Sept. 12, 2024

Oregon’s Consumption-Based Greenhouse Gas Emissions

1990 – 2021

Technical Report in support of DEQ’s report to the Legislature on Opportunities to Reduce Greenhouse Gas Emissions Caused by Oregon’s Consumption

DEQ

This document was prepared by
Oregon Department of Environmental Quality
Materials Management Program
700 NE Multnomah Street, Portland Oregon, 97232

Contact: David Allaway
Phone: 503-229-5479
www.oregon.gov/deq

State of Oregon
DEQ Department of Environmental Quality

Translation or other formats

Español | 한국어 | 繁體中文 | **Русский** | **Tiếng Việt** | العربية

800-452-4011 | TTY: 711 | deqinfo@deq.oregon.gov

Non-discrimination statement

DEQ does not discriminate on the basis of race, color, national origin, disability, age or sex in administration of its programs or activities. Visit DEQ's Civil Rights and Environmental Justice page.

Acknowledgements

The production of this report was a collaborative effort supported by multiple staff within the Oregon Department of Environmental Quality and with contributions from additional organizations.

Report authors: David Allaway and Martin Brown, Oregon Department of Environmental Quality.

Additional inventory, data and report content and review provided by:

- Daniel Redick, Mia Weitz, Jenna Throckmorton, Katie Romano, Elizabeth Elbel, Peter Spendelow, Michele Shepperd, Bill Peters, Christa McDermott and Jaclyn Palermo, Oregon Department of Environmental Quality.
- Robbie Andrew and Glen Peters, CICERO Center for International Climate Research, Oslo, Norway.
- Vincent Camobreco, U.S. Environmental Protection Agency, Office of Atmospheric Protection.
- Joseph McGill, U.S. Department of Transportation, Bureau of Transportation Statistics.
- City of Portland Bureau of Planning and Sustainability.
- Sara Mihm, Multnomah County.
- Angie Marzano, Lane County Public Works, Waste Management Division.
- Jen Brown, Benton County.
- Kathy Feser and Alexis Torres Diaz, Corvallis School District 509J.
- Jackie Wilson (Mueller), Bend-La Pine Schools.

DEQ also wishes to acknowledge the Stockholm Environment Institute which created the original model used to estimate consumption-based emissions for Oregon, and the state’s Environmental Quality Commission and Climate Action Commission (formerly Global Warming Commission) for supporting this work.

Executive Summary

Climate change poses significant threats to society, the environment, and economy. Oregon has a policy to reduce our contribution to this problem by reducing emissions of heat-trapping greenhouse gases. This presents a fundamental question: In evaluating our responsibility to reduce emissions and opportunities to do so, what emissions should be counted?

Since the goal of greenhouse gas mitigation is to reduce emissions, a reasonable answer is that we should count the emissions that we contribute to, because these are also emissions that we may be able to reduce.

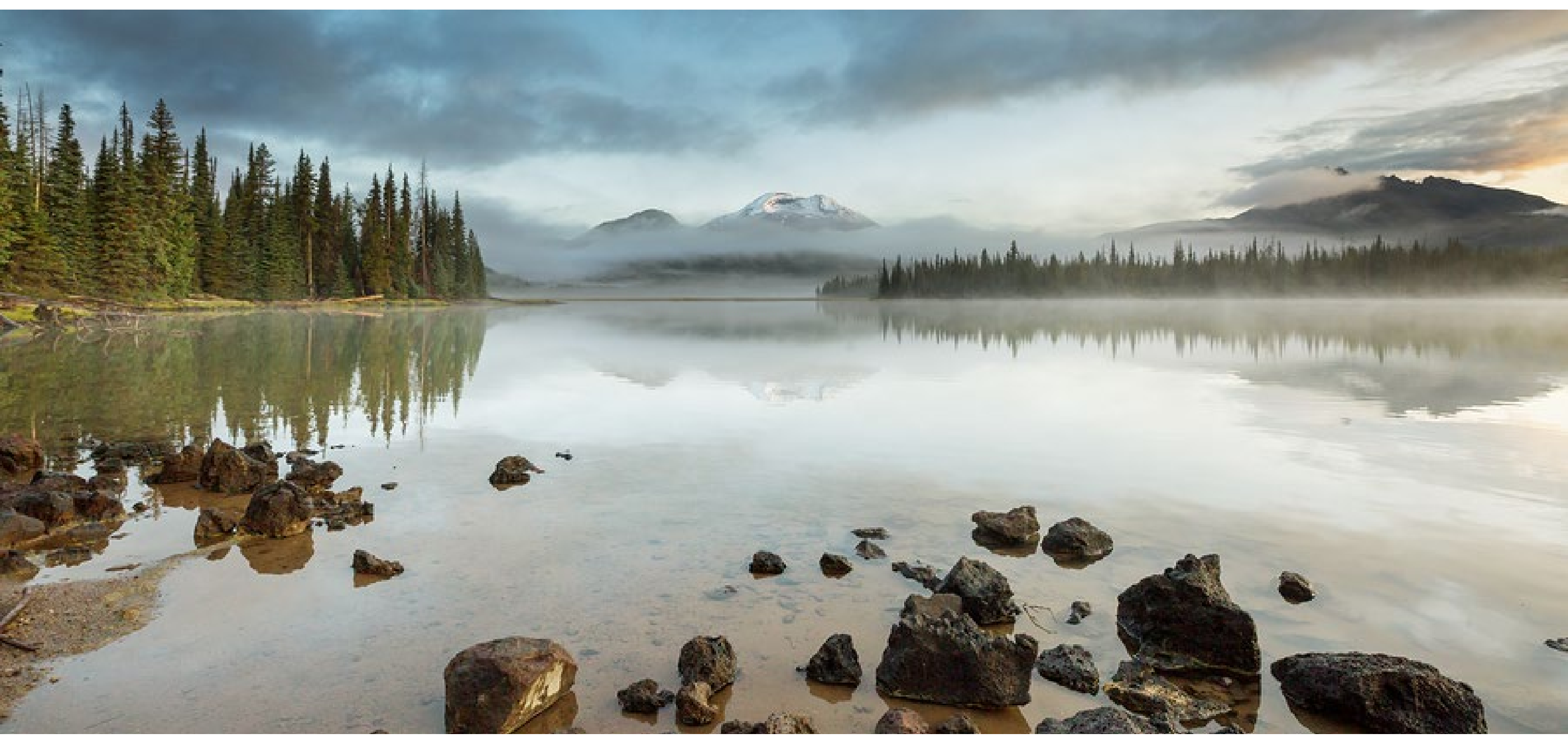
Most human activities that result in greenhouse gas emissions arise ultimately as a consequence of consumption, which includes the purchase of energy, goods and services by households and governments. Such emissions can be inventoried using a method called a "consumption-based emissions inventory".

Oregon's Consumption-Based Emissions Inventory

Oregon pioneered this practice, commissioning the first consumption-based greenhouse gas emissions inventory at a subnational scale in North America, for calendar year 2005. Oregon DEQ subsequently updated the inventory for years 1990, 2010 and 2015. This report extends that analysis to include calendar year 2021.

Oregon's consumption-based emissions inventory supplements and complements the sector-based inventory, which focuses primarily on in-state sources of emissions (with an adjustment for imported electricity). Neither inventory, by itself, paints a comprehensive picture of how the state contributes to emissions.

Oregon's consumption-based inventory supplements the sector-based inventory by revealing additional ways in which Oregon contributes to emissions, and opportunities to reduce them. Indeed, the consumption-based inventory for 2021 brings into consideration 59 million metric tons of *additional* CO2e emissions – emissions that are not otherwise included in the sector-based inventory, and yet which Oregon contributes to through consumption. These additional emissions are almost as large as the entire sector-based inventory in its entirety, which measures in at just over 61 million metric tons of CO2e.



Executive summary page 2

Key Results
The consumption-based emissions inventory illuminates many other important details about Oregon's global carbon footprint. These include:

- Oregon's consumption-based emissions have risen from 62.4 million metric tons of CO2e in 1990 to 95.6 million metric tons in 2021 – a 53 percent increase in 31 years.
- In 1990, Oregon's consumption-based emissions were only about 5 million metric tons CO2e higher (9 percent higher) than the state's sector-based emissions. That gap has grown steadily, and by 2021 consumption-based emissions were 34 million metric tons (56 percent) higher.
- Oregon has made progress at reducing emissions in the sector-based inventory through energy conservation and decarbonization efforts, and more. However, these emissions reductions have been more than offset by increases in emissions elsewhere – especially in the supply chains and production of materials, such as food and construction products, used in Oregon.
- Almost half (48 percent) of Oregon's consumption-based emissions result from the purchase of materials, such as food and building materials.
- 71 percent of all consumption-based emissions occur *prior* to the use of energy-consuming devices such as cars and furnaces.
- Within households, consumption-based emissions are correlated with income. High-income households contribute more emissions on average, and by extension have more opportunities and greater ability to reduce emissions. Lower-income households contribute less to these emissions and have fewer opportunities to reduce them, even as they are also generally more vulnerable to negative impacts from climate change.

The Importance of this Report
Oregon's climate and economy are tied to that of the rest of the world, and Oregon's consumption-based emissions arise from sources both inside Oregon's borders (32 percent) as well as in other states (42 percent) and nations (26 percent). As such, not all of these emissions are readily subject to direct regulatory control by the State. Regardless, they are all subject to potential influence by people and policies in Oregon, and all of these emissions contribute to global climate change, including impacts here in Oregon.

While Oregon DEQ has maintained this inventory for fifteen years, this year's report is significant in that it responds to a mandate from the Oregon Legislature to update the State's consumption-based inventory and make recommendations for future updates (Section 52 of House Bill 3409, 2023). More significantly, the legislature also directed DEQ to produce a report identifying opportunities to reduce consumption-based emissions through programs and policies, and to evaluate the economic, social and environmental impacts of such emissions. This technical report on Oregon's consumption-based GHG emissions inventory serves as a primary and foundational information resource for both DEQ's report to the legislature and an accompanying technical report that evaluates opportunities to reduce emissions in greater detail.

Contents

1. Introduction

This report updates Oregon’s consumption-based greenhouse gas emissions inventory through calendar year 2021. It also serves as a technical report in support of DEQ’s report to the Oregon Legislature on opportunities to reduce consumption-based greenhouse gas emissions, as required by Section 52 of House Bill 3409 (2023).

What is a Consumption-Based Greenhouse Gas Emissions Inventory?

Consumption is widely considered to be the root driver of economic activity, and by extension, the driver of most if not all human-caused emissions that contribute to global climate change and other environmental impacts. However, there is often a geographic separation between where an act of consumption occurs and where the associated emissions arise. We live in a globally integrated economy, and so consumption in one geographic area often results in emissions elsewhere. For example, Oregonians’ demand for electricity is satisfied by electricity generation at facilities across the Western U.S., and the resulting emissions are counted in Oregon’s sector-based greenhouse gas inventory regardless of whether they occur in Oregon, Montana, or elsewhere. The consumption-based inventory extends this logic to all purchases by Oregon consumers: cars from Michigan, bananas from Mexico, petroleum from Saudi Arabia and clothes from China as examples. All of these consumption activities result in emissions of greenhouse gases, and these emissions have the same effect on Oregon’s climate as do emissions that physically originate within the state.

Oregon's consumption-based emissions inventory estimates the global greenhouse gas emissions that result from Oregon’s consumption. “Consumption” here includes purchases by households and governments. To be consistent with standards for national economic accounting, “consumption” also includes capital and inventory formation by Oregon businesses.

The inventory has some overlap with Oregon’s sector-based inventory: both include emissions resulting from the use of fuels and electricity by Oregon households and government operations, and both include emissions from in-state industrial, commercial and agricultural activities that satisfy consumption by Oregonians. But the inventories also have significant differences, which are detailed later in this report. In short, Oregon’s sector-based inventory uniquely includes emissions associated with in-state production of goods and services that are exported, while the consumption-based inventory includes emissions associated with imported goods and services.[1]

Oregon estimates consumption-based greenhouse gas emissions because a significant portion of Oregon's "carbon footprint" occurs in other states and nations, and is not accounted for in the sector-based inventory. Evaluating consumption-based emissions alongside the traditional sector-based inventory provides Oregonians with a more complete understanding of how we contribute to global climate change and by extension, opportunities to reduce it. Ultimately, reducing emissions in both sets of inventories (sector-based and consumption-based) will be essential if Oregon is to make a meaningful contribution to climate stability.

As this report demonstrates, focusing exclusively on evaluating and reducing emissions in the sector-based inventory, without parallel consideration of consumption-based emissions, creates several risks to Oregon and the global climate. These risks include:

- overlooking important and potentially cost-effective opportunities to reduce emissions that are absent from the sector-based inventory but which the consumption-based inventory is able to daylight,
- the potential for creating a misleading sense of progress (if sector-based emissions decline even as consumption-based emissions rise), and
- the potential for inadvertently incentivizing or celebrating "leakage," where Oregon producers move operations – and emissions – elsewhere, resulting in an apparent reduction of emissions as measured by the sector-based inventory but potentially increasing global emissions.

Consumption-based accounting reduces these risks, and when performed alongside a traditional, sector-based inventory, provides policymakers and the public with a more comprehensive assessment of how Oregon contributes to emissions, and by extension, opportunities to reduce them.

History of Consumption-Based Emissions Accounting for Oregon

Oregon was the first state in the U.S. to produce a sub-national consumption-based greenhouse gas inventory (for calendar year 2005, published in 2011). This inventory was created for the Oregon DEQ by the Stockholm Environment Institute. DEQ produced an update for calendar year 2010 (published in 2013) and another update for calendar year 2015 (published in 2018). The 2015 update included several methodological improvements that were also carried backwards into updates for the 2005 and 2010 inventories. The 2015 report also included for the first time an estimate of total consumption-based greenhouse gas emissions for calendar year 1990.

This report represents the fourth iteration in consumption-based greenhouse gas accounting for Oregon. It continues the legacy approach used for prior years (2005, 2010, and 2015) and extends it to estimate consumption-based greenhouse gas emissions for calendar year 2021. While prior inventories were updated on a 5-year cycle, DEQ chose to skip estimating emissions for calendar year 2020, given the highly anomalous economic conditions associated with the COVID-19 public health emergency.

Future inventories may be performed more frequently and eventually with an updated modeling approach that may replace the legacy approach used in this report; details on this topic are included in Section Five of this report.

Why this Report?

The 2023 Oregon Legislature adopted House Bill 3409. Among its many climate-related elements, Section 52 of HB 3409 requires DEQ to submit a report to the Oregon Legislature by September 15, 2024. The report must include, along with an assessment of opportunities to reduce consumption-based emissions, an update to Oregon's consumption-based greenhouse gas emissions inventory, and recommendations for future updates.

This inventory report describes in the detail the methodological framework by which DEQ has estimated consumption-based greenhouse gas emissions (for years 1990 – 2021), and detailed results from the recent update through calendar year 2021. Summary-level results from this technical report are also included in DEQ's report to the Legislature. A companion technical report, prepared by Stockholm Environment Institute explores opportunities to reduce consumption-based emissions through state policy. That technical report draws heavily on information contained in this inventory report and the underlying data and model.

Organization of this Report

Section Two of this report introduces terminology (consumers, categories, sub-categories, etc.) and provides a high-level overview of the methodology used to estimate Oregon's 2021 consumption-based emissions. This provides important context for Section Three, which presents the inventory results.

Section Three highlights top-line results from 2021 (emissions by category and subcategory, life cycle stage, geographic location, consumer type, and household income strata), an assessment of how consumption-based emissions have changed over time, and how they compare against the state's sector-based inventory, and a deeper dive into emissions intensities and drivers of change.

Section Four of this report details the methodology used to estimate Oregon’s consumption-based greenhouse gas emissions for 2005 – 2021, as well as a first-order estimate of consumption-based emissions for 1990.

Section Five discusses considerations for increasing the frequency for future updates to Oregon’s consumption-based greenhouse gas emissions inventory, as well as options for streamlining the effort required to estimate these emissions and several possible methodological improvements.

This report ends with a list of references and an appendix that lists the 546 commodities used to model Oregon’s 2021 consumption-based emissions, with corresponding model meta-categories, categories, and sub-categories.

2. Overview of Consumption-Based Accounting

Consumption-based emissions for Oregon are the global emissions of greenhouse gases associated with Oregon's consumption of goods and services (including energy). Consumption is defined in economic terms consistent with "final demand" of goods and services by Oregon households and government (federal, state, and local) facilities located in Oregon. To be consistent with standards for national economic accounting, consumption also includes capital investment (and net inventory formation) by Oregon businesses. This inventory includes global emissions associated with the wide range of "stuff" that Oregonians purchase, including food, vehicles, appliances, furnishings, and electronics, as well as services, fuels and electricity. Consumption-based greenhouse gas emissions are included in this inventory regardless of whether they physically originate in Oregon or elsewhere.

The consumption perspective is informative because, in economic terms, consumption is the root driver of all economic activity. By extension, understanding the emissions associated with Oregon's consumption provides valuable perspective on root drivers of greenhouse gas emissions. The consumption-based inventory also complements other inventory perspectives. For example, while the state's sector-based inventory estimates the energy used by Oregon buildings, the consumption-based inventory shows the emissions associated with producing the materials and furnishings used during construction and remodeling. Similarly, while the sector-based inventory includes the emissions at the point of power generation for electricity used in Oregon, the consumption-based inventory adds to these "upstream" emissions, such as those associated with mining, processing, and transporting the coal used to produce electricity.[2]

The consumption-based inventory reveals additional information about emissions. It estimates the emissions associated with all government procurement. It includes life cycle emissions of goods and services (including electric power and fuels) consumed in Oregon, and explores where in the life cycle, and where in the world, most of these emissions actually occur. It can be used to understand how households with different consumption patterns – and incomes – contribute to climate change. Because the inventory is derived from an economic model, it also estimates the "emissions intensities" (emissions per dollar spent) of different types of consumption. This can be used to understand how emissions might change if consumers shift from high-intensity spending (e.g., air travel) to lower-intensity spending (e.g., "staycations"). The inventory, and the underlying analysis that informs it, may be used to prioritize policy development or work areas, to help businesses better understand the average carbon footprints of different types of products, to reduce emissions throughout a supply chain, and to communicate to consumers how they contribute to emissions.

It is important to understand how the consumption-based emissions inventory treats the emissions associated with use of energy, such as fuels and electricity. Globally, most greenhouse gas emissions result from the combustion of fossil fuels, and that is also the case of Oregon's consumption-based emissions, even as the emissions are assigned to the various (non-energy) commodities being consumed and used. In the consumption-based inventory, emissions associated with the direct use of fuels and electricity by consumers (households and government) are counted and assigned to the commodities using the fuels or electricity (such as vehicles or lighting fixtures). Emissions from energy use by Oregon businesses are included only if the energy is used to satisfy Oregon consumption; emissions from using energy to produce exports for final consumption elsewhere are not included. The consumption-based inventory also includes the emissions from energy use by out-of-state producers that are selling into Oregon or otherwise involved in the supply chain of products consumed in Oregon. In all cases of business energy use, emissions are categorized not as "energy" but rather according to the type of commodity consumed by the final consumer.

Biogenic emissions, including changes in the atmospheric concentration of greenhouse gases associated with land-use change are not included in the consumption-based inventory. For example, carbon storage by regional forests, or carbon releases as tropical forests are replaced with plantations are not included.

Emissions that originate from sources inside Oregon are also not included if they don't contribute to satisfying consumption by Oregon, as Oregon businesses produce many goods and services that are exported for consumption elsewhere.

Consistent with Oregon's sector-based inventory, IPCC Fourth Assessment Report global warming potentials are used for all production and emissions that occur inside Oregon and elsewhere in the United States. While emissions intensities for domestic production are derived from the U.S. Greenhouse Gas Inventory, which uses global warming potentials from the Fifth Assessment Report, those emissions are first re-scaled using Fourth Assessment Report potentials before calculating emissions intensities. Emissions intensities for foreign production are derived from an international trade model for foreign emissions, produced by the Center for International Climate Research (CICERO) in Norway, and that model also uses IPCC Fourth Assessment Report global warming potentials.

Classification of Emissions

The model used to construct the consumption-based inventory produces complex results. Classifications of variables allow the emissions from consumption to be evaluated and shown in different ways. These classifications fall in to four categories:

- **Type of consumer:** Emissions are estimated for four different types of consumers: households, federal government, state/local government, and business capital and investment.
- **Commodity type:** 546 different commodities are grouped into 62 subcategories, 16 categories, and 4 meta-categories (materials, services, fuel, and electricity). For example, the commodity "hospital services" is part of the subcategory "healthcare services", which is in the "healthcare" category. It is classified as a "service". In contrast, the commodity involving pharmaceuticals, while also part of the "healthcare" category, is assigned to the subcategory "medicines" and the meta-category of "materials."
- **Life-cycle phase:** Emissions are further divided into five life-cycle phases: production, pre-purchase transportation, wholesale/retail, use, and post-consumer disposal.
- **Location of emission:** Emissions are divided into the locations in which they occur based on three geographic regions: in-state, other-US, and foreign. The wide range of variables used in this model allow estimation of fairly specific types of emissions such as the foreign vs. domestic emissions associated with production of tires (one of the 546 commodities) purchased by Oregon households.

Following are further descriptions of these classification types.

Type of consumer

- Oregon **households** purchase commodities for their final use, including goods, services, fuel for vehicles and home heating, and electricity. *In 2021, an estimated 65 percent of Oregon's consumption (in dollars) came from households.*[3]
- Oregon-based local, state and federal **government** entities purchase commodities including goods, services, fuel, and electricity. *Oregon-based federal government activities are responsible for 3 percent of Oregon's final demand in 2021, while local and state government activities account for 15 percent.* Transfer payments are not included in Oregon-based federal government activities, except to the extent that the revenue from such payments is used by Oregon households or local/state governments to engage in consumption. Federal government consumption does not include Oregon's "share" of or

"contribution" to (via taxes or voting) out-of-state emissions associated with federal government activities such as foreign affairs and military activities.

- Most business purchases are not consumption, but one category is: **capital and investment** purchases, or the equipment and inventory that businesses purchase but don't sell in the same year.[4] *Business investment accounted for 18 percent of Oregon's 2021 final demand in dollars.* Emissions associated with construction of nonresidential buildings are included as "investment", while emissions associated with construction of residential buildings are modeled as "investment" expenses but portrayed in results as "household" consumption.

Commodity type

- **Commodities:** Data are calculated and reported in 546 types of commodities. Some of these commodities, such as oilseeds and copper ore, have no "final demand" in Oregon, that is, Oregon's consumers (households, governments) do not purchase these products directly; however, they may have an "intermediate" use in production and are purchased by businesses that use them to make additional intermediate products as well as commodities for final consumption. A full list of commodities is provided as an appendix to this report.
- **Sub-categories:** The 546 commodity sectors are grouped into 62 sub-categories.
- **Categories:** The 62 sub-categories are grouped into 16 categories: appliances, clothing, construction, electronics, food and beverages, furnishings and supplies, healthcare, lighting and fixtures, other manufactured goods, services, transportation services, vehicles and parts, retailers, wholesale, water and wastewater, and other. A few of the categories require additional explanation, as follows:
  - "Retailers" and "wholesalers" represent the energy-related and other direct emissions from retail and wholesale operations (lighting, refrigeration, etc.) as well as emissions from their supply chains *other than* the goods that are being sold (e.g., emissions from manufacturing grocery bags, receipt paper, advertising, etc.).
  - "Transportation services" includes all transportation of finished goods from final producers through wholesale channels to retailers, along with emissions from services that transport people, such as airplane flights and Amtrak.
- **Meta-categories:** The 536 commodity sectors are also grouped into 4 meta-categories: materials, services, fuels and electricity. A few commodities, such as restaurants and construction-related activities are simultaneously classified as both “materials” and

"services." When results are presented by meta-categories, emissions for these commodity sectors are allocated equally (50 percent each) into "materials" and "services".

Life-cycle phase

- **Pre-purchase phase:** The pre-purchase phase is an umbrella that includes three phases that occur prior to final purchase:
  - **Production phase:** Emissions from the manufacture of goods are classified as production phase emissions. For example, in the case of a cookie, this phase includes not only the emissions from the cookie factory itself, but also the emissions that resulted from making all of the supplies purchased by the factory, including flour, sugar, chocolate, oils, water, electricity, and packaging. Emissions further up the supply chain are also included (e.g., organic chemicals used to make fertilizers that are used to grow wheat that in turn is used to make flour). For services, such as a haircut, production phase emissions include the emissions associated with providing the service (e.g., operating the hair salon) as well as emissions resulting from making all of the supplies and services purchased by the service provider (e.g., smocks, shampoo, scissors, brooms, electricity, water, accounting, tax preparation, advertising, insurance, etc.).
  - **Pre-purchase transportation phase:** Consumer products, and the supplies used to manufacture them, often make several stops on their way from factory to retail store. Transportation emissions from raw material and intermediate suppliers (the growers of wheat and cacao and manufacturers of the flour and chocolate in the cookie example above) to the final producer (the cookie factory), and then to wholesale warehouse and retail store are all classified as pre-purchase transportation. [5] However, the *commodity* to which pre-purchase transportation emissions are applied to is variable. Transportation in the supply chain, prior to final production, is assigned to the commodity being consumed. [6] In contrast, transportation from the final producer through wholesale to retail is assigned to the "transportation services" category.[7] For example, consider a bakery that purchases flour from a flour mill and ships bread to a retailer. Both sets of transportation-related emissions are assigned to the pre-purchase transportation phase. The upstream supply chain emissions (transporting wheat to the flour mill and flour to the bakery) are assigned to the commodity "bread and bakery product manufacturing" (in the "food and beverages" category). The emissions from transportation of the finished bread to the retailer are assigned to the commodity "truck transport" in the "transportation services" category. To complete this example, emissions from post-purchase transportation (bringing the bread home from the store) are assigned to the "use" phase of vehicles, below.

- **Wholesale and retail phase:** Warehouses and retail stores cause greenhouse gas emissions from activities such as lighting, electronics and temperature control. This phase includes direct and upstream (including electricity and fuel) emissions of wholesalers and retailers. As with pre-purchase transportation, once a final good is produced, the wholesale and retail emissions are assigned to the "wholesale" and "retail" commodities. In contrast, wholesale and retail activities upstream of the final producer (for example, a law office purchasing paper from a retailer, or a manufacturer of car parts purchasing packaging from a wholesaler) are still assigned to the wholesale and retail phase, but for the final commodity being produced (e.g., legal services, vehicle parts).

- **Use phase:** Some products cause emissions when used by the final consumer. For example, the combustion of heating fuel in a household's furnace results in direct emissions, as does the combustion of gasoline in a police vehicle. The use phase also includes emissions associated with electricity used by consumers, such as for lighting or computers. Emissions from the use of refrigerants (in refrigerators and home and vehicle air conditioners) as well as vehicle lubricants are also included. Use phase emissions include emissions at the point of combustion, as well as supply chain emissions associated with fuels that are combusted (e.g., emissions from petroleum refineries and coal mines) and lubricant production.

- **Post-consumer disposal phase:** The final life-cycle phase is disposal. This phase includes only the emissions that result from the post-consumer landfilling or combustion of products. This phase does not include emissions from disposal of industrial or commercial waste, which are instead classified as production emissions (and included only to the extent that they occur as a result of Oregon consumption). This phase does not include any "credits" for emissions reductions resulting from recycling or composting, except to the extent that recycling and composting reduce emissions from landfilling and combustion. To the extent that materials purchased for consumption in Oregon already contain "average" levels of recycled content, any associated greenhouse gas reductions resulting from virgin feedstock displacement are already reflected in the pre-purchase emissions. With regard to those pre-purchase emissions, Oregon's CBEI at present does not account for that fact that Oregon may recycle certain types of wastes at rates higher or lower than the global average (and thereby contribute more or less to reductions in pre-purchase emissions than the global average). Similarly, because Oregon's CBEI does not account for changes in biogenic carbon flux, impacts such as sequestration of biogenic carbon via compost application or landfilling, or induced increases in forest carbon storage resulting from recycling, are also not included.

Location of emissions

- **Oregon in-state:** these are emissions occurring in Oregon associated with Oregon consumption. These include upstream requirements of production for Oregon consumption but only when the intermediate products are made in Oregon.
- **Other-49-state:** emissions in other U.S. states associated with Oregon consumption. These include U.S.-made upstream requirements of production for Oregon consumption.
- **Foreign** emissions are foreign production for Oregon consumption, both final production (e.g., cars) as well as production of intermediate commodities (e.g., steel) that are subsequently used in production of other goods and services.

3. Results

2021 Top-Line Results

2021 Consumption-Based Greenhouse Gas Emissions in Total, and Compared to Sector-Based Emissions

In 2021, Oregon's consumption-based greenhouse gas emissions were estimated to total 95.6 million metric tons of carbon dioxide equivalent (MTCO2e). This compared against the state's sector-based inventory, with a preliminary estimate of 61.4 million MTCO2e.

Figure 3-1 graphically represents the overlap between the two inventories.

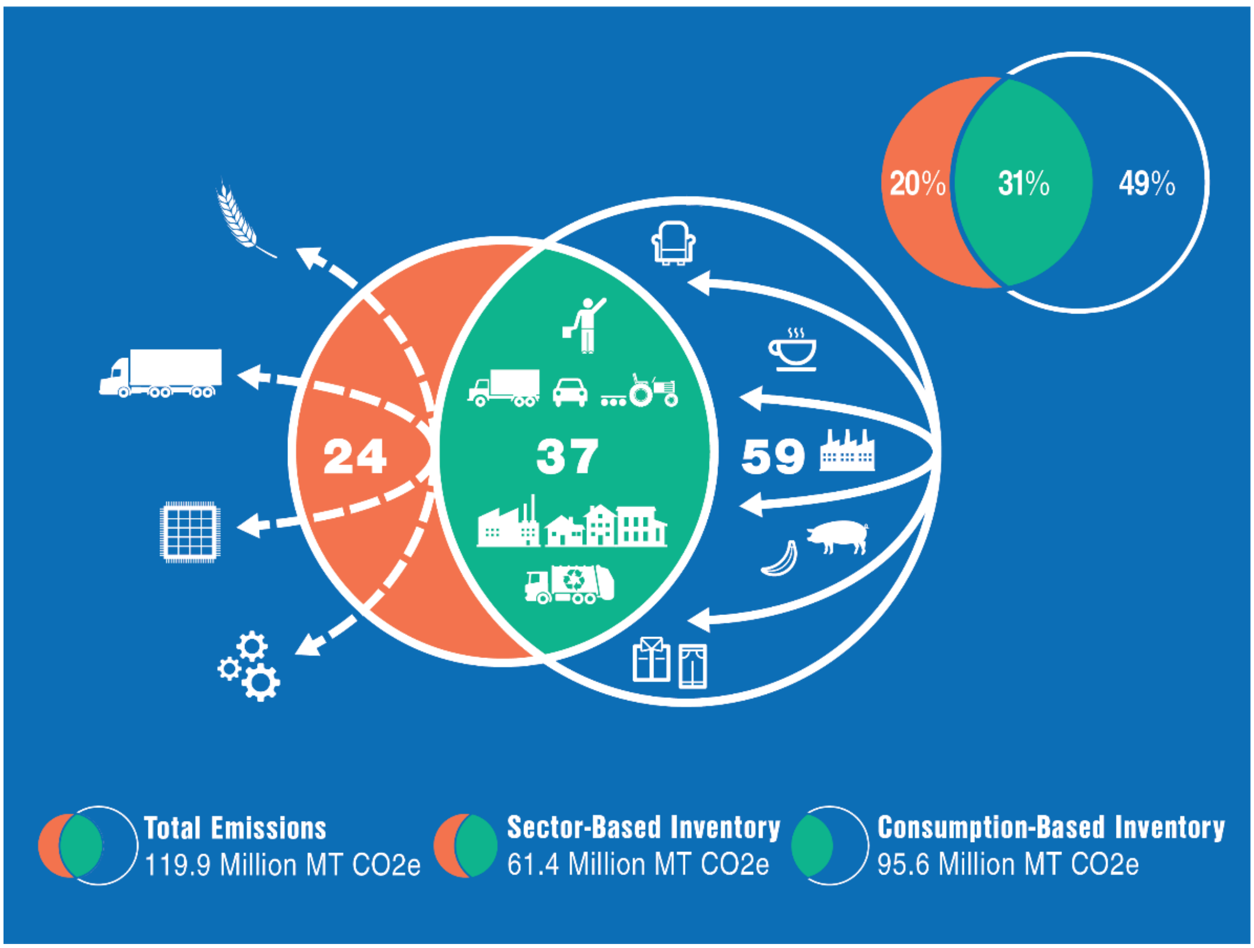


Figure 3-1
Comparison of Oregon's 2021 sector- and consumption-based greenhouse gas emissions

The two inventories share approximately 37 million MTCO2e in common. These shared emissions include direct emissions from vehicle and appliance use by households and governments, emissions at the point of electricity generation used by households and governments, and other emissions in the commercial and industrial sectors that occur in-state and which were part of supply chains that satisfied Oregon consumption.

