Appendix A and B: Oregon’s Greenhouse Gas Emissions though 2015:

An assessment of Oregon’s sector-based and consumption-based greenhouse gas emissions

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Department of Environmental Quality

Appendix A

Appendix A includes emission values and details on the methodology utilized to quantify emissions for the sector-based greenhouse gas inventory 2015 report. The inventory utilizes three primary sources of data including:

- EPA's State Inventory Tool (SIT)
- DEQ's Mandatory Greenhouse Gas Reported data
- Emissions estimates from DEQ's Materials Management section.

The tables in the first section of this document contain summary and detailed emissions data from the sector-based inventory. The second section provides a table describing the primary data source, by sub-category, used to calculate the emissions values. Additional information on sector-based emissions quantification methodology, mandatory reported emissions data and the full set of emissions data are available from DEQ's Greenhouse Gas Reporting Program: GHGReport@deq.state.or.us.

Preliminary emissions data

Emissions data for calendar year 2016 is considered preliminary. DEQ integrates mandatory greenhouse gas reported data for the industrial, natural gas, electricity, waste and fuel sectors with the most recent data outputs from the EPA State Inventory Tool to develop these preliminary emissions estimates. When an updated version of the State Inventory Tool becomes available, DEQ updates and finalizes preliminary emission estimates. DEQ is committed to updating the sector-based inventory on an annual basis.

1. Emissions data

The sector-based emissions inventory accounts for anthropogenic carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and high global warming potential gases (HGWP) including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3). The accounting methods utilize Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) global warming potentials (GWP) using a 100-year time horizon, as currently recommended by the United Nations Framework Convention on Climate Change (UNFCCC). All data is represented in million metric tons of carbon dioxide equivalent (million MTCO2e)[1].

Table A-1
Sector-based emissions summary (million MTCO2e)
Emissions from all sources are summed into the four key sectors.

Emissions by Key Sector	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Transportation	21	23	24	25	23	22	22	21	21	23	24
Residential & Commercial	16	20	23	22	24	22	21	22	21	22	20
Industrial	14	17	18	14	12	12	12	12	12	13	12
Agriculture	5	5	5	6	5	6	6	6	6	6	6
Total Emissions	**56**	**65**	**70**	**66**	**64**	**62**	**61**	**61**	**60**	**63**	**62**

[1] Totals for tables may not sum due to rounding.

Table A-2
Sector-based detail data 1990-2016 (million $MTCO_2e$)
Tables below include detailed emissions data for each sector listed in Table A-1.

Transportation		**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
CO_2	Motor Gasoline	11.61	12.40	13.06	13.20	12.11	11.66	11.64	11.11	11.28	12.49	13.20
CO_2	Distillate Fuel	4.53	4.57	5.52	6.36	6.73	6.64	6.72	6.34	6.51	6.50	6.87
CO_2	Jet Fuel, Kerosene	1.25	2.05	2.57	2.21	1.75	1.84	1.86	1.78	1.80	2.04	2.16
CO_2	Natural Gas	0.49	0.40	0.65	0.41	0.42	0.31	0.28	0.26	0.23	0.30	0.30
CO_2	Residual Fuel	1.72	1.49	0.59	0.88	0.73	0.43	0.38	0.27	0.05	0.12	0.13
CO_2	Lubricants	0.22	0.21	0.23	0.19	0.18	0.17	0.16	0.16	0.17	0.19	0.19
CO_2	Aviation Gasoline	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.04	0.04
CO_2	Liquefied Petroleum Gas	0.04	0.03	0.01	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05
CO_2	Light Rail Electricity	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO_2	Jet Fuel, Naphtha	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH_4	Passenger & Light Vehicles	0.10	0.08	0.07	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.03
CH_4	Non-Road Vehicles & Equipment	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CH_4	Heavy-Duty Vehicles	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH_4	Natural Gas Distribution (sector share)	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	Passenger & Light Vehicles	0.76	0.94	0.93	0.58	0.27	0.23	0.20	0.16	0.15	0.15	0.15
N_2O	Non-Road Vehicles & Equipment	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04
N_2O	Heavy-Duty Vehicles	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
HGWP	Refrigerants, A/C, Fire Protection	0.00	0.18	0.47	0.61	0.88	0.90	0.93	0.96	1.00	1.06	1.06
Transportation Sub-total		**20.97**	**22.54**	**24.29**	**24.68**	**23.27**	**22.38**	**22.36**	**21.24**	**21.38**	**23.03**	**24.25**

Residential & Commercial		**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
CO_2	Residential Electricity Use	5.93	7.55	8.43	7.99	8.32	7.46	7.00	7.41	7.06	7.24	6.25
CO_2	Commercial Electricity Use	4.66	6.27	7.28	6.70	6.83	6.05	5.87	6.17	6.08	6.35	5.49
CO_2	Residential Natural Gas Combustion	1.27	1.56	2.12	2.19	2.58	2.83	2.56	2.86	2.50	2.33	2.33
CO_2	Commercial Natural Gas Combustion	1.11	1.24	1.56	1.52	1.72	1.84	1.70	1.89	1.72	1.61	1.61
CO_2	Commercial Petroleum Combustion	0.79	0.56	0.54	0.34	0.42	0.33	0.24	0.20	0.22	0.56	0.60

CO_2	Residential Petroleum Combustion	0.76	0.65	0.62	0.46	0.35	0.34	0.29	0.29	0.27	0.26	0.27
CO_2	Waste Incineration	0.08	0.08	0.09	0.09	0.10	0.09	0.10	0.10	0.10	0.10	0.10
CO_2	Residential Coal Combustion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2	Commercial Coal Combustion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH_4	Municipal Solid Waste Landfills	1.15	1.02	1.21	1.38	1.57	1.57	1.34	1.37	1.40	1.45	1.45
CH_4	Natural Gas Distribution	0.20	0.26	0.24	0.26	0.26	0.36	0.31	0.30	0.29	0.24	0.24
CH_4	Municipal Wastewater	0.23	0.25	0.27	0.29	0.31	0.31	0.31	0.31	0.32	0.32	0.32
CH_4	Residential Combustion Byproducts	0.06	0.08	0.07	0.08	0.11	0.11	0.10	0.14	0.14	0.10	0.10
CH_4	Commercial Combustion Byproducts	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CH_4	Waste Incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH_4	Compost	0.00	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
N_2O	Fertilization of Landscaped Areas	0.06	0.06	0.04	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
N_2O	Residential Combustion Byproducts	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	Waste Incineration	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	Compost	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N_2O	Commercial Combustion Byproducts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	Municipal Wastewater	0.08	0.09	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12
HGWP	Refrigerants, Aerosols, Fire Protection	0.00	0.13	0.33	0.43	0.61	0.63	0.65	0.67	0.70	0.74	0.74
Residential & Commercial Sub-total		**16.45**	**19.88**	**22.99**	**22.02**	**23.51**	**22.25**	**20.82**	**22.04**	**21.17**	**21.67**	**19.87**

Industrial		**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
CO_2	Industrial Electricity Use	5.98	7.33	7.57	5.52	5.17	4.59	4.46	4.68	4.80	5.13	4.43
CO_2	Natural Gas Combustion	2.60	3.74	4.07	3.75	3.45	3.38	3.33	3.47	3.36	3.36	3.37
CO_2	Petroleum Combustion	2.62	2.50	2.60	1.43	1.32	1.64	1.57	1.38	1.41	1.62	1.71
CO_2	Cement Manufacture	0.22	0.21	0.44	0.44	0.46	0.46	0.45	0.49	0.69	0.71	0.57
CO_2	Coal Combustion	0.14	0.27	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2	Ammonia Production	0.07	0.07	0.07	0.06	0.11	0.13	0.11	0.13	0.13	0.10	0.11
CO_2	Urea Consumption	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CO_2	Waste Incineration	0.07	0.10	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00

CO_2	Iron & Steel Production	0.70	0.70	0.75	0.34	0.03	0.03	0.03	0.04	0.03	0.04	0.03
CO_2	Soda Ash Production & Consumption	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
CO_2	Limestone and Dolomite Use	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.02	0.02	0.02
CO_2	Lime Manufacture	0.09	0.16	0.15	0.09	0.05	0.05	0.05	0.05	0.06	0.06	0.06
CO_2	Pulp & Paper including wastewater	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.14	0.14	0.14	0.13
CH_4	Natural Gas Distribution & Production	0.26	0.46	0.52	0.60	0.64	0.55	0.60	0.63	0.61	0.66	0.66
CH_4	Industrial Landfills	0.07	0.08	0.11	0.13	0.16	0.17	0.17	0.18	0.18	0.18	0.18
CH_4	Combustion Byproducts	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02
CH_4	Food Processing Wastewater	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CH_4	Waste Incineration	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
N_2O	Combustion Byproducts	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.04
N_2O	Waste Incineration	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	Nitric Acid Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HGWP	Semiconductor Manufacturing	0.36	0.62	0.96	1.06	0.36	0.55	0.59	0.45	0.61	0.54	0.57
HGWP	Refrigerant, Foam, Solvent, Aerosol Use	0.00	0.06	0.14	0.18	0.15	0.10	0.13	0.11	0.11	0.13	0.12
HGWP	Aluminum Production	0.31	0.26	0.27	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Sub-total		**13.81**	**16.87**	**17.97**	**14.06**	**12.22**	**11.98**	**11.83**	**11.90**	**12.28**	**12.83**	**12.10**

Agriculture		**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
CO_2	Urea Fertilization	0.06	0.07	0.05	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13
CO_2	Liming of Agricultural Soils	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.05	0.05	0.06	0.06
CH_4	Enteric Fermentation	2.58	2.94	2.82	2.97	2.68	2.80	2.82	2.72	2.68	2.71	2.71
CH_4	Manure Management	0.30	0.32	0.35	0.49	0.50	0.54	0.57	0.57	0.59	0.59	0.59
CH_4	Agricultural Residue Burning	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00
N_2O	Agricultural Soil Management	1.80	1.94	1.49	1.91	1.84	2.00	2.00	1.95	2.01	2.01	2.01
N_2O	Manure Management	0.14	0.15	0.16	0.16	0.14	0.14	0.15	0.14	0.15	0.15	0.15
N_2O	Agricultural Residue Burning	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture Sub-total		**4.91**	**5.46**	**4.92**	**5.70**	**5.32**	**5.67**	**5.71**	**5.57**	**5.62**	**5.65**	**5.65**

Table A-3
Greenhouse gas emissions by gas

Total greenhouse gas emissions by gas including carbon dioxide (CO2), methane (CH4), nitrous oxide (N20), and high global warming potential gases (HGWP) including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Carbon dioxide	47.40	54.56	59.31	54.70	53.32	50.79	49.32	49.56	48.97	51.61	50.26
Methane	5.08	5.61	5.81	6.39	6.40	6.58	6.39	6.37	6.38	6.42	6.43
Nitrous oxide	2.97	3.34	2.90	3.00	2.61	2.73	2.72	2.63	2.69	2.69	2.69
High global warming potential	0.67	1.24	2.17	2.37	1.99	2.18	2.30	2.19	2.42	2.46	2.49
Total	**56.13**	**64.75**	**70.18**	**66.46**	**64.32**	**62.28**	**60.73**	**60.75**	**60.45**	**63.18**	**61.87**

Table A-4
Industrial process emissions by type (million MTCO2e)

Certain industrial processes emit greenhouse gases. This table includes non-energy related emissions from industrial activities. Starting with the 2010 emissions year industrial process emissions data is provided by DEQ’s Greenhouse Gas Reporting program.

Data Source	EPA SIT data estimates				DEQ mandatory reported data						
Year	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Aluminum Production	0.313	0.256	0.272	0.087	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ammonia Production	0.069	0.071	0.067	0.056	0.113	0.130	0.115	0.129	0.130	0.101	0.110
Cement Manufacture	0.216	0.207	0.445	0.443	0.455	0.461	0.452	0.490	0.694	0.713	0.571
Food Processing Wastewater	0.012	0.012	0.009	0.008	0.008	0.009	0.009	0.009	0.009	0.009	0.009
Iron & Steel Production	0.704	0.704	0.750	0.340	0.030	0.031	0.030	0.035	0.033	0.038	0.027
Lime Manufacture	0.085	0.157	0.145	0.095	0.051	0.052	0.052	0.054	0.055	0.055	0.055
Limestone and Dolomite Use	0.009	0.011	0.008	0.009	0.000	0.000	0.014	0.015	0.018	0.018	0.018
Nitric Acid Production	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Pulp & Paper	0.186	0.186	0.186	0.186	0.186	0.192	0.180	0.138	0.139	0.140	0.133
Semiconductor Manufacturing	0.357	0.619	0.957	1.064	0.356	0.548	0.588	0.449	0.608	0.540	0.571
Soda Ash Production & Consumption	0.031	0.032	0.032	0.032	0.027	0.026	0.026	0.026	0.027	0.026	0.026
Urea Consumption	0.008	0.009	0.007	0.015	0.016	0.017	0.016	0.017	0.017	0.017	0.017

Table A-5
Gross production emissions

For national data and US DOE state-level reporting, the federal government uses emissions attributable to in-state power generation (production based). The sector-based inventory uses power consumption and includes emissions produced outside of the state (emissions from electricity use). For purposes of comparison, emissions data using the production based method are below:

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Sector-based inventory total	56	65	70	66	64	62	61	61	60	63	62
Add in-state electric power generation	2	3	8	8	10	7	7	9	8	9	8
Remove electricity consumption total	(17)	(21)	(23)	(20)	(20)	(18)	(17)	(18)	(18)	(19)	(16)
Gross emissions, Production Basis	**42**	**47**	**54**	**54**	**54**	**51**	**51**	**52**	**51**	**53**	**54**

2. Data sources for the sector-based inventory

The sector-based inventory data are primarily derived from two sources: Data reported to DEQ's mandatory greenhouse gas reporting program and model outputs from the EPA's State Inventory Tool (SIT). The SIT is the primary source of data for the sector-based inventory from 1990 through 2009. Starting in 2010 DEQ's mandatory reporting program data is the source for approximately 80% of the inventory data. Table A-6 lists the source of data utilized for each emissions category listed in the sector-based inventory starting in 2010. Within each sector, sources are divided by type of greenhouse gas (CO_2, CH_4, N_2O and HGWP gases). DEQ's materials management program provides emissions data for small landfills, waste incineration and compost portions of the inventory for all years.

