied from 2022 because the next ***U.S. Census of Agriculture*** will not be published until 2027. Once the 2027 ***U.S. Census of Agriculture*** is published, linear interpolation will be used to revise the 2023-2026 livestock population estimates. DEM leveraged IPCC emissions factors – embedded within EPA's SIT – to estimate livestock CH_4 and N_2O emissions.

***Linear interpolation** is a mathematical equation that uses a step formula to connect two data points. For example, linear interpolation assumes Rhode Island is linearly gaining – or losing – animals between census years.*

RESULTS AND TRENDS

In the early 1950s, Rhode Island was home to over 400 dairy farms. A combination of factors, including significant development pressure on farmland and a 1962 State-enacted prohibition on raw milk, led to a drastic decline in the number of dairy farms. Since 1990, Rhode Island lost ~3,200 dairy and beef cattle. The formation of the Rhode Island Dairy Farms Cooperative in 2004 stabilized the number of dairy cows in the state relative to the drastic decline from the mid-20th century. In 2023, Rhode Island had ~1,250 dairy cattle and ~3,000 beef cattle. ~79,000 domesticated chickens and turkeys and ~4,000 pigs, sheep, goats, and horses are kept in Rhode Island. Livestock produced 0.01 $MMTCO_2e$ of in 2023 – predominantly CH_4 via through enteric fermentation. Emissions from livestock declined by 44.8% since 1990.

Rhode Island DEM photo

Soil Management

BACKGROUND

Rhode Island is home to approximately 16,665 acres of cropland per the 2022 ***U.S. Census of Agriculture***.[19] The state's top agricultural commodities – nursery stock, turf grass production, and fruit/vegetable crops – all use fertilizer to enhance the soil for increased productivity. Synthetic (nitrogen-based) fertilizers emit N_2O when applied to soil. Additionally, urea-based fertilizers produce CO_2 when urea is oxidized by microorganisms in the soil. The application of lime to agricultural soils improves plant growth by reducing acidity. As lime dissolves, CO_2 is released into the atmosphere as the bicarbonate breaks down into CO_2 and water.

METHODOLOGY

A variety of data sources are used to estimate soil management emissions. Commercial fertilizer consumption data for 1990-2013 was collected from the American Association of Plant Food Control Officials (AAPFCO) ***Commercial Fertilizers Report***. For 2014-2023, commercial fertilizer data was gathered from DEM's Division of Agriculture and Forest Environment (DAFE), which compiles the ***Single Nutrient Tonnage Report*** as required by R.I. Gen. Laws § 2-7-6.20 Urea fertilizer consumption was obtained from the Tennessee Valley Authority for 1990-1994 and the AAPFCO ***Commercial Fertilizers Report*** for 1995-2022 (proxied for 2023). Consumption of lime for agricultural purposes was estimated from ***USGS Mineral Yearbook*** data for 1990-2006. For 2007-2023, agricultural lime consumption data was gathered from DEM's DAFE ***Single Nutrient Tonnage Report***. All soil management emissions are calculated with emissions factors from the ***2006 IPCC Guidelines*** embedded within EPA's SIT.

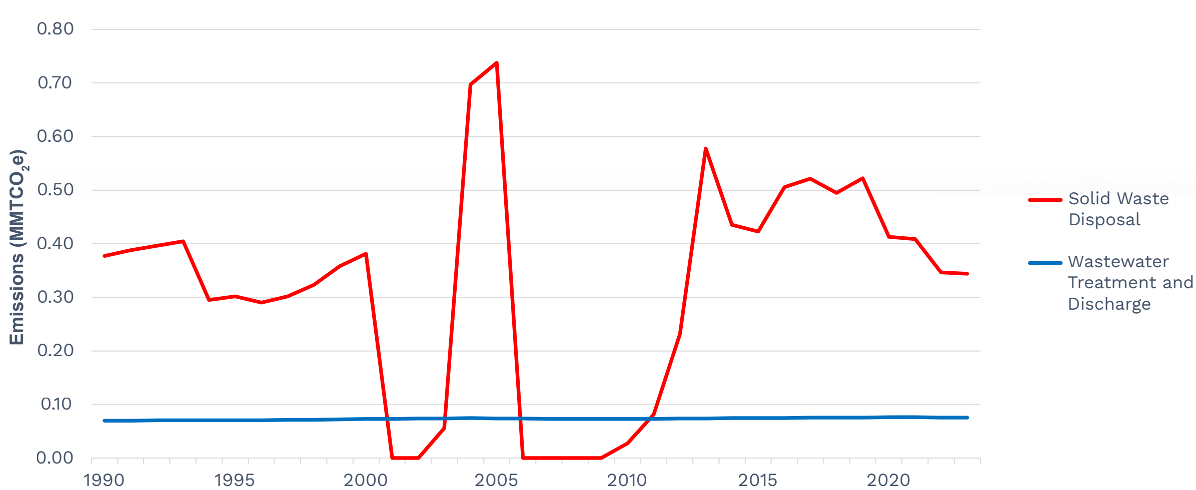
RESULTS AND TRENDS

Soil management emissions contributed 0.1% (0.01 $MMTCO_2e$) of the state's total emissions in 2023. The largest component of soil management emissions is synthetic fertilizer use. Urea and lime applied to agricultural soils result in a significantly smaller quantity of soil management emissions. Since 1990, soil management emissions have decreased 74.2% (-0.03 $MMTCO_2e$), primarily due to the decline of field agriculture in Rhode Island. The state has lost 9,456 acres of cropland since 1987.[21] DEM's DAFE ***Single Nutrient Tonnage Report*** for synthetic fertilizer and agricultural lime provides sales data, not consumption data. Thus, there is more uncertainty in soil management emissions than other components of the GHGI.

Waste

In Rhode Island, emissions from the treatment and management of waste are a small source of emissions. Waste-related emissions stem from landfills (active and inactive) and wastewater treatment facilities. In 2023, waste accounted for 4.0% of the state's emissions. Organic matter (e.g., food waste) deposited at landfills directly generates CH_4 as it decays. CO_2 from the flaring of landfill gas is considered biogenic and is not reported as part of the GHGI's official total.[10] The treatment and subsequent discharge of wastewater primarily produces CH_4 and a small quantity of N_2O. Emissions from anaerobic digestion at biogas facilities are not presently included in the GHGI.

GREENHOUSE GAS EMISSIONS FROM WASTE



Solid Waste Disposal

BACKGROUND

Rhode Island Resource Recovery Corporation photo
The Central Landfill in Johnston

Solid waste disposal practices have greatly evolved in Rhode Island since the mid-20th century. The state was once home to dozens of unregulated dumps and landfills, some of which accepted hazardous waste. The establishment of EPA in 1970 and DEM in 1977 led to the eventual closure of all municipal dumps by 2022. Today, most of the municipal solid waste generated in-state is disposed of at the Rhode Island Resource Recovery Corporation's (RIRRC) Central Landfill in Johnston. RIRRC prohibits all out-of-state waste from the Central Landfill. Deposited waste is estimated to continuously emit CH_4 over a period of approximately 30 years (e.g., waste disposed of in 1960 continued to produce emissions through 1990). Anaerobic microorganisms produce landfill gas – primarily CH_4 – as organic matter decays. Most landfill gas produced at the Central Landfill is captured and used to generate electricity (CH_4 and N_2O from the combustion of landfill gas for electricity are counted in the energy sector). The Central Landfill emits CH_4 directly to the atmosphere in areas that have not yet been covered with material. Closed municipal landfills also emit CH_4, though there is more uncertainty with the estimates for these sites than the Central Landfill.

METHODOLOGY

DEM uses EPA's SIT to estimate solid waste disposal emissions, which leverages a first order decay (FOD) model that calculates emissions based on the quantity of waste deposited in landfills over the previous 30 years. The FOD model in SIT considers a state-specific CH_4 generation rate based on local climate. The estimated quantity of solid waste disposed of statewide for each year, 1960-2023, was used to calculate emissions. Historical disposal data for 53 sites was obtained from DEM's Office of Land Revitalization and Sustainable Materials Management. The CH_4 emissions curve generated by the FOD model was adjusted for CH_4 avoided through landfill-gas-to-energy projects and flaring. EIA landfill gas electricity generation and fuel consumption data was used to estimate avoided CH_4 in accordance with guidance developed by EPA's Landfill Methane Outreach Program. Please see the **Technical Appendix** for recent methodology changes.

RESULTS AND TRENDS

Solid waste disposal emissions were 0.34 $MMTCO_2e$ in 2023, an 8.8% decrease from 1990 levels. RIRRC's Central Landfill has a highly efficient landfill gas collection system. In 2023, the facility generated 241,221 MWh of electricity. 230,607 MWh of this power was settled in Rhode Island to reduce emissions from electricity consumption. The quantity of landfill gas that is collected to generate electricity has grown since 1990 due to the expanding size of the landfill and better collection technology. Flaring of landfill gas only occurs at RIRRC's Central Landfill when the electric turbines are shut down for routine maintenance or unforeseen issues. Qualitatively, the amount of organic waste disposed of at RIRRC has potentially decreased in the past few years due to the introduction of anerobic digestion technology.