The orange crescent in the left side of Figure 3-1 are emissions that are unique to Oregon's sector-based inventory. In 2021, these emissions were estimated at 24 million MTCO2e. These include emissions from in-state businesses producing goods and services consumed by, or as part of the supply chain of goods and services consumed by, households and governments not based in Oregon.

The blue crescent on the right side of Figure 3-1 are emissions that are unique to Oregon's consumption-based inventory. In 2021, these emissions were estimated at 59 million MTCO2e. These include emissions in other states and nations associated with satisfying consumption by Oregon households, governments and businesses. For energy, these "imported" emissions are primarily upstream emissions associated with fuel extraction (and in the case of liquid fuels, "well to pump" emissions such as petroleum refining). Many of the emissions are associated with the consumption of imported materials. **Significantly, these imported emissions (58.5 million MTCO2e) are almost as large as Oregon's entire sector-based inventory (61.4 million MTCO2e).** Oregon's consumption-based inventory spotlights additional emissions (and opportunities to reduce emissions) almost as large in quantity as the traditional inventory that forms the basis for most climate-related policy in Oregon.

2021 Consumption-Based Greenhouse Gas Emissions by Category and Life-Cycle Stage

Figure 3-2 and Table 3-1 show Oregon's 2021 consumption-based greenhouse gas emissions, organized by category and life-cycle stage, using the condensed (pre-purchase, use, post-consumer disposal) life-cycle phases introduced in Section Two, above.

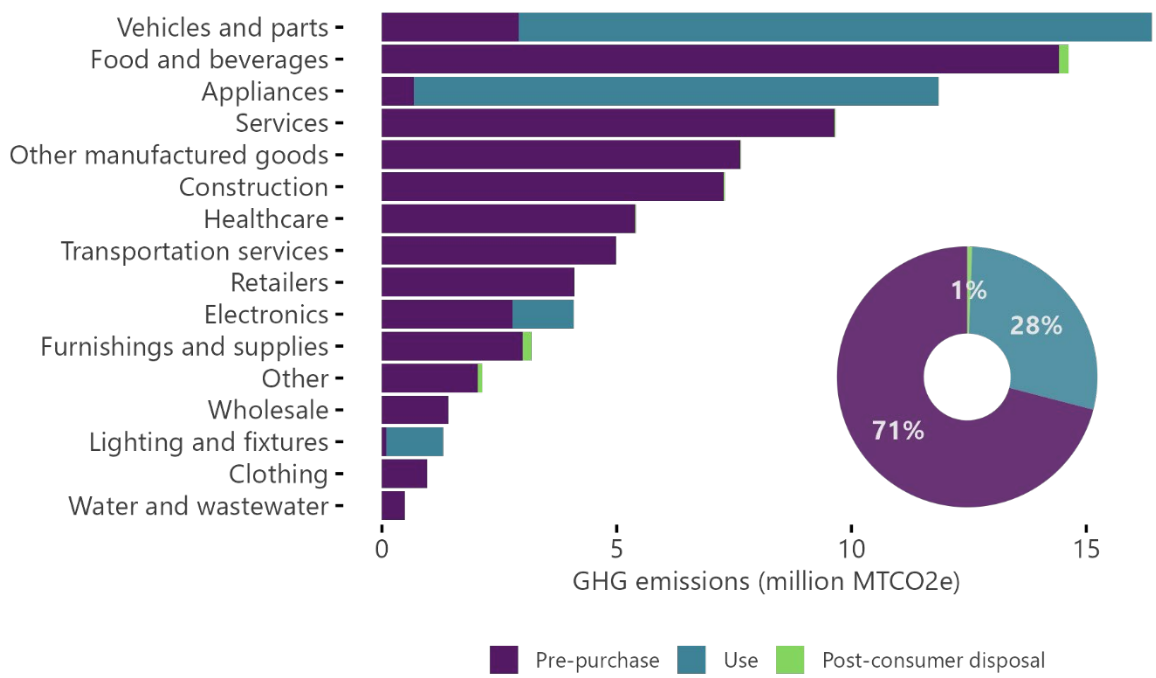


Figure 3-2
Oregon 2021 consumption-based GHG emissions, by category and life-cycle phase (Million MT CO2e) by category and life cycle stage

Figure 3-2 and Table 3-1 demonstrates several important issues. One category – vehicles and parts – represents 17 percent of all of Oregon's consumption-based emissions, followed closely by food and beverages (15 percent). Seventy percent of all emissions are associated with just the six highest-emitting categories: vehicles, food and beverages, appliances, services, "other manufactured goods" (which are dominated by capital and inventory investments by businesses) and construction.

Table 3-1
Oregon 2021 consumption-based GHG emissions, by category and life-cycle phase (Million MT CO2e)

Category	Pre-purchase	Use	Post-consumer disposal	Total	% of Total
Vehicles and parts	2.9	13.5	0.0	**16.4**	17%
Food and beverages*	14.4	0.0	0.2	**14.6**	15%
Appliances	0.7	11.2	0.0	**11.9**	12%
Services*	9.6	0.0	0.0	**9.7**	10%
Other manufactured goods*	7.6	0.0	0.0	**7.6**	8%
Construction*	7.3	0.0	0.0	**7.3**	8%
Healthcare*	5.4	0.0	0.0	**5.4**	6%
Transportation services*	5.0	0.0	0.0	**5.0**	5%
Retailers*	4.1	0.0	0.0	**4.1**	4%
Electronics	2.8	1.3	0.0	**4.1**	4%
Furnishings and supplies*	3.0	0.0	0.2	**3.2**	3%
Wholesale*	1.4	0.0	0.0	**1.4**	1%
Lighting and fixtures	0.1	1.2	0.0	**1.3**	1%
Clothing*	1.0	0.0	0.0	**1.0**	1%
Water and wastewater*	0.5	0.0	0.0	**0.5**	1%
Other*	2.0	0.0	0.1	**2.1**	2%
Total	**67.8**	**27.2**	**0.6**	**95.6**	**100%**

Totals may not add exactly due to rounding.
*Use phase emissions from these categories are zero, although in some cases emissions may be associated with the use of products in one category but assigned to another category. For example, emissions associated with washing clothes are included under the use phase of "appliances", as are the emissions associated with home eating and food preparation (e.g., use of refrigerators, ranges, ovens, microwaves, and blenders).

Nearly seventy-one percent of all emissions occur upstream of the consumer as "pre-purchase" emissions. Emissions from the use of energy, refrigerants and engine lubricants (to operate vehicles, appliances, electronics and lighting) contribute another 28 percent. Less than 1 percent of emissions stem from post-consumer disposal of wastes. But within different categories, the relative contribution of different life cycle stages varies:

- For appliances and lighting, the vast majority of emissions are a result of use; production and transportation of the appliances and lighting fixtures contribute very little.
- Tailpipe emissions during the use of vehicles also dominate that category, although emissions from production (auto manufacturing) and parts are not trivial. At 2.9 million MTCO2e, emissions from producing vehicles and parts are a bit larger than all emissions associated with the use of lighting, the purchase of clothing, and wastewater treatment combined.
- Production also dominates many other categories, including food, where emissions are almost entirely upstream of the consumer, in farms and factories and their supply chains.

Additional detail is provided in Table 3-2, which reports consumption-based emissions by category and sub-category and uses all five life cycle phases as introduced in Section Two, above. Due to their small size and also modeling limitations, post-consumer disposal emissions are not disaggregated at the level of sub-categories, so are reported for full categories only.

Table 3-2
Oregon 2021 consumption-based GHG emissions, by category, sub-category and life-cycle phase (Thousand MT CO2e)

Category Subcategory	**Production**	**Pre-purchase transportation**	**Wholesale/ Retail**	**Use**	**Post-consumer disposal**	**Total**
Appliances	**649**	**22**	**2**	**11,187**	**2**	**11,862**
Heating and cooling appliances	164	9	1	7,663		7,837
Ranges and microwaves	106	3	0	830		940
Refrigerators and freezers	119	4	0	958		1,082
Washers and dryers	103	4	0	954		1,061
Other appliances	157	2	0	781		941
Clothing	**952**	**6**	**0**	**-**	**11**	**969**
Construction	**6,477**	**756**	**47**	**-**	**27**	**7,306**
Concrete, cement, lime and gypsum	5	0	0	-		5
Residential construction and remodeling	2,630	290	25	-		2,945

Non-residential construction and remodeling	3,842	466	22	-		4,330
Electronics	**2,709**	**70**	**3**	**1,306**	**3**	**4,091**
Computers and peripherals	1,198	18	1	390		1,607
Computer service and equipment	407	44	0	-		451
Other electronics	1,104	8	1	916		2,029
Food and beverage	**13,479**	**913**	**34**	**-**	**201**	**14,627**
Beverages	906	85	4			996
Condiments, oils and sweeteners	296	24	1			321
Dairy	1,605	87	3			1,695
Fruit and vegetables	1,036	53	2			1,090
Grains, baked goods, cereals, nuts	1,591	134	5			1,730
Poultry and eggs	415	73	2			490
Other meat (beef, pork, etc.)	2,967	163	4			3,134
Seafood	81	7	0			89
Pet food	351	30	1			382
Other animal products	207	3	0			210
Other frozen food	242	20	1			263
Restaurants	3,271	195	10			3,476
Other food and agriculture	511	37	1			549
Beverages	906	85	4			996
Furnishings and supplies	**2,865**	**127**	**6**	**-**	**188**	**3,186**
Furnishings	844	36	2			882
Household supplies	987	49	3			1,038
Lawn and garden	355	13	1			369
Media	347	9	0			356

Office supplies	332	20	1			353
Healthcare	**5,079**	**297**	**22**	**-**	**5**	**5,403**
Healthcare services	851	273	18			1,142
Medicines	4,227	25	3			4,255
Lighting and fixtures	**94**	**3**	**0**	**1,210**	**0**	**1,308**
Other manufactured goods	**7,265**	**341**	**21**	**-**	**15**	**7,642**
Forestry, mills, paper	71	6	0			77
Foundries, metal processing	86	1	0			87
Heavy transportation equipment	3,024	41	3			3,068
Machinery manufacturing	553	128	9			691
Missiles, weapons	25	12	1			37
Mobile homes	196	4	0			200
Retailers	**2,863**	**315**	**924**		**-**	**4,103**
Services	**8,914**	**697**	**25**	**-**	**27**	**9,663**
Banks and financial services	667	70	1			739
Building services	142	20	1			163
Car rental, repair and wash	495	42	4			541
Education and day care	697	41	-			738
Entertainment and media	789	75	3			867
Hotels and motels	412	18	1			431
Legal, real estate, insurance	2,823	135	4			2,962
Personal services	281	25	-			305
Other services	2,608	271	10			2,889
Transportation services	**524**	**4,452**	**4**		**1**	**4,981**

Vehicles and parts	**2,748**	**153**	**13**	**13,481**	**3**	**16,398**
Vehicles	2,453	137	12	13,481		16,083
Vehicle parts	294	16	1			311
Water and wastewater	**433**	**58**	**1**		**0**	**492**
Wholesale	**926**	**122**	**363**		**-**	**1,411**
Other	**1,868**	**161**	**10**	**-**	**95**	**2,134**
Oil and gas	940	27	1			968
Other mining	232	58	1			291
Other	696	76	9			780
Total	**57,845**	**8,495**	**1,475**	**27,184**	**577**	**95,577**

In Table 3-2, "retailers" and "wholesale" are shown both as categories (rows) and as a life-cycle phase (column). In this table, emissions in the wholesale/retail life cycle phase are direct emissions only (e.g., emissions from on-site natural gas combustion in warehouses and grocery stores).

For categories other than "transportation services", "retail" and "wholesale" (for example, clothing or electronics), emissions in the "pre-purchase" transportation column are limited to emissions associated with supply chain transportation, that is, transporting component parts or supplies, or emissions from airline travel by employees or suppliers. Similarly, emissions in the "wholesale/retail" column are emissions upstream of the final producer, in the supply chain of finished goods, such as the emissions from wholesaling component parts or construction materials used by a contractor.

"Production" emissions for the "retailer" and "wholesale" categories are emissions upstream of establishments providing wholesaling and retailing of finished commodities (purchased by consumers). These include emissions from electricity use, upstream emissions from direct fuel combustion, and purchased goods and services (advertising, legal, supplies, etc.).

Similarly, most of the emissions from the "transportation services" category occur as direct emissions in the "pre-purchase transportation" phase, while some are reported as "production" emissions – these are primarily indirect emissions associated with fuel extraction and refining, that occur upstream of the provision of transportation service.

To confirm, emissions from wholesaling or retailing of intermediate goods are assigned to the category of final consumption that they support, while emissions associated with wholesaling and retailing of finished goods are reported in the "retail" and "wholesale" categories.

For these reasons, the totals for the life cycle phases of "pre-purchase transportation" and "wholesale/retail" do not match those in 3-10, below. Table 3-2 shows *direct emissions only* from pre-purchase transportation, wholesale and retail, across all categories of consumption, while Table 3-10 reports life-cycle emissions for the categories of transportation services, wholesale and retail.

When thinking about the causes of greenhouse gases, transportation often looms large in the minds of the public. But emissions from production activities (manufacturing, supply chain) are typically larger. For example, while the use of personal and government vehicles (in the "vehicles" category) is one of the largest single contributors to Oregon's consumption-based emissions (13.5 million MTCO2e), the production of food contributes slightly more (14.4 million MTCO2e, when all pre-purchase phases are included).

Indeed, for most materials, production contributes more to emissions than transportation. This can be understood by comparing columns in Table 3-2. For example, production phase emissions for food and beverage are estimated at 13.5 million MTCO2e, while pre-purchase transportation (in the supply chains) for those foods and beverages are only 0.9 million MTCO2e.

Such emissions only include transportation emissions upstream of the final producer. A full picture of freight requires adding several different data points in Table 3-2:

- Emissions associated with transporting finished goods to wholesalers and retailers are included in the category "transportation services" (5.0 million MTCO2e) – but due to the underlying data in the model, this category also includes all emissions from the transportation of people for pay, such as airplane tickets and taxi rides. Only some portion of "transportation services" emissions are associated with freight.
- Upstream transportation (transportation of supplies and components, prior to final production) contributes an additional 4.0 million MTCO2e, a number derived by taking the total for "pre-purchase transportation" in Table 3-2 and then subtracting out emissions from the category of "transportation services" (to avoid double-counting). The resulting 4.0 million MTCO2e include all pre-purchase transportation phase emissions for all categories of consumption other than "transportation services".

Comparing the sum of those data points (something less than 9.0 million MTCO2e) with the estimated 57.8 million MTCO2e from Table 3-2 associated with production (including non-transportation elements of supply chains) confirms at the level of the whole economy what many life cycle assessments find at the level of individual materials: transportation can be a meaningful contribution to the life cycle impacts of materials, but is often not as impactful as what materials are used, what they're made of, and how they're made.[8]

2021 Consumption-Based Greenhouse Gas Emissions by Category and Location of Emissions

Figure 3-3 and Table 3-3 shows that most of Oregon's consumption-based emissions, while driven by consumption by Oregonians buying and using goods and services (mostly) in Oregon, actually occur elsewhere. While this is difficult to estimate precisely, **just under one-third (32 percent) of Oregon's consumption-based emissions are estimated to physically originate within Oregon's borders.** Forty-two percent originate elsewhere in the U.S., and approximately 26 percent occur in other nations.

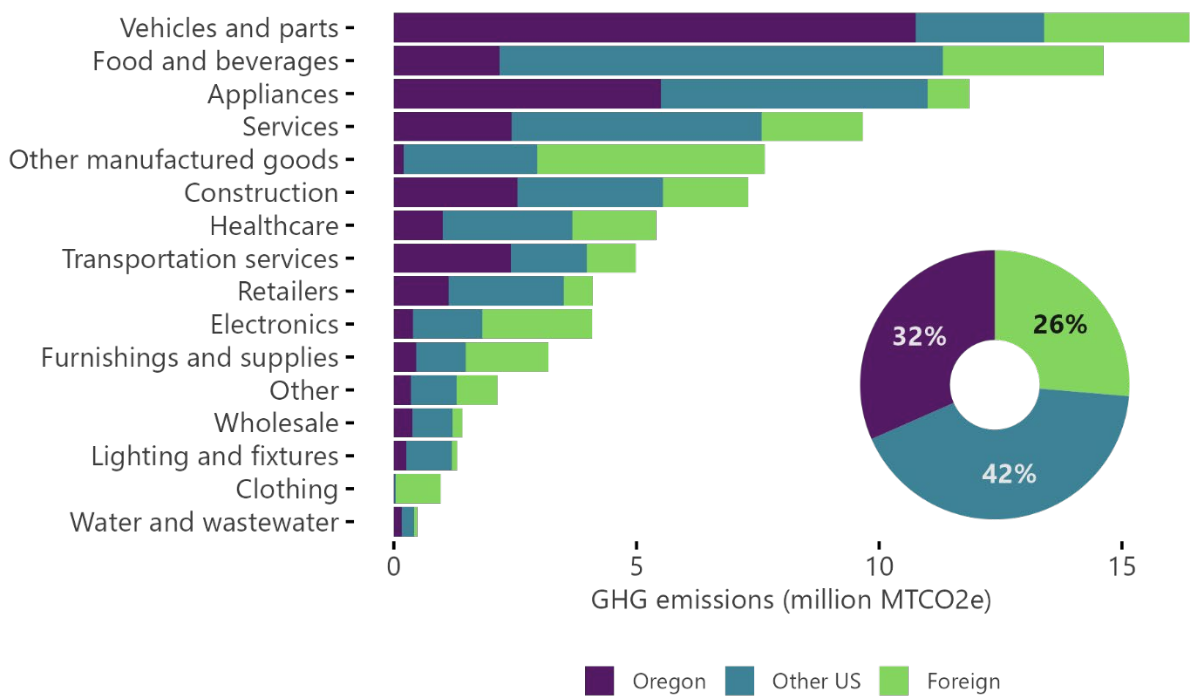


Figure 3-3
Oregon 2021 consumption-based GHG emissions, by category and location of emissions (Million MT CO2e)

Table 3-3
Oregon 2021 consumption-based GHG emissions, by category and location of emissions (Million MT CO2e)

Category	In Oregon	Other US	Foreign	Total
Vehicles and parts	10.7	2.6	3.0	**16.4**
Food and beverages	2.2	9.1	3.3	**14.6**
Appliances	5.5	5.5	0.9	**11.9**
Services	2.4	5.1	2.1	**9.7**
Other manufactured goods	0.2	2.8	4.7	**7.6**
Construction	2.6	3.0	1.8	**7.3**
Healthcare	1.0	2.7	1.7	**5.4**
Transportation services	2.4	1.6	1.0	**5.0**
Retailers	1.1	2.4	0.6	**4.1**
Electronics	0.4	1.4	2.3	**4.1**
Furnishings and supplies	0.5	1.0	1.7	**3.2**
Wholesale	0.4	0.8	0.2	**1.4**
Lighting and fixtures	0.3	0.9	0.1	**1.3**
Clothing	0.0	0.0	0.9	**1.0**
Water and wastewater	0.2	0.3	0.1	**0.5**
Other	0.4	0.9	0.8	**2.1**
Total	**30.2** (32%)	**40.2** (42%)	**25.2** (26%)	**95.6**

Totals may not add exactly due to rounding.

The location of emissions varies by type of consumption. For example, nearly all emissions associated with clothing are a result of foreign manufacturing, while food-related emissions primarily occur elsewhere in the U.S., such as in California and the Midwest. The only category where more than half of emissions occur in Oregon is vehicles and parts (due to vehicle use).

2021 Consumption-Based Greenhouse Gas Emissions by Category and Type of Consumer

Figure 3-4 and Table 3-4 shows 2021 consumption-based emissions by category and type of consumer.

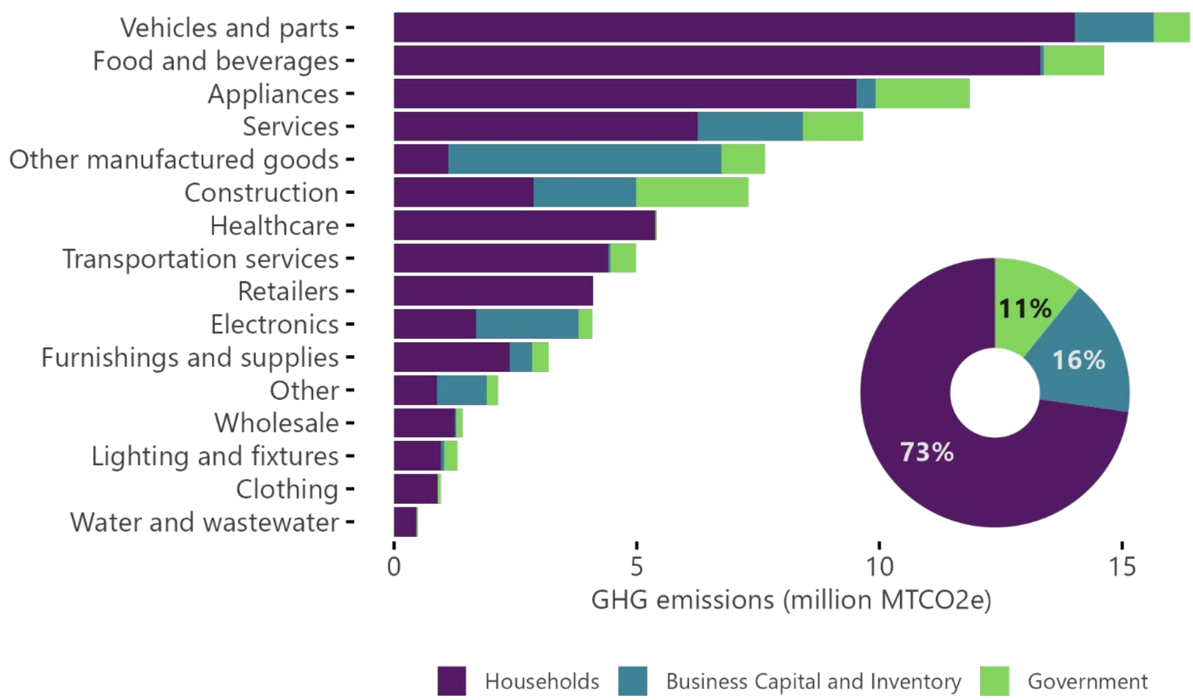


Figure 3-4
Oregon 2021 consumption-based GHG emissions, by category and type of consumer (Million MT CO2e)

Approximately 73 percent of Oregon's 2021 consumption-based emissions stem from household consumption activities, with the remainder divided between governments (11 percent) and business capital formation and inventory (16 percent). Households contributed about 65 percent of Oregon's 2021 consumption as measured in dollars, but their relative contribution to the state's carbon footprint is higher. The reason for this is what they buy: households spend proportionately more of their money on more carbon-intensive goods and services than do governments or business capital investments.

- For households, the three categories of purchases with highest emissions (in order) are the same as the state as a whole (households, government and business capital): vehicles and parts (14.0 million MTCO2e), food and beverages (13.3 million MTCO2e) and appliances (9.5 million MTCO2e).

- Government's three largest categories of emissions are construction (2.3 million MTCO2e), appliances (1.9 million MTCO2e) and food/beverages and services (tied at 1.2 million MTCO2e each).
- For business capital and inventory, "other manufactured goods" such as machinery are the single largest category of emissions (5.6 million MTCO2e), followed by services (2.2 million MTCO2e). The inclusion of services is an anomaly, since services are not typically thought of as investments or inventory; this peculiar finding is a consequence of the underlying consumption estimate (see Section Four). Other categories contributing significant emissions for business capital and inventory are those that are capital-intensive: construction (2.1 million MTCO2e), electronics (2.1 million MTCO2e), and vehicles and parts (1.6 million MTCO2e).

Similarly, Table 3-4 illustrates that emissions in different categories arise from different types of consumers. Emissions from vehicles and parts as well as food and beverages largely arise as a consequence of household consumption. This pattern is even stronger for categories such as healthcare and retailing. Government is a relatively larger contributor to emissions from construction (largely due to road and other infrastructure construction), while business capital and inventory formation dominates emissions from "other manufactured goods", which includes items such as manufacturing equipment, other heavy machinery, and heavy transportation equipment.

Table 3-4
Oregon 2021 consumption-based GHG emissions, by category and type of consumer (Million MT CO2e)

Category	Households	Government	Business Capital and Inventory	Total
Vehicles and parts	14.0	0.8	1.6	**16.4**
Food and beverages	13.3	1.2	0.1	**14.6**
Appliances	9.5	1.9	0.4	**11.9**
Services	6.3	1.2	2.2	**9.7**
Other manufactured goods	1.1	0.9	5.6	**7.6**
Construction	2.9	2.3	2.1	**7.3**
Healthcare	5.4	0.0	0.0	**5.4**
Transportation services	4.4	0.5	0.0	**5.0**
Retailers	4.1	0.0	0.0	**4.1**
Electronics	1.7	0.3	2.1	**4.1**
Furnishings and supplies	2.4	0.3	0.5	**3.2**
Wholesale	1.2	0.1	0.0	**1.4**
Lighting and fixtures	1.0	0.3	0.1	**1.3**
Clothing	0.9	0.1	0.0	**1.0**
Water and wastewater	0.5	0.0	0.0	**0.5**
Other	0.9	0.2	1.0	**2.1**
Total	**69.5** (73%)	**10.3** (11%)	**15.8** (16%)	**95.6**

Totals may not add exactly due to rounding.

2021 Consumption-Based Greenhouse Gas Emissions by Category and Household Income Strata

While households contribute most of Oregon's consumption-based emissions, not all households are the same. Table 3-5 and Figure 3-5 illustrate average per-household annual emissions (for 2021) for various Oregon households in different income ranges.

Table 3-5
Average 2021 consumption-based GHG emissions per Oregon household, by annual income strata (MT CO2e)

Category	<$15k	$15-30k	$30-40k	$40-50k	$50-70k	$70-100k	$100-150k	$150-200k	$200k +
Vehicles and parts	3.9	4.5	6.2	6.8	8.0	9.3	10.5	11.6	13.7
Food and beverages	4.5	4.3	6.1	6.4	6.4	7.8	10.8	11.4	14.2
Appliances	3.7	4.3	4.7	4.9	5.3	5.8	6.4	7.1	8.7
Services	1.5	1.9	2.5	2.2	2.8	3.9	4.3	6.2	10.0
Healthcare	0.9	2.7	2.0	2.7	3.0	3.5	3.7	5.2	5.1
Transportation services	1.0	1.1	1.4	1.4	2.1	2.4	3.2	5.2	7.0
Retailers	1.2	1.4	1.7	1.8	2.1	2.3	3.3	3.8	4.9
Construction	0.7	1.0	1.1	1.2	1.4	1.7	2.1	2.8	3.7
Furnishings and supplies	0.6	0.7	1.0	0.9	1.2	1.3	1.9	2.4	3.1
Electronics	0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.4	1.6
Wholesale	0.4	0.4	0.5	0.6	0.6	0.7	0.9	1.1	1.4
Other manufactured goods	0.4	0.4	0.5	0.5	0.5	0.6	0.9	1.0	1.3
Lighting and fixtures	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.8
Clothing	0.3	0.3	0.3	0.4	0.4	0.4	0.7	0.8	1.5
Water and wastewater	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4
Other	0.2	0.2	0.3	0.3	0.4	0.5	0.7	0.9	1.4
Total	**20.5**	**24.5**	**29.6**	**31.7**	**36.1**	**42.3**	**51.4**	**61.9**	**78.8**

Totals may not add exactly due to rounding.

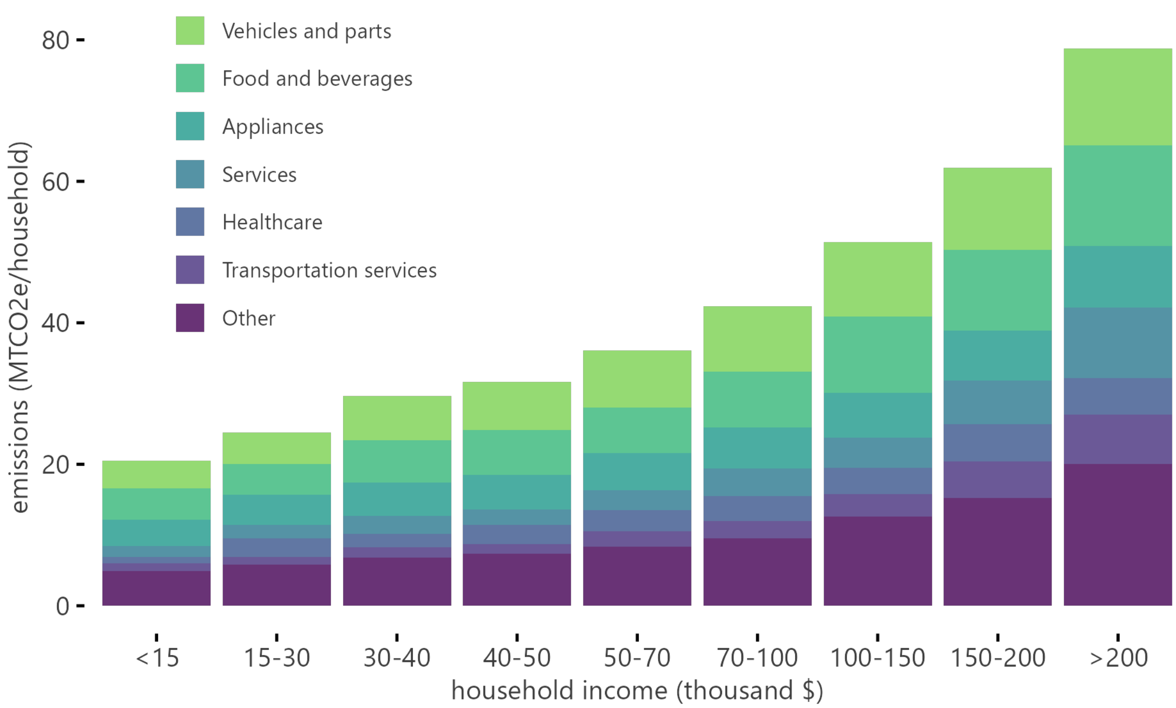


Figure 3-5
Average 2021 consumption-based GHG emissions per Oregon household, by annual income strata (MT CO2e)

Average per-household consumption-based greenhouse gas emissions (household emissions only, not including government or business capital/investment) for 2021 were 40.7 MTCO2e. While the estimates in Table 3-5 and Figure 3-5 are averages, it clearly suggests that some Oregon households contribute more to global climate change than others, and that emissions are generally correlated with income (and by extension, expenditures). It is important to note that this analysis makes the simplifying assumption that emissions intensities (emissions per dollar spent) for any given commodity are the same across all income strata. This is a limitation of the underlying economic model and may not be entirely realistic, as it ignores a relationship between price and quality. For example, the production of a $100,000 car will likely result in more emissions than production of a $25,000 car, but not necessarily four times as much.