Abbreviations:
MR = Oregon Department of Environmental Quality Greenhouse Gas Reporting Program (mandatory reporting)
SIT = US Environmental Protection Agency State Inventory Tool
EIA SEDS = Energy Information Administration State Energy Data System (from US Department of Energy)
HGWP = High Global Warming Potential gases (HFCs, PFCs, and SF6)

Table A-6.
Data sources for the sector-based inventory

Gas	Emissions Source Category	MP	SIT	Data Sources, Methodologies, and Assumptions
Transportation				
CO_2	Motor Gasoline	X		Applied EIA SEDS transportation sector proportion to derive share of Emissions from data reported by fuel importers.
	Distillate Fuel	X		Applied EIA SEDS transportation sector proportion to derive share of emissions from data reported by fuel importers.
	Jet Fuel, Kerosene	X		Applied EIA SEDS transportation sector proportion to derive share of emissions from data reported by fuel importers.
	Natural Gas	X		Applied EIA SEDS transportation sector proportion to derive share of emissions from data reported by natural gas suppliers
	Residual Fuel	X		Applied EIA SEDS transportation sector proportion to derive share of emissions from data reported by fuel importers.
	Lubricants		X	Derived from EIA SEDS
	Aviation Gasoline	X		Applied EIA SEDS transportation sector proportion to derive share of emissions from data reported by fuel importers.
	LPG		X	Derived from EIA SEDS
	Light Rail Electricity Use	X		Applied EIA SEDS sector proportion to the emissions reported to DEQ by utilities
	Jet Fuel, Naphtha		X	Derived from EIA SEDS
CH_4	Passenger & Light Vehicles		X	EPA modeling outputs
	Non-Road Vehicles & Equipment		X	EPA modeling outputs
	Heavy-Duty Vehicles		X	EPA modeling outputs
	Natural Gas Distribution (sector share)		X	Proportional sector share of total SIT natural gas distribution based on EIA SEDS sector proportion
N_2O	Passenger & Light Vehicles		X	EPA modeling outputs
	Non-Road Vehicles & Equipment		X	EPA modeling outputs
	Heavy-Duty Vehicles		X	EPA modeling outputs
HGWP	Refrigerants, A/C, Fire Protection Use		X	50% of total modeled HGWP gases (population-based from national total) assigned to sector based on consumption modeling for US national inventory

Residential & Commercial				
CO_2	Residential Electricity Use	**X**		Applied EIA SEDS residential sector proportion to derive share of emissions from data reported by utilities
	Commercial Electricity Use	**X**		Applied EIA SEDS commercial sector proportion to derive share of emissions from data reported by utilities
	Residential Natural Gas Combustion	**X**		Applied EIA SEDS residential sector proportion to derive share of emissions from data reported by natural gas suppliers
	Commercial Natural Gas Combustion	**X**		Applied EIA SEDS commercial sector proportion to derive share of emissions from data reported by natural gas suppliers
	Commercial Petroleum Combustion	**X**		Applied EIA SEDS commercial sector proportion to derive share of emissions from data reported by fuel importers.
	Residential Petroleum Combustion	**X**		Applied EIA SEDS residential sector proportion to derive share of emissions from data reported by fuel importers.
	Waste Incineration	neither		Data provided by DEQ Materials Management program
	Residential Coal Combustion		**X**	Derived from EIA SEDS
	Commercial Coal Combustion		**X**	Derived from EIA SEDS
CH_4	Municipal Solid Waste Landfills	**X**		Data reported by MSW landfills, supplemented with DEQ estimates for non-reporting landfills
	Natural Gas Distribution (sector share)		**X**	Proportional sector share of total SIT natural gas distribution based on EIA SEDS sector proportion
	Municipal Wastewater		**X**	Derived from population and US national inventory
	Residential Combustion Byproducts	**X**	**X**	Reported data for natural gas, SIT data for other fuels (fuel oil, propane, etc.)
	Commercial Combustion Byproducts	**X**	**X**	Reported data for natural gas, SIT data for other fuels (fuel oil, propane, etc.)
	Waste Incineration	neither		Data provided by DEQ Materials Management program
N_2O	Fertilization of Landscaped Areas		**X**	EPA modeling outputs (see national inventory)
	Residential Combustion Byproducts	**X**	**X**	Reported data for natural gas, SIT data for other fuels (fuel oil, propane, etc.)
	Waste Incineration	neither		Data provided by DEQ Materials Management program
	Commercial Consumption Byproducts	**X**	**X**	Reported data for natural gas, SIT data for other fuels (fuel oil, propane, etc.)
	Municipal Wastewater		**X**	Derived from population and US national inventory
HGWP	Refrigerants, Aerosols, Fire Protection Use		**X**	35% of total modeled HGWP gases (population-based from national total) assigned to sector based on consumption modeling for US national inventory

Industrial				
CO_2	Industrial Electricity Use	**X**		Applied EIA SEDS industrial sector proportion to derive share of emissions from data reported by utilities
	Natural Gas Combustion	**X**		Applied EIA SEDS industrial sector proportion to derive share of emissions from data reported by natural gas suppliers
	Petroleum Combustion	**X**		Applied EIA SEDS industrial sector proportion to derive share of emissions from data reported by fuel importers.
	Cement Manufacture	**X**		Reported data
	Coal Combustion		**X**	Derived from EIA SEDS
	Ammonia Production & Urea Consumption	**X**		Reported data
	Waste Incineration	neither		Data provided by DEQ Materials Management program
	Iron & Steel Production	**X**		Reported data
	Soda Ash Production & Consumption	**X**		Reported data
	Limestone and Dolomite Use	**X**		Reported data
	Lime Manufacture	**X**		No reported emissions
CH_4	Pulp & Paper Wastewater	**X**		Reported data
	Natural Gas Distribution & Production		**X**	Proportional sector share of total SIT natural gas distribution based on EIA SEDS sector proportion, plus additional emissions associated with production
	Industrial Landfills	neither		Data provided by DEQ Materials Management program
	Combustion Byproducts	**X**	**X**	Reported data for natural gas, SIT data for other fuels (fuel oil, propane, etc.)
	Food Processing Wastewater		**X**	Derived from estimates of processed foods in the Oregon Agripedia (ODA statistics book)
N_2O	Combustion Byproducts	**X**	**X**	Reported data for natural gas, SIT data for other fuels (fuel oil, propane, etc.)
	Waste Incineration	neither		Data provided by DEQ Materials Management program
	Nitric Acid Production	**X**		Reported data
HGWP	Semiconductor Manufacturing	**X**		Reported data
	Refrigerant, Foam, Solvent, Aerosol Use	**X**		Reported data (note: approach taken in industrial sector for HGWP gases is different from in other sectors, but accuracy of data justifies differing treatment. Some emission sources likely missing.)
	Aluminum Production	**X**		No reported emissions, no known production in OR

Agriculture				
CO_2	Urea Fertilization		X	Derived from Oregon Agripedia (ODA statistics book)
	Liming of Agricultural Soils		**X**	Derived from Oregon Agripedia (ODA statistics book)
CH_4	Enteric Fermentation		**X**	EPA modeling outputs (see national inventory)
	Manure Management		**X**	EPA modeling outputs (see national inventory)
	Agricultural Residue Burning		**X**	EPA modeling outputs (see national inventory)
N_2O	Agricultural Soil Management		**X**	Derived from Oregon Agripedia (ODA statistics book)
	Manure Management		**X**	EPA modeling outputs (see national inventory)
	Agricultural Residue Burning		**X**	EPA modeling outputs (see national inventory)

In-State Electric Power Generation				
CO_2	OR Power Plant Natural Gas Combustion	**X**		Reported data
	OR Power Plant Coal Combustion	**X**		Reported data
	OR Power Plant Petroleum Combustion	**X**		Reported data
CH_4	OR Power Plant Combustion Byproducts	**X**		Reported data
N_2O	OR Power Plant Combustion Byproducts	**X**		Reported data
HGWP	Transmission and Distribution Systems		**X**	EPA modeling outputs (see national inventory)

Appendix B

This appendix provides additional details regarding Oregon's consumption-based greenhouse gas emissions and inventory. It is organized into nine sections, as follows:

1. Overview of consumption-based accounting.
2. Classification of emissions and definitions.
3. 2005 - 2015 data tables and results: consumption-based emissions; emissions intensities; changes over time.
4. Description of the 2015 consumption-based emissions inventory data sources and methodology.
5. Summary of major changes in methodology and data sources from previous years; summary of updates to Oregon's 2005 and 2010 consumption-based emissions inventory.
6. An overview of the initial derivation of total 1990 consumption-based emissions.
7. Brief overview of possible future inventory updates.
8. List of 2015 commodities, grouped by category and sub-category, with cross-reference to meta-categories.
9. References.

While this appendix is expected to satisfy most information needs regarding Oregon's consumption-based emissions inventory, additional information is available. Custom modeling and analysis may also be available, as resources allow. Questions can be directed to David Allaway, Oregon DEQ: allaway.david@deq.state.or.us.

1. Overview of Consumption-Based Emissions Accounting

Oregon's consumption-based emissions inventory (CBEI) was originally developed by Stockholm Environment Institute's (SEI) US Center under contract to the Oregon Department of Environmental Quality (DEQ). SEI produced a 2005 consumption-based inventory for Oregon, which was published in 2011. At the time, it was the first such inventory at the sub-national scale in the United States. DEQ updated the consumption-based inventory for calendar year 2010, publishing results in 2013. While rough estimates of consumption-based emissions were produced for 2012 and 2014, this report represents the third full and robust estimate, this time for calendar year 2015.

Consumption-based emissions for Oregon are the global emissions of greenhouse gases associated with satisfying 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 the emissions physically occur 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 compliments other inventory perspectives. For example, while the sector-based inventory described in Chapter 2 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 also be used to help prioritize consumer actions, to communicate to consumers how they contribute to emissions, and to help businesses better understand the average carbon footprints of different types of products.

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 in the course of satisfying 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. The consumption-based emissions inventory relies on an international trade model for foreign emissions, produced by the Center for International Climate Research (CICERO) in Norway, and that model uses IPCC Second Assessment Report global warming potentials. These foreign emissions account for approximately 22 percent of Oregon's consumption-based emissions, and are dominated by carbon dioxide, which has a constant global warming potential (1 kg CO2 = 1 kg CO2e) across all assessment reports. The inconsistency for foreign gases other than CO2 is expected to add a very small degree of inaccuracy to Oregon's results.

[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.

2. Classification of Emissions

The model used to construct the consumption-based inventory produces complex results. Certain variables, some of which can be aggregated or disaggregated for varying amounts of detail, allow the emissions from consumption to be shown in different ways. Before presenting the results, it is important to describe the classification systems that afford this flexibility. 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: 536 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 (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 536 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 2015, 68 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 (up from 2 percent in 2005), while local and state government activities account for 14 percent (up from 12 percent in 2005). 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 accounts for 15 percent of Oregon's final demand in dollars, down from 18 percent in 2005. 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:

[3] Consumption is sometimes 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.

Commodities: Data are calculated and reported in 536 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 other products, both additional intermediate products and commodities for final consumption.

Sub-categories: The 536 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 consumers, 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 purchased by the service provider (e.g., smocks, shampoo, scissors, brooms, electricity, water, 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 intermediate producer (the makers 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] 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"

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[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.

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 be clear, 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 primarily from 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, heating fuel causes emissions when burned in the consumer's furnace, and gasoline causes emissions when burned in the consumer's car engine. 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 for fuels 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 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.

Location of emission:

Oregon in-state: 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.

[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.

3. Oregon 2005 - 2015 Consumption-Based Greenhouse Gas Emissions (Data Tables and Supplemental Results)

3.1 2015 Consumption-Based Emissions

Table B-1 shows Oregon's 2015 consumption-based greenhouse gas emissions organized by category and life-cycle stage, using the condensed (pre-purchase, use, post-consumer disposal) categorization system introduced in Section 2, above.

