CAPE COD COMMISSION

Cape Cod Greenhouse Gas Emissions Inventory Framework

DECEMBER 2019

Prepared by the Cape Cod Commission

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This document establishes a greenhouse gas emissions inventory framework for Cape Cod. It presents an overview of select inventories from across the United States reviewed to aid Commission staff in developing this framework.

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CAPE COD COMMISSION

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Executive Summary

Greenhouse gas (GHG) emissions are widely acknowledged to contribute to climate change. The 2018 Cape Cod Regional Policy Plan includes a recommended Cape Cod Commission (Commission) planning action to encourage and engage communities to better understand regional GHG emissions, and specifically to develop an estimated baseline of GHG emissions for the region (Barnstable County, also known as Cape Cod) using available models and data. This baseline can provide communities with the information to understand the contributing factors to Cape Cod's GHG emissions.

Prior to determining the GHG accounting method that best fits the land uses and development patterns of Cape Cod, Commission staff reviewed GHG inventories from eight (8) cities and towns, seven (7) regions, two (2) states, and the United States national inventory to better understand the considerations, challenges, and accounting methods used in calculating GHG emissions. Commission staff reviewed these inventories in part to determine the accounting framework, accounting tools or resources, what data sets were used, what sectors emissions were calculated for, and what gases were evaluated related to GHG emissions.

Following review of these inventories, Commission staff recommend a framework to calculate an estimated GHG emissions inventory for Cape Cod using a production-based method, capturing emissions from activities occurring inside Barnstable County (direct emissions), and including emissions from certain consumption-based activities outside of Barnstable County (indirect emissions).

Commission staff recommend the inventory calculate emissions for: stationary energy; industrial processes and product use; transportation; agriculture; land use, land use change, and forestry; and, waste. Gases to be inventoried include: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); and fluorinated gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6).

This framework is similar in approach to the structure of inventories calculated using the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* established by the International Council for Local Environmental Initiatives (ICLEI), the World Resources Institute, and C40 Cities, and the Intergovernmental Panel on Climate Change *Guidelines for National Greenhouse Gas Inventories*.

A foundational methodology to calculate the inventory will be established which may include Barnstable County-specific data and methodology where possible and appropriate. The Commission will also calculate emissions attributable to Barnstable County government operations and will consider seasonality in emissions where appropriate and feasible.

Introduction

The 2018 Cape Cod Regional Policy Plan identified key regional challenges facing the natural, built, and community systems of Cape Cod. Among them, climate change was recognized to pose many threats to the region.

Sea level rise poses a major and particular threat to Cape Cod, which has 586 miles of vulnerable, tidal shoreline. Projected sea level rise will increase flooding, elevating the height of storm and non-storm surges and flood levels, and exacerbate inundation and storm surge by sending floodwaters further inland, resulting in potential inoperable first response facilities and substantial loss to property, economic prosperity, and habitat. In addition to structural and economic losses, sea level rise also threatens Cape Cod's groundwater with potential higher groundwater levels and, to a lesser effect, saltwater intrusion.

Flooding and erosion will be exacerbated by sea level rise and changing storm frequency and intensity. Scientists anticipate that climate change will bring stronger storms with more precipitation and the threat of more frequent and extensive flooding to the region. Storms have resulted in power outages, which limits access to necessary services, and increased storm activity is likely to further impact the region's power resources. In addition, temperatures are anticipated to rise, with related degradation of air quality, strain on local indigenous flora and fauna, increases in foreign pest migration, and more health-related problems, and significantly for Cape Cod, changes in sea surface temperature and the viability of the coastal environments for the region's native wildlife.

It is likely that the region's vulnerability will increase in the future as sea levels continue to rise, climate change intensifies, and the region experiences an increase in storm activity and severity, all of which can cause loss of life, damage buildings and infrastructure, impair coastal environments, and otherwise impact a community's economic, social, and environmental well-being.

To prevent climate change from worsening, it is critical for cities, states and regions to understand their impacts on this challenge. One way to do so is by creating an inventory of the greenhouse gas (GHG) emissions within a particular boundary to identify how to reduce future emissions. A 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report projects continued sea level rise into the next century, with the rate of rise depending on how future GHG emissions are managed.

Overview of Inventories Review

The following represents the review of a variety of GHG inventories from across the United States which will aid the Cape Cod Commission (Commission) in determining a framework and methodology for creating a GHG emissions inventory for Cape Cod. The inventories included in this document represent eight (8) cities and towns, seven (7) regions, two (2) states, and the United States national inventory. These inventories were selected to provide a variety of perspectives, methodologies, framework considerations, and data presentation styles, and to represent development densities and land use patterns similar to and different from Cape Cod. Overall, this document provides high-level information on how other locations determine their GHG emissions and will assist the Commission in creating a comprehensive GHG emissions inventory. This document provides an overview of inventories reviewed by the Commission. See the Appendix for additional information provided in these inventories. Individual inventories should be reviewed for complete information.

CITY AND TOWN INVENTORIES

The following inventories represent cities and towns of varying size and development patterns in Massachusetts, New England, and other geographies.

Falmouth, Massachusetts

2002 Cities for Climate Protection Campaign for the Town of Falmouth

As a member of the International Council for Local Environmental Initiatives (ICLEI) Cities for Climate Protection (CCP) campaign, Falmouth wanted to understand the sources of GHG emissions being produced within the town of Falmouth to reduce GHG emissions in the future. Emissions from municipal operations were calculated separately from the residential and commercial community. Falmouth created their own accounting method in order to best suit their needs while using software from the CCP.

Amherst, Massachusetts

2017 Town of Amherst

Amherst joined the ICLEI CCP campaign to aid the town's goals for climate action. This campaign is a five-milestone process where the first step is to complete a greenhouse gas inventory. The guidance of the CPP campaign directed how the data was collected. This method allowed Amherst to create an inventory and forecast emissions of greenhouse gases, evaluate policies to reduce emissions, and prepare a GHG emission reduction action plan.

This inventory focused on five sectors: residential; commercial; industrial; transportation; and waste. The method calculated community-based emissions and commercial/government-based emissions separately.

Boston, Massachusetts

2018 City of Boston

The City of Boston calculates their GHG emissions to track progress toward their goal of being carbon neutral by 2050. In 2015, the Mayor of Boston signed on to the Global Covenant of Mayors, which uses of *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) developed by ICLEI, the World Resources Institute, and C40 Cities. Emissions are calculated for the following sectors: stationary energy use from residents, businesses, and other activities, including municipal buildings; on-road and off-road transportation, including the municipal vehicle fleet; and solid waste and wastewater disposal and treatment. Emissions were calculated from sources within the city boundary and from energy produced outside of the city but used within the city boundary (Scopes 1 and 2).

Burlington, Vermont

2010 City of Burlington

Burlington calculated their inventory using the ICLEI Greenhouse Gas (GHG) Emissions Analysis Protocol (since replaced by the GPC). Vermont is a state which is deeply connected to nature with many of its tourist appeals being natural resource based. This means that with climate change, many of the state's main income areas, such as winter recreation will be jeopardized. In order to help prevent this, it was critical for Burlington to develop a GHG inventory to determine how best to reduce their emissions to protect their state's natural resources.

Burlington collected emissions data from the following sectors: government operations, airports, and the community. For community emissions, data was collected on solid waste, transportation, natural gas and electricity usage.

Portland, Maine

2001 City of Portland

The Commission reviewed both Portland's baseline inventory of 2001 and an updated inventory for 2010 to understand considerations over time.

Portland will be greatly affected by climate change in the future given the current course of events as it is a city which relies on tourism and fishing. As a member of ICLEI, Portland chose to conduct both community and corporate (municipal) inventories for the year 2001 in order to create a comprehensive baseline understanding of their emissions.

Portland used the GPC method to calculate their inventory. For the community inventory, Portland calculated emissions from the following sectors: community heating oil, community propane, community transportation, community residential, community waste and recycling, community commercial and industrial. For the corporate (municipal) inventory, emissions from the following sectors were measured: energy consumption, heating oil, water and wastewater, solid waste management and the municipal fleet.

Portland, Maine

2010 City of Portland

For this updated version of their inventory, Portland chose to use The Climate Registry General Reporting Protocol (GRP). Portland chose to use "The Operational Control Approach" due to the vast size of the Portland community. Emissions were calculated for the following sectors: solid waste, residential, commercial and industrial. The inventory was divided into Scope I and Scope II.

South Portland, Maine

2016 Greater Portland Council of Governments for the City of South Portland

South Portland is a member of ICLEI and in 2007, signed the U.S. Mayors Climate Protection Agreement. As such, South Portland must monitor and update their GHG emissions inventories in order to continue to make progress towards having a greener city. South Portland chose to use the ICLEI Local Government Operations Protocol (LGOP) in order to develop their inventory.

For this inventory, South Portland chose to exclusively study emissions from their municipal operations focusing on the following sectors: stationary combustion, mobile combustion, fugitive emissions and indirect emissions both from electricity and from other sources.

Alexandria, Virginia

2018 Metropolitan Washington Council of Governments for the City of Alexandria

The city of Alexandria developed their inventory in accordance with the Washington Regional GHG Inventory methodology. Both the regional and local inventories follow ICLEI U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Alexandria has committed to continuing to reduce their GHG emissions before 2050 and as such wanted to have a base understanding of their GHG emissions. Additionally, the city wanted to exemplify that even as populations continue to grow, reductions in emissions can still be made.

Alexandria calculated emissions for seven (7) sectors: process and fugitive emissions; residential energy; commercial energy; agriculture; water and wastewater; solid waste; and transportation and mobile sources.

San Antonio, Texas

2019 City of San Antonio

San Antonio supports the Mayor's National Climate Action Agenda to uphold the Paris Climate Agreement goals. A GHG emissions inventory was included in their Climate Action & Adaption Plan to track progress to reducing emissions in the city.

REGIONAL INVENTORIES

The following inventories represent regions of varying size and development density in New England, the Mid-Atlantic, and other coastal regions.