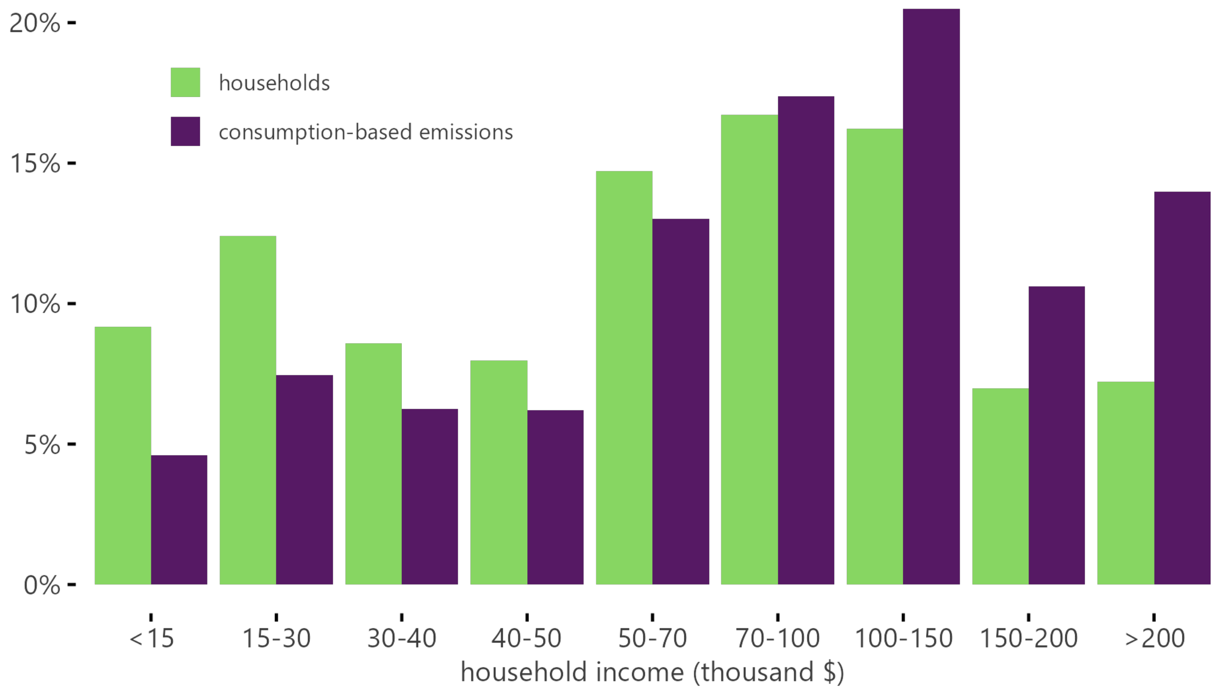


Figure 3-6
Number and consumption-based emissions of Oregon households, distributed by annual income (2021)

Figure 3-6 shows the relative distribution of Oregon households into different income strata, as well as each strata's relative contribution to household consumption-based emissions. For example, households with annual incomes of $15,000 or less represent nine percent of all Oregon households, but these same households contribute less than five percent of household consumption-based emissions. On the other end of the income spectrum, approximately seven percent of Oregon households have incomes in excess of $200,000, but these same households contribute 14 percent of Oregon's total consumption-based greenhouse emissions from households.

Oregon Consumption-Based Emissions Over Time

Emissions by Category, 2005 – 2021

Figure 3-7 and Table 3-6 illustrate how Oregon's consumption-based greenhouse gas emissions, by category, have changed over the four inventory years of 2005, 2010, 2015 and 2021.

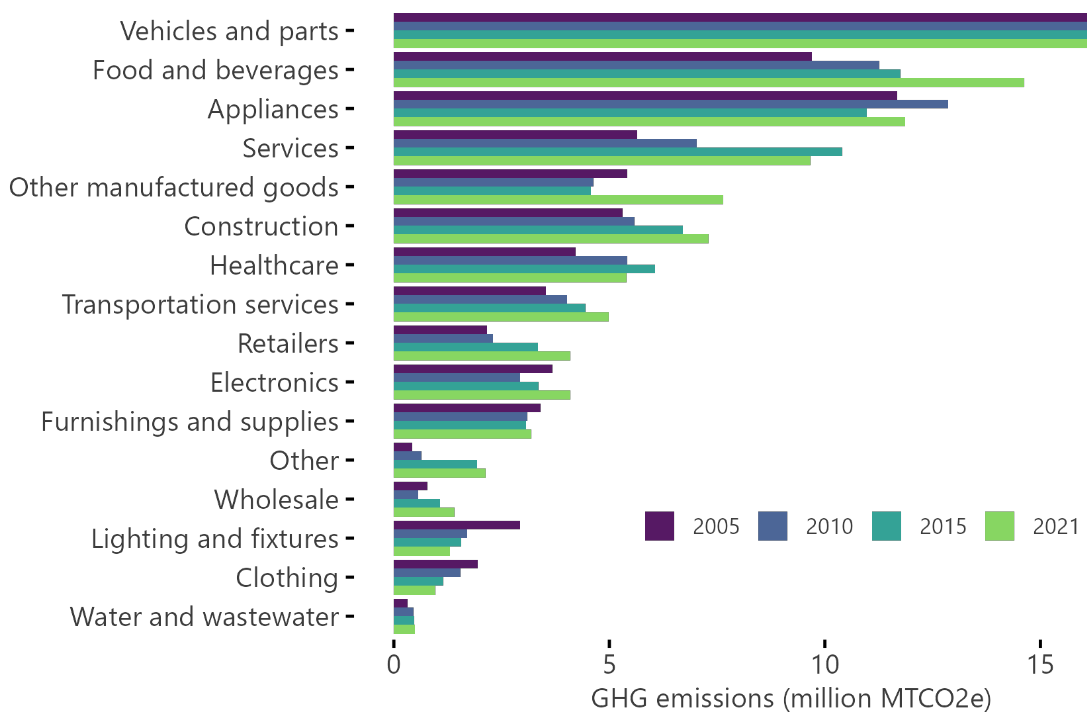


Figure 3-7
Oregon consumption-based GHG emissions, by category, 2005 - 2021
(Million MT CO2e)

The sixteen years covered by these four inventories reveal some interesting patterns. While the four largest categories of emissions (vehicles and parts, food and beverages, appliances, and services) have consistently ranked in the top four, there has been significant growth in emissions from food and beverages as well as services. In contrast, the trend-line for vehicles and parts and appliances is less consistent.

Other categories demonstrating significant change over time include several where emissions have generally trended upwards over time, including other manufactured goods, construction, transportation services, retailers, and wholesale. In contrast, emissions from lighting and fixtures and clothing have trended downwards.

Table 3-6
Oregon consumption-based GHG emissions, by category, 2005 - 2021
(Million MT CO2e)

Category	2005	2010	2015	2021
Vehicles and parts	18.5	16.1	17.8	16.4
Food and beverages	9.7	11.3	11.8	14.6
Appliances	11.7	12.9	11.0	11.9
Services	5.6	7.0	10.4	9.7
Other manufactured goods	5.4	4.6	4.6	7.6
Construction	5.3	5.6	6.7	7.3
Healthcare	4.2	5.4	6.1	5.4
Transportation services	3.5	4.0	4.4	5.0
Retailers	2.2	2.3	3.3	4.1
Electronics	3.7	2.9	3.4	4.1
Furnishings and supplies	3.4	3.1	3.1	3.2
Wholesale	0.8	0.6	1.1	1.4
Lighting and fixtures	2.9	1.7	1.6	1.3
Clothing	1.9	1.6	1.1	1.0
Water and wastewater	0.3	0.5	0.5	0.5
Other	0.4	0.6	1.9	2.1
Total	**79.6**	**80.2**	**88.7**	**95.6**

Totals may not add exactly due to rounding.

Emissions by Type of Consumer, 2005 -2021

As discussed in Section Two, Oregon's consumption-based GHG emissions inventory is constructed in a manner consistent with standards for national economic accounting. "Consumption" is defined as purchases by three types of consumers: households, governments, and "business capital and inventory formation". Other business purchases (supplies, component parts, energy, etc.) are not considered to be consumption but rather are made in *response* to consumption by others.

Figure 3-8 illustrates how consumption (in dollars) and consumption-based emissions arising from these three categories of consumers have changed over time. The graphs on the left show the absolute and relative contribution of each type of consumer to economic final demand; all figures are expressed in real (inflation-adjusted) 2021 dollars. The graphs on the right show absolute and relative contributions of each type of consumer to consumption-based greenhouse gas emissions.

Real (inflation-adjusted) final demand from all three consumer types in Oregon has grown significantly between 2005 and 2021, although almost all of this growth occurred after 2010. Indeed, final demand for Oregon in 2010 was only marginally larger than in 2005 (and on a per-capita basis, final demand in 2010 was lower than in 2005); in 2010 Oregon was only starting to emerge from the impacts of the Great Recession of 2007 – 2009.

As shown in Table 3-7 and Figure 3-8 composition of overall final demand has also changed slightly. Households contributed 65 percent to final demand in 2021 (compared to 68 percent in 2005). Business capital (investment) and inventory formation dipped between 2005 and 2010 (from 18 percent to 13 percent) and then rebounded back to 18 percent of total consumption by 2021. Government's contribution has grown steadily (and at the highest rate) – from 14 percent in 2005 to 18 percent in 2021.

Table 3-7
Oregon consumption (final demand), by type of consumer, 2005 - 2021
(real [inflation adjusted] 2021 US dollars, in billions)

Type of Consumer	2005	2010	2015	2021
Households	$137.7	$147.7	$178.9	$205.0
Government	$28.6	$34.0	$43.8	$55.7
Business Capital and Inventory	$36.2	$27.3	$40.4	$55.9
Total	**$202.4**	**$209.0**	**$263.1**	**$316.6**

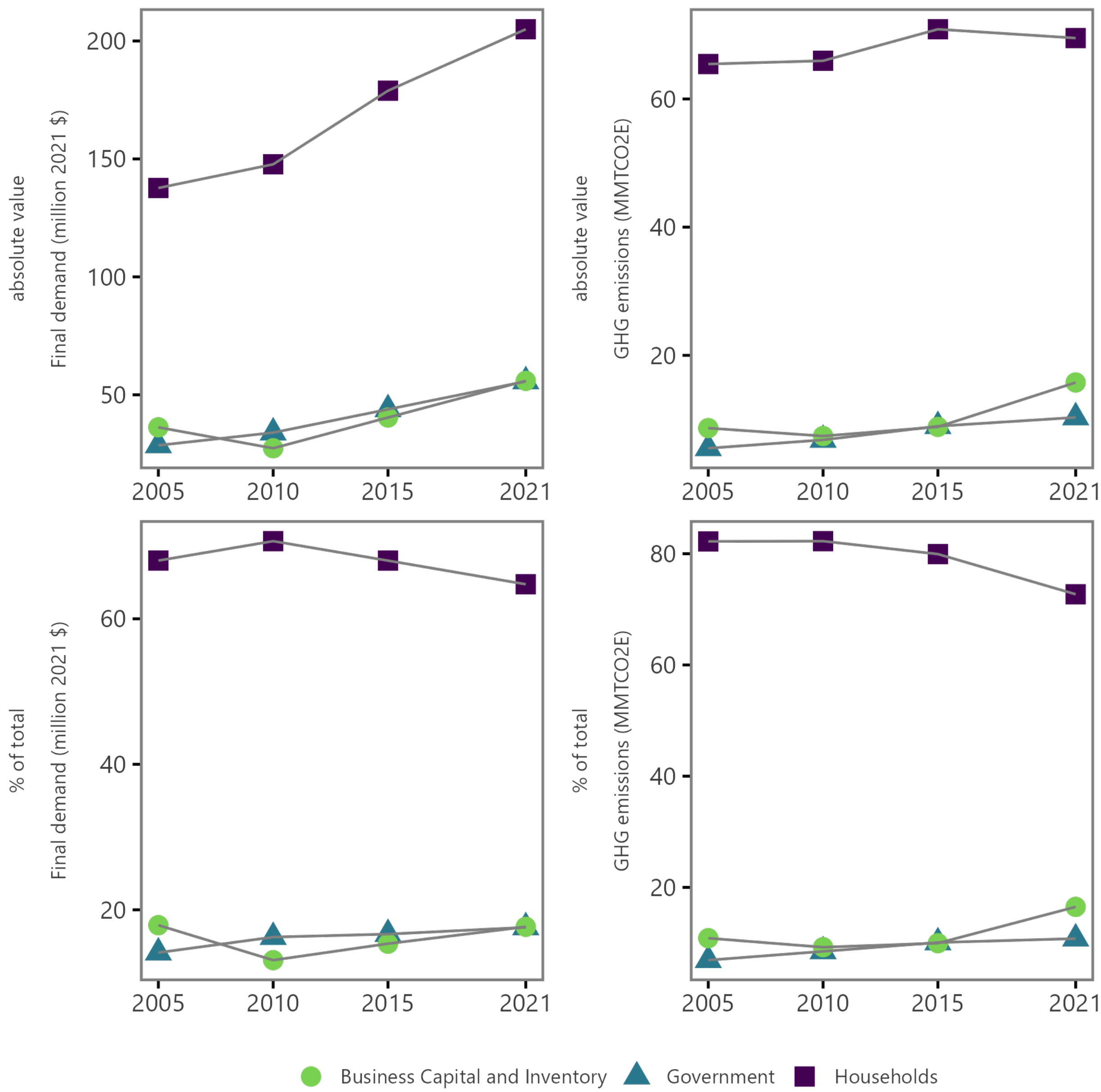


Figure 3-8
Oregon consumption (final demand) and consumption-based emissions, by type of consumer, 2005 - 2021

Turning to consumption-based greenhouse gas emissions, Figure 3-8 and Table 3-8 illustrate how these emissions have changed over time. Household consumption-based emissions rose modestly between 2005 and 2015 and then fell slightly between 2015 and 2021, even as real (inflation-adjusted) consumption rose. This suggests a degree of "absolute decoupling": gains such as energy efficiency or changes in consumption patterns (a shift away from consumption of high-intensity items) were more than enough to offset increases in emissions brought about by rising consumption – but only for household consumers, and not at the level of the full economy (see Figure 3-13 and Table 3-11).

In contrast to households, emissions from government consumption has risen steadily, increasing by 87% from 2005 to 2021 (consistent with a 95% increase in inflation-adjusted consumption). Emissions resulting from business capital and inventory formation follow a similar pattern as consumption expenditures, dipping in 2010 (post-Great Recession) before rebounding and then increasing significantly. Interestingly, between 2015 and 2021, inflation-adjusted consumption spending (on investments, capital, and inventory formation) by businesses rose 38 percent, while associated emissions increased by 78 percent. This suggests that while some of the increase in emissions is caused by more consumption, there has also been a shift towards consumption of more emissions-intensive goods or services.

Table 3-8
Oregon consumption-based GHG emissions, by type of consumer, 2005 – 2021
(Million MT CO2e)

Type of Consumer	2005	2010	2015	2021
Households	65.4	66.0	70.9	69.5
Government	5.5	6.8	8.9	10.3
Business Capital and Inventory	8.7	7.4	8.8	15.8
Total	**79.6**	**80.2**	**88.7**	**95.6**

Consumption- and Sector-Based Emissions, 1990 – 2021

Figure 3-9 illustrates how Oregon's consumption-based and sector-based emissions have changed over a 31-year long time span.

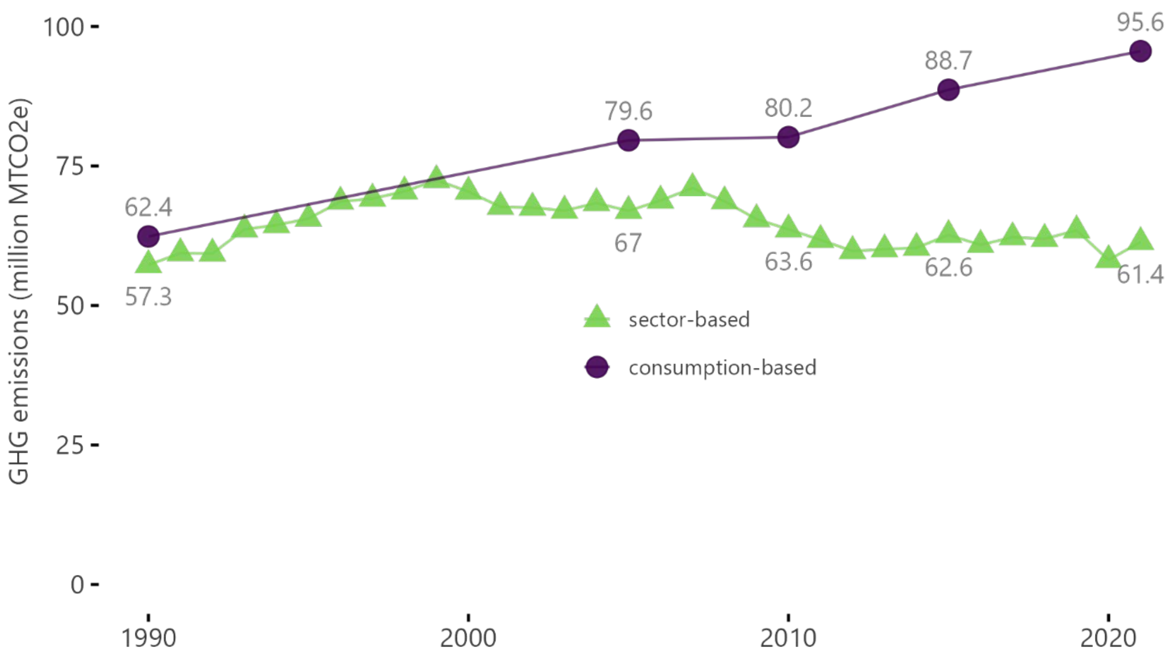


Figure 3-9
Oregon consumption-based and sector-based GHG emissions, fig – 2021

Sector-based emissions are drawn from the state's sector-based inventory, which has estimated emissions for all years 1990 – 2021. Estimates of consumption-based emissions are available only for the years 1990, 2005, 2010, 2015 and 2021 (please see below for details on the estimate for 1990).

Regardless, Figure 3-9 illustrates several significant trends.

Oregon's consumption-based emissions have risen steadily over time. In contrast, Oregon's sector-based emissions rose during the 1990s, peaked in 1999, fluctuated some and then have generally fallen from that peak, with some movement between years (in both directions). Emissions in 2020 were low, corresponding to the circumstances surrounding the COVID 19 public health emergency, and returned in 2021 to pre-COVID levels.

Importantly, the gap between the two inventories has grown significantly: consumption-based emissions were about 5 million MTCO2e higher in 1990, with the gap widening to 13 million MTCO2e (2005), 17 million MTCO2e (2010), 26 million MTCO2e (2015) and most recently (2021), 34 million MTCO2e. This widening gap might be explained by several concurrent factors including: rising consumption by Oregon, increased reliance on imports (from outside of Oregon), offshoring of domestic (and in-state) production, and Oregon decarbonizing its sector-based emissions at a faster rate than states and nations that produce items consumed by Oregon.

Consumption-Based Emissions by Metacategory (Materials, Services, Electricity, Fuels), 2005 – 2021

Another way to consider the relative contribution to consumption-based greenhouse gas emissions is through the use of "metacategories". This concept reduces all forms of consumption into just four groups: materials, services, electricity and fuels. Emissions are assigned to the metacategory associated with the item being consumed – so even though many of the emissions associated with materials are due to energy used to produce those materials, the metacategory view assigns such emissions to "materials", since it is the consumption of materials which cause the energy to be used. In this view, electricity and fuels are limited to direct consumption (final demand) of those commodities.

Figures 3-10 and 3-11 and Table 3-9 illustrate Oregon's consumption-based emissions by metacategory for years 2005, 2010, 2015 and 2021.

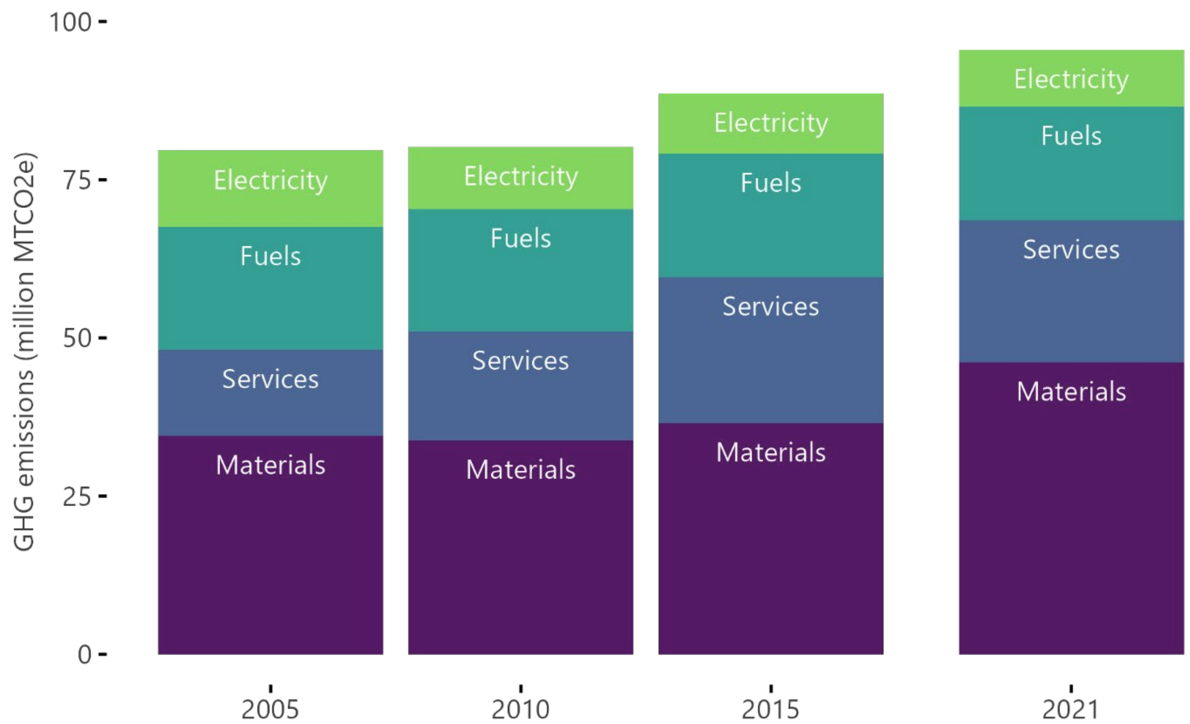


Figure 3-10
Oregon consumption-based GHG emissions, by metacategory, 2005 – 2021

Certain commodities in the underlying model might be considered either a material, or a service. Chief among these are construction and consumption at restaurants. In these cases, emissions are allocated equally between the two metacategories.

Figures 3-10 and 3-11 illustrate some important trends. Materials contribute the most to consumption-based emissions, and while those emissions dipped slightly in 2010 they now contribute almost half (48%) of all consumption-based emissions for Oregon. Services contribute close to one-quarter of the total (24%) and in terms of relative change have increased the most (although materials added more in absolute terms between 2005 and 2021). Emissions from direct consumption of fuels has been generally flat during the study period, with a small decrease observed between 2015 and 2021. Finally, emissions from the consumption of electricity have demonstrated a steady decrease, both in absolute terms (12 MMTCO2e in 2005 to 9 MMTCO2e in 2021) and as a percentage of the whole (15% in 2005 to 9% in 2021).

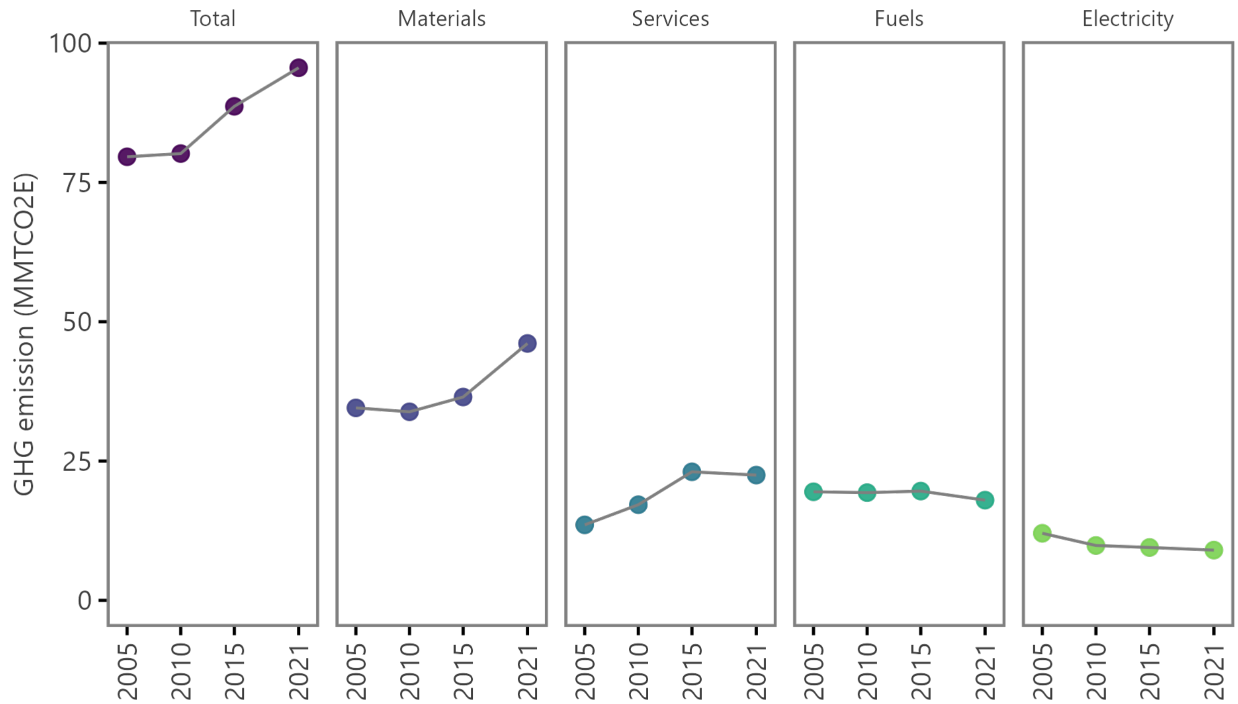


Figure 3-11
Oregon consumption-based GHG emissions, by metacategory, 2005 – 2021

Table 3-9
Oregon consumption-based GHG emissions, by metacategory, 2005 – 2021 (Million MT CO2e)

Metacategory	2005	2010	2015	2021
Materials	34.5 (43%)	33.8 (42%)	36.5 (41%)	46.1 (48%)
Services	13.5 (17%)	17.2 (21%)	23.1 (26%)	22.5 (24%)
Fuels	19.5 (24%)	19.3 (24%)	19.6 (22%)	18.0 (19%)
Electricity	12.0 (15%)	9.8 (12%)	9.5 (11%)	9.0 (9%)
Total	**79.6**	**80.2**	**88.7**	**95.6**

Consumption-Based Emissions by Life Cycle Phase, 2005 – 2021

As described in Section Two, consumption-based emissions are calculated for each of five phases. Figure 3-12 and Table 3-10 illustrate how these have changed over time.

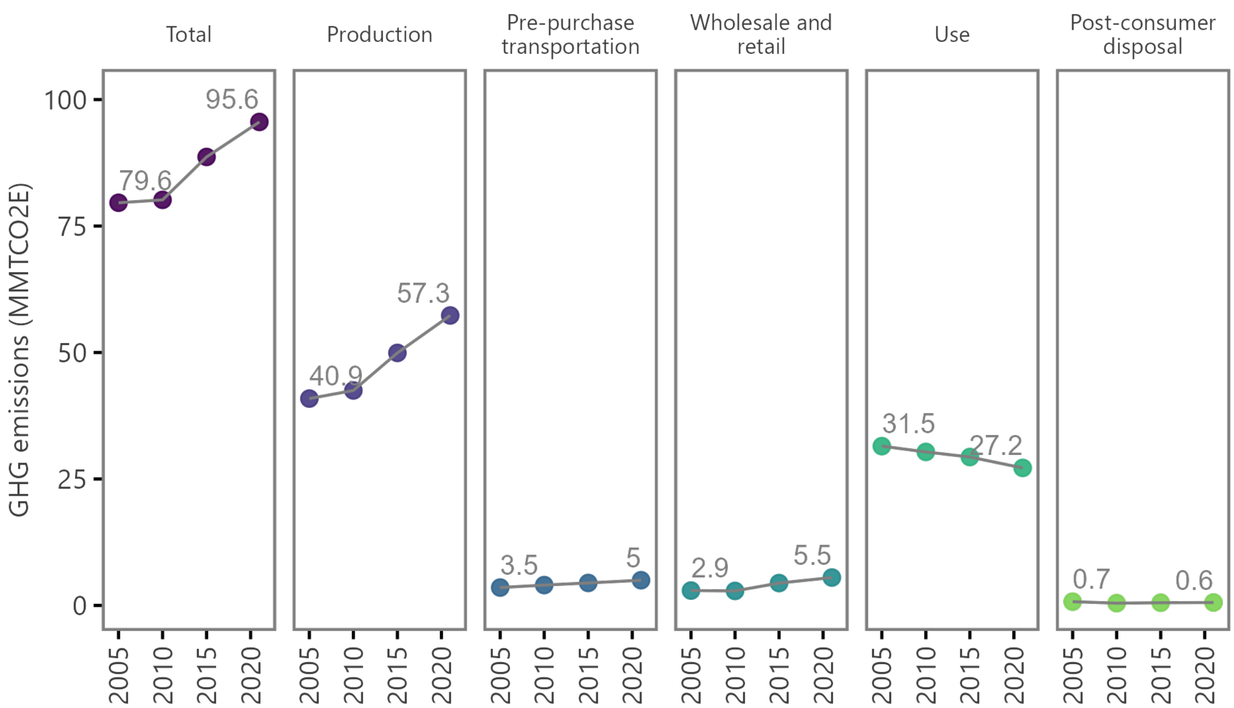


Figure 3-12
Oregon consumption-based GHG emissions, by life cycle phase, 2005 – 2021

Remarkable trends are observed in Figure 3-12 and Table 3-10. In 2005, emissions associated with the "use" phase (emissions from the driving of vehicles and use of appliances, lighting and electronics) contributed 31.5 million MTCO2e and 40% of Oregon's consumption-based GHG emissions. Yet by 2021, and despite significant growth in population, these emissions had fallen modestly: to 27.2 million MTCO2e and only 28% of Oregon's consumption-based emissions. Much of this decrease may be attributed to the effectiveness of conventional climate policy: residential energy efficiency, decarbonization of the electricity supply, appliance efficiency standards, vehicle improvements and the like.