Table B-1.
Oregon 2015 consumption-based GHG emissions, by category and life-cycle stage (Million MTCO2e)

Category	Pre-purchase	Use	Post-consumer disposal	Total	% of Total
Vehicles and parts	2.5	15.3	<0.1	**17.8**	**20%**
Food and beverages	11.6	*	0.2	**11.8**	**13%**
Appliances	0.3	10.7	<0.1	**11.0**	**12%**
Services	10.4	*	<0.1	**10.4**	**12%**
Construction	6.7	*	<0.1	**6.7**	**8%**
Healthcare	6.0	*	<0.1	**6.1**	**7%**
Other manufactured goods	4.6	*	<0.1	**4.6**	**5%**
Transportation services	4.4	*	<0.1	**4.4**	**5%**
Electronics	1.5	1.9	<0.1	**3.4**	**4%**
Retailers	3.3	*	0.0	**3.3**	**4%**
Furnishings and supplies	2.9	*	0.2	**3.1**	**3%**
Lighting and fixtures	0.1	1.5	<0.1	**1.6**	**2%**
Clothing	1.1	*	<0.1	**1.1**	**1%**
Wholesale	1.1	*	0.0	**1.1**	**1%**
Water and wastewater	0.5	*	<0.1	**0.5**	**1%**
Other	1.9	*	<0.1	**1.9**	**2%**
Total	58.8	29.3	0.5	**88.7**	**100%**

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

Additional detail is provided in Table B-2, which reports consumption-based emissions by category and sub-category, and using all five phases of life cycle phases introduced in Section 2 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 B-2.
Oregon 2015 consumption-based GHG emissions, by category, sub-category and life-cycle stage (Thousand MTCO2e)

	Production	Pre-purchase transportation	Wholesale/ retail	Use	Post-consumer disposal	Total
Oregon total emissions	**50,243**	**7,169**	**1,371**	**29,337**	**536**	**88,656**

		Production	Pre-purchase transportation	Wholesale/ retail	Use	Post-consumer disposal	Total
Appliances		**300**	**13**	**1**	**10,656**	**2**	**10,972**
	Heating and cooling appliances	47	3	0	7,027		
	Ranges and microwaves	58	3	0	693		
	Refrigerators and freezers	61	3	0	1,396		
	Washers and dryers	47	3	0	816		
	Other appliances	88	1	0	724		
Clothing		**1,127**	**6**	**0**	**0**	**15**	**1,149**
Construction		**6,091**	**539**	**43**	**0**	**30**	**6,703**
	Concrete, cement, lime and gypsum	6	0	0	0		
	Non-residential construction and remodeling	3,558	312	18	0		
	Residential construction and remodeling	2,527	226	25	0		
Electronics		**1,412**	**53**	**3**	**1,882**	**3**	**3,354**
	Computer service	412	28	1	0		
	Computers and peripherals	349	21	3	700		
	Other electronics	651	4	0	1,182		
Food and Beverages		**10,730**	**821**	**29**	**0**	**181**	**11,761**
	Beverages	911	92	4	0		
	Condiments, oils and sweeteners	265	22	1	0		
	Dairy	1,257	84	3	0		
	Fruit and vegetables	721	39	2	0		
	Grains, baked goods, cereals, nuts	1,246	120	5	0		
	Poultry and eggs	376	63	2	0		
	Other meat (beef, pork, etc.)	2,167	133	2	0		
	Seafood	69	6	0	0		
	Pet food	409	38	1	0		
	Other animal products	81	1	0	0		
	Other frozen food	207	20	1	0		
	Restaurants	2,718	177	8	0		
	Other food and agriculture	303	26	1	0		
Furnishings and Supplies		**2,736**	**123**	**6**	**0**	**201**	**3,067**
	Furnishings	795	32	2	0		
	Household supplies	941	44	2	0		
	Lawn and garden	234	9	0	0		

		Production	Pre-purchase transportation	Wholesale/ retail	Use	Post-consumer disposal	Total
	Media	397	14	0	0		
	Office supplies	369	25	1	0		
Healthcare		**5,709**	**317**	**21**	**0**	**9**	**6,057**
	Healthcare services	4,069	257	16	0		
	Medicines	1,641	60	6	0		
Lighting and fixtures		**50**	**1**	**0**	**1,517**	**0**	**1,569**
Other manufactured goods		**4,301**	**247**	**13**	**0**	**15**	**4,577**
	Forestries, mills, paper	42	3	0	0		
	Foundries, metal processing	21	1	0	0		
	Heavy transportation equipment	561	44	3	0		
	Machinery manufacturing	1,743	98	6	0		
	Missiles, weapons	49	3	0	0		
	Mobile homes	23	3	0	0		
	Other manufactures	1,862	94	5	0		
Retailers		**2,196**	**254**	**893**	**0**	**0**	**3,343**
Services		**9,764**	**586**	**21**	**0**	**28**	**10,399**
	Banks and financial services	618	67	1	0		
	Building services	67	8	0	0		
	Car rental, repair and wash	324	25	3	0		
	Education and day care	1,301	83	2	0		
	Entertainment and media	1,312	86	4	0		
	Hotels and motels	458	16	1	0		
	Legal, real estate, insurance	2,478	68	2	0		
	Personal services	539	35	2	0		
	Other services	2,668	198	7	0		
Transportation Services		**625**	**3,817**	**4**	**0**	**1**	**4,446**
Vehicles and Parts		**2,320**	**149**	**10**	**15,282**	**6**	**17,767**
	Vehicles	2,087	137	10	15,282		
	Vehicle parts	233	12	1	0		
Water and Wastewater		**473**	**3**	**0**	**0**	**0**	**476**
Wholesale		**679**	**86**	**313**	**0**	**0**	**1,078**
Other		**1,729**	**153**	**11**	**0**	**44**	**1,938**
	Oil and gas	197	9	0	0		
	Other mining	35	1	0	0		
	Other	1,497	143	11	0		

Totals may not add exactly due to rounding.

In Table B-2, “retailers” and “wholesale” are shown both as categories (rows) and as a life-cycle stage (column). In this table, emissions in the wholesale/retail life cycle stage are direct emissions only (e.g., emissions from on-site natural gas combustion). “Production” emissions for the “retailer” and “wholesale” categories are emissions upstream of the retail and wholesale establishments, including 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.

For other categories in Table B-2, the emissions shown as “pre-purchase transportation” represent each category’s use of transportation services (e.g., airlines) for employee travel as well as supply chain transport of goods. Wholesale/retail emissions are direct emissions (only) at wholesalers and retailers providing intermediate goods, such as the wholesaling of goods used in construction.

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

Tables B-1 and B-2 demonstrate several important issues. One category – vehicles and parts – represents fully 20 percent of all of Oregon’s consumption-based emissions. Nearly two-thirds of all emissions are associated with just the five highest-emitting categories: vehicles, food and beverages, appliances, services, and construction.

Sixty-six percent of all emissions occur upstream of the consumer as “pre-purchase” emissions. Emissions from the use of energy, refrigerants and lubricants (to operate vehicles, appliances, electronics and lighting) contribute another 33 percent. Just 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. Emissions from the use of vehicles also dominate that category, although emissions from production (auto manufacturing) and parts are not trivial. At 2.3 million MTCO2e, emissions from producing vehicles and parts are a bit larger than all emissions associated with the use of lighting and computers 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.

When thinking about the causes of greenhouse gases, transportation often looms large in the minds of the public. And the use of personal and government vehicles (in the "vehicles" category) is by far the largest single contributor to Oregon's consumption-based emissions (15.3 million MTCO2e). But for most materials, production contributes more to emissions than transportation. The category "transportation services" (4.4 million MTCO2e) includes all emissions from transporting finished products from the final producer to the retailer, but also includes all emissions from the transportation of consumers, such as airplane tickets. Only some portion of those emissions are associated with freight. Upstream transportation (transportation of supplies and components, prior to final production) contributes a bit more - setting aside transportation services, still only about 3.4 million MTCO2e, compared to the estimated 50.2 million MTCO2e associated with production (including non-transportation supply chains).

Table B-3 shows 2015 consumption-based emissions by category and type of consumer. 80 percent of Oregon’s consumption-based emissions stem from household consumption activities, with the remainder evenly divided between governments and business capital formation and investment. Households contributed about 68 percent of Oregon’s 2015 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 vehicles and parts (15.9 million MTCO2e), food and beverages (10.9 million MTCO2e) and appliances (9.0 million MTCO2e).
- Government's three largest categories of emissions are construction (2.1 million MTCO2e), appliances (1.9 million MTCO2e) and vehicles/parts (0.9 million MTCO2e).
- For business capital and investments, the three largest categories of emissions are "other manufactured goods" such as machinery (2.7 million MTCO2e), construction (1.9 million MTCO2e) and vehicles and parts (1.0 million MTCO2e).

Table B-3.
Oregon 2015 consumption-based GHG emissions, by category and type of consumer (Million MTCO2e)

Category	Households	Governments	Business Capital + Investment	**Total**
Vehicles and parts	15.9	0.9	1.0	**17.8**
Food and beverages	10.9	0.8	0.1	**11.8**
Appliances	9.0	1.9	0.1	**11.0**
Services	8.6	0.8	1.0	**10.4**
Construction	2.8	2.1	1.9	**6.7**
Healthcare	6.0	0.1	0.0	**6.1**
Other manufactured goods	1.1	0.8	2.7	**4.6**
Transportation services	3.6	0.4	0.5	**4.4**
Electronics	2.1	0.5	0.8	**3.4**
Retailers	3.3	0.0	0.1	**3.3**
Furnishings and supplies	2.4	0.3	0.4	**3.1**
Lighting and fixtures	1.3	0.3	0.0	**1.6**
Clothing	1.1	0.0	0.0	**1.1**
Wholesale	0.8	0.1	0.2	**1.1**
Water and wastewater	0.4	0.0	0.0	**0.5**
Other	1.7	0.1	0.1	**1.9**
Total	70.9 (80%)	8.9 (10%)	8.8 (10%)	**88.7**

Totals may not sum exactly due to rounding

Households are responsible for nearly all emissions in the categories of healthcare, retailers, clothing, and water/wastewater. Government dominates none of the categories, breaking over 25% of the total in only one category: construction (due to the construction and maintenance of schools, highways and bridges). Industry is responsible for more than half of all consumption-based emissions in the "other manufactured goods" category, which includes transportation equipment, manufacturing equipment and heavy machinery.

While households contribute most of Oregon's consumption-based emissions, not all households are the same. Table B-4 illustrates average per-household annual emissions (for 2015) for various Oregon households in different income ranges.

Table B-4.
2015 Average Per-Household Consumption-Based Greenhouse Gas Emissions (MTCO2e), by Income Strata (Thousand $ per Year)

	<$15k	$15-30k	$30-40k	$40-50k	$50-70k	$70-100k	$100-150k	$150-200k	$200k+
Vehicles and parts	4.15	6.08	8.23	9.43	10.70	12.57	15.04	16.11	17.44
Food and beverages	3.77	4.39	5.55	5.24	6.49	8.16	10.13	12.92	14.99
Appliances	3.46	4.55	5.05	5.22	5.71	6.28	7.31	8.32	9.71
Services	3.04	3.62	4.37	4.24	4.94	6.13	7.74	10.40	14.72
Construction	0.81	1.10	1.28	1.31	1.58	2.10	2.68	3.51	4.54
Healthcare	2.06	3.33	2.97	2.72	3.43	4.48	5.34	7.24	6.34
Other manufactured goods	0.32	0.42	0.49	0.55	0.58	0.80	1.03	1.30	1.92
Transportation services	0.83	1.16	1.37	1.57	1.95	2.63	3.64	5.30	8.74
Electronics	0.79	1.03	1.14	1.21	1.30	1.48	1.69	2.04	2.41
Retailers	0.92	1.26	1.54	1.65	1.89	2.45	3.07	4.07	5.55
Furnishings and supplies	0.58	0.81	0.98	1.22	1.31	1.75	2.34	3.26	5.83
Lighting and fixtures	0.52	0.67	0.74	0.76	0.81	0.89	0.98	1.07	1.23
Clothing	0.29	0.40	0.51	0.45	0.59	0.87	1.07	1.74	2.56
Wholesale	0.24	0.32	0.39	0.42	0.47	0.59	0.75	0.94	1.24
Water and wastewater	0.13	0.18	0.20	0.21	0.25	0.33	0.43	0.56	0.72
Other	0.30	0.45	0.57	0.68	0.92	1.36	1.97	2.59	3.99
Total	22.21	29.76	35.38	36.86	42.92	52.87	65.22	81.38	101.90

Totals may not sum exactly due to rounding.

Average per-household consumption-based greenhouse gas emissions (household emissions only, not including government or business capital/investment) for 2015 were 44.5 MTCO2e. While the figures in Table B-4 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 $20,000 car, but not necessarily five times as much.

Table B-5 shows that many 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 over one-third (34 percent) of Oregon's consumption-based emissions are estimated to physically originate within Oregon's borders. Forty-four percent are estimated to originate elsewhere in the U.S., while approximately 22 percent occur in other nations.

Table B-5.
Oregon 2015 consumption-based GHG emissions, by category and location of emissions (Million MTCO2e)

Category	In Oregon	Other US	Foreign
Vehicles and parts	12.2	2.6	2.9
Food and beverages	1.7	7.7	2.4
Appliances	5.1	5.4	0.4
Services	2.3	5.8	2.3
Construction	2.3	2.6	1.8
Healthcare	1.1	3.2	1.7
Other manufactured goods	0.2	2.0	2.4
Transportation services	2.2	1.3	0.9
Electronics	0.4	1.9	1.0
Retailers	0.9	1.9	0.6
Furnishings and supplies	0.4	1.2	1.5
Lighting and fixtures	0.2	1.3	0.1
Clothing	0.0	0.0	1.1
Wholesale	0.3	0.6	0.2
Water and wastewater	0.4	0.0	0.1
Other	0.5	1.0	0.5
Total	**30.3 (34%)**	**38.6 (44%)**	**19.8 (22%)**

Totals may not sum 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 two categories where more than half of emissions occur in Oregon are vehicles and parts (due to vehicle use) and transportation services.

3.2 Oregon 2015 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 CO2e) 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 that 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 demonstrate the relative magnitude of different hypothetical rebound scenarios.

Table B-6 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 include the emissions associated with the use of disposal of commodities.

