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Consumption-Based Greenhouse Gas Inventories for Northeastern States

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Consumption-Based Greenhouse Gas Inventories for Northeastern States

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Disclaimer

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Abbreviations

CBE	consumption-based emissions
CBEI	consumption-based emissions inventory
CO_2e	carbon dioxide equivalents
CoA	Census of Agriculture
EEIO	Environmentally-Extended Input-Output model
ERG	Eastern Research Group
FBS	Flow-By-Sector
FLOWSA	Flow Sector Attribution tool
GHG	greenhouse gas
GHGI	greenhouse gas inventory
IEF	import emission factor
MECS	Manufacturer Energy Consumption Survey
MMT	million metric tons
NAICS	North American Industry Classification System
NEWMOA	Northeast Waste Management Officials' Association
RoUS	rest of the United States (excluding SoI)
RoW	rest of the world
SIT	State Inventory and Projection Tool
SoI	state of interest
USEEIO	US Environmentally-Extended Input-Output
USEPA	United States Environmental Protection Agency

1 Executive Summary

Many U.S. states compile regular annual greenhouse gas (GHG) inventories, which are used as a benchmark in measuring their progress toward GHG emissions reduction goals. These traditional territorial inventories cover GHG emissions occurring within the state's borders. GHG emissions are a driver of climate change, which is a global environmental issue. However, territorial inventories do not include GHG emissions that occur when producing and delivering the goods and services out-of-state that are consumed by final consumers within the state. Final consumers include all residents (households), investors, and all levels of government present in the state (from local to federal government facilities present in a state). A consumption-based emissions inventory (CBEI) is an accounting method that can be applied to a region, including a state, that quantifies emissions associated with all goods and services consumed within the region, regardless of where they were produced.

The Northeast Waste Management Officials' Association (NEWMOA) approached the U.S. Environmental Protection Agency (USEPA) seeking assistance with performing CBEIs of GHGs for states in their region. CBEIs require new tools to estimate emissions associated with the consumption of goods and services. USEPA recently developed a set of models, called the US Environmentally-Extended Input-Output (USEEIO) State Models, that enable tracking of the environmental flows — including GHG emissions — associated with all goods and services consumed within a state. USEPA also developed a set of import emission factors for representing GHG emissions associated with U.S. imports from abroad. Additionally, USEPA recently began publishing annual territorial GHG emissions for states.

The authors of this report leveraged the USEEIO State Models and the import emission factors along with state GHG emission inventories either provided by the state or by USEPA to prepare CBEIs for eight Northeast states: Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. CBEIs were prepared for each state that quantify annual emissions from consumption from 2012 through 2020. This report provides more background on the CBEIs and the models used in the CBEIs, a detailed methods section, and chapters on results for all Northeast states, as well as a chapter that provides a deeper exploration of the CBEI for Maine.

1.1 Key Results/Takeaways

- The CBEIs show that consumption-based GHG emissions from northeastern states are 40–60% greater than territorial emissions.
- Manufactured goods are the largest category contributing to the states' consumption-based emissions (CBEs), and the emissions from this category are largely from commodities made out of state.
- All states in the region have a trade emissions deficit that is about 50% as large as their CBEs. About two-thirds of the emissions embodied within imports are

associated with imports from the rest of the U.S., the remaining third are associated with international imports.

- Emissions per dollar spent over the 2012-2019 period decreased by 15-30% in the northeastern states.
- Increases in the consumption of goods and services from 2012-2019 have negated the reduction in emissions per dollar.
- The consumption intensity per resident ranged from a high of 26.2 metric tons of carbon dioxide equivalent (CO_2e) in New Hampshire to a low of 20.9 metric tons of CO2e in Rhode Island.

A deeper evaluation of the CBEs for Maine revealed that:

- Real consumption from households steadily increased from 2015 to 2020, outpacing government expenditures or investment. Over approximately the same period, the embodied carbon consumption intensity in Maine decreased by about 13%. This decrease in intensity neutralized the emission effects of increases in real consumption.
- In Maine, the purchase of manufactured goods, personal transportation, and residential heating and cooking are the largest contributors to CBEs. The largest contributors among manufactured goods are food, petroleum products (mainly gasoline and diesel), chemicals, and vehicles.
- Most emissions for categories including clothing, computers, and furniture, are associated with imported goods. Imported clothing and leather goods have an emissions intensity five times higher than those domestically produced. Similarly, the emissions intensity of imported furniture is four times greater than domestic furniture.

The CBEI illustrates states' greater sphere of influence by recognizing opportunities to shift and reduce demand, which is driving consumption. The accuracy of these CBEIs is limited by the assumptions and data gaps in the underlying models, but they can be instructive in providing states with direction on important GHG emission sources and their locations. This information can potentially serve as a benchmark in efforts to reduce emissions from consumption of goods and services.

2 Background and Study Goal

2.1 A Consumption-Based Approach in the Context of U.S. State Greenhouse Gas Reporting

Many U.S. states compile regular annual greenhouse gas inventories (GHGIs) that are used as a benchmark in measuring progress toward greenhouse gas (GHG) emissions reduction goals (Maine Department of Environmental Protection 2024; NYDEC 2023; Vermont Agency of Natural Resources 2024). These territorial (also called sector-based) inventories typically cover GHG emissions occurring within the state's borders. They commonly include emissions associated with transportation, electricity production, industry, land use and forestry, commercial and residential buildings, and waste disposal. Many states already have initiatives to reduce sources of these territorial emissions. But GHG emissions are a driver of climate change, which is a global environmental issue. Emissions occurring out-of-state might also be associated with activities that are supporting a state, especially when a state is a consumer of a good that is produced or uses source materials or energy from another state or country. From a consumer perspective, states can therefore also reduce emissions related to the goods and services that their residents, businesses, and government consume, even when those emission occur outside the state. However, emissions associated with producing the goods and services consumed within a state are not traditionally quantified if they occur outside its territorial borders.

A consumption-based emissions inventory (CBEI) is an accounting method that can be applied to a region, including a state, that quantifies emissions associated with all goods and services consumed by a state, regardless of their origin. This approach allows these regions to more comprehensively account for emissions that their activities are directly and indirectly driving. A CBEI is commonly referred to by other names, such as a "GHG footprint".

The differences and commonalities between a territorial inventory (e.g., GHGI) and a consumption-based inventory (e.g., CBEI) have been depicted in Venn diagrams (e.g. BCIT and Cora Hallsworth Consulting (2017)), such as in Figure 1.

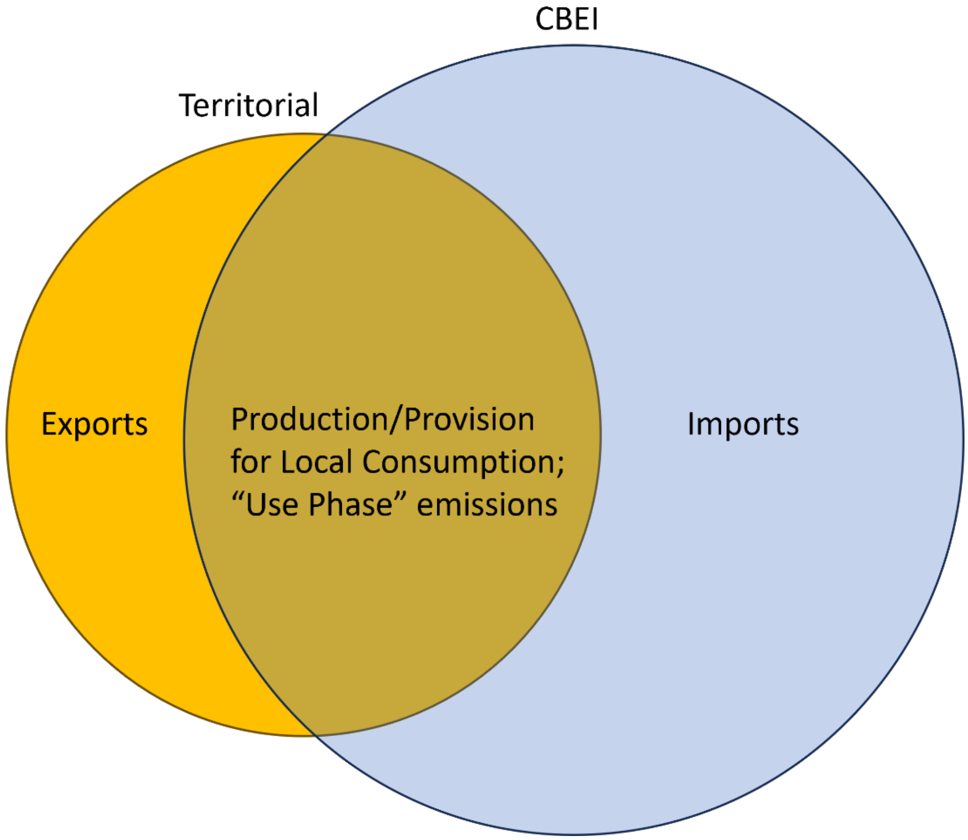

Figure 1. Venn diagram showing coverage of territorial inventory (GHGI) compared to a consumption-based inventory (CBEI).

GHGI and CBEI differences can be described in the context of a U.S. state. Where emissions associated with producing goods and services consumed in a state occur within that state, they appear in both the GHGI and CBEI. However, these emissions may be associated with the final consumed good and service, rather than the sector in which they occur. GHGIs will include all emissions associated with producing goods and services in a state, even those exported to other states, but a CBEI will not include these emissions. Instead, CBEIs include emissions occurring outside the state to make imports and deliver imported goods and services to consumers in a state. CBEIs can help regions understand the types of goods and services consumed that lead to the greatest GHG emissions and identify the upstream sources and locations where the emissions occur. This approach can help drive policy decisions focused on sustainable consumption and circularity (Hertwich 2005).

2.2 Who has used Consumption-Based Inventories for Regional Emission Quantification?

International organizations, other nations, subnational areas including states, and many cities have pursued estimations of consumption-based emissions. The International Panel on Climate Change, the international body providing the most authoritative global reports on climate change, uses consumption-based approaches as one metric in measuring progress toward emissions reductions, finding in 2023 that the top 10% of households with the highest per capita emissions contribute 34–45% of global consumption-based household GHG emissions (IPCC 2023). The Organization for Economic Development (OECD) has developed a methodology as a well as a database for estimating consumption-based emissions for member nations, including the U.S. (Yamano and Guilhoto 2020). The OECD regularly updates the consumption-based emissions as part of its greenhouse gas footprint indicators series (OECD 2024). The International Resource Panel that is governed by the United Nations Environment Programme regularly evaluates the impacts of global resource use in the *Global Resource Outlook*, and it uses a consumption-based approach to assess climate-related and other impacts associated with global resource use. They find that high-income countries drive 10 times more GHG emissions through consumption than low-income countries (United Nations Environment Programme 2024).

Many nations are now tracking consumption-based emissions using a CBEI or similar approach. The United Kingdom has adopted a CBEI as an official statistic (UK DEFRA 2024; Barrett et al. 2013) that is published annually by the Department of the Environment, Food, and Rural Affairs (DEFRA). Many other U.S. allies have national laws or policies requiring regular estimation and reporting of consumption-based emissions, including Canada (Environment and Climate Change Canada 2020), France (Bérengère et al. 2024), Sweden (Lind, Andersen, and Jensen 2024; Sanderson et al. 2024), Denmark (Lind, Andersen, and Jensen 2024; Sanderson et al. 2024; Statistics Sweden 2022) and Australia (Australian Government Department of Climate Change, Energy, the Environment and Water 2022). Other nations, such as Norway (Katkjær et al. 2021), have not adopted CBEIs as an official statistic or policy but have funded or sponsored one or more studies of their consumption-based emissions.

San Francisco, California, was one of the first cities to use CBEI models to estimate their GHG emissions. A CBEI model developed by the Stockholm Environment Institute was used to estimate emissions within and outside of San Francisco's geographic borders (Stanton et al. 2011). The state of Oregon used the same model to estimate the GHG emissions from producing, transporting, using, and disposing of their consumed goods and services using OR data (Erickson et al. 2012). The city of Seattle, Washington, also adapted this approach to estimate their emissions from household consumption in the 2012 Seattle Community Greenhouse Gas Emissions Inventory (Erickson and Tempest 2014). Similar models were then used for estimating the GHG emissions for the Oregon cities of Eugene (Good Company 2017) and Lake Oswego (Good Company 2012). The Urban Sustainability Directors Network has developed a guide for performing CBEIs (USDN 2019) that is largely based upon the Stockholm Environmental Institute guidance for performing CBEI at the city scale (Broekhoff, Erickson, and Piggot 2019).

Oregon was the first U.S. state to conduct a CBEI which was published in 2011 and covered calendar year 2005 (Erickson et al. 2012). The Oregon Department of Environmental Quality has since published updated CBEIs 3 times with coverage of years including (OR DEQ 2024). Minnesota published a CBEI in 2012 (MPCA 2021).

2.3 Using USEPA's Environmentally-Extended Input-Output Models to Perform a CBEI

There is no international standard for performing a CBEI. However, environmentally-extended input-output (EEIO) models are the dominant type of model used to performed regional CBEIs and have become the *de facto* standard approach (Wiedmann 2009; Barrett et al. 2013). The U.S. Environmental Protection Agency (USEPA) has developed a family of EEIO models to assess the comprehensive environmental impacts of goods and services consumed and produced within the U.S. economy. The U.S. Environmentally-Extended Input-Output (USEEIO) models couple economic input-output data with environmental data to derive estimates of potential life cycle environmental and economic impacts of goods and services produced or consumed in the United States (Yang et al. 2017; Ingwersen et al. 2022; USEPA 2020a). USEPA uses USEEIO models for its Sustainable Materials Management Prioritization Tools, which provide national and organizational perspectives on the life cycle of goods and services (USEPA 2020b). USEEIO models are widely used and are the basis for USEPA's supply chain GHG factors for U.S. industries and commodities (Ingwersen and Li 2020). Many organizations use these supply chain factors in their Scope 3 GHG inventories (World Resources Institute 2018). Organizations have already leveraged emissions data in the USEEIO model to conduct CBEIs and related analyses. Some examples are the New York City household CBEI (EcoDataLab 2023), the Seattle Communitywide Consumption-based GHG Emissions Inventory (EcoDataLab and Stockholm Environment Institute 2023), and the Alameda County, California, supply chain sustainability report (Alameda County 2021).

2.4 Motivation and Approach for this Study

State government representatives to the Northeast Waste Management Officials' Association (NEWMOA) approached USEPA seeking assistance with performing CBEIs for states in their region. Recent USEEIO model development efforts by USEPA have enabled the expansion of USEEIO to support state-level CBEIs. Specifically, USEPA has developed state-specific USEEIO State Models to provide environmental and economic information on goods and services that is reflective of state economies (Ingwersen et al. 2024a; Ingwersen et al. 2024b; Li et al. 2022). USEPA has also developed an approach to determine the embodied environmental flows related to imported goods, which include embodied GHG emissions (USEPA 2024). From this work, an initial set of import emission factors (IEFs) for GHGs were derived to use in USEEIO models.

In this report, the USEEIO State Models and the IEFs are integrated with traditional territorial GHGIs to develop CBEIs for eight northeastern U.S. states. While individual states and communities have undertaken their own CBEI efforts, this project represents the first attempt for a multi-state collaboration to build a common framework for state-level CBEI in coordination with USEPA. The report provides CBEI results for Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Rhode Island, and Vermont (Figure 2) and covers emissions from 2012 through 2020.

However, the modeling framework described here in the Methods and Data Sources section can be applied to calculate consumption-based emissions for any U.S. state.

Figure 2. Northeastern states included in CBEI results.

3 Methods and Data Sources

This work combines state-level territorial inventories with a family of state-specific models derived from the USEEIO model to create a framework for generating CBEIs for any state. Allocating emissions sources to U.S. industries follows an approach similar to the one first developed by USEPA in the National Greenhouse Gas Industry Attribution Model (Yang et al. 2020). Figure 3 highlights how these data sources are used to assign emissions to the state of interest (SoI) as well as the rest of the United States (RoUS) for a CBEI approach. The method for assigning GHG emissions resulting from purchases from other countries — denoted as the rest of the world (RoW) — are described further in the methods below.