Rhode Island DEM photo

Wastewater Treatment and Discharge

BACKGROUND

Wastewater-related emissions originate from Rhode Island's 19 wastewater treatment facilities that purify approximately 100,000,000 gallons of human and industrial sewage each day.[22] Additionally, over 150,000 septic systems treat wastewater from homes and businesses not connected to municipal sewers.[23] Emissions from wastewater are primarily generated by microorganisms that break down waste in oxygen-free (anaerobic) environments. Many wastewater facilities treat wastewater aerobically (i.e., with water exposed to open air). Emissions occur when anaerobic pockets form within the system, generating CH_4. Septic systems exclusively treat wastewater in anaerobic conditions and are more emissions-intensive than municipal sewers. Nearly all wastewater treatment and discharge emissions are CH_4. A small quantity of N_2O emissions is produced when biological nitrogen removal occurs.[24]

METHODOLOGY

Emissions from municipal wastewater treatment and discharge are estimated with EPA's SIT, which calculates emissions based on U.S. Census Bureau state population data. SIT is customized with (1) a state-specific estimate for the fraction of all residents that utilize septic systems and (2) the amount of biosolids that are beneficially reused. Both figures are provided by DEM's Office of Water Resources. In Rhode Island, industrial wastewater treatment and discharge emissions are very small and result from meat, fruit, and vegetable processing. DEM proxies state food production data with livestock population data and specialty crop (i.e., fruits and vegetables) production data from the ***U.S. Census of Agriculture***. SIT leverages emissions factors from the ***2006 IPCC Guidelines*** to calculate all wastewater-related emissions.

RESULTS AND TRENDS

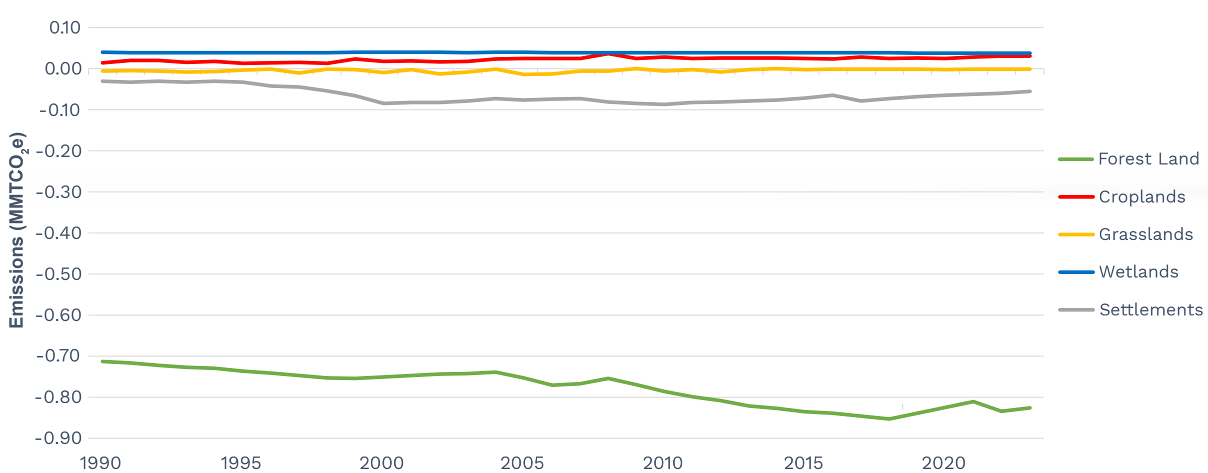
Rhode Island's emissions from wastewater treatment and discharge have slightly increased since 1990. In 2023, emissions were 0.08 $MMTCO_2e$ – an increase of 8.7% (0.01 $MMTCO_2e$) over the last 33 years. Wastewater treatment and discharge comprises just 0.7% of total emissions. Trends in wastewater-related emissions are tied to state population. The population of Rhode Island grew by 8.9% between 1990 and 2023, closely in line with wastewater-related emissions.[25] CH_4 from industrial wastewater is mainly from fruit and vegetable processing and red meat processing. A smaller amount originates from poultry processing. Industrial wastewater emissions were estimated to be only 0.0002 $MMTCO_2e$ and likely stem from a handful of facilities.

Natural and Working Lands

Rhode Island DEM Photo
Wixaboxet Management Area, West Greenwich

Rhode Island's 1,034 square miles of land is a mosaic of forests, farmland, wetlands, suburbs, and urban areas. The entire land area within the state's borders is considered ***managed land***, which the IPCC defines as "...land where human interventions and practices have been applied to perform production, ecological, or social functions.".[26] Emissions and removals from managed land are reported in the GHGI. Nearly all ***unmanaged land*** in the United States – aside from freshwater wetlands – are in remote areas of Alaska where significant human intervention has not occurred. The GHGI separates the natural and working lands (NWL) sector into five categories: forest land, cropland, grassland, wetlands, and settlements. NWLs in Rhode Island are a net ***sink*** of carbon. The state's trees remove significantly more carbon than is emitted through deforestation, forest fires, soils, and flooded lands each year. In 2023, NWLs offset 7.9% of the state's emissions.

GREENHOUSE GAS EMISSIONS AND REMOVALS FROM NATURAL AND WORKING LANDS



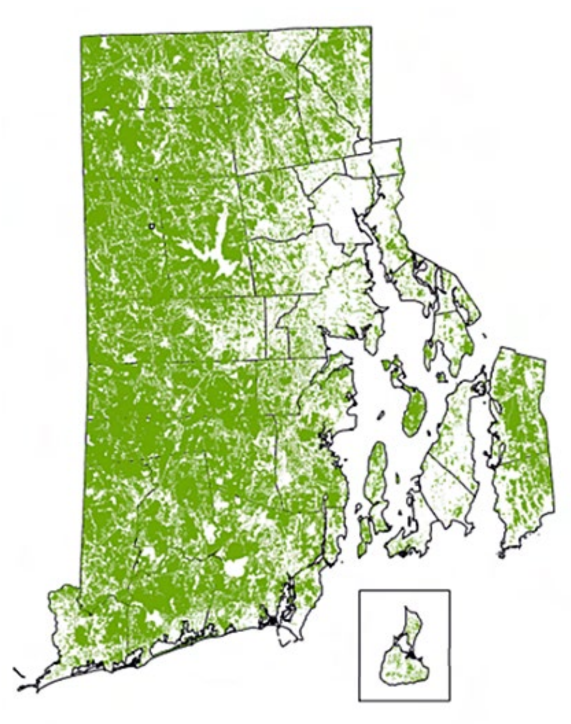
Forest Land

BACKGROUND

The largest component of Rhode Island's NWL sector is forest land, which occupied 377,545 acres in 2023 per the U.S. Forest Service (USFS). Forest land includes all land whose primary cover is woody vegetation (i.e., trees and shrubs) that is not settled. Over half of Rhode Island is forested. The rural communities of Foster, West Greenwich, and Exeter contain some of the largest contiguous tracts of forest land. While most forest land is privately owned, DEM manages more than 57,000 acres of State-owned forests.[27] The average acre of forest land in Rhode Island removes 1.3 $MTCO_2$ per year and stores between 75 and 91 $MTCO_2$ per year. Some forest types, such as the oak/pine group, remove more CO_2 per year than other forest types. In 2023, ~60% of Rhode Island's forest land was classified as oak/hickory (deciduous) forest. Coniferous forests include white, red, and pitch pine and are more common in southern areas. Pine forests are also found in areas where erosion control was implemented, such as the land surrounding the Scituate Reservoir. The boundary between forest land and settlements is becoming increasingly gray. Forest land that is converted to settled land (e.g., a residential neighborhood) sometimes retain a high amount of tree canopy after development. For this reason, the NWL sector has a higher level of uncertainty than other sectors of the GHGI. The forest land category also includes carbon stored in harvested wood products (HWPs), which are products and materials made from wood that are cut from a forest.

METHODOLOGY

DEM leverages USFS's Forest Inventory and Analysis (FIA) dataset to estimate the amount of CO_2 sequestered by trees (i.e., aboveground and belowground biomass) on forest land. USFS selects numerous plots – some on State land and some on private land – as representative samples. USFS FIA staff conduct detailed surveys and record information about tree species, age, health, growth and mortality rate, and timber output. The number of acres for each forest type is multiplied by sequestration factors from the ***Rhode Island 2020 Forest Action Plan*** to estimate CO_2 removal.[27] Forest fire acreage data, provided by DEM's DAFE, is used to estimate CH_4 and N_2O emissions from forest fires in EPA's SIT. CO_2 emissions from forest fires are not counted in the GHGI because they are considered biogenic carbon.[10] Carbon storage and removal data from EPA's U.S. GHGI by State is incorporated in the GHGI for other components of forest land (deadwood, litter, mineral soil, and organic soil).[33] DEM uses USFS FIA timber harvest data in conjunction with a tool developed by the Woodwell Climate Institute to estimate the amount of carbon stored in harvested wood products (HWPs). See the **Technical Appendix** for details about this addition to the GHGI.