In contrast, emissions associated with the "production" phase rose by an even greater amount: from 40.9 million MTCO2e (and 51% of statewide consumption-based emissions) in 2005, to 57.3 million MTCO2e (and 60% of Oregon's consumption-based emissions) by 2021. Many of these emissions are largely "invisible" to consumers, as they occur at the point of final production and supply chains, oftentimes located in other states and nations. These upstream emissions have not been a significant focus of climate policy in Oregon. Many of these emissions are associated with consumption of materials and services, which have also grown rapidly (see Table 3-9), and these emissions are more likely to be located outside of Oregon (see Table 3-3).

Table 3-10
Oregon consumption-based GHG emissions, by life cycle phase, 2005 – 2021 (Million MT CO2e)

Life Cycle Phase	2005	2010	2015	2021
Production	40.9 (51%)	42.5 (53%)	49.9 (56%)	57.3 (60%)
Pre-purchase transportation	3.5 (4%)	4.0 (5%)	4.4 (5%)	5.0 (5%)
Wholesale and retail	2.9 (4%)	2.9 (4%)	4.4 (5%)	5.5 (6%)
Use	31.5 (40%)	30.3 (38%)	29.3 (33%)	27.2 (28%)
Post-consumer disposal	0.7 (1%)	0.4 (1%)	0.5 (1%)	0.6 (1%)
Total	**79.6**	**80.2**	**88.7**	**95.6**

Drivers of Change in Consumption-Based Emissions

Overall, Oregon's consumption-based greenhouse gas emissions rose approximately 20 percent between 2005 and 2021. Figure 3-13 and Table 3-11 explore some of the factors behind this increase.

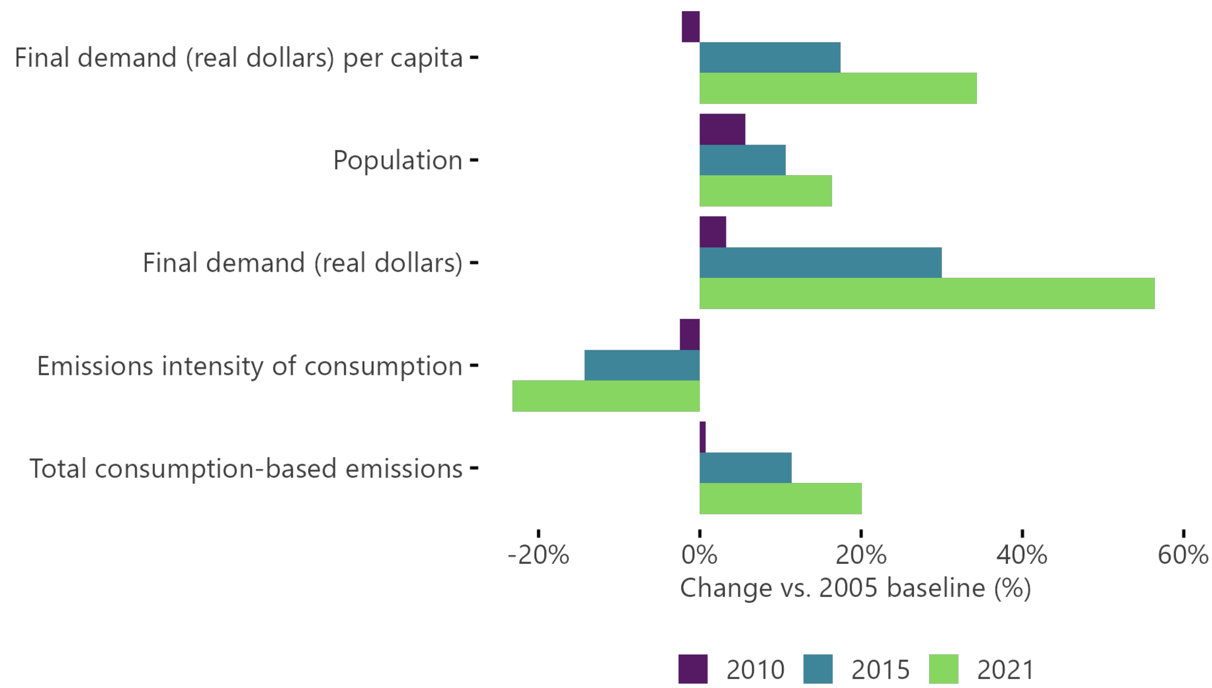


Figure 3-13
Drivers of change in Oregon's consumption-based GHG emissions

Figure 3-13 shows changes in several key drivers for 2010, 2015, and 2021, relative to a 2005 baseline. After adjusting for inflation, statewide consumption (in dollars) divided by Oregon's population ("final demand per capita") was lower in 2010 than in 2005; this may reflect the lingering effects of the Great Recession. But by 2015, per-capita consumption in real (inflation-adjusted) dollar terms was 17.4 percent above 2005 levels and by 2021, it was 34.3 percent above 2005 levels. During the same time period (2005 to 2021), Oregon's population grew by 16.4 percent. More people, each spending more on average (including government and business capital/investment spending) resulted in overall consumption (again, in real, inflation-adjusted terms) being 56 percent higher in 2021 than in 2005.

Other factors helped to mitigate, to some extent, the impacts of this growth in consumption, as shown in emissions intensities. Emissions intensities are a measure of emissions per dollar of economic activity. Sector-based inventories often express emissions intensities on the basis of economic production, but here, intensities are expressed on the basis of consumption: the amount of global greenhouse gas emissions associated with satisfying one average dollar of Oregon consumption. After adjusting for inflation, Oregon's emissions intensities in 2021 were 23.2 percent lower than 2005. This reflects both limited decarbonization and shifts in consumption. Industry in Oregon - and many other areas - produced more output with fewer emissions in 2021 than in 2005. And consumers had shifted their basket of consumption, favoring more services, which tend to have lower emissions intensities than materials or fuels (see below for more details on this point).

However, the benefits of these efficiency improvements that result in lower emissions intensities - fuel switching, cleaner energy mixes and consumption shifts - were over-ridden by the effects of rising overall consumption. Between 2005 and 2021, consumption rose faster (up 56 percent) than emissions intensities fell (down 23 percent). The result was an overall increase in emissions of 20 percent.

Table 3-11
Oregon population, per-capita and total consumption (final demand), 5-phase emissions intensities, and consumption-based greenhouse gas emissions, 2005 - 2021
(Million MT CO2e)

	2005	2010	2015	2021
Per-capita consumption (nominal dollars)	$40,230	$43,904	$57,339	$74,970
Per-capita consumption, 2021$ (real 2021 dollars)	$55,818	$54,557	$65,552	$74,970
Oregon population	3,626,938	3,831,074	4,013,845	4,222,611
Total consumption, 2021$ (billion $)	$202.4	$209.0	$263.1	$316.6
5-phase emissions intensities (kg CO2e/2021$)	0.39	0.38	0.34	0.30
Consumption-based GHG emissions (MMTCO2e)	79.6	80.2	88.7	95.6

Several alternative scenarios illustrate how Oregon might have achieved different outcomes. For example, if per-capita consumption, after adjusting for inflation, had remained constant between 2005 and 2021, overall consumption would have grown in step with Oregon's population, a 16.4 percent increase. Coupling this with a 23.2 percent drop in emissions intensities would have resulted in about an 11 percent decline in consumption-based emissions. Instead, these emissions rose 20 percent.

Alternatively, without any efficiency improvements or other reductions in emissions intensities, consumption-based emissions would have risen 56 percent. This illustrates the benefits of reductions in emissions intensities. Efficiency improvements, fuel switching, and production changes are just some of the many emissions reduction strategies that will be required to reduce both in-state emissions (as reflected in Oregon's sector-based inventory) and consumption-based emissions.

Unfortunately, during the sixteen-year period studied in detail here, Oregon, U.S. and global emissions reductions have not kept pace with the increase in our overall consumption, the root driver of emissions at the global scale. The consequence has been an increase in Oregon's consumption-based greenhouse gas emissions.

Additional Results

Emissions Intensities

Emissions intensities represent a measure of emissions per dollar spent. In Oregon's consumption-based greenhouse gas emissions inventory, they represent the average quantity of greenhouse gases (in kilograms CO_2e) associated with consumption of $1 worth of a given commodity (or sub-category, category, or meta-category).

Emissions intensities are helpful for understanding the rebound effect, which is when consumers engage in a conservation measure that saves them money, then turn around and spend the money on some other activity which results in emissions. Rebound effects explain why conservation isn't necessarily "bad" for the economy: money still circulates, just in different ways. But rebound effects can also undermine the climate or other environmental benefits of certain conservation efforts.

Direct rebound effects are more frequently discussed, and represent shifts in consumer behavior within the same type of purchase. A common example is a household who replaces an incandescent light bulb with an LED, and then chooses to operate the light for more hours. But indirect rebound effects may be more common. An example of an indirect rebound effect is when an individual purchases a more fuel-efficient vehicle, and then uses a portion of the savings at the pump to purchase airplane tickets or meals at a restaurant.

While rebound effects are subject to wide variability (due to differences in individual consumer circumstances and behaviors), emissions intensities can help people understand the relative magnitude of different hypothetical rebound scenarios.

Pre-Purchase (3-phase) Emissions Intensities

Table 3-12 illustrates average emissions intensities (kg CO2e per dollar) for "pre-purchase" emissions in each of sixteen different broad categories of consumption. These values represent only the emissions upstream of consumers in production, supply chain, pre-purchase transportation, retail and wholesale. It does not include the emissions associated with the use or disposal of commodities.

Table 3-12
Pre-purchase (3-phase) greenhouse gas emissions intensities for Oregon consumption, 2021, by category

Category	Pre-purchase emissions (million MTCO2e)	Final demand (million 2021$)	Emissions intensity (kg CO2e/$)
Appliances	673	1,456	0.46
Clothing	959	1,575	0.61
Construction	7,280	23,386	0.31
Electronics	2,782	10,275	0.27
Food and beverages	14,425	24,803	0.58
Furnishings and supplies	2,998	9,870	0.30
Healthcare	5,398	38,008	0.14
Lighting and fixtures	98	219	0.45
Other manufactured goods	7,628	19,275	0.40
Retailers	4,103	23,177	0.18
Services	9,636	74,793	0.13
Transportation services	4,980	4,726	1.05
Vehicles and parts	2,913	7,456	0.39
Water and wastewater	492	1,054	0.47
Wholesale	1,411	11,649	0.12
Other	2,040	57,348	0.04
Total	**67,815**	**309,067**	**0.22**

Average pre-purchase emissions intensities are 0.22 kg CO2e per dollar across all categories. But not all categories have similar emissions intensities. Transportation services, which include airplane tickets as well as freight delivery, have the highest intensity at 1.05 kg CO2e. Clothing, food, appliances, lighting fixtures, other manufactured goods, water/wastewater, and vehicles also have emissions intensities well above the average. In fact, most goods have emissions intensities above the average, while most other services (including healthcare) have lower emissions intensities, reflecting the larger fraction of consumer expenditures in those categories that go to pay wages and salaries, as opposed to energy or manufactured items.

Whole Life Cycle (5-phase) Emissions Intensities

Table 3-13 expands on the prior analysis to include all consumption, including use- and disposal-phases. While adding relatively little to final demand (in terms of absolute dollars spent), the inclusion of fuels and electricity (as well as waste disposal) brings in many more emissions. Table 3-13 shows emissions and emissions intensities across the full life-cycle of consumed commodities, and organizes emissions according to four broad meta-categories. Services have the highest expenditures, which results in the lowest emissions intensity (0.12 kg CO2e/$, on average). Direct purchases of fuels (2.53 kg CO2e/$) and electricity (6.13 kg CO2e/$) both have emissions intensities much higher than the average for all consumption (0.30 kg CO2e/$). The consumption of materials contributes the most to emissions (45.6 MTCO2e) and has average emissions intensities of 0.41 kg CO2e/$, which slightly higher than the average across all metacategories.

Table 3-13
Whole life cycle (5-phase) greenhouse gas emissions intensities for Oregon consumption, 2021, by metacategory

Metacategory	Pre-purchase emissions (million MTCO2e)	Final demand (million 2021$)	Emissions intensity (kg CO2e/$)
Materials	46.1	113,776	$0.41
Services	22.5	194,204	$0.12
Fuels (direct purchases)	18.0	7,118	$2.53
Electricity (direct purchases)	9.0	1,471	$6.13
Total	**95.6**	**316,569**	**$0.30**

It should be noted that materials and services each have many different commodities included in them, and the average emissions intensities shown here are just that: averages. Certain commodities have emissions intensities much higher (or lower) than the average. For example, air transportation (a service) has an average 2021 emissions intensity of 1.04 kg CO2e per dollar (much higher than the average of 0.12 for all services), while rail travel (another service) has an average 2021 emissions intensity of only 0.40 kg CO2e per dollar spent. Similarly, meats (other than poultry and seafood) have average 2021 emissions intensity of 1.90 kg CO2e per dollar, more than double the emissions intensity for fruits and vegetables (0.72 kg CO2e per dollar) and higher still than the average of 0.41 for all materials.

Consumption, Emissions Intensities and Emissions

Another way of understanding consumption-based emissions is to consider this basic formula:

Consumption x Emissions Intensities = Emissions

Emissions (in MTCO2e) are calculated by multiplying consumption (in $) by emissions intensities (in MTCO2e per dollar). This simplified explanation is not exactly how Oregon's CBEI is derived (see Section Four for details) but nevertheless allows for a visual exposition of the relationship between consumption, emissions intensities, and emissions, as illustrated in Figure 3-14.

The categories in Figure 3-14 deviate from categories used elsewhere in this report given a different treatment of use- and disposal-phase emissions. In Figure 3-14, emissions associated with the use of electricity and fuels, as well as emissions from post-consumer waste disposal, are reported separately from the standard 16 categories. However, emissions associated with the use of refrigerants (in appliances and vehicles) and lubricants (in vehicle engines) are associated with those categories.

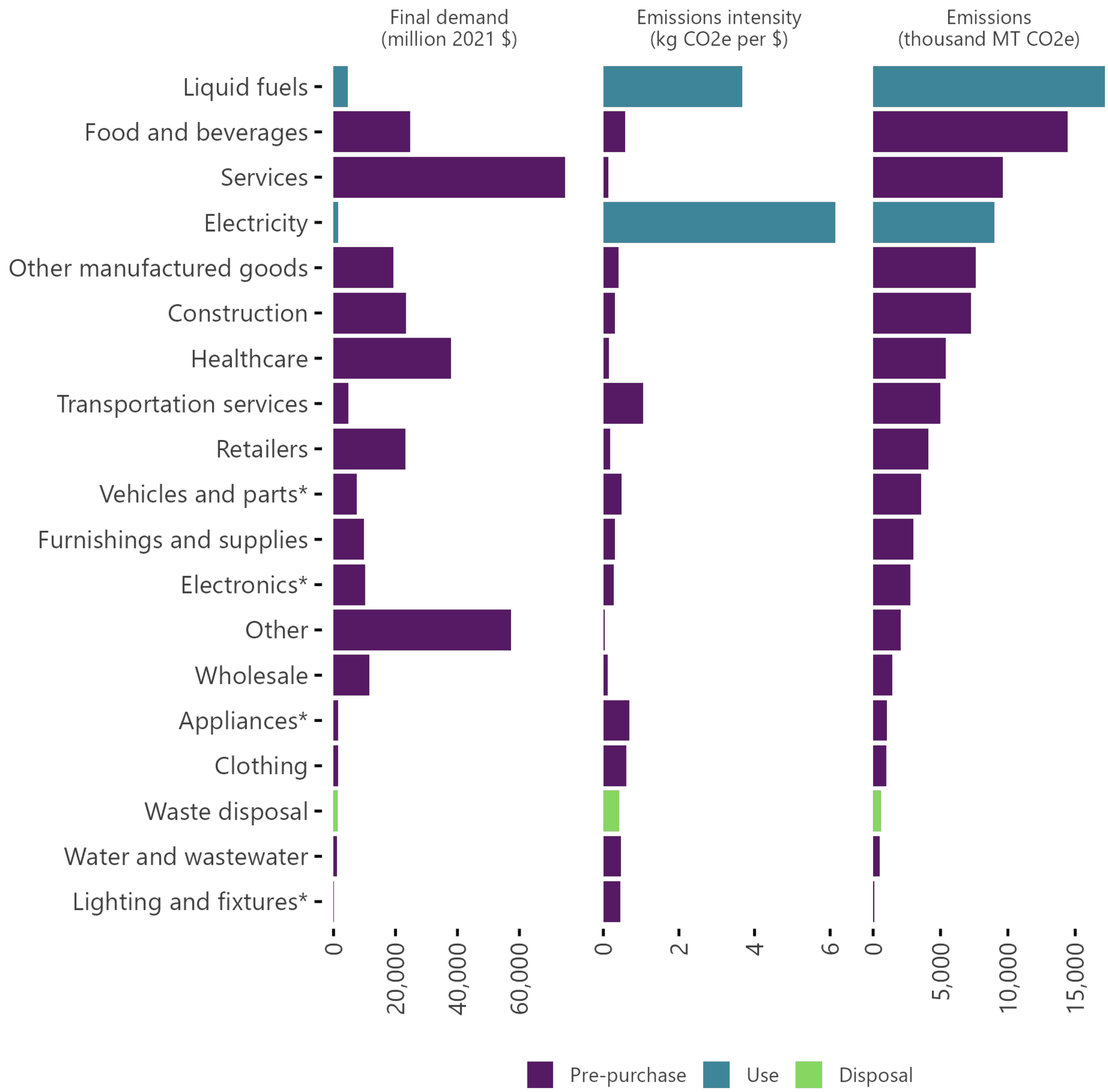


Figure 3-14
Major components of Oregon's 2021 consumption-based emissions, by spending category and life cycle stage

Regardless, Figure 3-14 illustrates the relationship between final demand, emissions intensities, and emissions. The categories with the highest emissions either have high final demand (e.g., services, construction), high emissions intensities (e.g., electricity, liquid fuels), or both (e.g., food and beverages).

4. Methodology

Methodology and Data Sources

Methodology Overview

The consumption-based emissions inventory (CBEI) for Oregon is an estimate of the greenhouse gas emissions resulting from the purchase of goods and services (including fuels and electricity) by Oregon consumers. CBEI follows the commodities (goods and services) purchased by Oregon's consumers and assigns to these commodities their total life-cycle emissions, from cradle (the production phase) to grave (the post-consumer disposal phase). For example, the cookies consumed by an Oregon resident may be produced in Oregon, California or Canada, but – when considered on a consumption basis – Oregon shares in the responsibility for these emissions. A consumption-based inventory takes the purchase of a final good or service as the act that defines whether a commodity's life-cycle emissions should be in or out of the inventory; in CBEI the life-cycle emissions of anything consumed (or in economic terms, "demanded") by Oregon consumers is included, regardless of where the consumption or emissions actually occur.[9]

CBEI encompasses the complete life cycle impacts of the state's consumption, divided into five phases: production, pre-purchase transportation (transport of materials used in production and transport of the final product from producer to wholesaler and retailer), wholesale and retail distribution, use, and post-consumer-disposal. The first three phases, also called "pre-purchase", include direct and indirect emissions, where "direct" are the emissions from the production of the final good or service purchased by Oregon consumers and "indirect" are the emissions associated with production of all of the intermediate (supply chain) goods and services used to produce the final good. The use phase similarly includes the direct and indirect emissions from fuel use by the state's household and government entities, and the direct and indirect emissions from the generation of electricity used by households and governments. The post-consumer disposal phase includes the direct and indirect emissions from households' and governments' waste disposal, both from landfilling and the combustion of solid wastes.

CBEI estimates consumption-based emissions for Oregon; it does not measure these results. The relative error at the aggregated level (e.g., all consumption for the entire state) is very likely to be narrower than the relative error at the level of an individual commodity (CBEI for 2021 models 546 different commodities). The accuracy of results, therefore, likely decreases as the focus becomes more specific. Further, model results are based on commodity sector averages, and there is potential for significant variability between similar products (brands) and/or producers of the same commodity. CBEI results should not be used to characterize the emissions or emissions intensity of any individual product (brand) or producer.

Step One: Three-Phase Pre-Purchase "Standard" Model

Emissions calculations begin with the dollar value of Oregon's consumer purchases (called final demand) – classified into 546 types of commodities – and use economic input-output analysis to calculate the upstream (supply chain) production requirements of these purchases, also called "intermediate" or "indirect" demand.[10] For example, the purchase of a washing machine by a household (final demand) requires an upstream chain of business-to-business purchases: the washing machine factory purchases steel, plastic, wiring, and electricity; the steel foundry purchases iron and coal; and so on. Final demand for each commodity creates intermediate demand for other commodities. The sum of final demand and intermediate demand for any given commodity is called "gross demand." For example, the gross demand of clothing would be the final demand of clothing (direct purchases of clothing by consumers) plus the intermediate demand for clothing resulting from all final demand of all commodities (such as the purchase of uniforms by hotels and the purchase of scrubs by hospitals). Demand is measured in dollars.

In the "standard" model calculations, the gross (final plus intermediate) demand associated with all final commodities purchased by Oregon consumers is multiplied by the appropriate emissions intensity (emissions per dollar) for each commodity to calculate the resultant emissions. This gross demand is divided into production in three regions: Oregon, the other 49 states, and other countries. Gross demand for products made in Oregon is multiplied by Oregon's emissions intensities; gross demand for products made in the other 49 U.S. states is multiplied by U.S. emissions intensities; and gross demand for products made in other countries is multiplied by the emissions intensities for foreign imports into the United States.[11] Land use emissions are not included in the CBEI model. For this reason, CBEI may underestimate total GHG emissions, and is insensitive to impacts of products that may have significant indirect land-use impacts, such as wood from unsustainably-managed tropical forests, and food made with palm oil from tropical plantations.

The resulting emissions are classified as production, pre-purchase transportation, or wholesale/retail, and are reported on an industry and location basis.[12] For example, in order to produce cars sold in Oregon, auto companies must purchase steel and other inputs. The emissions from production of the steel used to make these cars are included in the calculation of production emissions, since they are part of the life-cycle emissions of cars sold in Oregon. However, in the "standard model", those emissions are reported as steel industry emissions (and not vehicle production emissions). In the "standard" model, a similar principle of classification applies to all other emissions from production of inputs or intermediate goods: All emissions are assigned to the industries that produce them (e.g. steel), even when the emissions are ultimately used to satisfy production of a final good in another industry (e.g. autos). CBEI three-phase pre-purchase "standard" is a life-cycle emissions analysis not for each type of consumer good, but for total Oregon consumption for a single year.

CBEI "standard" emissions are reported by emission location as well as industry, distinguishing emissions that occur in Oregon, in the rest of the United States, and in other countries. This reporting convention does not reflect causation: for example, Oregon's purchases of domestically produced cars may cause emissions from steel produced in Mexico or Korea, and imported for use in U.S. automobile production. In this example, the emissions from steel production are reported in CBEI's standard model as foreign steel industry emissions, while the emissions from the assembly of the same automobile would be reported as U.S. auto industry emissions.

Step Two: Three-Phase Pre-Purchase "LCA" Model

The CBEI "standard" model, described above, performs a life-cycle emissions analysis on Oregon's total consumption of goods and services where emissions "upstream" of the consumer (pre-purchase three-phase emissions) are classified according to producing industry. CBEI's "standard" results do not classify emissions according to commodities consumed. "Standard" emissions in the clothing category, for example, are not the life-cycle emissions of clothing; if a consumer's purchase of clothing results in upstream emissions from the clothing industry's purchase of equipment, buttons, packaging, or fuel, these emissions are classified in the "standard" model as equipment, buttons, packaging, or fuel, and are not readily observable as having resulted from the purchase of clothing. Similarly, if a consumer's purchase of hotel stays, doctor's visits, or computers results in upstream emissions from the clothing industry (associated with the manufacture of clothing for housekeeping staff or medical scrubs, or clean-room "bunny suits"), these emissions are classified as clothing, and are not readily observable as having resulted from the purchase of hotel stays, doctor's visits, or computers.

Rerunning CBEI in its "LCA" mode reorganizes the three-phase results according to the commodities consumed; these results are referred to as "CBEI-LCA" emissions. Both modes (the "Standard" mode and the "LCA" mode) result in the same grand total of emissions for the Oregon consumption-based inventory, but very different allocations of emissions among sectors. CBEI's "LCA" results are the life-cycle emissions of each and every sector of Oregon consumption *separately*. Emissions are assigned to the sector of the good or service consumed. For example, in LCA mode, emissions from the production of any good or service that are associated with the consumption of clothing (cotton growing, dye manufacture, and advertising) are assigned to clothing. All emissions shown in this report are CBEI-LCA emissions.

Note that a given commodity category's CBEI "LCA" results do not include emissions from wholesalers, retailers, or the transportation of a final commodity from factory to wholesaler to retailer; rather, these results are broken out in the pre-purchase transportation and wholesale/retail phases. For example, beer emissions, as reported here, are the result of final demand for beer (or the dollar value of beer purchased at the factory), not of the dollar value of beer purchased in a store or bar. This is consistent with the treatment of final demand in CBEI's underlying economic data. In these economic data, a consumer purchase of any one commodity (such as beer) is treated as four separate purchases: a purchase of beer (from the beer producer), a purchase of transportation services (from the final producers to the retailer), a purchase of wholesale services, and a purchase of retail services.

Step Three: CBEI Five-Phase Final Results

The final step in CBEI calculations adds two additional phases to the pre-purchase "LCA" results: use and post-consumer disposal.

The calculation of CBEI's use phase includes additional emissions from direct fuel use (not included in the three-phase pre-purchase model) and direct electricity (the direct electricity results modeled in the three-phase model are discarded in favor of reported data), and a transfer of some emissions from the production phase to the use phase. Fuels are an important category of Oregon's consumer purchases, but the three-phase pre-purchase model only includes the upstream impacts of refining and distributing fuels, and of businesses' burning fuels to make and transport products; it does not include the use phase impacts of consumers burning fuels in their cars and furnaces.

Use phase calculations take the emissions from consumers' burning fuels (which are not included in the pre-purchase model) and electricity (from the sector-based inventory) and add to them separate estimates of upstream emissions ("well-to-pump" emissions for fuels and "pre-combustion" or "pre-generation" emissions for electricity), along with emissions from the use of refrigerants and vehicle lubricants. Upstream emissions associated with production of engine lubricants are transferred from the production phase.

These emissions are allocated to the various appliances, lights, electronics and vehicles that use fuels and electricity. To be clear, use phase emissions are not classified according to the commodity purchased (fuel, electricity, etc.); instead, these emissions (both direct and upstream) are allocated to the commodities that use fuel and electricity, in proportion to Oregon consumers' use of appliances, lights, electronics and vehicles.

Post-consumer disposal phase emissions calculations make an additional transfer from the production phase. These include direct emissions from the landfilling and combustion of waste originating from Oregon consumers (households and government facilities); the upstream emissions of materials, energy and services purchased by disposal businesses; and an estimate of emissions associated with direct burning of garbage by households.

Emissions associated with purchased waste services are subtracted from the three-phase pre-purchase “LCA” model’s calculation of the production phase and replaced with an estimate of disposal-related emissions from households and governments. These are assigned to the post-consumer disposal phase, allocated to all various commodities in proportion to the types of items found in Oregon’s municipal waste. Again, post-consumer disposal phase emissions are not classified according to the commodity purchased (waste disposal services), but instead according to the types of commodities that Oregon consumers throw away.

Model Structure

The estimate of Oregon’s consumption-based greenhouse gas emissions is derived through a complex model that operates using Microsoft Excel. The current version of the model consists of seven linked workbooks:

1. OR2021 CBEI Final Demand
2. OR2021 CBEI Emissions Factors
3. OR2021 CBEI GHG Coefficients
4. OR2021 CBEI Emissions
5. OR2021 CBEI Demand Modeler
6. OR2021 CBEI Use and Disposal
7. OR2021 CBEI Final Results

Each of the workbooks consists of a series of separate worksheets (approximately 125 in total). Step two described above (Three-Phase Pre-Purchase “LCA” Model) requires the use of a custom macro that was first developed for DEQ by SEI.

US and Oregon Emissions Factors

The model estimates direct (on-site) emissions for each of 546 industries in Oregon and the US, and then uses these to estimate the emissions factor (emissions per dollar of economic output) for production in those industries. The industries and their 2021 economic output are taken from the IMPLAN database. IMPLAN is a leading economic modeling software product that includes national and state income and production accounts data and input-output models of the U.S. and Oregon economies, developed using data form the U.S. Commerce Department’s Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other sources.

U.S. and Oregon calculations are performed separately, although using similar processes. US direct emissions factors are described first.

US Emissions Factors

U.S. GHG emissions for 2021 are assigned to 546 U.S. industries as identified by the IMPLAN model. The U.S. GHG emissions are drawn directly from the U.S. 2021 GHG inventory (US EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 - 2021 (2023)). The model begins by taking U.S. in-boundary GHG emissions and assigning them to one of nine categories:

- CO2 industrial non-combustion
- CO2 industrial combustion (which includes electricity generation)
- Non-energy uses of fuels
- CO2 commercial
- Transportation (all gases)
- CH4
- N2O
- High impact gases
- Other (excluded)

Gases in the first eight of these nine categories are then allocated amongst the 546 IMPLAN industries using a variety of techniques. These are described in detail below. In all eight cases the model references economic output for each industry (2021$) as reported by IMPLAN.

Different greenhouse gases (carbon dioxide, methane, nitrous oxide, etc.) have different relative effects, which are characterized through the use of “global warming potentials”. EPA’s 2021 inventory reports emissions using global warming potentials from the IPCC’s Fifth Assessment Report. However, Oregon’s sector-based GHG emissions inventory currently uses global warming potentials from the IPCC’s Fourth Assessment Report (AR-4). For consistency with Oregon’s sector-based inventory, EPA emissions are first converted to carbon dioxide equivalents using AR-4 values.

Emissions in the ”other” category, which are not allocated to IMPLAN industries, include emissions from residential on-site energy combustion and residential use of HFCs, emissions from U.S. territories, and biogenic CO2 emissions from wood biomass, ethanol and biodiesel use.

US CO2 industrial non-combustion

Industrial non-combustion emissions of CO2 are those emissions that do not result from the combustion of fuels. Many industrial processes involve chemical reactions that result in the release of CO2. EPA's 2021 GHG inventory includes 253 million MT CO2e of industrial non-combustion emissions.

Emissions are assigned to IMPLAN industries by matching source activities to the most closely related industrial sectors.

In some cases, emissions are assigned to a single industry. For example, emissions from cement production (41.3 million MT CO2e) are assigned exclusively to IMPLAN industry 203, cement manufacturing.

Where the source activity description is too aggregated, emissions are distributed amongst the appropriate IMPLAN sectors in proportion to their economic output. For example, emissions from glass production (2.0 million MT CO2e) are allocated to three IMPLAN industries (200 - 202) that involve glass production.

Where the source activity description is too disaggregated, emissions are assigned to the IMPLAN sector that included that NAICS sector.

In a few instances, data from EPA's GHG inventory are first disaggregated into sub-categories prior to allocation to IMPLAN industries. Such disaggregation is based on supplemental information included in EPA's report. One example of this are the emissions resulting from "other process uses of carbonates". These are first allocated into the subcategories of flux stone, flue gas desulfurization, and "other miscellaneous uses" and from there further allocated to individual IMPLAN industries.

US CO2 industrial combustion

Industrial combustion emissions include emissions from fuels (other than transportation) used in the generation of electricity and by industry, which includes agriculture, mining, construction and manufacturing.