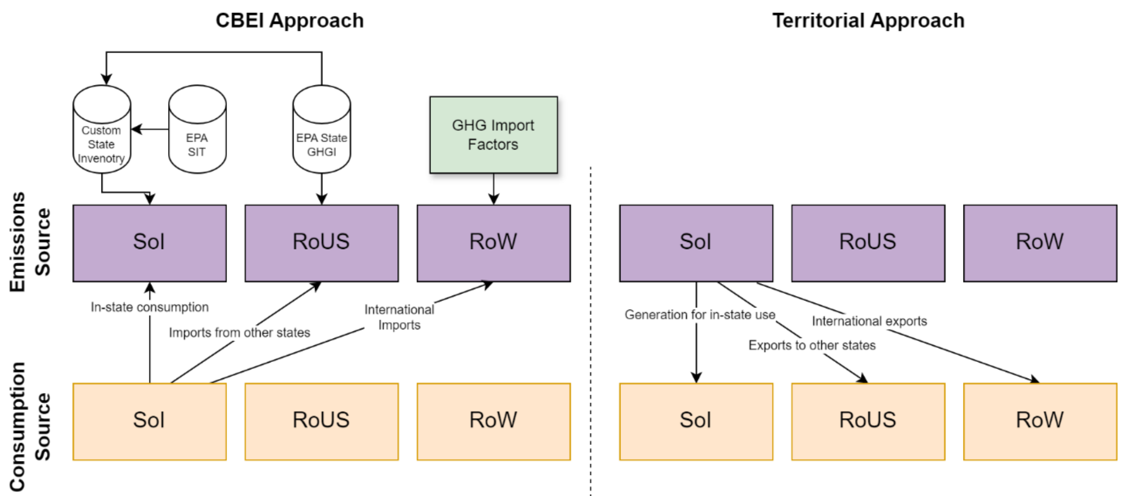

Figure 3. CBEI emissions attribution in contrast with territorial inventory emissions attribution. SIT = State Inventory and Projection Tool, SoI = State of Interest, RoUS = Rest of the United States, RoW = Rest of the World.

3.1 State GHG Emissions

Data sets of GHG emissions by state and industry are created in the Flow Sector Attribution (FLOWSA) tool v2.0.0 (Birney et al. 2023). This tool attributes emissions from primary data sources to industries using secondary data sources to create a Flow-By-Sector (FBS) data set. A full description of FLOWSA can be found in Birney et al. (2022) and its use in creating GHG FBS models in Young et al. (2024).

GHG FBS models are created specific to each state, where the target SoI reflects emissions data specific to that state's territorial GHGI, and the data for the remaining states reflects the emissions in USEPA's State GHG Emissions and Removals (USEPA 2023).

Details are provided below on the State Inventory and Projection Tool data, other state-provided GHGI data, and USEPA's State GHG Emissions and Removals data. Details on additional data used to create the state FBS files are included in Appendix D.

3.1.1 State Inventory and Projection Tool

Many states use USEPA's State Inventory and Projection Tool (SIT) as the basis for some or all of their GHGI. The SIT is a spreadsheet-based tool designed to help states develop GHG emissions inventories by streamlining data collection and calculations. It consists of 11 estimation modules and one overarching synthesis module that compiles data from the estimation modules. The 11 sector-level modules are:

- Carbon Dioxide, Methane, and Nitrous Oxide Emissions from Agriculture
- Direct CO_2 Emissions from Combustion of Fossil Fuels
- Methane Emissions from Coal Mining
- CO_2 Emissions from Electricity Consumption
- Industrial Processes
- Emissions and Sinks from Land Use, Land-Use Change, and Forestry
- CH_4 and N_2O Emissions from Mobile Combustion
- Emissions from Natural Gas and Oil Systems
- Municipal Solid Waste
- CH_4 and N_2O Emissions from Stationary Combustion
- Wastewater

Most of the major emission categories in the SIT overlap with those in the national GHGI; however, the national GHGI includes a few minor categories that are not captured in the SIT such as abandoned oil and gas wells, aerosols, composting, and ferroalloy production. The SIT includes default factors (e.g., activity data) by state and allows for individual state customization.

Maine and Vermont both use the SIT as the basis for their state-level GHGIs and provided the sector-level and synthesis modules to use in this effort. In the case of these two states, data from the SIT were used in place of USEPA's state-level GHG inventories. Data from the SIT modules were parsed and attributed to North American Industry Classification System (NAICS) industries, which is further aggregated in the USEEIO models using the FLOWSA tool to create FBS data sets. In some instances, the SIT provides emissions data as an amalgamation of multiple gases, such as emissions of perfluorocarbons from aluminum production reported as a single value in carbon dioxide equivalent (CO_2e). In such instances, the amalgamated data from the SIT were disaggregated and apportioned to specific GHGs (e.g., 89% CF_4, 11% C_2F_6) based on national totals from USEPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks.

3.1.2 State-Specific GHG Emissions Inventories

Maine, Vermont, and New York provided custom GHGI data sets that supplemented or superseded — either in whole or in part — the SIT data.

In the case of Maine, biogenic emissions associated with ethanol combustion, biodiesel combustion, wood combustion, and solid waste management were separately tracked by the Maine Department of Environmental Protection and provided for use in this effort. Since the SIT does not account for these categories of biogenic emissions, they were separately parsed using the FLOWSA tool to create an FBS data set and included as a supplement to the SIT data.

In the case of Vermont, methane emissions from natural gas distribution, emissions from ozone-depleting substances, emissions from semiconductor manufacturing, and methane emissions from solid waste were tracked separately by the Vermont Department of Environmental Conservation and provided for use in this effort. Since the SIT includes these categories of emissions, data from the SIT were removed and replaced by the custom data.

In the case of New York, the state's Department of Environmental Conservation has not historically relied on the SIT as the basis for their state-level GHG inventories, but rather developed their own custom statewide GHG emissions inventory, which was provided for use in this effort. The custom statewide GHG emissions inventory was parsed and attributed to industries using the FLOWSA tool to create an FBS data set. The custom statewide GHG emissions inventory had emissions categories and coverage that closely resembled those of the SIT, enabling the use of a comparable apportionment method.

3.1.3 EPA State GHG Inventories

EPA's State GHG Emissions and Removals provides estimates of state emissions by source that are consistent with the national GHGI (USEPA 2023). It includes time series estimates by gas, source/sink, and sector. It covers all anthropogenic sources and sinks, and seven gases: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. A description of the data set and its use in developing a state level GHG FBS from the EPA state GHG inventories is in Young et al. (2024). For this study, we used a state level GHG FBS based on the EPA state GHG inventories for Connecticut, Massachusetts, New Hampshire, New Jersey, and Rhode Island in our calculations of the CBEI for those respective states.

3.2 EEIO Model Development

GHG FBS are used as inputs into USEEIO State Models, a collection of two-region input-output models that track the flow of goods and services between a single state and the RoUS (Li et al. 2022). The development and structure of the USEEIO State Models are described in Ingwersen et al. (2024a), with new developments documented below. Appendix A provides a complete list of commodities included in the USEEIO State Models

3.2.1 Emissions from Foreign Imports

EPA implemented a coupled model approach to better characterize the GHG emissions embedded in imported goods and services (USEPA 2024). Previously, the USEEIO model managed imported goods and services under the domestic technology assumption; that is, the environmental burdens from the manufacturing of internationally sourced products equaled those of comparable products made in the United States. Furthermore, the USEEIO model relied on economic data that did not delineate the sources of imported goods and services, which is important for understanding what the average production emission profiles are for imported goods and services when they are produced in a variety of countries with their own technological, social, and political contexts affecting those values.

Emissions data from the EXIOBASE (v3.8.2) multi-region environmentally-extended input-output model were paired with trade data from the Bureau of Economic Analysis and the U.S. Census Bureau to generate weighted average emission factors of imports to the United States. These average factors were then incorporated into the USEEIO based on the split of domestic versus international production that is metabolized by the U.S. economy. This process resulted in differing levels of variation for the emission profiles of USEEIO commodities, with some imports emission factors falling below and above domestic production.

For USEEIO State Models, the import emission factors are the same as they are for the national model for a given year; in other words, the embodied emissions associated with importing $10,000 of computers in 2019 is the same for Maine as it is for California.

3.2.2 Consumption-based emissions with USEEIO

Preparing a CBEI for a given state of interest (SoI) using a USEEIO state model requires using the total final consumption of commodities by the SoI, which is internal to the model, to calculate the direct and indirect GHG emissions. Consumption is defined as the total goods and services to meet the needs of the final consumers in the SoI, including goods and services consumed by industries that produce, directly or indirectly, goods and services purchased by final consumers in the SoI. Final consumers include households, state and federal governments, and private firms making investments that don't contribute immediately to their production, such as fixed assets like equipment and real estate. To date, direct emissions from households or other final demands have not been included in USEEIO models (Ingwersen et al. 2022). However, environmental extensions compiled for use in USEEIO models regularly include emissions attributed to households, such as from personal vehicle transport or stationary combustion of fuels (Young, Birney, and Ingwersen 2024). For this effort, the domestic household emissions were added to USEEIO State Models. Appendix C provides the equations used to calculate CBEs.

3.2.3 Emissions Trade Balance

The emissions trade balance is defined as the sum of exported emissions minus imported emissions. Imported emissions are those occurring in the RoUS and RoW that are associated with SoI consumption. Exported emissions are those occurring in the SoI that are associated with consumption in the RoUS and RoW. Detailed equations for the emissions trade balance are provided in Appendix C.

4 Consumption-Based Emissions for Northeast States

We present the results of the CBE inventories first as totals across time and then compare these results to the state's respective territorial GHGI. We then evaluate changes over time in CBE in the context of changes in state resident population and consumption. Lastly, we evaluate emissions per resident and emissions per dollar consumed in an effort to better understand trends in CBEs. Appendix B provides additional results tables.

4.1 General Trends

Table 1 presents total consumption-based emissions (CBE) by state, for the whole Northeast, and for the U.S. for 2012–2020 in million metric tons (MMT) of CO_2e. The large differences in state CBE values reflect different population sizes and economies. Generally, CBEs declined over this period. More specifically, there was an increase in CBEs at first, followed by a decrease beginning around 2014 and slight increase again in 2019, followed again by a decline during 2020, which was the first year of the COVID-19 pandemic that caused a slowdown in economic activity. If the year 2020 is removed due to its atypical nature, the overall regional CBE trend does not show any significant decline or growth at the end of the period. The CBE of the Northeast comprises about 13% of the U.S. CBE. The Northeast CBE is the total of the CBE for the eight states in this study.

Table 1. Annual CBEs by state, for all the Northeast ("All NE"), and for the United States for 2012–2020 in MMT of CO_2e.

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT	77.1	78.9	81.3	82.0	79.9	77.2	81.0	78.3	71.7
MA	158.7	162.0	165.6	165.5	164.1	161.0	163.9	160.9	147.8
ME	28.8	29.9	30.4	30.9	30.2	29.8	29.6	29.0	27.4
NH	33.3	34.0	34.6	34.9	34.1	33.5	34.7	33.8	31.1
NJ	216.0	221.4	228.0	224.7	219.6	211.2	214.9	208.6	189.6
NY	438.0	448.7	457.6	457.8	447.0	437.6	454.7	467.3	395.4
RI	22.3	22.7	23.3	23.3	22.6	22.2	23.7	23.0	21.1
VT	13.9	13.9	13.9	14.3	14.0	13.7	14.2	14.0	12.8
All NE	988.1	1,011.4	1,034.8	1,033.4	1,011.7	986.1	1,016.8	1,014.9	897.0
U.S.	7,400.7	7,535.1	7,731.2	7,686.9	7,616.2	7,473.3	7,725.6	7,550.1	6,936.7

As discussed in the introduction, CBEs include emissions occurring upstream of the point of consumption; when those emissions occur out of state, they would not appear in the state's territorial inventory. The CBEI results are contrasted with the state territorial emissions in Figure 4.

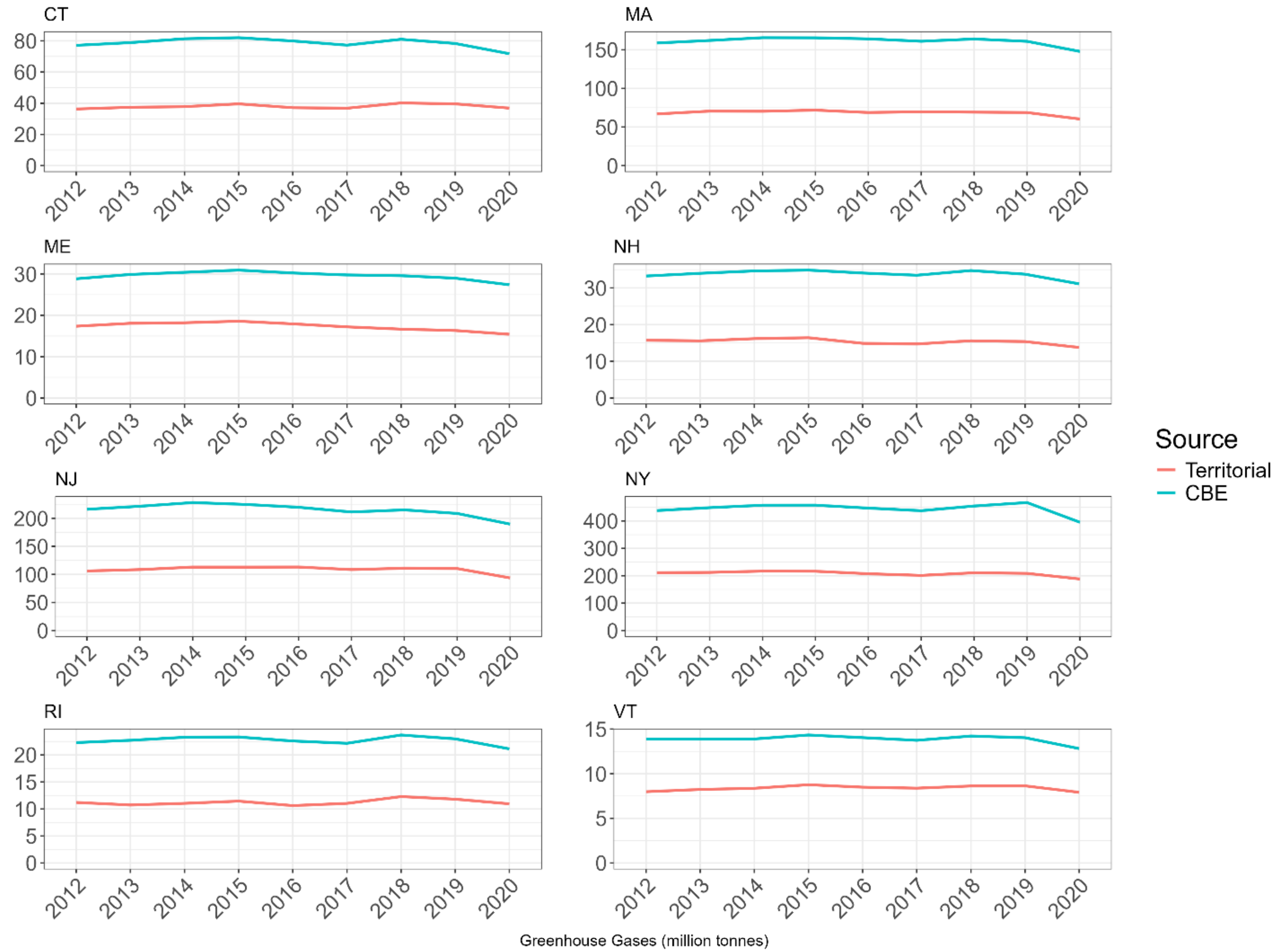

Figure 4. Comparison of CBEI and territorial inventory totals across time by state. GHGs from events like forest fires are excluded from the territorial inventory values as well as all other biogenic carbon emissions. The territorial GHG emissions range from about 40% of the CBE for Massachusetts to 61% of the CBE for Vermont. The trends in CBEs largely track the territorial emission trends but are not tied to it; for example, New York's CBE increased by ~3% from 2018 to 2019, but its

territorial GHGs decreased by 1%. It should be noted that there are some territorial emissions that are exported to make commodities consumed in other states or countries; therefore, this comparison is relative rather than territorial as a percent of CBE. Figure 5 shows the trends in CBE per resident when controlling for the population differences across states.