Pioneer Valley, Massachusetts

» Hampden and Hampshire Counties

2014 Pioneer Valley Planning Commission

The Pioneer Valley Planning Commission researched local, regional, and private corporation GHG accounting methods prior to calculating baseline emissions for their Pioneer Valley planning area. This inventory focused on six emissions sectors: transportation, heat for buildings, electricity consumption, industry, waste, and agriculture. This work included calculating carbon dioxide absorption by trees and plants (carbon sequestration), recognizing the amount of forests and green spaces in this planning area. Also, emissions from Hampshire and Hampden counties were separated to better understand regional emissions.

Mid-Hudson Region, New York

» Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, and Westchester Counties

2012 ICF International for the New York State Energy Research and Development Authority

This inventory used the New York GHG Protocol, developed to ensure that all regions of New York are collecting the same types of data in the same way to allow for them to be easily compared and their results compiled as the state continues work to reduce GHG emissions. Emissions were calculated for the following sectors: energy; transportation; industrial processes; agriculture; waste; and land use, land use change and forestry.

Western Region, New York

» Allegany, Cattaraugus, Chautauqua, Erie, and Niagara Counties

2012 Ecology and Environment, Inc. for the New York State Energy Research and Development Authority

This GHG inventory used the standard New York Greenhouse Gas Protocol. The Western New York region's inventory calculates emissions from the following sectors: energy; transportation; industrial processes; waste; agriculture; and forestry. This inventory includes an analysis of carbon sequestration potential for the region.

Northern New Jersey

» Bergen, Essex, Hudson, Hunterdon, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union, and Warren Counties

2011 E.H. Pechan and Associates Inc. for the North Jersey Transportation Planning Authority

Northern New Jersey has committed to reducing their emissions to 1990 levels by 2020. An inventory method unique to the region was developed to track progress to their goals while still including many of the same sectors as other regional or large city inventories. This allowed for an inventory tailored to the specific needs and emissions sources of the region. This inventory calculates emissions for the following sectors: electric power production and use; stationary fuel use; transportation; industrial processes; fossil fuel industry; agriculture; land use, land use change, and forestry; and solid waste management. The inventory includes emissions calculated for the following greenhouse gases: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Direct emissions were calculated along with consumption-based emissions for electricity generation, transportation, and solid waste.

Delaware Valley, Pennsylvania and New Jersey

» **Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania, and, Burlington, Camden, Gloucester, and Mercer Counties in New Jersey**

2018 Delaware Valley Regional Planning Commission

The Delaware Valley Regional Planning Commission (DVRPC) wanted a method that was easily replicable for updating the inventory, and to track regional energy use, energy expenditures, and GHG emissions for developing future regional policies. DVRPC divided their inventory into three main sectors: stationary energy use, mobile energy use, and other emissions and sequestration sources.

Northern Illinois

» **Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will Counties**

2018 ICF for the Chicago Metropolitan Agency for Planning

In planning for climate change and trying to increase resiliency, the Chicago Region calculated an inventory to understand regional GHG emissions which will be used to track progress towards reducing emissions over time. This inventory includes emissions from: stationary energy; transportation; and, waste.

Southern California

» **Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties**

2012 The Center for Climate Strategies for the Southern California Association of Governments

Southern California estimated a past greenhouse gas inventory, a present/reference inventory, and a "business as usual" forecast inventory, for use in regional planning. This inventory includes emissions calculated for eight (8) sectors: electricity supply and use; residential, commercial and industrial fuel combustion; transportation energy use; industrial processes; fossil fuel industries; agriculture; waste management; forestry and land use.

STATE INVENTORIES

The following inventories were reviewed to understand state considerations in determining GHG emissions.

Massachusetts

2016 Massachusetts Department of Environmental Protection

The Massachusetts greenhouse gas inventory is used to track progress towards the state's obligations under the Massachusetts Global Warming Solutions Act. The inventory includes emissions for: fossil fuel combustion from residential, commercial, industrial, transportation, and electric generation sectors; industrial processes; transmission and distribution of natural gas; waste management; and agriculture and land use.

Rhode Island

2012 Northeast States for Coordinated Air Use Management for the Rhode Island Department of Environmental Management

To compare their data with other states in the region, Rhode Island chose to develop a GHG emissions baseline and current GHG inventory using the EPA SIT tool to identify the major sources of emissions in the state. Rhode Island collected data from six main sectors: electricity; transportation; industrial; residential and commercial; land use, land change, and forestry; municipal solid waste.

U.S. INVENTORY

United States Inventory

2019 United States Environmental Protection Agency

The U.S. EPA prepares the official U.S. Inventory of Greenhouse Gas Emissions and Sinks to comply with existing commitments under the United Nations Framework Convention on Climate Change (UNFCCC), which the United States signed and ratified in 1992. This inventory follows the methods outlined in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)*.

Summary of Findings

In total, this review comprises inventories that include 68 counties and over 1,900 communities across the United States (excluding the U.S. inventory). Overall, information was collected on valuable considerations, frameworks, and methods used within these inventories.

Most of the Cities and Towns reviewed are members of ICLEI, estimating separate inventories for municipal operations and community emissions, using the ICLEI Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories. At a minimum, these inventories accounted for the energy, transportation, and waste sectors. Some locations included accounting for industrial processes and/or agriculture, as appropriate to the land uses and development patterns of the individual city/town. Approximately half of the cities and towns focused on emissions from within the municipality's boundary, while the other half included out of boundary emissions associated with electric generation. Two inventories included out of boundary emissions for waste disposal and one included out of boundary emissions for transportation. Most of the inventories accounted for CO_2, CH_4, and N_2O, while a third of the inventories only reported the CO_2 equivalent (CO_{2e}) emissions for each sector.

The methods used to calculate regional inventories varied broadly, as some states have guidelines for how regional inventories should be calculated to better align them with state inventories. Largely, all the regional inventories reviewed were similar to the IPCC framework and sectors. Several different accounting tools were used, incorporating data from the national, state, and facility level. Each inventory included the energy, transportation, and waste sectors. Often, rail, waterborne, and aviation emissions were included in transportation emissions. Most inventories included industrial processes, agriculture, and land use emissions. Carbon sequestration potential of the region was also included in most inventories. Most regions calculated emissions in boundary and out of boundary for electric generation. Some included out of boundary waste disposal. Most regions calculated emissions of the gases CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.

The state and national inventories are largely similar to the regional inventories' framework, sectors incorporated, and gases calculated. All three included in boundary emissions and out of boundary emissions for electric generation and a carbon sequestration analysis.

Several software tools, databases, and data sources were identified which can be supplemented by Cape Cod-specific data where available and appropriate.

Recommendations

To understand our regional GHG emissions sectors and contribution to global climate change, the Commission proposes the following framework to guide how a comprehensive greenhouse gas inventory of the region is established.

The inventory will incorporate the five (5) accounting principles from the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)* developed by the World Resources Institute, C40 Cities, and the International Council for Local Environmental Initiatives (ICLEI) of:

1. **Relevance:** The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption patterns of the city. The inventory will also serve the decision-making needs of the city, taking into consideration relevant local, subnational, and national regulations. The principle of relevance applies when selecting data sources, and determining and prioritizing data collection improvements.

2. **Completeness:** Cities shall account for all required emissions sources within the inventory boundary. Any exclusion of emission sources shall be justified and clearly explained. Notation keys shall be used when an emission source is excluded and/or not occurring.

3. **Consistency:** Emissions calculations shall be consistent in approach, boundary, and methodology. Using consistent methodologies for calculating GHG emissions enables meaningful documentation of emission changes over time, trend analysis, and comparisons between cities. Calculating emissions should follow the methodological approaches provided by the GPC. Any deviation from the preferred methodologies shall be disclosed and justified.

4. **Transparency:** Activity data, emission sources, emission factors, and accounting methodologies require adequate documentation and disclosure to enable verification. The information should be sufficient to allow individuals outside of the inventory process to use the same source data and derive the same results. All exclusions shall be clearly identified, disclosed and justified.

5. **Accuracy:** The calculation of GHG emissions shall not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process shall be reduced to the extent that it is possible and practical.

These accounting principles are largely similar to the five (5) guidelines for inventory quality used by the United Nations Intergovernmental Panel on Climate Change (IPCC) of Transparency, Completeness, Consistency, Comparability, and Accuracy.

The inventory will calculate emissions from the following sectors:

- Stationary Energy
- Transportation
- Industrial Processes and Product Use
- Agriculture
- Land Use, Land Use Change, and Forestry
- Waste

The inventory will use a production-based method, capturing emissions from activities occurring inside Barnstable County (direct emissions), and including consumption-based emissions from certain activities outside of Barnstable County (indirect emissions), namely energy generation, waste, and transportation.

The inventory will calculate emissions of the following greenhouse gases, which are included in the Massachusetts 2016 state inventory:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

Greenhouse gas emissions will be reported in metric tons and expressed by CO_2 equivalent (CO_2e) of activity emissions, using the most recent Global Warming Potential (GWP) of the gas published by the IPCC or the same GWPs used in the most recent state inventory.

Lastly, the Commission will consider the seasonality of data or emissions where feasible and appropriate (e.g., transportation, energy, waste).