Manufacturing-related CO2 combustion emissions are allocated first into 15 categories based on special studies of manufacturing sector "carbon footprints" published by the U.S. Department of Energy. Because this portion of the CBEI model is calculating direct (on-site) and not supply-chain related emissions, we draw from these special studies only the "onsite" combustion-related emissions. These emissions estimates include all combustion-related gases including CH4 and N2O and are based on the 2018 U.S. Manufacturing Energy Consumption Survey. Reported values are converted to CO2 only based on the ratio of US industrial non-electric CO2e (all gases):US industrial non-electric CO2 only, derived from the 2015 Oregon CBEI.

Emissions are then scaled to 2021 based on the ratio of 2021:2018 US non-electric industrial CO2 combustion emissions.

The adjusted manufacturing CO2 combustion emissions for each of the 15 manufacturing categories are then matched against the NAICS codes included in that category and compared against total energy use as reported in the 2018 Manufacturing Energy Consumption Survey (MECS). In some cases, the category is associated with multiple line items in MECS (called here "subcategories"), and so emissions are allocated amongst the MECS subcategories in proportion to each subcategory's use of energy, less electricity and "other" (which includes a variety of non-fossil based energy sources, such as wood).

Emissions from each subcategory (or category where no subcategories exist, such as cement) are then allocated to associated IMPLAN industries using the same standards as described in industrial non-combustion CO2, above.

Not all manufacturing sectors are represented in the 15 categories that were profiled for carbon footprints by the US DOE. Fortunately, US DOE also estimated the carbon footprint for all U.S. manufacturing. Emissions from the 15 profiled categories are subtracted from the U.S. manufacturing total, and the remainder is then distributed among all remaining IMPLAN manufacturing sectors.

The total of manufacturing sector CO2 combustion emissions (740 MMTCO2 for 2021, adjusted from the 780 MMTCO2e for 2018) are then subtracted from 2021 industrial CO2 combustion emissions as estimated in EPA's US greenhouse gas inventory (776 MMTCO2e). As noted above, "industry" is defined to include manufacturing but also agriculture, mining and construction. The difference is allocated to these other IMPLAN sectors (agriculture, mining and construction) in proportion to their economic output.

Finally, US CO2 combustion emissions from electricity generation are assigned to the associated electricity generation industries in IMPLAN (1540.5 MMTCO2e to IMPLAN industry 40 - electricity generation from fossil fuels, and 0.4 MMCO2e to IMPLAN industry 44 - electricity generation geothermal), consistent with electricity-related emissions profiles in the US EPA inventory.

US non-energy uses of fuels

Approximately 140 million MTCO2e of CO2 emissions occurred in 2021 as a result of what EPA refers to as "non-energy uses of fuels". These are carbon-containing fuels that are used for non-energy purposes and that eventually release the fossil-derived CO2 to the atmosphere. Examples include coking coal, petrolatum, waxes, and solvents.

EPA provided DEQ with a more detailed accounting of these emissions, broken into five major categories: feedstocks, asphalt, lubricants, waxes and other. Within these categories, EPA provided additional detail (for example, "feedstocks" include antifreeze and deicers, abraded tire rubber, food additives, pesticides, soaps and detergents, and solvents). This categorization was allocated to IMPLAN industries using one-to-one mapping where appropriate, or economic allocation across multiple industries, when more than one IMPLAN industry could be associated with a specific source.

US CO2 commercial

Commercial (non-industrial) businesses are also sources of CO2 emissions. According to the US GHG inventory, emissions from this sector were 233 MMTCO2e in 2021. These emissions are allocated first into 15 different "principal building activities" (PBAs), in proportion to each PBA's relative use of non-electrical energy, as estimated in the most recent (2018) U.S. Commercial Building Energy Consumption Survey (CBECS).

Next, for each commercial IMPLAN sector, the corresponding NAICS code(s) was identified, and this was used to identify the associated PBA or PBAs. The Energy Information Administration provides a table identifying which types of businesses for each major (2-digit) NAICS code "very likely", "somewhat likely" or "possibly" are located in each of the PBAs. For example, businesses in NAICS 51 ("Information") are "very likely" to be found in buildings with a primary building activity of "office", "somewhat likely" to be found in buildings with a PBA designation of "enclosed mercantile and strip mall", "public assembly", or "other", and are possibly located in several other types of buildings including those with PBAs of "education", "warehouse and storage" and several others.

Emissions from any given PBA are allocated to specific IMPLAN industries that are "very likely" or "somewhat likely" to be associated with that PBA in proportion to *adjusted* economic output for any given industry relative to the sum of adjusted economic outputs of all IMPLAN industries associated with that PBA. For example, if Industry X contributes 3 percent of the adjusted economic output among all industries sharing the PBA of "public assembly", then 3 percent of emissions allocated to that PBA are sub-allocated to Industry X.

Raw economic outputs of these IMPLAN industries are adjusted as follows:

For each IMPLAN industry, the number of PBAs it might “very likely” be associated with is counted. A similar count is conducted for the number of PBAs it is “somewhat likely” to be associated with.

These factors are combined into a “weighting factor” defined as ((1 – 1/(count of “very likely” PBAs + 1) + (1/(2 x count of “somewhat likely” PBAs))/(count of “very likely PBAs”). In rare cases where there are no “somewhat likely” PBAs, the weighting factor is simply the 1 divided by the number of very likely PBAs.

For example, if an IMPLAN sector is “very likely” associated with 2 different types of PBAs and has no “somewhat likely” PBAs, then the weighting factor is simply 0.5. However, if there are 2 different types of “very likely” PBAs and 1 “somewhat likely” PBA, the weighting factor falls to 0.42. And if the number of “somewhat likely” PBAs rises to 2 or 3, then the weighting factor falls again, to 0.40 or 0.38, respectively.

The weighting factor is then used for each IMPLAN producing sector to calculate “adjusted industry output”. For any PBA where the industry has no or only “possible” locations, adjusted industry output is assumed to be zero. On the other hand, for any PBA where the industry has a “very likely” location, adjusted industry output is calculated as the industry’s total economic output, multiplied simply by the weighting factor. In intermediate cases, where the industry is “somewhat likely” to be located in one or more PBAs, the adjusted industry output in that PBA is any residual output (total output less output assigned to “very likely” PBAs) divided by the number of PBAs for which the industry is “somewhat likely” to be associated.

For example, consider an industry that is “very likely” to be associated with PBAs of “office” and “service” and also “somewhat likely” to be associated with PBAs of “education” and “other”. In this case, the count of “very likely” and “somewhat likely” PBAs are 2 each, and continuing the example above, the weighting factor is 0.40. Total economic output from that sector is then allocated to the PBAs as follows: “offices” and “services” receive 40% each, and “education” and “other” receive 10% each (100% less 80% previously allocated, then divided by two).

This approach reflects that fact that some economic sectors, such as schools, are associated with a large number of PBAs. For example, schools are associated with the PBA “outpatient health care”, and yet one dollar of economic output of a school does not translate into the same health-care related emissions as one dollar of economic output of a hospital or clinic, where health care is a primary or more central activity.

For each PBA, adjusted economic output across all relevant commercial sectors is then added together, and used to sub-allocate the commercial CO2 emissions allocated previously to that PBA. The emissions are sub-allocated to each IMPLAN commercial sector in proportion to their relative contribution to adjusted economic output associated with that PBA.

US transportation

Emissions resulting from transportation equipment or activities are allocated to IMPLAN industries using a series of allocation methods and algorithms unlike any of the other types of emissions. Because these allocation methods are used for all transport-related emissions (CO_2, CH_4, N_2O, and high impact gases), all transportation-related emissions in the US inventory are allocated in this module. This includes:

- 1,752 MMTCO2e of CO_2 associated with transportation fuel combustion,
- an additional 80 MMTCO2e of CO_2 associated with the combustion of "international bunker fuels" which are reported as an informational item in (but not included in the sum of) the U.S. Inventory,
- 2 MMTCO2e of CH_4 emissions associated with mobile combustion,
- 19 MMTCO2e of N_2O emissions associated with mobile combustion,
- 33 MMTCO2e of emissions from HFCs (used as refrigerants in the transport sector), and
- 8 MMTCO2e of CO_2 emissions from the use of lubricants by the transport sector.

For all emissions other than CO_2 from lubricants, transportation emissions are first assigned to fuel and vehicle types (such as "gasoline - passenger cars" or "jet fuel - military aircraft") using additional data contained in Tables 2-10, 2-13, 3-10, 3-13, 3-14, and 3-15 of EPA's 2021 U.S. GHG Inventory. CO_2 emissions from use of lubricants are allocated to different vehicle types in amounts proportionate to the vehicle-miles traveled by different vehicle types as reported by the U.S. Bureau of Transportation Statistics for 2021.

Once emissions are assigned to vehicle type, they are further allocated to "private" and "public", or "private - household", "private - commercial", and "public (government") using a variety of data sources, including data from the Federal Highway Administration's (FHA) annual report of motor vehicle registrations, the most recent FHA National Household Travel Survey (2009), the US Census Bureau's 2021 Vehicle Inventory and Use Survey (2021), US Bureau of Transportation Statistics (2024), US Bureau of Labor Statistics (2021 and 2024), and Federal Aviation Administration General Aviation Surveys (2015).

Out of this process, the total US transportation emissions of 1,895 MMTCO2e are allocated into three broad categories: households (900 MMTCO2e), government (57 MMTCO2e), and commercial (938 MMTCO2e).

The commercial transport emissions are then further sub-allocated as follows:

- Emissions from commercial use of cars, light-duty trucks and motorcycles are assigned to a general category of "commercial". These are then further allocated among IMPLAN industries 1 – 448, 450 – 524, 526, 528, 531, and 534 using economic allocation.

- Emissions from medium- and heavy-duty trucks are wholly assigned to IMPLAN industry 417 ("truck transport").
- Emissions from commercial use of buses are allocated between IMPLAN industries 418 ("transit and ground passenger transportation") and 420 ("scenic and sightseeing transportation and support activities for transportation") using economic allocation.
- Emissions from commercial use of rail are assigned wholly to IMPLAN industry 415, "rail transportation".
- Emissions from ships and non-recreational boats (commercial, not government) are assigned wholly to IMPLAN industry 416, "water transportation".
- Emissions from commercial aircraft are assigned fully to IMPLAN industry 414 ("air transport")
- The commercial portion of emissions from general aviation aircraft (after removing household aircraft emissions) are allocated across multiple IMPLAN industries in proportion to the number of hours flown for different purposes as reported to the Federal Aviation Administration. Examples of these industries include 482 "other educational services" (which includes flight schools), 19 "support activities for agriculture and forestry" (for agricultural application of pesticides), and 414 "air transport" (which includes "air taxi" services for hire). A portion of these emissions are also allocated to a general category of "commercial", representing corporate-owned jets (not commuter jets for hire). As with on-road vehicles, these general "commercial" emissions are allocated across IMPLAN industries 1 – 448, 450 – 524, 526, 528, 531, and 534 using economic allocation.
- Other air-related emissions that are not specified as either commercial aircraft or general aviation aircraft (CH4, N2O, and lubricants) are allocated to all industries receiving emissions from commercial aircraft or general aviation aircraft, in proportion to those emissions.
- Emissions from pipelines (both fugitive emissions of methane and CO2 emissions from compressors used in pipelines) are assigned fully to IMPLAN industry 419 ("pipeline transportation").
- Distillate fuel (diesel) and residual fuel oil classified as bunker fuels are assigned to IMPLAN industry 416 ("water transportation").
- CH4 and N2O emissions from "agricultural equipment" are allocated across all agricultural industries in IMPLAN using economic allocation.
- CH4 and N2O emissions from "construction and mining equipment" are allocated across all construction and mining industries in IMPLAN using economic allocation.
- Commercial emissions from "other" and "alternative fuel on-road vehicles" are allocated across IMPLAN industries 1 – 448, 450 – 524, 526, 528, 531, and 534 using economic allocation.

- Nitrous oxide and methane emissions from uses of bunker fuels are allocated proportionately to carbon dioxide emissions from bunker fuels.

US CH4

The US inventory includes 638 MMTCO2e of methane emissions (using AR-4 global warming potentials), not including emissions are from residential sources or mobile combustion, which is assigned to the "US transportation" module. The 638 MMTCO2e are allocated in this section. Major categories of emissions include methane from enteric fermentation, natural gas systems, landfills, manure management and coal mining.

Emissions are assigned to IMPLAN industries one a one-for-one basis where possible (e.g., emissions from landfills are assigned entirely to IMPLAN Industry 479, "Waste management and remediation services"), or to multiple industries using economic allocation where more than one industry is known to contribute to emissions (for example, emissions from "field burning of agricultural residues" are allocated across all farming/cropping industries in IMPLAN).

In some instances, supplemental details contained in EPA's 2021 inventory of emissions are used to allocate emissions. For example, methane emissions from petroleum systems are speciated by EPA as 0.2 MMTCO2e from "exploration" (assigned to IMPLAN industry 35, "drilling oil and gas wells"), 43.7 MMTCO2e from "production" (assigned to IMPLAN industry 20, "oil and gas extraction"), 0.2 MMTCO2e from "crude oil transportation" (assigned to IMPLAN industries 415 [rail transportation], 416 [water transportation], and 419 [pipeline transportation], on the basis of economic allocation), and 0.7 MMTCO2e from "refining" (assigned to IMPLAN industry 154, "petroleum refineries").

US N2O

The US inventory includes 423 MMTCO2e of nitrous oxide emissions (using AR-4 global warming potentials), exclusive of emissions from residential sources and mobile combustion, which is assigned to the "US transportation" module. Agricultural soil management is by far the single largest contributor to these emissions (contributing more than 78 percent), although the US inventory includes several other, smaller sources.

Emissions are assigned to IMPLAN industries on a one-for-one basis where possible (e.g., emissions from "nitric acid production" are assigned entirely to IMPLAN Industry 167, "Nitrogenous fertilizer manufacturing"), or to multiple industries using economic allocation where more than one industry is known to contribute to emissions.

In some instances, supplemental details contained in EPA's 2021 inventory of emissions are used to allocate emissions. For example, nitrous oxide emissions from agricultural soil management are speciated by EPA as:

- 229.7 MMTCO2e from “crop lands” - these are further allocated across IMPLAN industries 1 through 10 (crop farming industries) using economic allocation, and
- 100.8 MMTCO2e from “grazing lands" - these are further allocated between IMPLAN industries 11 and 12 ("beef cattle ranching" and "dairy cattle and milk production") using economic allocation.

One small contributor to nitrous oxide emissions is called by EPA "nitrous oxide from product uses". EPA describes several "main uses" of N2O: medical, dental and veterinary anesthetics, as well as "a propellant in pressure and aerosol products, the largest application being pressure-packaged whipped cream". EPA names additional uses but describes them as "small quantities". For simplicity, these emissions were allocated across four industries using economic allocation: IMPLAN industry 84 (fluid milk production), IMPLAN industry 467 (veterinary services), IMPLAN industry 484 (offices of dentists) and IMPLAN industry 490 (hospitals). Although emissions of N2O from propellant in consumer products are technically a "use phase" emission, they are assigned here to an IMPLAN industry for simplicity. The net impact on Oregon's estimate of consumption-based emissions should be the same: when consumers purchase and then use pressure packed whipped cream (the production of which IMPLAN assigns to IMPLAN industry 84), the resulting emissions will be counted.

US High Impact Gases

The US inventory includes 115 MMTCO2e of high impact gases (using global warming potentials contained in the IPCC Fourth Assessment Report), excluding emissions from residential uses and transport-related refrigeration. These gases are primarily HFCs but also include PFCs, SF_6 and NF_3.

EPA provided DEQ with additional information on the sector allocation of HFCs, which are primarily used as substitutes to ozone-depleting substances in refrigeration. 49.8 MMTCO2e are associated with residential uses (air conditioning) and are not allocated to specific industries; an additional 33.2 MMTCO2e are used in the transportation sector and are allocated in the "US transportation" module. Much of the remainder are associated with either commercial or industrial refrigeration, and are allocated to IMPLAN's commercial and industrial sectors (independently) using economic allocation. Additional industrial uses such as aerosols, foams, solvents and fire extinguishing are assigned to one or more IMPLAN industries based on additional documentation provided in the US inventory report; economic allocation is used when more than one industry is involved.

Emissions of other high impact gases are associated with specific industries (e.g., semiconductor manufacturing) are and assigned to that associated IMPLAN industry.

US Industry Direct Emissions Factors

Emissions as allocated to each of the 546 IMPLAN industries in each of the eight major categories above (CO_2 industrial combustion, transportation, N_2O, etc.) are then summed across all categories to produce an estimate of total GHGs by IMPLAN industry. These industry-specific total emissions (in MMTCO2e) are then divided by 2021 economic output for each industry (in 2021 US$) to arrive at industry-specific direct emissions intensities - an estimate of the total GHG emissions per dollar of U.S. economic output. These direct emissions intensities are used elsewhere in the model to estimate emissions, as described later in this report.

Oregon Emissions Factors

Preliminary estimates of 2021 GHG emissions from Oregon's sector-based inventory are assigned to Oregon industries as identified by the IMPLAN model. The number of industries in the Oregon IMPLAN model is the same as those in the U.S. IMPLAN model but in some cases (such as cotton farming), these industries have zero economic activity in Oregon. In such cases, no emissions are assigned to them. The model begins by taking Oregon GHG emissions and assigning them to one of nine categories:

- Oregon electric power (which includes all gases)
- CO_2 industrial combustion
- CO_2 commercial combustion
- CO_2 non-combustion
- Transportation (all gases)
- CH_4
- N_2O
- High impact gases
- Other (excluded)

Emissions in the "other" category, which are not allocated to IMPLAN industries, include emissions from:

- Household and government vehicle use (for estimation methods, see "Oregon Transportation" below);
- Light-rail electricity use (a "government" emissions counted separately in the "use" phase);
- Emissions from residential stationary electricity, natural gas and petroleum use (counted separately in the "use" phase);
- Emissions from government stationary electricity, natural gas and petroleum use (counted separately in the "use phase), estimated as a percentage of "commercial"

energy use based on government vs. private commercial square footage in the US Commercial Energy Building Consumption Survey;

- A portion of emissions from "waste incineration" (specifically, the estimate of emissions from at-home burning of garbage by Oregon residences; these are counted separately in the "use" phase);
- Emissions from residential and government use of high global warming potential gases used as refrigerants and in fire protection systems; and
- Emissions from commercial and industrial electricity use.

On this last point, the calculation of direct emissions factors excludes commercial and industrial electricity use as estimated in Oregon's sector-based inventory, because these are not direct (on-site) emissions. Rather, they are indirect emissions that should be calculated alongside all other indirect (supply chain) emissions that are captured through estimates of gross demand as described below. Rather, this calculation of direct emissions factors includes (and assigns to the electric power and distribution industries) emissions from in-state electric power generation (CO_2, CH_4, and N_2O, as well as high global warming potential gases from transmission and distribution systems).

Oregon Electric Power

Oregon's sector-based inventory reports emissions from in-state generation and distribution of electric power as an information item, but the inventory total excludes these emissions, counting instead emissions at the point of generation associated with all electric power *used* in Oregon. (These are sometimes referred to as "consumption-based electricity emissions" but do not represent consumption in the same sense as Oregon's consumption-based emissions inventory, as they include emissions from industries using electricity to satisfy final demand [consumption] by others, not themselves.) While this accounting convention is now widely accepted and standard practice for the sector-based inventory, it does not comport with the framework of the consumption-based inventory or its underlying economic model. Rather, IMPLAN treats the purchase of electricity by Oregon businesses like any other purchase (paper, parts, food. etc.), including both purchases from in-state sources as well as imports.

To comport with IMPLAN's approach, the consumption-based inventory uses "direct" (on-site) emissions from *in-state* electricity generation and transmission when estimating direct emissions intensities. Specifically:

- 8.5 $MMTCO_2$ from Oregon power plant natural gas, coal and petroleum combustion, are assigned to IMPLAN industry 40 "Electric power generation – fossil fuel".
- 0.1 $MMTCO_2e$ of high global warming potential gases resulting from in-state electricity transmission and distribution are assigned to IMPLAN industry 47 "electric power transmission and distribution".

Emissions associated with the use of electricity by consumers (households and government) are estimated separately (see "Use and Disposal") for inclusion in use-phase emissions in CBEI. The same is true for light-rail electricity use in the transportation sector, since the use of electricity is wholly associated with government final demand.

Oregon industrial combustion CO2

Emissions from the sector-based inventory for “industrial natural gas combustion” (2.7 MMTCO2), “industrial petroleum combustion” (1.4 MMTCO2) and “industrial coal combustion” (0.1 MMTCO2) are allocated across IMPLAN industries 1 – 19 (agriculture), 20 – 38 (mining and drilling), 48 - 49 (non-electric utilities), 50 – 62 (construction and maintenance) and 63 – 391 (manufacturing) using economic allocation (proportional to the economic output of each industry in Oregon).

A very small quantity of emissions (less than 0. 1 MMTCO2) associated with industrial waste incineration is similarly allocated but only to industries associated with manufacturing, based on DEQ’s knowledge of where these wastes are burned.

Oregon commercial combustion CO2

Emissions from the sector-based inventory for “commercial natural gas combustion” (1.6 MMTCO2) and “commercial petroleum combustion” (0.7 MMTCO2) are first partitioned into government vs. private commercial emissions based on the ratio of floorspace in government-owned vs. non-government owned buildings using natural gas or fuel oil as an energy supply, respectively, as reported in the US Energy Information Administration’s 2018 Commercial Energy Building Consumption Survey. The resulting private (non-government) emissions are then allocated across IMPLAN industries 392 – 448, 450 – 524, 526, 528, 531, and 534, using economic allocation (proportional to the economic output of each industry in Oregon).

“Residential and commercial waste incineration CO2 emissions” (0.10 MMTCO2) from the sector-based inventory are divided into commercial (emissions from incineration of municipal solid waste at Oregon’s sole waste incinerator) and residential (residential open burning) based on DEQ’s underlying modeling that generated this figure in the first place. The commercial emissions (0.08 MMTCO2) are assigned to IMPLAN industry 479, “waste management and remediation services”. Residential open burning emissions are accounted for in the “Use and Disposal” section.

Oregon non-combustion CO_2

Oregon's sector-based emissions inventory includes 0.8 million metric tons of CO_2 from non-combustion sources, the largest of which (0.5 MMTCO2e) is cement production. Other sources include, as examples, ammonia production, iron and steel production, lime manufacturing, liming of agricultural soils, and urea fertilization (both agricultural and non-agricultural).

Many of these individual emissions estimates are allocated solely to individual IMPLAN industries (such as cement manufacturing). A few special cases are noted here:

- Emissions from agricultural urea fertilization and liming of agricultural soils are allocated across IMPLAN industries 1 – 10 (farming) using economic allocation.
- Emissions from pulp and paper are allocated across IMPLAN's three pulp and paper manufacturing industries using economic allocation.
- Emissions from urea consumption for non-agricultural purposes (lawns, golf courses) are assigned to IMPLAN industry 167, "nitrogenous fertilizer manufacturing". This is not technically ideal, as the emissions occur during use of the fertilizer, not production of it. Alternatively, use-phase emissions from government and residential use of fertilizer, if known, could be treated in "Use and Disposal", while non-agricultural uses (private golf courses, landscaping firms, etc.) would need to be allocated across multiple economic sectors. However, ultimately all of these users are purchasing fertilizer from fertilizer manufacturers, so assigning these emissions to the manufacturing industry provides an indirect method of allocating these emissions. Because these emissions are quite small (0.03 MMTCO2), this irregularity in accounting will not have a meaningful impact on results.
- Oregon's sector-based inventory estimates 0.01 MMT of CO_2 emissions from "limestone and dolomite use". This corresponds with four separate line-items in the US CO_2 industrial noncombustion emissions model (see above): glass production, flux stone, flue gas desulfurization, and "other miscellaneous uses". For each of these, emissions for Oregon industries are first estimated using ratios of (US industry-specific emissions)/(US industry-specific economic output), multiplied by OR industry-specific economic output (assuming that the emissions per $ of economic output for each industry will be the same for Oregon as it is for the US). These estimates are then adjusted in equal proportions so that their grand total (across all industries) equals the total in Oregon's sector-based inventory.
- A similar method is used to allocate 0.03 MMT of CO_2 emissions associated with soda ash production and consumption.

Oregon Transportation

Emissions from the transportation portion of Oregon's sector-based inventory are allocated (partially) to different economic sectors (industries) in the IMPLAN model using methods and data sources either identical or very similar to those used for allocating US transportation emissions (described above), with the following exceptions:

- Lacking detailed information for Oregon as contained in the U.S. nation-wide inventory, emissions from the Oregon sector-based inventory are allocated into different uses (e.g., gasoline into highway vs. non-highway, and gasoline highway into passenger cars, light-duty trucks, heavy duty vehicles, and motorcycles) using ratios provided in the U.S. EPA's State Inventory Tool (SIT).
- Oregon's transportation-related emissions include a separate line-item for light rail electricity use, which is wholly allocated to government.
- Oregon employment data for 2021 (from the Oregon Employment Department) is used to allocate non-highway "utility" CO2 emissions from gasoline and diesel use between government and commercial (private) sectors.
- Methane and nitrous oxide emissions from aircraft fuel use are allocated between households, government, and commercial sectors in proportion to those sectors' estimated emissions of carbon dioxide.

Oregon CH4

Approximately 6.2 MMTCO2e of methane emissions (excluding transportation) are included in Oregon's sector-based inventory. Consistent with the U.S. inventory, enteric fermentation, landfills, and natural gas systems are the three largest contributors, although natural gas systems have a proportionately smaller contribution to Oregon's inventory.

Transportation-related CH4 emissions are assigned to the transportation module, and residential as well as an estimate of government-sector emissions are reported in "Use and Disposal". As with other gases, government's share of commercial emissions is estimated using data from the US EIA's Commercial Building Energy Consumption Survey.

Emissions are assigned to IMPLAN industries on a one-for-one basis where possible (e.g., emissions from "landfills" are assigned entirely to IMPLAN Industry 479, "Waste management and remediation services"), or to multiple industries using economic allocation where more than one industry is known to contribute to emissions (for example, emissions from enteric fermentation are allocated across three different livestock industries in IMPLAN). The 2021 State Inventory Tool is also used to allocate natural gas sector emissions between processing (very small) and transmission/distribution.

Oregon N2O

Approximately 3.7 MMTCO2e of N2O emissions (excluding transportation) are included in Oregon's sector-based inventory. Consistent with the U.S. inventory, agricultural soil management dominates these emissions.

Transportation-related N2O emissions are assigned to the transportation module, and residential as well as an estimate of government-sector emissions are reported in "Use and Disposal". As with other gases, government's share of commercial emissions are estimated using data from the US EIA's Commercial Building Energy Consumption Survey.

Emissions are assigned to IMPLAN industries on a one-for-one basis where possible (e.g., emissions from "nitric acid production" are assigned entirely to IMPLAN Industry 167, "Nitrogenous fertilizer manufacturing"), or to multiple industries using economic allocation where more than one industry is known to contribute to emissions (for example, emissions from "field burning of agricultural residues" are allocated across all farming/cropping industries in IMPLAN).

Oregon High Impact Gases

Approximately 1.4 MMTCO2e of emissions from high impact gases from the Oregon sector-based inventory are brought forward and assigned to IMPLAN industries. This excludes approximately 0.9 MMTCO2e from transportation refrigerants and air conditioning (allocated in the transportation module, described above) and 0.3 MMTCO2e of gases associated with residential or government use of refrigerants and aerosols. These are estimated by taking the total estimate of residential and commercial refrigerant and aerosol use from the sector-based inventory, partitioning it into residential and commercial fractions using EPA data for the U.S., and further partitioning the commercial fractions into government vs. non-government based on the relative floorspace of cooled government vs. cooled non-government buildings, as reported in the US EIA's Commercial Building Energy Consumption Survey. Residential and government uses of refrigerants and aerosols are transferred to the "Use and Disposal" portion of the model.

Of the remaining emissions from high impact gases:

- 1.0 MMTCO2e associated with semiconductor manufacturing are assigned entirely to IMPLAN industry 307 "semiconductor and related device manufacturing".
- 0.2 MMTCO2e from commercial refrigeration uses are allocated across IMPLAN industries 392 – 448, 450 – 524, 526, 528, 531, and 534 using economic allocation.
- 0.1 MMTCO2e from industrial uses are allocated into five broad uses (industrial refrigeration, aerosols, foams, solvents, and fire protection) consistent with national

estimates provided by the U.S. EPA, and from there into corresponding IMPLAN industries either on a one-for-one basis or using economic allocation.

Oregon Industry Direct Emissions Factors

Emissions as allocated to each of the 546 IMPLAN industries in each of the eight major categories above (CO2 industrial combustion, transportation, N2O, etc.) are then summed across all categories to produce an estimate of total GHGs by IMPLAN industry. These industry-specific total emissions (in MMTCO2e) are then divided by 2021 economic output (in 2021 US$) for each industry to arrive at industry-specific direct emissions factors - an estimate of the total GHG emissions per dollar of economic output in Oregon. These direct emissions intensities are used elsewhere in the model to estimate emissions, as described below.

Final and Gross Demand

The IMPLAN economic model provides estimates of final demand (in dollars), from each of several different types of consumers (households, federal government, state/local government, business capital, and business inventory formation), for each of 546 commodities.

Final demand in IMPLAN is estimated (not actual). For household consumption (the largest share of Oregon's total), IMPLAN begins by estimating total U.S. household consumption by combining U.S. Bureau of Economic Analysis (BEA) benchmark input-output data, BEA National Income and Product Accounts personal consumption expenditures (PCE) data, and data from the Consumer Expenditure Survey (CEX). Total U.S. household consumption is then apportioned to states using a combination of CEX data by state and region, and U.S. Census data on population and incomes. An important part of this process is determining the shares of nine PCE income categories for the study area in the data year; IMPLAN makes the assumption that individuals and households in the PCE income categories have similar consumption patterns throughout the United States.

While "final demand" refers to direct expenditures by consumers (households, government, business inventory/capital),“gross demand” includes final demand along with all associated supply chain activity. Using cheese as an example, final demand for cheese results in gross demand for cheese as well as a wide variety of goods and services used in the production of cheese, such as milk, natural gas, and packaging. Similarly, final demand for air travel results in gross demand for air travel as well as airport services, packaged snacks, uniforms worn by the flight crew, advertising services, fuel, and the like.

For each of four major categories of consumers, a series of calculations convert total final demand (by commodity) into resulting gross demand within Oregon and the US, as well as foreign imports. Gross demand is calculated using IMPLAN input-output matrices. Input-output matrices represent all of the inputs (from each of 546 industries) required to produce one dollar of output in each of the 546 industries. It includes the compounded effects of all tiers of suppliers (not just first-tier suppliers). Gross demand is calculated for Oregon (including Oregon's final and intermediate purchases of commodities produced in Oregon), and for the other 49 states (including Oregon's final and intermediate purchase of commodities produced elsewhere in the U.S., where intermediate purchases are used to produce final products consumed in Oregon). As described later, gross demand for these two locations of production are combined with the appropriate emissions intensities (calculated above) to estimate emissions inside Oregon and other states.

IMPLAN's reported final demand in a given commodity sector reflects payments to that commodity's production sector, not the retail price paid by the ultimate purchasers of the commodity. Few retail purchases are made directly from industrial sectors. Instead, finished products typically pass through several hands before reaching the customer, and a portion of each consumer dollar spent on any product is retained by wholesale, retail and transportation firms. For example, for the purchase of a $1 cookie, $0.25 may be retained by retailer, $0.09 by the wholesaler, $0.03 for transportation, and the remaining $0.63 paid to the cookie manufacturer. The portions retained by businesses other than the producer are the "margins".