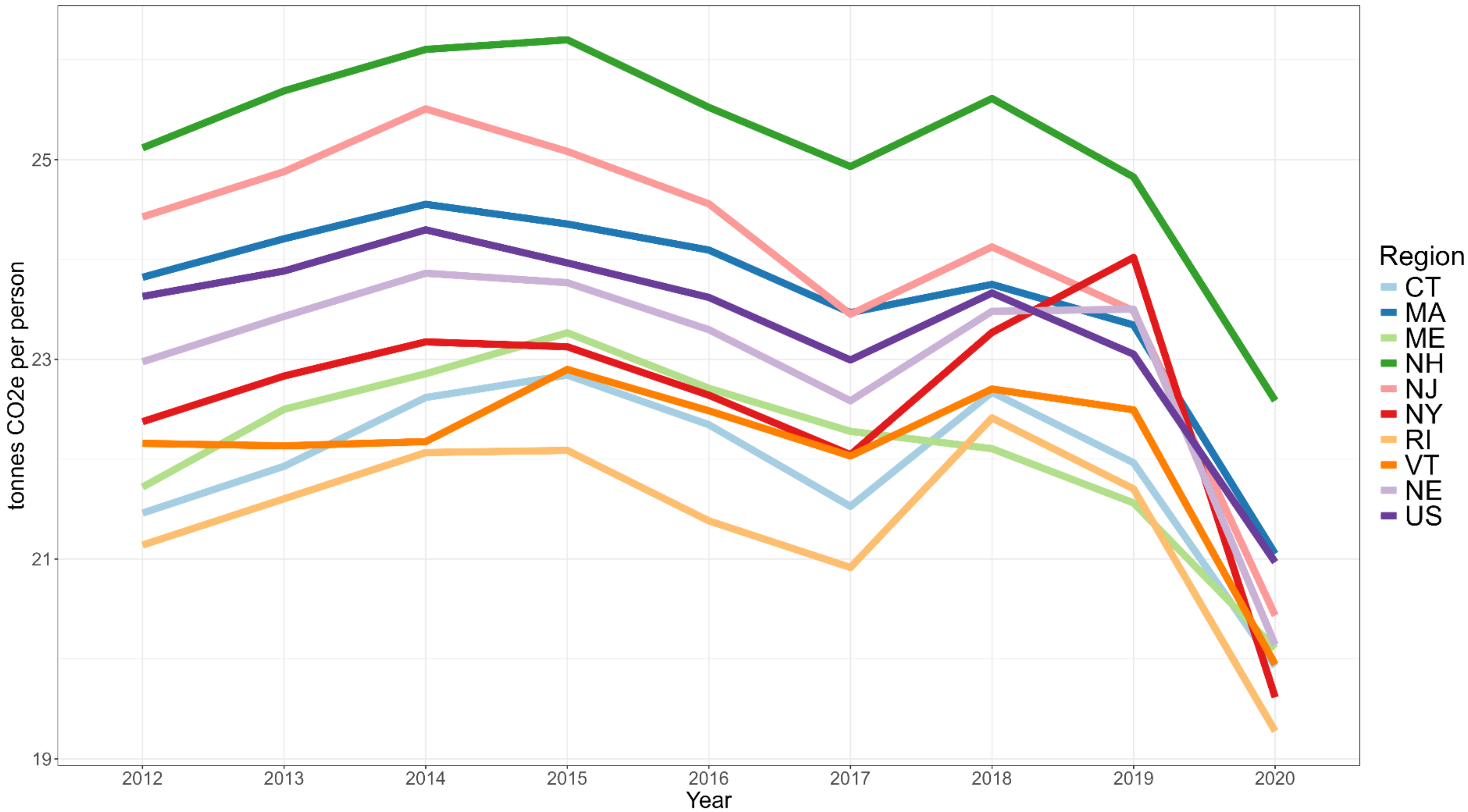

Figure 5. CBE per capita for Northeast states for 2012–2020. Units are in metric tons CO_2e per person. Note the y-axis is not fixed at 0 in order to show differences between states and over time. The trends mostly mirror the CBE trends, but there are notable differences between states. New Hampshire and New Jersey have higher CBEs per resident than other states across the time frame; Rhode Island, Connecticut and Maine have lower CBEs per resident.

Figure 6 shows the trends in final consumption per person, while Figure 7 shows the trends in emissions per U.S. dollar spent by final consumers.

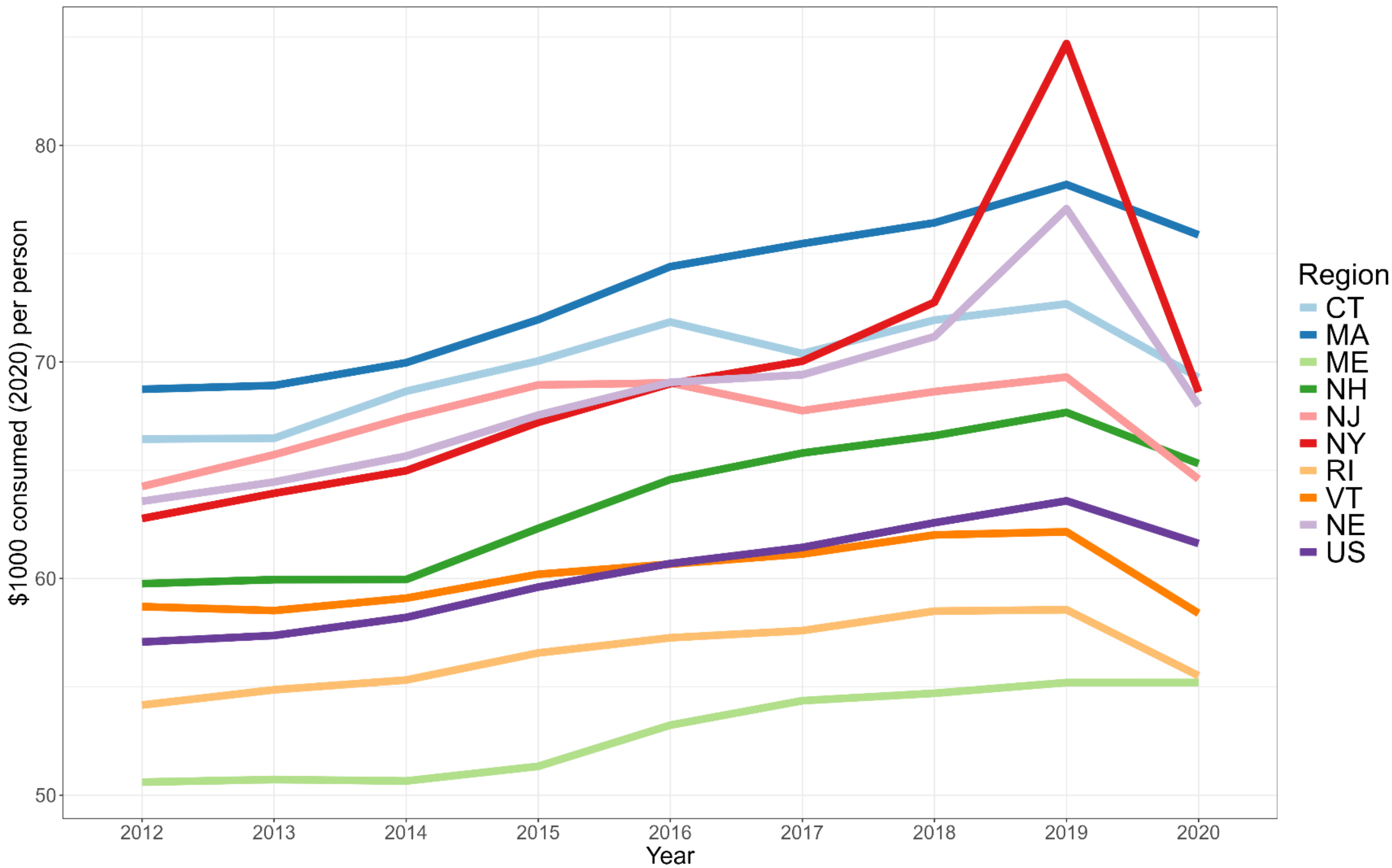

Figure 6. Consumption (2020 dollars) per person for Northeast states for 2012-2020. Note the y-axis is not fixed at 0 in order to show differences between states and over time. Consumption has trended upwards over time in all regions (excluding 2020).

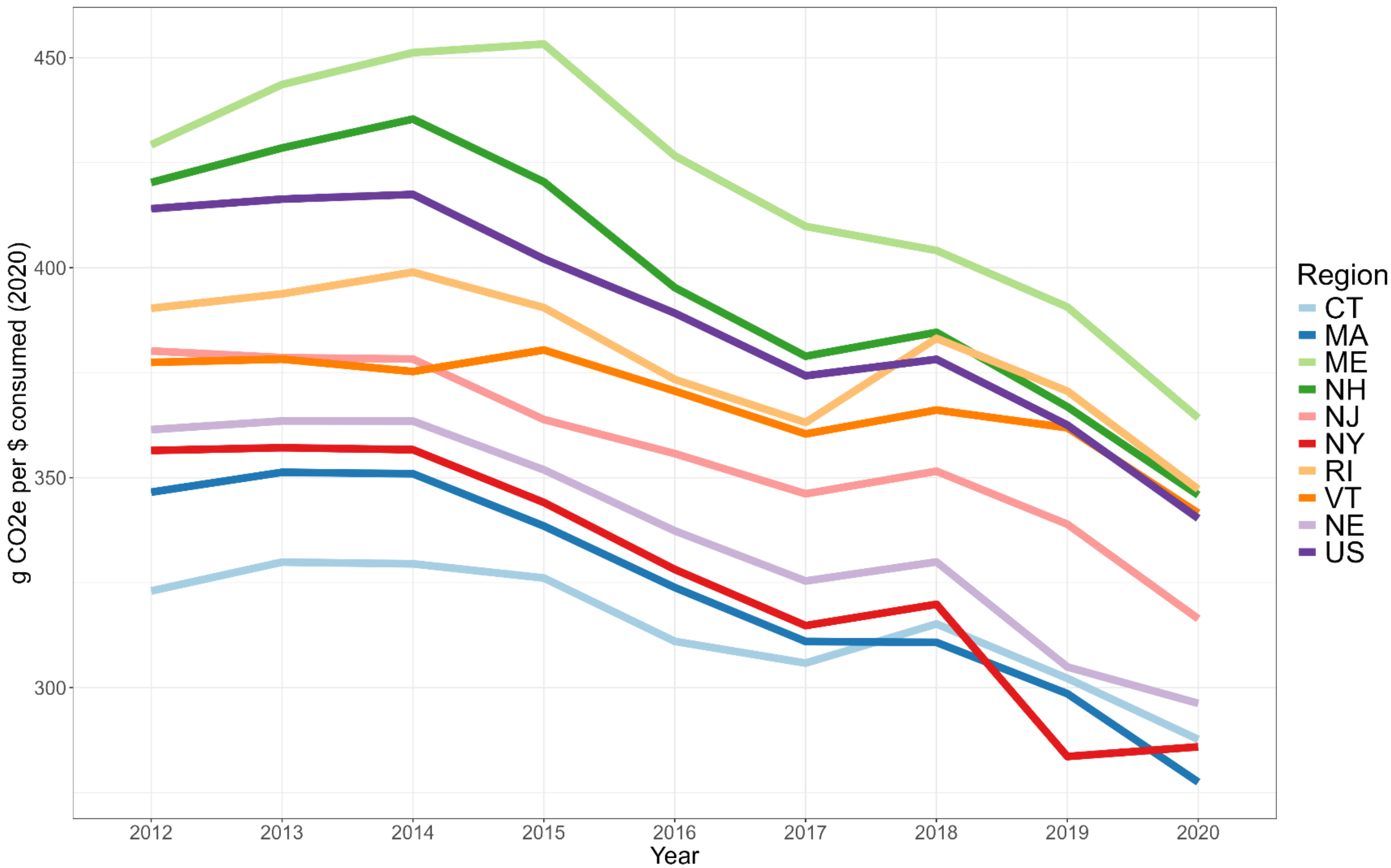

Figure 7. CBE per dollar consumed for Northeast states for 2012–2020. Note the y-axis is not fixed at 0 in order to show differences between states and over time. In contrast with CBE per resident, which does not change strongly between 2012 and 2019 (excluding 2020), the CBE per dollar decreases fairly consistently over the time frame. The states with higher CBEs per dollar relative to other states are not the same as those with higher CBEs per resident; those with higher CBE per dollar include Maine, New Hampshire, and Rhode Island.

Figure 8 shows the composition of the CBE by broader category. This figure compares states' CBEs per dollar by contributing category of goods and services consumed. Figure 9 shows a similar breakdown of CBE by category but shows this as an intensity of emission per dollar consumed in each state.

CT
MA
ME
NH
NJ
NY
RI
VT
Agriculture, forestry, fishing, and hunting
Mining
Utilities
Construction
Manufacturing
Wholesale trade
Retail trade
Transportation and warehousing
Information
Finance, insurance, real estate, rental, and leasing
Professional and business services
Educational services, health care, and social assistance
Arts, entertainment, recreation, accommodation, and food services
Other services, except government
Government
Households - Mobile
Households - Stationary
Region
State
RoUS
RoW
Greenhouse Gases (million tonnes)

Figure 8. CBE for Northeast states by category in 2020. Aggregate categories are shown in Appendix A. This figure also shows the origin of those commodities by region. By this categorization, manufactured goods are the largest category contributing to the state CBE, and the emissions mostly come from commodities made in RoUS or RoW and less so from within the state, but the breakdown varies by state. Household emissions from mobile combustion, utilities, government, and household stationary combustion are other important sources of emissions that come from within state, although a large portion of utilities CBEs for some states come from out of state. Education and health care services, construction, finance/insurance and real estate, retail trade, and transportation are significant sources in all states.