Appendix

ABBREVIATIONS

AFV	Alternative fuel vehicle
ARB	Air Resources Board (California)
CAMD	Clean Air Markets Database
CCP	Cities for Climate Protection
CH_4	Methane
CIRIS	City Inventory Reporting and Information System
CNG	Compressed natural gas
CO_2	Carbon dioxide
CO_{2e}	Carbon dioxide equivalent
COLE	Carbon OnLine Estimator
Commission	Cape Cod Commission
DOE	Department of Energy
DOT	Department of Transportation
DPW	Department of Public Works
DVRPC	Delaware Valley Regional Planning Commission
EDMS	Emission and Dispersion Modeling System
eGRID	Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FIDO	Forest Inventory Data Online
FLIGHT	Facility Level Information on Greenhouse Gases Tool
FTA	Federal Transit Administration
GHG	Greenhouse gas
GHGRP	Greenhouse Gas Reporting Program (EPA)
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
GRP	General Reporting Protocol (The Climate Registry)
GWP	Global Warming Potential
HDD	Heating degree days
HFCs	Hydrofluorocarbons
HPMS	Highway Performance Monitoring System
ICLEI	International Council for Local Environmental Initiatives (aka ICLEI-Local Governments for Sustainability)
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt hour
LGOP	Local Government Operations Protocol
LPG	Liquified petroleum gas
LULUCF	Land Use, Land Use Change, and Forestry
MA	Massachusetts
MOVES	Motor Vehicle Emissions Simulator
MT	Metric ton
MTCE	Metric ton carbon equivalent
N_2O	Nitrous oxide
NASS	National Agricultural Statistics Service
NEI	National Emissions Inventory
NTD	National Transit Database
PFCs	Perfluorocarbons
SF_6	Sulfur hexafluoride
SIT	State Inventory Tool
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
USDA	United States Department of Agriculture
VMT	Vehicle miles traveled

CITY AND TOWN INVENTORIES

The following inventories represent cities and towns of varying size and development patterns in Massachusetts, New England, and other geographies.

Falmouth, Massachusetts

2002 Cities for Climate Protection Campaign for the Town of Falmouth

BACKGROUND

As a member of the International Council for Local Environmental Initiatives (ICLEI) Cities for Climate Protection (CCP) campaign, Falmouth wanted to understand the sources of GHG emissions being produced within the town of Falmouth to reduce GHG emissions in the future. Emissions from municipal operations were calculated separately from the residential and commercial community. Falmouth created their own accounting method in order to best suit their needs while using software from the CCP.

SOFTWARE USED

ICLEI CCP software; ICLEI Vehicle Miles Traveled (VMT) Calculator

ACCOUNTING METHODS FOR RESIDENTIAL AND COMMERCIAL COMMUNITY EMISSIONS

Emissions associated with energy use at residential homes and commercial/industrial operations were calculated using the average consumption of fuels such as natural gas, light oil, propane, and wood and were multiplied by the number of customers using those fuels.

The ICLEI VMT Calculator was used to calculate the estimated carbon dioxide (CO_2) emissions from residential and commercial transportation. This Calculator uses inputs from three different types of roads: collectors and local roads; limited access highway; and major arterial roads. The data includes the length of the road (from the Road Directory of Falmouth) as well as the average daily traffic on the road (from the Cape Cod Commission).

For solid waste disposal, the total tonnage of solid waste provided by the Falmouth Department of Public Works (DPW) was converted into an estimated CO_2 value using a method developed by the United States (U.S.) Environmental Protection Agency (EPA) for incinerated waste, which multiples the total tonnage by 0.11 metric ton carbon equivalent (MTCE) and then multiples the product by 4.042 to convert from MTCE to estimated CO_2.

ACCOUNTING METHODS FOR MUNICIPAL RESOURCES

To estimate emissions from municipal sources, Falmouth collected data on buildings, vehicle fleet, streetlights, solid waste, water and sewer. For buildings emissions, Falmouth "[created] a list of accounts for energy sources, and [had] the local utilities send or fax the account histories for each building or facility," (Enoki 11) except for schools who collect their own data. Water and sewer data were collected in the same way as that of buildings.

For determining the vehicle fleet consumption, the DPW provided data on the emissions and usage of their fleet, not including boats/vehicles owned by the Harbormaster/Waterways Commission. The Harbormaster/Waterways Commission "fuel use was extrapolated using a month's ratio of gasoline and diesel fuel" (Enoki 11).

For determining emissions from streetlights, data was collected from NSTAR as all of the streetlights are under the same account number.

For determining solid waste data, the average amount of waste produced per municipal employee, according to a study conducted by the California Integrated Waste Management Board, was used to calculate the amount of emissions using the following method:

1. Gather total employee figures
2. Multiply an estimate 0.59 tons/employee/year for total tonnage of waste generated
3. Multiply product by diversion rate (0.6 in year 2000 obtained from the Cape Cod Commission) for waste taken to Otis
4. Multiply 0.11 MTCE/ton for amount of carbon released
5. Convert from MTCE to the CO_2 equivalent (CO_{2e}) by multiplying 4.042

DATA USED

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Community	Residential Home	Cape Light Compact (electricity usage), KEYSPAN ENERGY (natural gas usage), Nelson Oil Co./Hall Oil Co./Self-Reliance (oil usage), Silva Firewood (wood usage), AmeriGas (fuel)
Community	Commercial and Industrial Operations	Same as residential home
Community	Transportation Methods	VMT Calculator software (emissions estimate), Road Directory of Falmouth 2001 (road type data), Cape Cod Commission (average daily traffic)
Community	Solid Waste Disposal	DPW (total tonnage of waste)
Municipal	Buildings	NSTAR (electricity), Falmouth Public Schools (energy consumption), all other town buildings

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Municipal	Vehicle Fleet	DPW (consumption and cost), Harbormaster/Waterways Commission
Municipal	Streetlights	NSTAR (electricity)
Municipal	Solid Waste	California Integrated Waste Management Board (waste per employee), Cape Cod Commission (diversion rate)
Municipal	Water and Sewer	Same as buildings

REFERENCE

"Greenhouse Gas Emissions Inventory for the Town of Falmouth"
http://www.falmouthmass.us/DocumentCenter/View/1693/Greenhouse-Gas-Emissions-Inventory-PDF

Amherst, Massachusetts

2017 Town of Amherst

BACKGROUND

Amherst joined the ICLEI CCP campaign to aid the town's goals for climate action. This campaign is a five-milestone process where the first step is to complete a greenhouse gas inventory. Following the guidance of the CPP campaign directed how the data was collected. This method allowed Amherst to create an inventory and forecast emissions of greenhouse gases, evaluate policies to reduce emissions, and prepare a GHG emission reduction action plan.

SOFTWARE USED

ICLEI Clean Air and Climate Protection Software

ACCOUNTING METHODS USED

This inventory focused on five sectors: residential; commercial; industrial; transportation; and waste. The method calculated community-based emissions and commercial/government-based emissions separately but combined them to create a total amount of energy used per sector.

DATA USED

No specific data sources were identified.

REFERENCE

"Town of Amherst Greenhouse Gas Inventory Report"
https://www.amherstma.gov/DocumentCenter/View/46230/6-a-1-Amherst-GHG-report?bidId=

Boston, Massachusetts

2018 City of Boston

BACKGROUND

The City of Boston calculates their GHG emissions to track progress toward their goal of being carbon neutral by 2050.

SOFTWARE USED

ICLEI's 2009 Clean Air and Climate Protection (CACP) software

ACCOUNTING METHODS USED

In 2015, the Mayor of Boston signed on to the Global Covenant of Mayors, which uses the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) developed by ICLEI, the World Resources Institute, and C40 Cities. Emissions are calculated for the following sectors: stationary energy use from residents, businesses, and other activities, including municipal buildings; on-road and off-road transportation, including the municipal vehicle fleet; and solid waste and wastewater disposal and treatment. Emissions were calculated from sources within the city boundary and from energy produced outside of the city but used within the city boundary (Scopes 1 and 2).

DATA USED

U.S. Census; economic data on jobs and gross city product from the Boston Planning and Development Agency; National Oceanic and Atmospheric Administration climate data; Electric, natural gas, steam providers; Mass Energy Consumers Alliance; U.S. Energy Information Administration (EIA); Boston Metropolitan Planning Organization; U.S. Federal Highway Administration (FHWA) Highway Statistics Series; Massachusetts (MA) Bay Transportation Authority; MA Water Resources Authority; Massport; Boston Water and Sewer Commission; Boston Public Schools

REFERENCE

"City of Boston Greenhouse Gas Emissions Inventory 2005-2017"
"Boston Greenhouse Gas Inventory Methodology 2018 Edition"
https://www.boston.gov/departments/environment/bostons-carbon-emissions#methodology

Burlington, Vermont

2010 City of Burlington

BACKGROUND

Burlington calculated their inventory using the ICLEI Greenhouse Gas (GHG) Emissions Analysis Protocol (since replaced by the GPC). Vermont is a state which is deeply connected to nature with many of its tourist appeals being natural based. This means that with climate change, many of the state's main income areas, such as winter recreation, will be jeopardized. In order to help prevent this, it was critical for Burlington to develop a GHG inventory to determine how best to reduce their emissions to protect their state's natural resources.

SOFTWARE USED

No specific software was identified.

ACCOUNTING METHODS USED

Burlington collected emissions data from the following sectors: government operations, airports, and the community. For government operations, emissions data was collected from the following areas: solid waste, employee commuting/personal vehicle business, vehicle fleet, natural gas and electricity. For airport operations, emissions data was collected on the vehicle fleet, natural gas usage and electricity usage. For community emissions, data was collected on solid waste, transportation, natural gas and electricity usage. The specific methods used to collect these data were not included in the report.

DATA USED

No specific data sources were identified; however, key participants are listed on page 25 of their inventory.

REFERENCE

"Burlington, VT Climate Action Plan"
https://www.burlingtonvt.gov/Sustainability/CAP

Portland, Maine

2001 City of Portland

The Commission reviewed both Portland's baseline inventory of 2001 and an updated inventory for 2010 to understand considerations over time.

BACKGROUND

Portland will be greatly affected by climate change in the future given the current course of events as it is a city which relies on tourism and fishing. As a member of ICLEI, Portland chose to conduct both community and corporate (municipal) inventories for the year 2001 in order to create a comprehensive baseline understanding of their emissions.

SOFTWARE USED

No specific software was identified.

ACCOUNTING METHODS USED

Portland used the GPC method to calculate their inventory. For the community inventory, Portland calculated emissions from the following sectors: community heating oil, community propane, community transportation, community residential, community waste and recycling, community commercial and industrial. For the corporate inventory, emissions from the following sectors were measured: energy consumption, heating oil, water and wastewater, solid waste management and the municipal fleet. In order to determine emissions for each of these different categories, consumption data was used and converted into CO_{2e} emissions through conversion factors. These methods are described throughout the document.