The consumption-based emissions inventory does not include any calculation of final demand from margining activities that would associate a particular good's emissions with the share of each consumer dollar spent on retail, wholesale, and transportation of a good prior to purchase. Instead, the model takes the dollars spent by Oregon consumers on margining activities (retail, wholesale, and transportation) to be separate purchases of these services, which is the convention followed in the IMPLAN economic model.

Calculations by Location of Emission

Goods and services consumed in Oregon are produced in one of three geographic areas:

- In-state: Demand for commodities produced in Oregon
- Other-49: Demand for imports into Oregon from the other 49 states
- Foreign: Demand for international imports into Oregon

Calculation of the geographic breakouts in the final demand data proceed as follows:

1. Oregon final demand of Oregon commodities is total final demand less total final imports to Oregon.
2. The U.S. foreign import rate is calculated for each of the 546 IMPLAN industry sectors. Foreign import rates are drawn from final demand data from IMPLAN for the United

States. The foreign import rate is imported final demand divided by total final demand. IMPLAN reports identical import rates by type of institution (household, federal government, state/local government, and investment).

3. Oregon final demand of U.S. (including Oregon) commodities is total final demand multiplied by one minus the U.S. foreign import rate. Oregon final demand for imports into Oregon from the other 49 states is the final demand of U.S. commodities less the final demand of Oregon commodities.
4. Oregon final demand for foreign imports is total final demand multiplied by the U.S. foreign import rate.

Using this four-step method, the calculation of Oregon's final demand by location of production is conducted separately for each of the 546 industries and for each of the four institution types. These four sets of calculations are strictly parallel. The result is twelve categories of final demand for each of 546 industries: in-state, other-49, and foreign production satisfying final demand from each of four types of institutions (households, federal government, state/local government, and business capital).

Gross Demand

Final demand for Oregon and other U.S. (excluding Oregon) commodities is next multiplied by IMPLAN's input-output matrices to calculate gross demand. These calculations proceed as follows:

1. Oregon gross demand for Oregon final and intermediate products is calculated as IMPLAN's Oregon Type I Multipliers (also called the Oregon Leontief inverse matrix), multiplied by Oregon final demand of Oregon commodities. The Oregon Leontief inverse matrix only includes in-state production; when producers of final goods in Oregon purchase from out-of-state suppliers, that intermediate demand is not included in Oregon gross demand.
2. Oregon gross demand for other-49 final and intermediate products is Oregon gross demand for U.S. final and intermediate products (that is, IMPLAN's U.S. Type I Multipliers multiplied by Oregon final demand for commodities from other-49 states).
3. The model does not calculate Oregon gross demand for foreign final and intermediate products, because upstream emissions are captured by foreign emissions intensities (described below).

At this point, gross demand is expressed on the basis of IMPLAN industries, not commodities. IMPLAN provides a list of 546 commodities and 546 corresponding industries. Final demand is expressed on the basis of commodities, while the Leontief inverse matrices are expressed on the basis of industries. Similarly, the emissions coefficients (emissions factors) are also calculated for specific IMPLAN industries. Commodities and industries do not have perfect (1-for-1) correlation although this model treats them as such. As a sensitivity analysis during development of the 2015 CBEI, DEQ performed additional calculations to take final demand (expressed on a per-commodity basis) and map it to final demand expressed on a per-industry basis, based on modified IMPLAN market shares. While total final demands are exactly the same, total gross demands are slightly different, although never by more than one percent. While this conversion is the technically accurate approach, it adds significantly to the computational (processing) requirements of the model and, for consistency across years, would require significant reprogramming of the models for earlier years. For these reasons, the consumption-based inventory uses the simpler approach as described previously (and used in prior years), which makes the simplifying assumption that final demand for commodities are interchangeable with the final demand from their corresponding industries.

GHG Coefficients

GHG coefficients represent the emissions of greenhouse gases per dollar of economic output for each industry. Direct coefficients for Oregon and U.S. production are developed using methods described above (see "US and Oregon Emissions Factors"). As described in "Three-Phase Greenhouse Gas Emissions" below, these direct coefficients (limited to the emissions in each industry) are multiplied by gross Oregon and other-49 demand from each industry.

However, calculations of gross demand are not available for foreign production, so the calculation of foreign emissions involve the multiplication of final demand by commodity/industry (imports) against a different set of GHG coefficients, reflecting both direct and indirect (supply chain) emissions. In fact, two different sets of foreign emissions intensities (GHG coefficients) are required: "US imports", representing the import of foreign-made and finished commodities, and "US global", for a calculation of emissions from Oregon consumption associated with the foreign intermediate goods used in domestic U.S. production (for example, Korean auto parts used in the assembly of automobiles in Indiana). The derivation of each of these two sets of GHG coefficients is discussed in turn.

Both sets of foreign GHG coefficients draw extensively from a 57-sector Multi-Regional Input-Output (MRIO) international model, developed by Glen Peters and Robbie Peters at CICERO (Center for International Climate Research) in Norway. MRIO uses Global Trade Analysis Project (GTAP) data and sector definitions. Emissions intensities for these 57 sectors are mapped to IMPLAN's 546 sectors by comparing detailed sector descriptions.

US Imports

U.S. import direct+indirect GHG coefficients represent the emissions from final production as well as supply chain emissions for commodities where final production occurs in foreign countries and the final products are imported into the U.S. to satisfy final demand. The method to convert emissions intensities from the MRIO 57-sector model to the IMPLAN 546-sector model is as follows:

1. Calculate values using Peters' International data set by sector (i), where (i) represents the 57 GTAP sectors:

   a. Emissions coefficient for final imports into the U.S. in i sectors:

   $$\text{PetersDIcoef\_Imports\_US} = \frac{(\text{US total emissions} - \text{US global emissions})}{(\text{US total output} - \text{US global output})}$$

   b. Value of final imports into the U.S. in i sectors:

   $$\text{PetersImports\_US} = \text{US total output} - \text{US global output}$$

   Note that we follow the MRIO naming conventions where "total" refers to final consumption including domestic production and imported final goods, and domestic and imported intermediate goods, and "global" refers to final production including domestic and imported intermediate goods.

2. Peters' International GHG coefficient data (2017 dollars) in sectors (i) are converted to 2021 dollars using the U.S. CPI-U.

3. Each IMPLAN sector (j) is mapped to a range of 1 to 3 Peters' (2021 dollars) sectors (i). In some cases several GTAP sectors fall under a single IMPLAN sector, and vice versa. Groupings of GTAP sectors into IMPLAN sectors are unique such that 57 GTAP sectors (i) become 51 GTAP-sector groups (m):

   $\text{i} = \text{57 GTAP sectors}$

   $\text{j} = \text{546 IMPLAN sectors}$

   $\text{k} = \text{1st/2nd/3rd GTAP sector per IMPLAN sector}$

   $\text{i}(\text{j},\text{k})$ maps IMPLAN to GTAP

   $\text{m}(\text{j}) = \text{i}(\text{j}, 1)$ - in practice, there are 51 unique values of m

   n = a GTAP sector or group of 2 or 3 sectors, all mapped to the same IMPLAN sector (i.e., a value taken on by m(j))

4. $\text{DIcoef\_IM\_US\_unweighted}_{j} = \frac{\sum_{k}\left(\text{PetersDIcoef\_Imports\_US}_{i(j,k)} * \text{PetersImports\_US}_{i(j,k)}\right)}{\sum_{k}\text{PetersImports\_US}_{i(j,k)}}$

5. $\text{US\_TCO}_{n} = \sum_{j}\text{US\_TCO}_{j}$, summed over all j for which $m(j) = n$

6. $\text{US\_TCOxDIcoef\_CBEI\_US}_{n} = \sum_{j}\left(\text{DIcoef\_CBEI\_US}_{j} * \text{US\_TCO}_{j}\right)$, summed over all j for which $m(j) = n$

7. $\text{DomesticWeight}_{j} = \frac{\text{US\_TCOxDIcoef\_CBEI\_US}_{m(j)}}{\text{US\_TCO}_{m(j)}}$

8. $\text{DIcoef\_IM\_US}_{j} = \text{DIcoef\_IM\_US\_unweighted}_{j} * \left(\frac{\text{DIcoef\_CBEI\_US}_{j}}{\text{DomesticWeight}_{j}}\right)^{0.5}$

9. For all IMPLAN sectors j associated with GTAP family of sectors n: $\text{Emissions\_unweighted}_n$ = $\sum_j$ ([final demand, imports] x $\text{DIcoef\_IM\_US\_unweighted}_j$)

10. For all IMPLAN sectors j associated with GTAP family of sectors n: $\text{Emissions\_weighted}_n$ = $\sum_j$ ([final demand, imports] x DIcoef_IM_US_j)

11. Adjustment factor_n = $\text{Emissions\_unweighted}_n$/$\text{Emissions\_weighted}_n$

12. $\text{DIcoef\_IM\_US\_adjusted}_j$ = DIcoeff_IM_US_j x Adjustment factor_n for that value of n corresponding to each IMPLAN sector j

Steps 1 – 8 above generate direct+indirect emissions factors for final commodities imported into the United States, as follows. Steps 1 and 2 take data from Peters' CICERO model, which is organized into 57 sectors. For each sector, a direct+indirect emissions coefficient for imports to the United States is calculated. Step 3 maps these sectors to the 546 IMPLAN sectors. Step 4 uses the CICERO results to calculate an "unweighted" direct+indirect emissions coefficient for each of the 546 IMPLAN sectors. When any one IMPLAN sector corresponds to a single sector in Peters' model, the "unweighted" direct+indirect coefficients are the same. However, when any one IMPLAN sector corresponds to more than a single sector in Peters' model (two or three sectors), then the "unweighted" direct+indirect coefficient (in CBEI) is calculated as an average of the coefficients from Peters' model, weighted by value of imports into the U.S.

The result of step four is a series of "unweighted" direct+indirect emissions coefficients for each of the 546 sectors in CBEI. However, as these are drawn from Peters' model, and the mapping of IMPLAN to Peters' model results in only 51 unique "families" of sectors, only 51 direct+indirect emissions coefficients are calculated for imports into the U.S. At this point, different commodity sectors in CBEI that correspond to the same “family” are assumed to have the same emissions coefficients. Steps 5 – 8 further differentiate these “unweighted” coefficients using the assumption that within any given family of sectors, emissions coefficients for imports will be distributed in a manner similar (although not identical) to the distribution between domestic coefficients in the same family, calculated in a manner such that the weighted average of all import coefficients in any given family equals the overall import coefficient for that family as calculated in step 4 above. This is done by first calculating the total domestic commodity output for each “family” of sectors (step 5). For each “family,” step 6 sums across all relevant IMPLAN sectors the product of domestic direct+indirect coefficients and total domestic commodity output. Step 7 divides this by the sum of total domestic commodity output for each family (from step 5), generating a weighted domestic coefficient. In step 8, “weighted” import emissions coefficients for each IMPLAN sector are calculated by multiplying the “unweighted” import coefficients (from step 4) by the square root of their unique domestic direct+indirect coefficient (from CBEI) divided by their “family’s” weighted domestic coefficient (from step 7).

Steps 1 through 8 were used in the original Oregon consumption-based greenhouse gas emissions inventory model developed by SEI for calendar year 2005. These steps were repeated for the 2010 inventory. Following completion of the 2010 inventory, DEQ discovered that the method used to derive industry-specific emissions factors (specifically, step 8 above) can result in a distribution of GHG coefficients within a given GTAP "family" that, in total, moderately under- or over-estimate total emissions for that family (when multiplied against U.S. imports for each sector). Beginning with the 2015 inventory, DEQ introduced steps 9 through 12, which adjust the GHG coefficients as originally derived (from step 8), either upward or downward by the same proportion (within any given family), in order to generate total emissions for each GTAP family that match the emissions for that family if CICERO's original emissions factors were applied uniformly across all IMPLAN commodities in that family.

US Global

In addition to these U.S. import coefficients for final demand of imported products, the inventory uses a second type of international coefficient, called "U.S. global," for a calculation of emissions from Oregon consumption associated with the foreign intermediate goods used in domestic U.S. production. "U.S. global" are the emission coefficients for the global (including domestic) processes, including supply chain, that are associated with final production in the U.S. They include emissions both inside the U.S. and in other nations. (“Three-Phase Greenhouse Gase Emissions”, below, explains how these are used.)

The method to convert CICERO's 57-sector data to IMPLAN's 546-sector data is as follows:

1. Calculate values using Peters' International data set by sector (i), where (i) represents the 57 GTAP sectors:
   a. U.S. global emission coefficients (for U.S. final production including domestic and imported intermediate goods – direct+indirect):
   $$\mathrm{PetersDIcoef\_Global\_US} = \frac{\mathrm{US\ global\ emissions}}{\mathrm{US\ global\ output}}$$
   b. U.S. domestic-only emissions (for U.S. final production including only domestic intermediate goods – direct+indirect):
   $$\mathrm{PetersDIcoef\_DomesticOnly\_US} = \mathrm{US\ domestic\ only}$$
   c. Ratio of Peters U.S. global to Peters U.S. domestic-only emissions:
   $$\mathrm{PetersCoefRatio} = \frac{\mathrm{PetersDIcoef\_Global\_US}}{\mathrm{PetersDIcoef\_DomesticOnly\_US}}$$
   d. Value of production in the U.S. by sector:
   $$\mathrm{PetersGlobal\_US} = \mathrm{US\ global\ output}$$
2. Each IMPLAN sector (j) is mapped to a range of 1 to 3 Peters' sectors (i). Because this algorithm simply uses ratios, it is not essential to convert to 2021 dollar values. In some cases several GTAP sectors fall under a single IMPLAN sector, and vice versa. Groupings of GTAP sectors into IMPLAN sectors are unique such that 57 GTAP sectors (i) become 51 GTAP-sector groups (m):
   $$\mathrm{i} = 57\ \mathrm{GTAP\ sectors}$$
   $$\mathrm{j} = 546\ \mathrm{IMPLAN\ sectors}$$
   $$\mathrm{k} = \mathrm{1st/2nd/3rd\ GTAP\ sector\ per\ IMPLAN\ sector}$$
   $\mathrm{i(j,k)}$ maps IMPLAN to GTAP
3. $$\mathrm{CoefRatio_j} = \frac{\sum_k \left(\mathrm{PetersCoefRatio_{i(j,k)}} * \mathrm{PetersGlobal\_US_{i(j,k)}}\right)}{\sum_k \mathrm{PetersGlobal\_US_{i(j,k)}}}$$
4. $$\mathrm{DIcoef\_GL\_US_j} = \mathrm{CoefRatio_j} * \mathrm{DIcoef\_CBEI\_US_j}$$

Steps 1 – 4 above generate direct+indirect global emissions factors for commodities where the final production occurs in the United States, as follows. Step 1 takes data from Peters' CICERO model, which is organized into 57 sectors. For each sector, Peters' estimate of global direct+indirect emissions coefficients for the U.S. (1a) and domestic-only emissions (1b) are estimated. These are divided into each other to produce a ratio of global:domestic direct+indirect emissions coefficients (step 1c) for the U.S.. Peters' estimates of U.S. global output by sector is also generated (1d). Step 2 maps these 57 sectors to the 546 IMPLAN sectors. Step 3 uses the CICERO results to calculate a ratio of global:domestic direct+indirect emissions coefficients for each of the 546 IMPLAN sectors. When any one IMPLAN sector corresponds to a single sector in Peters' model, the ratios of coefficients are the same. However, when any one IMPLAN sector corresponds to more than a single sector in Peters' model (two or three sectors), then the ratio is calculated as an average of the ratios from Peters' model, weighted by value of production in the U.S. Step 4 multiplies this ratio by the direct+indirect (domestic) emissions coefficients (calculated separately) to generate the U.S. global coefficients.

Three-Phase Greenhouse Gas Emissions

Three-phase (pre-purchase) GHG emissions are calculated as follows:

1. In-state emissions from Oregon's consumption of Oregon-made final commodities are the product of Oregon's in-state gross demand and the Oregon direct coefficients for each of the 546 IMPLAN sectors.
2. All other domestic emissions from Oregon's consumption of U.S.-made final commodities (including U.S. upstream emissions) are the product of Oregon's other-49 gross demand and the U.S. direct coefficients for each of the 546 IMPLAN sectors.
3. Foreign emissions from Oregon's consumption of final commodities is calculated in two pieces:
    a. Oregon's final demand for foreign-made commodities is multiplied by the MRIO direct+indirect coefficients for U.S. imports.
    b. Emissions from the production of foreign-made intermediate goods used in Oregon and other-49 state production for Oregon's final consumption are the product of Oregon's U.S. final demand and the "U.S. global" direct+indirect coefficients, less the product of Oregon's U.S. final demand and U.S. direct+indirect coefficients, which are calculated by matrix multiplying U.S. direct coefficients and the U.S. Type I Leontief inverse matrix.

Emissions are estimated in total, by location of production, type of consumer, and life-cycle phase. Total emissions are also sorted into commodity categories and sub-categories for ease of reference.

Oregon's total pre-purchase emissions by the 546 IMPLAN sectors are also divided into the three life-cycle phases addressed in this portion of the inventory: production, pre-purchase transportation, and wholesale/retail. Calculation of the GHG emissions by phase proceeds as follows:

1. Emissions from the wholesale and retail IMPLAN sectors are assigned to the wholesale/retail phase.
2. Emissions from the transportation IMPLAN sectors are assigned to the transportation phase.
3. All other emissions are classified as production phase emissions.

LCA Processing

The “Standard” CBEI results described thus far are the life-cycle emissions of Oregon as a whole. CBEI’s “LCA” mode (running CBEI in its “Life Cycle Analysis” mode) calculates the life-cycle emissions for each single sector of final demand separately by re-running CBEI 546 times using the appropriately circumscribed demand vector (i.e., demand for each sector is run separately); these results are labeled “CBEI-LCA”. Each time CBEI is run, the sum (across sectors) of emissions is recorded by institution, phase, and location of emission – effectively compressing 546 sectors of information into a single row of results. Note that emissions coefficients are not impacted by the LCA processing – all coefficients remain constant.

By running CBEI analysis on each of Oregon’s 546 sectors of demand individually and recording the total emissions generated by that run as that sector’s emissions, consumption-based emissions are reorganized from producing sector to consuming sector. This method results in the same total CBEI emissions for the Oregon as a normal run, but a different distribution of emissions across sectors.

The technical process behind the LCA mode is as follows. In Excel, a Visual Basic Macro was constructed that repeats these steps 546 times:

1. Erase all original IMPLAN final demand and import data.
2. Replace original IMPLAN final demand and import data for all for institutions of sector X.
3. “Calculate” CBEI.
4. Record total emissions by institution, phase, and location of emission in the row labeled sector X.
5. Repeat for the next sector.

Use Phase Emissions

The "use" life-cycle phase includes all post-purchase emissions, with the exception of emissions from post-consumer disposal. Specifically, the use phase consists of emissions from direct fuel use by households and government (for heating or other appliances); direct emissions from use of refrigerants in stationary equipment by households and government; direct household and government fuel, refrigerant and lubricant use for transportation; the upstream emissions for household and government fuel and lubricant purchases; direct electricity emissions for households and government; and upstream emissions for household and government use of electricity.

Use phase calculations disaggregate the direct+indirect fuel, electricity, refrigerant and vehicle lubricant emissions into the categories and sub-categories of commodities that utilize fuel and electricity: vehicles, appliances (including furnaces), electronics, and lighting. (Double-counting is corrected by zeroing out certain emissions which the LCA model estimates as pre-production emissions; see "Adjustments, Model Reconciliation and Final Results" below).

Direct residential and government fuel and refrigerant emissions are calculated using emissions from the sector-based inventory and weights constructed from the U.S. Energy Information Administration's Residential Energy Consumption Survey and Commercial Energy Consumption Survey, as well as data from the Northwest Power and Conservation Council.

Direct residential and government transportation (vehicle) use emissions are derived from the Oregon transportation module described in "Oregon Emissions Factors", above.

Upstream emissions from residential and government use of petroleum and natural gas (including transportation fuels) are derived using ratios and data provided by the Oregon Clean Fuels Program.

Direct electricity use emissions (at the point of power generation) for households and governments are taken from the sector-based inventory. Government emissions are calculated as a percentage of commercial emissions, based on square footage data in the US Commercial Energy Consumption Survey. The indirect-to-direct emissions ratio for purchased electricity is drawn from an addendum to ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2020. This value is very similar to the ratio used in previous versions of this model, which was drawn from a National Renewable Energy Laboratory report. Electricity emissions are disaggregated into CBEI's commodity sub-categories using consumption data from the EIA and Northwest Power and Conservation Council.

Disposal Phase Emissions

The "disposal" life-cycle phase consists of emissions from post-consumer waste in landfills and waste combustion, and emissions from composting facilities. Landfill emissions here are calculated on the basis of future lifetime emissions from disposal occurring during the inventory year (sometimes called "methane commitment"). Lifetime landfill emissions are adjusted for Oregon's projected current and future rates of landfill methane capture. Waste combustion includes both mass combustion at Oregon's sole municipal waste incinerator (in Brooks), as well as estimates of emissions from on-site combustion by households (backyard burning).

Emissions from landfilling are estimated using estimates of total Oregon tonnage disposed of in landfills, estimates of waste composition from Oregon's 2015 waste composition study, material/waste-specific methane generation potentials from the U.S. EPA, and an estimate of the statewide percentage of methane generation potential that is ultimately emitted (methane not oxidized or collected through landfill gas systems). Combustion emissions for mass burn are similarly drawn from estimates of total Oregon tonnage disposed of via incineration, waste composition estimates, and material-specific emissions factors from the U.S. EPA. Emissions from composting are based on estimates of materials managed through industrial compost facilities (from DEQ's annual material recovery survey) and emissions factors from the U.S. EPA. Emissions from residential burning are drawn from an emissions model produced for the U.S. EPA.

These algorithms only estimate direct emissions from landfills, incinerators and compost facilities. Indirect (upstream) emissions are estimated using emissions estimates allocated to the associated IMPLAN industry from other sources (described in "Oregon Emissions Factors", above) as well as a ratio of (direct+indirect):direct life cycle emissions previously derived from the "LCA" model for the 2015 CBEI.

Not all post-consumer waste (and associated emissions) result from household or government disposal activities, so emissions estimates are scaled based on estimates of household and government contributions to total waste disposal. Household estimates are based on 2010 data (a 2023 study will provide for an updated estimate, but results won't be available until later). Government estimates are derived from a model that combines per-unit (employee or student) disposal data from DEQ surveys conducted in 2011 and 2024 of local and state government units, community colleges, universities and school districts with updated 2021 unit data (numbers of employees and students). 2011 survey results have been adjusted for the 2021 CBEI based on estimates of remote work provided by Oregon DAS and the U.S. Office of Personnel Management.

Final (adjusted) emissions by waste category are then mapped onto CBEI categories. Disposal emissions are mapped directly to categories but not to sub-categories because of insufficient data. Most waste categories correspond directly to a single CBEI category. The exceptions to this simple mapping process are paper and plastic packaging, which are, instead, apportioned into CBEI commodity categories using IMPLAN data. Shares of the value of intermediate products in final goods are calculated using a "partial products matrix," i.e. by multiplying IMPLAN's unadjusted final demand by the Type I input-output multipliers (which measure the direct and indirect production requirements per unit of final demand). Partial products for IMPLAN sectors 147 (paperboard containers) and 148 (paper bags and coated and treated papers) are summed for paper packaging; sectors 186 (plastic packaging materials and unlaminated film and sheet) and 192 (plastic bottles) are summed for plastic packaging.

Consistent with the logic of the input-output calculation, energy generated by waste-to-energy plants and by landfill methane capture and combustion is treated as part of the energy sectors, not the disposal process. Carbon sequestration in landfills does not appear in the model, since that carbon was never emitted as CO2 or methane by any economic activity, and the CBEI model does not include carbon flux associated with land use, land use change, and forest carbon changes.

Adjustments, Model Reconciliation and Final Results

Results from the LCA three-phase model, use phase emissions, and disposal phase emissions are summed to estimate Oregon's total ("5-phase") consumption-based greenhouse gas emissions. In order to avoid double-counting, all three-phase emissions in IMPLAN commodities 3048 (natural gas), 3154 (petroleum), 3039-3047 and 3527, 3530, and 3533 (electric power) and 3479 (waste management and remediation services) are deleted; estimates in the use and disposal phase models and derived from physical units (mWh of power produced, tons of waste disposed, etc.) are expected to be more accurate. LCA three-phase emissions from IMPLAN commodity 3157 (petroleum lubricating oil) are also deleted, as these emissions were previously transferred to the use phase.

Results for one specific commodity are adjusted due to a change in the IMPLAN economic system that occurred between the 2010 and 2015 estimates of consumption-based emissions. As originally modeled, life-cycle emissions for the water/wastewater commodity rose sharply and unexpectedly, from approximately 500 thousand MTCO2e in 2010 to 1,500 thousand MTCO2e in 2015. These emissions are dominated by methane and nitrous oxide during treatment of wastewater solids. Total emissions from wastewater processing in the sector-based inventory did not change significantly, but IMPLAN reported much lower final demand for water and wastewater in 2015 than in 2010. Lower demand (the denominator of direct coefficients) results in higher direct coefficients, and thus a higher estimate of emissions. Further research revealed that the 2015 IMPLAN model assigns much more of the delivery of wastewater services to the industry of "local government (non-education)", which is likely realistic for Oregon, but direct coefficients for that industry do not reflect or include emissions from wastewater treatment. Rather than overriding the IMPLAN model, or accepting a patently false model result, DEQ estimated life cycle emissions for this commodity using a different method, beginning in 2015. 2021 consumption-based emissions for water and wastewater services are estimated as 2010 consumption-based emissions, adjusted using the ratio of 2021 vs. 2010 direct methane and nitrous oxide emissions from the sector-based inventory allocated to this industry.

Finally, household residential construction emissions are reclassified from the investment institution to the household institution. In national income accounting - the basis of all IMPLAN data - household investment in new homes is grouped with business investments in plants, machinery and inventory. Oregon's model reclassifies household investment in new homes as part of the institution "household" for greater consistency with CBEI's overall presentation of data.

LCA Demand Modeler

CBEI “Demand Modeler” is a separate tool used to calculate emissions for a user-determined subset of Oregon final demand. The “Modeler” can be used, for example, to view the life-cycle emissions of the demand for a single IMPLAN sector, where emission results are disaggregated by producing industry, type of consumer, life-cycle phase, and location of emission. Emission results for a single sector of demand can be viewed in CBEI “LCA” emissions summed across sectors, but to see emissions by contributing producing industries, it is necessary to do a sector-specific analysis using the “Modeler.”

In the “Control” tab the user can enter an original demand matrix either by entering new values or by selecting which sectors, sub-categories, or categories of demand to include or exclude. The user then launches a macro (see label “Run LCA Modeler”).

The LCA Modeler performs analysis for each filtered sector, F_x, and the entire filtered set of sectors, F, where $0 \leq x \leq 546$. In Excel, a Visual Basic Macro was constructed to run both Standard and LCA results.

The Standard run performs these steps 1 time:

1. Erase all original IMPLAN final demand and import data.
2. Replace original IMPLAN final demand and import data in producer prices for all institutions of filtered set F.
3. “Calculate” CBEI.
4. Record emissions by institution, phase, and location of emission for the filtered set F.

The LCA run repeats these steps for each sector, F_x, represented in the set F:

1. Erase all original IMPLAN final demand and import data.
2. Replace original IMPLAN final demand and import data in producer prices for all for institutions of sector F_x.
3. “Calculate” CBEI.
4. Record total emissions by institution, phase, and location of emission in the row labeled sector F_x.
5. Repeat for the next sector.

LCA Modeler processing can be launched from the "Control" tab of the *OR2021 CBEI Demand Modeler.xlsm* workbook. The three-phase pre-purchase Standard and LCA model results are recorded in the "Standard" and "LCA" tabs respectively in the *OR2021 CBEI Demand Modeler.xlsm* workbook. (See worksheet "Instructions" for additional details.)

In using LCA Modeler, it is important to remember that all expenditures need to be expressed in "producer prices and terms". This is consistent with the treatment of final demand in CBEI's underlying economic data. A consumer purchase of any one commodity (such as beer) needs to be treated as four separate purchases: a purchase of beer (from the beer producer), a purchase of transportation services (from the final producers to the retailer), a purchase of wholesale services, and a purchase of retail services. Results in LCA Modeler for any single purchase (such as beer) will show emissions in the transportation, wholesale and retail sectors. These results, however, only reflect the emissions "upstream" of the final producer, and do not include transportation, wholesale, and retail sector emissions as the product moves from the final producer to the retailer.

This is an important part of the CBEI model that is still under development. The organization of IMPLAN data makes it necessary for CBEI to treat the services of the retailer as a separate purchase – the dollars spent to buy bread are not readily connected to the retail "margin" (the mark-up that the retailer charges). IMPLAN data includes estimated margins by sector for Oregon, and in a future version of CBEI, it may be possible to use IMPLAN's margin data to make this connection and present emissions for purchases made at the store, not the factory.

Changes from Prior Inventory Years

Oregon's 2021 consumption-based GHG emissions inventory builds extensively on the original 2005 model created by SEI, as modified for 2010 and 2015 by DEQ. DEQ implemented a number of updates to the model for the 2021 inventory, making several changes along the way. Of course, updated data sets were used where available, including but not limited to updated final demand, import, and inter-industry supply/trade data from IMPLAN, the 2021 US GHG Emissions Inventory, preliminary 2021 Oregon sector-based inventory, and a 2024 update to CICERO's MIRO model (for calendar year 2017). Beyond these and other data updates, several methodological changes were made as well. These include the following:

- The algorithm for allocating US commercial CO2 emissions across different "primary business areas" was updated.
- IMPLAN's 2021 economic model uses a 546-sector classification system that differs from the 536-sector classification system used for 2015. All sectors were reviewed and assigned

to categories, subcategories and meta-categories, which did not change from the 2015 inventory. Similarly, all industry categories were reviewed for the association with the different GTAP categories used in foreign GHG coefficients.

- An updated method was used to estimate the upstream (supply chain) emissions for electricity generation.
- Estimates of the percentage of total waste disposal originating from government sources were updated to reflect lower per-employee waste disposal amounts in 2021 associated with post-pandemic changes in work locations. This data was drawn from recent disposal data provided to DEQ by various government entities across Oregon.

In addition, DEQ updated the 2015 emissions estimate to correct for a minor error in disposal emissions calculations.

Summary of Limitations

Limitations of the 2021 consumption-based greenhouse gas emissions inventory for Oregon include the following:

- Pre-purchase emissions are estimated through the use of consumption estimates provided by IMPLAN coupled with emissions intensities derived from the US and Oregon sector-based inventories and CICERO’s global MRIO model. All of these data sources, as well as the process of allocating emissions to economic sectors, have error in them, and such error propagates forward into the estimate of consumption-based emissions.
- In particular, IMPLAN’s estimates of consumption (final demand) for Oregon are derived from sources including the Bureau of Labor Statistics’ Consumer Expenditure Survey, and represent an estimate of consumption. The market basket of commodities purchased by Oregon consumers (how much red meat vs. fresh vegetables, for example) may differ from IMPLAN’s estimates.
- Purchases may also differ from regional or national averages *within* individual categories. Oregon’s CBEI, like all economic input-output models, is not sensitive to differences in quality (or impact) between competing products. As an input-output model, it suffers from the “price-quality” problem, where for example a $100,000 car is assumed to have four times the production-related emissions as a $25,000 car.
- Emissions factors in CBEI are derived from national inventories (such as the US EPA’s greenhouse gas inventory) and Oregon’s sector-based inventory. To the extent that source inventories may be undercounting emissions (for example, methane sources), the CBEI would as well.
- Biogenic carbon and changes in atmospheric concentrations of CO2 associated with land use changes are not accounted for in the CBEI.