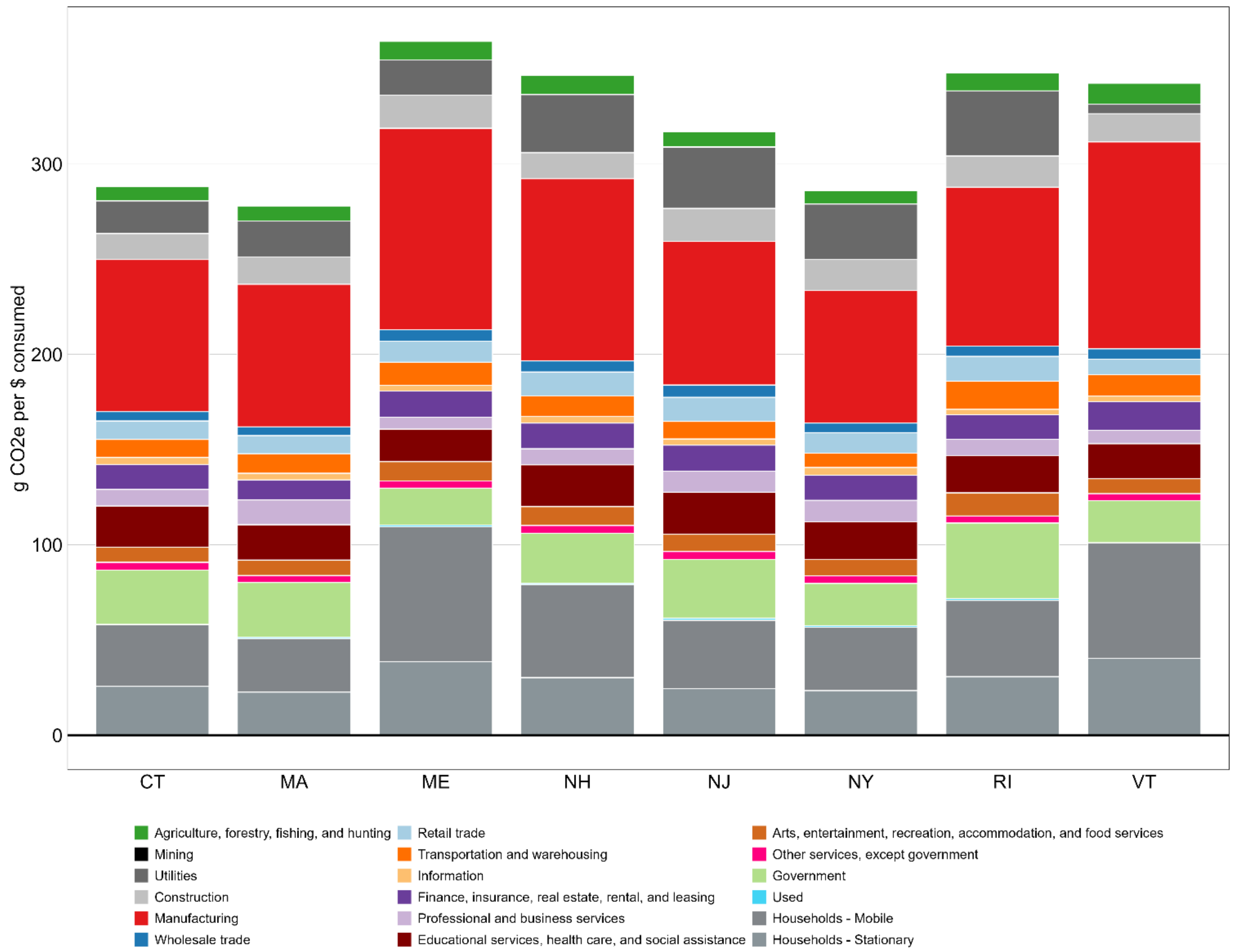

Figure 9. CBE comparison for Northeast states in 2020. This figure combines the data on CBEs per U.S. dollar consumed with the data on the purchase categories of CBE, comparing states for a single year. Household emissions from stationary and mobile combustion appear to be the purchase category contributing the most to the difference in CBEs per dollar across states, with Maine and Vermont having the highest shares of household emissions per dollar consumed.

The location of where CBEs occur is not captured in Figure 8 and Figure 9, as the regions indicate where the given commodities ship from, but emissions in their supply chains may occur in other regions. A balance of emissions is another way of assessing emissions from a consumption-based perspective. A trade balance in economics is typically defined as exports from a region minus the imports into the region, where a trade surplus indicates more goods and services leaving the region that coming in from outside the region. Analogously, trade balance information can be used to derive a trade emissions balance for each region. Emissions are exported from the SoI when they occur in the SoI but are associated with a commodity that is consumed outside the state, either in the RoUS or RoW. Imported emissions are those occurring out of state but associated with a commodity consumed by the SoI. Here, a positive trade balance is associated with a net import of emissions. Figure 10 presents a trade balance of emissions for each state in the region for 2012–2020. A detailed table of emissions trade balance with import and export emissions by region is provided in the Appendix in Table 13.

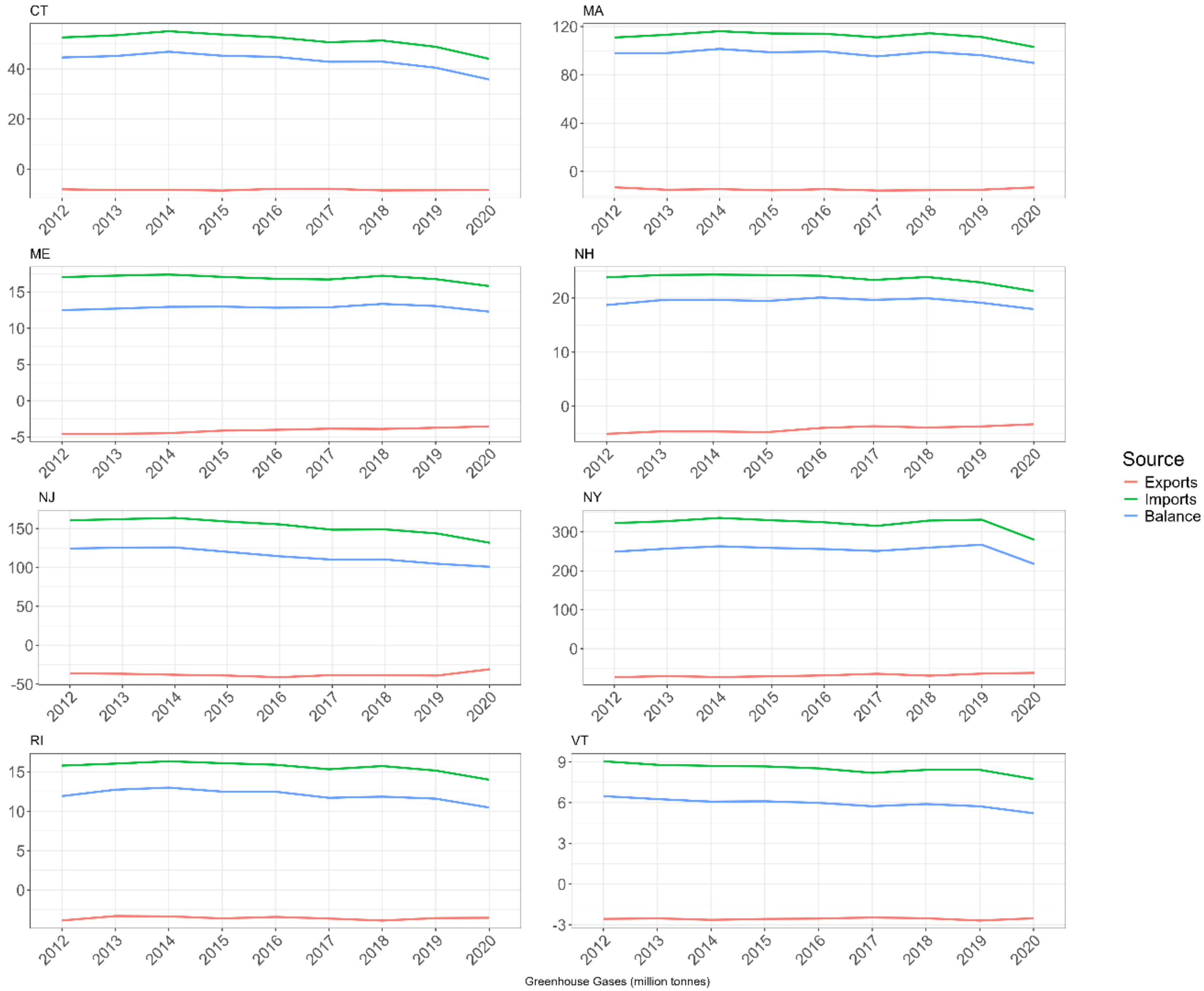
CT
MA
ME
NH
NJ
NY
RI
VT
2012
2013
2014
2015
2016
2017
2018
2019
2020
Source
Exports
Imports
Balance
Greenhouse Gases (million tonnes)

Figure 10. CBE trade balance for Northeast states from 2012–2020. All states in the region have a trade emissions deficit, on the order of about 50% as large as their total CBE. Imports of emissions that occur in the RoUS are the largest driver of this deficit, followed by emissions occurring in the RoW.

5 Maine Consumption-based Emissions in Depth

For deeper evaluation of the CBEI, we focused on the state of Maine. We evaluate the contributions to total CBE from purchase categories and of source regions of the purchases, and then delve into select goods and infrastructure including food, clothing, furniture, and the built environment to understand sources of emissions in these categories.

A CBE increase can be driven by an increase in the consumption of goods and services or in the embodied carbon intensity, measured in GHG emissions per dollar spent on goods and services, or by increases in both. Changes in consumption as measured in current U.S. dollars, which are the dollar value for the year in which goods are consumed, can be influenced by the changing value of the dollar when inflation or deflation are present. Changes in real consumption are better measured by using a constant dollar value across time to control for this effect. Figure 11 shows real consumption in Maine by source region. Figure 12 shows consumption by final consumer type.

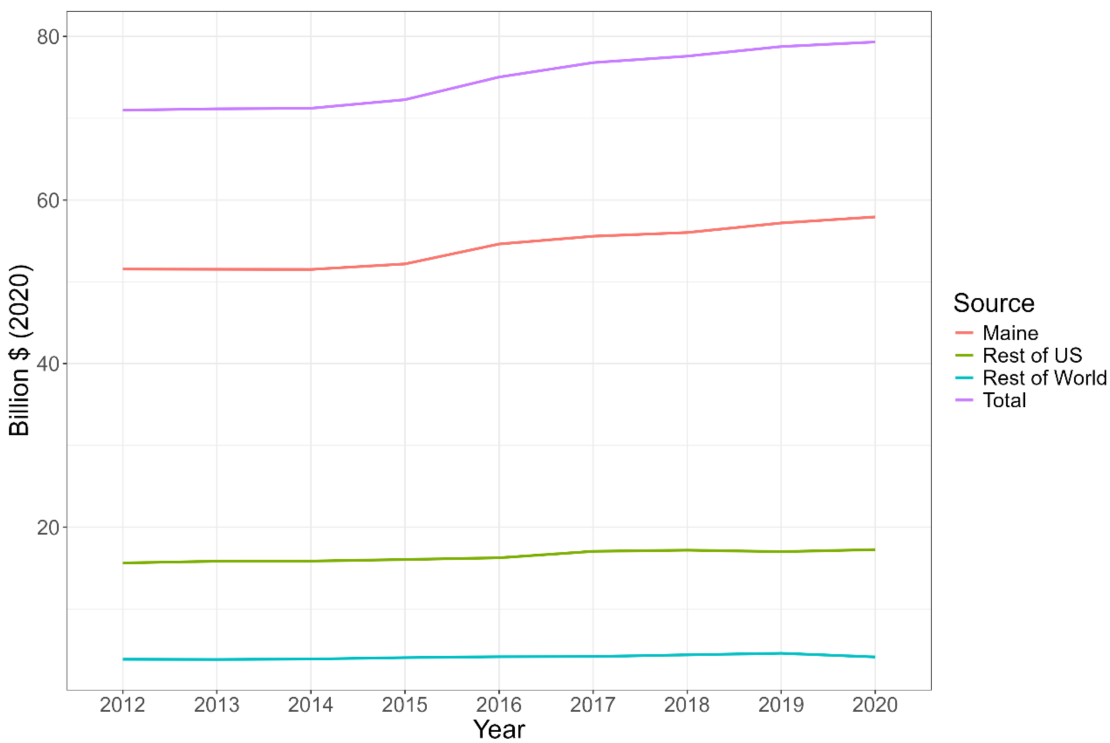

Figure 11. Maine consumption from 2012–2020, in constant 2020 dollars. Consumption of commodities sourced in the three regions are shown on separate lines, along with a total consumption line. A constant dollar is used to control for inflation and deflation. The majority of Maine-consumed goods and services come from within Maine and are consumed by households (in comparison with investors and the government). Real consumption was constant in the initial years but started to steadily increase, especially from Maine sources, from 2015–2020.

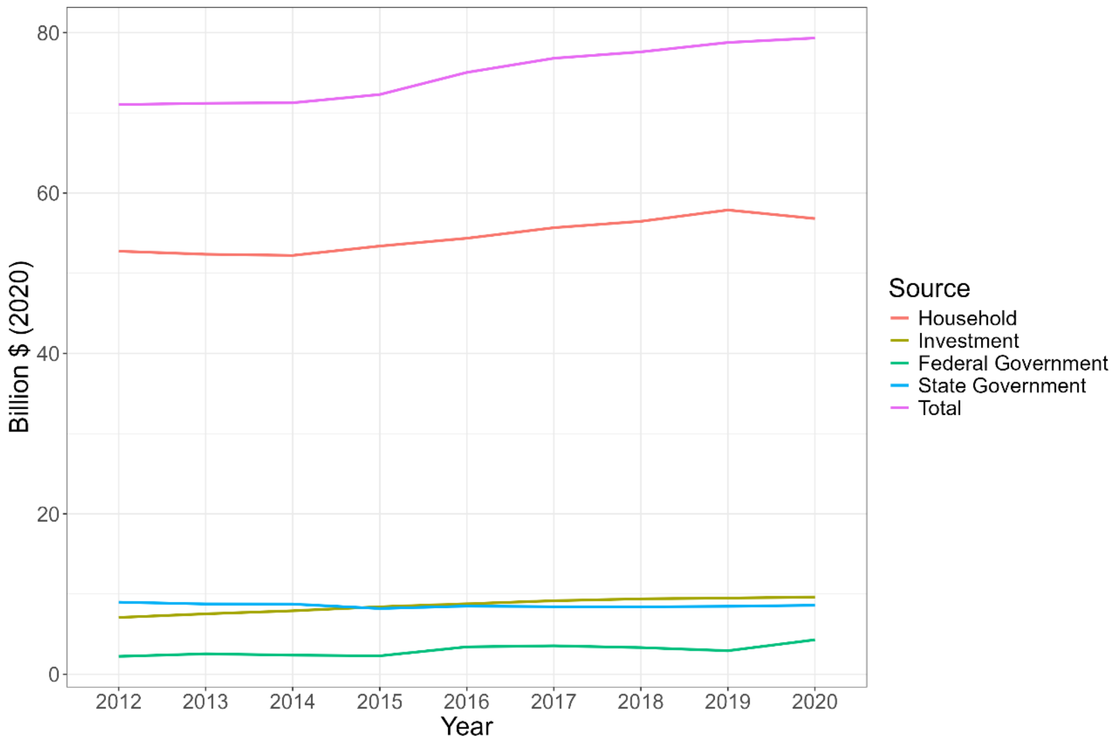

Figure 12. Trends in Maine consumption by consumer category in constant 2020 dollars. This figure shows that the increase in demand in Maine is driven primarily by households as opposed to changes in government expenditures or investment.

Table 2 presents the embodied carbon intensity of total consumption in Maine from 2012–2020. Maine embodied carbon consumption intensity increases in the initial study years and then decreases from 2015–2020 from 428 g CO2e per dollar spent to 345, approximately a 19% decrease over the time period.

Table 2. Trends in CBE, demand, and CBE per dollar spent in Maine over the study period. Demand and denominator of embodied emission intensity are in constant 2020 USD.

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020
CBE (MMT CO2e)	28.8	29.9	30.4	30.9	30.2	29.8	29.6	29.0	27.4
Spending (Billion USD 2020)	71.0	71.2	71.3	72.3	75.0	76.8	77.6	78.8	79.3
CBE / $ (grams per $)	406	420	427	428	403	387	381	368	345

In light of a decrease in overall CBE, an increase in real consumption, and a decrease in embodied carbon intensity, as shown in Table 2, it is clear that the decrease in CBE is driven by the decrease in the embodied carbon intensity of consumption over the time frame, which outweighs the effects of the increase in real consumption. However, this finding applies only to total CBE trends and does not provide insight into the variation that may exist across the categories of goods and services. A similar analysis of each category of goods and services would be required to see these differences by category.

Figure 13 shows the trend in CBE broken down by the category of goods and services purchased. Figure 14 also depicts the trends in these categories as a line graph to increase the ability to detect changes in categories. A table of results by sector is shown in Table 12 in Appendix B.