DATA USED

Community Heating and Oil: Residential Energy Consumption Survey, 1997. This report can be found at: http://www.eia.doe.gov/emeu/recs/recs97/rx97toc.html and data extracted from Assessor's database by City of Portland MIS

Community Propane: Suburban Propane

Community Waste and Recycling: Solid Waste Coordinator, City of Portland

Community Transportation: MaineDOT – using TIDE model to generate DVMT

Community Residential: Profile of General Demographic Characteristics – 2000 U.S. Census

Community Commercial and Industrial: Northern Utilities

Corporate: CMP; Union Oil Company; Portland School Department; Portland Water District; Portland Fleet Manager – City of Portland Public Works Department

REFERENCE

"Greenhouse Gas Inventory and Energy Audit"
https://www.portlandmaine.gov/2387/Climate-Action

Portland, Maine

2010 City of Portland

BACKGROUND

For this updated version of their inventory, Portland chose to use The Climate Registry General Reporting Protocol (GRP). In this report, the community and municipal emissions were combined to create the emissions totals for Portland. Portland chose to use "The Operational Control Approach" due to the vast size of the Portland community.

SOFTWARE USED

No specific software was identified.

ACCOUNTING METHODS USED

In order to develop this inventory, emissions were calculated for the following sectors: solid waste, residential, commercial and industrial. The inventory was divided into two scopes: Scope I and Scope II. Scope I includes stationary and mobile combustion emissions sources within the region and Scope II includes all indirect emissions from electricity. The estimated consumption for stationary combustion fuel sources was converted to metric tons of emissions using constants given by GRP. For Scope I mobile combustion emissions, data was taken from automobile, aviation and waterborne emissions sources. Each of these required using vehicle miles traveled to calculate emissions based on fuel types. For Scope II indirect emissions, electrical power data in kilowatt hours (kWh) were converted to metric tons using the electricity emissions factor provided by The Climate Registry.

DATA USED

Scope I Stationary Combustion Data: estimated based on Maine information from the State Energy Data System from the Energy Information Administration.

Scope I Mobile Combustion Data: Maine Department of Transportation (DOT), the Portland Office of the Treasury, the U.S. Bureau of Transportation Statistics, and the U.S. EPA

Scope II Indirect Emissions: "Electrical power data was obtained from Central Maine Power Company in the form of kilowatt-hours per sector (residential, commercial, and industrial)," (Portland 7).

REFERENCE

"Greenhouse Gas Inventory and Energy Audit"
https://www.portlandmaine.gov/2387/Climate-Action

South Portland, Maine

2016 Greater Portland Council of Governments for the City of South Portland

BACKGROUND

South Portland is a member of ICLEI and in 2007, signed the U.S. Mayors Climate Protection Agreement. As such, South Portland must monitor and update their GHG emissions inventories in order to continue to make progress towards having a greener city. South Portland chose to use the ICLEI Local Government Operations Protocol (LGOP) in order to develop their inventory.

SOFTWARE USED

ICLEI USA ClearPath Pro

ACCOUNTING METHODS USED

For this inventory, South Portland chose to exclusively study emissions from their municipal operations focusing on the following sectors: stationary combustion, mobile combustion, fugitive emissions and indirect emissions both from electricity and from other sources. More specifically, Portland studied emissions from: buildings, wastewater, vehicle fleet, lights & traffic signals, and their transit fleet. Like Portland's 2010 inventory, South Portland used scopes to organize their inventory. In order to determine emissions from each of these sectors, consumption data was taken from the city's Sustainability Office and converted into emissions of greenhouse gases using the ICLEI ClearPath tool.

DATA USED

No specific data sources were provided.

REFERENCE

"South Portland 2014 Greenhouse Gas (GHG) Emissions Inventory"
https://www.southportland.org/departments/sustainability-office/energy-climate/municipal-climate/

Alexandria, Virginia

2018 Metropolitan Washington Council of Governments for the City of Alexandria

BACKGROUND

The city of Alexandria developed their inventory in accordance with the Washington Regional GHG Inventory methodology. Both the regional and local inventories follow ICLEI U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Alexandria has committed to continuing to reduce their GHG emissions before 2050 and as such wanted to have a baseline understanding of their GHG emissions. Additionally, the city wanted to exemplify that even as populations continue to grow, reductions in emissions can still be made.

SOFTWARE USED

ICLEI ClearPath Tool, EPA's Motor Vehicle Emissions Simulator (MOVES), EPA's State Inventory Tool (SIT), EPA's Chesapeake Assessment Scenario Tool; EPA's Emissions & Generation Resource Integrated Database (eGRID)

ACCOUNTING METHODS USED

Alexandria used the ICLEI U.S. Community Protocol along with the ICLEI ClearPath Tool to calculate emissions for seven sectors: process and fugitive emissions; residential energy; commercial energy; agriculture; water and wastewater; solid waste; and transportation and mobile sources.

DATA USED

Utility data was collected from local suppliers and emissions were calculated using EPA's eGRID. On and off-road transportation emissions were calculated using the EPA MOVES and VMT data provided by the local transportation board. Air travel emissions data were calculated by scaling national data using population and regional survey data. Commuter rail emissions data were calculated "using

MARC [Maryland Area Regional Commuter] and VRE [Virginia Railway Express] diesel consumption data scaled to the region" (Alexandria 2). Emissions from landfills and wastewater were calculated using data from local sources. Agricultural emissions data were collected "using the EPA's State GHG Inventory Tool and data from EPA's Chesapeake Assessment Scenario Tool and USDA's Census of Agriculture" (Alexandria 2). Data from ozone depleting chemicals were scaled to local levels based on national data.

REFERENCE

"City of Alexandria, Virginia Community-Wide Greenhouse Gas Inventory Summary Factsheet" https://www.alexandriava.gov/tes/eco-city/info/default.aspx?id=109861

San Antonio, Texas

2019 City of San Antonio

BACKGROUND

San Antonio supports the Mayor's National Climate Action Agenda to uphold the Paris Climate Agreement goals. A GHG emissions inventory was included in their Climate Action & Adaption Plan to track progress toward reducing emissions in the city.

SOFTWARE USED

The City Inventory Reporting and Information System (CIRIS) tool developed by C40 cities was used for the community emissions calculation. Another reporting tool was developed for the city to use in the municipal account which was adapted for more current data.

ACCOUNTING METHODS USED

San Antonio used the GPC developed by the World Resources Institute, C4O Cities, and ICLEI for their community scale emissions inventory. For the municipal GHG inventory, San Antonio used the LGOP developed by ICLEI. Greenhouse gases calculated were CO_2, CH_4, and N_2O. To compare these gases, the CO_{2e} unit was used by converting the gas-specific global warming potential (GWP) for each gas.

For community emissions, San Antonio used the BASIC reporting level of the GPC while also including the largest industrial process emissions. San Antonio collected emissions data from "electricity and natural gas usage in buildings; vehicular transportation within city boundaries; waste including solid waste and wastewater; energy production and energy use in energy industries; [and] industrial processes" (San Antonio 63). The specific data used in the emissions account originated from the CIRIS tool. Additionally, electricity data was supplied by CPS Energy, which supplies electricity to the city.

To calculate municipal emissions, San Antonio used the LGOP protocol to collect data from "electricity and natural gas usage in city-owned facilities, streetlights and traffic signals, city-owned vehicles, as well as city-owned and operated landfills" (San Antonio 63). Much of the data which was used for these calculations originated from a reporting tool created for the city in 2014 when the city conducted its first account. Additionally, San Antonio collected data provided by various city agencies for the number of vehicle miles traveled, volume of gas used, and the amount of waste generated.

DATA USED

Specific data sources were not provided.

REFERENCE

"SA Climate Ready: A Pathway for Climate Action & Adaptation"
https://saclimateready.org/

REGIONAL INVENTORIES

The following inventories represent regions of varying size and development density in New England, the Mid-Atlantic, and other coastal regions.

Pioneer Valley, Massachusetts

(Hampden and Hampshire Counties)

2014 Pioneer Valley Planning Commission

BACKGROUND

The Pioneer Valley Planning Commission researched local, regional, and private corporation GHG accounting methods prior to calculating baseline emissions for their Pioneer Valley planning area. The method used by the Pioneer Valley Planning Commission follows the Massachusetts Department of Environmental Protection's technical memo "Final 2006 - 2008 Massachusetts Greenhouse Gas Emissions Inventory." This inventory focused on six emissions sectors: transportation, heat for buildings, electricity consumption, industry, waste, and agriculture. This work included calculating carbon dioxide absorption by trees and plants (carbon sequestration), recognizing the amount of forests and green spaces in this planning area. Also, emissions from Hampshire and Hampden counties were separated to better understand regional emissions.