- Similarly, the CBEI does not account for contributors to climate change where scientific evidence or methods to assign global warming characterization factors remains emergent, such as black carbon.
- Not all of the benefits of waste recovery (primarily recycling) of wastes generated in Oregon are accounted for in the CBEI. From a climate perspective, the benefits of recycling generally fall into three categories. One of the largest, which is the potential benefit of increasing forest carbon storage through induced changes in demand, is not accounted for at all (consistent with the exclusion of biogenic carbon generally). Another significant benefit of recycling is associated with the displacement of virgin resources in production. However, not all wastes collected for recycling in Oregon necessarily displace virgin resources (increasing the supply of materials for industry inherently lowers the costs of those resources, thereby increasing resource use), and to the extent they do, those benefits are accounted for in production-phase emissions factors based on national and global average recycling rates. To the extent that Oregon's recycling rates are higher or lower than global averages, some impacts are not included, although separate modeling by DEQ suggests that those impacts are likely small. Finally, to the extent that recycling reduces emissions from landfilling and incineration, such benefits are fully accounted for in the CBEI, although they tend to be many times smaller than the other benefits mentioned above.

Estimate of 1990 Consumption-Based Greenhouse Gas Emissions

With this report, DEQ includes an estimate of 1990 consumption-based greenhouse gas emissions for Oregon. This estimate is for total consumption-based emissions only, and lacks most detail regarding categories, locations, etc. found in the 2005, 2010, 2015, and 2021 inventories. The estimate for 1990 is not as precise as estimates for other years, but provides a reasonable estimate usable for comparing changes in emissions over a longer time horizon. Oregon's statutory goals for greenhouse gas reductions set emissions targets for 2020 and 2050 relative to a 1990 baseline. One utility of a 1990 baseline is it allows for an evaluation of whether Oregon's consumption-based emissions are being reduced at a rate equivalent to the goals in statute.

To derive the estimate of total 1990 consumption-based emissions, DEQ began with 2005 consumption-based emissions, divided into three major phases: pre-purchase, use and disposal. Each of these three phases were then adjusted as described below.

Three-phase pre-purchase emissions (production, pre-purchase transport, and wholesale/retail) for 2005 were further divided into three geographic areas: Oregon, other US, and foreign. These emissions were then scaled to 1990 in a three-step process:

First, emissions from each region were scaled to 1990 levels based on estimated changes in Oregon consumption between 1990 and 2005. Consumption was assumed to change proportional to changes in Oregon's gross state product, expressed in real (inflation adjusted) dollars.

Second, these emissions were further adjusted in proportion to changes in economy-wide emissions intensities. For Oregon, the economy-wide emissions intensities were derived by dividing in-state emissions (on a production basis) by inflation adjusted gross state product for both 1990 and 2005. The same process was used for the US, but using the EPA's US GHG inventory and gross domestic product. As a proxy, the change in US economy-wide emissions intensities was also applied to adjusted 1990 foreign emissions.

Last, to account for the relative increase in foreign imports between 1990 and 2005, 1990 foreign and 1990 other-US emissions were adjusted based on changes in total US imports as a percentage of US gross domestic product for 1990 and 2005, and the ratio of in-state and other US emissions intensities to foreign emissions intensities drawn from the Technical Report for Oregon's 2005 consumption-based inventory.

Use-phase emissions for 1990 were derived by taking 2005 use-phase emissions by use type (residential vehicle use, government electricity use, etc.), matching each use type to a corresponding emissions category (or categories) in Oregon's sector-based inventory, and scaling consumption-based emissions for each use type based on the ratio of 1990-to-2005 sector-based emissions for the associated emissions category.

Disposal-phase emissions for 1990 were estimated by taking 2005 consumption-based disposal emissions, and scaling them in proportion to estimated 1990 vs. 2005 waste disposal from in-state sources. As a rough proxy to reflect changes in landfill gas controls during this time period, these emissions were further adjusted based on the change in "waste emissions intensity" between 1990 and 2005: a measure of selected waste sector emissions from the in-sector inventory divided by tons of waste disposed of in that year.

5. Recommendations for regularly updating Oregon’s CBEI

Dedicate staff and resources for regular updates

This report shows the deep value of consumption-based accounting for informing Oregon’s GHG policy. Oregon’s CBEI reveals Oregon’s role in emissions happening both in Oregon and elsewhere, and uncovers new opportunities for reducing those emissions via actions close to home. Oregon’s CBEI is an essential counterpart to the state’s sector-based inventory, and in comparison to that inventory, requires considerably less effort for each update.

However CBEI, unlike the sector-based inventory, has no dedicated staff time or resources. CBEI has been produced at roughly 5-year intervals because its staff experts at DEQ have many other responsibilities.

Regular updates to CBEI would be greatly facilitated by securing dedicated staff time and budget.

Create an updated modeling system compatible with emerging national standards

Oregon has been a pioneer in the realm of consumption-based accounting. Our CBEI was a groundbreaking product when it was first published[13] in 2011 – the first full consumption-based inventory for a subnational area in North America. Oregon remains one of the few US states with both a consumption- and sector-based inventory, and the detail produced by Oregon’s model is very high – it estimates consumption-based emissions for twelve different groups of consumers (nine different types of households, stratified by income, along with federal government, state/local government, and business investment, capital and inventory formation), and separates GHG emissions into five discrete life cycle phases and three geographic regions (Oregon, rest of US, and rest of world), whereas most consumption-based models focus only on household consumption and lump all phases and regions together.

Nonetheless, regular updates to Oregon’s CBEI are hampered by its lack of compatibility with emerging national resources and standards. For example, currently Oregon creates *de novo* many of the components (data sources and computational modules) used to calculate its CBEI. While a decade ago it was necessary to create everything “from scratch,” today the US EPA publishes and regularly updates many suitable components[14] – but using them would require an overhaul of Oregon's system.

While a major upgrade to Oregon's CBEI modeling system would be substantial work, the resulting system would allow much faster updates. In addition, the upgrade would allow Oregon's model to incorporate numerous improvements desirable to both analysts and end users, including: full transparency and reproducibility of calculations, outputs in diverse impact categories beyond GHG emissions (for example, water use, PM2.5 emissions, and even job creation effects), and easy translation to dashboards and other web apps.

Calibrate updated model against legacy model to assure consistency in timelines

CBEIs are complex models, and it is unlikely the "new," upgraded system will produce precisely the same results as the current ("legacy") model. Analysts need to thoroughly understand any differences between the model results to assure the legitimacy of certain types of trends – for example, increases or decreases in emissions over time. For this reason, the new model and the legacy model should be run concurrently for at least one full measurement cycle, and a substantial comparative analysis conducted.

6. References

American Chemistry Council. Statistics on the Plastics Resins Industry: 2022 Resin Sales and Captive Use by Major Market.

Andrew, R. and Peters G. (2024). A multi-region input-output table based on the global trade analysis project database (GTAP-MRIO). Center for International Climate Research.

ASHRAE (2022). ANSI/ASHRAE/ICC/USGBC/IES Addendum m to ANSI/ASHARE/ICC/USGBC/ISE Standard 189.1-2020. Standard for the Design of High-Performance Green Buildings.

Association for the Advancement of Sustainability in Higher Education. Sustainability Tracking, Assessment & Rating System: reports for various Oregon universities and community colleges (viewed 2024).

Benton County (2023). Adopted Biennium Budget, 2023-2025.

Bond, Nancy, Portland Public Schools (2009). Personal conversation with Oregon DEQ regarding waste disposal from district operations.

Brown, Jen, Benton County (2024). Personal conversation with Oregon DEQ regarding waste disposal from county operations.

California Air Resources Board (2023). Technical Support Documentation for Lookup Table Pathways: Proposed Amendments for the Low Carbon Fuel Standard Regulation.

Camobreco, Vincent, U.S. Environmental Protection Agency (2024). Personal conversation with Oregon DEQ regarding allocation of emissions from HCFCs.

Chism, Pete, City of Portland (2009). Personal conversation with Oregon DEQ regarding waste disposal from city operations.

Dias, Alex Torres, Corvallis School District (2024). Personal conversation with Oregon DEQ regarding waste disposal from district operations.

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Alumina and Aluminum (NAICS 3313).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: All Manufacturing (NAICS 31-33).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Cement (NAICS 327310).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Chemicals (NAICS 325).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Computers, Electronics and Electrical Equipment (NAICS 334, 335).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Fabricated Metals (NAICS 332).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Food and Beverage (NAICS 311, 312).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Forest Products (NAICS 321, 322).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Foundries (NAICS 3315).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Glass and Glass Products (NAICS 3272, 327993).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Iron and Steel (NAICS 3311, 3312).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Machinery (NAICS 333).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Petroleum Refining (NAICS 324110).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Plastics Materials and Resins (NAICS 325211).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Textiles (NAICS 313-316).

Energetics Incorporated, on behalf of the U.S. Department of Energy, Advanced Manufacturing Office (2021). Manufacturing Energy and Carbon Footprint: Transportation Equipment (NAICS 336).

Erickson, P., Lazarus, M., Stanton, E.A., and Ackerman, F., on behalf of the Oregon Department of Environmental Quality (2011). Local Consumption, Global Impact: Greenhouse Gas Emissions from Consumption in Oregon. Stockholm Environment Institute-U.S. Center.

Gazaway, Wright, KATU (2023). Thousands of City of Portland workers continue working remotely at least half the workweek.

IMPLAN (2024). IMPLAN economic impact modeling system: U.S. and Oregon 2021 datasets.

LaGlow, Betty, Centennial School District (2009). Personal conversation with Oregon DEQ regarding waste disposal from district operations.

Lane County (2021). Lane County Adopted Budget, Fiscal Year 2021-2022.

Marzano, Angie, Lane County (2024). Personal communication with Oregon DEQ regarding waste disposal from county operations.

Mihm, Sara, Multnomah County (2024). Personal communication with Oregon DEQ regarding waste disposal from county operations.

Multnomah County Department of County Management (2023). Multnomah County Employment Trends.

Northwest Power and Conservation Council (2022). The 2021 Northwest Power Plan and Residential Sector Energy Use Forecasts.

Oregon Department of Administrative Services (2021). Employee engagement survey results.

Oregon Department of Education. Student Enrollment Reports for School Year 2020-21 and School Year 2020-21.

Oregon Department of Environmental Quality (2013). 2010 Consumption-Based Greenhouse Gas Emissions Inventory.

Oregon Department of Environmental Quality (2017). 2015-2016 Statewide Waste Characterization Study data.

Oregon Department of Environmental Quality (2018). Oregon's Greenhouse Gas Emissions through 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions.

Oregon Department of Environmental Quality (2024). 1990 – 2021 Sector-Based Greenhouse Gas Emissions Inventory data.

Oregon Department of Environmental Quality (2024). 2020 internal landfill greenhouse gas emissions model.

Oregon Department of Environmental Quality (2024). 2021 material recovery survey data.

Oregon Department of Environmental Quality (2024). 2021 solid waste disposal data.

Oregon Department of Environmental Quality (2024). Clean Fuels Program data.

Oregon Department of Environmental Quality (2024). 2020 statewide open burning GHG emissions estimate.

Oregon Employment Department. Oregon 2021 employment statistics.

Oregon Higher Education Coordinating Commission. 2020-2021 and 2021-2022 student enrollment data.

Portland State University, Population Research Center (2022). 2021 Annual Population Report.

Shepard, Elin, Oregon Department of Administrative Services (2009). Personal conversation with DEQ regarding waste disposal from state operations.

Stanton, E.A, Bueno, R., Ackerman, F., Erickson, P., Hammerschlag, R, and Cegan, J., on behalf of the Oregon Department of Environmental Quality (2011). Greenhouse Gas Impacts of Oregon's Consumption: Technical Report. Stockholm Environment Institute-U.S. Center.

U.S. Department of Commerce, Census Bureau (2023). 2021 Economic Census of the U.S., Vehicle Inventory and Use Survey.

U.S. Department of Energy, Energy Information Administration (2021). 2018 Manufacturing Energy Consumption Survey Data.

U.S. Department of Energy, Energy Information Administration (2022). 2018 Commercial Building Energy Consumption Survey Data.

U.S. Department of Labor, Bureau of Labor Statistics (2024). Consumer Price Index Statistics.

U.S. Department of Transportation, Bureau of Transportation Statistics (2023). National Transportation Statistics: U.S. Highway Vehicle-Miles for 2021.

U.S. Department of Transportation, Bureau of Transportation Statistics (2023). National Transportation Statistics: Fuel Consumption by Mode of Transportation in Physical Units.

U.S. Department of Transportation, Federal Aviation Administration (2023). General Aviation and Part 135 Activity Surveys - Calendar Year 2021.

U.S. Department of Transportation, Federal Highway Administration (2023). Highway Statistics 2021.

U.S. Department of Transportation, Federal Highway Administration. 2009 National Household Travel Survey.

U.S. Environmental Protection Agency (2017). Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 – 2015.

U.S. Environmental Protection Agency (2023). Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model, version 16.

U.S. Environmental Protection Agency (2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 – 2021.

U.S. Environmental Protection Agency (2024). State Inventory and Projection Tool for 2021.

U.S. Office of Personnel Management (2022). Status of Telework in the Federal Government: Report to Congress, Fiscal Year 2021.

Wilson, Jackie, Bend La-Pine School District (2024). Personal conversation with Oregon DEQ regarding waste disposal from district operations.

Wolfe, Holly, David Douglas School District (2009). Personal conversation with Oregon DEQ regarding waste disposal from district operations

7. Endnotes

[1] While the meaning of "imports" and "exports" are intuitively obvious for goods, services require some explanation. The CBEI tracks consumption by residents and governments domiciled in Oregon, regardless of where the act of consumption actually occurs. "Imported" services could be services that residents of Oregon purchase and that do not physically occur in Oregon – a tourist from Oregon hailing an Uber while visiting Barcelona, for example, or a resident of Oregon sitting at home and buying house insurance from an on-line broker located in Chicago. "Exported" services are services that are provided inside Oregon but to consumers that are not domiciled in Oregon. Examples of "exported" services include the sale of tickets by a hotel on the Oregon coast to out-of-state residents, and the provision of advertising services to out-of-state businesses.

[2] However, upstream emissions in the consumption-based inventory are only included for fuels used in the course of satisfying consumption, not all electricity used in Oregon as in the sector-based inventory. Fuels used to satisfy consumption are those used directly by Oregon households and governments, and those used by any businesses (including power generators) in the course of satisfying other consumption (including electricity, materials and services) by Oregon households and governments, as well as business capital formation. Use of electricity and fuels by Oregon businesses for the purpose of export for final consumption or intermediate goods that support final consumption by other states or nations are not counted as part of consumption-based emissions.

[3] Consumption is sometimes also referred to as "final demand."

[4] In contrast, the inventory that firms purchase or produce and then sell *in the same year* create emissions that are assessed in the consumption-based inventory, but these purchases do not constitute final consumption and therefore only enter into the inventory when the resulting final good is purchased by an Oregon consumer.

[5] This represents a change in presentation of results from the original (Stockholm Environment Institute) report (2005 inventory). The 2005 inventory assigned supply chain transportation (prior to final production) to the "production" stage of the life cycle, thus mixing it with manufacturing other process-related emissions.

[6] For example, wheat used to make flour and flour used to make bread, as well as the transportation of these supply chain components, would be assigned to the category of "food and beverages" if the bread were ultimately purchased by a household or government. If the bread were purchased by a hospital to

serve to patients, then the bread itself is an intermediate commodity that is used to satisfy a different type of final demand (healthcare services), and the emissions would be assigned to the "healthcare" category.

[7] This is a consequence of the underlying economic model, which treats any consumer purchase of a finished good as four discrete purchases: one of the good itself, a separate purchase of transportation (from the final producer to the point of sale), and separate purchases of wholesaling and retailing services. This means that for any direct retail purchase of goods by a consumer (such as clothing or food), total emissions include all those assigned to the category itself (which includes all emissions, including upstream supply chain transportation, up to the point of final production), as well as a portion of each of "transportation services" (post-production transport), "wholesale" and "retail" categories.

[8] For examples, please see separate DEQ research related to life cycle impacts of food (https://www.oregon.gov/deq/mm/food/pages/product-category-level-footprints.aspx), food and transportation (https://www.oregon.gov/deq/FilterDocs/PEF-FoodTransportation-FullReport.pdf), residential housing (https://www.oregon.gov/deq/FilterDocs/ADU-ResBldgLCA-Report.pdf), drinking water delivery (https://www.oregon.gov/deq/filterdocs/wprlcycleassessdw.pdf), and e-commerce packaging (www.oregon.gov/deq/FilterDocs/LifeCycleInventory.pdf).

[9] Consumption follows the consumer, not the location of consumption. So consumption by Oregonians while in other states or countries is included, while consumption by visitors to Oregon is not included.

[10] Both the estimates of consumer purchases and the input-output matrices are provided as part of the IMPLAN economic modeling software package, which is used extensively by industry, academia and government for understanding economic impacts of consumer spending.

[11] The CBEI methodology for calculating the emissions embodied in Oregon's foreign imports is slightly different from that of Oregon's domestic imports and Oregon production for in-state consumption. These differences are explained in further detail below.

[12] Emissions emitted in foreign countries as a result of Oregon consumption are reported on a commodity basis.

[13] See Erickson, P., Allaway, D., Lazarus, M., & Stanton, E. A. (2012). A Consumption-Based GHG Inventory for the U.S. State of Oregon. Environmental Science & Technology, 46(7), 3679–3686. https://doi.org/10.1021/es203731e

[14] For example Li, M., Ingwersen, W. W., Young, B., Vendries, J., & Birney, C. (2022). useeior: An Open-Source R Package for Building and Using US Environmentally-Extended Input–Output Models. Applied Sciences, 12(9), Article 9. https://doi.org/10.3390/app12094469