DEM Division of Agriculture and Forest Environment

Extent of forests in Rhode Island.

Note, overlap exists between forest land and settlements.

RESULTS AND TRENDS

Rhode Island DEM photo

Big River Management Area in West Greenwich/Coventry

In 2023, forest land was estimated to remove 0.86 $MMTCO_2e$ from the atmosphere. Inefficient combustion of woody biomass by forest fires emitted a very small amount of non-CO_2 GHGs. Most CO_2 sequestered by forest land is removed via aboveground and belowground biomass (-0.50 $MMTCO_2e$), which are living trees. When trees die and remain in the forest, their ***stored*** carbon also remains. For example, most carbon stored in an oak tree that died in 2023 may be transferred to the dead wood carbon pool in 2023, though some is gradually released to the atmosphere via decomposition. This ***appears*** as a net removal of CO_2 because the stock change method is used for this sector of the GHGI.[28] By 2023, many standing dead trees from the spongy moth outbreak of 2015- 2018 remained in the ecosystem. These dead trees continue to store carbon, which is why NWLs offset a greater percentage of Rhode Island's gross emissions in 2023 than in 1990. Conversely, Rhode Island's forest land sequestered 4.5% less CO_2 from the atmosphere than it did 33 years ago. This is attributed to the loss of ~30,000 acres of forest land since 1990.

Cropland and Grassland

BACKGROUND

Rhode Island is home to a local and vibrant agricultural scene. The state's cropland and grassland produce and store a small quantity of CO_2 every year. Cropland includes all land dedicated to cultivating adapted crops, such as turfgrass, nursery stock, and fruit/vegetable crops. Grassland – also known as pastureland – encompasses open fields used for the harvesting forage or grazing livestock. The CO_2 flux from woody crops (e.g., fruit trees and Christmas trees) is counted in the cropland carbon pool. Emissions from the alteration of cropland, such as the addition of fertilizer to soil, are counted in the agriculture sector.[29]

Carbon flux is the direction and rate of transfer — or flow — of carbon between Earth's carbon pools, such as the oceans, atmosphere, land, and living things.[34]

METHODOLOGY

The GHGI's cropland and grassland CO_2 flux estimates are directly pulled from EPA's U.S. GHGI by State.[33] EPA calculates the CO_2 flux from cropland and grassland based on USDA's Natural Resources Conservation Service (NRCS) ***Natural Resources Inventory*** (NRI).[30] This publication, like FIA, uses survey plots to identify cropland and pastureland areas at the county level. DEM does not have access to plot-level data, but state- and county-level data are publicly available.

RESULTS AND TRENDS

In 2023, Rhode Island's cropland was a net source of CO_2 emissions (0.03 $MMTCO_2e$), and grassland was a small carbon sink (-0.0009 $MMTCO_2e$). All emissions from cropland originate from the disturbance of carbon in organic and mineral soils. Aboveground biomass on cropland removed a very small amount of carbon from the atmosphere (-0.0006 $MMTCO_2e$) in 2023. Grassland mineral carbon stocks are a net sink of carbon, while organic soil found in grassland is a net source. The net CO_2 flux from cropland and grassland has not substantially changed since 1990.

Wetlands

BACKGROUND

Rhode Island DEM photo

Colt State Park in Bristol

Wetlands in Rhode Island take many forms, including freshwater swamps, marshes, bogs, and wet meadows. Coastal wetlands include vegetated and unvegetated open water – such as saltwater marshes – that are subject to tidal inundation. Salinity contents greater than 0.5 parts per thousand are also indicative of coastal wetlands.[31] In the context of the GHGI, flooded lands (constructed reservoirs, canals, and freshwater ponds) and managed peatlands (areas where peat is harvested) are also considered wetlands. DEM follows the ***2006 IPCC Guidelines*** and its refinements and only estimates the emissions flux from coastal wetlands, flooded land, and offsite peatlands.[32] DEM does not currently include the emissions flux for non-tidal perennial (palustrine) wetlands due to data limitations and methodology uncertainty. While submerged aquatic vegetation (i.e., seagrasses and kelp) sequester CO_2 and aquaculture produces N_2O, these components are not currently estimated due to data limitations. Submerged aquatic vegetation and aquaculture could be a future addition to the GHGI.

METHODOLOGY

Estimates for wetland emissions and removals are directly pulled from EPA's U.S. GHGI by State.[33] The GHGI assumes no CH_4 is emitted by coastal wetlands because saltwater suppresses CH_4 production. EPA calculates the emissions flux for coastal wetlands with satellite images from NOAA's Coastal Change Analysis Program (CCAP). Flooded land emissions are estimated with data from a variety of sources, including the ***USGS National Hydrography Dataset***, the U.S. Army Corps of Engineers' ***National Inventory of Dams***, the U.S. Fish and Wildlife Service's ***National Wetlands Inventory***, and EPA's ***Safe Drinking Water Information System***. Reservoirs are considered flooded land if they are larger than 8 hectares (19.77 acres) in size. Since flooded land emits significantly more CH_4 in the first 20 years after inundation, a different emissions factor is used for newly constructed waterbodies.

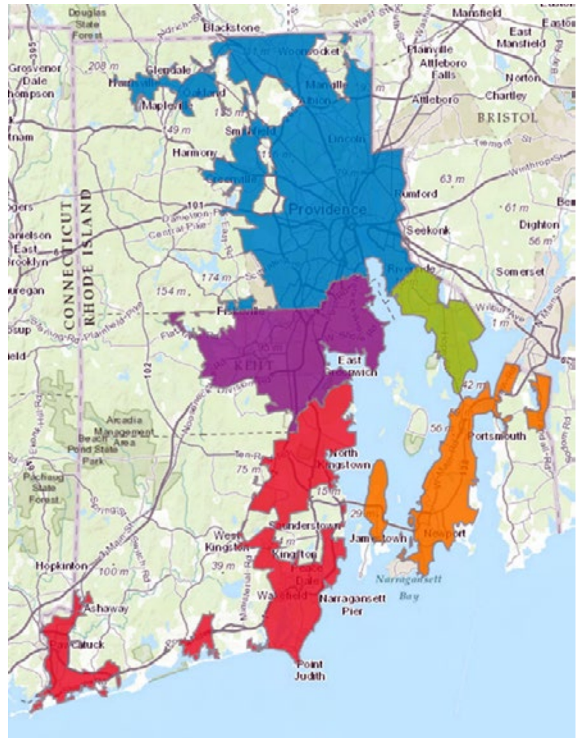
RESULTS AND TRENDS

In 2023, wetlands were a net source of emissions in Rhode Island, producing 0.04 $MMTCO_2e$. Coastal wetlands sequestered 0.01 $MMTCO_2e$ from the atmosphere and stored it in soil. If seagrasses and kelp were included in the GHGI, the annual sequestration of coastal wetlands is likely higher. Flooded land was responsible 0.05 $MMTCO_2e$ of CH_4 in 2023, primarily from large reservoirs. Offsite peatlands (i.e., the consumption of peat for horticultural applications) produced just 0.0002 $MMTCO_2e$ in 2023. In the past 33 years, the net emissions flux from wetlands has remained relatively stable. The inclusion of aquaculture-related N_2O emissions would likely make an indiscernible difference in the GHGI since total U.S. aquaculture emissions were 0.01 $MMTCO_2e$ in 2023.[34]

Settlements

BACKGROUND

Settlements include all ***developed*** land in Rhode Island, which accounts for approximately 37.8% of the state's total land area. Examples of settled land include urban areas, suburban neighborhoods, land along roadways, golf courses, and manicured parkland. Rhode Island's urban and suburban areas were developed over hundreds of years. The state's diverse land use pattern complicates the boundary between settlements and other NWL categories. There is likely significant overlap between the land area DEM considers settlements and other land areas identified by USFS's FIA (forest land), NRCS's NRI (cropland and grassland), and NOAA's CCAP (wetlands). Settlements in Rhode Island are a net carbon sink. Trees and landfilled yard trimmings (branches, food scraps, grass, and leaves) remove CO_2 from the atmosphere, while the conversion of other land types to settlements is a large emissions source of stored CO_2. Settlement soils are also known to emit a small amount of N_2O from synthetic fertilizers applied to lawns, golf courses, and other landscaped areas.



DEM Division of Agriculture and Forest Environment

Extent of urban area in Rhode Island from iTree study. Note, overlap exists between forest land and settlements. Different colors indicate different counties.