SOFTWARE USED

2005 EPA State Inventory Tool (Electricity); I-Tree Vue with Pioneer Valley Land Cover mapping.

ACCOUNTING METHODS USED

To determine emissions from the six main sectors, the following equations were used:

$$\textbf{Electricity MTCO}_{\mathbf{2e}} = \text{Total}\,\frac{kWh}{yr}\ x\ \text{GHG Factor}\ x\ \text{Metric Tons Factor}$$

$$\textbf{Heating MTCO}_{\mathbf{2e}} = \text{ResGHG} + \text{ComGHG} + \text{IndGHG}\ x\ \text{MT Factor}$$

Where:

$$\text{Res GHG} = \sum [\text{Regional \% of State Residential fuel use} \times \text{State Residential fuel BTU total} \times \text{GHG Factor}]$$

$$\text{ComGHG} = \sum [\text{Regional \% of State Residential fuel use} \times \text{State Commercial fuel BTU total} \times \text{GHG Factor}]$$

$$\text{IndGHG} = \sum_{all\ fuels} [\text{Adjusted Regional \% of State Industrial fuel use} \times \text{State Industrial fuel BTUs} \times \text{GHG Factor}]$$

Adjusted Regional % of State Industrial fuel use = (Regional % of state manufacturing employment / Regional % of homes) x Regional % of state residential fuel use

$$\textbf{Transportation MTCO}_{\mathbf{2e}} = \sum \text{Vehicle Fuel Used}\ x\ \text{BTU Fuel Factor}\ x\ \text{GHG Fuel Factor}$$

When the vehicle fuel used is unknown:

$$\text{Vehicle Fuel Used} = \sum \frac{[\text{Vehicle type \% of all regional vehicles}\ x\ \text{Regional annual VMT}]}{\text{Vehicle type MPG}}$$

$$\textbf{Industry MTCO}_{\mathbf{2e}} = \text{Refinery} + \text{Power Plant} + \text{Chemical} + \text{Metals} + \text{Mineral} + \text{Pulp and Paper} + \text{Gov and Com}$$

$$\textbf{Solid Waste MTCO}_{\mathbf{2e}} = \text{Landfill emissions}$$

$$\textbf{Agriculture MTCO}_{\mathbf{2e}} = \text{Enteric Fermentation} + \text{Manure Management}$$

Where:

$$\text{Enteric Fermentation} = \sum [\text{Livestock Population}\ x\ \text{Enteric Methane Factor}\ x\ \text{GHG Factor}]$$

$$\text{Manure Management} = \sum [\text{Livestock Population}\ x\ \text{Manure Methane Factor}\ x\ \text{GHG Factor}]$$

Calculation of the CO_{2e} storage per year was estimated using data on impervious surfaces, tree canopy, and land use from the Pioneer Valley Land Cover Map and data from spatial tree cover maps from I-Tree Vue.

DATA USED

ACCOUNTING CATEGORY	DATA TYPE	Units	SOURCE
Electricity	Electricity consumed per municipality	kWh	*WMECo, National Grid, Massachusetts Municipal Wholesale Electric Company*
Electricity	GHG Factor	CO2e lbs/kWh	*2005 EPA State Inventory*
Electricity	Metric Tons factor	MT/lbs	*http://www.epa.gov/cleanenergy/e N / A nergy-resources/refs.html*
Heating	Number of households per fuel type	Housing units	*2005-2010 American Community Survey*
Heating	Total State BTU	British Thermal Units	*Energy Information Administration (2009)*
Heating	Manufacturing employment	Number of employees	*County Business Patterns (2009)*
Heating	GHG Factor for each fuel type	CO2e kgs/Fuel Type Mbtu	*U.S. EPA, Direct Emissions from Stationary Combustion Sources, Appendix B, May 2008*
Heating	MT Factor	MT/kgs	*N/A*
Transportation	Number of registered vehicles in PV	Vehicles by type	*Mass. Dept. of Revenue, Municipal Databank/Local Aid Section*
Transportation	MPG for type of registered vehicles	MPG, by vehicle type	*FHWA Highway Statistics 2001*
Transportation	PV annual VMT all private vehicles	Miles	*2012 Regional Transportation Plan, PVPC*
Transportation	Gallons of fuel used by PVTA fleet	Gallons of fuel	*PVTA 2011 Records for SATCO, VATCO and UMass Fleets*
Transportation	MPG for PVTA vehicles	MPG, by vehicle type	*PVTA 2011 Records for SATCO, VATCO and UMass Fleets*
Transportation	BTU Factor for each fuel type	Btu/gal for fuel type	*1996 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 2 (Energy Section)*
Transportation	GHG Factor for each fuel type	CO2e lbs/Btu of fuel type	*U.S. EPA, Direct Emissions from Mobile Combustion Sources, Appendix B, May 2008*
Transportation	MT GHG conversion	CO2e MT/lbs	*N/A*

ACCOUNTING CATEGORY	DATA TYPE	Units	SOURCE
Industry	Refinery emissions, Power Plants, Chemical emissions, Metals emissions, Mineral emissions, Pulp and Paper emissions	MTCO2e	*US EPA GHG Reporting Program: "Large GHG Emissions from Large Facilities" http://ghgdata.epa.gov*
Solid Waste	Landfill emissions	MTCO2e	*Massachusetts DEP, Climate Change Registry*
Agriculture	Livestock population by species	Number of animals	*US Agricultural Census (2007)*
Agriculture	Enteric Methane Factor	CH4/Livestock species	*2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 10, Emissions from Livestock and Manure Management*
Agriculture	Manure Methane Factor	CH4/Livestock species	*2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 10, Emissions from Livestock and Manure Management*
Agriculture	GHG Factor	CO2e/CH4	*IPCC - Fourth Assessment Report on Climate Change (2007)*
Carbon Sequestration	Pioneer Valley Land Cover Map	N/A	*National Land Cover Database (2006)*
Carbon Sequestration	I - Tree Vue	N/A	*United States Forest Service, www.itreetools.org*
Historical Data	Vulcan Project	N/A	*NASA/DOE*

Additionally, the Pioneer Valley Planning Commission used data on historical emissions from the Vulcan Project.

REFERENCE

"Pioneer Valley Climate Action and Clean Energy Plan"
http://www.pvpc.org/plans/climate-action-and-clean-energy-plan

Mid-Hudson Region, New York

(Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, and Westchester Counties)

2012 ICF International for the New York State Energy Research and Development Authority

BACKGROUND

This inventory used the New York GHG Protocol, developed to ensure that all regions of New York are collecting the same types of data in the same way to allow for their results to be easily compared and compiled as the state continues work to reduce GHG emissions.

SOFTWARE USED

EPA's Greenhouse Gas Reporting Program; EPA's State Inventory Tool (for Wastewater)

ACCOUNTING METHODS USED

New York calculated emissions from the following sectors: energy; transportation; industrial processes; agriculture; waste; and land use, land use change and forestry. Stationary energy consumption includes direct emissions from the combustion of natural gas, coal, kerosene, distillate, motor gasoline and other fuels, and indirect emissions from electricity consumption. Transportation emissions for on-road and off-road transportation were calculated. The waste sector includes solid waste and wastewater. Solid waste emissions include landfills located within the region regardless of where the waste originated and emissions from waste generated by the region regardless of where the wasted is ultimately transported.

Data for each of the sectors was first calculated at the municipal level for each of the counties included in the inventory, then totaled to create data for the regional level.

Detailed calculation methods for each sector and subsector are provided throughout the inventory. For example:

Emissions from electricity generation were estimated by multiplying total fuel consumption for each plant by the appropriate CO_2, CH_4, and N_2O emission factors to calculate the total emission by gas. Losses due to transmission and distribution were calculated using energy consumption data and the Eastern regional loss factor from eGRID. Emissions from electricity consumption were calculated using a combination of reported usage from utilities and, where utility data are unavailable, consumption estimates.

Natural gas consumption was estimated using a combination of reported usage from utilities and, where utility data are unavailable, consumption estimates. Natural gas losses from transmission and distribution were gathered from state reporting data.

For all other fuels, usage was calculated using a weighted estimate based on the occupancy of different dwelling types, energy use per housing unit by different types of dwellings, the average Heating Degree Days (HDD) for each region in the state, and the use of household heating fuels by household count.

On-road transportation emissions were estimated using vehicle miles traveled, fuel economy, and vehicle mix data.

Calculations estimated the average annual rate of change for carbon sequestration: (1) Subtracted the 2005 acres of forest per county from the 2010 acres of forest per county; (2) Divided the change by five (years) to get the annual rate of change in acres; (3) Converted acres of forest to hectares; (4) Multiplied the annual rate of change in hectares by the composite carbon sequestration rate.

DATA USED

Multiple national and state datasets were used to calculate emissions from various sectors and subsectors. For example:

The primary data source for electricity generation is the U.S. EIA Form 923 facility production data for 2010. Emissions from electricity consumption were calculated using a combination of reported usage from utilities and, where utility data are unavailable, consumption estimates. Central Hudson Gas & Electric, ConEdison, NYSEG, and Orange & Rockland Utilities provided their electricity usage data.

On-road transportation use was taken based on household data from the American Community Survey 5-year estimates looking at how many people per household commute to work. Off-road transportation data was based on population density. For waste emissions, data was derived based on census information and data from the EPA's State Inventory Tool (SIT). Industrial processes data were taken from the sole plant in the area. Agricultural data included the U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS), and the New York State Department of Agriculture and Markets dataset of total fertilizer and nutrients by county for calendar year 2010.

Two datasets were collected to calculate net emissions from Land Use, Land Use Change, and Forestry (LULUCF): (1) the acres of forested land by county in 2005 and 2010 and (2) the carbon sequestration rates for forests in the region. The acres of forested land were retrieved from the U.S. Forest Service's Forest Inventory and Analysis database via the Forest Inventory Data Online (FIDO) website. Carbon sequestration rates for forested land were obtained from the Carbon OnLine Estimator (COLE).

REFERENCE

"Mid-Hudson Regional Greenhouse Gas Emissions Inventory"
https://www.dec.ny.gov/energy/57170.html

Western Region, New York

(Allegany, Cattaraugus, Chautauqua, Erie, and Niagara Counties)

2012 Ecology and Environment, Inc. for the New York State Energy Research and Development Authority

BACKGROUND

This GHG inventory used the standard New York Greenhouse Gas Protocol.

SOFTWARE USED

EPA State Inventory Tool (wastewater); Emission and Dispersion Modeling System (EDMS Version 5.1.3 (aircraft emissions)

ACCOUNTING METHODS USED

The Western New York region's inventory calculates emissions from the following sectors: energy; transportation; industrial processes; waste; agriculture; and forestry. For the energy sector, consumption and generation data were collected and converted to emissions using standard conversion factors. In the specific case of fuel use, a top-down approach was used where state data was allocated to each region based on a variety of different specific factors.