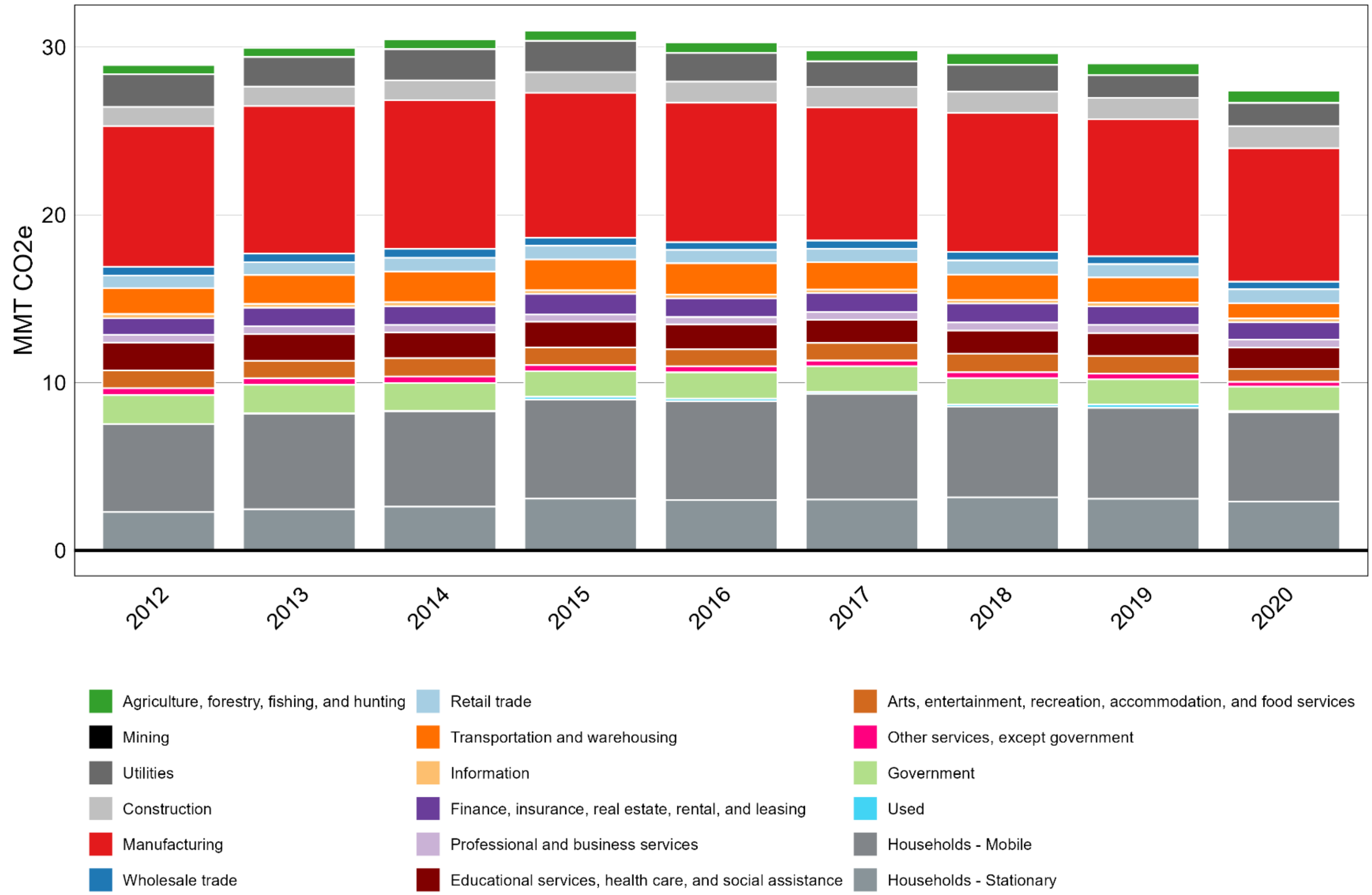

Figure 13. CBE broken down by aggregate purchase category for Maine from 2012–2020. Manufactured goods, personal transportation and residential heating and cooking are the largest contributors to CBE.

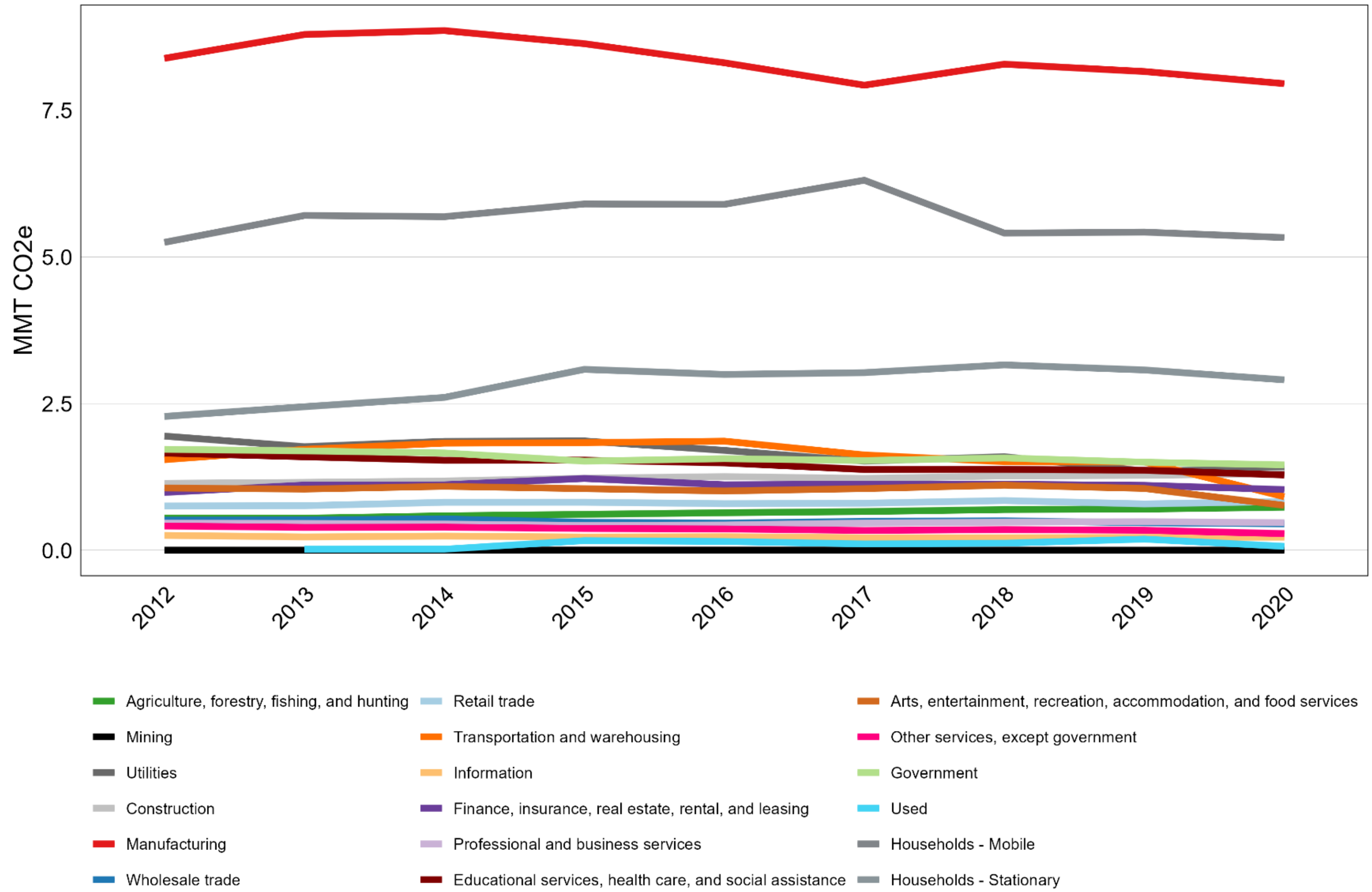

Figure 14. CBE broken down by aggregate purchase category for Maine from 2012–2020. Manufactured goods embodied emissions increase until 2014, then decrease, and then level off in the last years of the period. Household mobile combustion increased until 2017, then declined and leveled off. *Transportation and warehousing* along with *Arts, entertainment, recreation, accommodation, and food services* decrease notably in 2020, but this is likely an aberration due to the COVID-19 pandemic.

Maine, like other U.S. states, consumes goods and services made within the state, made in other U.S. states or the District of Columbia, or made outside the United States The relative shares of CBE by source region and aggregate purchase category are depicted in Figure 15. This figure replicates the smaller panel version for ME and all NE states in Figure 8.

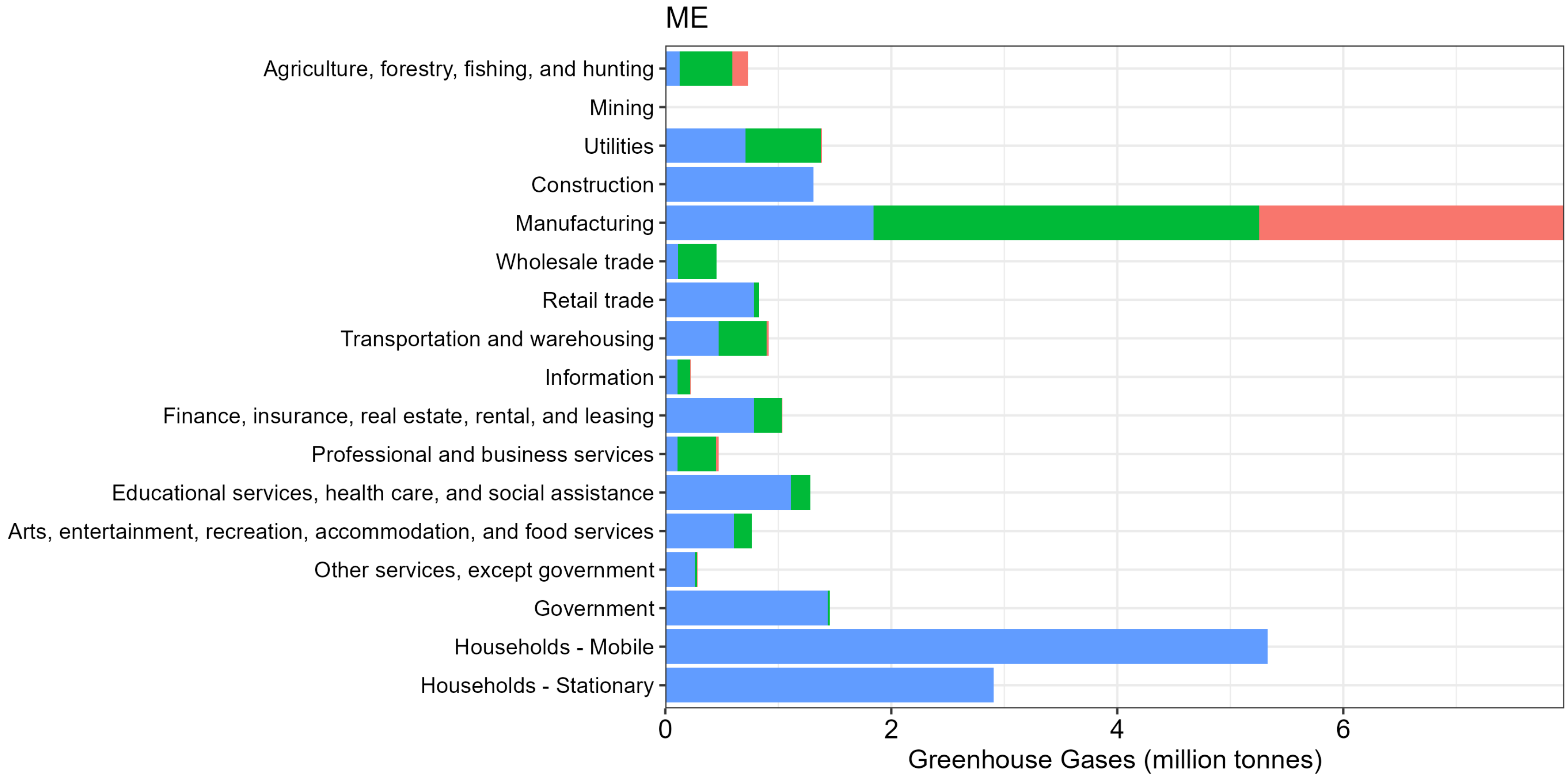

Figure 15. CBE by aggregate purchase category and source region for Maine. All goods and services categories are listed on the left with a stacked bar for the magnitude of GHG emissions. The bars break down total emissions by source region with Maine, Rest of U.S. and Rest of World as regions. Most categories have an unequal distribution of contributions from source regions. Most of manufactured good CBE is from the RoW and then the RoUS. Sources and embodied emissions for utilities, retail, and services (except for professional/business and finance and insurance services) are mostly from Maine. All emissions from households occur directly from residents, and therefore directly from Maine.

A view of CBE from more detailed purchases categories within manufacturing is presented in Figure 16.

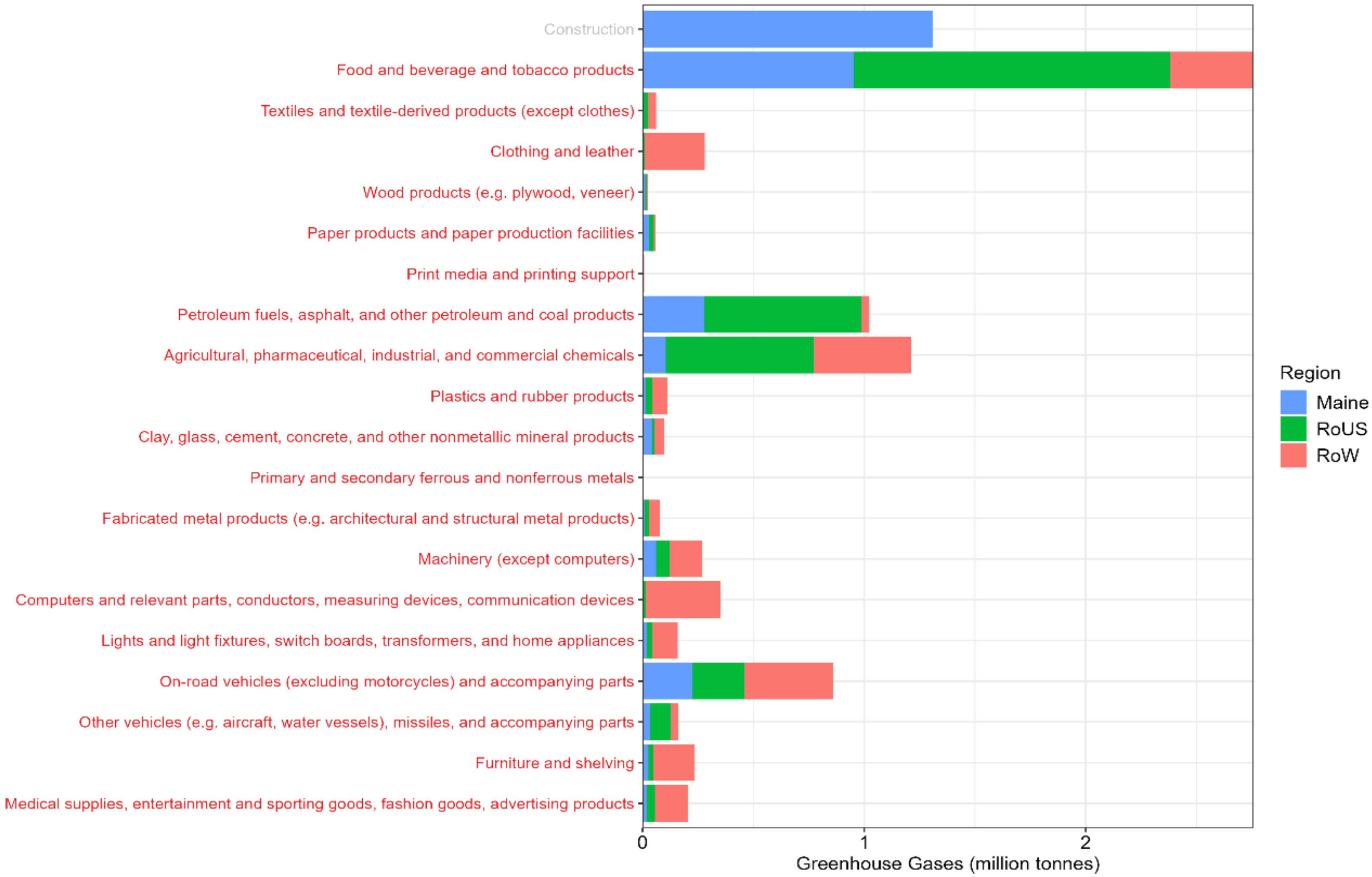

Figure 16. CBE by detailed purchase category and source region for Maine. All goods and services are listed on left with a

stacked bar for the magnitude of GHG emissions. The bars break down total emissions by region where the commodity was manufactured. The largest contributors among manufactured goods are food, petroleum products (mainly gasoline and diesel), chemicals, and vehicles. For categories like clothing, computers, and furniture, most emissions are associated with imported goods.