Table B-6.
Pre-purchase (3-phase) greenhouse gas emissions intensities for Oregon consumption, 2015, by category.

Category	Pre-purchase emissions (million MTCO2e)	Final demand (in millions 2015$)	Emissions intensities (kg CO2e/$)
Appliances	0.3	614	0.51
Clothing	1.1	1,460	0.78
Construction	6.7	15,759	0.42
Electronics	1.5	6,502	0.23
Food and beverages	11.6	17,367	0.67
Furnishings and supplies	2.9	6,829	0.42
Healthcare	6.0	31,256	0.19
Lighting and fixtures	0.1	83	0.62
Other manufactured goods	4.6	10,098	0.45
Retail sales	3.3	16,122	0.21
Services	10.4	57,249	0.18
Transportation services	4.4	4,023	1.10
Vehicles and parts	2.5	6,334	0.39
Water and wastewater	0.5	614	0.78
Wholesale	1.1	7,709	0.14
Other	1.9	42,874	0.04
Total	**58.7**	**224,894**	**0.26**

Totals may not sum exactly due to rounding.

Average pre-purchase emissions intensities are 0.26 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 1.1 kg CO2e. Clothing, food, and lighting fixtures 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.

Table B-7 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 B-7 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 (0.16 kg CO2e/$, on average). Direct purchases of fuels (6.07 kg CO2e/$) and electricity (4.37 kg CO2e/$) both have emissions intensities much higher than the total (0.39 kg CO2e/$). The consumption of materials contributes the most to emissions (36.5 MTCO2e) and has average emissions intensities close to the average (0.45 kg CO2e/$).

Table B-7.
Whole life cycle (5-phase) greenhouse gas emissions intensities for Oregon consumption, 2015, by meta-category.

Meta-Category	Five-phase emissions (million MTCO2e)	Final demand (in millions 2015$)	Emissions intensities (kg CO2e/$)
Materials	36.5	80,384	0.45
Services	23.1	144,361	0.16
Fuels (direct purchases)	19.6	3,232	6.07
Electricity (direct purchases)	9.5	2,172	4.37
Total	**88.7**	**230,148**	**0.39**

Totals may not sum exactly due to rounding.

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 2015 emissions intensity of 1.27 kg CO2e per dollar (much higher than the average of 0.16 for services), and meats (other than poultry and seafood) have average 2015 emissions intensity of 1.92 kg CO2e per dollar (much higher than the average of 0.46 for all materials).

3.3 2005, 2010 and 2015 Consumption-Based Emissions Compared

Tables B-8 through B-10 illustrate Oregon's consumption-based greenhouse gas emissions over the ten-year period 2005 - 2015, organized by category (Table B-8), meta-category (Table B-9) and life cycle stage (Table B-10).

Table B-8.

Oregon consumption-based GHG emissions, by category 2005 - 2015 (Million MTCO2e)

Category	**2005**	**2010**	**2015**
Vehicles and parts	18.5	16.1	17.8
Food and beverages	9.7	11.3	11.8
Appliances	11.7	12.9	11.0
Services	5.6	7.0	10.4
Construction	5.3	5.6	6.7
Healthcare	4.2	5.4	6.1
Other manufactured goods	5.4	4.6	4.6
Transportation services	3.5	4.0	4.4
Electronics	3.7	2.9	3.4
Retailers	2.2	2.3	3.3
Furnishings and supplies	3.4	3.1	3.1
Lighting and fixtures	2.9	1.7	1.6
Clothing	1.9	1.5	1.1
Wholesale	0.8	0.6	1.1
Water and wastewater	0.3	0.5	0.5
Other	0.4	0.6	1.9
Total	**79.6**	**80.2**	**88.7**

Totals may not sum exactly due to rounding.

Table B-9.

Oregon consumption-based GHG emissions, by meta-categories 2005 - 2015 (Million MTCO2e)

Meta-category	**2005**	**2010**	**2015**
Materials	34.5 (43%)	33.8 (42%)	36.5 (41%)
Services	13.5 (17%)	17.2 (21%)	23.1 (26%)
Fuels (direct purchases)	19.5 (24%)	19.3 (24%)	19.6 (22%)
Electricity (direct purchases)	12.0 (15%)	9.8 (12%)	9.5 (11%)
Total	**79.6**	**80.2**	**88.7**

Totals may not sum exactly due to rounding.

14% of Oregon's 2015 consumption-based emissions occur in categories that could be considered both materials and services. These are primarily construction and restaurants, as well as rail and air transport, and a few much smaller commodities. These emissions are divided evenly between the "materials" and "services" meta-categories in Table B-9.

Table B-10.

Oregon consumption-based GHG emissions, by life-cycle stage 2005 - 2015 (Million MTCO2e)

Life-cycle stage	**2005**	**2010**	**2015**
Producer	40.8	42.5	49.9
Pre-purchase transportation + transportation services to consumers	3.5	4.0	4.4
Wholesale + retail	2.9	2.9	4.4
Use	31.5	30.3	29.3
Post-consumer disposal	0.7	0.4	0.5
Total	**79.6**	**80.2**	**88.7**

Totals may not sum exactly due to rounding.

As noted previously, Table B-10 reports wholesale and retail emissions as life-cycle (direct + indirect) emissions from all wholesale and retail activities serving consumers directly, not the wholesale and retail activities supporting pre-production activities (such as retail sales to law offices). Similarly, "pre-purchase transportation" is limited to the transport of finished goods and transportation services to consumers; it does not include supply-chain transportation of people or intermediate goods used in production.[8]

Looking at the broad patterns of change in Tables B-8 through B-10 a few general trends are observed:

First, consumption-based emissions rose very slightly between 2005 and 2010, despite the fact that Oregon in 2010 was just coming out of the Great Recession. Emissions in 2015 were significantly higher than either 2005 or 2010.

Food and beverages have overtaken appliances as the second most significant category of consumption-based emissions. Emissions associated with services have also risen significantly (both as a category, in Table B-8, and a meta-category, in Table B-9).

[8] Estimates of the direct emissions from wholesalers, retailers and transportation services supporting supply chain activities are included in Table B-2.

Between 2005 and 2015, emissions from direct purchases of electricity by Oregon consumers have fallen, both in absolute terms (12.0 million MTCO2e in 2005 to 9.5 million MTCO2e in 2015) and as a percent of the total. Emissions from fuel purchases have remained steady in absolute terms (around 19.5 million MTCO2e) despite a growing population. Efforts during this time period to address emissions from electricity and fuels (such as electricity conservation, renewable power programs, fuel efficiency standards and land use changes to effect transportation patterns) are showing some benefits. Yet overall consumption-based emissions have continued to rise, due to increases in emissions in two areas that have received much less attention: services and materials.

Use-phase emissions, dominated by fuel and electricity use for vehicles, appliances, lighting and electronics fell steadily from 2005 levels. Again, this historically has been a primary area of focus for climate policy, and efforts there appear to be bearing some fruit (although not sufficient to achieve the state’s statutory emissions goals). Waste disposal emissions are also down from 2005 levels, reflecting a mix of more recycling, lightweighting of some materials (less material overall, such as newspapers and packaging), and improvements in landfill gas controls. Emissions from wholesale and retail stages have grown, perhaps reflecting changes brought about by the growth of e-commerce platforms. So have transportation services, which include the transport of finished goods from producers to retailers, as well as personal services such as airplane travel. But the life-cycle stage that has seen the strongest growth is the one that is both the largest and also the least visible to consumers: the production (including associated supply chain inputs) of materials and services, which added 9.1 million MTCO2e to Oregon's emissions between 2005 and 2015.

The following tables explores a few of the individual categories in more detail, beginning with Table B-11, which focuses on emissions from vehicles and parts.

Table B-11.
Oregon consumption-based GHG emissions from vehicles and vehicle parts (use and pre-purchase only), 2005 - 2015
(Million MTCO2e)

	2005	2010	2015
Use	15.8	14.8	15.3
. . . households	15.0	13.8	14.5
. . . governments	0.8	1.0	0.8
Pre-purchase	2.6	1.3	2.5
. . . households	1.8	0.9	1.4
. . . governments	0.1	0.1	0.1
. . . industry (capital)	0.8	0.3	1.0
Total	**18.5**	**16.1**	**17.8**

Totals may not sum exactly due to rounding.

Emissions from vehicles are dominated by two life-cycle phases: use (tailpipe and life-cycle emissions from fuels) and pre-purchase (auto and part manufacturing). The use of vehicles dominates, which is why it often makes good sense to replace inefficient cars with highly efficient vehicles: the added pulse of greenhouse gas emissions associated with manufacturing a new vehicle can be fairly quickly recouped through reduced fuel use. Regardless, emissions from overall as well as household vehicle use dipped in 2010 and then rebounded in 2015 (although not quite to 2005 levels, which is impressive considering population growth during the same time period). But emissions from the production of vehicles (and parts) showed a similar but much more pronounced pattern - falling 50% between 2005 and 2010 before rebounding very strongly. Spending on vehicles and parts was approximately $4.8 billion in 2005$, $2.9 billion in 2010$, and $6.4 billion in 2015$. More than one-half of the decline in emissions between 2005 and 2010, and two-thirds of the rebound between 2010 and 2015, was due to changes in vehicle purchases, as opposed to use.

Table B-12.
Oregon consumption-based GHG emissions from food and beverage purchases (pre-purchase only), 2005 - 2015
(Million MTCO2e)

	2005	**2010**	**2015**
Restaurants	2.2	2.3	2.9
Beef, pork	1.8	2.1	2.3
Grains, baked goods, cereals, nuts	0.9	1.3	1.4
Dairy	1.3	1.2	1.3
Beverages	0.9	1.0	1.0
Fruit and vegetables	0.8	0.8	0.8
Pet food	0.2	0.5	0.4
Poultry and eggs	0.5	0.7	0.4
All others (condiments, oils, sweeteners, seafood, other)	0.9	1.1	1.0
Total	**9.5**	**11.1**	**11.6**

Totals may not sum exactly due to rounding.

Table B-12 explores changes in consumption-based emissions for another significant driver of emissions: the purchase of food and beverages. Emissions have risen during the ten-year period studied, and most of the increase has been observed in three large sub-categories: restaurants, beef/pork, and grains/baked goods/cereals/nuts. Some increase has also been observed in the much smaller subcategory of pet food. Emissions from consumption of dairy, produce, poultry/eggs, and other foods are generally flat, despite a growing population.

The third largest category of household consumption-based emissions in 2015 were appliances, which include furnaces and air conditioners. Even more so than vehicles, emissions from appliances are dominated by their use, as shown in Table B-13.

Table B-13.
Oregon consumption-based GHG emissions from appliances (use and pre-purchase only), 2005 - 2015
(Million MTCO2e)

	2005	**2010**	**2015**
Use	11.4	12.6	10.7
. . . households	10.1	10.9	8.7
. . . governments	1.3	1.7	1.9
Use	11.4	12.6	10.7
. . . fuels	3.6	4.4	4.1
. . . electricity	7.7	8.2	6.1
. . . refrigerants	N/A	N/A	0.4
Pre-purchase	0.3	0.3	0.3
. . . households	0.3	0.3	0.2
. . . governments	<0.05	<0.05	<0.05
. . . businesses	<0.05	<0.05	0.1
Total	**11.7**	**12.9**	**11.0**

Totals may not sum exactly due to rounding.

Emissions from household use declined significantly between 2010 and 2015, while government emissions rose slightly. Some of this decline was due to differences in the electricity mix serving Oregon in 2010 vs. 2015. 2010 was a poor year for hydroelectric generation, resulting in a higher-than-usual reliance on fossil fuels.

In prior years, the broad category of services (which excludes healthcare and transportation services) was of moderate importance, but by 2015 emissions from this category had grown significantly. Table B-14 reports emissions by sub-category and a few select individual commodities.

Table B-14.
Oregon consumption-based GHG emissions from "services" category (pre-purchase only), 2005 - 2015 (Million MTCO2e)

	2005	**2010**	**2015**
Legal, real estate and insurance	1.4	0.9	2.5
. . . real estate	1.0	0.6	2.1
. . . insurance	0.3	0.2	0.3
. . . legal	0.1	0.1	0.1
Entertainment and media	0.8	0.8	1.4
. . . wired and wireless telecommunications, Internet service providers	0.3	0.3	0.8
. . . all other	0.5	0.5	0.6
Education and day care	0.6	1.7	1.4
Services from religious organizations	0.1	0.1	0.8
Scientific research and development	<0.05	0.1	0.7
Banks and financial services	0.7	1.0	0.7
Personal services	0.5	0.4	0.6
Hotels and motels	0.2	0.4	0.5
Car rental, repair and wash	0.4	0.2	0.4
All other services	1.0	1.4	1.4
Total	**5.6**	**7.0**	**10.4**

Totals may not sum exactly due to rounding.

A few subcategories and individual commodities were responsible for much of the increase in emissions. Real estate services contracted in 2010 and then grew rapidly by 2015 (4.9 billion $ in 2010$ vs. $7.2 billion $ in 2015$). Wired and wireless telecommunication services also had emissions more than double. These are pre-purchase emissions and so represent the emissions associated with providing services (such as cloud storage) as opposed to device use (household plug loads). Education and day care also saw significant growth in emissions, possibly due to low estimates of consumer expenditures in 2005. This may be an anomaly associated with the underlying economic model and would benefit from further research. Two other very specific commodities also showed very dramatic growth in both expenditures and emissions: religious organizations (2005 spending of $626 million vs. 2015 spending of $4.1 billion) and scientific research and development (largely from business investment).