8. Appendix: List of Commodities

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Appliances	*Heating and cooling appliances*	Heating equipment (except warm air furnaces)	3274	Materials
Appliances	*Heating and cooling appliances*	Air conditioning, refrigeration, and warm air heating equipment	3275	Materials
Appliances	*Ranges and microwaves*	Household cooking appliances	3325	Materials
Appliances	*Refrigerators and freezers*	Household refrigerators and home freezers	3326	Materials
Appliances	*Washers and dryers*	Household laundry equipment	3327	Materials
Appliances	*Other appliances*	Small electrical appliances	3324	Materials
Appliances	*Other appliances*	Other major household appliances	3328	Materials
Clothing	*Clothing*	Hosiery and socks	3122	Materials
Clothing	*Clothing*	*Not a unique commodity (other knitted apparel)	3123	Materials
Clothing	*Clothing*	Cut and sewn apparel from contractors	3124	Materials
Clothing	*Clothing*	Mens and boys cut and sew apparel	3125	Materials
Clothing	*Clothing*	Womens and girls cut and sew apparel	3126	Materials
Clothing	*Clothing*	Other cut and sew apparel	3127	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Clothing	*Clothing*	Apparel accessories and other apparel	3128	Materials
Clothing	*Clothing*	Footwear	3130	Materials
Clothing	*Clothing*	Other leather and allied products	3131	Materials
Construction	*Concrete, cement, lime and gypsum*	Cement	3203	Materials
Construction	*Concrete, cement, lime and gypsum*	Ready-mix concrete	3204	Materials
Construction	*Concrete, cement, lime and gypsum*	Concrete blocks and bricks	3205	Materials
Construction	*Concrete, cement, lime and gypsum*	Concrete pipes	3206	Materials
Construction	*Concrete, cement, lime and gypsum*	Other concrete products	3207	Materials
Construction	*Concrete, cement, lime and gypsum*	Lime	3208	Materials
Construction	*Concrete, cement, lime and gypsum*	Gypsum products	3209	Materials
Construction	*Non-residential construction and remodeling*	Newly constructed health care structures	3050	Materials or Services
Construction	*Non-residential construction and remodeling*	Newly constructed manufacturing structures	3051	Materials or Services
Construction	*Non-residential construction and remodeling*	Newly constructed power and communication structures	3052	Materials or Services
Construction	*Non-residential construction and remodeling*	Newly constructed educational and vocational structures	3053	Materials or Services
Construction	*Non-residential construction and remodeling*	Newly constructed highways and streets	3054	Materials or Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Construction	*Non-residential construction and remodeling*	Newly constructed commercial structures, including farm structures	3055	Materials or Services
Construction	*Non-residential construction and remodeling*	Newly constructed nonresidential structures	3056	Materials or Services
Construction	*Non-residential construction and remodeling*	Maintained and repaired nonresidential structures	3060	Materials or Services
Construction	*Non-residential construction and remodeling*	Maintained and repaired highways, streets, bridges, and tunnels	3062	Materials or Services
Construction	*Residential construction and remodeling*	Newly constructed single-family residential structures	3057	Materials or Services
Construction	*Residential construction and remodeling*	Newly constructed multifamily residential structures	3058	Materials or Services
Construction	*Residential construction and remodeling*	Newly constructed residential structures	3059	Materials or Services
Construction	*Residential construction and remodeling*	Maintained and repaired residential structures	3061	Materials or Services
Electronics	*Computers and peripherals*	Electronic computers	3298	Materials
Electronics	*Computers and peripherals*	Computer storage devices	3299	Materials
Electronics	*Computers and peripherals*	Computer terminals and other computer peripheral equipment	3300	Materials
Electronics	*Computer service and equipment*	Data processing, hosting, and related services	3436	Services
Electronics	*Computer service and equipment*	Custom computer programming services	3459	Services
Electronics	*Computer service and equipment*	Computer systems design services	3460	Services
Electronics	*Computer service and equipment*	Other computer related services, including facilities management services	3461	Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Electronics	*Other electronics*	Photographic and photocopying equipment	3271	Materials
Electronics	*Other electronics*	Telephone apparatus	3301	Materials
Electronics	*Other electronics*	Broadcast and wireless communications equipment	3302	Materials
Electronics	*Other electronics*	Audio and video equipment	3304	Materials
Food and beverages	*Beverages*	Coffee and tea	3099	Materials
Food and beverages	*Beverages*	Bottled and canned soft drinks and water	3104	Materials
Food and beverages	*Beverages*	Manufactured ice	3105	Materials
Food and beverages	*Beverages*	Beer, ale, malt liquor and nonalcoholic beer	3106	Materials
Food and beverages	*Beverages*	Wine and brandies	3107	Materials
Food and beverages	*Beverages*	Distilled liquors except brandies	3108	Materials
Food and beverages	*Condiments, oils and sweeteners*	Wet corn	3068	Materials
Food and beverages	*Condiments, oils and sweeteners*	Fats and oils refining and blending	3070	Materials
Food and beverages	*Condiments, oils and sweeteners*	Beet sugar	3072	Materials
Food and beverages	*Condiments, oils and sweeteners*	Sugar cane	3073	Materials
Food and beverages	*Condiments, oils and sweeteners*	Flavoring syrup and concentrate	3100	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Food and beverages	*Condiments, oils and sweeteners*	Mayonnaise, dressings, and sauces	3101	Materials
Food and beverages	*Condiments, oils and sweeteners*	Spices and extracts	3102	Materials
Food and beverages	*Dairy*	Dairy cattle and milk products	3012	Materials
Food and beverages	*Dairy*	Cheese	3082	Materials
Food and beverages	*Dairy*	Dry, condensed, and evaporated dairy products	3083	Materials
Food and beverages	*Dairy*	Fluid milk	3084	Materials
Food and beverages	*Dairy*	Creamery butter	3085	Materials
Food and beverages	*Dairy*	Ice cream and frozen dessert	3086	Materials
Food and beverages	*Fruit and vegetables*	Vegetables and melons	3003	Materials
Food and beverages	*Fruit and vegetables*	Fruit	3004	Materials
Food and beverages	*Fruit and vegetables*	Frozen fruits, juices and vegetables	3077	Materials
Food and beverages	*Fruit and vegetables*	Canned fruits and vegetables	3079	Materials
Food and beverages	*Fruit and vegetables*	Dehydrated food products	3081	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Grains	3002	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Tree nuts	3005	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Food and beverages	*Grains, baked goods, cereals, nuts*	Flour	3065	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Rice	3066	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Malt	3067	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Breakfast cereal	3071	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Nonchocolate confectioneries	3074	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Confectioneries from purchased chocolate	3076	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Frozen cakes and other pastries	3087	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Bread and bakery products, except frozen	3093	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Cookies and crackers	3094	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Dry pasta, mixes, and dough	3095	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Tortillas	3096	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Roasted nuts and peanut butter	3097	Materials
Food and beverages	*Grains, baked goods, cereals, nuts*	Other snack foods	3098	Materials
Food and beverages	*Pet food*	Dog and cat food	3063	Materials
Food and beverages	*Pet food*	Other animal food	3064	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Food and beverages	*Poultry and eggs*	Poultry and egg products	3013	Materials
Food and beverages	*Poultry and eggs*	Processed poultry meat products	3088	Materials
Food and beverages	*Seafood*	Fish	3017	Materials
Food and beverages	*Seafood*	Seafood products	3092	Materials
Food and beverages	*Other meat (beef, pork, etc.)*	Beef cattle	3011	Materials
Food and beverages	*Other meat (beef, pork, etc.)*	Meat (except poultry) produced in slaughtering plant	3089	Materials
Food and beverages	*Other meat (beef, pork, etc.)*	Meat processed from carcasses	3090	Materials
Food and beverages	*Other meat (beef, pork, etc.)*	Processed animal rendered byproducts	3091	Materials
Food and beverages	*Other animal products*	Animal products, except cattle and poultry and eggs	3014	Materials
Food and beverages	*Other frozen food*	Animal products, except cattle and poultry and eggs	3014	Materials
Food and beverages	*Restaurants*	Full-service restaurant services	3509	Materials or Services
Food and beverages	*Restaurants*	Limited-service restaurant services	3510	Materials or Services
Food and beverages	*Restaurants*	All other food and drinking place services	3511	Materials or Services
Food and beverages	*Other food and agriculture*	Oilseeds	3001	Materials
Food and beverages	*Other food and agriculture*	Tobacco	3007	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Food and beverages	*Other food and agriculture*	Cotton	3008	Materials
Food and beverages	*Other food and agriculture*	Sugarcane and sugar beets	3009	Materials
Food and beverages	*Other food and agriculture*	All other crops	3010	Materials
Food and beverages	*Other food and agriculture*	Soybean and other oilseed processing	3069	Materials
Food and beverages	*Other food and agriculture*	Chocolate and confectioneries from cacao beans	3075	Materials
Food and beverages	*Other food and agriculture*	Canned specialties	3080	Materials
Food and beverages	*Other food and agriculture*	All other food products	3103	Materials
Furnishings and supplies	*Furnishings*	Carpets and rugs	3117	Materials
Furnishings and supplies	*Furnishings*	Curtains and linens	3118	Materials
Furnishings and supplies	*Furnishings*	Upholstered household furniture	3366	Materials
Furnishings and supplies	*Furnishings*	Nonupholstered wood household furniture	3367	Materials
Furnishings and supplies	*Furnishings*	Other household nonupholstered furniture	3368	Materials
Furnishings and supplies	*Furnishings*	Institutional furniture	3369	Materials
Furnishings and supplies	*Furnishings*	Wood office furniture	3370	Materials
Furnishings and supplies	*Furnishings*	Custom architectural woodwork and millwork	3371	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Furnishings and supplies	*Furnishings*	Office furniture, except wood	3372	Materials
Furnishings and supplies	*Furnishings*	Mattresses	3374	Materials
Furnishings and supplies	*Furnishings*	Blinds and shades	3375	Materials
Furnishings and supplies	*Household supplies*	Sanitary paper products	3150	Materials
Furnishings and supplies	*Household supplies*	Soaps and other detergents	3177	Materials
Furnishings and supplies	*Household supplies*	Polish and other sanitation goods	3178	Materials
Furnishings and supplies	*Household supplies*	Surface active agents	3179	Materials
Furnishings and supplies	*Household supplies*	Toilet preparations	3180	Materials
Furnishings and supplies	*Household supplies*	Plastics packaging materials and unlaminated films and sheets	3186	Materials
Furnishings and supplies	*Household supplies*	Pottery, ceramics, and plumbing fixtures	3197	Materials
Furnishings and supplies	*Household supplies*	Flat glass	3199	Materials
Furnishings and supplies	*Household supplies*	Other pressed and blown glass and glassware	3200	Materials
Furnishings and supplies	*Household supplies*	Glass products made of purchased glass	3202	Materials
Furnishings and supplies	*Household supplies*	Cutlery, utensils, pots, and pans	3233	Materials
Furnishings and supplies	*Household supplies*	Storage batteries	3333	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Furnishings and supplies	*Household supplies*	Primary batteries	3334	Materials
Furnishings and supplies	*Household supplies*	Ophthalmic goods	3379	Materials
Furnishings and supplies	*Household supplies*	Jewelry and silverware	3381	Materials
Furnishings and supplies	*Household supplies*	Brooms, brushes, and mops	3389	Materials
Furnishings and supplies	*Household supplies*	Greeting cards	3427	Materials
Furnishings and supplies	*Lawn and garden*	Greenhouse, nursery, and floriculture products	3006	Materials
Furnishings and supplies	*Lawn and garden*	Pesticides and other agricultural chemicals	3170	Materials
Furnishings and supplies	*Lawn and garden*	Lawn and garden equipment	3261	Materials
Furnishings and supplies	*Media*	Software and other prerecorded and record reproducing	3321	Materials
Furnishings and supplies	*Media*	Dolls, toys, and games	3383	Materials
Furnishings and supplies	*Media*	Newspapers	3423	Materials
Furnishings and supplies	*Media*	Periodicals	3424	Materials
Furnishings and supplies	*Media*	Books	3425	Materials
Furnishings and supplies	*Media*	Motion pictures and videos	3429	Materials or Services
Furnishings and supplies	*Media*	Sound recordings	3430	Materials or Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Furnishings and supplies	*Office supplies*	Paper from pulp	3145	Materials
Furnishings and supplies	*Office supplies*	Stationery products	3149	Materials
Furnishings and supplies	*Office supplies*	Software publishers	3428	Services
Healthcare	*Healthcare services*	Offices of physicians	3483	Services
Healthcare	*Healthcare services*	Offices of dentists	3484	Services
Healthcare	*Healthcare services*	Offices of other health practitioners	3485	Services
Healthcare	*Healthcare services*	Outpatient care centers	3486	Services
Healthcare	*Healthcare services*	Medical and diagnostic laboratories	3487	Services
Healthcare	*Healthcare services*	Home health care services	3488	Services
Healthcare	*Healthcare services*	Other ambulatory health care services	3489	Services
Healthcare	*Healthcare services*	Hospital services	3490	Services
Healthcare	*Healthcare services*	Nursing and community care services	3491	Services
Healthcare	*Healthcare services*	Residential intellectual disability, mental health, substance abuse and other facilities	3492	Services
Healthcare	*Medicines*	Medicines and botanicals	3171	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Healthcare	*Medicines*	Pharmaceuticals	3172	Materials
Healthcare	*Medicines*	In-vitro diagnostic substances	3173	Materials
Healthcare	*Medicines*	Biological products (except diagnostic)	3174	Materials
Lighting and fixtures	*Lighting and fixtures*	Electric lamp bulbs and parts	3322	Materials
Lighting and fixtures	*Lighting and fixtures*	Lighting fixtures	3323	Materials
Other manufactured goods	*Forestries, mills, paper*	Forest, timber, and forest nursery products	3015	Materials
Other manufactured goods	*Forestries, mills, paper*	Logs and roundwood	3016	Materials
Other manufactured goods	*Forestries, mills, paper*	Dimension lumber	3132	Materials
Other manufactured goods	*Forestries, mills, paper*	Preserved wood products	3133	Materials
Other manufactured goods	*Forestries, mills, paper*	Veneer and plywood	3134	Materials
Other manufactured goods	*Forestries, mills, paper*	Wood pulp	3144	Materials
Other manufactured goods	*Forestries, mills, paper*	Paperboard from pulp	3146	Materials
Other manufactured goods	*Forestries, mills, paper*	Paperboard containers	3147	Materials
Other manufactured goods	*Forestries, mills, paper*	Paper bags and coated and treated paper	3148	Materials
Other manufactured goods	*Forestries, mills, paper*	All other converted paper products	3151	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Foundries, metal processing*	Iron and steel and ferroalloy products	3215	Materials
Other manufactured goods	*Foundries, metal processing*	* Not a unique commodity (iron, steel pipes and tubes from purchased steel)	3216	Materials
Other manufactured goods	*Foundries, metal processing*	* Not a unique commodity (rolled steel shapes)	3217	Materials
Other manufactured goods	*Foundries, metal processing*	Steel wire	3218	Materials
Other manufactured goods	*Foundries, metal processing*	Aluminum products	3219	Materials
Other manufactured goods	*Foundries, metal processing*	* Not a unique commodity (secondary smelting and alloying of aluminum)	3220	Materials
Other manufactured goods	*Foundries, metal processing*	Aluminum sheets, plates, and foils	3221	Materials
Other manufactured goods	*Foundries, metal processing*	Rolled, drawn, and extruded aluminum	3222	Materials
Other manufactured goods	*Foundries, metal processing*	Nonferrous metal (exc aluminum) smelting and refining	3223	Materials
Other manufactured goods	*Foundries, metal processing*	Rolled, drawn, extruded, and alloyed copper	3224	Materials
Other manufactured goods	*Foundries, metal processing*	Nonferrous metal, except copper and aluminum, shaping	3225	Materials
Other manufactured goods	*Foundries, metal processing*	Secondary processing of other nonferrous metals	3226	Materials
Other manufactured goods	*Foundries, metal processing*	Ferrous metals	3227	Materials
Other manufactured goods	*Foundries, metal processing*	Nonferrous metals	3228	Materials
Other manufactured goods	*Foundries, metal processing*	Crowned and stamped metals	3230	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Foundries, metal processing*	Iron and steel forgings	3231	Materials
Other manufactured goods	*Foundries, metal processing*	Nonferrous forgings	3232	Materials
Other manufactured goods	*Foundries, metal processing*	Heat treated products	3249	Materials
Other manufactured goods	*Foundries, metal processing*	Coated and engraved products	3250	Materials
Other manufactured goods	*Foundries, metal processing*	Electroplated, anodized, and colored metal	3251	Materials
Other manufactured goods	*Heavy transportation equipment*	Overhead cranes, hoists, and monorail systems	3289	Materials
Other manufactured goods	*Heavy transportation equipment*	Industrial trucks, trailers, and stackers	3290	Materials
Other manufactured goods	*Heavy transportation equipment*	Heavy duty trucks	3342	Materials
Other manufactured goods	*Heavy transportation equipment*	Truck trailers	3344	Materials
Other manufactured goods	*Heavy transportation equipment*	Aircrafts	3354	Materials
Other manufactured goods	*Heavy transportation equipment*	Aircraft engines and engine parts	3355	Materials
Other manufactured goods	*Heavy transportation equipment*	Other aircraft parts and auxiliary equipment	3356	Materials
Other manufactured goods	*Heavy transportation equipment*	Railroad rolling stock	3359	Materials
Other manufactured goods	*Heavy transportation equipment*	Ships	3360	Materials
Other manufactured goods	*Machinery manufacturing*	Power boilers and heat exchangers	3241	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Machinery manufacturing*	Farm machinery and equipment	3260	Materials
Other manufactured goods	*Machinery manufacturing*	Construction machinery	3262	Materials
Other manufactured goods	*Machinery manufacturing*	Mining machinery	3263	Materials
Other manufactured goods	*Machinery manufacturing*	Oil and gas field machinery	3264	Materials
Other manufactured goods	*Machinery manufacturing*	Semiconductor machinery	3265	Materials
Other manufactured goods	*Machinery manufacturing*	Food product machinery	3266	Materials
Other manufactured goods	*Machinery manufacturing*	Sawmill, woodworking, and paper machinery	3267	Materials
Other manufactured goods	*Machinery manufacturing*	Printing machinery and equipment	3268	Materials
Other manufactured goods	*Machinery manufacturing*	All other industrial machinery	3269	Materials
Other manufactured goods	*Machinery manufacturing*	Optical instruments and lenses	3270	Materials
Other manufactured goods	*Machinery manufacturing*	Other commercial service industry machinery	3272	Materials
Other manufactured goods	*Machinery manufacturing*	Air purification and ventilation equipment	3273	Materials
Other manufactured goods	*Machinery manufacturing*	Industrial molds	3276	Materials
Other manufactured goods	*Machinery manufacturing*	Special tool, die, jig, and fixture	3277	Materials
Other manufactured goods	*Machinery manufacturing*	Cutting tool and machine tool accessory	3278	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Machinery manufacturing*	Machine tool	3279	Materials
Other manufactured goods	*Machinery manufacturing*	Rolling mill and other metalworking machinery	3280	Materials
Other manufactured goods	*Machinery manufacturing*	Turbine and turbine generator set units	3281	Materials
Other manufactured goods	*Machinery manufacturing*	Speed changers, industrial high-speed drives, and gears	3282	Materials
Other manufactured goods	*Machinery manufacturing*	Mechanical power transmission equipment	3283	Materials
Other manufactured goods	*Machinery manufacturing*	Other engine equipment	3284	Materials
Other manufactured goods	*Machinery manufacturing*	Pump and pumping equipment	3285	Materials
Other manufactured goods	*Machinery manufacturing*	Air and gas compressors	3286	Materials
Other manufactured goods	*Machinery manufacturing*	Elevators and moving stairways	3287	Materials
Other manufactured goods	*Machinery manufacturing*	Conveyor and conveying equipment	3288	Materials
Other manufactured goods	*Machinery manufacturing*	Welding and soldering equipment	3292	Materials
Other manufactured goods	*Machinery manufacturing*	Packaging machinery	3293	Materials
Other manufactured goods	*Machinery manufacturing*	Industrial process furnaces and ovens	3294	Materials
Other manufactured goods	*Machinery manufacturing*	Fluid power cylinders and actuators	3295	Materials
Other manufactured goods	*Machinery manufacturing*	Fluid power pumps and motors	3296	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Machinery manufacturing*	Scales, balances, and miscellaneous general purpose machinery	3297	Materials
Other manufactured goods	*Machinery manufacturing*	Other communications equipment	3303	Materials
Other manufactured goods	*Machinery manufacturing*	Semiconductors and related devices	3307	Materials
Other manufactured goods	*Machinery manufacturing*	Electromedical and electrotherapeutic apparatus	3311	Materials
Other manufactured goods	*Machinery manufacturing*	Search, detection, and navigation instruments	3312	Materials
Other manufactured goods	*Machinery manufacturing*	Automatic environmental controls	3313	Materials
Other manufactured goods	*Machinery manufacturing*	Industrial process variable instruments	3314	Materials
Other manufactured goods	*Machinery manufacturing*	Totalizing fluid meters and counting devices	3315	Materials
Other manufactured goods	*Machinery manufacturing*	Electricity and signal testing instruments	3316	Materials
Other manufactured goods	*Machinery manufacturing*	Analytical laboratory instruments	3317	Materials
Other manufactured goods	*Machinery manufacturing*	Irradiation apparatus	3318	Materials
Other manufactured goods	*Machinery manufacturing*	Power, distribution, and specialty transformers	3329	Materials
Other manufactured goods	*Machinery manufacturing*	Switchgear and switchboard apparatus	3331	Materials
Other manufactured goods	*Machinery manufacturing*	Relay and industrial controls	3332	Materials
Other manufactured goods	*Machinery manufacturing*	Wiring devices	3337	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Machinery manufacturing*	All other miscellaneous electrical equipment and components	3339	Materials
Other manufactured goods	*Machinery manufacturing*	Commercial and industrial machinery and equipment repair and maintenance	3515	Services
Other manufactured goods	*Missiles, weapons*	Small arms ammunition	3255	Materials
Other manufactured goods	*Missiles, weapons*	Ammunition, except for small arms	3256	Materials
Other manufactured goods	*Missiles, weapons*	Small arms, ordnance, and accessories	3257	Materials
Other manufactured goods	*Missiles, weapons*	Guided missiles and space vehicles	3357	Materials
Other manufactured goods	*Missiles, weapons*	Propulsion units and parts for space vehicles and guided missiles	3358	Materials
Other manufactured goods	*Missiles, weapons*	Military armored vehicles, tanks, and tank components	3363	Materials
Other manufactured goods	*Mobile homes*	Manufactured homes (mobile homes)	3141	Materials
Other manufactured goods	*Other manufactures*	Cigarettes, cigars, smoking and chewing tobacco, and reconstituted tobacco	3109	Materials
Other manufactured goods	*Other manufactures*	Fiber filaments, yarn, and thread	3110	Materials
Other manufactured goods	*Other manufactures*	Broadwoven fabrics and felts	3111	Materials
Other manufactured goods	*Other manufactures*	Narrow fabrics and schiffli machine embroidery	3112	Materials
Other manufactured goods	*Other manufactures*	Nonwoven fabrics	3113	Materials
Other manufactured goods	*Other manufactures*	Knitted fabrics	3114	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Finished textiles and fabrics	3115	Materials
Other manufactured goods	*Other manufactures*	Coated fabric coating	3116	Materials
Other manufactured goods	*Other manufactures*	Textile bags and canvas	3119	Materials
Other manufactured goods	*Other manufactures*	Rope, cordage, twine, tire cord and tire fabric	3120	Materials
Other manufactured goods	*Other manufactures*	Other textile products	3121	Materials
Other manufactured goods	*Other manufactures*	Tanned and finished leather and hides	3129	Materials
Other manufactured goods	*Other manufactures*	Engineered wood members and trusses	3135	Materials
Other manufactured goods	*Other manufactures*	Reconstituted wood products	3136	Materials
Other manufactured goods	*Other manufactures*	Wood windows and doors	3137	Materials
Other manufactured goods	*Other manufactures*	Cut stock, resawn and planed lumber	3138	Materials
Other manufactured goods	*Other manufactures*	Other millwork, including flooring	3139	Materials
Other manufactured goods	*Other manufactures*	Wood containers and pallets	3140	Materials
Other manufactured goods	*Other manufactures*	Prefabricated wood buildings	3142	Materials
Other manufactured goods	*Other manufactures*	All other miscellaneous wood products	3143	Materials
Other manufactured goods	*Other manufactures*	Printed materials	3152	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Printing support services	3153	Materials
Other manufactured goods	*Other manufactures*	Asphalt paving mixtures and blocks	3155	Materials
Other manufactured goods	*Other manufactures*	Asphalt shingles and coating materials	3156	Materials
Other manufactured goods	*Other manufactures*	Synthetic dyes and pigments	3161	Materials
Other manufactured goods	*Other manufactures*	Other basic inorganic chemicals	3162	Materials
Other manufactured goods	*Other manufactures*	Other basic organic chemicals	3163	Materials
Other manufactured goods	*Other manufactures*	Plastics materials and resins	3164	Materials
Other manufactured goods	*Other manufactures*	Synthetic rubbers	3165	Materials
Other manufactured goods	*Other manufactures*	Artificial and synthetic fibers and filaments	3166	Materials
Other manufactured goods	*Other manufactures*	Nitrogenous fertilizer	3167	Materials
Other manufactured goods	*Other manufactures*	Phosphatic fertilizer	3168	Materials
Other manufactured goods	*Other manufactures*	* Not a unique commodity (fertilizer mixing)	3169	Materials
Other manufactured goods	*Other manufactures*	Paints and coatings	3175	Materials
Other manufactured goods	*Other manufactures*	Adhesives	3176	Materials
Other manufactured goods	*Other manufactures*	Printing inks	3181	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Explosives	3182	Materials
Other manufactured goods	*Other manufactures*	Compounded resins	3183	Materials
Other manufactured goods	*Other manufactures*	Photographic films and chemicals	3184	Materials
Other manufactured goods	*Other manufactures*	Other miscellaneous chemical products	3185	Materials
Other manufactured goods	*Other manufactures*	Unlaminated plastics profile shapes	3187	Materials
Other manufactured goods	*Other manufactures*	Plastics pipes and pipe fittings	3188	Materials
Other manufactured goods	*Other manufactures*	Laminated plastics plates, sheets (except packaging), and shapes	3189	Materials
Other manufactured goods	*Other manufactures*	Polystyrene foam products	3190	Materials
Other manufactured goods	*Other manufactures*	Urethane and other foam products (except polystyrene)	3191	Materials
Other manufactured goods	*Other manufactures*	Plastics bottles	3192	Materials
Other manufactured goods	*Other manufactures*	Other plastics products	3193	Materials
Other manufactured goods	*Other manufactures*	Rubber and plastics hoses and belts	3195	Materials
Other manufactured goods	*Other manufactures*	Other rubber products	3196	Materials
Other manufactured goods	*Other manufactures*	Bricks, tiles, and other structural clay products	3198	Materials
Other manufactured goods	*Other manufactures*	Glass containers	3201	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Abrasive products	3210	Materials
Other manufactured goods	*Other manufactures*	Cut stone and stone products	3211	Materials
Other manufactured goods	*Other manufactures*	Ground or treated mineral and earth products	3212	Materials
Other manufactured goods	*Other manufactures*	Mineral wool	3213	Materials
Other manufactured goods	*Other manufactures*	Miscellaneous nonmetallic mineral products	3214	Materials
Other manufactured goods	*Other manufactures*	Custom roll formed metals	3229	Materials
Other manufactured goods	*Other manufactures*	Handtools	3234	Materials
Other manufactured goods	*Other manufactures*	Prefabricated metal buildings and components	3235	Materials
Other manufactured goods	*Other manufactures*	Fabricated structural metal products	3236	Materials
Other manufactured goods	*Other manufactures*	Plates	3237	Materials
Other manufactured goods	*Other manufactures*	Metal windows and doors	3238	Materials
Other manufactured goods	*Other manufactures*	Sheet metal work (except stampings)	3239	Materials
Other manufactured goods	*Other manufactures*	Ornamental and architectural metal products	3240	Materials
Other manufactured goods	*Other manufactures*	Metal tanks (heavy gauge)	3242	Materials
Other manufactured goods	*Other manufactures*	Metal cans	3243	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Metal barrels, drums and pails	3244	Materials
Other manufactured goods	*Other manufactures*	Hardware	3245	Materials
Other manufactured goods	*Other manufactures*	Spring and wire products	3246	Materials
Other manufactured goods	*Other manufactures*	Machined products	3247	Materials
Other manufactured goods	*Other manufactures*	Turned products and screws, nuts, and bolts	3248	Materials
Other manufactured goods	*Other manufactures*	Valve and fittings, other than plumbing	3252	Materials
Other manufactured goods	*Other manufactures*	Plumbing fixture fittings and trims	3253	Materials
Other manufactured goods	*Other manufactures*	Balls and roller bearings	3254	Materials
Other manufactured goods	*Other manufactures*	Fabricated pipes and pipe fittings	3258	Materials
Other manufactured goods	*Other manufactures*	Other fabricated metals	3259	Materials
Other manufactured goods	*Other manufactures*	Power-driven handtools	3291	Materials
Other manufactured goods	*Other manufactures*	Printed circuit assemblies (electronic assemblies)	3305	Materials
Other manufactured goods	*Other manufactures*	Bare printed circuit boards	3306	Materials
Other manufactured goods	*Other manufactures*	Capacitors, resistors, coils, transformers, and other inductors	3308	Materials
Other manufactured goods	*Other manufactures*	Electronic connectors	3309	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Other electronic components	3310	Materials
Other manufactured goods	*Other manufactures*	Watches, clocks, and other measuring and controlling devices	3319	Materials
Other manufactured goods	*Other manufactures*	Blank magnetic and optical recording media	3320	Materials
Other manufactured goods	*Other manufactures*	Motors and generators	3330	Materials
Other manufactured goods	*Other manufactures*	Fiber optic cables	3335	Materials
Other manufactured goods	*Other manufactures*	Other communication and energy wires	3336	Materials
Other manufactured goods	*Other manufactures*	Carbon and graphite products	3338	Materials
Other manufactured goods	*Other manufactures*	Motor vehicle bodies	3343	Materials
Other manufactured goods	*Other manufactures*	All other transportation equipment	3364	Materials
Other manufactured goods	*Other manufactures*	Wood kitchen cabinets and countertops	3365	Materials
Other manufactured goods	*Other manufactures*	Showcases, partitions, shelvings, and lockers	3373	Materials
Other manufactured goods	*Other manufactures*	Surgical and medical instruments	3376	Materials
Other manufactured goods	*Other manufactures*	Surgical appliance and supplies	3377	Materials
Other manufactured goods	*Other manufactures*	Dental equipment and supplies	3378	Materials
Other manufactured goods	*Other manufactures*	Dental laboratories	3380	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other manufactured goods	*Other manufactures*	Sporting and athletic goods	3382	Materials
Other manufactured goods	*Other manufactures*	Office supplies (except paper)	3384	Materials
Other manufactured goods	*Other manufactures*	Signs	3385	Materials
Other manufactured goods	*Other manufactures*	Gaskets, packings, and sealing devices	3386	Materials
Other manufactured goods	*Other manufactures*	Musical instruments	3387	Materials
Other manufactured goods	*Other manufactures*	Fasteners, buttons, needles, and pins	3388	Materials
Other manufactured goods	*Other manufactures*	Burial caskets	3390	Materials
Other manufactured goods	*Other manufactures*	All other miscellaneous manufactured products	3391	Materials
Other manufactured goods	*Other manufactures*	Directories, mailing lists, and other published materials	3426	Materials
Retailers	*Retailers*	Retail services - Motor vehicle and parts dealers	3402	Materials
Retailers	*Retailers*	Retail services - Furniture and home furnishings stores	3403	Materials
Retailers	*Retailers*	Retail services - Electronics and appliance stores	3404	Materials
Retailers	*Retailers*	Retail services - Building material and garden equipment and supplies stores	3405	Materials
Retailers	*Retailers*	Retail services - Food and beverage stores	3406	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Retailers	*Retailers*	Retail services - Health and personal care stores	3407	Materials
Retailers	*Retailers*	Retail services - Gasoline stores	3408	Fuels
Retailers	*Retailers*	Retail services- Clothing and clothing accessories stores	3409	Materials
Retailers	*Retailers*	Retail services - Sporting goods, hobby, musical instrument and book stores	3410	Materials
Retailers	*Retailers*	Retail services - General merchandise stores	3411	Materials
Retailers	*Retailers*	Retail services - Miscellaneous store retailers	3412	Materials
Retailers	*Retailers*	Retail services - Nonstore retailers	3413	Materials
Services	*Banks and financial services*	Nondepository credit intermediation and related activities	3439	Services
Services	*Banks and financial services*	Securities and commodity contracts intermediation and brokerage	3440	Services
Services	*Banks and financial services*	Monetary authorities and depository credit intermediation	3441	Services
Services	*Banks and financial services*	Other financial investment services	3442	Services
Services	*Banks and financial services*	Funds, trusts, and other financial services	3446	Services
Services	*Building services*	Services to buildings	3476	Services
Services	*Building services*	Landscape and horticultural services	3477	Services
Services	*Car rental, repair and wash*	Automotive equipment rental and leasing services	3450	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Services	*Car rental, repair and wash*	Automotive repair and maintenance, except car washes	3512	Services
Services	*Car rental, repair and wash*	Car washes	3513	Services
Services	*Education and day care*	Elementary and secondary schools	3480	Services
Services	*Education and day care*	Junior colleges, colleges, universities, and professional schools	3481	Services
Services	*Education and day care*	Other educational services	3482	Services
Services	*Education and day care*	Child day care services	3494	Services
Services	*Entertainment and media*	Radio and television broadcasts	3431	Services
Services	*Entertainment and media*	Cable and other subscription programming	3432	Services
Services	*Entertainment and media*	Wired telecommunications	3433	Services
Services	*Entertainment and media*	Wireless telecommunications (except satellite)	3434	Services
Services	*Entertainment and media*	Satellite, telecommunications resellers, and all other telecommunications	3435	Services
Services	*Entertainment and media*	Internet publishing and broadcasting and web search portals	3438	Services
Services	*Entertainment and media*	Video tape and disc rental services	3452	Materials
Services	*Entertainment and media*	Performing arts	3496	Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Services	*Entertainment and media*	Commercial sports except racing	3497	Services
Services	*Entertainment and media*	Racing and track operation services	3498	Services
Services	*Entertainment and media*	Independent artists, writers, and performers	3499	Services
Services	*Entertainment and media*	Promotional services for performing arts and sports and public figures	3500	Services
Services	*Entertainment and media*	Museum, heritage, zoo, and recreational services	3501	Services
Services	*Entertainment and media*	Amusement parks and arcades	3502	Services
Services	*Entertainment and media*	Gambling recreation	3503	Services
Services	*Entertainment and media*	Other amusement and recreation	3504	Services
Services	*Entertainment and media*	Bowling activities	3506	Services
Services	*Hotels and motels*	Hotels and motel services, including casino hotels	3507	Services
Services	*Hotels and motels*	Other accommodation services	3508	Services
Services	*Legal, real estate, insurance*	Direct life insurance carriers	3443	Services
Services	*Legal, real estate, insurance*	Insurance carriers, except direct life	3444	Services
Services	*Legal, real estate, insurance*	Insurance agencies, brokerages, and related services	3445	Services
Services	*Legal, real estate, insurance*	Other real estate	3447	Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Services	*Legal, real estate, insurance*	Tenant-occupied housing	3448	Services
Services	*Legal, real estate, insurance*	Legal services	3455	Services
Services	*Personal services*	Veterinary services	3467	Services
Services	*Personal services*	Fitness and recreational sports center services	3505	Services
Services	*Personal services*	Personal care services	3517	Services
Services	*Personal services*	Dry-cleaning and laundry services	3519	Services
Services	*Personal services*	Other personal services	3520	Services
Services	*Personal services*	Cooking, housecleaning, gardening, and other services to private households	3525	Services
Services	*Waste management*	Waste management and remediation services	3479	Materials or Services
Services	*Other services*	Support activities for agriculture and forestry	3019	Services
Services	*Other services*	Couriers and messengers services	3421	Services
Services	*Other services*	Warehousing and storage services	3422	Services
Services	*Other services*	News syndicates, libraries, archives and all other information services	3437	Services
Services	*Other services*	General and consumer goods rental services except video tapes and discs	3451	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Services	*Other services*	Commercial and industrial machinery and equipment rental and leasing services	3453	Materials
Services	*Other services*	Accounting, tax preparation, bookkeeping, and payroll services	3456	Services
Services	*Other services*	Architectural, engineering, and related services	3457	Services
Services	*Other services*	Specialized design services	3458	Services
Services	*Other services*	Management consulting services	3462	Services
Services	*Other services*	Environmental and other technical consulting services	3463	Services
Services	*Other services*	Scientific research and development services	3464	Services
Services	*Other services*	Advertising, public relations, and related services	3465	Services
Services	*Other services*	Photographic services	3466	Services
Services	*Other services*	Marketing research and all other miscellaneous professional, scientific, and technical services	3468	Services
Services	*Other services*	Management of companies and enterprises	3469	Services
Services	*Other services*	Office administrative services	3470	Services
Services	*Other services*	Facilities support services	3471	Services
Services	*Other services*	Employment services	3472	Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Services	*Other services*	Business support services	3473	Services
Services	*Other services*	Travel arrangement and reservation services	3474	Services
Services	*Other services*	Investigation and security services	3475	Services
Services	*Other services*	Other support services	3478	Services
Services	*Other services*	Individual and family services	3493	Services
Services	*Other services*	Community food, housing, and other relief services, including rehabilitation services	3495	Services
Services	*Other services*	Electronic and precision equipment repair and maintenance	3514	Services
Services	*Other services*	Personal and household goods repair and maintenance	3516	Services
Services	*Other services*	Death care services	3518	Services
Services	*Other services*	Grantmaking, giving, and social advocacy services	3522	Services
Services	*Other services*	Business and professional services	3523	Services
Services	*Other services*	Labor and civic services	3524	Services
Services	*Other services*	US Postal delivery services	3526	Services
Services	*Other services*	Other products and services of Fed Govt enterprises	3528	Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Services	*Other services*	Other products and services of State Govt enterprises	3531	Services
Services	*Other services*	Other products and services of Local Govt enterprises	3534	Services
Transportation services	*Transportation services*	Air transportation services	3414	Materials or Services
Transportation services	*Transportation services*	Rail transportation services	3415	Materials or Services
Transportation services	*Transportation services*	Water transportation services	3416	Materials
Transportation services	*Transportation services*	Truck transportation services	3417	Materials
Transportation services	*Transportation services*	Transit and ground passenger transportation services	3418	Services
Transportation services	*Transportation services*	Pipeline transportation services	3419	Fuels
Transportation services	*Transportation services*	Scenic and sightseeing transportation services and support activities for transportation	3420	Services
Transportation services	*Transportation services*	* Not a unique commodity (passenger transit by state govt)	3529	Services
Transportation services	*Transportation services*	* Not a unique commodity (passenger transit by local govt)	3532	Services
Vehicles and parts	*Vehicles*	Automobiles	3340	Materials
Vehicles and parts	*Vehicles*	Light trucks and utility vehicles	3341	Materials
Vehicles and parts	*Vehicles*	Motor homes	3345	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Vehicles and parts	*Vehicles*	Travel trailers and campers	3346	Materials
Vehicles and parts	*Vehicles*	Boats	3361	Materials
Vehicles and parts	*Vehicles*	Motorcycles, bicycles, and parts	3362	Materials
Vehicles and parts	*Vehicle parts*	Petroleum lubricating oil and grease	3157	Materials
Vehicles and parts	*Vehicle parts*	Tires	3194	Materials
Vehicles and parts	*Vehicle parts*	Motor vehicle gasoline engines and engine parts	3347	Materials
Vehicles and parts	*Vehicle parts*	Motor vehicle electrical and electronic equipment	3348	Materials
Vehicles and parts	*Vehicle parts*	Motor vehicle transmission and power train parts	3349	Materials
Vehicles and parts	*Vehicle parts*	Motor vehicle seating and interior trim	3350	Materials
Vehicles and parts	*Vehicle parts*	Motor vehicle stamped metal	3351	Materials
Vehicles and parts	*Vehicle parts*	Other motor vehicle parts	3352	Materials
Vehicles and parts	*Vehicle parts*	Motor vehicle steering, suspension components (except spring), and brake systems	3353	Materials
Water and wastewater (Utilities†)	*Gasoline, heating fuels, other petroleum products*	Refined petroleum products	3154	Fuels
Water and wastewater (Utilities†)	*Natural gas distribution*	Natural gas distribution	3048	Fuels

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Water and wastewater (Utilities†)	*Power generation and supply*	Electricity generation	3039	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from fossil fuels)	3040	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from nuclear)	3041	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from solar)	3042	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from wind)	3043	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from geothermal)	3044	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from biomass)	3045	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from all other sources)	3046	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	Electricity transmission and distribution	3047	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from fed govt utilities)	3527	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from state govt utilities)	3530	Electricity
Water and wastewater (Utilities†)	*Power generation and supply*	* Not a unique commodity (electricity from local govt utilities)	3533	Electricity
Water and wastewater (Utilities†)	*Water, sewage and other systems*	Water, sewage and other systems	3049	Materials or Services
Wholesale	*Wholesale*	Wholesale - Motor vehicle and motor vehicle parts and supplies	3392	Materials
Wholesale	*Wholesale*	Wholesale - Professional and commercial equipment and supplies	3393	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Wholesale	*Wholesale*	Wholesale - Household appliances and electrical and electronic goods	3394	Materials
Wholesale	*Wholesale*	Wholesale - Machinery, equipment, and supplies	3395	Materials
Wholesale	*Wholesale*	Wholesale - Other durable goods merchant wholesalers	3396	Materials
Wholesale	*Wholesale*	Wholesale - Drugs and druggists' sundries	3397	Materials
Wholesale	*Wholesale*	Wholesale - Grocery and related product wholesalers	3398	Materials
Wholesale	*Wholesale*	Wholesale - Petroleum and petroleum products	3399	Fuels
Wholesale	*Wholesale*	Wholesale - Other nondurable goods merchant wholesalers	3400	Materials
Wholesale	*Wholesale*	Wholesale - Wholesale electronic markets and agents and brokers	3401	Materials
Other	*Oil and gas*	Oil and gas extraction	3020	Fuels
Other	*Oil and gas*	Oil and gas wells	3035	Services
Other	*Oil and gas*	Support activities for oil and gas operations	3036	Services
Other	*Oil and gas*	All other petroleum and coal products	3158	Materials
Other	*Oil and gas*	Petrochemicals	3159	Materials
Other	*Oil and gas*	Industrial gases	3160	Materials
Other	*Other mining*	Coal	3021	Materials

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other	*Other mining*	Copper, nickel, lead, and zinc mining	3022	Materials
Other	*Other mining*	Iron ore	3023	Materials
Other	*Other mining*	Gold ore	3024	Materials
Other	*Other mining*	Silver ore	3025	Materials
Other	*Other mining*	Uranium-radium-vanadium ore	3026	Materials
Other	*Other mining*	Other metal ore	3027	Materials
Other	*Other mining*	Stone	3028	Materials
Other	*Other mining*	Sand and gravel	3029	Materials
Other	*Other mining*	Other clay, ceramic, refractory minerals	3030	Materials
Other	*Other mining*	Potash, soda, and borate mineral	3031	Materials
Other	*Other mining*	Phosphate rock	3032	Materials
Other	*Other mining*	Other chemical and fertilizer mineral	3033	Materials
Other	*Other mining*	Other nonmetallic minerals	3034	Materials
Other	*Other mining*	Metal services	3037	Services
Other	*Other mining*	Other nonmetallic minerals services	3038	Services

Category	*Subcategory*	Commodity	**IMPLAN Commodity #**	**Meta-Category**
Other	*Other*	Wild game products, pelts, and furs	3018	Materials
Other	*Other*	Imputed rental services of owner-occupied dwellings	3449	Services
Other	*Other*	Leasing of nonfinancial intangible assets	3454	Services
Other	*Other*	Used and secondhand goods	3535	Materials
Other	*Other*	Scrap	3536	Materials
Other	*Other*	Rest of the world adjustment	3537	Materials or Services
Other	*Other*	Noncomparable imports	3538	Materials or Services
Other	*Other*	* Employment and payroll of state govt, education	3539	Services
Other	*Other*	* Employment and payroll of state govt, hospitals and health services	3540	Services
Other	*Other*	* Employment and payroll of state govt, other services	3541	Services
Other	*Other*	* Employment and payroll of local govt, education	3542	Services
Other	*Other*	* Employment and payroll of local govt, hospitals and health services	3543	Services
Other	*Other*	* Employment and payroll of local govt, other services	3544	Services
Other	*Other*	* Employment and payroll of federal govt, military	3545	Services
Other	*Other*	* Employment and payroll of federal govt, non-military	3546	Services

†While the category "Water and wastewater" includes other utilities (fuels and power), those emissions are fully transferred to the "use" phase of the model.