METHODOLOGY

Several different data sources and methodologies were used to estimate the emissions and removals of settlements. DEM's DAFE Urban and Community Forestry program used the peer-reviewed, state-of-the-art, iTree software to calculate the average tree canopy cover of Rhode Island's urban area in 2015 (37.7%). This was assumed to be constant for all years of the GHGI. DEM's Division of Planning and Development provided urban land area estimates based on the U.S. Census, which increased from 276 mi^2 in 1990 to 391 mi^2 in 2020. EPA's SIT was used to estimate the amount of CO_2 removed by urban trees with these inputs. All other components of settlement emissions and removals were directly pulled from EPA's U.S. GHGI by State.[33] The above map displays the area DEM's DAFE considered urban area for its iTree canopy cover study.

RESULTS AND TRENDS

In 2023, the net emissions flux of settlements was -0.06 $MMTCO_2e$. While settlement trees removed 0.27 $MMTCO_2e$ from the atmosphere, the conversion of other land types (primarily forest land) to settlements resulted in the loss of 0.20 $MMTCO_2e$ of stored carbon. An additional 0.01 $MMTCO_2e$ of N_2O was produced by synthetic fertilizers applied to settlement soils. Note, there is likely overlap between this estimate and the synthetic fertilizers emissions estimate in the agriculture sector. The net emissions flux of settlements has grown by -0.03 $MMTCO_2e$ since 1990; this increase is attributed to the reclassification of existing trees from the forest land category to the settlements category.

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Newport bridge from Taylor's Point

Conclusion

While Rhode Island emitted 1.4% more GHG's in 2023 than 2022, the state has reduced its collective emissions 19.5% below 1990 levels. Similar to previous iterations to the GHGI, transportation, residential buildings, and electricity consumption remain the three largest sources of the state's emissions. A 0.19 $MMTCO_2e$ (5.1%) jump in transportation emissions was largely responsible for the recent increase. A small upward shift in VMT, which mirrors a trend seen nationally, primarily drove this increase in transportation emissions.[15] Total emissions were 1.5% higher in 2023 than pre-pandemic 2019 levels. This is likely because 2019 was 1.2°F milder[12] across Rhode Island and the state received significantly more unclaimed nuclear electricity at that time. Emissions have dropped 5.4% in the last five years. A similar rate of decrease between 2024 and 2030 would not allow the state to achieve the Act on Climate's requirement of 45% below 1990 levels by 2030. Emissions must decline an additional 3.02 $MMTCO_2e$ (average of 4.5% per year) in the next seven years to comply with the Act on Climate. Significant decarbonization of transportation, electricity consumption, and buildings are instrumental to attain net-zero emissions by mid-century.

The attached **Technical Appendix** details methodology updates implemented since the ***2022 Rhode Island Greenhouse Gas Inventory*** was published in December 2024. DEM is committed to scientifically evaluating Rhode Island's path towards net-zero emissions and will tentatively publish the ***2024 Rhode Island Greenhouse Gas Inventory*** no later than December 2026. For more information, visit dem.ri.gov/ghg-inventory. Learn more about Rhode Island's climate change mitigation and resilience efforts at climatechange.ri.gov.

GREENHOUSE GAS EMISSIONS BY SECTOR

All Units in Million Metric Tons Carbon Dioxide Equivalent ($MMTCO_2e$)

	1990	2010	2020	2021	2022	2023
Energy	**11.86**	**10.82**	**8.58**	**9.46**	**9.29**	**9.40**
Transportation	*4.48*	*4.46*	*3.59*	*3.77*	*3.66*	*3.85*
Aviation	0.33	0.26	0.06	0.20	0.23	0.16
Highway Vehicles	3.98	4.06	3.34	3.37	3.24	3.52
Non-Road Sources	0.17	0.14	0.19	0.21	0.19	0.18
Electricity Consumption	*2.90*	*2.43*	*1.74*	*2.01*	*2.01*	*2.01*
Residential Buildings	*2.38*	*2.25*	*1.82*	*2.12*	*2.09*	*2.04*
Commercial Buildings	*1.11*	*0.92*	*0.72*	*0.86*	*0.85*	*0.80*
Industrial Buildings	*0.63*	*0.57*	*0.55*	*0.54*	*0.53*	*0.55*
Natural Gas Systems	*0.37*	*0.18*	*0.15*	*0.15*	*0.14*	*0.15*
Industrial Processes and Product Use	**0.11**	**0.39**	**0.55**	**0.54**	**0.47**	**0.49**
Chemical Industry	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Mineral Industry	*0.02*	*0.04*	*0.03*	*0.03*	*0.03*	*0.02*
Metal Industry	*0.01*	-	-	-	-	-
Electronics Industry	*0.01*	-	-	-	-	-
Product Use	*0.06*	*0.34*	*0.50*	*0.49*	*0.42*	*0.45*
Agriculture	**0.06**	**0.04**	**0.03**	**0.03**	**0.02**	**0.02**
Livestock	*0.03*	*0.02*	*0.02*	*0.01*	*0.01*	*0.01*
Soil Management	*0.05*	*0.04*	*0.02*	*0.02*	*0.02*	*0.01*
Waste	**0.45**	**0.10**	**0.49**	**0.48**	**0.42**	**0.42**
Solid Waste Disposal	*0.38*	*0.03*	*0.41*	*0.41*	*0.35*	*0.34*
Wastewater Treatment and Discharge	*0.07*	*0.07*	*0.08*	*0.08*	*0.08*	*0.08*
TOTAL GROSS EMISSIONS	**12.55**	**11.42**	**9.71**	**10.57**	**10.27**	**10.40**
Natural and Working Lands	*-0.68*	*-0.81*	*-0.84*	*-0.82*	*-0.84*	*-0.82*
TOTAL NET EMISSIONS	**11.81**	**10.55**	**8.81**	**9.69**	**9.38**	**9.52**

** Emissions converted to $MMTCO_2e$ with the Intergovernmental Panel on Climate Change's (IPCC) GWP_{100} from the Fifth Assessment Report (AR5), available at ipcc.ch/report/ar5/syr/. For the 1990-2023 complete dataset, visit dem.ri.gov/ghg-inventory. Sector totals may not align with gross and net totals due to rounding.*

GREENHOUSE GAS EMISSIONS BY GAS

All Units in Million Metric Tons Carbon Dioxide Equivalent ($MMTCO_2e$)

	1990	2010	2020	2021	2022	2023
Carbon Dioxide	**10.60**	**9.72**	**7.51**	**8.38**	**8.21**	**8.31**
Methane	**0.95**	**0.38**	**0.73**	**0.73**	**0.66**	**0.67**
Nitrous Oxide	**0.17**	**0.10**	**0.05**	**0.07**	**0.07**	**0.07**
Fluorinated Gases	**0.06**	**0.34**	**0.50**	**0.49**	**0.42**	**0.45**
Perfluorocarbons and Nitrogen Trifluoride	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sulfur Hexafluoride	*0.06*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*
Hydrofluorocarbons	*0.00*	*0.32*	*0.50*	*0.49*	*0.42*	*0.45*
TOTAL GROSS EMISSIONS	**12.55**	**11.42**	**9.71**	**10.57**	**10.27**	**10.40**
TOTAL NET EMISSIONS	**11.81**	**10.55**	**8.81**	**9.69**	**9.38**	**9.52**

** Emissions converted to $MMTCO_2e$ with the Intergovernmental Panel on Climate Change's (IPCC) GWP_{100} from the Fifth Assessment Report (AR5), available at ipcc.ch/report/ar5/syr. For the complete 1990-2022 dataset, visit dem.ri.gov/ghg-inventory. Gas totals may not align with gross and net totals due to rounding.*

Technical Appendix

The Rhode Island Department of Environmental Management (DEM) strives to incorporate contemporary climate science into the ***Rhode Island Greenhouse Gas Inventory*** (GHGI) whenever possible. The *2006 IPCC Guidelines* and its refinements, internationally recognized as the gold standard for greenhouse gas (GHG) inventories, is the accounting framework unless endorsements are made by the Rhode Island Executive Climate Change Coordinating Council (EC4). This Technical Appendix serves to inform interested readers of methodology changes and updates since the 2022 GHGI was published in December 2024. Additionally, **see page 39** for supplemental information on biogenic carbon dioxide (CO_2) emissions.

ADJUSTMENTS TO HISTORICAL EMISSIONS ESTIMATES

In October 2023, DEM opened a 14-day public comment period on proposed methodology improvements to the GHGI's 1990 baseline. In addition to revising the 1990 baseline for the first time in a decade, feedback was solicited about applying relevant methodology updates to the 1990 baseline and subsequent years on an as-needed basis in the future. This practice was implemented in June 2024 with the release of the 2021 GHGI. Since the inventory's timeseries is now recalculated each year to incorporate new emissions factors or new datasets, past iterations of the GHGI should not be used as a direct comparison. The following table showcases numerical adjustments to years 1990 and 2022 and their comparison to 2023. It is important to note that similar adjustments have been applied to all historical estimates where applicable. The complete 1990-2023 dataset can be found at dem.ri.gov/ghg-inventory.