As noted previously, "consumption" represents expenditures by three discrete populations: households, governments, and a subset of business expenditures (limited to capital, investment and net inventory formation).

This last type of consumption is included for consistency with standards for national economic accounting and because of the structure of the economic input-output model that underlies the pre-purchase portion of the consumption-based emissions inventory. Table B-15 illustrates the change in emissions by type of consumer over time.

Table B-15.
Oregon consumption-based GHG emissions, by type of consumer 2005 - 2015 (Million MTCO2e)

Type of consumer	**2005**	**2010**	**2015**
Households	65.4	66.0	70.9
Governments	5.5	6.8	8.9
Business Capital, Investment + Inventory	8.7	7.4	8.8
Total	**79.6**	**80.2**	**88.7**

Totals may not add exactly due to rounding.

Looking at the big picture of all consumption-based emissions, emissions have increased over the ten-year period evaluated here, even as emissions intensities have fallen. This is illustrated in Table B-16.

Table B-16.
Oregon population, per-capita and total consumption (final demand), 5-phase emissions intensities, and consumption-based greenhouse gas emissions, 2005 – 2015

	2005	**2010**	**2015**
Per-capita consumption (nominal dollars)	40,230	43,832	57,339
Per-capita consumption, 2015$ (real dollars)	48,824	47,644	57,339
Oregon population	3,626,938	3,837,300	4,013,845
Total consumption, 2015$ (million dollars)	177,081	182,823	230,148
5-phase emissions intensities (kg CO2e/2015$)	0.45	0.44	0.39
Consumption-based greenhouse gas emissions (MMTCO2e)	**79.6**	**80.2**	**88.7**

The first row of Table B-16 reports per-capita consumption as measured in the economic value of the US dollar for that year (nominal basis). The second row adjusts these values based on the US Consumer Price Index for all urban areas (CPI-U). After adjusting for inflation, per-capita consumption in 2010 (coming out of the nadir of the Great Recession) was indeed a bit lower than it was in 2005. Oregon's population grew steadily, resulting in a steady rise in total consumption (measured in real dollars). While overall 5-phase emissions intensities (again, evaluated in real 2015 dollars) fell, this decline was not enough to offset the rise in consumption, and so overall consumption-based emissions rose, most sharply between 2010 and 2015.

4. 2015 Consumption-Based Emissions Inventory Methodology

4.1 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 2015 models 536 different commodities). The accuracy of results, therefore, likely decreases as the focus becomes narrower. 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.

CBEI emissions are calculated in three steps:

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 536 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

[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.

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.

These 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. Those emissions, however, are reported as steel industry emissions in the "standard" model. 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 embedded in 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. For example, Oregon purchases of domestically produced cars may cause emissions from steel produced in Mexico or Korea, and imported for use in U.S. automobile production. 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 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 buttons, packaging, or fuel, these emissions are classified in the "standard" model as 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

[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.

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, 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’s “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 from lubricant use 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 the average Oregon consumer’s 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 waste landfilling and combustion; 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.

4.2 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. OR2015 CBEI Final Demand
2. OR2015 CBEI Emissions Factors
3. OR2015 CBEI GHG Coefficients
4. OR2015 CBEI Emissions
5. OR2015 CBEI Demand Modeler
6. OR2015 CBEI Use and Disposal
7. OR2015 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.

4.3 Oregon and US Emissions Factors

The model estimates direct (on-site) emissions for each of 538 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 2015 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.

4.3.1 US Emissions Factors

U.S. GHG emissions for 2015 are assigned to 536 U.S. industries as identified by the IMPLAN model. The U.S. GHG emissions are drawn directly from the U.S. 2015 GHG inventory (US EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 - 2015 (2017)). 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 536 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 (2015$) as reported by IMPLAN.

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 2015 GHG inventory includes 236.2 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 (39.3 million MT CO2e) are assigned exclusively to IMPLAN industry 205, 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 (1.3 million MT CO2e) are allocated to three IMPLAN industries (201 - 203) 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 including 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 2010 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, taken from the 2010 Oregon CBEI. Emissions are then scaled to 2015 based on the ratio of 2015:2010 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 2010 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 (600.5 MMTCO2 for 2015, adjusted from the 580 MMTCO2e for 2010) are then subtracted from 2015 industrial CO2 combustion emissions as estimated in EPA's US greenhouse gas inventory (805.5 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 (1900.3 MMTCO2e to IMPLAN industry 42 - electricity generation from fossil fuels, and 0.4 MMCO2e to IMPLAN industry 46 - electricity generation geothermal), consistent with electricity-related emissions profiles in the US EPA inventory.

US non-energy uses of fuels

Approximately 126 million MTCO2e of CO2 emissions occur 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 was (or 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 246.2 MMTCO2e. These emissions are allocated first into 15 different "principal building activities" (PBAs), plus a 16th ("vacant") in proportion to each PBA’s relative use of non-electrical energy, as estimated in the most recent (2012) 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 for each major NAICS code identifying the primary ("most likely") PBA and associated ("secondary") PBAs. For example, the primary PBA for NAICS 447 (gasoline stations) is “service” although it is also associated with “food sales”. Allocated emissions for each PBA were then sub-allocated to the individual IMPLAN sectors using a multi-attribute weighting process, as follows:

- If an IMPLAN industry (and its associated NAICS code) has only one PBA, then emissions from that PBA are allocated to that industry in proportion to its economic output (unadjusted) relative to the sum of economic outputs (unadjusted and adjusted) of all IMPLAN industries associated with that PBA.

- If an IMPLAN industry has more than one PBA, then emissions from its associated PBAs are allocated to that industry in proportion to *adjusted* economic output relative to the sum of economic outputs (unadjusted and adjusted) of all IMPLAN industries associated with that PBA. Economic outputs of these IMPLAN industries are adjusted as follows:
    - For the primary PBA, adjusted economic output = unadjusted economic output multiplied by (1/2 + 1/(2N)) where N is the number of PBAs associated with that IMPLAN industry. As N becomes larger, adjusted economic output for the primary PBA shrinks but never below 50 percent of unadjusted economic output. For example, if there are 3 PBAs (one primary and two others), then 2/3 (1/2 + 1/(2*3)) of unadjusted economic output is assigned to the primary PBA. (If N = 1, indicating no secondary PBAs, this function reduces to 1.)
    - For any secondary PBAs, adjusted economic output = (1 - adjusted primary output)/(N - 1). Continuing the example above with 3 PBAs, each secondary PBA would be assigned 1/6 of unadjusted economic output (1 - 2/3)/(3 - 1).
    - As such for any industry with N PBAs, the sum of adjusted economic outputs used across all PBAs equals unadjusted economic output.

This 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.

There is one exception to this algorithm, and that involves IMPLAN industry 414, " Scenic and sightseeing transportation and support activities for transportation", which covers multiple NAICS codes that have different primary PBAs. In this case, the two primary PBAs are each assigned half of the adjusted economic output calculated as if there was only one primary PBA, and the remainder of the economic output is allocated among the remaining (non-primary) PBAs in equal amounts.

Finally, emissions associated with "vacant" buildings are allocated among all commercial IMPLAN industries in proportion to their (unadjusted) economic output.

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 (CO2, CH4, N2O, and high impact gases), all transportation-related emissions in the US inventory are allocated in this module. This includes:

- 1,736 MMTCO2 of CO2 associated with transportation fuel combustion,
- an additional 111 MMTCO2 of CO2 associated with the combustion of "international bunker fuels" which are reported as an informational item in the U.S. Inventory,
- 2 MMTCO2 of CH4 emissions associated with mobile combustion,
- 16 MMTCO2 of N2O emissions associated with mobile combustion,
- 45 MMTCO2 of emissions from HFCs (used as refrigerants in the transport sector), and
- 10 MMTCO2 of CO2 emissions from the use of lubricants by the transport sector.

For all emissions other than CO2 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 3-12, 3-13, 3-14, and 2-13 of EPA's 2015 U.S. GHG Inventory. CO2 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 2014 (published 2017).

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 the Federal Highway Administration's (FHA) annual report of motor vehicle registrations, the most recent FHA National Household Travel Survey (2009), a special US Economic Census report (2002), US Bureau of Transportation Statistics (2014), US Maritime Administration (2011), and Federal Aviation Administration General Aviation Surveys (2015).

Out of this process, the total US transportation emissions of 1,920 MMTCO2e are allocated into three broad categories: households (890 MMTCO2e), government (55 MMTCO2e), and commercial (974 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 - 516 using economic allocation.
- Emissions from medium- and heavy-duty trucks are wholly assigned to IMPLAN industry 411 ("truck transport").
- Emissions from commercial use of buses are allocated between IMPLAN industries 412 ("transit and ground passenger transportation") and 414 ("scenic and sightseeing transportation and support activities for transportation") using economic allocation.
- Emissions from commercial use of rail are assigned wholly to IMPLAN industry 409, "rail transportation".
- Emissions from ships and non-recreational boats (commercial, not government) are assigned wholly to IMPLAN industry 410, "water transportation".
- Emissions from commercial aircraft are assigned fully to IMPLAN industry 408 ("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 474 "other educational services" (which includes flight schools), 19 "support activities for agriculture and forestry" (for agricultural application of pesticides), and 408 "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 - 516 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 413 ("pipeline transportation").
- Distillate fuel (diesel) and residual fuel oil classified as bunker fuels are assigned to IMPLAN industry 410 ("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 - 516 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 656 MMTCO2e of methane emissions (using a global warming potential for methane of 25). A few of these emissions are from residential sources or mobile combustion, which is assigned to the "US transportation" module. The remainder 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 471, "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 2015 inventory of emissions are used to allocate emissions. For example, methane emissions from petroleum systems are speciated by EPA as:

- 39.0 MMTCO2e from "production" (assigned to IMPLAN industry 20, "extraction of natural gas and crude petroleum"),
- 0.2 MMTCO2 from "crude oil transportation" (allocated to IMPLAN industries for rail, water, and pipeline transportation using economic allocation), and
- 0.6 MMTCO2e from "refining" (assigned to IMPLAN industry 156 "petroleum refineries").
-

US N2O

The US inventory includes 335 MMTCO2e of nitrous oxide emissions (using a global warming potential for nitrous oxide of 298). A few of these emissions are from residential sources or mobile combustion, which is assigned to the "US transportation" module. Agricultural soil management is by far the single largest contributor to these emissions, although the US inventory includes 11 other, smaller contributors.

Emissions are assigned to IMPLAN industries one a one-for-one basis where possible (e.g., emissions from "nitric acid production" are assigned entirely to IMPLAN Industry 169, "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).

In some instances, supplemental details contained in EPA's 2015 inventory of emissions are used to allocate emissions. For example, nitrous oxide emissions from agricultural soil management are speciated by EPA as:

- 185.7 MMTCO2e from "crop lands" - these are further allocated across IMPLAN industries 1 through 10 (crop farming industries) using economic allocation, and
- 65.6 MMTCO2 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 459 (veterinary services), IMPLAN industry 476 (offices of dentists) and IMPLAN industry 482 (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 185 MMTCO2e of high impact gases (using global warming potentials contained in the IPCC Fourth Assessment Report): primarily HFCs but also 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. 48.4 MMTCO2e are associated with residential uses (air conditioning) and are not allocated to specific industries; an additional 45.0 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 536 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 2015 economic output (in 2015 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 in Sections 4.5 and 4.6, below.

4.3.2 Oregon Emissions Factors

2015 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)
- CO2 industrial combustion
- CO2 commercial combustion
- CO2 non-combustion
- Transportation (all gases)
- CH4
- N2O
- 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 in Section 4.4, 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.) 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:

- 8.68 $MMTCO_2$ from Oregon power plant natural gas, coal and petroleum combustion, along with 0.03 $MMTCO_2e$ from power plant combustion byproducts (CH_4 and N_2O) are assigned to IMPLAN industry 42 "Electric power generation – fossil fuel".
- 0.05 $MMTCO_2e$ of high global warming potential gases resulting from in-state electricity transmission and distribution are assigned to IMPLAN industry 49 "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 CO_2

Emissions from the sector-based inventory for "industrial natural gas combustion" (3.36 MMTCO2) and "industrial petroleum combustion" (1.62 MMTCO2) are allocated across IMPLAN industries 1 – 19 (agriculture), 20 – 40 (mining and drilling), 50 – 51 (non-electric utilities), 52 – 64 (construction and maintenance) and 65 – 394 (manufacturing) using economic allocation (proportional to the economic output of each industry in Oregon).

A very small quantity of emissions (less than 0.01 MMTCO2) associated with industrial waste incineration is similarly allocated but only to industries associated with manufacturing.

Oregon commercial combustion CO2

Emissions from the sector-based inventory for "commercial natural gas combustion" (1.22 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 as an energy supply, as reported in the US Energy Information Administration's 2012 Commercial Energy Building Consumption Survey (revised 2016). A similar method is used to partition the smaller emissions for commercial petroleum (0.39 MMTCO2), although using the 2003 Commercial Energy Building Consumption Survey (published 2008), as the 2012 survey did not report petroleum use. The resulting private (non-government) emissions are then allocated across IMPLAN industries 395 – 407 (wholesale and retail trade) and 415 – 440 and 442 - 516 (all other non-transport related, private, non-household commercial sectors) 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 (0.07 MMTCO2) are assigned to IMPLAN industry 471, "waste management and remediation services". Residential open burning emissions are accounted for in the "Use and Disposal" section.

Oregon non-combustion CO2

Oregon's sector-based emissions inventory includes 1.30 million metric tons of CO2 from non-combustion sources, the largest of which (0.71 MMTCO2e) is cement production. Other sources include, as examples, ammonia production, iron and steel production, lime manufacturing, pulp and paper (including wastewater) 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 169, "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 (0.02 MMTCO2), this irregularity in accounting will not have a meaningful impact on results.