5.1 Contributions to Consumption-Based Emissions for Selected Commodities

The state of Maine Governor's Office of Policy Innovation and the Future convened various task forces to develop draft strategies for an updated state climate plan. The Materials Management Task Force strategy describes some plans to increase material circularity in the state to reduce or avoid direct emissions associated with materials (Maine MMTF 2024). A specific recommendation is built around food, which is the major CBE contributor among manufactured commodities. Other more general strategies describe means of increasing reuse and repair, which would apply to commodities such as clothing and furniture. In addition, the Buildings, Infrastructure and Housing working group developed a recommendation around lowering the impacts of embodied building materials (Maine BIHWG 2024).

The following sections explore the emissions intensity of food, clothing, furniture and building and infrastructure construction. Chemicals, petroleum and coal products, vehicles, computers and electronics, and machinery are also important sources of embodied emissions in Maine that are not explored in depth here. However, note that driving-related emissions are found in *Household Mobile* category for personal vehicle use and the *Transportation and Warehousing* category for commercial vehicle use.

5.1.1 Food

Figure 17 shows the embodied emissions contributions from a dollar of food made in Maine as well as from a dollar of food made in the RoUS and the RoW.

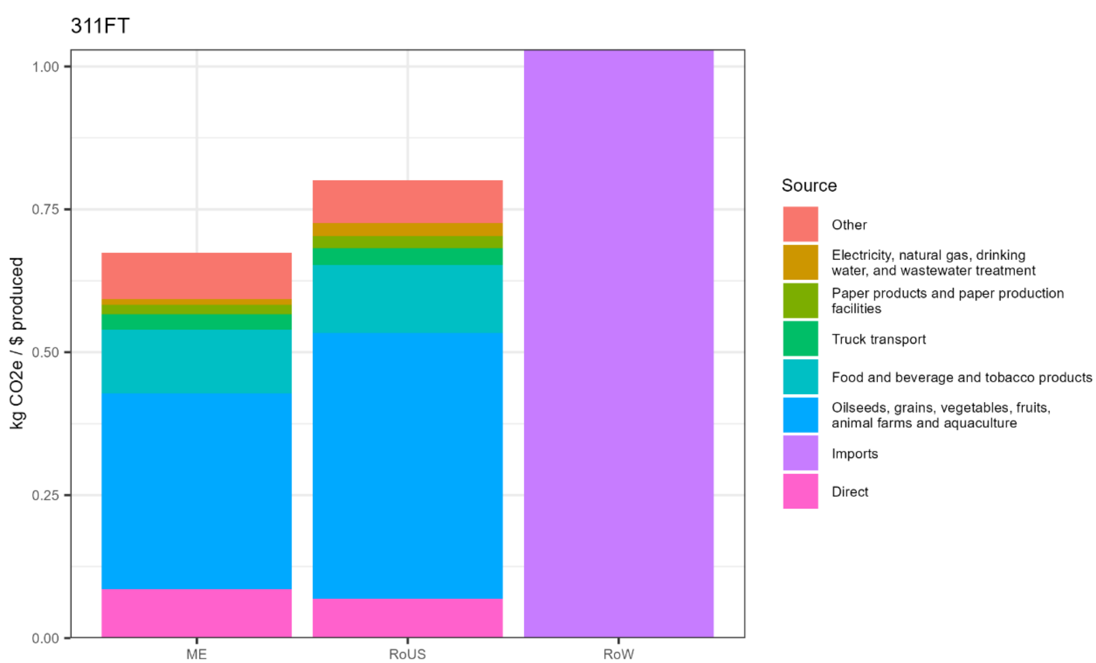

Figure 17. Embodied emissions per dollar of produced food by region. Food made in Maine is one stacked bar and food made in the RoUS is the other stacked bar. The "Direct" segment reflects emissions associated with the final processing stage of the

product. The other segments are contributions from purchases by the food manufacturer to make the food product. Imported food from the RoW embodies greater emissions per dollar than domestically produced food. Embodied emission intensity of food made in Maine is slightly less than that of food made in the RoUS, which embodies more emissions per dollar from farm products. The farm stage emissions are clearly the most significant, followed by emissions related to incorporating other food products (e.g., a manufacturer of microwave dinner might acquire multiple food products and assemble them in a tray for freezing), and direct emissions from food manufacturing facilities. Some of the embodied emissions in the ME and RoUS supply chains may come from imports. Note that these values do not embody the additional transportation requirements involved in moving the food to Maine consumers — which would likely increase these differences in intensity — nor the impacts of managing the food at the end-of-life stage.

5.1.2 Clothing

Figure 18 shows a similar profile for emissions intensity of clothing and leather goods.

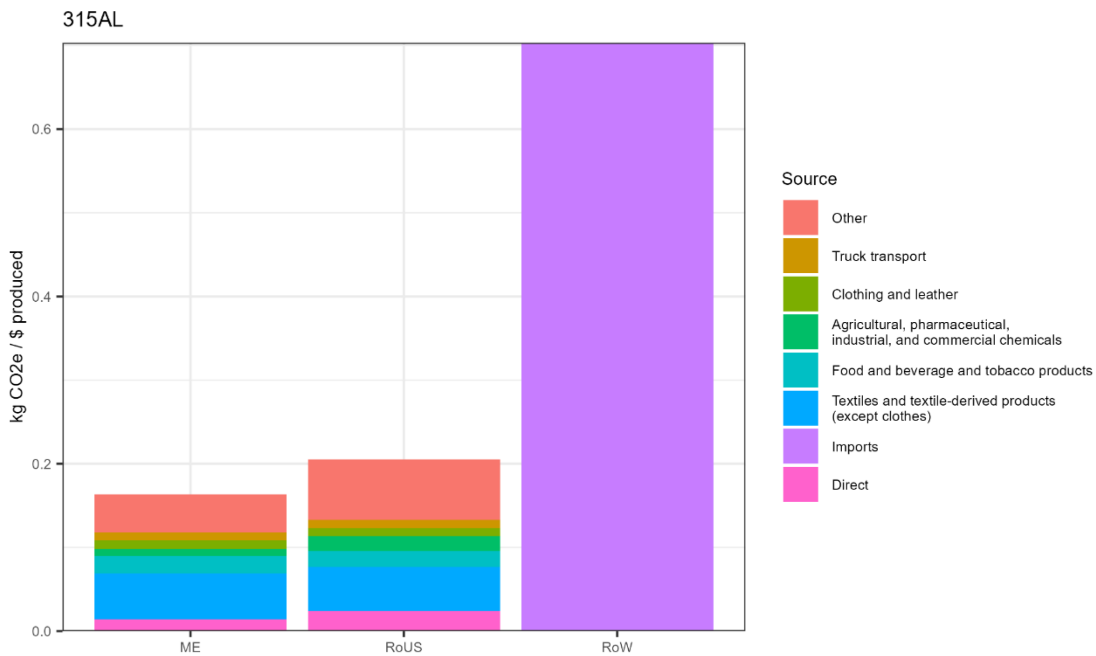

Figure 18. Comparison of production intensity for *Clothing Manufacturing*. Like for food, the imported products have a higher CO_2e in comparison with the domestic products, but in this case over five times as high. As shown in Figure 16, nearly all the CBE for this category comes from imports. Textile production is the largest embodied GHG contributor to domestically produced clothing both in Maine and the RoUS.

5.1.3 Furniture

Figure 19 shows embodied emission intensity of furniture.

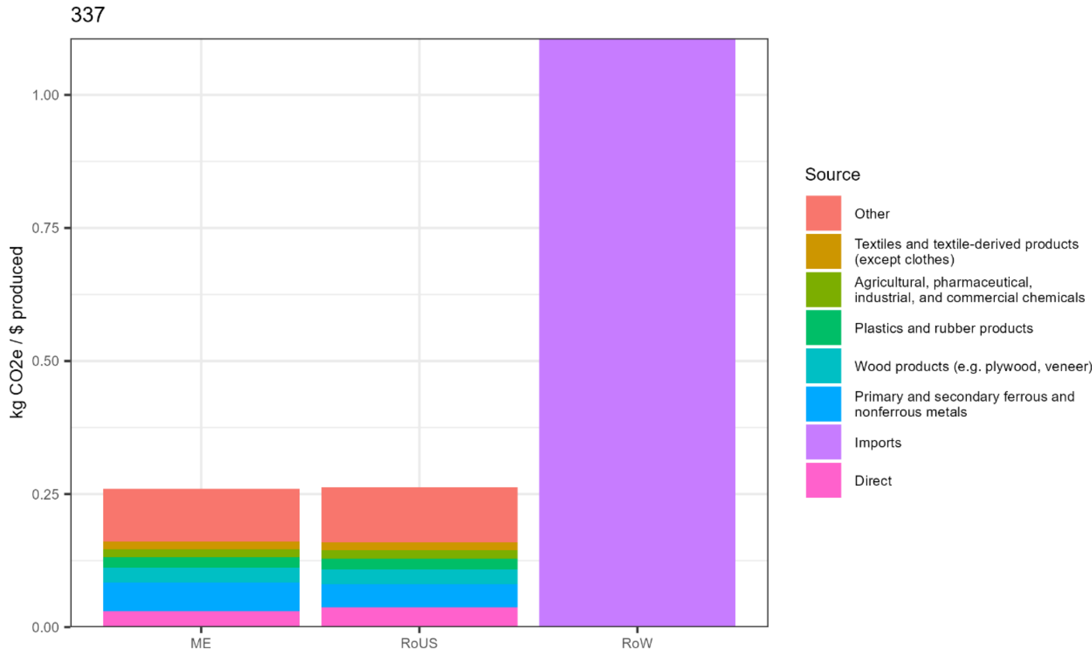

Figure 19. Comparison of production intensity for *Furniture Manufacturing*. Like for food and clothing, imported furniture has much higher (four times) the emissions intensity as domestic furniture. As with clothing, the differences between the Maine and the RoUS intensity appears small and likely insignificant. A diverse set of material production activities reflecting of the diversity of materials that furniture is composed of—including metals, wood, plastics and textiles—contribute to impacts, along with many other inputs that are grouped as "Other" due to their relatively small contributions.

5.1.4 Construction

Figure 20 shows the emissions intensity of the Construction sector in Maine and relative contribution of upstream emissions.

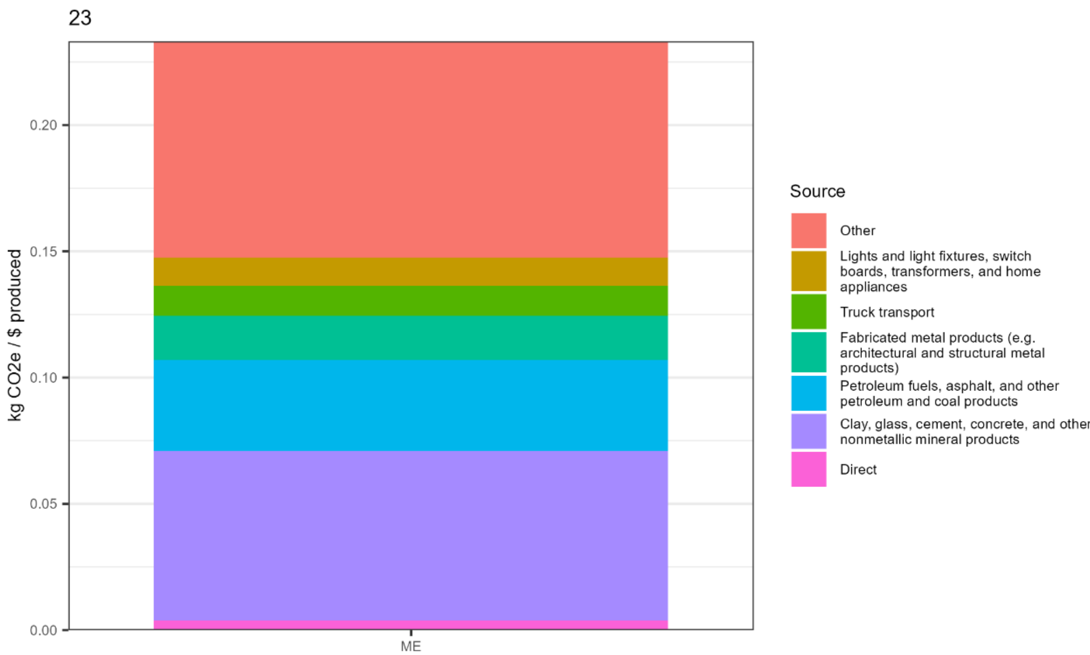

Figure 20. Comparison of production intensity for *Construction* activities. Profiles of other regions are not shown because Maine final consumers only purchase construction services from Maine providers in the Maine USEEIO model. These construction services include all built environment construction activities, including private single- and multi-family homes; commercial, industrial, and institutional buildings; highways and bridges; and utility infrastructure. Materials commodities are the primary contributors to the embodied emissions. In order of greatest contribution, they are: nonmetallic mineral products like concrete and glass, petroleum-based products (most likely asphalt), metal products, and raw materials, which are most likely construction sand and gravel.

6 Summary and Discussion

Complete CBEIs can be prepared for U.S. states using state-specific territorial GHGIs where emissions have been allocated to industries, along with USEEIO State Models that incorporate the GHG emissions for international imports. We prepared CBEIs for eight states in the Northeast covering 2012–2020. CBEs range from 40–60% higher than territorial GHG emissions for these states over this time frame. Overall change in CBE from 2012–2019 is very small or insignificant; 2020 CBE is less, but this year is not considered representative of a longer-term trend due to the COVID-19 pandemic. States are increasing their consumption of goods and services through this time frame, but this increase is offset by decreases in overall emissions per dollar consumed. We also explored the Maine CBEI in more depth, showing how the CBEI can be used to better understand sources of overall trends and to prioritize goods and services based on their contribution to CBE, as well as how emissions profiles compare for goods produced within state, out of state, and abroad.

The CBEIs are produced using models that are based exclusively on open access data and open source code. R markdown files are available so anyone with the requisite technical skills could build any of the USEEIO State Models for the years available (currently 2012–2020, the same years used for the CBEIs presented here) and compute a CBEI for any U.S. state, as well as replicate many of the same CBEI results presented here. Please see the Data and Code Availability section for more details.

Due to the vast amount of data and other models that they incorporate, these CBEIs have many dependencies, including the USEPA StateIO economic input-output models and associated stateior R package, USEPA's disaggregated state-level GHG inventories or state-provided GHG inventories and sector attribution models and the associated FLOWSA tool, the useeior R package, and import emission factors compatible with USEEIO from a global multi-regional input-output model. Each of those in turn has many data dependencies. These resources will need to be updated and maintained, at minimum, to produce CBEIs for states using these models for later or early years than the given time series. If any of the public statistics used in any of these models change or are no longer available, new data sources and methods will need to be developed to fill the gaps.

Each of these resources that support the models have limitations that will in turn limit the accuracy of the CBEI, particularly those model assumptions used to fill data gaps, such as the need to estimate state-level input-output tables, which are not produced as official statistics. As a consequence, the StateIO models use assumptions underlying the production structure of the states and the use structure of commodities by other industries, meaning they predominately reflect national-level structures (Ingwersen et al. 2024). Another shortcoming is the level of resolution of the StateIO and USEEIO State Models, which have only 73 categories of commodities, some of which are highly aggregated (like one commodity for fresh farm products). This level of aggregation does not allow differentiation of products with different CBEs that fall within the same category. These limitations could be overcome only through the systematic compilation of more state-specific industry statistics. The two-region format of the USEEIO state models also means each good or service made out-of-state has emissions that reflect the average emissions of that good or service made in the rest of the U.S., and not in the specific-state in which the product is made. However, a previous study performed by USEPA showed that for pollutants that are commonly reported and for which strong data exists, which is true for greenhouse gases, the use of the two-region form introduces a potential error of less than 20% for any given commodity (Yang, Ingwersen, and Meyer 2018). Unless the Northeast states here are consuming goods made primarily in one or more states with a very different emissions profile than the rest of the U.S., and that the emissions associated with consumption of that good are significant in the total state CBE, the results are unlikely to be meaningfully changed using a more complex model where imports from different U.S. states or regions are uniquely represented.