WHAT'S NEW?

ENERGY SECTOR

- Applied in-house electricity consumption methodology to years 1990-2009.
- Corrected non-road source emissions estimates, **see page 30.**
- Revised emissions estimates for passenger and freight rail, **see pages 31 and 32.**
- Accounted for the effects of the Biodiesel Heating Oil Act, **see page 33.**
- Corrected industrial buildings emissions estimates, **see page 34.**
- New estimates for fugitive emissions from natural gas systems, **see page 35.**

INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR

- Added three applications of carbonates: flue gas desulfurization (FGD), flux stone (when carbonates are used as a flux in metallurgy), and acidic water treatment.

WASTE SECTOR

- Revised solid waste disposal emissions estimates, **see pages 36 and 37.**

NATURAL AND WORKING LANDS SECTOR

- Included carbon stored in harvested wood products, **see page 38.**

HIGHLIGHTED ADJUSTMENTS TO THE 1990 BASELINE AND 2022

All Units in Million Metric Tons Carbon Dioxide Equivalent ($MMTCO_2e$)

	1990 (Previous)	1990 (New)	2022 (Previous)	2022 (New)	2023 (New)
Energy	**11.93**	**11.86**	**9.60**	**9.29**	**9.40**
Transportation	*4.63*	*4.48*	*3.78*	*3.66*	*3.85*
Aviation	0.33	0.33	0.23	0.23	0.16
Highway Vehicles	3.98	3.98	3.24	3.24	3.52
Non-Road Sources	0.33	0.17	0.32	0.19	0.18
Electricity Consumption	*2.82*	*2.90*	*1.92*	*2.01*	*2.01*
Residential Buildings	*2.38*	*2.38*	*2.12*	*2.09*	*2.04*
Commercial Buildings	*1.13*	*1.11*	*0.93*	*0.85*	*0.80*
Industrial Buildings	*0.65*	*0.63*	*0.59*	*0.53*	*0.55*
Natural Gas Systems	*0.33*	*0.37*	*0.25*	*0.14*	*0.15*
Industrial Processes and Product Use	**0.10**	**0.11**	**0.62**	**0.47**	**0.49**
Chemical Industry	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Mineral Industry	*0.01*	*0.02*	*0.00*	*0.03*	*0.02*
Metal Industry	*0.01*	*0.01*	-	-	-
Electronics Industry	*0.01*	*0.01*	-	-	-
Product Use	*0.06*	*0.06*	*0.60*	*0.42*	*0.45*
Agriculture	**0.06**	**0.07**	**0.02**	**0.03**	**0.03**
Livestock	*0.02*	*0.03*	*0.01*	*0.01*	*0.01*
Soil Management	*0.04*	*0.05*	*0.01*	*0.02*	*0.01*
Waste	**0.28**	**0.45**	**0.11**	**0.42**	**0.42**
Solid Waste Disposal	*0.18*	*0.38*	*0.00*	*0.35*	*0.34*
Wastewater Treatment and Discharge	*0.10*	*0.07*	*0.11*	*0.08*	*0.08*
TOTAL GROSS EMISSIONS	**12.37**	**12.55**	**10.35**	**10.27**	**10.40**
Natural and Working Lands	*-0.61*	*-0.68*	*-0.75*	*-0.84*	*-0.82*
TOTAL NET EMISSIONS	**11.76**	**11.81**	**9.60**	**9.38**	**9.52**

** Emissions converted to $MMTCO_2e$ with the metric GWP_{100} from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), also available at ipcc.ch/report/ar5/syr/. "Previous" denotes values from the 2022 Rhode Island Greenhouse Gas Inventory. For the complete 1990-2023 dataset, visit dem.ri.gov/ghg-inventory.*

Energy Sector Improvements

TRANSPORTATION:
CORRECTION OF NON-ROAD SOURCE EMISSIONS ESTIMATES

Transportation emissions from non-road sources have historically been estimated with default data and emissions factors from the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT). In February 2025, DEM discovered prior iterations of the GHGI may have double-counted emissions between the transportation, commercial buildings, and industrial buildings categories. This was confirmed by EPA and ICF International, Inc., the creator of SIT. All fuel consumption data used to calculate emissions in SIT's Carbon Dioxide from Fossil Fuel Combustion (CO_2FFC) module and Stationary module originate from the U.S. Energy Information Administration's (EIA) State Energy Data System (SEDS). Fuel consumption data in the Mobile Combustion module is a combination of EIA SEDS data and U.S. Federal Highway Administration (FHWA) data. Correspondence with EPA confirmed the following data in the Mobile Combustion module is also included in the data used to calculate emissions in the CO_2FFC module and Stationary module:

1. *All off-highway uses of diesel fuel (agricultural, construction, and heavy-duty utility equipment) is included in EIA SEDS's **Industrial Distillate Fuel** data.*
2. *Off-highway uses of gasoline for agricultural and construction equipment are included in EIA SEDS's **Industrial Motor Gasoline** data.*
3. *Off-highway uses of gasoline for lawn and garden equipment are included in EIA SEDS's **Commercial Motor Gasoline** data.*

Thus, emissions from "Industrial Distillate Fuel" and "Industrial Motor Gasoline" were double counted between the industrial buildings and transportation categories and "Commercial Motor Gasoline" was double counted between the commercial buildings and transportation categories. The following solutions were implemented for the 2023 GHGI:

1. **Industrial Distillate Fuel:** the Mobile Combustion module was adjusted to exclude all off-highway uses of diesel fuel (agricultural, construction, and heavy-duty utility equipment) from the emissions calculation. It is not possible to separate these uses of diesel fuel from EIA's "Industrial Distillate Fuel" data since EIA derives it from their extinct ***Fuel Oil and Kerosene Survey***.
2. **Industrial Motor Gasoline:** the Mobile Combustion module was adjusted to exclude agricultural and construction equipment off-highway uses of gasoline. Since EIA's "Industrial Motor Gasoline" consumption data already includes these end uses, emissions are now calculated in the CO_2FFC module and Stationary module.
3. **Commercial Motor Gasoline:** the Mobile Combustion module was adjusted to exclude off-highway uses of gasoline for lawn and garden equipment. Since EIA's "Commercial Motor Gasoline" consumption data already includes these end uses, emissions are now calculated in the CO_2FFC module and Stationary module.

Non-road source emissions are no longer double counted between the commercial buildings, industrial buildings, and transportation categories. All off-highway uses of motor gasoline are accurately counted in the transportation category instead of the industrial and commercial buildings categories. This is not a perfect solution because EIA does not separate agricultural and construction equipment from their "Industrial Distillate Fuel" data because these end uses are included in their definition of the industrial sector. Henceforth, it is noted that non-road source uses of distillate fuel (agricultural, construction, and heavy-duty utility equipment) are counted in the industrial buildings category instead of the transportation category.

Kyle Apuzzo, @ri_picture_guy

Providence and Worcester Railroad

TRANSPORTATION:
REVISED EMISSIONS ESTIMATES FOR PASSENGER AND FREIGHT RAIL

Emissions from distillate fuel used by railroads have historically been estimated with data from EIA, which created distillate fuel consumption estimates for railroads with data collected from their annual ***Fuel Oil and Kerosene Survey***. On February 14, 2022, EIA permanently suspended this survey and discontinued state-level estimates of railroad distillate fuel consumption. DEM used this dataset in EPA's SIT to estimate emissions from rail. For the 2022 GHGI, DEM requested distillate fuel sales to railroads data from EIA, but they cautioned these estimates rely on nationally disaggregated data from the U.S. Surface Transportation Board and do not meet the quality standards to calculate emissions. As part of an ongoing effort to improve the GHGI, DEM obtained state specific distillate fuel consumption data from all railroads operating in Rhode Island for the first time.

The Rhode Island Department of Transportation (RIDOT) provided contact information for all railroads that currently operate in the state: (1) Amtrak, (2) Massachusetts Bay Transportation Authority (MBTA), (3) Providence and Worcester (P&W) Railroad, (4) Seaview Railroad, and (5) Newport and Narragansett Bay Railroad (NNBR) – formerly known as the "Newport Dinner Train".

Amtrak: Also known as the National Railroad Passenger Corporation, Amtrak is the largest railroad that operates in Rhode Island. On January 31, 2000, Amtrak's Northeast Corridor between New Haven, CT and Boston, MA was electrified to provide high-speed rail service. All Amtrak trains that operated between New York City and Boston used distillate fuel prior to 2000. DEM's 1990 National Emissions Inventory (NEI) submittal to EPA contained a distillate fuel consumption calculation with robust state-specific train mileage and fuel efficiency data provided by Amtrak. Unfortunately, subsequent iterations of this calculation did not occur. Amtrak indicated they do not possess distillate fuel consumption data for the Northeast Corridor prior to 2013, so the 1990 NEI estimate for Amtrak was proxied through 1999 due to lack of historical data. This is a just assumption because the original calculation used detailed information and Amtrak's Northeast Corridor route changed little between 1990 and 2000. Further data is not required from Amtrak because they only operate electric locomotives in Rhode Island today.