- Oregon’s sector-based inventory estimates 0.018 MMT of CO2 emissions from “limestone and dolomite use”. This corresponds with four separate line-items in the US CO2 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 0.026 MMT of CO2 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). Because the SIT model for 2015 was not available when this portion of the model was developed, DEQ used ratios from the 2014 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 2015 (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 direct aircraft fuel use are allocated between households, government, and commercial sectors in proportion to those sectors’ estimated emissions of carbon dioxide from aircraft fuels.

Oregon CH4

Approximately 6.4 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 are estimated using data from the US EIA’s Commercial Building Energy Consumption Survey.

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 471, "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 2014 State Inventory Tool is also used to allocate natural gas sector emissions between production (very small) and transmission/distribution.

Oregon N2O

Approximately 2.5 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 one a one-for-one basis where possible (e.g., emissions from "nitric acid production" are assigned entirely to IMPLAN Industry 169, "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 1.0 MMTCO2e of emissions from high impact gases from the Oregon sector-based inventory are brought forward and assigned to IMPLAN industries. This excludes approximately 1.1 MMTCO2e from transportation refrigerants and air conditioning (allocated in the transportation module, described above) and 0.5 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:

- 0.54 MMTCO2e associated with semiconductor manufacturing are assigned entirely to IMPLAN industry 309 "semiconductor and related device manufacturing".
- 0.29 MMTCO2e from commercial refrigeration uses are allocated across IMPLAN industries 395 – 407 (wholesale and retail trades) and 415 – 440 and 442 - 516 (all other non-transport related, private, non-household commercial sectors) using economic allocation.
- 0.13 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 536 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 2015 economic output (in 2015 US$) 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 in Sections 4.5 and 4.6, below.

4.4 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 536 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, in-flight magazines, pillow covers, 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 536 industries) required to produce one dollar of output in each of the 536 industries. They include 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 in Section 4.6, gross demand for these two locations of production are combined with the appropriate emissions intensities (from Section 4.3) 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.

4.4.1 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 536 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 536 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 536 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).

4.4.2 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 (see Sections 4.5 and 4.6, below).

At this point, gross demand is expressed on the basis of IMPLAN industries, not commodities. IMPLAN provides a list of 536 commodities and 536 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 for 2015, 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 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.

4.5 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 in Section 4.3, above. As described in Section 4.6, 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 Andrew at CICERO (Center for International Climate and Environmental Research) in Norway. CICERO’s MRIO model uses Global Trade Analysis Project (GTAP) data and sector definitions. Emissions intensities for these 57 sectors are mapped to IMPLAN's 536 sectors by comparing detailed sector descriptions.

4.5.1 U.S. 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 536-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 (2011 dollars) in sectors (i) are converted to 2015 dollars using the U.S. CPI-U.

3. Each IMPLAN sector (j) is mapped to 1 to 3 Peters' (2015 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):
   $\mathrm{i} = 57$ GTAP sectors
   $\mathrm{j} = 536$ IMPLAN sectors
   $\mathrm{k} = 1\mathrm{st}/2\mathrm{nd}/3\mathrm{rd}$ GTAP sector per IMPLAN sector
   $\mathrm{i(j,k)}$ maps IMPLAN to GTAP
   $\mathrm{m(j)} = \mathrm{i(j,1)}$ - 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. $\mathrm{DIcoef\_IM\_US\_unweighted_j} = \frac{\sum_k(\mathrm{PetersDIcoef\_Imports\_US_{i(j,k)}} * \mathrm{PetersImports\_US_{i(j,k)}})}{\sum_k \mathrm{PetersImports\_US_{i(j,k)}}}$

5. $\mathrm{US\_TCO_n} = \sum_j \mathrm{US\_TCO_j}$, summed over all j for which $m(j) = n$

6. $\mathrm{US\_TCOxDIcoef\_CBEI\_US_n} = \sum_j(\mathrm{DIcoef\_CBEI\_US_j} * \mathrm{US\_TCO_j})$, summed over all j for which $m(j) = n$

7. $\mathrm{DomesticWeight_j} = \frac{\mathrm{US\_TCOxDIcoef\_CBEI\_US_{m(j)}}}{\mathrm{US\_TCO_{m(j)}}}$

8. $\mathrm{DIcoef\_IM\_US_j} = \mathrm{DIcoef\_IM\_US\_unweighted_j} * \left(\frac{\mathrm{DIcoef\_CBEI\_US_j}}{\mathrm{DomesticWeight_j}}\right)^{0.5}$

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

10. For all IMPLAN sectors j associated with GTAP family of sectors n: $\mathrm{Emissions\_weighted_n} = \sum_j$ ([final demand, imports] x $\mathrm{DIcoef\_IM\_US_j}$)

11. $\mathrm{Adjustment\ factor_n} = \mathrm{Emissions\_unweighted_n}/\mathrm{Emissions\_weighted_n}$

12. $\mathrm{DIcoef\_IM\_US\_adjusted_j} = \mathrm{DIcoeff\_IM\_US_j} \times \mathrm{Adjustment\ factor_n}$ 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 536 IMPLAN sectors. Step 4 uses the CICERO results to calculate an "unweighted" direct+indirect emissions coefficient for each of the 536 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 536 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. 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.

4.5.2 U.S. 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, which are associated with final production in the U.S. They include emissions both inside the U.S. and in other nations. (Section 4.6 explains how these are used.)

The method to convert CICERO's 57-sector data to IMPLAN's 536-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):
    $$\text{PetersDIcoef\_Global\_US} = \frac{\text{US global emissions}}{\text{US global output}}$$
    b. U.S. domestic-only emissions (for U.S. final production including only domestic intermediate goods – direct+indirect):
    $$\text{PetersDIcoef\_DomesticOnly\_US} = \text{US domestic only}$$
    c. Ratio of Peters U.S. global to Peters U.S. domestic-only emissions:
    $$\text{PetersCoefRatio} = \frac{\text{PetersDIcoef\_Global\_US}}{\text{PetersDIcoef\_DomesticOnly\_US}}$$
    d. Value of production in the U.S. by sector:
    $$\text{PetersGlobal\_US} = \text{US global output}$$

2. Each IMPLAN sector (j) is mapped to 1 to 3 Peters sectors (i). Because this algorithm simply uses ratios, it is not essential to convert to 2015 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):

$\mathrm{i} = 57$ GTAP sectors
$\mathrm{j} = 536$ IMPLAN sectors
$\mathrm{k} = 1\mathrm{st}/2\mathrm{nd}/3\mathrm{rd}$ GTAP sector per IMPLAN sector
$\mathrm{i(j,k)}$ maps IMPLAN to GTAP

3. $\mathrm{CoefRatio_j} = \frac{\sum_k(\mathrm{PetersCoefRatio}_{i(j,k)} * \mathrm{PetersGlobal\_US}_{i(j,k)})}{\sum_k \mathrm{PetersGlobal\_US}_{i(j,k)}}$

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, global direct+indirect emissions coefficients for the U.S. (1a) and domestic-only emissions (1b) are derived from the CICERO model. 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 536 IMPLAN sectors. Step 3 uses the CICERO results to calculate a ratio of global:domestic direct+indirect emissions coefficients for each of the 536 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 using direct coefficients from Section 4.3 and IMPLAN's Leontief inverse matrix) to generate the U.S. global coefficients.

4.6 3-Phase Greenhouse Gas Emissions

3-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 536 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 536 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 536 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.

4.7 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 536 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 536 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 536 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 536 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.

4.8 Use

The "use" life-cycle phase includes emissions from the use of vehicles, appliances, electronics and lighting. 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 subtracting from the production phase the emissions estimated in the use phase; see Section 4.10 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 Section 4.3.2, 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 is calculated using data from a relevant ASHRAE standard (Standard 105-2014) and EPA's eGRID emissions database (using data for the WEC Northwest eGRID subregion). The result is very close 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.

4.9 Disposal

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 Section 4.3.2) as well as a ratio of (direct+indirect):direct life cycle emissions for IMPLAN industry 471 (waste management and remediation) drawn from the "LCA" model described in Section 4.7.

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, while government estimates are derived from a model that combines per-unit (employee or student) disposal data from a 2011 DEQ survey of local and state government units, community colleges, universities and school districts with updated 2015 unit data (numbers of employees and students).

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 granularity of 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 149 (paperboard containers) and 150 (paper bags and coated and treated papers) are summed for paper packaging; sectors 188 (plastic packaging materials and unlaminated film and sheet) and 194 (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.

4.10 Adjustments, Model Reconciliation and Final Results

Results from the LCA 3-phase model (Section 4.7), use phase emissions (Section 4.8) and disposal phase emissions (Section 4.9) are added together 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 3050 (natural gas), 3156 (petroleum), 3041-3049 and 3519, 3522, and 3525 (electric power) and 3471 (waste management and remediation services) are deleted; estimates in the use phase model and derived from physical units (mWh of power produced, tons of waste disposed, etc.) are expected to be more accurate. Emissions from IMPLAN commodity 3159 (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 since the last (2010) full estimate of consumption-based emissions. As originally modeled, life-cycle emissions for the water/wastewater commodity rose sharply and unexpectedly, from approximately 0.5 million MTCO2e in 2010 to 1.5 million MTCO2e in 2015. These emissions are dominated by methane and nitrous oxide during treatment of wastewater solids. While total emissions from wastewater processing in the sector-based inventory did not change significantly, IMPLAN reported much lower final demand from the water and wastewater *industry* 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 an obviously false model result, DEQ has chosen to estimate life cycle emissions for this commodity using a different method. 2015 consumption-based emissions for water and wastewater services are estimated as 2010 consumption-based emissions, adjusted using the ratio of 2015 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 and product 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.

4.11 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 $0 \leq x \leq 536$. 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 *OR2015 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 *OR2015 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, we hope to use IMPLAN's margin data to make this connection and present emissions for purchases made at the store, not the factory.

5. Summary of Major Updates

Oregon's 2015 estimate of consumption-based greenhouse gas emissions builds extensively on the original 2005 model created by SEI, as modified in 2010. DEQ undertook a full update of the model for the 2015 inventory, making a number of changes along the way. Of course, updated data sets were used where available, including 2015 IMPLAN data, the 2015 US GHG Emissions Inventory, 2015 Oregon sector-based inventory, and the 2011 update to CICERO's MRIO model. Beyond these and other data updates, several methodological changes were made as well. These include the following:

- In calculating direct emissions factors for the US, the 2015 model uses newer manufacturing "carbon footprint" analyses produced for calendar year 2010 for the U.S. Department of Energy (see Section 4.3.1).
- The algorithm for allocating US commercial CO2 emissions across different "primary business areas" was also updated (see Section 4.3.1).
- Steps 9 - 12 were added to the calculation of GHG coefficients for US Imports, as described in Section 4.5.1.
- IMPLAN’s 2015 economic model uses a 536-sector classification system that differs from the 440-sector classification system used in 2010. All sectors were reviewed and assigned to categories, subcategories and meta-categories. In a few instances, sectors were assigned to different categories, subcategories and/or meta-categories than their similar sectors had been in previous years.
- Similarly, all industry categories were reviewed for their association with the different GTAP categories used in foreign GHG coefficients, and some assignments were changed from 2010.
- The original (CY 2005) consumption-based emissions inventory used a customized allocation method to assign Oregon transportation-sector emissions to household, government, and various commercial and industrial sectors. This approach was largely replaced in the 2010 inventory with results from the Oregon Department of Transportation’s GreenStep emissions model. After consultation with ODOT, it was determined that the GreenStep model is not well suited for emissions inventory purposes, and so for 2015 we reverted back to the original allocation method, with minor improvements (additions).
- Well-to-pump (upstream) emissions for transportation and other fuels were drawn from new data reported to DEQ as part of the Oregon Clean Fuels Program.
- An updated method was used to estimate the upstream (supply chain) emissions for electricity generation.
- A new data source from the Northwest Power and Conservation Council was identified that allows for more refined allocation of household energy use to subcategories in the “appliances” and “electronics” categories.

The changes above were made to the emissions inventory for 2015. For consistency and comparability, many of the same changes were also (retroactively) programmed into the 2005 and 2010 inventories, thus updating results as published in this report. Due to time limitations, a few of the less-impactful updates were not made; these are not expected to materially affect the results. Upstream fuel factors were not changed because the Clean Fuels Program dataset only begins with data from 2016. Changes to the upstream emissions estimate for electricity (for 2015) were also not made retroactive, as the results were quite similar to those developed using the prior methodology (used in 2005 and 2010).

However, several other updates were made to the 2005 and 2010 inventories. Updated estimates of US and Oregon sector-based inventories were used to update US and Oregon direct emissions factors; the 2010 GreenStep transportation results were replaced with an estimate consistent with the 2005 and 2015 inventories; and an inconsistency in landfill modeling was corrected in the 2005 inventory. Also, new steps 9 – 12 for calculating U.S. import GHG coefficients (see Section 4.5.1) were also implemented for 2005 and 2010.

6. Initial derivation of total 1990 consumption-based emissions

With this report, DEQ has generated the first 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 and 2015 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.