The model does not currently differentiate the transportation impacts of commodities from different regions (SoI, RoUS, RoW), so the transport requirements are not differentiated, nor are they associated with the commodities purchased. However, the factory-to-user transportation emissions are included in the Transportation and Warehousing sector.

While the CBEI results do include emissions from the use and disposal of commodities consumed in an SoI, emissions from the use and disposal phases are not associated with specific commodities, but rather aggregated together. Use phase emissions for commodities that are fuel-powered like automobiles, natural gas/oil home heating systems, and lawnmowers are included in “Households – mobile” and “Households – stationary”. Emissions associated with generation and distribution of electricity to power commodities like televisions, refrigerators, and mobile phones are found in "Utilities". Waste phase emissions for commodities that result in solid waste at end-of-life are included in the “Waste management and remediation services” sector.

7 Data and Code Availability

Supporting data including the USEEIO State models for all years and northeastern states for which a CBEI was performed along with more detailed CBE by sector are available in a supporting data entry Northeastern U.S. State Consumption-Based Emission Inventories - Supporting Files (Young and Ingwersen 2024).

The USEEIO State Model specification files used for the CBEI and example code to build models and produce CBEI results for any state are available at USEEIO-State on USEPA github. The specification files are provided for the time series 2012–2020 as shown in Table 4. The USEEIO State Models in this report are identified as v1.1 models. All state models that use the USEPA disaggregated state GHGIs are created in the master specification file named like “StateEEIOv1.1-GHG”. States that use a state-specific, or custom, GHG FBS based on the state-provided GHGI are denoted with “GHGc” in place of “GHG” and have their own custom specification files. Links to the custom FBS files for these states are included in Table 5.

The underlying StateIO economic data (v0.2.1) and the State GHG FBS (v2.0.0) remain unchanged from the USEEIO State Models v1.0 (Ingwersen et al. 2024). However, the v1.1 models include Import Emission Factors for GHGs (Table 3) and are constructed using useeior v1.6.1.

Table 3. Import Emission Factor data sets used in USEEIO State Models for CBEI.

Year	IEF_file
2012	US_summary_import_factors_exio_2012_12sch.csv
2013	US_summary_import_factors_exio_2013_12sch.csv
2014	US_summary_import_factors_exio_2014_12sch.csv
2015	US_summary_import_factors_exio_2015_12sch.csv
2016	US_summary_import_factors_exio_2016_12sch.csv
2017	US_summary_import_factors_exio_2017_12sch.csv
2018	US_summary_import_factors_exio_2018_12sch.csv
2019	US_summary_import_factors_exio_2019_12sch.csv
2020	US_summary_import_factors_exio_2020_12sch.csv

Table 4. USEEIO State Model specification files for 2020; for other years, the final two digits are replaced by the desired year.

Region	File
ME	MEEEIOv1.1-GHGc-20.yml
NY	NYEEIOv1.1-GHGc-20.yml
VT	VTEEIOv1.1-GHGc-20.yml
All states	StateEEIOv1.1-GHG-20.yml

Table 5. Flow-by-Sector output files for custom state GHG inventories.

State	Year	File
ME	2012	GHGc state ME 2012
ME	2013	GHGc state ME 2013
ME	2014	GHGc state ME 2014
ME	2015	GHGc state ME 2015
ME	2016	GHGc state ME 2016
ME	2017	GHGc state ME 2017
ME	2018	GHGc state ME 2018
ME	2019	GHGc state ME 2019
ME	2020	GHGc state ME 2020
NY	2012	GHGc state NY 2012
NY	2013	GHGc state NY 2013
NY	2014	GHGc state NY 2014
NY	2015	GHGc state NY 2015
NY	2016	GHGc state NY 2016
NY	2017	GHGc state NY 2017
NY	2018	GHGc state NY 2018
NY	2019	GHGc state NY 2019
NY	2020	GHGc state NY 2020
VT	2012	GHGc state VT 2012
VT	2013	GHGc state VT 2013
VT	2014	GHGc state VT 2014
VT	2015	GHGc state VT 2015
VT	2016	GHGc state VT 2016
VT	2017	GHGc state VT 2017
VT	2018	GHGc state VT 2018
VT	2019	GHGc state VT 2019
VT	2020	GHGc state VT 2020

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Good Company. 2017. "Eugene, Oregon Community Greenhouse Gas Inventory, Sector-Based Inventory for 2010 – 2015, Consumption-Based Inventory for 2013." Eugene, OR. https://www.eugene-or.gov/DocumentCenter/View/31137/2015-Community-GHG-Inventory---FINAL.

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Appendices

Appendix A. Commodity Code Descriptions

Commodity codes and descriptions for the models used in this report are shown in Table 6.

Table 6. Commodity codes and names.

Aggregate Category	Code	Name
Agriculture	111CA	Oilseeds, grains, vegetables, fruits, animal farms and aquaculture
Agriculture	113FF	Raw forest products, wild-caught fish and game, agriculture and forestry support
Mining	211	Unrefined oil and gas
Mining	212	Metal ores, dimensional stone, nonmetallic minerals
Mining	213	Well drilling and support activities for mining
Utilities	22	Electricity, natural gas, drinking water, and wastewater treatment
Construction	23	Construction
Manufacturing	321	Wood products (e.g. plywood, veneer)
Manufacturing	327	Clay, glass, cement, concrete, and other nonmetallic mineral products
Manufacturing	331	Primary and secondary ferrous and nonferrous metals
Manufacturing	332	Fabricated metal products (e.g. architectural and structural metal products)
Manufacturing	333	Machinery (except computers)
Manufacturing	334	Computers and relevant parts, conductors, measuring devices, communication devices
Manufacturing	335	Lights and light fixtures, switch boards, transformers, and home appliances
Manufacturing	3361MV	On-road vehicles (excluding motorcycles) and accompanying parts
Manufacturing	3364OT	Other vehicles (e.g. aircraft, water vessels), missiles, and accompanying parts
Manufacturing	337	Furniture and shelving
Manufacturing	339	Medical supplies, entertainment and sporting goods, fashion goods, advertising products
Manufacturing	311FT	Food and beverage and tobacco products
Manufacturing	313TT	Textiles and textile-derived products (except clothes)
Manufacturing	315AL	Clothing and leather
Manufacturing	322	Paper products and paper production facilities
Manufacturing	323	Print media and printing support
Manufacturing	324	Petroleum fuels, asphalt, and other petroleum and coal products
Manufacturing	325	Agricultural, pharmaceutical, industrial, and commercial chemicals
Manufacturing	326	Plastics and rubber products
Wholesale trade	42	Wholesale trade

Aggregate Category	Code	Name
Retail trade	441	Vehicles and parts sales
Retail trade	445	Food and beverage stores
Retail trade	452	General merchandise stores
Retail trade	4A0	Other retail
Transportation and warehousing	481	Air transport
Transportation and warehousing	482	Rail transport
Transportation and warehousing	483	Water transport (boats, ships, ferries)
Transportation and warehousing	484	Truck transport
Transportation and warehousing	485	Passenger ground transport
Transportation and warehousing	486	Pipeline transport
Transportation and warehousing	487OS	Couriers, messengers, transportation for leisure activities
Transportation and warehousing	493	Warehouses
Information	511	Media, literature, and software
Information	512	Film and sound-based entertainment
Information	513	Radio, TV, telecommunication
Information	514	Data processing, internet publishing, and other information services
Finance, insurance, real estate, rental, and leasing	521CI	Monetary authorities, depository and nondepository credit intermediation and related activities
Finance, insurance, real estate, rental, and leasing	523	Financial investments, exchanges, and advising
Finance, insurance, real estate, rental, and leasing	524	Insurance agencies, carriers, and brokerages
Finance, insurance, real estate, rental, and leasing	525	Funds, trusts, and financial vehicles
Finance, insurance, real estate, rental, and leasing	HS	Housing
Finance, insurance, real estate, rental, and leasing	ORE	Other real estate
Finance, insurance, real estate, rental, and leasing	532RL	Renting and leasing of goods, equipment, vehicles and nonfinancial intangible assets

Aggregate Category	Code	Name
Professional and business services	5411	Legal services
Professional and business services	5415	Computer programming and systems design
Professional and business services	5412OP	Miscellaneous professional, scientific, and technical services
Professional and business services	55	Company and enterprise management
Professional and business services	561	Administrative and support services
Professional and business services	562	Waste management and remediation services
Educational services, health care, and social assistance	61	Educational institutions and services
Educational services, health care, and social assistance	621	Healthcare professions, laboratories, and ambulances
Educational services, health care, and social assistance	622	Hospitals
Educational services, health care, and social assistance	623	Nursing, community, mental health, and substance abuse facilities
Educational services, health care, and social assistance	624	Child day care, community food services, housing services, and other relief services
Arts, entertainment, recreation, accommodation, and food services	711AS	Performing arts, spectator sports, museums, and related activities
Arts, entertainment, recreation, accommodation, and food services	713	Amusement facilities, gambling facilities, resort and recreation facilities
Arts, entertainment, recreation, accommodation, and food services	721	Hotels and campgrounds
Arts, entertainment, recreation, accommodation, and food services	722	Food and beverage establishments
Other services, except government	81	Other services, except government
Government	GFGD	Federal general government (defense)
Government	GFGN	Federal general government (nondefense)
Government	GFE	Federal electric utilities and postal service

Aggregate Category	Code	Name
Government	GSLG	State and local general government
Government	GSLE	Other state and local government enterprises including transit and utilities
Used	Used	Scrap, used and secondhand goods
Other	Other	Noncomparable imports and rest-of-the-world adjustment

Appendix B. Additional Result Tables

Table 7. Territorial emissions by region, MMT CO_2e.

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT	36.3	37.4	37.8	39.6	37.1	36.8	40.2	39.6	36.9
MA	66.9	70.5	70.3	71.8	68.7	69.7	69.2	68.7	60.3
ME	17.4	18.1	18.2	18.6	17.9	17.2	16.7	16.3	15.4
NH	15.8	15.6	16.2	16.4	14.9	14.7	15.6	15.4	13.8
NJ	106.1	108.6	113.0	113.0	113.1	108.6	111.0	110.4	93.7
NY	211.2	212.1	216.7	216.3	207.2	201.3	210.7	208.6	188.2
RI	11.2	10.7	11.0	11.4	10.6	11.0	12.3	11.8	11.0
VT	8.0	8.2	8.4	8.8	8.5	8.4	8.6	8.6	7.9
All NE	472.8	481.3	491.7	495.9	478.2	467.8	484.2	479.5	427.2
U.S.	6,610.5	6,791.6	6,846.8	6,690.2	6,538.8	6,502.6	6,685.9	6,571.4	5,982.0

Table 8. CBE per capita, metric tons CO_2e per person.

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT	21.5	21.9	22.6	22.8	22.3	21.5	22.7	22.0	19.9
MA	23.8	24.2	24.6	24.4	24.1	23.5	23.8	23.3	21.1
ME	21.7	22.5	22.8	23.3	22.7	22.3	22.1	21.6	20.1
NH	25.1	25.7	26.1	26.2	25.5	24.9	25.6	24.8	22.6
NJ	24.4	24.9	25.5	25.1	24.6	23.5	24.1	23.5	20.4
NY	22.4	22.8	23.2	23.1	22.6	22.0	23.3	24.0	19.6
RI	21.1	21.6	22.1	22.1	21.4	20.9	22.4	21.7	19.3
VT	22.2	22.1	22.2	22.9	22.5	22.0	22.7	22.5	19.9
All NE	23.0	23.4	23.9	23.8	23.3	22.6	23.5	23.5	20.1
U.S.	23.6	23.9	24.3	24.0	23.6	23.0	23.7	23.1	21.0

Table 9. CBE per U.S. dollar consumed in grams CO_2e per dollar (2020 dollars).

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT	323	330	329	326	311	306	315	302	288
MA	347	351	351	338	324	311	311	299	277
ME	429	444	451	453	427	410	404	391	364
NH	420	429	435	420	395	379	385	367	346
NJ	380	379	378	364	356	346	352	339	316
NY	356	357	357	344	328	315	320	284	286
RI	390	394	399	390	373	363	383	371	347
VT	377	378	375	380	371	360	366	362	342
All NE	361	363	363	352	337	325	330	305	296
U.S.	414	416	417	402	389	374	378	363	340

Table 10. Consumption per capita, dollars (2020 dollars) per person.

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT	66,437	66,474	68,647	70,044	71,843	70,387	71,931	72,679	69,274
MA	68,739	68,913	69,964	71,953	74,399	75,462	76,422	78,189	75,865
ME	50,601	50,720	50,654	51,330	53,231	54,360	54,703	55,197	55,198
NH	59,762	59,949	59,954	62,315	64,572	65,794	66,594	67,668	65,306
NJ	64,249	65,716	67,438	68,937	69,032	67,750	68,629	69,300	64,587
NY	62,770	63,934	64,978	67,209	68,995	70,036	72,753	84,696	68,608
RI	54,160	54,863	55,314	56,564	57,266	57,596	58,496	58,559	55,514
VT	58,704	58,520	59,093	60,196	60,666	61,131	62,013	62,158	58,394
All NE	63,567	64,457	65,652	67,545	69,060	69,407	71,167	77,077	67,986
U.S.	57,072	57,370	58,205	59,604	60,692	61,436	62,576	63,586	61,618

Table 11. Population, million persons.

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT	3.59	3.60	3.60	3.59	3.58	3.59	3.57	3.57	3.60
MA	6.66	6.69	6.75	6.79	6.81	6.86	6.90	6.89	7.02
ME	1.33	1.33	1.33	1.33	1.33	1.34	1.34	1.34	1.36
NH	1.32	1.32	1.33	1.33	1.33	1.34	1.36	1.36	1.38
NJ	8.84	8.90	8.94	8.96	8.94	9.01	8.91	8.88	9.28
NY	19.57	19.65	19.75	19.80	19.75	19.85	19.54	19.45	20.15
RI	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.10
VT	0.63	0.63	0.63	0.63	0.62	0.62	0.63	0.62	0.64
All NE	43.01	43.17	43.37	43.48	43.43	43.67	43.30	43.18	44.54
U.S.	313.2	315.5	318.2	320.7	322.4	325.0	326.5	327.5	330.8

Table 12. CBE for Maine, MMT CO2e.

Aggregate Category	2012	2013	2014	2015	2016	2017	2018	2019	2020
Agriculture, forestry, fishing, and hunting	0.55	0.547	0.587	0.613	0.64	0.66	0.694	0.702	0.734
Mining	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.002
Utilities	1.947	1.766	1.857	1.864	1.703	1.52	1.595	1.352	1.385
Construction	1.14	1.157	1.18	1.228	1.256	1.225	1.267	1.277	1.31
Manufacturing	8.377	8.787	8.855	8.634	8.31	7.93	8.288	8.163	7.956
Wholesale trade	0.515	0.518	0.535	0.476	0.463	0.493	0.502	0.47	0.452
Retail trade	0.755	0.759	0.818	0.818	0.795	0.802	0.847	0.79	0.831
Transportation and warehousing	1.545	1.72	1.826	1.835	1.861	1.625	1.51	1.505	0.913
Government	1.72	1.694	1.658	1.52	1.562	1.53	1.574	1.501	1.456
Information	0.254	0.227	0.241	0.226	0.231	0.213	0.214	0.218	0.223
Finance, insurance, real estate, rental, and leasing	0.986	1.111	1.116	1.224	1.117	1.127	1.127	1.107	1.034
Professional and business services	0.463	0.457	0.447	0.423	0.431	0.465	0.48	0.487	0.47
Educational services, health care, and social assistance	1.656	1.594	1.534	1.537	1.49	1.377	1.38	1.364	1.283
Arts, entertainment, recreation, accommodation, and food services	1.061	1.043	1.09	1.05	1.011	1.052	1.109	1.055	0.765
Other services, except government	0.413	0.39	0.394	0.371	0.364	0.337	0.353	0.341	0.284

Aggregate Category	2012	2013	2014	2015	2016	2017	2018	2019	2020
Other	-0.067	-0.068	-0.061	-0.052	-0.046	-0.043	-0.045	-0.04	-0.015
Used	-0.023	0.017	0.018	0.164	0.15	0.108	0.12	0.19	0.066
Households - Mobile	5.25	5.708	5.688	5.905	5.898	6.309	5.408	5.425	5.331
Households - Stationary	2.282	2.448	2.606	3.085	2.998	3.029	3.161	3.074	2.906

Table 13. Detailed trade balance by state. Positive values indicate net imports of emissions.