Massachusetts Bay Transportation Authority: Distillate fuel consumption data for MBTA was obtained from the U.S. Federal Transit Administration (FTA) for 1998-2023. Since MBTA operates in Massachusetts and Rhode Island, DEM apportioned MBTA's total distillate fuel consumption to Rhode Island based on track mileage (6.4% in 2023). The amount of MBTA's track mileage in Rhode Island has grown since 1990 with the extension of commuter rail service from Providence to Warwick in 2010 (R.I. T.F. Green Int'l Airport) and to North Kingstown (Wickford Junction) in 2012. Due to lack of historical data, MBTA's 1998 distillate fuel consumption estimate was proxied back to 1990.

Providence and Worcester Railroad: DEM contacted P&W's parent company, Genesee & Wyoming (G&W) Railroad, for the fuel consumption data embedded in their annual ***Environmental, Social, and Governance Report*** (ESG). G&W provided distillate fuel consumption data for P&W back to 2017, the year they acquired the railroad. Since P&W operates between Connecticut, Massachusetts, and Rhode Island, DEM apportioned P&W's total distillate fuel consumption to Rhode Island based on track mileage (20.1%). Fortunately, DEM's 1990 NEI contained a distillate fuel consumption estimate for P&W. Linear interpolation was used to calculate distillate fuel consumption for P&W between 1991-2016.

Seaview Railroad and Newport and Narragansett Bay Railroad: The owner of Seaview Railroad and NNBR readily responded to DEM's first information request with distillate fuel consumption data for Seaview Railroad back to 2012 and NNBR back to 2015. Prior to 2012 and 2015, these railroads were owned by different companies and the current owner did not possess the historical data. Seaview Railroad has continuously operated since 1978 and NNBR began steadily operating in 1995. Due to lack of historical data, Seaview Railroad's 2012 distillate fuel consumption estimate was proxied to 1990 and NNBR's 2015 distillate fuel consumption estimate was proxied to 1995. This is a just assumption because Seaview Railroad and NNBR are very small relative to other railroads that operate in Rhode Island.

Although rail is a small source of transportation sector emissions, accurate estimation lends more credibility to its use as an alternative transportation source for people and freight. DEM's collection of distillate fuel consumption for all railroads in Rhode Island is a significant step away from the nationally disaggregated data previously used in the GHGI.

	1990 (Gallons)	2000 (Gallons)	2010 (Gallons)	2023 (Gallons)
Amtrak	*805,568*	-	-	-
Massachusetts Bay Transportation Authority	*276,999*	*193,757*	*516,808*	*829,306*
Newport & Narragansett Bay Railroad	-	*5,297*	*5,297*	*7,774*
Providence & Worcester Railroad	*100,533*	*148,036*	*195,539*	*248,695*
Seaview Railroad	*19,928*	*19,928*	*19,928*	*21,232*
TOTAL	**1,203,028**	**367,017**	**737,572**	**1,107,007**

RESIDENTIAL AND COMMERCIAL BUILDINGS:
ACCOUNTING FOR THE BIODIESEL HEATING OIL ACT

In May 2023, DEM requested EIA develop residential and commercial sector biodiesel consumption estimates for Rhode Island. Historically, EIA only reported biodiesel consumption in the transportation sector. The Biodiesel Heating Oil Act (R.I. Gen. Laws § 23-23.7) presently requires all distillate fuel sold in Rhode Island for building heating to meet the minimum standards for B20 (a biodiesel blend in which the volume of biodiesel fuel in the blend is between 19.5% to 20.5%). This accelerates to B50 by July 1, 2030. DEM stated EIA's practice of reporting all biodiesel consumption in the transportation sector would become increasingly out of sync with actual consumption patterns in Rhode Island. EIA acknowledged this and agreed to research potential data sources. Fortunately, DEM maintains compliance data that demonstrates how much bioproduct is blended into distillate fuel sold in Rhode Island. EIA obtained this sales data from DEM to create consumption estimates for the residential and commercial sectors. In February 2025, EIA released this new data series alongside revised residential and commercial distillate fuel consumption estimates.

BIODIESEL HEATING OIL ACT REQUIREMENTS

1. ***July 1, 2021:** all distillate fuel sold in the state for heating is required to contain B5 biodiesel**
2. ***July 1, 2023:** all distillate fuel sold in the state for heating is required to contain B10 biodiesel**
3. ***July 1, 2025:** all distillate fuel sold in the state for heating is required to contain B20 biodiesel**
4. ***July 1, 2030:** all distillate fuel sold in the state for heating is required to contain B50 biodiesel**

*** See RI Gen. Laws § 23-23.7-4 for the specific requirements***

Biodiesel is a biogenic product, which means the carbon dioxide (CO_2) from combustion is treated as CO_2e-neutral for purposes of compliance with the Act on Climate. This principle assumes that all CO_2 emissions from biodiesel, which can be manufactured from vegetable oils, animal fats, or recycled greases, are equally balanced by the carbon uptake prior to harvest. The net CO_2 emission from biodiesel is simplified as zero. The 2023 GHGI excludes biodiesel from distillate fuel consumption, which results in lower residential and commercial buildings emissions than previous iterations of the GHGI. The following table demonstrates the impact of the Biodiesel Heating Oil Act in 2022, the last full calendar year when all distillate fuel sold for heating in Rhode Island was required to meet the minimum standards for B5.

	Distillate Fuel Energy Use (including Biodiesel)	Distillate Fuel Energy Use (excluding Biodiesel)	Distillate Fuel CO2 Emissions (including Biodiesel)	Distillate Fuel CO2 Emissions (excluding Biodiesel)	Percent Difference
Residential Buildings	*33,979 BBtu*	*33,497 BBtu*	*2.10 MMTCO2e*	*2.07 MMTCO2e*	*-1.43%*
Commercial Buildings	*15,873 BBtu*	*15,778 BBtu*	*0.92 MMTCO2e*	*0.91 MMTCO2e*	*-1.20%*

EIA will likely publish its 2024 data series in February 2026. At that time, DEM will have a more accurate portrayal of how distillate fuel that meets the minimum standards for B10 affects emissions. The statute's recent increase to B20 on July 1, 2025, and eventually to B50 in 2030, will have a significantly greater impact. DEM estimates B20 and B50 could reduce residential building emissions by ~5% and ~13%, respectively, below 2022 levels. The Biodiesel Heating Oil Act remains an important policy lever to decarbonize the residential and commercial building sectors. Accurate quantification of this statute's impact in the GHGI is critical to assess the progress of building decarbonization in Rhode Island.

INDUSTRIAL BUILDINGS:
CORRECTION TO NATURAL GAS EMISSIONS ESTIMATES (1990-1999)

DEM obtains fuel consumption data from EIA SEDS for each year to estimate emissions from residential, commercial, and industrial buildings. In the 1990s, industrial natural gas consumption reported by SEDS exhibited a sudden and dramatic increase, peaking at 48,714 billion British thermal units (BBtu) in 1992. Across the decade, levels far exceeded the 1960-1990 average (4,927 BBtu/year) and the 2000-2023 average (7,639 BBtu/year). Rhode Island Energy (RIE) confirmed no facility (or facilities) metered as “industrial” could have consumed the vast quantities of natural gas reported by SEDS in the 1990s. Inclusion of this discrepancy misleadingly peaked Rhode Island’s overall emissions in 1992. Realistically, the state’s emissions most likely peaked in the early 2000s alongside U.S. emissions. It was necessary to research alternative datasets for industrial natural gas consumption in the 1990s to ensure this decade of the GHGI is accurate.

DEM requested National Grid, the former owner/operator of the gas distribution system, to search their archives for wholesale data between 1990 and 1999. National Grid could not uncover any data older than 2006 due to a change in customer rate codes. However, a grant awarded to Brown University by DEM in 2000 provided more insight. Researchers from Brown University’s Center for Environmental Studies (presently the Institute for Environment and Society), led by Dr. Harold Ward, compiled the first GHGI for Rhode Island. This publication mainly leveraged EIA fossil fuel consumption data to estimate emissions. Dr. Ward and his colleagues verified the accuracy of the EIA’s consumption data for one sector:

> ***“In the one case where we were able to obtain independent reliable data against which EIA data could be cross-checked (natural gas consumption by the industrial sector), the EIA data were found to be seriously in error.”***
> ***– Brown University, September 2000.***

The following table compares EIA’s industrial natural gas consumption for Rhode Island with the data obtained by Brown University for 1990-1996. Linear interpolation was employed for 1997-1999 because Brown University did not obtain data for this period. The industrial natural gas consumption data obtained by Brown University for the state’s first GHGI is now used to estimate industrial building emissions once again. Depending on the year, statewide emissions decreased between 1.8% to 14.7% with the inclusion of this dataset compared to the 2022 GHGI. The peak of statewide emissions shifted from 1992 to 2004, which aligns the GHGI with nationally observed trends.