7. Possible future inventory updates

DEQ plans to continue to periodically estimate the state’s consumption-based greenhouse gas emissions. Future inventories may continue to evolve the methodology, both as new data sources continue to become available and also to otherwise improve accuracy and precision. While DEQ has not committed to specific changes, possible future changes include, but are not limited to:

- Accounting for biogenic carbon (as an informational item).
- Accounting for the life-cycle benefits of waste recovery (primarily recycling) of Oregon-generated wastes, not elsewhere accounted for in this inventory.
- Including additional drivers of climate change, such as black carbon.
- Improving the estimate of Oregon-specific consumption, which currently is derived from national surveys coupled with local demographic data.

8. List of commodities

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Appliances		
Heating and cooling appliances		
Heating equipment (except warm air furnaces)	3276	Materials
Air conditioning, refrigeration, and warm air heating equipment	3277	Materials
Ranges and microwaves		
Household cooking appliances	3328	Materials
Refrigerators and freezers		
Household refrigerators and home freezers	3329	Materials
Washers and dryers		
Household laundry equipment	3330	Materials
Other appliances		
Small electrical appliances	3327	Materials
Other major household appliances	3331	Materials
Clothing		
Clothing		
Hosiery and socks	3124	Materials
*Not a unique commodity (other knitted apparel)	3125	Materials
Cut and sewn apparel from contractors	3126	Materials
Mens and boys cut and sew apparel	3127	Materials
Womens and girls cut and sew apparel	3128	Materials
Other cut and sew apparel	3129	Materials
Apparel accessories and other apparel	3130	Materials
Footwear	3132	Materials
Other leather and allied products	3133	Materials
Construction		
Concrete, cement, lime and gypsum		
Cement	3205	Materials
Ready-mix concrete	3206	Materials
Concrete blocks and bricks	3207	Materials
Concrete pipes	3208	Materials
Other concrete products	3209	Materials
Lime	3210	Materials
Gypsum products	3211	Materials
Non-residential construction and remodeling		
Newly constructed health care structures	3052	Materials or Services

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Newly constructed manufacturing structures	3053	Materials or Services
Newly constructed power and communication structures	3054	Materials or Services
Newly constructed educational and vocational structures	3055	Materials or Services
Newly constructed highways and streets	3056	Materials or Services
Newly constructed commercial structures, including farm structures	3057	Materials or Services
Newly constructed nonresidential structures	3058	Materials or Services
Maintained and repaired nonresidential structures	3062	Materials or Services
Maintained and repaired highways, streets, bridges, and tunnels	3064	Materials or Services
Residential construction and remodeling		
Newly constructed single-family residential structures	3059	Materials or Services
Newly constructed multifamily residential structures	3060	Materials or Services
Newly constructed residential structures	3061	Materials or Services
Maintained and repaired residential structures	3063	Materials or Services
Electronics		
Computer service and equipment		
Data processing, hosting, and related services	3430	Services
Custom computer programming services	3451	Services
Computer systems design services	3452	Services
Other computer related services, including facilities management services	3453	Services
Computers and peripherals		
Electronic computers	3301	Materials
Computer storage devices	3302	Materials
Computer terminals and other computer peripheral equipment	3303	Materials
Other electronics		
Photographic and photocopying equipment	3273	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Telephone apparatus	3304	Materials
Broadcast and wireless communications equipment	3305	Materials
Audio and video equipment	3307	Materials
Food and beverages		
Beverages		
Coffee and tea	3101	Materials
Bottled and canned soft drinks and water	3106	Materials
Manufactured ice	3107	Materials
Beer, ale, malt liquor and nonalcoholic beer	3108	Materials
Wine and brandies	3109	Materials
Distilled liquors except brandies	3110	Materials
Condiments, oils and sweeteners		
Wet corn	3070	Materials
Fats and oils refining and blending	3072	Materials
Beet sugar	3074	Materials
Sugar cane	3075	Materials
Flavoring syrup and concentrate	3102	Materials
Mayonnaise, dressings, and sauces	3103	Materials
Spices and extracts	3104	Materials
Dairy		
Dairy cattle and milk products	3012	Materials
Fluid milk	3084	Materials
Creamery butter	3085	Materials
Cheese	3086	Materials
Dry, condensed, and evaporated dairy products	3087	Materials
Ice cream and frozen dessert	3088	Materials
Fruit and vegetables		
Vegetables and melons	3003	Materials
Fruit	3004	Materials
Frozen fruits, juices and vegetables	3079	Materials
Canned fruits and vegetables	3081	Materials
Dehydrated food products	3083	Materials
Grains, baked goods, cereals, nuts		
Grains	3002	Materials
Tree nuts	3005	Materials
Flour	3067	Materials
Rice	3068	Materials
Malt	3069	Materials
Breakfast cereal	3073	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Nonchocolate confectioneries	3076	Materials
Confectioneries from purchased chocolate	3078	Materials
Bread and bakery products, except frozen	3094	Materials
Frozen cakes and other pastries	3095	Materials
Cookies and crackers	3096	Materials
Dry pasta, mixes, and dough	3097	Materials
Tortillas	3098	Materials
Roasted nuts and peanut butter	3099	Materials
Other snack foods	3100	Materials
Other animal products		
Animal products, except cattle and poultry and eggs	3014	Materials
Other frozen food		
Frozen specialties	3080	Materials
Other meat (beef, pork, etc.)		
Beef cattle	3011	Materials
Meat (except poultry) produced in slaughtering plant	3089	Materials
Meat processed from carcasses	3090	Materials
Processed animal rendered byproducts	3091	Materials
Pet food		
Dog and cat food	3065	Materials
Other animal food	3066	Materials
Poultry and eggs		
Poultry and egg products	3013	Materials
Processed poultry meat products	3092	Materials
Restaurants		
Full-service restaurant services	3501	Materials or Services
Limited-service restaurant services	3502	Materials or Services
All other food and drinking place services	3503	Materials or Services
Seafood		
Fish	3017	Materials
Seafood products	3093	Materials
Other food and agriculture		
Oilseeds	3001	Materials
Tobacco	3007	Materials
Cotton	3008	Materials
Sugarcane and sugar beets	3009	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
All other crops	3010	Materials
Soybean and other oilseed processing	3071	Materials
Chocolate and confectioneries from cacao beans	3077	Materials
Canned specialties	3082	Materials
All other food products	3105	Materials
Furnishings and supplies		
Furnishings		
Carpets and rugs	3119	Materials
Curtains and linens	3120	Materials
Upholstered household furniture	3369	Materials
Nonupholstered wood household furniture	3370	Materials
Other household nonupholstered furniture	3371	Materials
Institutional furniture	3372	Materials
Wood office furniture	3373	Materials
Custom architectural woodwork and millwork	3374	Materials
Office furniture, except wood	3375	Materials
Mattresses	3377	Materials
Blinds and shades	3378	Materials
Household supplies		
Sanitary paper products	3152	Materials
Soaps and other detergents	3179	Materials
Polish and other sanitation goods	3180	Materials
Surface active agents	3181	Materials
Toilet preparations	3182	Materials
Plastics packaging materials and unlaminated films and sheets	3188	Materials
Pottery, ceramics, and plumbing fixtures	3199	Materials
Flat glass	3201	Materials
Other pressed and blown glass and glassware	3202	Materials
Glass products made of purchased glass	3204	Materials
Cutlery, utensils, pots, and pans	3235	Materials
Storage batteries	3336	Materials
Primary batteries	3337	Materials
Ophthalmic goods	3382	Materials
Jewelry and silverware	3384	Materials
Brooms, brushes, and mops	3392	Materials
Greeting cards	3421	Materials
Lawn and garden		
Greenhouse, nursery, and floriculture products	3006	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Pesticides and other agricultural chemicals	3172	Materials
Lawn and garden equipment	3263	Materials
Media		
Software and other prerecorded and record reproducing	3324	Materials
Dolls, toys, and games	3386	Materials
Newspapers	3417	Materials
Periodicals	3418	Materials
Books	3419	Materials
Motion pictures and videos	3423	Materials or Services
Sound recordings	3424	Materials or Services
Office supplies		
Paper from pulp	3147	Materials
Stationery products	3151	Materials
Software publishers	3422	Services
Healthcare		
Healthcare services		
Offices of physicians	3475	Services
Offices of dentists	3476	Services
Offices of other health practitioners	3477	Services
Outpatient care centers	3478	Services
Medical and diagnostic laboratories	3479	Services
Home health care services	3480	Services
Other ambulatory health care services	3481	Services
Hospital services	3482	Services
Nursing and community care services	3483	Services
Residential mental retardation, mental health, substance abuse and other care services	3484	Services
Medicines		
Medicines and botanicals	3173	Materials
Pharmaceuticals	3174	Materials
In-vitro diagnostic substances	3175	Materials
Biological products (except diagnostic)	3176	Materials
Lighting and fixtures		
Lighting and fixtures		
Electric lamp bulbs and parts	3325	Materials
Lighting fixtures	3326	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Other manufactured goods		
Forestries, mills, paper		
Forest, timber, and forest nursery products	3015	Materials
Logs and roundwood	3016	Materials
Dimension lumber	3134	Materials
Preserved wood products	3135	Materials
Veneer and plywood	3136	Materials
Wood pulp	3146	Materials
Paperboard from pulp	3148	Materials
Paperboard containers	3149	Materials
Paper bags and coated and treated paper	3150	Materials
All other converted paper products	3153	Materials
Foundries, metal processing		
Iron and steel and ferroalloy products	3217	Materials
* Not a unique commodity (iron, steel pipes and tubes from purchased steel)	3218	Materials
* Not a unique commodity (rolled steel shapes)	3219	Materials
Steel wire	3220	Materials
Aluminum products	3221	Materials
* Not a unique commodity (secondary smelting and alloying of aluminum)	3222	Materials
Aluminum sheets, plates, and foils	3223	Materials
Rolled, drawn, and extruded aluminum	3224	Materials
Nonferrous metal (exc aluminum) smelting and refining	3225	Materials
Rolled, drawn, extruded, and alloyed copper	3226	Materials
Nonferrous metal, except copper and aluminum, shaping	3227	Materials
Secondary processing of other nonferrous metals	3228	Materials
Ferrous metals	3229	Materials
Nonferrous metals	3230	Materials
Iron and steel forgings	3231	Materials
Nonferrous forgings	3232	Materials
Crowned and stamped metals	3234	Materials
Heat treated products	3251	Materials
Coated and engraved products	3252	Materials
Electroplated, anodized, and colored metal	3253	Materials
Heavy transportation equipment		
Overhead cranes, hoists, and monorail systems	3292	Materials