State	2012	2013	2014	2015	2016	2017	2018	2019	2020
CT									
Exports to RoUS	-6.48	-6.82	-6.82	-7.04	-6.49	-6.46	-6.99	-6.97	-7.09
Exports to RoW	-1.49	-1.44	-1.36	-1.42	-1.32	-1.32	-1.42	-1.37	-1.12
Imports from RoUS	31.52	32.50	32.45	31.09	30.19	29.97	29.59	27.98	25.35
Imports from RoW	21.04	20.89	22.58	22.63	22.45	20.68	21.74	20.85	18.68
Balance	**44.59**	**45.14**	**46.86**	**45.27**	**44.83**	**42.86**	**42.92**	**40.49**	**35.81**
MA									
Exports to RoUS	-9.97	-11.69	-11.44	-12.63	-11.72	-12.52	-12.47	-11.92	-10.96
Exports to RoW	-3.18	-3.46	-3.21	-2.97	-2.95	-3.27	-3.06	-3.19	-2.27
Imports from RoUS	68.31	71.51	72.17	69.39	68.42	68.38	69.83	68.24	63.39
Imports from RoW	42.67	41.73	44.01	44.87	45.67	42.73	44.66	43.12	39.68
Balance	**97.83**	**98.08**	**101.52**	**98.66**	**99.41**	**95.32**	**98.96**	**96.25**	**89.83**
ME									
Exports to RoUS	-3.45	-3.42	-3.38	-3.13	-3.09	-3.15	-3.15	-3.03	-3.02
Exports to RoW	-1.08	-1.12	-1.06	-0.97	-0.90	-0.69	-0.72	-0.69	-0.50
Imports from RoUS	10.47	10.56	10.36	9.96	9.82	10.13	10.16	9.94	9.45
Imports from RoW	6.57	6.69	7.04	7.13	7.01	6.59	7.08	6.83	6.37
Balance	**12.51**	**12.71**	**12.96**	**12.99**	**12.84**	**12.89**	**13.36**	**13.06**	**12.30**
NH									
Exports to RoUS	-4.66	-4.21	-4.20	-4.37	-3.61	-3.32	-3.54	-3.35	-3.05
Exports to RoW	-0.45	-0.44	-0.46	-0.44	-0.43	-0.38	-0.40	-0.40	-0.28
Imports from RoUS	16.11	16.50	16.37	15.91	15.72	15.54	15.57	14.90	13.88
Imports from RoW	7.72	7.77	7.98	8.35	8.41	7.81	8.34	8.01	7.41
Balance	**18.71**	**19.61**	**19.69**	**19.46**	**20.10**	**19.65**	**19.97**	**19.16**	**17.96**
NJ									
Exports to RoUS	-29.41	-29.66	-31.76	-33.11	-35.10	-32.24	-33.20	-33.62	-27.37
Exports to RoW	-6.77	-6.96	-6.14	-5.81	-5.94	-6.10	-5.41	-5.29	-3.42
Imports from RoUS	112.52	113.70	112.58	107.10	103.16	100.49	98.24	94.56	87.15
Imports from RoW	47.97	48.44	51.06	51.86	52.21	47.95	50.65	49.08	44.55
Balance	**124.31**	**125.52**	**125.74**	**120.05**	**114.33**	**110.09**	**110.27**	**104.73**	**100.91**
NY									
Exports to RoUS	-58.17	-57.01	-58.19	-58.33	-55.12	-52.60	-55.89	-51.76	-51.29
Exports to RoW	-15.22	-13.56	-14.74	-12.73	-13.73	-11.96	-13.61	-12.49	-10.93
Imports from RoUS	223.29	226.90	230.45	220.49	215.01	212.31	218.34	214.62	184.53
Imports from RoW	99.32	100.69	105.52	109.38	109.76	103.24	110.85	116.70	95.21
Balance	**249.22**	**257.01**	**263.04**	**258.82**	**255.93**	**250.99**	**259.68**	**267.08**	**217.53**
RI									
Exports to RoUS	-3.48	-2.94	-2.96	-3.24	-3.05	-3.24	-3.53	-3.22	-3.29

State	2012	2013	2014	2015	2016	2017	2018	2019	2020
Exports to RoW	-0.39	-0.37	-0.39	-0.37	-0.38	-0.39	-0.36	-0.36	-0.24
Imports from RoUS	11.13	11.38	11.41	11.02	10.76	10.53	10.57	10.15	9.42
Imports from RoW	4.67	4.68	4.95	5.10	5.16	4.81	5.18	5.03	4.60
Balance	**11.93**	**12.75**	**13.01**	**12.50**	**12.49**	**11.71**	**11.86**	**11.60**	**10.48**
VT									
Exports to RoUS	-2.02	-2.01	-2.15	-2.09	-2.09	-2.06	-2.11	-2.29	-2.19
Exports to RoW	-0.55	-0.52	-0.49	-0.48	-0.45	-0.40	-0.41	-0.39	-0.33
Imports from RoUS	5.05	5.07	4.95	4.76	4.61	4.53	4.52	4.66	4.28
Imports from RoW	4.00	3.72	3.76	3.91	3.91	3.66	3.89	3.76	3.46
Balance	**6.48**	**6.26**	**6.07**	**6.10**	**5.98**	**5.74**	**5.90**	**5.73**	**5.22**

Appendix C. Equations

The total final consumption of an SoI is calculated as in USEEIO v2 in Equation 1.

$$\mathbf{y_c} = \mathbf{y_h} + \mathbf{y_v} + \mathbf{y_g} \qquad (1)$$

where, $\mathbf{y_h}$ = household consumption, $\mathbf{y_v}$ = investment, $\mathbf{y_g}$ = federal, state, and local government consumption.

The data on each of these components is taken from the SoI model Use table.

These components can also be split into consumption of imports and domestic commodities, as in Equation 2 and Equation 3.

$$\mathbf{y_c}, \mathbf{d} = \mathbf{y_h}, \mathbf{d} + \mathbf{y_v}, \mathbf{d} + \mathbf{y_g}, \mathbf{d} \qquad (2)$$

$$\mathbf{y_c}, \mathbf{m} = \mathbf{y_h}, \mathbf{m} + \mathbf{y_v}, \mathbf{m} + \mathbf{y_g}, \mathbf{m} \qquad (3)$$

Since these equations are concerned with final consumption, $\mathbf{y_{c_d}}$ can be written as $\mathbf{y_d}$ for the final demand for domestic commodities, and $\mathbf{y_{c_m}}$ as $\mathbf{y_m}$ for the final demand for imported commodities.

This matrix contains direct emissions and resource use per 1 U.S. dollar only for the household sector (F010). Total direct household emissions, $\mathbf{e_h}$, is used to derive $\mathbf{h_h}$, the household emissions associated with a given consumption quantity in a model calculation, as shown in Equation 4.

$$\mathbf{h_h} = \mathbf{c}\mathbf{b_h}(\bar{\mathbf{y}}_\mathbf{h}\mathbf{i}) \qquad (4)$$

$\mathbf{b_h}$ is derived in Equation 5.

$$\mathbf{b_h} = \mathbf{e_h}\widehat{(\mathbf{y_h}\mathbf{\imath})}^{-1} \qquad (5)$$

From the CBE, total household demand is used for the calculation, meaning $\bar{\mathbf{y}}_\mathbf{h}$ = $\mathbf{y_h}$, and therefore $\mathbf{h_h}$ is more simply derived as Equation 6.

$$\mathbf{h_h} = \mathbf{c}\mathbf{e_h} \qquad (6)$$

These demand vectors are used with the SoI model to calculate the CBE in a three-part calculation, which builds off the three-part calculation of the total indirect and direct flows matrix $\mathbf{G^l}$ using the coupled model approach described in USEPA (2024).

First, we calculate the emissions from the SoI consumption of domestic commodities in Equation 7. Second, we calculate the emissions from the imported commodities used to make domestic goods consumed by the SoI in Equation 8. Third, we calculate the emissions from the SoI direct final consumption of imported commodities in Equation 9.

$$\mathbf{h_d^l} = \mathbf{c}\mathbf{M_d}\widehat{\mathbf{y_d}} + \mathbf{h_h} \qquad (7)$$

$$\mathbf{h_{mi}^l} = \mathbf{c}\mathbf{M_m}\mathbf{A_m}\mathbf{L_d}\widehat{\mathbf{y_d}} \qquad (8)$$

$$\mathbf{h}_{\mathbf{mf}}^{\mathbf{l}} = \mathbf{c}\mathbf{M}_{\mathbf{m}}\widehat{\mathbf{m}_{\mathbf{f}}} \qquad (9)$$

In these equations, $\mathbf{h}^{\mathbf{l}}$ are vectors of total emissions in CO_2e for all commodities, and $\mathbf{c}$ is a vector of CO_2e derived from the International Panel for Climate Change from the 5th Assessment Report (IPCC 2014; Young, Cashman, and Ingwersen 2023). $\mathbf{M}_{\mathbf{d}}$ is the direct and indirect GHG per dollar commodity output matrix (i.e., multiplier matrix) derived from the model. $\mathbf{M}_{\mathbf{m}}$ are the import emission factors (USEPA 2024). $\mathbf{A}_{\mathbf{m}}$ is the direct requirements matrix for imports only and $\mathbf{A}_{\mathbf{d}}$ is the direct requirements matrix for domestic commodities only. $\mathbf{L}_{\mathbf{d}}$ is the total requirements matrix for domestic commodities. The derivation of $\mathbf{M}_{\mathbf{d}}$, $\mathbf{L}_{\mathbf{d}}$, and $\mathbf{A}_{\mathbf{d}}$ and as described for USEEIO 2 models (Ingwersen et al. 2022), and the specifics of these matrices in USEEIO State Models in terms of shape are described in the USEEIO State Models report (Ingwersen et al. 2024).

The product of the three-part equations is combined by the region from which the consumed product comes (SoI, RoUS, or RoW) in the arrangement described in Equation 10.

$$\mathbf{h}^{\mathbf{l,soi}} = \begin{bmatrix} \mathbf{h}_{\mathbf{d}_{soi}}^{\mathbf{l}} + \mathbf{h}_{\mathbf{mi}_{soi}}^{\mathbf{l}} \\ \mathbf{h}_{\mathbf{d}_{rous}}^{\mathbf{l}} + \mathbf{h}_{\mathbf{mi}_{rous}}^{\mathbf{l}} \\ \mathbf{h}_{\mathbf{mf}}^{\mathbf{l}} \end{bmatrix} \qquad (10)$$

The sum total of $\mathbf{h}^{\mathbf{l,soi}}$ is the CBE total for the SoI.

Emissions Trade Balance

The emissions trade balance for a state is defined in Equation 11.

$$(E^{m,rous} + E^{m,row}) - (E^{x,rous} + E^{x,row}) \qquad (11)$$

$E^{x,rous}$ is exported emission to the RoUS. It includes the emissions from RoUS consumption + RoUS foreign exports occurring in the SoI.

$E^{x,row}$ is exported emissions to the RoW. It includes the emissions associated with production of foreign exports occurring in the SoI.

$E^{m,rous}$ is imported emissions from the RoUS. It includes the emissions from SoI consumption + SoI foreign exports occurring in the RoUS.

$E^{m,row}$ is imported emissions from the RoW. It includes the emissions from international imports consumed to make goods that are consumed in Maine and international imports consumed by final consumers.

$$E^{x,rous} = \mathbf{h}_{\mathbf{d}}^{\mathbf{r,rous}}{}_{soi} \qquad (12)$$

$$E^{x,row} = \bar{\mathbf{h}}_{\mathbf{d}}^{\mathbf{r,soi}}{}_{soi} \qquad (13)$$

where the y is the export vector.

$$E^{m,rous} = \mathbf{h}_{\mathbf{d}}^{\mathbf{r,soi}}{}_{rous} \qquad (14)$$

$$E^{m,row} = \mathbf{h}_{\mathbf{mi}}^{\mathbf{r,soi}} + \mathbf{h}_{\mathbf{mf}}^{\mathbf{r,soi}} \qquad (15)$$

Derivation of an “M” and “N” matrix for USEEIO models with Import Emission Factors

USEEIO Models that are built with import emission factors as described in Ingwersen et al. (2024) including the models used for the state CBEIs herein include matrices for direct and indirect flows from domestic production, $\mathbf{M_d}$, and from imports, $\mathbf{M_m}$ and associated matrices with characterized flows in $\mathbf{N_d}$ and $\mathbf{N_m}$. These matrices are used in model result calculations for this form of USEEIO model. However, for model analysis it is still useful to have common $\mathbf{M}$ and $\mathbf{N}$ matrices. These matrices can be derived using the following equations.

$$\mathbf{M_d} = \mathbf{BL_d} \qquad (16)$$

$$\mathbf{M_{mi}} = \mathbf{M_m A_m L_d} \qquad (17)$$

$$\mathbf{M} = \mathbf{M_d} + \mathbf{M_{mi}} \qquad (18)$$

Equation 16 shows the derivation of $\mathbf{M_d}$, which represents the direct and indirect environmental flows (domestic flows only) per dollar produced associated with domestic total requirements $\mathbf{L_d}$, where $\mathbf{B}$ are the direct domestic flows. Equation 17 shows the derivation of $\mathbf{M_{mi}}$, which represents the embodied environmental flows in imports $\mathbf{M_m}$ from the use of imports by domestic industries to make their commodities both directly, in $\mathbf{A_m}$, and indirectly by scaling it to total requirements of domestic production using $\mathbf{L_d}$.

Summing them in Equation 18 provides $\mathbf{M}$.

$$\mathbf{N} = \mathbf{CM} \qquad (19)$$

$\mathbf{N}$ is derived as previously described simply by left-multiplying $\mathbf{M}$ by $\mathbf{C}$ as shown in Equation 19.

These matrices are used in the estimation of embodied flows per dollar produced in a region as shown in the report in Figures 17 - 20.

Appendix D. Additional Flow-By-Sector and Import Emission Factor Data Details

Flow-By-Sector Allocation Sources

Allocation data sources used to allocate state GHGI totals to sectors include the Manufacturer Energy Consumption Survey (MECS), Detailed National Use tables, and the Census of Agriculture's (CoA's) Cropland by NAICS data sets. These data sets are not all annual data sets, and therefore some are used for allocation for multiple years. The allocation data source data years used in allocated state GHGI data by year are shown in Table 14.

Table 14. Data years for allocation sources by year.

Allocation Source	2012	2013	2014	2015	2016	2017	2018	2019	2020
EIA MECS	2014	2014	2014	2014	2018	2018	2018	2018	2018
Detail Use	2012	2013	2014	2015	2016	2017	2018	2019	2020
CoA Cropland NAICS	2012	2012	2012	2017	2017	2017	2017	2017	2017

Import Emission Factor Data Note

Summary-level IEFs were integrated into the USEEIO State Models built here with years of the IEFs corresponding to the model year. The only difference between these summary-level IEFs and those recently published (Namovich et al. 2024) is that the IEFs were created to correspond with the Bureau of Economic Analysis 2012 summary-level schema, which is the schema used to build the USEEIO v1.0 State Models, so they correspond perfectly with these models.

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