	1990 (BBtu)	1991 (BBtu)	1992 (BBtu)	1993 (BBtu)	1994 (BBtu)	1995 (BBtu)	1996 (BBtu)
U.S. EIA	*4,498*	*27,593*	*48,714*	*9,712*	*42,300*	*36,049*	*28,385*
Brown University	*4,376*	*6,865*	*10,703*	*9,492*	*7,033*	*8,686*	*7,973*
% Difference	**-2.7%**	**-75.1%**	**-78.0%**	**-2.3%**	**-83.4%**	**-75.9%**	**-71.9%**

NATURAL GAS SYSTEMS:
NEW FUGITIVE EMISSIONS ESTIMATES

The ***2006 IPCC Guidelines*** and its refinements identify many sources of fugitive emissions from natural gas systems, including exploration, production, processing, transmission, storage, and distribution. Past iterations of the GHGI have only included fugitive methane (CH_4) emissions from the distribution segment. Rhode Island produces emissions from other components of the natural gas industry, such as interstate transmission pipelines, compressor stations, meter and regulator stations, and customer meters. Behind-the-meter consumer appliances, combined heat and power generators, and electric power plants also produce fugitive emissions. In May 2025, DEM published a white paper, ***Fugitive Greenhouse Gas Emissions from Natural Gas Systems***, that detailed new data sources and methodologies used to estimate emissions from all segments of this sector that occur in Rhode Island.

Fugitive emissions result from the direct release of a gas to the atmosphere** (i.e., not through **combustion). The Industrial Processes and Product Use, Agriculture, Waste, and Natural and Working Lands sectors also produce fugitive emissions.

KEY TAKEAWAYS

- Natural gas systems produced 0.15 MMTCO2e in 2023, 59.5% lower than 1990 levels.
- Emissions are now estimated from all segments of natural gas systems for the first time.
- The estimates for 2022 in the 2023 GHGI are 44% lower than the 2022 GHGI (published Dec. 2024):
  - DEM no longer corrects for soil oxidation when estimating cast iron pipeline emissions.
  - Plastic pipelines were found to leak 85% less than the last comprehensive study (1996).
- A high degree of uncertainty remains when correlating atmospheric-based studies with the activity-based GHGI.

DEM leveraged the emissions factors from EPA's ***Inventory of U.S. Greenhouse Gas Emissions and Sinks*** (U.S. GHGI) to estimate fugitive CO_2 and CH_4 emissions.[15] These emission factors were developed with significantly newer methods to quantify emissions than those used in previous iterations of the GHGI. Specifically, these emissions factors reconcile differences in studies undertaken during the 1990s and 2010s to measure gas leaks. Robust information about the physical characteristics of Rhode Island's natural gas industry was collected data back to 1990 to estimate the entire timeseries. Infrastructure data was obtained from publicly accessible federal databases, primarily from the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA), and from DEM-regulated facilities under 250-RICR-120-05-14 (Part 14: Record Keeping and Reporting).

The new fugitive emissions estimates are believed to be more representative of Rhode Island's natural gas systems than those in the 2022 GHGI. Other literature presents different results. Several studies around Boston, MA suggest much higher rates of fugitive CH_4 from natural gas infrastructure in urban environments. The similarities between the Boston and Providence gas distribution systems (i.e., age, composition, and climate) raise the question of whether the proposed emissions estimates are under-counted. Reconciling atmospheric based studies with activity-based inventories are not well understood, especially for small geographic regions such as Rhode Island. DEM cautions comparisons between atmospheric-based studies and the GHGI until street-level CH_4 emissions are thoroughly studied in the Providence area. Those that rely on the GHGI to inform policy decisions should be aware of the uncertainty associated with the data and methodologies used to estimate emissions; more details about this improvement can be found at dem.ri.gov/ghg-inventory.

***Atmospheric-based studies** measure emissions on a regional scale, such as recording emissions concentrations with air monitoring equipment.*

***Activity-based inventories** measure emissions on a device scale from a representative sample of equipment.*

Source: nrel.gov

Waste Sector Improvements

SOLID WASTE DISPOSAL:
INCLUSION OF EMISSIONS FROM CLOSED MUNICIPAL LANDFILLS

In previous iterations of the GHGI, CH_4 emissions from solid waste disposal were estimated with a default run of EPA's SIT for 1990-2009 and data reported to EPA's Greenhouse Gas Reporting Program (GHGRP) for the Rhode Island Resource Recovery Corporation's (RIRRC) Central Landfill for 2010-2022. On September 12, 2025, EPA proposed to effectively end the GHGRP, which including Subpart HH (Municipal Solid Waste Landfills). DEM will no longer have access to GHGRP data for the GHGI. However, this presented an opportunity to ensure new iterations of the GHGI are comparable to 1990, as SIT and the GHGRP calculate emissions differently.

SIT METHODOLOGY,
FORMERLY USED FOR 1990-2009

SIT employs a first order decay (FOD) model that calculates emissions based on the quantity of waste deposited in landfills over the previous 30 years. The FOD model in SIT considers a state-specific CH_4 generation rate based on local climate, as arid and temperate regions produce CH_4 differently. The output of the FOD model is adjusted for flaring and landfill gas-to-energy (LFGTE) collection. SIT's default disposal data is proxied based on state population and national landfilling rates. Flaring and LFGTE data are provided by EPA's Landfill Methane Outreach Program (LMOP).

GHGRP METHODOLOGY,
FORMERLY USED FOR 2010-2022

RIRRC calculated emissions with two different methodologies for EPA's GHGRP. Between 2010 and 2019, RIRRC used a "bottom-up" approach to estimate emissions based on methane recovery and destruction. In 2020, RIRRC switched to a "top-down approach" that estimated emissions based on modeled methane generation. The methodology switch caused solid waste disposal emissions to drop 84.6% in 2020 since RIRRC did not back-calculate historical emissions with the same methodology.

To backstop the loss of the GHGRP and ensure new iterations of the GHGI are comparable to 1990, DEM chose to calculate all solid waste disposal emissions (1990-2023) with SIT for new iterations of the GHGI. SIT is best suited to estimate this sector's emissions because it can be customized with state-specific data. Conversely, using EPA's GHGRP for the entire solid waste disposal sector only considers emissions from RIRRC's Central Landfill for 2010-2022. Dozens of closed municipal landfills and dumps across Rhode Island continue to emit CH_4 and should also be counted in the GHGI. To ensure SIT's FOD model captures the entire state, the quantity of municipal solid waste (MSW) disposed of annually, 1960-present, was aggregated for the first time.

DEM's Office of Land Revitalization and Sustainable Materials Management provided a complete list of all known solid waste disposal sites in Rhode Island. 53 sites were identified as primarily accepting MSW after 1960. To obtain the quantity of MSW disposed of annually, the total amount of waste-in-place was evenly divided amongst all years the landfill or dump operated. Site investigation reports that cited one disposal figure (e.g., 50 tons/day) were extrapolated for all years the landfill or dump operated. If two figures were provided (e.g. 4,875 tons/year in 1968 and 10,500 tons/year in 1996), linear interpolation was used to estimate the interim years.

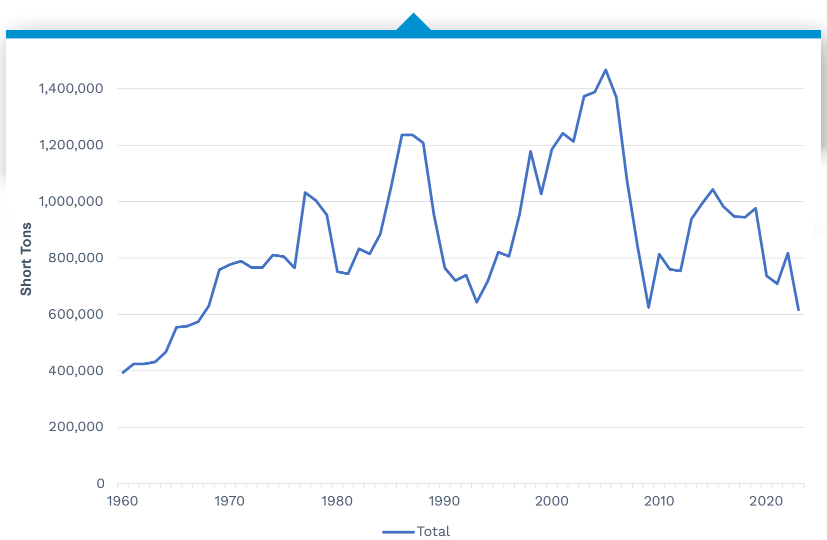
Rhode Island DEM photo

Closed landfill on Block Island

It was assumed all disposal data was recorded in U.S. tons. Of the 53 identified MSW sites, disposal data was not found for seven: Cumberland Municipal Landfill, East Greenwich Landfill, Field's Point City Dump, Foster Town Landfill, Jamestown Landfill, Manton Avenue Landfill, and Newport City Dump. These sites either never recorded disposal data, or it was simply lost to time. After the MSW disposal data was aggregated for 1960-2023, it was placed into SIT to run the FOD model. The CH_4 emissions curve from the FOD model was adjusted with SIT default data for CH_4 avoided through LFGTE projects and flaring.