For the transportation sector, both on-road and off-road data were collected. In each of the different focused transportation areas, the fuel consumption data based on vehicle miles traveled were multiplied by the specific conversion factors for each fuel type. These focus sectors include on-road, aviation, marine, rail and off-road equipment emissions.

Industrial process emissions were highly specific to the region, such as calculating emissions based on metal processing. Solid waste and wastewater emissions were based on waste generated rather than waste received in the plants. Agricultural emissions data were collected for N_2O from soils, emissions of CH_4 and N_2O from manure management; and CH_4 emissions from livestock digesting their feed, known as enteric fermentation. The data from each of these categories is based on consumption/population data specific to the region.

For carbon sequestration by forests, "the amount of CO_2 stored by forests is calculated by multiplying the acres of each type of forest in the region (defined by the dominant species or group of species) (USFS 2010) times a factor representing the quantity of carbon stored per acre of each type of forest (called the carbon stock factor) (NCASI 2012)" (WNY 3-13). For urban trees, "the amount of CO_2 sequestered by urban trees can be estimated as a function of the size of urban areas and the percentage of that area with tree cover (data provided by Greenfield 2012)" (WNY 3-14).

DATA USED

U.S. Department of Energy (DOE) Energy Information Administration (EIA) reporting programs (Form 923) (USEIA2011); Electricity consumption in the region is based on utility sales data; US Census; fuel economy data from the Federal Highway Administration; EPA's 2008 National Emission Inventory

(NEI) for commercial marine emissions; EPA NONROAD model; EPA Greenhouse Gas Reporting Program (GHGRP) (EPA 2012c) for industrial process emissions; EPA SIT; USDA Census of Agriculture

REFERENCE

"GHG Inventory Report"
https://www.dec.ny.gov/energy/57170.html

Northern New Jersey

(Bergen, Essex, Hudson, Hunterdon, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union, and Warren Counties)

2011 E.H. Pechan and Associates Inc for the North Jersey Transportation Planning Authority

BACKGROUND

Northern New Jersey has committed to reducing their emissions to 1990 levels by 2020. An inventory method unique to the region was developed to track progress to their goals while still including many of the same sectors as other regional or large city inventories. This allowed for an inventory tailored to the specific needs and emissions sources of the region.

SOFTWARE USED

Argonne National Laboratory Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) model (electricity module)

ACCOUNTING METHODS USED

This inventory calculates emissions for the following sectors: electric power production and use; stationary fuel use; transportation; industrial processes; fossil fuel industry; agriculture; land use, land use change, and forestry; solid waste management. The inventory includes emissions calculated for the following greenhouse gases: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Direct emissions were calculated along with consumption-based emissions for electricity generation, transportation, and solid waste.

DATA USED

EPA Clean Air Markets Database (CAMD); EPA eGRID; EPA NEI; private energy suppliers; EPA MOVES; USDA Census of Agriculture

REFERENCE

"NJTPA Regional Greenhouse Gas Emissions Inventory and Forecast Final Report"
https://www.njtpa.org/Planning/Regional-Programs/Studies/Completed/2011/Region-wide-Greenhouse-Gas-Emissions-Inventory-Pro.aspx

Delaware Valley, Pennsylvania and New Jersey

(Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania, and, Burlington, Camden, Gloucester, and Mercer Counties in New Jersey)

2018 Delaware Valley Regional Planning Commission

BACKGROUND

The Delaware Valley Regional Planning Commission (DVRPC) wanted a method that was easily replicable for updating the inventory, and to track regional energy use, energy expenditures, and GHG emissions for developing future regional policies.

SOFTWARE USED

EPA State Inventory and Projection Tool; EPA Motor Vehicle Emission Simulator; DVRPC Travel Improvement Model

ACCOUNTING METHODS USED

DVRPC divided their inventory into three main sectors: stationary energy use emissions, mobile energy use emissions, and other emissions and sequestration sources. The stationary energy use sector was divided into three subsections: electricity generation, direct fuel consumption, and steam production. The mobile energy use sector was divided into eight subsections: on-highway vehicles, freight rail, intercity passenger rail, transit rail, commercial aviation, general aviation, marine and port related activities, and off-road vehicles and equipment. The other emissions sector was divided into emissions from: natural gas transmission, hydrogen production, iron and steel production, petroleum refining, ozone-depleting substances substitutes, municipal solid waste landfilling, wastewater treatment, agriculture, and sequestration by forests/urban trees.

DATA USED

To estimate energy use and GHG emissions resulting from electricity generation, DVRPC collected electricity consumption data, grid loss factors, average regional emissions factors, and fuel consumption and energy use estimates based on the electricity generation mix. Emissions from natural gas transmission and distribution were estimated using national emissions and consumption data from U.S. EIA.

DVRPC used its regional travel demand model, the U.S. FHWA Performance Monitoring System (HPMS), and the EPA MOVES2014a to calculate on-road emissions. For rail and aviation, DVRPC apportioned the national estimate of emissions using rail transport tonnage estimates and flight miles traveled, respectively. DVRPC estimated fuel consumption and energy used by marine vessels and associated port activities using EPA estimates of emissions for marine vessels. For off-road vehicle emissions, DVRPC used MOVES2014a.

Landfill CH_4 was estimated using the first order decay equation in the U.S. EPA's AP-42 *Compilation of Air Emissions Factors* guidance:

The first order decay equation is:

$$QTx = A \times k \times Rx \times Lo \times e^{-k(T - x)}$$

Where:

QTx = Amount of CH_4 generated in year T by the waste Rx,

T = Current year,

x = Year of waste input,

A = Normalization factor, $(1-e^{-k})/k$,

k = CH_4 generation rate (yr^{-1}),

Rx = Amount of waste landfilled in year x,

Lo = CH_4 generation potential.

For wastewater treatment, population data and wastewater treatment data were used.

For agricultural emissions, emissions from the national inventory were apportioned to the counties then added for a regional estimate.

Carbon sequestration of urban trees outside of the City of Philadelphia was calculated using data on the region's total urbanized acreage outside of Philadelphia from the U.S. Census Bureau along with state specific data on tree coverage ratios and net sequestration rates from the EPA SIT to develop an estimate of the net annual sequestration by trees located in urbanized areas (so called "urban trees") outside of Philadelphia. DVRPC also developed county and municipal allocations based on the extent of urban acreage located in these geographic areas.

REFERENCE

"Energy Use and Greenhouse Gas Emissions Inventory for Greater Philadelphia: Methods and Sources"
https://www.dvrpc.org/EnergyClimate/Inventory/

Northern Illinois

(Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will Counties)
2018 ICF for the Chicago Metropolitan Agency for Planning

BACKGROUND

In planning for climate change and trying to increase resiliency, the Chicago Region calculated an inventory to understand regional GHG emissions which will be used to track progress towards reducing emissions over time.

SOFTWARE USED

EPA MOVES model version MOVES2014a [U.S. EPA 2018a]

ACCOUNTING METHODS USED

This inventory includes emissions from: stationary energy; transportation; and, waste. Emissions were calculated using the GPC BASIC level. For stationary energy emissions, data from residential buildings, commercial and institutional buildings and facilities, manufacturing industries, energy industries, and oil and natural gas systems were collected. For residential buildings, data from electricity and natural gas usage were collected from utilities that serve the region. Electricity consumption data were multiplied by region-specific GHG emission factors to determine electricity emissions. A similar method was used for natural gas except that the consumption data were multiplied by a different set of emission factors.

For commercial and institutional buildings, a similar method was used for electric and natural gas emissions. However, the use of biogas was also included. Biogas emissions were calculated by multiplying consumption data by an emissions factor.

For manufacturing industries, electric and natural gas emissions were calculated in the same way as the other two subsectors. Additionally, emissions from natural gas combustion and from construction equipment were eliminated from this category to prevent double counting.

For energy industries, data was "taken directly from EPA's GHGRP (U.S. EPA 2017c). These estimates include facility-level stationary combustion emissions from power plants in the Chicago Region" (Chicago B-4).

For fugitive emissions from oil and natural gas systems, data was "taken directly from EPA's GHGRP (U.S. EPA 2017c). These estimates include facility-level fugitive emissions from petroleum refining, natural gas systems for refineries, and natural gas transmission and distribution facilities in the Chicago Region" (Chicago B-4).

For transportation emissions, data was collected from on-road, railways, waterborne navigation, aviation and off-road sources. On-road emissions were calculated using estimated vehicle miles traveled per vehicle type. Alternative fuel vehicle (AFV) VMT was calculated using electric vehicle VMT data scaled to the region via population data and then subtracted from the overall VMT data to avoid double counting. Electricity emissions from AFV was calculated by multiplying consumption by emission factors.

For railway emissions, passenger train emissions were calculated using "fuel consumption and electric propulsion data from the Federal Transit Administration's (FTA) National Transit Database (NTD) (FTA 2010 and 2015)" (Chicago B-5). Emissions from electricity use for passenger trains were calculated by "multiplying consumption data by a region-specific CO_2, CH_4, and N_2O emission factor obtained from EPA's eGRID (U.S. EPA 2017b)" (Chicago B-6). Emissions from diesel use for passenger trains were calculated by "by multiplying consumption data by CO_2, CH_4, and N_2O emission factors from the U.S. EPA (2015 and 2016)" (Chicago B-6).

For Amtrak trains, the following method was used: “the length of each route was determined using Google Earth. Fuel efficiency for Amtrak trains was calculated using total train miles and total fuel consumption for the entire Amtrak system (Bureau of Transportation Statistics 2018). The track miles were then multiplied by system fuel efficiency to estimate fuel consumption. Finally, emissions were calculated by multiplying consumption data by diesel fuel CO_2, CH_4, and N_2O emission factors from the U.S. EPA (2015 and 2016)” (Chicago B-6).

For freight rail, ton mile data from Oak Ridge National Laboratory for the Chicago Region was used. Following this, “fuel consumption was then derived by multiplying ton-mile data by the miles-per-gallon efficiency from two of the largest Class I freight rail operators that serve the region (Union Pacific 2015 and Burlington Northern Santa Fe 2015). Finally, emissions were calculated by multiplying consumption data by diesel fuel CO_2, CH_4, and N_2O emission factors from the U.S. EPA (2015 and 2016)” (Chicago B-6).