Category *Subcategory* Commodity	IMPLAN Commodity #	Meta-Category
Industrial trucks, trailers, and stackers	3293	Materials
Heavy duty trucks	3345	Materials
Truck trailers	3347	Materials
Aircrafts	3357	Materials
Aircraft engines and engine parts	3358	Materials
Other aircraft parts and auxiliary equipment	3359	Materials
Railroad rolling stock	3362	Materials
Ships	3363	Materials
Machinery manufacturing		
Power boilers and heat exchangers	3243	Materials
Farm machinery and equipment	3262	Materials
Construction machinery	3264	Materials
Mining machinery	3265	Materials
Oil and gas field machinery	3266	Materials
Food product machinery	3267	Materials
Semiconductor machinery	3268	Materials
Sawmill, woodworking, and paper machinery	3269	Materials
Printing machinery and equipment	3270	Materials
All other industrial machinery	3271	Materials
Optical instruments and lenses	3272	Materials
Other commercial service industry machinery	3274	Materials
Air purification and ventilation equipment	3275	Materials
Industrial molds	3278	Materials
Special tool, die, jig, and fixture	3279	Materials
Cutting tool and machine tool accessory	3280	Materials
Machine tool	3281	Materials
Rolling mill and other metalworking machinery	3282	Materials
Turbine and turbine generator set units	3283	Materials
Speed changers, industrial high-speed drives, and gears	3284	Materials
Mechanical power transmission equipment	3285	Materials
Other engine equipment	3286	Materials
Pump and pumping equipment	3287	Materials
Air and gas compressors	3288	Materials
Measuring and dispensing pumps	3289	Materials
Elevators and moving stairways	3290	Materials
Conveyor and conveying equipment	3291	Materials
Welding and soldering equipment	3295	Materials
Packaging machinery	3296	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Industrial process furnaces and ovens	3297	Materials
Fluid power cylinders and actuators	3298	Materials
Fluid power pumps and motors	3299	Materials
Scales, balances, and miscellaneous general purpose machinery	3300	Materials
Other communications equipment	3306	Materials
Semiconductors and related devices	3309	Materials
Electromedical and electrotherapeutic apparatus	3314	Materials
Search, detection, and navigation instruments	3315	Materials
Automatic environmental controls	3316	Materials
Industrial process variable instruments	3317	Materials
Totalizing fluid meters and counting devices	3318	Materials
Electricity and signal testing instruments	3319	Materials
Analytical laboratory instruments	3320	Materials
Irradiation apparatus	3321	Materials
Power, distribution, and specialty transformers	3332	Materials
Switchgear and switchboard apparatus	3334	Materials
Relay and industrial controls	3335	Materials
Wiring devices	3340	Materials
All other miscellaneous electrical equipment and components	3342	Materials
Commercial and industrial machinery and equipment repair and maintenance	3507	Services
Missiles, weapons		
Small arms ammunition	3257	Materials
Ammunition, except for small arms	3258	Materials
Small arms, ordnance, and accessories	3259	Materials
Guided missiles and space vehicles	3360	Materials
Propulsion units and parts for space vehicles and guided missiles	3361	Materials
Military armored vehicles, tanks, and tank components	3366	Materials
Mobile homes		
Manufactured homes (mobile homes)	3143	Materials
Other manufactures		
Cigarettes, cigars, smoking and chewing tobacco, and reconstituted tobacco	3111	Materials
Fiber filaments, yarn, and thread	3112	Materials
Broadwoven fabrics and felts	3113	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Narrow fabrics and schiffli machine embroidery	3114	Materials
Nonwoven fabrics	3115	Materials
Knitted fabrics	3116	Materials
Finished textiles and fabrics	3117	Materials
Coated fabric coating	3118	Materials
Textile bags and canvas	3121	Materials
Rope, cordage, twine, tire cord and tire fabric	3122	Materials
Other textile products	3123	Materials
Tanned and finished leather and hides	3131	Materials
Engineered wood members and trusses	3137	Materials
Reconstituted wood products	3138	Materials
Wood windows and doors	3139	Materials
Cut stock, resawn and planed lumber	3140	Materials
Other millwork, including flooring	3141	Materials
Wood containers and pallets	3142	Materials
Prefabricated wood buildings	3144	Materials
All other miscellaneous wood products	3145	Materials
Printed materials	3154	Materials
Printing support services	3155	Materials
Asphalt paving mixtures and blocks	3157	Materials
Asphalt shingles and coating materials	3158	Materials
Synthetic dyes and pigments	3163	Materials
Other basic inorganic chemicals	3164	Materials
Other basic organic chemicals	3165	Materials
Plastics materials and resins	3166	Materials
Synthetic rubbers	3167	Materials
Artificial and synthetic fibers and filaments	3168	Materials
Nitrogenous fertilizer	3169	Materials
Phosphatic fertilizer	3170	Materials
* Not a unique commodity (fertilizer mixing)	3171	Materials
Paints and coatings	3177	Materials
Adhesives	3178	Materials
Printing inks	3183	Materials
Explosives	3184	Materials
Compounded resins	3185	Materials
Photographic films and chemicals	3186	Materials
Other miscellaneous chemical products	3187	Materials
Unlaminated plastics profile shapes	3189	Materials
Plastics pipes and pipe fittings	3190	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Laminated plastics plates, sheets (except packaging), and shapes	3191	Materials
Polystyrene foam products	3192	Materials
Urethane and other foam products (except polystyrene)	3193	Materials
Plastics bottles	3194	Materials
Other plastics products	3195	Materials
Rubber and plastics hoses and belts	3197	Materials
Other rubber products	3198	Materials
Bricks, tiles, and other structural clay products	3200	Materials
Glass containers	3203	Materials
Abrasive products	3212	Materials
Cut stone and stone products	3213	Materials
Ground or treated mineral and earth products	3214	Materials
Mineral wool	3215	Materials
Miscellaneous nonmetallic mineral products	3216	Materials
Custom roll formed metals	3233	Materials
Handtools	3236	Materials
Prefabricated metal buildings and components	3237	Materials
Fabricated structural metal products	3238	Materials
Plates	3239	Materials
Metal windows and doors	3240	Materials
Sheet metal work (except stampings)	3241	Materials
Ornamental and architectural metal products	3242	Materials
Metal tanks (heavy gauge)	3244	Materials
Metal cans	3245	Materials
Metal barrels, drums and pails	3246	Materials
Hardware	3247	Materials
Spring and wire products	3248	Materials
Machined products	3249	Materials
Turned products and screws, nuts, and bolts	3250	Materials
Valve and fittings, other than plumbing	3254	Materials
Plumbing fixture fittings and trims	3255	Materials
Balls and roller bearings	3256	Materials
Fabricated pipes and pipe fittings	3260	Materials
Other fabricated metals	3261	Materials
Power-driven handtools	3294	Materials
Bare printed circuit boards	3308	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Capacitors, resistors, coils, transformers, and other inductors	3310	Materials
Electronic connectors	3311	Materials
Printed circuit assemblies (electronic assemblies)	3312	Materials
Other electronic components	3313	Materials
Watches, clocks, and other measuring and controlling devices	3322	Materials
Blank magnetic and optical recording media	3323	Materials
Motors and generators	3333	Materials
Fiber optic cables	3338	Materials
Other communication and energy wires	3339	Materials
Carbon and graphite products	3341	Materials
Motor vehicle bodies	3346	Materials
All other transportation equipment	3367	Materials
Wood kitchen cabinets and countertops	3368	Materials
Showcases, partitions, shelvings, and lockers	3376	Materials
Surgical and medical instruments	3379	Materials
Surgical appliance and supplies	3380	Materials
Dental equipment and supplies	3381	Materials
Dental laboratories	3383	Materials
Sporting and athletic goods	3385	Materials
Office supplies (except paper)	3387	Materials
Signs	3388	Materials
Gaskets, packings, and sealing devices	3389	Materials
Musical instruments	3390	Materials
Fasteners, buttons, needles, and pins	3391	Materials
Burial caskets	3393	Materials
All other miscellaneous manufactured products	3394	Materials
Directories, mailing lists, and other published materials	3420	Materials
Retailers		
Retailers		
Retail services - Motor vehicle and parts dealers	3396	Materials
Retail services - Furniture and home furnishings stores	3397	Materials
Retail services - Electronics and appliance stores	3398	Materials
Retail services - Building material and garden equipment and supplies stores	3399	Materials
Retail services - Food and beverage stores	3400	Materials
Retail services - Health and personal care stores	3401	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Retail services - Gasoline stores	3402	Fuels
Retail services- Clothing and clothing accessories stores	3403	Materials
Retail services - Sporting goods, hobby, musical instrument and book stores	3404	Materials
Retail services - General merchandise stores	3405	Materials
Retail services - Miscellaneous store retailers	3406	Materials
Retail services - Nonstore retailers	3407	Materials
Services		
Banks and financial services		
Monetary authorities and depository credit intermediation	3433	Services
Nondepository credit intermediation and related activities	3434	Services
Securities and commodity contracts intermediation and brokerage	3435	Services
Other financial investment services	3436	Services
Funds, trusts, and other financial services	3439	Services
Building services		
Services to buildings	3468	Services
Landscape and horticultural services	3469	Services
Car rental, repair and wash		
Automotive equipment rental and leasing services	3442	Materials
Automotive repair and maintenance, except car washes	3504	Services
Car washes	3505	Services
Education and day care		
Elementary and secondary schools	3472	Services
Junior colleges, colleges, universities, and professional schools	3473	Services
Other educational services	3474	Services
Child day care services	3487	Services
Entertainment and media		
Radio and television broadcasts	3425	Services
Cable and other subscription programming	3426	Services
Wired telecommunications	3427	Services
Wireless telecommunications (except satellite)	3428	Services
Satellite, telecommunications resellers, and all other telecommunications	3429	Services

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Internet publishing and broadcasting and web search portals	3432	Services
Video tape and disc rental services	3444	Materials
Performing arts	3488	Services
Commercial sports except racing	3489	Services
Racing and track operation services	3490	Services
Promotional services for performing arts and sports and public figures	3491	Services
Independent artists, writers, and performers	3492	Services
Museum, heritage, zoo, and recreational services	3493	Services
Amusement parks and arcades	3494	Services
Gambling recreation	3495	Services
Other amusement and recreation	3496	Services
Bowling activities	3498	Services
Hotels and motels		
Hotels and motel services, including casino hotels	3499	Services
Other accommodation services	3500	Services
Legal, real estate, insurance		
Insurance	3437	Services
Insurance agencies, brokerages, and related services	3438	Services
Real estate buying and selling, leasing, managing, and related services	3440	Services
Legal services	3447	Services
Personal services		
Veterinary services	3459	Services
Fitness and recreational sports center services	3497	Services
Personal care services	3509	Services
Dry-cleaning and laundry services	3511	Services
Other personal services	3512	Services
Cooking, housecleaning, gardening, and other services to private households	3517	Services
Waste management		
Waste management and remediation services	3471	Materials or Services
Other services		
Support activities for agriculture and forestry	3019	Services
Couriers and messengers services	3415	Services
Warehousing and storage services	3416	Services

Category / *Subcategory* / Commodity	**IMPLAN Commodity #**	**Meta-Category**
News syndicates, libraries, archives and all other information services	3431	Services
General and consumer goods rental services except video tapes and discs	3443	Materials
Commercial and industrial machinery and equipment rental and leasing services	3445	Materials
Accounting, tax preparation, bookkeeping, and payroll services	3448	Services
Architectural, engineering, and related services	3449	Services
Specialized design services	3450	Services
Management consulting services	3454	Services
Environmental and other technical consulting services	3455	Services
Scientific research and development services	3456	Services
Advertising, public relations, and related services	3457	Services
Photographic services	3458	Services
Marketing research and all other miscellaneous professional, scientific, and technical services	3460	Services
Management of companies and enterprises	3461	Services
Office administrative services	3462	Services
Facilities support services	3463	Services
Employment services	3464	Services
Business support services	3465	Services
Travel arrangement and reservation services	3466	Services
Investigation and security services	3467	Services
Other support services	3470	Services
Individual and family services	3485	Services
Community food, housing, and other relief services, including rehabilitation services	3486	Services
Electronic and precision equipment repair and maintenance	3506	Services
Personal and household goods repair and maintenance	3508	Services
Death care services	3510	Services
Services from religious organizations	3513	Services
Grantmaking, giving, and social advocacy services	3514	Services
Business and professional services	3515	Services
Labor and civic services	3516	Services
US Postal delivery services	3518	Services
Other products and services of Fed Govt enterprises	3520	Services

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Other products and services of State Govt enterprises	3523	Services
Other products and services of Local Govt enterprises	3526	Services
Transportation services		
Transportation services		
Air transportation services	3408	Materials or Services
Rail transportation services	3409	Materials or Services
Water transportation services	3410	Materials
Truck transportation services	3411	Materials
Transit and ground passenger transportation services	3412	Services
Pipeline transportation services	3413	Fuels
Scenic and sightseeing transportation services and support activities for transportation	3414	Services
* Not a unique commodity (passenger transit by state govt)	3521	Services
* Not a unique commodity (passenger transit by local govt)	3524	Services
Vehicles and parts		
Vehicle parts		
Petroleum lubricating oil and grease	3159	Materials
Tires	3196	Materials
Motor vehicle gasoline engines and engine parts	3350	Materials
Motor vehicle electrical and electronic equipment	3351	Materials
Motor vehicle steering, suspension components (except spring), and brake systems	3352	Materials
Motor vehicle transmission and power train parts	3353	Materials
Motor vehicle seating and interior trim	3354	Materials
Motor vehicle stamped metal	3355	Materials
Other motor vehicle parts	3356	Materials
Vehicles		
Automobiles	3343	Materials
Light trucks and utility vehicles	3344	Materials
Motor homes	3348	Materials
Travel trailers and campers	3349	Materials
Boats	3364	Materials
Motorcycles, bicycles, and parts	3365	Materials
Water and wastewater		
Gasoline, heating fuels, other petroleum products		

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Refined petroleum products	3156	Fuels
Natural gas distribution		
Natural gas distribution	3050	Fuels
Power generation and supply		
Electricity generation	3041	Electricity
* Not a unique commodity (electricity from fossil fuels)	3042	Electricity
* Not a unique commodity (electricity from nuclear)	3043	Electricity
* Not a unique commodity (electricity from solar)	3044	Electricity
* Not a unique commodity (electricity from wind)	3045	Electricity
* Not a unique commodity (electricity from geothermal)	3046	Electricity
* Not a unique commodity (electricity from biomass)	3047	Electricity
* Not a unique commodity (electricity from all other sources)	3048	Electricity
Electricity transmission and distribution	3049	Electricity
* Not a unique commodity (electricity from fed govt utilities)	3519	Electricity
* Not a unique commodity (electricity from state govt utilities)	3522	Electricity
* Not a unique commodity (electricity from local govt utilities)	3525	Electricity
Water- sewage and other systems		
Water, sewage and other systems	3051	Materials or Services
Wholesale		
Wholesale		
Wholesale trade distribution services	3395	Materials
Other		
Oil and gas		
Natural gas and crude petroleum	3020	Fuels
* Not a unique commodity (natural gas liquids)	3021	Fuels
Oil and gas wells	3037	Services
Support activities for oil and gas operations	3038	Services
All other petroleum and coal products	3160	Materials
Petrochemicals	3161	Materials
Industrial gases	3162	Materials
Other mining		
Coal	3022	Materials

Category / *Subcategory* / Commodity	IMPLAN Commodity #	Meta-Category
Iron ore	3023	Materials
Gold ore	3024	Materials
Silver ore	3025	Materials
Lead and zinc ore	3026	Materials
Copper ore	3027	Materials
Uranium-radium-vanadium ore	3028	Materials
Other metal ore	3029	Materials
Stone	3030	Materials
Sand and gravel	3031	Materials
Other clay, ceramic, refractory minerals	3032	Materials
Potash, soda, and borate mineral	3033	Materials
Phosphate rock	3034	Materials
Other chemical and fertilizer mineral	3035	Materials
Other nonmetallic minerals	3036	Materials
Metal services	3039	Services
Other nonmetallic minerals services	3040	Services
Other		
Wild game products, pelts, and furs	3018	Materials
Imputed rental services of owner-occupied dwellings	3441	Services
Leasing of nonfinancial intangible assets	3446	Services
Used and secondhand goods	3527	Materials
Scrap	3528	Materials
Rest of the world adjustment	3529	Materials or Services
Noncomparable imports	3530	Materials or Services
* Employment and payroll of state govt, non-education	3531	Services
* Employment and payroll of state govt, education	3532	Services
* Employment and payroll of local govt, non-education	3533	Services
* Employment and payroll of local govt, education	3534	Services
* Employment and payroll of federal govt, non-military	3535	Services
* Employment and payroll of federal govt, military	3536	Services

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