In the 2022 iteration of the GHGI, solid waste disposal emissions for 2022 were 0.005 $MMTCO_2e$ as reported by RIRRC for EPA's GHGRP.[20] Emissions calculated with SIT's FOD model were 0.34 $MMTCO_2e$ for 2023. This is a significantly higher estimate because 45 additional closed municipal dumps and landfills across are included. **DEM plans to improve the calculation for CH_4 avoided through flaring and LFGTE projects by obtaining landfill gas collection data directly from RIRRC.** Policymakers should note this future improvement will likely (1) improve the accuracy of the waste sector and (2) significantly alter the magnitude of the solid waste disposal emissions estimate.

RHODE ISLAND MUNICPAL SOLID WASTE DISPOSAL



Natural and Working Lands Sector Improvements

INCLUSION OF HARVESTED WOOD PRODUCTS

Previous iterations of the GHGI excluded carbon stocks in harvested wood products (HWPs), which are products and materials that are made from wood that have been cut from a forest. When considering the carbon flux of HWPs, two pools are identified: (1) HWPs in use and (2) HWPs in solid waste disposal sites. In 2019, the IPCC released updated guidance for estimating emissions and removals from HWPs. Three primary accounting approaches were detailed: (1) the stock-change approach, (2) the production approach, and (3) the atmospheric-flow approach. Climate scientists have strived to adapt these approaches for sub-national use. Accurate estimation of HWP carbon stocks is difficult and depends on several factors, such as end-product types, lifespans, disposal methods, and supply chains. Despite this complexity, it is useful to include HWPs in the GHGI because it represents a definitive component of carbon sequestration not currently captured.

The Woodwell Climate Research Center – formerly known as the Woods Hole Research Center – provides an open-access Microsoft Excel-based calculator that estimates the average quantity of carbon for the current year's harvest that remains stored in products and landfills ("HWP calculator"). Users enter annual harvest data for a specified area and period to which regional coefficients are applied to generate the amount of carbon stored in HWPs. The HWP calculator adapts the IPCC's production approach; its methodology is detailed in the USFS's *Quantifying greenhouse gas fluxes in agriculture and forestry: Methods for entity-scale inventory*.[35] Rhode Island-specific timber harvest data from USFS's Forest Inventory and Analysis (FIA) program – which continuously collects, analyzes, and reports data on the health, extent, and status of U.S. forests – was used in the HWP calculator. Specifically, data for "Annual removals (thousand cubic feet) of growing stock on timberland in the United States" from the USFS Forest Resource reports from 1991, 1996, 2002, 2006, 2011 and 2016 were used as annual harvest estimates. The HWP calculator was run for each individual year to obtain an estimate of HWP carbon stock. Linear interpolation was implemented to "fill in the gaps" for missing years. Beginning in 2008, USFS provided more detailed state-level timber harvest data, accessible through the online tool *EVALIDator*. This dataset contains the "Average annual harvest removals of merchantable bole wood volume of growing stock trees (at least 5 inches d.b.h. [diameter at breast height]), in cubic feet, on timberland", which is comparable to the table used from the USFS Forest Resource reports.

Though *EVALIDator* data was first available in 2008, consultation with USFS revealed that changes were applied to FIA's data collection methods and definitions between 2008 and 2016. This resulted in high fluctuations between estimates. Therefore, harvest data from USFS Forest Resource reports were used through 2016 for consistency. Since FIA collects data on plots throughout the state (and all plots are sampled over a period of several years), each consecutive year's data only varies because the latest year's data is dropped when a new year's data is added. Rhode Island has a relatively small number of plots, which can result in high variation and uncertainty between consecutive years. USFS advised DEM to compare data from several years apart to avoid skewed results. Data from ***EVALIDator*** was pulled for every four years and linear interpolation was used for the interim years.

The HWP calculator allocated timber harvest into different wood types and product types based on a regional average for the Northeast U.S. The HWP calculator required DEM to choose a representative forest type of hardwood and softwood to implement the calculations: "maple-beech-birch" was used hardwood, and "spruce-fir" was used for softwood. The average amount of carbon from the timber harvest that remained in products or landfills was calculated with regional estimates for the Northeast U.S. Once the final HWP carbon stock estimates were estimated, linear interpolation was used for the interim years. HWPs were estimated to store 0.02 $MMTCO_2e$ in 1990 and 0.03 $MMTCO_2e$ in 2023. Though small, the inclusion of HWPs in the GHGI provides a more holistic view of the carbon sequestration of forest land in Rhode Island.

Biogenic Emissions Supplement

As required by the *Rhode Island 2022 Climate Update*, and in alignment with federal greenhouse gas reporting conventions, CO_2 from the combustion or decay of biogenic material is treated as CO_2e-neutral for purposes of compliance with the Act on Climate. This is in accordance with the United Nations Framework Convention on Climate Change (UNFCCC) approach to separate biogenic emissions sources from anthropogenic emissions sources and is based on the following assumptions:

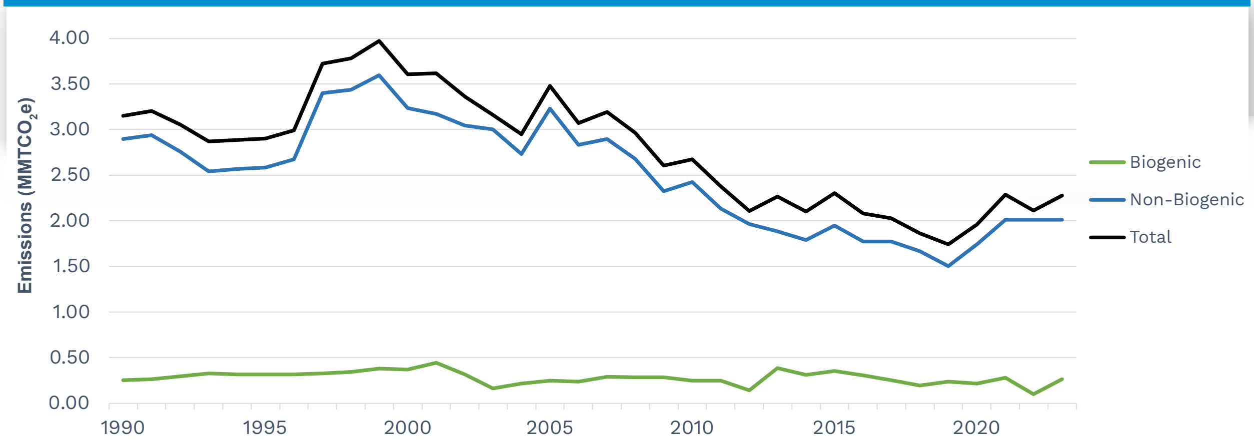
1. For short-lived biogenic material (e.g., corn ethanol, soy oil) harvested in-state or out-of-state, CO_2 emissions are balanced by the carbon uptake prior to harvest, within the uncertainties of the estimates, so the net CO_2 emission is zero.
2. For long-lived biogenic material (e.g., wood) harvested in-state, CO_2 emissions from combustion are not included in the energy or waste sectors and are quantified as harvested wood products in the natural and working lands sector.
3. For long-lived biogenic material harvested out-of-state, CO_2 emissions from combustion are not included in the energy or waste sectors based on the principle that the jurisdiction where the material originated from quantified such material as a harvested wood product in their state's greenhouse gas inventory.

Biogenic emissions from electricity consumption are reported for informational purposes only. DEM will work to publish supplemental information on biogenic emissions from other sectors in future iterations of this report.

ELECTRICITY CONSUMPTION

Biogenic emissions from electricity consumption arise from the settlement of biogas, biomass, digester gas, and landfill gas certificates from in-and-out-of-state facilities. Additionally, a small amount of biogenically-produced electricity is included in the ISO New England residual mix. Biogenic CO_2 emissions from electricity produced 0.26 $MMTCO_2e$ in 2023.

GREENHOUSE GAS EMISSIONS FROM ELECTRICITY CONSUMPTION BY SOURCE



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11. Degree days are the difference between the daily mean temperature and 65°F. If the daily mean temperature is below 65°F, then heating degree days (HDDs) are calculated. Conversely, if the daily mean temperature is above 65°F, then cooling degree days (CDDs) are calculated. Years with greater amounts of HDDs correlate with higher residential, and to some extent commercial, building emissions.
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