For waterborne navigation emissions, data for both recreational and commercial boats were used. “Emissions were calculated by multiplying the diesel and gasoline consumption data by emission factors from the U.S. EPA (2015). For commercial boats, emissions were also quantified by multiplying consumption data by diesel fuel CO_2, CH_4, and N_2O emission factors from the U.S. EPA (2015)” (Chicago B-6).

For aviation, emissions were calculated by multiplying fuel consumption data with aviation and jet fuel GHG emissions factors. The fuel consumption data originated from regional fuel service providers and the emissions factors came from the U.S. EPA (Chicago B-7).

For off-road vehicles, emissions “were quantified using emissions and fuel consumption data by equipment type from the NONROAD component of U.S. EPA’s MOVES2014a model (U.S. EPA 2018a). Carbon dioxide emissions were taken directly from the MOVES2014a model. Methane and N_2O emissions were quantified by multiplying consumption data by fuel-specific CH_4 and N_2O emission factors from *EPA’s Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA 2018b)” (Chicago B-7).

For waste emissions, this sector was split into three subsections: solid waste disposal, biological waste treatment and wastewater emissions. For solid waste disposal, the methane commitment method was used. This method can be completed by “calculating landfill emissions based on the amount of waste disposed in a given year and assigning emissions to the year of waste generation under the assumption that the emissions will actually occur in future years as waste decays and produces methane” (Chicago B-8).

Emissions from the biological treatment of waste were calculated based on the amount of waste which was diverted as compost. This was then multiplied by the CH_4 and N_2O emission factors in order to determine the amount of emissions produced (Chicago B-9). Additionally, emissions from wastewater generated in the area were calculated by collecting data on the total amount of wastewater from the area as well as the emissions from the plants which process and treat this wastewater (Chicago B-10).

DATA USED

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Stationary Energy Emissions - Residential, Commercial & Institutional Buildings, Manufacturing	Electricity Consumption Data	*Commonwealth Edison (ComEd), Illinois Municipal Electric Agency (IMEA)*
Stationary Energy Emissions - Residential and Commercial & Institutional Buildings, Manufacturing	Natural Gas Consumption Data	*Nicor Gas and People's Gas*
Stationary Energy Emissions - Residential and Commercial & Institutional Buildings, Manufacturing	Electricity region-specific CO2, CH4, and N2O emission factor	*U.S. Environmental Protection Agency's (EPA) Emissions & Generation Resource Integrated Database (eGRID) (US EPA 2017b)*
Stationary Energy Emissions - Residential and Commercial & Institutional Buildings, Manufacturing	Natural Gas CO2, CH4, and N2O emission factors	*EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks (U.S. EPA 2017a)*
Stationary Energy Emissions - Commercial & Institutional Buildings	Biogas Consumption Data	*Metropolitan Water Reclamation District (MWRD)*
Stationary Energy Emissions - Commercial & Institutional Buildings	Biogas emissions factors	*2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006)*
Stationary Energy Emissions - Energy Industries	Emissions	*EPA'S GHGRP (U.S. EPA 2017c)*
Stationary Energy Emissions - Fugitive emissions form oil and natural gas systems	Emissions	*EPA'S GHGRP (U.S. EPA 2017c)*
Transportation Emissions - On-Road	VMT Data	*CMAP derived from EPA's Motor Vehicle Emissions Simulator (MOVES) model (version MOVES2014a [U.S. EPA 2018a])*
Transportation Emissions - On-Road	Alternative Fuel Vehicle VMT	*EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks (U.S. EPA 2017a).*
Transportation Emissions - On-Road	Electricity Consumption Data for AFV	*GREET2016 model (Argonne National Laboratory 2014)*
Transportation Emissions - On-Road	Emissions Factors for AFV	*eGRID emission factors for the RFC West region (U.S. EPA 2017b)*

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Transportation Emissions - Railways	Fuel consumption and electric propulsion data for passenger trains	*Federal Transit Administration's (FTA) National Transit Database (NTD) (FTA 2010 and 2015)*
Transportation Emissions - Railways	Emissions from electricity use for passenger trains	*EPA's eGRID (U.S. EPA 2017b*
Transportation Emissions - Railways	Emissions from diesel use for passenger trains	*U.S. EPA (2015 and 2016)*
Transportation Emissions - Railways	Amtrak train route and frequency information	*Amtrak's website (Amtrak 2017a and 2017b)*
Transportation Emissions - Railways	Amtrak route length	*Google Earth*
Transportation Emissions - Railways	Total train miles and total fuel consumption for the entire Amtrak system	*Bureau of Transportation Statistics 2018*
Transportation Emissions - Railways	Ton-mile data for the Chicago Region	*Oak Ridge National Laboratory*
Transportation Emissions - Railways	Miles-per-gallon efficiency	*Union Pacific 2015 and Burlington Northern Santa Fe 2015*
Transportation - Waterborne Navigation	Fuel consumption for recreational boats	*NONROAD component of the MOVES2014a model (U.S. EPA 2018a)*
Transportation - Waterborne Navigation	Fuel consumption for commercial boats	*2015 Chicago inventory (City of Chicago 2017) and from commercial tour boat operators in the region (ICF 2017a).*
Transportation - Aviation	Fuel consumption data	*ICF 2017b*
Transportation - Aviation	Aviation gasoline and jet fuel CO2, CH4, and N2O emission factors	*U.S. EPA 2015*
Transportation - Off-road	Emissions and fuel consumption data by equipment type	*NONROAD component of U.S. EPA's MOVES2014a model (U.S. EPA 2018a)*
Transportation - Off-road	CH4 and N2O emission factors	*EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks (U.S. EPA 2018b).*
Waste Emissions - Solid Waste	Estimates of the mass of solid waste sent to landfill in the inventory year	*City of Chicago 2017; Cook County 2017; DuPage County Environmental Division 2017; SWALCO 2014; Will County 2017a; Will County 2018*

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Waste Emissions - Solid Waste	Waste composition in the Chicago Region	*2015 Illinois Commodity/Waste Generation and Characterization Update (Illinois Recycling Association 2015)*
Waste Emissions - Solid Waste	The destination landfill for waste generated in the Chicago Region, the fraction of methane recovered at those landfills, and the oxidation factor for those landfills	*Data and reports issued by county solid waste agencies and the City of Chicago, as well as data from EPA's GHGRP (U.S. EPA 2017c)*
Waste Emissions - Biological Treatment	Mass of solid waste diverted to composting	*Data and reports issued by county solid waste agencies and the City of Chicago (City of Chicago 2017; DuPage County 2017; Kane County 2017; Kendall County 2017; Will County 2017b)*
Waste Emissions - Biological Treatment	Emissions Factors	*2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006)*
Waste Emissions - Wastewater	Quantity of wastewater generated	*U.S. EPA Integrated Compliance Information System (ICIS) (U.S. EPA 2017d)*
Waste Emissions - Wastewater	Emissions measurements from MWRD plants treating wastewater generated in the region	*MWRD 2018*

REFERENCE

"2015 Chicago Regional Greenhouse Gas Emissions Inventory"
https://www.cmap.illinois.gov/onto2050/strategy-papers/ghg

Southern California

(Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties)

2012 The Center for Climate Strategies for the Southern California Association of Governments

BACKGROUND

Southern California estimated a past greenhouse gas inventory, a present/reference inventory, and a "business as usual" forecast inventory, for use in regional planning.

SOFTWARE USED

Southern California Public Power Authority SCAPPA MODEL (electricity), EPA SIT, California Emission Factor EMFAC2007 model (transportation), COLE modeling data from the U.S. Forest Service's Forest Inventory & Analysis surveys.

ACCOUNTING METHODS USED

Southern California chose to focus on six greenhouse gases when creating their inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), and eight sectors: electricity supply and use; residential, commercial and industrial fuel combustion; transportation energy use; industrial processes; fossil fuel industries; agriculture; waste management; forestry and land use.

For electricity supply and use, all sources of power were identified in the region, with the assumption that all of the energy from these power supplies were used to power locations within Southern California. The total annual net generation and fuel use by fuel type was calculated for regulated utilities, independent power producers and industrial/commercial combined heat and power facilities associated with total power generated. The data was combined, and the appropriate emissions factors and global warming potentials were applied. For the electricity that was imported into the region, data was taken from a model developed by the Southern California Public Power Authority (for 2001-2010) and from the California Air Resources Board (ARB) (for 1990-2000) (Southern California A-2).

For residential, commercial and industrial combustion, emissions were estimated based on the EPA SIT software and methods were adapted from the EPA Air Emission Inventory Improvement Program guidance document for residential, commercial, and industrial fossil and wood fuel combustion. These estimates were then updated in order to use data from sources used by ARB for their State inventory (data sources for each fuel/GHG combination were verified in the Documentation of California's 2000-2008 GHG Inventory (Southern California B-2).

For transportation energy use, "Emissions for gasoline and diesel on road vehicles were estimated using ARB's EMFAC2007 model. Emissions for compressed natural gas (CNG), liquefied petroleum gas (LPG), marine gasoline, and aviation gasoline were estimated by allocating state consumption to the region. Commercial aviation emissions were estimated based on landing-takeoff operation data, and commercial marine emissions were taken from GHG inventories developed for the region's ports" (Southern California C-1).

For industrial processes, Southern California focused on four areas of emissions:

- Carbon dioxide (CO_2) from:
    - Production of cement, lime, and ammonia;
    - Consumption of limestone, dolomite, soda ash, and CO_2;
    - Fuel consumption as feedstock to hydrogen production.

- Sulfur hexafluoride (SF_6) from transformers used in electric power transmission and distribution systems;
- Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) from consumption of substitutes for ozone-depleting substances used in cooling and refrigeration equipment; and
- HFCs, PFCs, and SF_6 from semiconductor manufacturing.

For oil and gas emissions, Southern California used data from the U.S. DOT Office of Pipeline Safety as well as default SIT data for the natural gas sector. Additionally, they used the ARB GHG Mandatory Reporting Program for Oil Refining emissions data (Southern California E-4). These data were compiled in order to create emissions accounts from past years as well as create an emissions forecast for the region. Table E-1 (Southern California E-4) summarizes the data used in their entirety.

Agriculture was divided into 10 subsections: fossil fuel consumption; livestock production – enteric fermentation; livestock production – manure management; livestock production, agricultural soils – livestock; crop production, agricultural soils – fertilizers; crop production, agricultural soils – crops; crop production, agricultural soils – liming; crop production, agricultural soils – rice cultivation; crop production, agricultural soils – soil carbon; and crop production, residue burning (Southern California F-2). Each of these subsections have specific methodologies relating to specific data found in California, such as the types of crops which are burnt as well as the amount of fertilizers used. Much of the data found in these subsections originated from agricultural reports from the area.

Waste management was divided into three subsections. Solid waste management involved determining methane emissions from solid waste landfills, nitrous oxide emissions from combustion of biogas at landfills, methane and nitrous oxide emissions from composting and carbon dioxide flux at landfills and composting operations. Solid waste combustion involved determining emissions from solid waste combustion in incinerators or waste to energy plants. Finally, for wastewater management, methane and nitrous oxide emissions from municipal and industrial wastewater sectors were determined (Southern California G-1). For specific equations used in wastewater management for California, refer to G-4.

The forestry and land use sector was divided into forested areas and urban forests. In order to determine the carbon stocks and carbon dioxide flux for forested areas, the following equations were used:

$$\textbf{County-level carbon stocks (tC)} = \text{carbon density (tC/ha)} \times \text{area (ha)}$$

$$\textbf{Carbon dioxide flux (tCO}_\mathbf{2}\textbf{)} = [\text{Carbon stocks Year 1 (tC)} - \text{Carbon stocks Year 2}] \times 44/12$$

For urban forests, “historic urban acreage was obtained from SCAG [Southern California Association of Governments] geographic information systems data. Urban forest sequestration was estimated by multiplying urban acreage by canopy cover percentage and a state-specific urban forest carbon sequestration rate. The estimated carbon sequestration rate is then multiplied by 44/12 to convert to CO_2" (Southern California H-3). Additionally, "emissions of N_2O from non-farm fertilizer application were also estimated. The US Environmental Protection Agency (EPA) State Inventory Tool (SIT) Land Use, Land Use Change and Forestry module was used to develop a state-level estimate. The state-level estimate was allocated to the SCAG [Southern California Association of Governments] region based on urban acreage (developed land)" (Southern California H-4). For emissions based on wildfires, the following equations were applied:

$$\textbf{Emissions (MMtCO2e/yr)} = A \times F \times CE \times EF \times 1/2.47 \times GWP \times 1/1012$$

Where:

A = area; acres

F = fuel loading; 150 kg dry matter/ha

CE = combustion efficiency; 34%

EF = emission factor; 8.1 g CH4/kg dry matter burned; 11 g N2O/kg dry matter burned;

2.47 = conversion from ha to acres;

GWP = global warming potential; 21 for CH4, 310 for N2O; 1/12 = conversion from grams to million metric tons

(Southern California H-5).

DATA USED

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Stationary Energy Emissions - Residential, Commercial & Institutional Buildings, Manufacturing	Electricity consumption data	California Energy Commission, ARB, EIA State Energy Data System
Electricity	Locations of electric power stations, total annual fuel use and net generation of electricity, total annual retail electricity sales, GHG emissions factors, CO2e intensity of imported electricity, historical transmission and distribution losses as a percentage of total electricity production	Described on A-3
Transportation	Vehicle miles traveled, fuel consumption data	Described on C-2
Industrial	Past data and forecasted data	Described on D-3 through D-6
Fossil Fuels	Past data and forecasted data	Described on E-4
Agriculture	Past data and forecasted data	Described on F-3 to F-4
Waste Management	Solid waste management	Final SCAG GHG Inventory and Reference Case Projection, CalRecycle

ACCOUNTING CATEGORY	DATA TYPE	SOURCE
Waste Management	Wastewater	US EPA Clean Watersheds Needs Survey database

REFERENCE

"Final Southern California Association of Governments (SCAG) Regional Greenhouse Gas Emissions Inventory and Reference Case Projections, 1990-2035"
http://www.scag.ca.gov/programs/Pages/GreenhouseGases.aspx

STATE INVENTORIES

The following inventories were reviewed to understand state considerations in determining GHG emissions.

Massachusetts

2016 Massachusetts Department of Environmental Protection

BACKGROUND

The Massachusetts greenhouse gas inventory is used to track progress towards the state's obligations under the Massachusetts Global Warming Solutions Act.

SOFTWARE USED

EPA State Greenhouse Gas Inventory Tool

ACCOUNTING METHODS USED

The EPA SIT estimates GHG emissions from sectors of concern in each state, based on the activities in key sectors in the state's economy. The inventory includes emissions for: fossil fuel combustion from residential, commercial, industrial, transportation, and electric generation sectors; industrial processes; transmission and distribution of natural gas; waste management; and agriculture and land use.

DATA USED

EPA SIT; U.S. DOE EIA State Energy Data System; energy distribution: New England Independent System Operator (ISO-NE) "Net Energy and Peak Load by Source" report and Environment Canada's National Inventory Report; MA Climate Registry Information System; EPA Facility Level Information on Greenhouse Gases Tool (FLIGHT); MA Water Resources Authority; U.S. DOT Pipeline and Hazardous Materials Safety Administration "Distribution, Transmission & Gathering, and Liquid Annual Data

REFERENCE

"Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection"
"Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection Update"
https://www.mass.gov/lists/massdep-emissions-inventories

Rhode Island

2012 Northeast States for Coordinated Air Use Management for the Rhode Island Department of Environmental Management

BACKGROUND

To compare their data with other states in the region, Rhode Island chose to develop a GHG emissions baseline and current GHG inventory using the EPA SIT tool to identify the major sources of emissions in the state.

SOFTWARE USED

EPA SIT

ACCOUNTING METHODS USED

Rhode Island collected data from six main sectors: electricity; transportation; industrial; residential and commercial; land use, land change, and forestry; municipal solid waste.

For electricity, emissions were calculated for CO_2 emissions from fossil fuel combustion (CO_2FFC Module) as well as CH_4 and N_2O emissions from fossil fuel and wood consumption (Stationary Source Module). This method is based largely on the fuel type used as how much of the fuel is fully combusted (Rhode Island 10).

For transportation, a three step process was conducted in order to fully collect emissions data: "1) characterizing the existing vehicle fleet; 2) identifying the activity associated with each vehicle class (e.g., VMT, engine hours, or fuel consumption); and 3) applying emission factors for each pollutant" (Rhode Island 11). Data was collected from highway vehicles, locomotives, marine vessels and aviation. Approximate data were used for agricultural and farming equipment.

For industrial emissions, this sector was split into four sub sectors for compiling the data: CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, Natural Gas and Oil Processes, and Industrial Processes. Much of the state specific data were taken from the facilities reporting system through Title V. Any other data were obtained through the EPA's emissions reporting program (OTIS) (Rhode Island 14).

For the residential and commercial sector, energy use data were used to determine the emissions totals and referenced carbon content in different types of fuels as well as their combustion efficiencies. Census data and data from the Rhode Island Department of Environmental

Management and the Public Utility Commission were used to determine how much of each fuel type is being used (Rhode Island 16).

For LULUCF, the amount of carbon absorbed and emitted were both measured. Overall, this sector acted as a sink rather than a source for emissions. Three main subsections were focused on: forest carbon flux, urban trees and carbon stored in landfilled yard trimmings. Data for these subsections were enhanced by Rhode Island Forestry data (Rhode Island 17).

For municipal solid waste, Rhode Island considered waste from "residences and businesses as well as waste imported from residences and businesses in other states" (Rhode Island 17) and waste from non-hazardous industrial landfills. To supplement the SIT data, Rhode Island also determined emissions from food waste and yard trimmings.

DATA USED

Refer to Table 2 on page 20 of 26 (24 of 91 on PDF) of the Rhode Island inventory for the complete list of data used. The "Data Upgrade" section refers to the data added by Rhode Island to replace the default data used by the SIT program.

REFERENCE

"2010 RI Greenhouse Gas Emissions Inventory"
http://www.dem.ri.gov/climate/pdf/gginv2010.pdf

UNITED STATES INVENTORY

2019 United States Environmental Protection Agency

BACKGROUND

The U.S. EPA prepares the official U.S. Inventory of Greenhouse Gas Emissions and Sinks to comply with existing commitments under the United Nations Framework Convention on Climate Change (UNFCCC), which the United States signed and ratified in 1992.

SOFTWARE USED

Colorado State University Natural Resource Ecology Laboratory Agriculture and Land Use National Greenhouse Gas Inventory Software; EPA Mobile6 Vehicle Emission Modeling Software; EPA MOVES

ACCOUNTING METHODS USED

This inventory follows the methods outlined in the *2006 IPCC* 28 *Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)*. This inventory adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and (2) a common and consistent format that enables Parties to the UNFCCC to compare the relative contribution of different emission sources and greenhouse gases to climate change.

DATA USED

The U.S. DOE EIA provides national fuel consumption data and the U.S. Department of Defense provides military fuel consumption and bunker fuels. Informal relationships also exist with other U.S. agencies to provide activity data for use in EPA's emission calculations. These include: the USDA, National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the FHWA, the DOT, the Bureau of Transportation Statistics, the Department of Commerce, and the Federal Aviation Administration. Academic and research centers also provide activity data and calculations to EPA, as well as individual companies participating in voluntary outreach efforts with EPA. See Figure 1-1 on page 1-12 (p. 67).

REFERENCE

"Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017"
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

CAPE COD
COMMISSION